FloPy Documentation

Release 3.5.0

FloPy Team

Nov 26, 2023

CONTENTS

FloPy3

a Python package to create, run, and post-process MODFLOW-based models

Documentation for version 3.5.0

Documentation is generated with Sphinx from the FloPy repository.

Contents:

The FloPy package consists of a set of Python scripts to run MODFLOW, MT3D, SEAWAT and other MODFLOW-related groundwater programs. FloPy enables you to run all these programs with Python scripts. The FloPy project started in 2009 and has grown to a fairly complete set of scripts with a growing user base. FloPy3 was released in December 2014 with a few great enhancements that make FloPy3 backwards incompatible. The first significant change is that FloPy3 uses zero-based indexing everywhere, which means that all layers, rows, columns, and stress periods start numbering at zero. This change was made for consistency as all array-indexing was already zero-based (as are all arrays in Python). This may take a little getting-used-to, but hopefully will avoid confusion in the future. A second significant enhancement concerns the ability to specify time-varying boundary conditions that are specified with a sequence of layer-row-column-values, like the WEL and GHB packages. A variety of flexible and readable ways have been implemented to specify these boundary conditions.

Recently, FloPy has been further enhanced to include full support for MODFLOW 6. The majority of recent development has focused on FloPy functionality for MODFLOW 6, helper functions to use GIS shapefiles and raster files to create MODFLOW datasets, and common plotting and export functionality.

FloPy provides separate APIs for interacting with MF6 and non-MF6 models. MODFLOW 6 class definitions are automatically generated from definition (DFN) files, text files describing the format of MF6 input files.

FloPy is an open-source project and any assistance is welcomed. Please email the development team if you want to contribute.

Return to the Github FloPy website.

CHAPTER

ONE

INSTALLATION

FloPy can be installed using conda (from the conda-forge channel) or pip.

To install with conda:

```
conda install -c conda-forge flopy
```

To install with pip:

```
pip install flopy
```

To install the bleeding edge version of FloPy from the git repository type:

```
pip install git+https://github.com/modflowpy/flopy.git
```

After FloPy is installed, MODFLOW and related programs can be installed using the command:

```
get-modflow :flopy
```

See documentation get_modflow.md for more information.

CHAPTER

TWO

RESOURCES

CHAPTER

THREE

DEVELOPMENT TEAM

FloPy is developed by a team of MODFLOW users that have switched over to using Python for model development and post-processing. Members of the team currently include:

- Mark Bakker
- Vincent Post
- Joseph D. Hughes
- Christian D. Langevin
- Jeremy T. White
- Andrew T. Leaf
- Scott R. Paulinski
- Jason C. Bellino
- Eric D. Morway
- Michael W. Toews
- Joshua D. Larsen
- Michael N. Fienen
- Jon Jeffrey Starn
- Davíd A. Brakenhoff
- Wesley P. Bonelli
- and others

CHAPTER FOUR

HOW TO CITE

- Groundwater Paper
- Software Citation

CHAPTER

FIVE

TUTORIALS

The following tutorials demonstrate basic FloPy features and usage with MODFLOW 2005, MODFLOW 6, and related programs.

5.1 FloPy

5.1.1 Formatting ASCII output arrays

Configuring numeric arrays written by FloPy

load and run the Freyberg model

[1]:
```python
import os
import sys
from tempfile import TemporaryDirectory

import matplotlib as mpl
import matplotlib.pyplot as plt
import numpy as np

import flopy

# Set name of MODFLOW exe
#  assumes executable is in users path statement
version = "mf2005"
exe_name = "mf2005"
mfexe = exe_name

# Set the paths
loadpth = os.path.join("..", "..", "examples", "data", "freyberg")
temp_dir = TemporaryDirectory()
modelpth = temp_dir.name

# make sure modelpth directory exists
if not os.path.isdir(modelpth):
    os.makedirs(modelpth)

print(sys.version)
print(f"numpy version: {np.__version__}")
```

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```
print(f"matplotlib version: {mpl.__version__}")
print(f"flopy version: {flopy.__version__}")
```

```
3.8.18 (default, Aug 28 2023, 08:27:22)
[GCC 11.4.0]
numpy version: 1.24.4
matplotlib version: 3.7.4
flopy version: 3.5.0
```

[2]:
```
ml = flopy.modflow.Modflow.load(
    "freyberg.nam", model_ws=loadpth, exe_name=exe_name, version=version
)
ml.model_ws = modelpth
ml.write_input()
success, buff = ml.run_model(silent=True, report=True)
if success:
    for line in buff:
        print(line)
else:
    raise ValueError("Failed to run.")

files = ["freyberg.hds", "freyberg.cbc"]
for f in files:
    if os.path.isfile(os.path.join(modelpth, f)):
        msg = f"Output file located: {f}"
        print(msg)
    else:
        errmsg = f"Error. Output file cannot be found: {f}"
        print(errmsg)
```

```

                                  MODFLOW-2005
    U.S. GEOLOGICAL SURVEY MODULAR FINITE-DIFFERENCE GROUND-WATER FLOW MODEL
                             Version 1.12.00 2/3/2017

 Using NAME file: freyberg.nam
 Run start date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:26:03

 Solving:  Stress period:     1    Time step:     1    Ground-Water Flow Eqn.
 Run end date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:26:03
 Elapsed run time:  0.007 Seconds

  Normal termination of simulation
Output file located: freyberg.hds
Output file located: freyberg.cbc
```

Each `Util2d` instance now has a `.format` attribute, which is an `ArrayFormat` instance:

[3]:
```
print(ml.lpf.hk[0].format)
```

```
ArrayFormat: npl:20,format:E,width:15,decimal6,isfree:True,isbinary:False
```

The `ArrayFormat` class exposes each of the attributes seen in the `ArrayFormat.___str___()` call. `ArrayFormat` also exposes `.fortran`, `.py` and `.numpy` atrributes, which are the respective format descriptors:

[4]:
```python
print(ml.dis.botm[0].format.fortran)
print(ml.dis.botm[0].format.py)
print(ml.dis.botm[0].format.numpy)
```

```
(FREE)
(20, '{0:15.6E}')
%15E.6
```

(re)-setting .format

We can reset the format using a standard fortran type format descriptor

[5]:
```python
ml.dis.botm[0].format.free = False
ml.dis.botm[0].format.fortran = "(20f10.4)"
print(ml.dis.botm[0].format.fortran)
print(ml.dis.botm[0].format.py)
print(ml.dis.botm[0].format.numpy)
print(ml.dis.botm[0].format)
```

```
(20F10.4)
(20, '{0:10.4F}')
%10F.4
ArrayFormat: npl:20,format:F,width:10,decimal4,isfree:False,isbinary:False
```

[6]:
```python
ml.write_input()
success, buff = ml.run_model(silent=True, report=True)
if success:
    for line in buff:
        print(line)
else:
    raise ValueError("Failed to run.")
```

```

                                  MODFLOW-2005
    U.S. GEOLOGICAL SURVEY MODULAR FINITE-DIFFERENCE GROUND-WATER FLOW MODEL
                             Version 1.12.00 2/3/2017

 Using NAME file: freyberg.nam
 Run start date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:26:03

 Solving:  Stress period:     1    Time step:     1    Ground-Water Flow Eqn.
 Run end date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:26:03
 Elapsed run time:  0.007 Seconds

  Normal termination of simulation
```

Let's load the model we just wrote and check that the desired `botm[0].format` was used:

[7]:
```python
ml1 = flopy.modflow.Modflow.load("freyberg.nam", model_ws=modelpth)
print(ml1.dis.botm[0].format)
```

```
ArrayFormat: npl:20,format:E,width:15,decimal6,isfree:True,isbinary:False
```

We can also reset individual format components (we can also generate some warnings):

```
[8]: ml.dis.botm[0].format.width = 9
     ml.dis.botm[0].format.decimal = 1
     print(ml1.dis.botm[0].format)
```

```
ArrayFormat warning:setting width less than default of 15
ArrayFormat warning: setting decimal less than default of 6
ArrayFormat warning: setting decimal less than current value of 6
ArrayFormat: npl:20,format:E,width:15,decimal6,isfree:True,isbinary:False
```

We can also select `free` format. Note that setting to free format resets the format attributes to the default, max precision:

```
[9]: ml.dis.botm[0].format.free = True
     print(ml1.dis.botm[0].format)
```

```
ArrayFormat: npl:20,format:E,width:15,decimal6,isfree:True,isbinary:False
```

```
[10]: ml.write_input()
      success, buff = ml.run_model(silent=True, report=True)
      if success:
          for line in buff:
              print(line)
      else:
          raise ValueError("Failed to run.")
```

```
                                  MODFLOW-2005
    U.S. GEOLOGICAL SURVEY MODULAR FINITE-DIFFERENCE GROUND-WATER FLOW MODEL
                             Version 1.12.00 2/3/2017

 Using NAME file: freyberg.nam
 Run start date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:26:03

 Solving:  Stress period:     1    Time step:     1    Ground-Water Flow Eqn.
 Run end date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:26:03
 Elapsed run time:  0.007 Seconds

  Normal termination of simulation
```

```
[11]: ml1 = flopy.modflow.Modflow.load("freyberg.nam", model_ws=modelpth)
      print(ml1.dis.botm[0].format)
```

```
ArrayFormat: npl:20,format:E,width:15,decimal6,isfree:True,isbinary:False
```

5.1.2 Exporting to netCDF and shapefile

```
[1]: import datetime
```

```
[2]: import os
     import sys
     from tempfile import TemporaryDirectory

     import flopy
```

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```
print(sys.version)
print(f"flopy version: {flopy.__version__}")
```

```
3.8.18 (default, Aug 28 2023, 08:27:22)
[GCC 11.4.0]
flopy version: 3.5.0
```

Load our old friend…the Freyberg model

[3]:
```
nam_file = "freyberg.nam"
model_ws = os.path.join(
    "..", "..", "examples", "data", "freyberg_multilayer_transient"
)
ml = flopy.modflow.Modflow.load(nam_file, model_ws=model_ws, check=False)
```

We can see the `Modelgrid` instance has generic entries, as does `start_datetime`

[4]:
```
ml.modelgrid
```

[4]:
```
xll:622241.1904510253; yll:3343617.741737109; rotation:15.0; crs:EPSG:32614; units:
↪meters; lenuni:2
```

[5]:
```
ml.modeltime.start_datetime
```

[5]:
```
'1/1/2015'
```

Setting the attributes of the `ml.modelgrid` is easy:

[6]:
```
ml.modelgrid.set_coord_info(
    xoff=123456.7, yoff=765432.1, angrot=15.0, crs=3070
)
ml.dis.start_datetime = "7/4/1776"
```

[7]:
```
ml.modeltime.start_datetime
```

[7]:
```
'7/4/1776'
```

Basic netCDF export capabilities

[8]:
```
# temporary directory
temp_dir = TemporaryDirectory()
pth = temp_dir.name
```

[9]:
```
# export the whole model (inputs and outputs)
fnc = ml.export(os.path.join(pth, f"{ml.name}.in.nc"))
```

```
initialize_geometry::
model crs: EPSG:3070
initialize_geometry::nc_crs = EPSG:4326
transforming coordinates using = proj=pipeline step inv proj=tmerc lat_0=0 lon_0=-90 k=0.
↪9996 x_0=520000 y_0=-4480000 ellps=GRS80 step proj=unitconvert xy_in=rad xy_out=deg
```

[10]:
```
# export outputs using spatial reference info
hds = flopy.utils.HeadFile(os.path.join(model_ws, "freyberg.hds"))
flopy.export.utils.output_helper(
    os.path.join(pth, f"{ml.name}.out.nc"), ml, {"hds": hds}
)
```

```
initialize_geometry::
model crs: EPSG:3070
initialize_geometry::nc_crs = EPSG:4326
transforming coordinates using = proj=pipeline step inv proj=tmerc lat_0=0 lon_0=-90 k=0.
↪9996 x_0=520000 y_0=-4480000 ellps=GRS80 step proj=unitconvert xy_in=rad xy_out=deg
```

[10]:
```
<flopy.export.netcdf.NetCdf at 0x7ff3c0bd5a30>
```

Export an array to netCDF or shapefile

[11]:
```
# export a 2d array
ml.dis.top.export(os.path.join(pth, "top.nc"))
ml.dis.top.export(os.path.join(pth, "top.shp"))
```

```
initialize_geometry::
model crs: EPSG:3070
initialize_geometry::nc_crs = EPSG:4326
transforming coordinates using = proj=pipeline step inv proj=tmerc lat_0=0 lon_0=-90 k=0.
↪9996 x_0=520000 y_0=-4480000 ellps=GRS80 step proj=unitconvert xy_in=rad xy_out=deg
```

sparse export of stress period data for a boundary condition package

- excludes cells that aren't in the package (aren't in `package.stress_period_data`)
- by default, stress periods with duplicate parameter values (e.g., stage, conductance, etc.) are omitted (`squeeze=True`); only stress periods with different values are exported
- argue `squeeze=False` to export all stress periods

[12]:
```
ml.drn.stress_period_data.export(os.path.join(pth, "drn.shp"), sparse=True)
```

Export a 3d array

[13]:
```
# export a 3d array
ml.upw.hk.export(os.path.join(pth, "hk.nc"))
ml.upw.hk.export(os.path.join(pth, "hk.shp"))
```

```
initialize_geometry::
model crs: EPSG:3070
initialize_geometry::nc_crs = EPSG:4326
transforming coordinates using = proj=pipeline step inv proj=tmerc lat_0=0 lon_0=-90 k=0.
↪9996 x_0=520000 y_0=-4480000 ellps=GRS80 step proj=unitconvert xy_in=rad xy_out=deg
```

Export a number of things to the same netCDF file

[14]:
```
# export lots of things to the same nc file
fnc = ml.dis.botm.export(os.path.join(pth, "test.nc"))
ml.upw.hk.export(fnc)
ml.dis.top.export(fnc)

# export transient 2d
ml.rch.rech.export(fnc)
```

```
initialize_geometry::
model crs: EPSG:3070
initialize_geometry::nc_crs = EPSG:4326
transforming coordinates using = proj=pipeline step inv proj=tmerc lat_0=0 lon_0=-90 k=0.
↪9996 x_0=520000 y_0=-4480000 ellps=GRS80 step proj=unitconvert xy_in=rad xy_out=deg
```

[14]:
```
<flopy.export.netcdf.NetCdf at 0x7ff38f8946a0>
```

Export a package to netCDF

[15]:
```
# export mflist
fnc = ml.wel.export(os.path.join(pth, "packages.nc"))
ml.upw.export(fnc)
```

```
initialize_geometry::
model crs: EPSG:3070
initialize_geometry::nc_crs = EPSG:4326
transforming coordinates using = proj=pipeline step inv proj=tmerc lat_0=0 lon_0=-90 k=0.
↪9996 x_0=520000 y_0=-4480000 ellps=GRS80 step proj=unitconvert xy_in=rad xy_out=deg
```

[15]:
```
<flopy.export.netcdf.NetCdf at 0x7ff38f894c10>
```

Export an entire model to netCDF

[16]:
```
fnc = ml.export(os.path.join(pth, "model.nc"))
```

```
initialize_geometry::
model crs: EPSG:3070
initialize_geometry::nc_crs = EPSG:4326
transforming coordinates using = proj=pipeline step inv proj=tmerc lat_0=0 lon_0=-90 k=0.
↪9996 x_0=520000 y_0=-4480000 ellps=GRS80 step proj=unitconvert xy_in=rad xy_out=deg
```

Export model outputs to netCDF

FloPy has utilities to export model outputs to a netcdf file. Valid output types for export are MODFLOW binary head files, formatted head files, cell budget files, seawat concentration files, and zonebudget output.

Let's use output from the Freyberg model as an example of these functions

[17]:
```
# load binary head and cell budget files
fhead = os.path.join(model_ws, "freyberg.hds")
```

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```
fcbc = os.path.join(model_ws, "freyberg.cbc")

hds = flopy.utils.HeadFile(fhead)
cbc = flopy.utils.CellBudgetFile(fcbc)

export_dict = {"hds": hds, "cbc": cbc}

# export head and cell budget outputs to netcdf
fnc = flopy.export.utils.output_helper(
    os.path.join(pth, "output.nc"), ml, export_dict
)
```

```
initialize_geometry::
model crs: EPSG:3070
initialize_geometry::nc_crs = EPSG:4326
transforming coordinates using = proj=pipeline step inv proj=tmerc lat_0=0 lon_0=-90 k=0.
↪9996 x_0=520000 y_0=-4480000 ellps=GRS80 step proj=unitconvert xy_in=rad xy_out=deg
error getting data for cell_by_cell_flowstorage at time 1.0:list index out of range
error getting data for cell_by_cell_flowstorage at time 1097.0:list index out of range
```

[18]:
```
try:
    # ignore PermissionError on Windows
    temp_dir.cleanup()
except:
    pass
```

5.1.3 Exporting to VTK

The Vtk() class in FloPy allows users to export Structured, Vertex, and Unstructured Grid based models to Visualization ToolKit files for display. This notebook demonstrates how to use FloPy to export to vtk (.vtu) files. This example will cover:

- basic exporting of information for a model, individual package, or array to Vtk()
- example usage of the Vtk() class object to output data
- exporting heads and model output data
- exporting modpath pathlines to Vtk()

[1]:
```
import os
import sys
from pathlib import Path
from tempfile import TemporaryDirectory

import numpy as np

import flopy
from flopy.export import vtk

sys.path.append(os.path.join("..", "common"))
import notebook_utils
```

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```
print(sys.version)
print(f"flopy version: {flopy.__version__}")
```

```
3.8.18 (default, Aug 28 2023, 08:27:22)
[GCC 11.4.0]
flopy version: 3.5.0
```

[2]:
```
# load model for examples
nam_file = "freyberg.nam"
prj_root = notebook_utils.get_project_root_path()
model_ws = prj_root / "examples" / "data" / "freyberg_multilayer_transient"
ml = flopy.modflow.Modflow.load(nam_file, model_ws=model_ws, check=False)
```

Create a temporary workspace.

[3]:
```
tempdir = TemporaryDirectory()
workspace = Path(tempdir.name)
```

Using the `.export()` method

For all exports **a folder path must be provided** and the `fmt` flag should be set to 'vtk'.

Exporting FloPy arrays to .vtu files

All array exports have the following optional keyword arguments: - `smooth`: True creates a smooth surface, default is False - `point_scalars`: True outputs point scalar values as well as cell values, default is False. - `name`: A name can be specified to use for the output filename and array scalar name, by default the FloPy array name is used - `binary`: argument that can be specified to switch between binary and ASCII, default is True - `xml`: True will write an xml base vtk file, default is False - `masked_values`: list or tuple of values to mask (set to nan) when writing a array - `vertical_exageration`: floating point value that can be used to scale the vertical exageration of the vtk points. Default is 1.

Tranient type array exports ("stress_period_data"; ex. recharge data, well flux, etc ...) have additional optional keyword arguments: - `pvd`: True will write a paraview data file with simulation time for animations. Default is False - `kper`: a list, tuple, or integer value of specific stess periods to output

Export model top

[4]:
```
# create output folder
output_dir = workspace / "arrays_test"
output_dir.mkdir(exist_ok=True)

# export model top
model_top_dir = output_dir / "TOP"
ml.dis.top.export(model_top_dir, fmt="vtk")
```

Export model bottoms

[5]:
```
# 3D Array export
# export model bottoms
model_bottom_dir = output_dir / "BOTM"
ml.dis.botm.export(model_bottom_dir, fmt="vtk")
```

Export transient array recharge

[6]:
```
# transient 2d array
# export recharge
model_recharge_dir = output_dir / "RECH"
ml.rch.rech.export(model_recharge_dir, fmt="vtk", pvd=True)
```

```
Switching to xml, ASCII and standard binary are not supported by Paraview's PVD reader
```

Export HK with point scalars

[7]:
```
# 3D Array export
# hk export, with points
model_hk_dir = output_dir / "HK"
ml.upw.hk.export(
    model_hk_dir, smooth=True, fmt="vtk", name="HK", point_scalars=True
)
```

Package export to .vtu files

Package export has the following keyword arguments: - `smooth`: True creates a smooth surface, default is False - `point_scalars`: True outputs point scalar values as well as cell values, default is False. - `name`: A name can be specified to use for the output filename and array scalar name, by default the FloPy array name is used - `binary`: argument that can be specified to switch between binary and ASCII, default is True - `xml`: True will write an xml base vtk file, default is False - `masked_values`: list or tuple of values to mask (set to nan) when writing a array - `vertical_exageration`: floating point value that can be used to scale the vertical exageration of the vtk points. Default is 1. - `pvd`: True will write a paraview data file with simulation time for animations. Default is False - `kper`: a list, tuple, or integer value of specific stess periods to output

Export dis and upw package

[8]:
```
# package export
# set up package export folder
output_dir = workspace / "package_output_test"
output_dir.mkdir(exist_ok=True)

# export dis
dis_output_dir = output_dir / "DIS"
ml.dis.export(dis_output_dir, fmt="vtk")
```

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```
# export upw with point scalars as a binary xml based vtk file
upw_output_dir = output_dir / "UPW"
ml.upw.export(upw_output_dir, fmt="vtk", point_scalars=True, xml=True)
```

Model export to .vtu files

Model export has the following optional keyword arguments:

- `package_names`: a list of package names to export, default is None and will export all packages in the model.
- `smooth`: True creates a smooth surface, default is False
- `point_scalars`: True outputs point scalar values as well as cell values, default is False.
- `name`: A name can be specified to use for the output filename and array scalar name, by default the FloPy array name is used
- `binary`: argument that can be specified to switch between binary and ASCII, default is True
- `xml`: True will write an xml base vtk file, default is False
- `masked_values`: list or tuple of values to mask (set to nan) when writing a array
- `vertical_exageration`: floating point value that can be used to scale the vertical exageration of the vtk points. Default is 1.
- `pvd`: True will write a paraview data file with simulation time for animations. Default is False
- `kper`: a list, tuple, or integer value of specific stess periods to output

Export model as a binary unstructured vtk file

[9]:
```
model_output_dir = workspace / "model_output_test"
ml.export(model_output_dir, fmt="vtk")
```

Using the `Vtk` class

To export custom arrays, or choose a custom combination of model inputs to view, the user first needs to instantiate a new `Vtk()` object. The `Vtk()` object has a single required parameter and a number of optional parameters that the user can take advantage of. These parameters are as follows:

- `model`: any flopy model object can be supplied to create the vtk geometry. Either the model (recommended!) or modelgrid parameter must be supplied to the Vtk() object.
- `modelgrid`: any flopy modelgrid object (StructuredGrid, VertexGrid, UnstructuredGrid) can be supplied, in leiu of a model object, to create the vtk geometery.
- `vertical_exageration`: floating point value that can be used to scale the vertical exageration of the vtk points. Default is 1.
- `binary`: boolean flag to switch between binary and ASCII vtk files. Default is True.
- `xml`: boolean flag to write xml based vtk files. Default is False
- `pvd`: boolean flag to write a paraview data file for transient series of vtu files. This file relates model time to vtu file for animations. Default is False. If set to True Vtk() will automatically write xml based vtu files.

- `shared_points`: boolean flag to write shared vertices within the vtk file. Default is False.
- `smooth`: boolean flag to interpolate vertex elevations using IDW based on shared cell elevations. Default is False.
- `point_scalars`: boolean flag to write interpolated data at each point.

[10]:
```
# create a binary XML VTK object and enable PVD file writing
vtkobj = vtk.Vtk(ml, xml=True, pvd=True, vertical_exageration=10)
vtkobj
```

[10]:
```
<flopy.export.vtk.Vtk at 0x7f3b3c20ae80>
```

Adding array data to the `Vtk` object

The `Vtk()` object has an `add_array()` method that lets the user add array data to the Field data section of the VTK file.

`add_array()` has a few parameters for the user: - `array` : numpy array that has a size equal to the number of cells in the model (modelgrid.nnodes). - `name` : array name (string) - `masked_values` : list of array values to mask/set to NaN

[11]:
```
# Create a vtk object
vtkobj = vtk.Vtk(ml, vertical_exageration=10)

## create some random array data
r_array = np.random.random(ml.modelgrid.nnodes) * 100

## add random data to the VTK object
vtkobj.add_array(r_array, "random_data")

## add the model botom data to the VTK object
vtkobj.add_array(ml.dis.botm.array, "botm")

## write the vtk object to file
vtkobj.write(output_dir / "Array_example" / "model.vtu")
```

Adding transient array data to the `Vtk` object

The `Vtk` class has an `add_transient_array()` method that allows the user to create a series of time varying VTK files that can be used for animation in VTK viewers.

The `add_transient_array()` method accepts a dictionary of array2d, array3d, or numpy array objects. Parameters include: - d: dictionary of array2d, array3d, or numpy array objects - `name`: parameter name, required when user provides a dictionary of numpy arrays - `masked_values`: optional list of values to set equal to NaN.

[12]:
```
# create a vtk object
vtkobj = vtk.Vtk(ml, xml=True, pvd=True, vertical_exageration=10)

## add recharge to the VTK object
recharge = ml.rch.rech.transient_2ds
vtkobj.add_transient_array(
    recharge,
```

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```
    "recharge",
    masked_values=[
        0,
    ],
)

## write vtk files
vtkobj.write(output_dir / "tr_array_example" / "recharge.vtu")
```

Adding transient list data to the Vtk object

The Vtk class has an add_transient_list() method that allows the user to create a series of time varying VTK files that can be used for animation in VTK viewers.

The add_transient_list() method accepts a FloPy mflist (transient list) type object. Parameters include: - mflist: flopy transient list object - masked_values: list of values to set equal to NaN

[13]:
```
# create the vtk object
vtkobj = vtk.Vtk(ml, xml=True, pvd=True, vertical_exageration=10)

## add well fluxes to the VTK object
spd = ml.wel.stress_period_data
vtkobj.add_transient_list(
    spd,
    masked_values=[
        0,
    ],
)

## write vtk files
vtkobj.write(output_dir / "tr_list_example" / "wel_flux.vtu")
```

Adding packages to the Vtk object

The Vtk class has a method for adding package data to a VTK file as Field Data. The add_package() method allows the user to add packages for subsequent export. add_package() takes the following parameters:

- pkg: flopy package object
- masked_values: optional list of values to set to NaN.

In the following example, a HFB package is added to the existing freyberg model and then exported with the WEL package.

[14]:
```
# create a HFB package for the example
hfb_data = []
for k in range(3):
    for i in range(20):
        rec = [k, i, 6, i, 7, 1e-06]
        hfb_data.append(rec)

hfb = flopy.modflow.ModflowHfb(ml, hfb_data=hfb_data)
```

[15]:
```python
# export HFB and WEL packages using Vtk()
vtkobj = vtk.Vtk(ml, vertical_exageration=10)

vtkobj.add_package(hfb)
vtkobj.add_package(ml.wel)

vtkobj.write(output_dir / "package_example" / "package_export.vtu")
```

Exporting heads to binary .vtu files

Once a `Vtk` object is instantiated (see above), the `add_heads()` method can be used to add head data. This method has a few parameters: - `hds`: a flopy FormattedHeadFile or HeadFile object. This method also accepts DrawdownFile, and ConcentrationFile objects. - `kstpkper`: optional list of zero based (timestep, stress period) tuples to output. Default is None and will output all data to a series of vtu files - `masked_values`: optional list of values to set to NaN, default is None.

[16]:
```python
# import the HeadFile reader and read in the head file
from flopy.utils import HeadFile

head_file = model_ws / "freyberg.hds"
hds = HeadFile(head_file)

# create the vtk object and export heads
vtkobj = vtk.Vtk(ml, xml=True, pvd=True, vertical_exageration=10)
vtkobj.add_heads(hds)
vtkobj.write(workspace / "heads_output_test" / "freyberg_head.vtu")
```

Export heads as point scalar arrays

[17]:
```python
# export heads as point scalars
vtkobj = vtk.Vtk(
    ml, xml=True, pvd=True, point_scalars=True, vertical_exageration=10
)

# export heads for time step 1, stress periods 1, 50, 100, 1000
vtkobj.add_heads(hds, kstpkper=[(0, 0), (0, 49), (0, 99), (0, 999)])
vtkobj.write(workspace / "heads_output_test_parameters" / "freyberg_head.vtu")
```

Export cell budget information

Once a `Vtk` object is instantiated (see above), the `add_cell_budget()` method can be used to export cell budget data. This method has a few parameters: - `cbc`: flopy CellBudgetFile object - `text`: Optional text identifier for a record type. Examples include 'RIVER LEAKAGE', 'STORAGE', etc… Default is None and will export all cell budget information to vtk files - `kstpkper`: optional list of zero based (timestep, stress period) tuples to output. Default is None and will output all data to a series of vtu files - `masked_values`: optional list of values to set to NaN, default is None.

[18]:
```
# import the CellBudgetFile reader and read the CBC file
from flopy.utils import CellBudgetFile

cbc_file = model_ws / "freyberg.cbc"
cbc = CellBudgetFile(cbc_file)

# export the cbc file to a series of Vtu files with a PVD file for animation
vtkobj = vtk.Vtk(ml, xml=True, pvd=True, vertical_exageration=10)
vtkobj.add_cell_budget(cbc, kstpkper=[(0, 0), (0, 9), (0, 10), (0, 11)])
vtkobj.write(workspace / "cbc_output_test_parameters" / "freyberg_cbc.vtu")
```

Export vectors from the cell budget file

The `Vtk` class has an `add_vector()` method that allows the user to write vector information to VTK files. This method can be used to export information such as cell centered specific discharge.

The `add_vector()` method accepts a numpy array of vector data. The array size must be 3 * the number of model cells (3 * modelgrid.nnodes). Parameters include: - `vector`: numpy array of size 3 * nnodes - `name`: name of the vector - `masked_values`: list of values to set equal to NaN

[19]:
```
# get frf, fff, flf from the Cell Budget file (or SPDIS when using MF6)
from flopy.utils import postprocessing

frf = cbc.get_data(text="FLOW RIGHT FACE", kstpkper=(0, 9), full3D=True)[0]
fff = cbc.get_data(text="FLOW FRONT FACE", kstpkper=(0, 9), full3D=True)[0]
flf = cbc.get_data(text="FLOW LOWER FACE", kstpkper=(0, 9), full3D=True)[0]

spdis = postprocessing.get_specific_discharge((frf, fff, flf), ml)

# create the Vtk() object
vtkobj = vtk.Vtk(ml, vertical_exageration=10)

# add the vector
vtkobj.add_vector(spdis, name="spdis")

# write to file
vtkobj.write(output_dir / "vector_example" / "spdis_vector.vtu")
```

Exporting MODPATH timeseries or pathline data

The `Vtk` class supports writing MODPATH pathline/timeseries data to a VTK file. To start the example, let's first load and run a MODPATH simulation (see flopy3_modpath7_unstructured_example for details) and then add the output to a `Vtk` object.

[20]:
```
# load and run the vertex grid model and modpath7
notebook_utils.run(workspace)

# check if model ran properly
modelpth = workspace / "mp7_ex2" / "mf6"
files = ["mp7p2.hds", "mp7p2.cbb"]
for f in files:
```

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```
    if os.path.isfile(modelpth / f):
        msg = f"Output file located: {f}"
        print(msg)
    else:
        errmsg = f"Error. Output file cannot be found: {f}"
        print(errmsg)
```

```
WARNING: Unable to resolve dimension of ('gwf6', 'disv', 'cell2d', 'cell2d', 'icvert')␣
↪based on shape "ncvert".
writing simulation...
  writing simulation name file...
  writing simulation tdis package...
  writing solution package ims...
  writing model mp7p2...
    writing model name file...
    writing package disv...
    writing package ic...
    writing package npf...
    writing package wel_0...
INFORMATION: maxbound in ('gwf6', 'wel', 'dimensions') changed to 1 based on size of␣
↪stress_period_data
    writing package rcha_0...
    writing package riv_0...
INFORMATION: maxbound in ('gwf6', 'riv', 'dimensions') changed to 21 based on size of␣
↪stress_period_data
    writing package oc...
                                   MODFLOW 6
                U.S. GEOLOGICAL SURVEY MODULAR HYDROLOGIC MODEL
                            VERSION 6.4.2 06/28/2023

   MODFLOW 6 compiled Jul 05 2023 20:29:14 with Intel(R) Fortran Intel(R) 64
   Compiler Classic for applications running on Intel(R) 64, Version 2021.7.0
                             Build 20220726_000000

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 Run start date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:29:27

 Writing simulation list file: mfsim.lst
 Using Simulation name file: mfsim.nam
```

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```
    Solving:  Stress period:     1    Time step:     1

 Run end date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:29:27
 Elapsed run time:  0.095 Seconds


WARNING REPORT:

  1. NONLINEAR BLOCK VARIABLE 'OUTER_HCLOSE' IN FILE 'mp7p2.ims' WAS
     DEPRECATED IN VERSION 6.1.1. SETTING OUTER_DVCLOSE TO OUTER_HCLOSE VALUE.
  2. LINEAR BLOCK VARIABLE 'INNER_HCLOSE' IN FILE 'mp7p2.ims' WAS DEPRECATED
     IN VERSION 6.1.1. SETTING INNER_DVCLOSE TO INNER_HCLOSE VALUE.
 Normal termination of simulation.

MODPATH Version 7.2.001
Program compiled Jul 05 2023 20:31:49 with IFORT compiler (ver. 20.21.7)


Run particle tracking simulation ...
Processing Time Step     1 Period     1.  Time =  1.00000E+03  Steady-state flow

Particle Summary:
         0 particles are pending release.
         0 particles remain active.
        16 particles terminated at boundary faces.
         0 particles terminated at weak sink cells.
         0 particles terminated at weak source cells.
         0 particles terminated at strong source/sink cells.
         0 particles terminated in cells with a specified zone number.
         0 particles were stranded in inactive or dry cells.
         0 particles were unreleased.
         0 particles have an unknown status.

Normal termination.

MODPATH Version 7.2.001
Program compiled Jul 05 2023 20:31:49 with IFORT compiler (ver. 20.21.7)


Run particle tracking simulation ...
Processing Time Step     1 Period     1.  Time =  1.00000E+03  Steady-state flow

Particle Summary:
         0 particles are pending release.
         0 particles remain active.
       416 particles terminated at boundary faces.
         0 particles terminated at weak sink cells.
         0 particles terminated at weak source cells.
         0 particles terminated at strong source/sink cells.
         0 particles terminated in cells with a specified zone number.
         0 particles were stranded in inactive or dry cells.
```

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```
        0 particles were unreleased.
        0 particles have an unknown status.

Normal termination.
Output file located: mp7p2.hds
Output file located: mp7p2.cbb
```

[21]:
```
# load the simulation and get the model
vertex_sim_name = "mfsim.nam"
vertex_sim = flopy.mf6.MFSimulation.load(
    sim_name=vertex_sim_name, exe_name="mf6", sim_ws=modelpth
)
vertex_ml6 = vertex_sim.get_model("mp7p2")

# load the MODPATH-7 results
mp_namea = "mp7p2a_mp"
fpth = modelpth / f"{mp_namea}.mppth"
p = flopy.utils.PathlineFile(fpth)
p0 = p.get_alldata()
```

```
loading simulation...
  loading simulation name file...
  loading tdis package...
  loading model gwf6...
    loading package disv...
WARNING: Unable to resolve dimension of ('gwf6', 'disv', 'cell2d', 'cell2d', 'icvert')␣
↪based on shape "ncvert".
    loading package ic...
    loading package npf...
    loading package wel...
    loading package rch...
    loading package riv...
    loading package oc...
  loading solution package mp7p2...
```

Create the `Vtk()` object and add all of the model data to it

[22]:
```
vtkobj = vtk.Vtk(vertex_ml6, xml=True, pvd=True, vertical_exageration=10)
vtkobj.add_model(vertex_ml6)
```

Add modpath data to the `Vtk()` object.

Note: this will create a second vtk file that has the file signature: `myfilename)_pathline.vtu`

[23]:
```
vtkobj.add_pathline_points(p0, timeseries=False)
vtkobj.write(output_dir / "mp7_vertex_example" / "vertex_ex.vtu")
```

Clean up the temporary workspace.

[24]:
```
try:
    # ignore PermissionError on Windows
    tempdir.cleanup()
except:
    pass
```

5.1.4 External file handling

[1]:
```python
import os
import shutil
import sys
from tempfile import TemporaryDirectory

import numpy as np

import flopy
from flopy.utils import flopy_io

print(sys.version)
print(f"numpy version: {np.__version__}")
print(f"flopy version: {flopy.__version__}")
```

```
3.8.18 (default, Aug 28 2023, 08:27:22)
[GCC 11.4.0]
numpy version: 1.24.4
flopy version: 3.5.0
```

[2]:
```python
# make a model
nlay, nrow, ncol = 10, 20, 5
temp_dir = TemporaryDirectory()
model_ws = temp_dir.name

# the place for all of your hand made and costly model inputs
array_dir = os.path.join(temp_dir.name, "array_dir")
os.mkdir(array_dir)

ml = flopy.modflow.Modflow(model_ws=model_ws)
dis = flopy.modflow.ModflowDis(
    ml, nlay=nlay, nrow=nrow, ncol=ncol, steady=False, nper=2
)
```

make an hk and vka array. We'll save hk to files - pretent that you spent months making this important model property. Then make an `lpf`

[3]:
```python
hk = np.zeros((nlay, nrow, ncol)) + 5.0
vka = np.zeros_like(hk)
fnames = []
for i, h in enumerate(hk):
    fname = os.path.join(array_dir, f"hk_{i + 1}.ref")
    fnames.append(fname)
    np.savetxt(fname, h)
    vka[i] = i + 1
lpf = flopy.modflow.ModflowLpf(ml, hk=fnames, vka=vka)
```

Let's also have some recharge with mixed args as well. Pretend the recharge in the second stress period is very important and precise

[4]:
```python
warmup_recharge = np.ones((nrow, ncol))
important_recharge = np.random.random((nrow, ncol))
fname = os.path.join(array_dir, "important_recharge.ref")
```

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```python
np.savetxt(fname, important_recharge)
rch = flopy.modflow.ModflowRch(ml, rech={0: warmup_recharge, 1: fname})
```

[5]:
```python
ml.write_input()
```

Let's look at the files that were created

[6]:
```python
from pprint import pprint

print("model_ws:", flopy_io.scrub_login(ml.model_ws))
pprint([flopy_io.scrub_login(p) for p in os.listdir(ml.model_ws)])
```

```
model_ws: /tmp/tmpd8qwka1j
['hk_8.ref',
 'hk_5.ref',
 'hk_2.ref',
 'hk_3.ref',
 'modflowtest.rch',
 'important_recharge.ref',
 'hk_1.ref',
 'hk_6.ref',
 'hk_10.ref',
 'array_dir',
 'hk_7.ref',
 'hk_4.ref',
 'modflowtest.nam',
 'modflowtest.lpf',
 'hk_9.ref',
 'modflowtest.dis']
```

We see that a copy of the hk files as well as the important recharge file were made in the `model_ws`.Let's looks at the `lpf` file

[7]:
```python
open(os.path.join(ml.model_ws, f"{ml.name}.lpf")).readlines()[:20]
```

[7]:
```
['# LPF package for MODFLOW-2005 generated by Flopy 3.5.0\n',
 '         0     -1E+30         0  \n',
 '         0         0         0         0         0         0         0         0  ␣
↪  0         0\n',
 '         0         0         0         0         0         0         0         0  ␣
↪  0         0\n',
 '   1.000000E+00    1.000000E+00    1.000000E+00    1.000000E+00    1.000000E+00    1.
↪000000E+00    1.000000E+00    1.000000E+00    1.000000E+00    1.000000E+00\n',
 '         0         0         0         0         0         0         0         0  ␣
↪  0         0\n',
 '         0         0         0         0         0         0         0         0  ␣
↪  0         0\n',
 'OPEN/CLOSE                       hk_1.ref                1      (FREE)  -1 hk layer 1  ␣
↪                  \n',
 'INTERNAL                1    (5E15.6) -1 #vka1                          \n',
 '   1.000000E+00    1.000000E+00    1.000000E+00    1.000000E+00    1.000000E+00\n',
 '   1.000000E+00    1.000000E+00    1.000000E+00    1.000000E+00    1.000000E+00\n',
 '   1.000000E+00    1.000000E+00    1.000000E+00    1.000000E+00    1.000000E+00\n',
```

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```
'    1.000000E+00    1.000000E+00    1.000000E+00    1.000000E+00    1.000000E+00\n',
'    1.000000E+00    1.000000E+00    1.000000E+00    1.000000E+00    1.000000E+00\n',
'    1.000000E+00    1.000000E+00    1.000000E+00    1.000000E+00    1.000000E+00\n',
'    1.000000E+00    1.000000E+00    1.000000E+00    1.000000E+00    1.000000E+00\n',
'    1.000000E+00    1.000000E+00    1.000000E+00    1.000000E+00    1.000000E+00\n',
'    1.000000E+00    1.000000E+00    1.000000E+00    1.000000E+00    1.000000E+00\n',
'    1.000000E+00    1.000000E+00    1.000000E+00    1.000000E+00    1.000000E+00\n',
'    1.000000E+00    1.000000E+00    1.000000E+00    1.000000E+00    1.000000E+00\n']
```

We see that the `open/close` approach was used - this is because `ml.array_free_format` is `True`. Notice that `vka` is written internally

[8]:
```
ml.array_free_format
```

[8]:
```
True
```

Now change `model_ws`

[9]:
```
ml.model_ws = os.path.join(model_ws, "new_external_demo_dir")
```

```

creating model workspace...
   ../../../../../../../tmp/tmpd8qwka1j/new_external_demo_dir
```

Now when we call `write_input()`, a copy of external files are made in the current `model_ws`

[10]:
```
ml.write_input()
```

[11]:
```
# list the files in model_ws that have 'hk' in the name
print(
    "\n".join(
        [
            name
            for name in os.listdir(ml.model_ws)
            if "hk" in name or "impor" in name
        ]
    )
)
```

```
hk_8.ref
hk_5.ref
hk_2.ref
hk_3.ref
important_recharge.ref
hk_1.ref
hk_6.ref
hk_10.ref
hk_7.ref
hk_4.ref
hk_9.ref
```

Now we see that the external files were copied to the new `model_ws`

Using external_path

It is sometimes useful when first building a model to write the model arrays as external files for processing and parameter estimation. The model attribute external_path triggers this behavior

[12]:
```
# make a model - same code as before except for the model constructor
nlay, nrow, ncol = 10, 20, 5
model_ws = os.path.join(model_ws, "external_demo")
os.mkdir(model_ws)

# the place for all of your hand made and costly model inputs
array_dir = os.path.join(model_ws, "array_dir")
os.mkdir(array_dir)

# lets make an external path relative to the model_ws
ml = flopy.modflow.Modflow(
    model_ws=model_ws, external_path=os.path.join(model_ws, "ref")
)
dis = flopy.modflow.ModflowDis(
    ml, nlay=nlay, nrow=nrow, ncol=ncol, steady=False, nper=2
)

hk = np.zeros((nlay, nrow, ncol)) + 5.0
vka = np.zeros_like(hk)
fnames = []
for i, h in enumerate(hk):
    fname = os.path.join(array_dir, f"hk_{i + 1}.ref")
    fnames.append(fname)
    np.savetxt(fname, h)
    vka[i] = i + 1
lpf = flopy.modflow.ModflowLpf(ml, hk=fnames, vka=vka)

warmup_recharge = np.ones((nrow, ncol))
important_recharge = np.random.random((nrow, ncol))
fname = os.path.join(array_dir, "important_recharge.ref")
np.savetxt(fname, important_recharge)
rch = flopy.modflow.ModflowRch(ml, rech={0: warmup_recharge, 1: fname})
```

We can see that the model constructor created both model_ws and external_path which is *relative to the model_ws*

[13]:
```
os.listdir(ml.model_ws)
```

[13]:
```
['array_dir', 'ref']
```

Now, when we call write_input(), any array properties that were specified as np.ndarray will be written externally. If a scalar was passed as the argument, the value remains internal to the model input files

[14]:
```
ml.write_input()
# open(os.path.join(ml.model_ws, ml.name + ".lpf"), "r").readlines()[:20]
```

```
Util2d:delr: resetting 'how' to external
Util2d:delc: resetting 'how' to external
Util2d:model_top: resetting 'how' to external
Util2d:botm layer 1: resetting 'how' to external
Util2d:botm layer 2: resetting 'how' to external
```

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```
Util2d:botm layer 3: resetting 'how' to external
Util2d:botm layer 4: resetting 'how' to external
Util2d:botm layer 5: resetting 'how' to external
Util2d:botm layer 6: resetting 'how' to external
Util2d:botm layer 7: resetting 'how' to external
Util2d:botm layer 8: resetting 'how' to external
Util2d:botm layer 9: resetting 'how' to external
Util2d:botm layer 10: resetting 'how' to external
Util2d:ss layer 1: resetting 'how' to external
Util2d:ss layer 2: resetting 'how' to external
Util2d:ss layer 3: resetting 'how' to external
Util2d:ss layer 4: resetting 'how' to external
Util2d:ss layer 5: resetting 'how' to external
Util2d:ss layer 6: resetting 'how' to external
Util2d:ss layer 7: resetting 'how' to external
Util2d:ss layer 8: resetting 'how' to external
Util2d:ss layer 9: resetting 'how' to external
Util2d:ss layer 10: resetting 'how' to external
```

Now, `vka` was also written externally, but not the storage properties.Let's verify the contents of the external path directory. We see our hard-fought `hk` and `important_recharge` arrays, as well as the `vka` arrays.

[15]:
```
ml.lpf.ss.how = "internal"
ml.write_input()
# open(os.path.join(ml.model_ws, ml.name + ".lpf"), "r").readlines()[:20]
```

```
Util2d:delr: resetting 'how' to external
Util2d:delc: resetting 'how' to external
Util2d:model_top: resetting 'how' to external
Util2d:botm layer 1: resetting 'how' to external
Util2d:botm layer 2: resetting 'how' to external
Util2d:botm layer 3: resetting 'how' to external
Util2d:botm layer 4: resetting 'how' to external
Util2d:botm layer 5: resetting 'how' to external
Util2d:botm layer 6: resetting 'how' to external
Util2d:botm layer 7: resetting 'how' to external
Util2d:botm layer 8: resetting 'how' to external
Util2d:botm layer 9: resetting 'how' to external
Util2d:botm layer 10: resetting 'how' to external
Util2d:ss layer 1: resetting 'how' to external
Util2d:ss layer 2: resetting 'how' to external
Util2d:ss layer 3: resetting 'how' to external
Util2d:ss layer 4: resetting 'how' to external
Util2d:ss layer 5: resetting 'how' to external
Util2d:ss layer 6: resetting 'how' to external
Util2d:ss layer 7: resetting 'how' to external
Util2d:ss layer 8: resetting 'how' to external
Util2d:ss layer 9: resetting 'how' to external
Util2d:ss layer 10: resetting 'how' to external
```

[16]:
```
print("\n".join(os.listdir(os.path.join(ml.model_ws, ml.external_path))))
```

```
hk_8.ref
hk_5.ref
hk_2.ref
vka9.ref
hk_3.ref
botm_layer_5.ref
vka5.ref
vka3.ref
botm_layer_8.ref
ss_layer_8.ref
ss_layer_9.ref
botm_layer_6.ref
botm_layer_1.ref
vka4.ref
important_recharge.ref
hk_1.ref
hk_6.ref
vka2.ref
delc.ref
hk_10.ref
ss_layer_1.ref
hk_7.ref
botm_layer_7.ref
ss_layer_7.ref
ss_layer_5.ref
hk_4.ref
delr.ref
botm_layer_4.ref
ss_layer_10.ref
model_top.ref
ss_layer_6.ref
botm_layer_10.ref
vka7.ref
vka6.ref
hk_9.ref
botm_layer_3.ref
botm_layer_2.ref
ss_layer_2.ref
rech_0.ref
ss_layer_4.ref
vka10.ref
vka1.ref
ss_layer_3.ref
vka8.ref
botm_layer_9.ref
```

Fixed format

All of this behavior also works for fixed-format type models (really, really old models - I mean OLD!)

[17]:
```
# make a model - same code as before except for the model constructor
nlay, nrow, ncol = 10, 20, 5

# lets make an external path relative to the model_ws
ml = flopy.modflow.Modflow(model_ws=model_ws, external_path="ref")

# explicitly reset the free_format flag BEFORE ANY PACKAGES ARE MADE!!!
ml.array_free_format = False

dis = flopy.modflow.ModflowDis(
    ml, nlay=nlay, nrow=nrow, ncol=ncol, steady=False, nper=2
)

hk = np.zeros((nlay, nrow, ncol)) + 5.0
vka = np.zeros_like(hk)
fnames = []
for i, h in enumerate(hk):
    fname = os.path.join(array_dir, f"hk_{i + 1}.ref")
    fnames.append(fname)
    np.savetxt(fname, h)
    vka[i] = i + 1
lpf = flopy.modflow.ModflowLpf(ml, hk=fnames, vka=vka)
ml.lpf.ss.how = "internal"
warmup_recharge = np.ones((nrow, ncol))
important_recharge = np.random.random((nrow, ncol))
fname = os.path.join(array_dir, "important_recharge.ref")
np.savetxt(fname, important_recharge)
rch = flopy.modflow.ModflowRch(ml, rech={0: warmup_recharge, 1: fname})

ml.write_input()
```

```
Note: external_path ref already exists
Util2d:delr: resetting 'how' to external
Util2d:delc: resetting 'how' to external
Util2d:model_top: resetting 'how' to external
Util2d:botm layer 1: resetting 'how' to external
Util2d:botm layer 2: resetting 'how' to external
Util2d:botm layer 3: resetting 'how' to external
Util2d:botm layer 4: resetting 'how' to external
Util2d:botm layer 5: resetting 'how' to external
Util2d:botm layer 6: resetting 'how' to external
Util2d:botm layer 7: resetting 'how' to external
Util2d:botm layer 8: resetting 'how' to external
Util2d:botm layer 9: resetting 'how' to external
Util2d:botm layer 10: resetting 'how' to external
Util2d hk layer 1: can't be free format...resetting
Util2d:ss layer 1: resetting 'how' to external
Util2d hk layer 2: can't be free format...resetting
Util2d:ss layer 2: resetting 'how' to external
Util2d hk layer 3: can't be free format...resetting
```

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```
Util2d:ss layer 3: resetting 'how' to external
Util2d hk layer 4: can't be free format...resetting
Util2d:ss layer 4: resetting 'how' to external
Util2d hk layer 5: can't be free format...resetting
Util2d:ss layer 5: resetting 'how' to external
Util2d hk layer 6: can't be free format...resetting
Util2d:ss layer 6: resetting 'how' to external
Util2d hk layer 7: can't be free format...resetting
Util2d:ss layer 7: resetting 'how' to external
Util2d hk layer 8: can't be free format...resetting
Util2d:ss layer 8: resetting 'how' to external
Util2d hk layer 9: can't be free format...resetting
Util2d:ss layer 9: resetting 'how' to external
Util2d hk layer 10: can't be free format...resetting
Util2d:ss layer 10: resetting 'how' to external
Util2d rech_2: can't be free format...resetting
```

We see that now the external arrays are being handled through the name file. Let's look at the name file

[18]:
```
open(os.path.join(ml.model_ws, f"{ml.name}.nam")).readlines()
```

[18]:
```
['# Name file for MODFLOW-2005, generated by Flopy version 3.5.0.\n',
 '#xll:0.0; yll:0.0; rotation:0.0; units:meters; lenuni:2; start_datetime:1-1-1970\n',
 'LIST               2  modflowtest.list\n',
 'DIS               11  modflowtest.dis\n',
 'LPF               15  modflowtest.lpf\n',
 'RCH               19  modflowtest.rch\n',
 'DATA            1001  ref/delr.ref\n',
 'DATA            1002  ref/delc.ref\n',
 'DATA            1003  ref/model_top.ref\n',
 'DATA            1004  ref/botm_layer_1.ref\n',
 'DATA            1005  ref/botm_layer_2.ref\n',
 'DATA            1006  ref/botm_layer_3.ref\n',
 'DATA            1007  ref/botm_layer_4.ref\n',
 'DATA            1008  ref/botm_layer_5.ref\n',
 'DATA            1009  ref/botm_layer_6.ref\n',
 'DATA            1010  ref/botm_layer_7.ref\n',
 'DATA            1011  ref/botm_layer_8.ref\n',
 'DATA            1012  ref/botm_layer_9.ref\n',
 'DATA            1013  ref/botm_layer_10.ref\n',
 'DATA            1014  ref/hk_1.ref\n',
 'DATA            1015  ref/vka1.ref\n',
 'DATA            1016  ref/ss_layer_1.ref\n',
 'DATA            1017  ref/hk_2.ref\n',
 'DATA            1018  ref/vka2.ref\n',
 'DATA            1019  ref/ss_layer_2.ref\n',
 'DATA            1020  ref/hk_3.ref\n',
 'DATA            1021  ref/vka3.ref\n',
 'DATA            1022  ref/ss_layer_3.ref\n',
 'DATA            1023  ref/hk_4.ref\n',
 'DATA            1024  ref/vka4.ref\n',
 'DATA            1025  ref/ss_layer_4.ref\n',
 'DATA            1026  ref/hk_5.ref\n',
```

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```
 'DATA            1027  ref/vka5.ref\n',
 'DATA            1028  ref/ss_layer_5.ref\n',
 'DATA            1029  ref/hk_6.ref\n',
 'DATA            1030  ref/vka6.ref\n',
 'DATA            1031  ref/ss_layer_6.ref\n',
 'DATA            1032  ref/hk_7.ref\n',
 'DATA            1033  ref/vka7.ref\n',
 'DATA            1034  ref/ss_layer_7.ref\n',
 'DATA            1035  ref/hk_8.ref\n',
 'DATA            1036  ref/vka8.ref\n',
 'DATA            1037  ref/ss_layer_8.ref\n',
 'DATA            1038  ref/hk_9.ref\n',
 'DATA            1039  ref/vka9.ref\n',
 'DATA            1040  ref/ss_layer_9.ref\n',
 'DATA            1041  ref/hk_10.ref\n',
 'DATA            1042  ref/vka10.ref\n',
 'DATA            1043  ref/ss_layer_10.ref\n',
 'DATA            1044  ref/rech_0.ref\n',
 'DATA            1045  ref/important_recharge.ref\n']
```

Free and binary format

[19]:
```
ml.dis.botm[0].format.binary = True
ml.write_input()
```

```
Util2d:delr: resetting 'how' to external
Util2d:delc: resetting 'how' to external
Util2d:model_top: resetting 'how' to external
Util2d:botm layer 1: resetting 'how' to external
Util2d:botm layer 2: resetting 'how' to external
Util2d:botm layer 3: resetting 'how' to external
Util2d:botm layer 4: resetting 'how' to external
Util2d:botm layer 5: resetting 'how' to external
Util2d:botm layer 6: resetting 'how' to external
Util2d:botm layer 7: resetting 'how' to external
Util2d:botm layer 8: resetting 'how' to external
Util2d:botm layer 9: resetting 'how' to external
Util2d:botm layer 10: resetting 'how' to external
Util2d:ss layer 1: resetting 'how' to external
Util2d:ss layer 2: resetting 'how' to external
Util2d:ss layer 3: resetting 'how' to external
Util2d:ss layer 4: resetting 'how' to external
Util2d:ss layer 5: resetting 'how' to external
Util2d:ss layer 6: resetting 'how' to external
Util2d:ss layer 7: resetting 'how' to external
Util2d:ss layer 8: resetting 'how' to external
Util2d:ss layer 9: resetting 'how' to external
Util2d:ss layer 10: resetting 'how' to external
```

[20]:
```
open(os.path.join(ml.model_ws, f"{ml.name}.nam")).readlines()
```

[20]:
```
['# Name file for MODFLOW-2005, generated by Flopy version 3.5.0.\n',
 '#xll:0.0; yll:0.0; rotation:0.0; units:meters; lenuni:2; start_datetime:1-1-1970\n',
 'LIST               2  modflowtest.list\n',
 'DIS               11  modflowtest.dis\n',
 'LPF               15  modflowtest.lpf\n',
 'RCH               19  modflowtest.rch\n',
 'DATA            1046  ref/delr.ref\n',
 'DATA            1047  ref/delc.ref\n',
 'DATA            1048  ref/model_top.ref\n',
 'DATA(BINARY)    1049  ref/botm_layer_1.ref\n',
 'DATA            1050  ref/botm_layer_2.ref\n',
 'DATA            1051  ref/botm_layer_3.ref\n',
 'DATA            1052  ref/botm_layer_4.ref\n',
 'DATA            1053  ref/botm_layer_5.ref\n',
 'DATA            1054  ref/botm_layer_6.ref\n',
 'DATA            1055  ref/botm_layer_7.ref\n',
 'DATA            1056  ref/botm_layer_8.ref\n',
 'DATA            1057  ref/botm_layer_9.ref\n',
 'DATA            1058  ref/botm_layer_10.ref\n',
 'DATA            1059  ref/hk_1.ref\n',
 'DATA            1060  ref/vka1.ref\n',
 'DATA            1061  ref/ss_layer_1.ref\n',
 'DATA            1062  ref/hk_2.ref\n',
 'DATA            1063  ref/vka2.ref\n',
 'DATA            1064  ref/ss_layer_2.ref\n',
 'DATA            1065  ref/hk_3.ref\n',
 'DATA            1066  ref/vka3.ref\n',
 'DATA            1067  ref/ss_layer_3.ref\n',
 'DATA            1068  ref/hk_4.ref\n',
 'DATA            1069  ref/vka4.ref\n',
 'DATA            1070  ref/ss_layer_4.ref\n',
 'DATA            1071  ref/hk_5.ref\n',
 'DATA            1072  ref/vka5.ref\n',
 'DATA            1073  ref/ss_layer_5.ref\n',
 'DATA            1074  ref/hk_6.ref\n',
 'DATA            1075  ref/vka6.ref\n',
 'DATA            1076  ref/ss_layer_6.ref\n',
 'DATA            1077  ref/hk_7.ref\n',
 'DATA            1078  ref/vka7.ref\n',
 'DATA            1079  ref/ss_layer_7.ref\n',
 'DATA            1080  ref/hk_8.ref\n',
 'DATA            1081  ref/vka8.ref\n',
 'DATA            1082  ref/ss_layer_8.ref\n',
 'DATA            1083  ref/hk_9.ref\n',
 'DATA            1084  ref/vka9.ref\n',
 'DATA            1085  ref/ss_layer_9.ref\n',
 'DATA            1086  ref/hk_10.ref\n',
 'DATA            1087  ref/vka10.ref\n',
 'DATA            1088  ref/ss_layer_10.ref\n',
 'DATA            1089  ref/rech_0.ref\n',
 'DATA            1090  ref/important_recharge.ref\n']
```

[21]:
```python
open(os.path.join(ml.model_ws, f"{ml.name}.dis")).readlines()
```

[21]:
```
['# DIS package for MODFLOW-2005 generated by Flopy 3.5.0\n',
 '        10        20         5         2         4         2\n',
 '  0  0  0  0  0  0  0  0  0  0\n',
 '      1046         1           (5E15.6)        -1 #delr\n',
 '      1047         1          (20E15.6)        -1 #delc\n',
 '      1048         1           (5E15.6)        -1 #model_top\n',
 '     -1049         1           (BINARY)        -1 #botm layer 1\n',
 '      1050         1           (5E15.6)        -1 #botm layer 2\n',
 '      1051         1           (5E15.6)        -1 #botm layer 3\n',
 '      1052         1           (5E15.6)        -1 #botm layer 4\n',
 '      1053         1           (5E15.6)        -1 #botm layer 5\n',
 '      1054         1           (5E15.6)        -1 #botm layer 6\n',
 '      1055         1           (5E15.6)        -1 #botm layer 7\n',
 '      1056         1           (5E15.6)        -1 #botm layer 8\n',
 '      1057         1           (5E15.6)        -1 #botm layer 9\n',
 '      1058         1           (5E15.6)        -1 #botm layer 10\n',
 '      1.000000             1  1.000000  TR\n',
 '      1.000000             1  1.000000  TR\n']
```

The `.how` attribute

Util2d includes a `.how` attribute that gives finer grained control of how arrays will written

[22]:
```python
ml.lpf.hk[0].how
```

[22]:
```
'external'
```

This will raise an error since our model does not support free format…

[23]:
```python
try:
    ml.lpf.hk[0].how = "openclose"
    ml.lpf.hk[0].how
    ml.write_input()
except Exception as e:
    print("\n", e, "\n")
```

```
Util2d:delr: resetting 'how' to external
Util2d:delc: resetting 'how' to external
Util2d:model_top: resetting 'how' to external
Util2d:botm layer 1: resetting 'how' to external
Util2d:botm layer 2: resetting 'how' to external
Util2d:botm layer 3: resetting 'how' to external
Util2d:botm layer 4: resetting 'how' to external
Util2d:botm layer 5: resetting 'how' to external
Util2d:botm layer 6: resetting 'how' to external
Util2d:botm layer 7: resetting 'how' to external
Util2d:botm layer 8: resetting 'how' to external
Util2d:botm layer 9: resetting 'how' to external
Util2d:botm layer 10: resetting 'how' to external

 Util2d error: 'how' is openclose, but model doesn't support free fmt
```

So let's reset hk layer 1 back to external. . .

[24]:
```
ml.lpf.hk[0].how = "external"
ml.lpf.hk[0].how
```

[24]:
```
'external'
```

[25]:
```
ml.dis.top.how = "external"
```

[26]:
```
ml.write_input()
```

```
Util2d:delr: resetting 'how' to external
Util2d:delc: resetting 'how' to external
Util2d:botm layer 1: resetting 'how' to external
Util2d:botm layer 2: resetting 'how' to external
Util2d:botm layer 3: resetting 'how' to external
Util2d:botm layer 4: resetting 'how' to external
Util2d:botm layer 5: resetting 'how' to external
Util2d:botm layer 6: resetting 'how' to external
Util2d:botm layer 7: resetting 'how' to external
Util2d:botm layer 8: resetting 'how' to external
Util2d:botm layer 9: resetting 'how' to external
Util2d:botm layer 10: resetting 'how' to external
Util2d:ss layer 1: resetting 'how' to external
Util2d:ss layer 2: resetting 'how' to external
Util2d:ss layer 3: resetting 'how' to external
Util2d:ss layer 4: resetting 'how' to external
Util2d:ss layer 5: resetting 'how' to external
Util2d:ss layer 6: resetting 'how' to external
Util2d:ss layer 7: resetting 'how' to external
Util2d:ss layer 8: resetting 'how' to external
Util2d:ss layer 9: resetting 'how' to external
Util2d:ss layer 10: resetting 'how' to external
```

[27]:
```
open(os.path.join(ml.model_ws, f"{ml.name}.dis")).readlines()
```

[27]:
```
['# DIS package for MODFLOW-2005 generated by Flopy 3.5.0\n',
 '         10        20         5         2         4         2\n',
 '  0   0   0   0   0   0   0   0   0   0\n',
 '      1104         1           (5E15.6)        -1 #delr\n',
 '      1105         1          (20E15.6)        -1 #delc\n',
 '      1106         1           (5E15.6)        -1 #model_top\n',
 '     -1107         1           (BINARY)        -1 #botm layer 1\n',
 '      1108         1           (5E15.6)        -1 #botm layer 2\n',
 '      1109         1           (5E15.6)        -1 #botm layer 3\n',
 '      1110         1           (5E15.6)        -1 #botm layer 4\n',
 '      1111         1           (5E15.6)        -1 #botm layer 5\n',
 '      1112         1           (5E15.6)        -1 #botm layer 6\n',
 '      1113         1           (5E15.6)        -1 #botm layer 7\n',
 '      1114         1           (5E15.6)        -1 #botm layer 8\n',
 '      1115         1           (5E15.6)        -1 #botm layer 9\n',
 '      1116         1           (5E15.6)        -1 #botm layer 10\n',
 '      1.000000             1  1.000000  TR\n',
 '      1.000000             1  1.000000  TR\n']
```

[28]:
```
open(os.path.join(ml.model_ws, f"{ml.name}.lpf")).readlines()
```

[28]:
```
['# LPF package for MODFLOW-2005 generated by Flopy 3.5.0\n',
 '         0    -1E+30         0  \n',
 '         0         0         0         0         0         0         0         0  ␣
↪  0         0\n',
 '         0         0         0         0         0         0         0         0  ␣
↪  0         0\n',
 '    1.000000E+00   1.000000E+00   1.000000E+00   1.000000E+00   1.000000E+00   1.
↪000000E+00   1.000000E+00   1.000000E+00   1.000000E+00   1.000000E+00\n',
 '         0         0         0         0         0         0         0         0  ␣
↪  0         0\n',
 '         0         0         0         0         0         0         0         0  ␣
↪  0         0\n',
 '      1117         1           (5E15.6)        -1 #hk layer 1\n',
 '      1118         1           (5E15.6)        -1 #vka1\n',
 '      1119         1           (5E15.6)        -1 #ss layer 1\n',
 '      1120         1           (5E15.6)        -1 #hk layer 2\n',
 '      1121         1           (5E15.6)        -1 #vka2\n',
 '      1122         1           (5E15.6)        -1 #ss layer 2\n',
 '      1123         1           (5E15.6)        -1 #hk layer 3\n',
 '      1124         1           (5E15.6)        -1 #vka3\n',
 '      1125         1           (5E15.6)        -1 #ss layer 3\n',
 '      1126         1           (5E15.6)        -1 #hk layer 4\n',
 '      1127         1           (5E15.6)        -1 #vka4\n',
 '      1128         1           (5E15.6)        -1 #ss layer 4\n',
 '      1129         1           (5E15.6)        -1 #hk layer 5\n',
 '      1130         1           (5E15.6)        -1 #vka5\n',
 '      1131         1           (5E15.6)        -1 #ss layer 5\n',
 '      1132         1           (5E15.6)        -1 #hk layer 6\n',
 '      1133         1           (5E15.6)        -1 #vka6\n',
 '      1134         1           (5E15.6)        -1 #ss layer 6\n',
 '      1135         1           (5E15.6)        -1 #hk layer 7\n',
 '      1136         1           (5E15.6)        -1 #vka7\n',
 '      1137         1           (5E15.6)        -1 #ss layer 7\n',
 '      1138         1           (5E15.6)        -1 #hk layer 8\n',
 '      1139         1           (5E15.6)        -1 #vka8\n',
 '      1140         1           (5E15.6)        -1 #ss layer 8\n',
 '      1141         1           (5E15.6)        -1 #hk layer 9\n',
 '      1142         1           (5E15.6)        -1 #vka9\n',
 '      1143         1           (5E15.6)        -1 #ss layer 9\n',
 '      1144         1           (5E15.6)        -1 #hk layer 10\n',
 '      1145         1           (5E15.6)        -1 #vka10\n',
 '      1146         1           (5E15.6)        -1 #ss layer 10\n']
```

[29]:
```
open(os.path.join(ml.model_ws, f"{ml.name}.nam")).readlines()
```

[29]:
```
['# Name file for MODFLOW-2005, generated by Flopy version 3.5.0.\n',
 '#xll:0.0; yll:0.0; rotation:0.0; units:meters; lenuni:2; start_datetime:1-1-1970\n',
 'LIST               2  modflowtest.list\n',
 'DIS               11  modflowtest.dis\n',
 'LPF               15  modflowtest.lpf\n',
 'RCH               19  modflowtest.rch\n',
```

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```
'DATA            1104  ref/delr.ref\n',
'DATA            1105  ref/delc.ref\n',
'DATA            1106  ref/model_top.ref\n',
'DATA(BINARY)    1107  ref/botm_layer_1.ref\n',
'DATA            1108  ref/botm_layer_2.ref\n',
'DATA            1109  ref/botm_layer_3.ref\n',
'DATA            1110  ref/botm_layer_4.ref\n',
'DATA            1111  ref/botm_layer_5.ref\n',
'DATA            1112  ref/botm_layer_6.ref\n',
'DATA            1113  ref/botm_layer_7.ref\n',
'DATA            1114  ref/botm_layer_8.ref\n',
'DATA            1115  ref/botm_layer_9.ref\n',
'DATA            1116  ref/botm_layer_10.ref\n',
'DATA            1117  ref/hk_1.ref\n',
'DATA            1118  ref/vka1.ref\n',
'DATA            1119  ref/ss_layer_1.ref\n',
'DATA            1120  ref/hk_2.ref\n',
'DATA            1121  ref/vka2.ref\n',
'DATA            1122  ref/ss_layer_2.ref\n',
'DATA            1123  ref/hk_3.ref\n',
'DATA            1124  ref/vka3.ref\n',
'DATA            1125  ref/ss_layer_3.ref\n',
'DATA            1126  ref/hk_4.ref\n',
'DATA            1127  ref/vka4.ref\n',
'DATA            1128  ref/ss_layer_4.ref\n',
'DATA            1129  ref/hk_5.ref\n',
'DATA            1130  ref/vka5.ref\n',
'DATA            1131  ref/ss_layer_5.ref\n',
'DATA            1132  ref/hk_6.ref\n',
'DATA            1133  ref/vka6.ref\n',
'DATA            1134  ref/ss_layer_6.ref\n',
'DATA            1135  ref/hk_7.ref\n',
'DATA            1136  ref/vka7.ref\n',
'DATA            1137  ref/ss_layer_7.ref\n',
'DATA            1138  ref/hk_8.ref\n',
'DATA            1139  ref/vka8.ref\n',
'DATA            1140  ref/ss_layer_8.ref\n',
'DATA            1141  ref/hk_9.ref\n',
'DATA            1142  ref/vka9.ref\n',
'DATA            1143  ref/ss_layer_9.ref\n',
'DATA            1144  ref/hk_10.ref\n',
'DATA            1145  ref/vka10.ref\n',
'DATA            1146  ref/ss_layer_10.ref\n',
'DATA            1147  ref/rech_0.ref\n',
'DATA            1148  ref/important_recharge.ref\n']
```

[30]:
```
try:
    # ignore PermissionError on Windows
    temp_dir.cleanup()
except:
    pass
```

5.2 MODFLOW 6

5.2.1 MODFLOW 6: Accessing Simulation Settings, Models, and Packages

This tutorial shows how to view, access, and change the underlying package variables for MODFLOW 6 objects in FloPy. Interaction with a FloPy MODFLOW 6 model is different from other models, such as MODFLOW-2005, MT3D, and SEAWAT, for example.

The MODFLOW 6 simulation structure is arranged in the following generalized way:

```
SIMULATION --> PACKAGE --> Data

SIMULATION --> MODEL --> PACKAGE (--> PACKAGE) --> Data
```

This tutorial focuses on accessing simulation-wide FloPy settings and how to create and access models and packages. Tutorial 3, 4, and 5 offer a more in depth look at observation, time series, and time array series packages, and tutorial 6, 7, 8, and 9 offer a more in depth look at the data.

Create Simple Demonstration Model

This tutorial uses a simple demonstration simulation with one GWF Model. The model has 3 layers, 4 rows, and 5 columns. The model is set up to use multiple model layers in order to demonstrate some of the layered functionality in FloPy.

[1]:
```python
# package import
from pathlib import Path
from tempfile import TemporaryDirectory
```

[2]:
```python
import flopy
```

[3]:
```python
temp_dir = TemporaryDirectory()
workspace = temp_dir.name
name = "tutorial01_mf6_data"
```

[4]:
```python
# set up simulation and basic packages
sim = flopy.mf6.MFSimulation(sim_name=name, sim_ws=workspace)
flopy.mf6.ModflowTdis(
    sim, nper=10, perioddata=[[365.0, 1, 1.0] for _ in range(10)]
)
flopy.mf6.ModflowIms(sim)
gwf = flopy.mf6.ModflowGwf(sim, modelname=name, save_flows=True)
flopy.mf6.ModflowGwfdis(gwf, nlay=3, nrow=4, ncol=5)
flopy.mf6.ModflowGwfic(gwf)
flopy.mf6.ModflowGwfnpf(gwf, save_specific_discharge=True)
flopy.mf6.ModflowGwfchd(
    gwf, stress_period_data=[[(0, 0, 0), 1.0], [(2, 3, 4), 0.0]]
)
budget_file = f"{name}.bud"
head_file = f"{name}.hds"
flopy.mf6.ModflowGwfoc(
    gwf,
    budget_filerecord=budget_file,
```

(continues on next page)

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```
    head_filerecord=head_file,
    saverecord=[("HEAD", "ALL"), ("BUDGET", "ALL")],
)
print("Done creating simulation.")
```

```
Done creating simulation.
```

Accessing Simulation-Level Settings

FloPy has a number of settings that can be set for the entire simulation. These include how much information FloPy writes to the console, how to format the MODFLOW package files, and whether to verify MODFLOW data.

The verbosity level, which determines how much FloPy writes to command line output. The options are 1 for quiet, 2 for normal, and 3 for verbose. Below we set the verbosity level to verbose.

[5]:
```
sim.simulation_data.verbosity_level = 3
```

We can also set the number of spaces to indent data when writing package files by setting the indent string.

[6]:
```
sim.simulation_data.indent_string = "    "
```

Next we set the precision and number of characters written for floating point variables.

[7]:
```
sim.float_precision = 8
sim.float_characters = 15
```

Lastly, we disable verify_data and auto_set_sizes for faster performance. With these options disabled FloPy will not do any checking or autocorrecting of your data.

[8]:
```
sim.verify_data = False
sim.auto_set_sizes = False
```

Accessing Models and Packages

At this point a simulation is available in memory. In this particular case the simulation was created directly using Python code; however, the simulation might also have been loaded from existing model files using the `FloPy.mf6.MFSimulation.load()` function.

Once a MODFLOW 6 simulation is available in memory, the contents of the simulation object can be listed using a simple print command.

[9]:
```
print(sim)
```

```
sim_name = tutorial01_mf6_data
sim_path = /tmp/tmpp_e3z2bo
exe_name = mf6

###################
Package mfsim.nam
###################

package_name = mfsim.nam
```

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```
filename = mfsim.nam
package_type = nam
model_or_simulation_package = simulation
simulation_name = tutorial01_mf6_data


###################
Package tutorial01_mf6_data.tdis
###################

package_name = tutorial01_mf6_data.tdis
filename = tutorial01_mf6_data.tdis
package_type = tdis
model_or_simulation_package = simulation
simulation_name = tutorial01_mf6_data


###################
Package ims_-1
###################

package_name = ims_-1
filename = tutorial01_mf6_data.ims
package_type = ims
model_or_simulation_package = simulation
simulation_name = tutorial01_mf6_data


@@@@@@@@@@@@@@@@@@@@
Model tutorial01_mf6_data
@@@@@@@@@@@@@@@@@@@@

name = tutorial01_mf6_data
model_type = gwf6
version = mf6
model_relative_path = .

###################
Package dis
###################

package_name = dis
filename = tutorial01_mf6_data.dis
package_type = dis
model_or_simulation_package = model
model_name = tutorial01_mf6_data


###################
Package ic
###################
```

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```
package_name = ic
filename = tutorial01_mf6_data.ic
package_type = ic
model_or_simulation_package = model
model_name = tutorial01_mf6_data


###################
Package npf
###################

package_name = npf
filename = tutorial01_mf6_data.npf
package_type = npf
model_or_simulation_package = model
model_name = tutorial01_mf6_data


###################
Package chd_0
###################

package_name = chd_0
filename = tutorial01_mf6_data.chd
package_type = chd
model_or_simulation_package = model
model_name = tutorial01_mf6_data


###################
Package oc
###################

package_name = oc
filename = tutorial01_mf6_data.oc
package_type = oc
model_or_simulation_package = model
model_name = tutorial01_mf6_data
```

Simulation-level packages, models, and model packages can be shown by printing the simulation object. In this case, you should see the all of the contents of simulation and some information about each FloPy object that is part of simulation.

To get the TDIS package and print the contents, we can do the following

[10]:
```
tdis = sim.tdis
print(tdis)
```

```
package_name = tutorial01_mf6_data.tdis
```

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(continued from previous page)

```
filename = tutorial01_mf6_data.tdis
package_type = tdis
model_or_simulation_package = simulation
simulation_name = tutorial01_mf6_data

Block dimensions
--------------------
nper
{internal}
(10)


Block perioddata
--------------------
perioddata
{internal}
([(365., 1, 1.) (365., 1, 1.) (365., 1, 1.) (365., 1, 1.) (365., 1, 1.)
 (365., 1, 1.) (365., 1, 1.) (365., 1, 1.) (365., 1, 1.) (365., 1, 1.)])
```

To get the Iterative Model Solution (IMS) object, we use the following syntax

[11]:
```
ims = sim.get_package("ims_-1")
print(ims)
```

```
package_name = ims_-1
filename = tutorial01_mf6_data.ims
package_type = ims
model_or_simulation_package = simulation
simulation_name = tutorial01_mf6_data
```

Or because there is only one IMS object for this simulation, we can access it as

[12]:
```
ims = sim.get_package("ims")
print(ims)
```

```
package_name = ims_-1
filename = tutorial01_mf6_data.ims
package_type = ims
model_or_simulation_package = simulation
simulation_name = tutorial01_mf6_data
```

When printing the sim object, there is also a simulation package called nam. This package contains the information that is written to the `mfsim.nam` file, which is the primary file that MODFLOW 6 reads when it first starts. The nam package is automatically updated for you by FloPy and does not require modification.

[13]:
```
nam = sim.get_package("nam")
print(nam)
```

```
package_name = mfsim.nam
filename = mfsim.nam
package_type = nam
model_or_simulation_package = simulation
simulation_name = tutorial01_mf6_data

Block timing
--------------------
tdis6
{internal}
(tutorial01_mf6_data.tdis)


Block models
--------------------
models
{internal}
([('gwf6', 'tutorial01_mf6_data.nam', 'tutorial01_mf6_data')])


Block solutiongroup
--------------------
solutiongroup
{internal}
([('ims6', 'tutorial01_mf6_data.ims', 'tutorial01_mf6_data')])
```

To see the models that are contained within the simulation, we can get a list of their names as follows

[14]:
```
print(sim.model_names)
```

```
['tutorial01_mf6_data']
```

`sim.model_names` returns the keys of an ordered dictionary, which isn't very useful to us, but we can convert that to a list and then go through that list and print information about each model in the simulation. In this case there is only one model, but had there been more models, we would see them listed here

[15]:
```
model_names = list(sim.model_names)
for mname in model_names:
    print(mname)
```

```
tutorial01_mf6_data
```

If we want to get a model from a simulation, then we use the `get_model()` method of the sim object. Here we go through all the models in the simulation and print the model name and the model type.

[16]:
```
model_names = list(sim.model_names)
for mname in model_names:
    m = sim.get_model(mname)
    print(m.name, m.model_type)
```

```
tutorial01_mf6_data gwf6
```

For this simple case here with only one GWF model, we can very easily get the FloPy representation of the GWF model as

[17]:
```
gwf = sim.get_model(name)
```

Now that we have the GWF object, we can print it, and see what's it contains.

[18]:
```
print(gwf)
```

```
name = tutorial01_mf6_data
model_type = gwf6
version = mf6
model_relative_path = .

###################
Package dis
###################

package_name = dis
filename = tutorial01_mf6_data.dis
package_type = dis
model_or_simulation_package = model
model_name = tutorial01_mf6_data


###################
Package ic
###################

package_name = ic
filename = tutorial01_mf6_data.ic
package_type = ic
model_or_simulation_package = model
model_name = tutorial01_mf6_data


###################
Package npf
###################

package_name = npf
filename = tutorial01_mf6_data.npf
package_type = npf
model_or_simulation_package = model
model_name = tutorial01_mf6_data


###################
Package chd_0
###################

package_name = chd_0
filename = tutorial01_mf6_data.chd
package_type = chd
```

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```
model_or_simulation_package = model
model_name = tutorial01_mf6_data


###################
Package oc
###################

package_name = oc
filename = tutorial01_mf6_data.oc
package_type = oc
model_or_simulation_package = model
model_name = tutorial01_mf6_data
```

What we see here is the information that we saw when we printed the sim object.

One of the most common operations on a model is to see what packages are in it and then get packages of interest. A list of packages in a model can obtained as

[19]:
```
package_list = gwf.get_package_list()
print(package_list)
```

```
['DIS', 'IC', 'NPF', 'CHD_0', 'OC']
```

As you might expect we can access each package in this list with gwf.get_package(). Thus, the following syntax can be used to obtain and print the contents of the `DIS` Package

[20]:
```
dis = gwf.get_package("dis")
print(dis)
```

```
package_name = dis
filename = tutorial01_mf6_data.dis
package_type = dis
model_or_simulation_package = model
model_name = tutorial01_mf6_data

Block dimensions
--------------------
nlay
{internal}
(3)

nrow
{internal}
(4)

ncol
{internal}
(5)
```

(continues on next page)

(continued from previous page)

```
Block griddata
--------------------
delr
{constant 1.0}

delc
{constant 1.0}

top
{constant 1.0}

botm
{constant 0.0}
```

The Python type for this dis package is simply

[21]:
```
print(type(dis))
```

```
<class 'flopy.mf6.modflow.mfgwfdis.ModflowGwfdis'>
```

[22]:
```
try:
    temp_dir.cleanup()
except PermissionError:
    # can occur on windows: https://docs.python.org/3/library/tempfile.html#tempfile.
↪TemporaryDirectory
    pass
```

5.2.2 MODFLOW 6: Observation packages

Introduction to Observations

Observations can be set for any package through the `package.obs` object, and each package.obs object has several attributes that can be set:

Attribute	Type	Description
package.obs.filename	str	Name of observations file to create. The default is packagename + '.obs'.
package.obs.continuous	dict	A dictionary that has file names as keys and a list of observations as the dictionary values.
package.obs.digits	int	Number of digits to write the observation values. Default is 10.
package.obs.print_input	bool	Flag indicating whether or not observations are written to listing file.

The following code sets up a simulation used in the observation examples.

[1]:
```
# package import
import os
```

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```
from pathlib import Path
from tempfile import TemporaryDirectory
```

[2]:
```
import numpy as np
```

[3]:
```
import flopy
```

[4]:
```
# set up where simulation workspace will be stored
temp_dir = TemporaryDirectory()
workspace = temp_dir.name
name = "tutorial02_mf6_data"
```

[5]:
```
# create the flopy simulation and tdis objects
sim = flopy.mf6.MFSimulation(
    sim_name=name, exe_name="mf6", version="mf6", sim_ws=workspace
)
tdis_rc = [(1.0, 1, 1.0), (10.0, 5, 1.0), (10.0, 5, 1.0), (10.0, 1, 1.0)]
tdis_package = flopy.mf6.modflow.mftdis.ModflowTdis(
    sim, time_units="DAYS", nper=4, perioddata=tdis_rc
)
# create the flopy groundwater flow (gwf) model object
model_nam_file = f"{name}.nam"
gwf = flopy.mf6.ModflowGwf(sim, modelname=name, model_nam_file=model_nam_file)
# create the flopy iterative model solver (ims) package object
ims = flopy.mf6.modflow.mfims.ModflowIms(sim, pname="ims", complexity="SIMPLE")
# create the discretization package
bot = np.linspace(-3.0, -50.0 / 3.0, 3)
delrow = delcol = 4.0
dis = flopy.mf6.modflow.mfgwfdis.ModflowGwfdis(
    gwf,
    pname="dis",
    nogrb=True,
    nlay=3,
    nrow=101,
    ncol=101,
    delr=delrow,
    delc=delcol,
    top=0.0,
    botm=bot,
)
# create the initial condition (ic) and node property flow (npf) packages
ic_package = flopy.mf6.modflow.mfgwfic.ModflowGwfic(gwf, strt=50.0)
npf_package = flopy.mf6.modflow.mfgwfnpf.ModflowGwfnpf(
    gwf,
    save_flows=True,
    icelltype=[1, 0, 0],
    k=[5.0, 0.1, 4.0],
    k33=[0.5, 0.005, 0.1],
)
```

Observation Example 1

One method to build the observation package is to pass a dictionary with the observations containing "observations" parameters of the parent package.

This example uses the observation package in a GHB package. First the stress period data for a ghb package is built.

[6]:
```
# build ghb stress period data
ghb_spd = {}
ghb_period = []
for layer, cond in zip(range(1, 3), [15.0, 1500.0]):
    for row in range(0, 15):
        ghb_period.append(((layer, row, 9), 1.0, cond, "Estuary-L2"))
ghb_spd[0] = ghb_period
```

The next step is to build the observation data in a dictionary. The dictionary key is the filename of the observation output file and optionally a "binary" keyword to make the file binary. When the optional "binary" keyword is used the dictionary key is a tuple, otherwise it is a string. The dictionary value is a list of tuples containing the contents of the observation package's continuous block, with each tuple containing one line of information.

[7]:
```
# build obs data
ghb_obs = {
    ("ghb_obs.csv", "binary"): [
        ("ghb-2-6-10", "GHB", (1, 5, 9)),
        ("ghb-3-6-10", "GHB", (2, 5, 9)),
    ],
    "ghb_flows.csv": [
        ("Estuary2", "GHB", "Estuary-L2"),
        ("Estuary3", "GHB", "Estuary-L3"),
    ],
}
```

The ghb package is now constructed with observations by setting the `observations` parameter to `ghb_obs` on construction of the ghb package.

[8]:
```
# build ghb package passing obs dictionary to package constructor
ghb = flopy.mf6.modflow.mfgwfghb.ModflowGwfghb(
    gwf,
    print_input=True,
    print_flows=True,
    save_flows=True,
    boundnames=True,
    observations=ghb_obs,
    pname="ghb",
    maxbound=30,
    stress_period_data=ghb_spd,
)
```

Observation information such as the print_input option can then be set using the package's `obs` parameter.

[9]:
```
ghb.obs.print_input = True
```

[10]:
```
# clean up for next example
gwf.remove_package("ghb")
```

Observation Example 2

Alternatively, an obs package can be built by initializing obs through `ghb.obs.initialize`.

First, a GHB package is built without defining observations.

[11]:
```
# build ghb package
ghb = flopy.mf6.modflow.mfgwfghb.ModflowGwfghb(
    gwf,
    print_input=True,
    print_flows=True,
    save_flows=True,
    boundnames=True,
    maxbound=30,
    stress_period_data=ghb_spd,
    pname="ghb",
)
```

Then the ghb observations are defined in a dictionary similar to example 1.

[12]:
```
# build obs data
ghb_obs = {
    ("ghb_obs.csv", "binary"): [
        ("ghb-2-6-10", "GHB", (1, 5, 9)),
        ("ghb-3-6-10", "GHB", (2, 5, 9)),
    ],
    "ghb_flows.csv": [
        ("Estuary2", "GHB", "Estuary-L2"),
        ("Estuary3", "GHB", "Estuary-L3"),
    ],
}
```

The observations can then be added to the ghb package using the obs attribute's initialize method. The observation package's file name, digits, and print_input options, along with the continuous block data are set in the initialize method.

[13]:
```
# initialize obs package
ghb.obs.initialize(
    filename="child_pkgs_test.ghb.obs",
    digits=9,
    print_input=True,
    continuous=ghb_obs,
)
```

[14]:
```
try:
    temp_dir.cleanup()
except PermissionError:
    # can occur on windows: https://docs.python.org/3/library/tempfile.html#tempfile.
↪TemporaryDirectory
    pass
```

5.2.3 MODFLOW 6: Time Series Packages

Introduction to Time Series

Time series can be set for any package through the `package.ts` object, and each `package.ts` object has several attributes that can be set:

Attribute	Type	Description
package.ts.filename	str	Name of time series file to create. The default is packagename + ".ts".
package.ts.timeseries	recarray	Array containing the time series information
package.ts.time_series_namere	str or list	List of names of the time series data columns. Default is to use names from timeseries.dtype.names[1:].
package.ts.interpolation_metho	str	Interpolation method. Must be only one time series record. If there are multiple time series records, then the methods attribute must be used.
package.ts.interpolation_metho	float	Scale factor to multiply the time series data column. Can only be used if there is one time series data column.
package.ts.sfacrecord_single	float	Scale factor to multiply the time series data column. Can only be used if there is one time series data column.
package.ts.sfacrecord	list (of floats)	Scale factors to multiply the time series data columns.

The following code sets up a simulation used in the time series examples.

[1]:
```
# package import
import os
from pathlib import Path
from tempfile import TemporaryDirectory
```

[2]:
```
import numpy as np
```

[3]:
```
import flopy
```

[4]:
```
# set up where simulation workspace will be stored
temp_dir = TemporaryDirectory()
workspace = temp_dir.name
name = "tutorial03_mf6_data"
```

[5]:
```
# create the flopy simulation and tdis objects
sim = flopy.mf6.MFSimulation(
    sim_name=name, exe_name="mf6", version="mf6", sim_ws=workspace
)
tdis_rc = [(1.0, 1, 1.0), (10.0, 5, 1.0), (10.0, 5, 1.0), (10.0, 1, 1.0)]
tdis_package = flopy.mf6.modflow.mftdis.ModflowTdis(
    sim, time_units="DAYS", nper=4, perioddata=tdis_rc
)
# create the Flopy groundwater flow (gwf) model object
model_nam_file = f"{name}.nam"
gwf = flopy.mf6.ModflowGwf(sim, modelname=name, model_nam_file=model_nam_file)
# create the flopy iterative model solver (ims) package object
ims = flopy.mf6.modflow.mfims.ModflowIms(sim, pname="ims", complexity="SIMPLE")
```

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```
# create the discretization package
bot = np.linspace(-3.0, -50.0 / 3.0, 3)
delrow = delcol = 4.0
dis = flopy.mf6.modflow.mfgwfdis.ModflowGwfdis(
    gwf,
    pname="dis",
    nogrb=True,
    nlay=3,
    nrow=101,
    ncol=101,
    delr=delrow,
    delc=delcol,
    top=0.0,
    botm=bot,
)
# create the initial condition (ic) and node property flow (npf) packages
ic_package = flopy.mf6.modflow.mfgwfic.ModflowGwfic(gwf, strt=50.0)
npf_package = flopy.mf6.modflow.mfgwfnpf.ModflowGwfnpf(
    gwf,
    save_flows=True,
    icelltype=[1, 0, 0],
    k=[5.0, 0.1, 4.0],
    k33=[0.5, 0.005, 0.1],
)
```

Time Series Example 1

One way to construct a time series is to pass the time series data to the parent package constructor.

This example uses time series data in a GHB package. First the GHB `stress_period_data` is built.

[6]:
```
# build ghb stress period data
ghb_spd_ts = {}
ghb_period = []
for layer, cond in zip(range(1, 3), [15.0, 1500.0]):
    for row in range(0, 15):
        ghb_period.append(((layer, row, 9), "tides", cond, "Estuary-L2"))
ghb_spd_ts[0] = ghb_period
```

Next the time series data is built. The time series data is constructed as a list of tuples, with each tuple containing a time and the value (or values) at that time. The time series data is put in a dictionary along with additional time series information including filename, time_series_namerecord, interpolation_methodrecord, and sfacrecord.

[7]:
```
# build ts data
ts_data = []
for n in range(0, 365):
    time = float(n / 11.73)
    val = float(n / 60.0)
    ts_data.append((time, val))
ts_dict = {
    "filename": "tides.ts",
    "time_series_namerecord": "tide",
```

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```
    "timeseries": ts_data,
    "interpolation_methodrecord": "linearend",
    "sfacrecord": 1.1,
}
```

The GHB package is then constructed, passing the time series data into the `timeseries` parameter.

[8]:
```
# build ghb package
ghb = flopy.mf6.modflow.mfgwfghb.ModflowGwfghb(
    gwf,
    print_input=True,
    print_flows=True,
    save_flows=True,
    boundnames=True,
    timeseries=ts_dict,
    pname="ghb",
    maxbound=30,
    stress_period_data=ghb_spd_ts,
)
```

```
WARNING: Unable to resolve dimension of ('ts', 'attributes', 'sfacrecord_single',
↪'sfacval') based on shape "time_series_name".
WARNING: Unable to resolve dimension of ('ts', 'attributes', 'sfacrecord_single',
↪'sfacval') based on shape "time_series_name".
```

Time series attributes, like `time_series_namerecord`, can be modified using the `ghb.ts` object.

[9]:
```
# set required time series attributes
ghb.ts.time_series_namerecord = "tides"
```

[10]:
```
# clean up for next example
gwf.remove_package("ghb")
```

Time Series Example 2

Another way to construct a time series is to initialize the time series through the `ghb.ts.initialize` method. Additional time series can then be appended using the `append_package` method.

First the `GHB` stress period data is built.

[11]:
```
# build ghb stress period data
ghb_spd_ts = {}
ghb_period = []
for layer, cond in zip(range(1, 3), [15.0, 1500.0]):
    for row in range(0, 15):
        if row < 10:
            ghb_period.append(((layer, row, 9), "tides", cond, "Estuary-L2"))
        else:
            ghb_period.append(((layer, row, 9), "wl", cond, "Estuary-L2"))
ghb_spd_ts[0] = ghb_period
```

Next the time series data is built. The time series data is constructed as a list of tuples, with each tuple containing a time and the value (or values) at that time.

[12]:
```
# build ts data
ts_data = []
for n in range(0, 365):
    time = float(n / 11.73)
    val = float(n / 60.0)
    ts_data.append((time, val))
ts_data2 = []
for n in range(0, 365):
    time = float(1.0 + (n / 12.01))
    val = float(n / 60.0)
    ts_data2.append((time, val))
ts_data3 = []
for n in range(0, 365):
    time = float(10.0 + (n / 12.01))
    val = float(n / 60.0)
    ts_data3.append((time, val))
```

A ghb package is constructed without the time series data

[13]:
```
# build ghb package
ghb = flopy.mf6.modflow.mfgwfghb.ModflowGwfghb(
    gwf,
    print_input=True,
    print_flows=True,
    save_flows=True,
    boundnames=True,
    pname="ghb",
    maxbound=30,
    stress_period_data=ghb_spd_ts,
)
```

The first time series data are added by calling the initialize method from the `ghb.ts` object. The times series package's file name, name record, method record, and sfac record, along with the time series data are set in the initialize method.

[14]:
```
# initialize first time series
ghb.ts.initialize(
    filename="tides.ts",
    timeseries=ts_data,
    time_series_namerecord="tides",
    interpolation_methodrecord="linearend",
    sfacrecord=1.1,
)
```

```
WARNING: Unable to resolve dimension of ('ts', 'attributes', 'sfacrecord_single',
↪'sfacval') based on shape "time_series_name".
WARNING: Unable to resolve dimension of ('ts', 'attributes', 'sfacrecord_single',
↪'sfacval') based on shape "time_series_name".
```

The remaining time series data are added using the `append_package` method. The `append_package` method takes the same parameters as the initialize method.

[15]:
```
# append additional time series
ghb.ts.append_package(
    filename="wls.ts",
```

(continues on next page)

(continued from previous page)

```
    timeseries=ts_data2,
    time_series_namerecord="wl",
    interpolation_methodrecord="stepwise",
    sfacrecord=1.2,
)
# append additional time series
ghb.ts.append_package(
    filename="wls2.ts",
    timeseries=ts_data3,
    time_series_namerecord="wl2",
    interpolation_methodrecord="stepwise",
    sfacrecord=1.3,
)
```

```
WARNING: Unable to resolve dimension of ('ts', 'attributes', 'sfacrecord_single',
↪'sfacval') based on shape "time_series_name".
WARNING: Unable to resolve dimension of ('ts', 'attributes', 'sfacrecord_single',
↪'sfacval') based on shape "time_series_name".
WARNING: Unable to resolve dimension of ('ts', 'attributes', 'sfacrecord_single',
↪'sfacval') based on shape "time_series_name".
WARNING: Unable to resolve dimension of ('ts', 'attributes', 'sfacrecord_single',
↪'sfacval') based on shape "time_series_name".
```

Information can be retrieved from time series packages using the `ts` attribute of its parent package. Below the interpolation method record for each of the three time series are retrieved.

[16]:
```
print(
    "{} is using {} interpolation".format(
        ghb.ts[0].filename,
        ghb.ts[0].interpolation_methodrecord.get_data()[0][0],
    )
)
print(
    "{} is using {} interpolation".format(
        ghb.ts[1].filename,
        ghb.ts[1].interpolation_methodrecord.get_data()[0][0],
    )
)
print(
    "{} is using {} interpolation".format(
        ghb.ts[2].filename,
        ghb.ts[2].interpolation_methodrecord.get_data()[0][0],
    )
)
```

```
tides.ts is using linearend interpolation
wls.ts is using stepwise interpolation
wls2.ts is using stepwise interpolation
```

[17]:
```
try:
    temp_dir.cleanup()
except PermissionError:
    # can occur on windows: https://docs.python.org/3/library/tempfile.html#tempfile.
```

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```
↪TemporaryDirectory
    pass
```

5.2.4 MODFLOW 6: Time Array Series Packages

Introduction to Time Array Series

Time array series can be set for any package through the `package.tas` object, and each `package.tas` object has several attributes that can be set:

Attribute	Type	Description
package.tas.filename	str	Name of time series file to create. The default is packagename + ".tas".
package.tas.tas_array	{double:[double	Array containing the time array series information for specific times.
package.tas.time_series_nar	str	Name by which a package references a particular time-array series. The name must be unique among all time-array series used in a package.
package.tas.interpolation_m	list (of strings)	List of interpolation methods to use for time array series. Method must be either "stepwise" or "linear".
package.tas.sfacrecord_sing	float	Scale factor to multiply the time array series data column. Can only be used if there is one time series data column.

The following code sets up a simulation used in the time array series examples.

[1]:
```
# package import
import os
from pathlib import Path
from tempfile import TemporaryDirectory
```

[2]:
```
import numpy as np
```

[3]:
```
import flopy
```

[4]:
```
# set up where simulation workspace will be stored
temp_dir = TemporaryDirectory()
workspace = temp_dir.name
name = "tutorial04_mf6_data"
```

[5]:
```
# create the Flopy simulation and tdis objects
sim = flopy.mf6.MFSimulation(
    sim_name=name, exe_name="mf6", version="mf6", sim_ws=workspace
)
tdis_rc = [(1.0, 1, 1.0), (10.0, 5, 1.0), (10.0, 5, 1.0), (10.0, 1, 1.0)]
tdis_package = flopy.mf6.modflow.mftdis.ModflowTdis(
    sim, time_units="DAYS", nper=4, perioddata=tdis_rc
)
# create the Flopy groundwater flow (gwf) model object
model_nam_file = f"{name}.nam"
gwf = flopy.mf6.ModflowGwf(sim, modelname=name, model_nam_file=model_nam_file)
```

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```
# create the flopy iterative model solver (ims) package object
ims = flopy.mf6.modflow.mfims.ModflowIms(sim, pname="ims", complexity="SIMPLE")
# create the discretization package
bot = np.linspace(-3.0, -50.0 / 3.0, 3)
delrow = delcol = 4.0
dis = flopy.mf6.modflow.mfgwfdis.ModflowGwfdis(
    gwf,
    pname="dis",
    nogrb=True,
    nlay=3,
    nrow=101,
    ncol=101,
    delr=delrow,
    delc=delcol,
    top=0.0,
    botm=bot,
)
# create the initial condition (ic) and node property flow (npf) packages
ic_package = flopy.mf6.modflow.mfgwfic.ModflowGwfic(gwf, strt=50.0)
npf_package = flopy.mf6.modflow.mfgwfnpf.ModflowGwfnpf(
    gwf,
    save_flows=True,
    icelltype=[1, 0, 0],
    k=[5.0, 0.1, 4.0],
    k33=[0.5, 0.005, 0.1],
)
```

Time Array Series Example 1

Time array series data can be passed into the `timearrayseries` parameter on construction of any package that supports time array series. This example uses the `timearrayseries` parameter to create a time array series and then uses the package's `tas` property to finish the time array series setup.

This example uses time array series data in a RCHA package. The time array series is built as a dictionary with the times as the keys and the recharge values as the values.

[6]:
```
tas = {0.0: 0.000002, 200.0: 0.0000001}
```

The time array series data is then passed into the `timearrayseries` parameter when the RCHA package is constructed.

[7]:
```
rcha = flopy.mf6.modflow.mfgwfrcha.ModflowGwfrcha(
    gwf, timearrayseries=tas, recharge="TIMEARRAYSERIES rcharray_1"
)
```

```
WARNING: Time array series name rcharray_1 not found in any time series file
```

Time array series attributes can be set by access the time array series package object through the `rcha.tas` attribute.

[8]:
```
# finish defining the time array series properties
rcha.tas.time_series_namerecord = "rcharray_1"
rcha.tas.interpolation_methodrecord = "LINEAR"
```

The simulation is then written to files and run.

[9]:
```
sim.write_simulation()
sim.run_simulation()
```

```
writing simulation...
  writing simulation name file...
  writing simulation tdis package...
  writing solution package ims...
  writing model tutorial04_mf6_data...
    writing model name file...
    writing package dis...
    writing package ic...
    writing package npf...
    writing package rcha_0...
    writing package tas_0...
FloPy is using the following executable to run the model: ../../home/runner/.local/bin/
↪modflow/mf6
                                   MODFLOW 6
                U.S. GEOLOGICAL SURVEY MODULAR HYDROLOGIC MODEL
                            VERSION 6.4.2 06/28/2023

   MODFLOW 6 compiled Jul 05 2023 20:29:14 with Intel(R) Fortran Intel(R) 64
   Compiler Classic for applications running on Intel(R) 64, Version 2021.7.0
                             Build 20220726_000000

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 Run start date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:29:50

 Writing simulation list file: mfsim.lst
 Using Simulation name file: mfsim.nam


ERROR REPORT:

  1. Invalid model name: TUTORIAL04_MF6_DATA
  2. Name length of 19 exceeds maximum length of 16
```

[9]:
```
(False, [])
```

[10]:
```
# clean up for next example
gwf.remove_package("rcha")
```

Time Array Series Example 2

A time array series can be added after a package is created by calling the package's `tas` attribute's `initialize` method. Initialize allows you to define all time array series attributes including file name, the time array series data, name record, and method record.

First a recharge package is built.

[11]:
```
# create recharge package with recharge pointing to a time array series
# not yet defined. FloPy will generate a warning that there is not yet a
# time series name record for recharray_1
rcha = flopy.mf6.modflow.mfgwfrcha.ModflowGwfrcha(
    gwf, recharge="TIMEARRAYSERIES rcharray_1"
)
```

```
WARNING: Time array series name rcharray_1 not found in any time series file
```

Then a time array series dictionary is created as done in example 1.

[12]:
```
tas = {0.0: 0.000002, 200.0: 0.0000001}
```

The time array series data are added by calling the `initialize` method from the 'RCHA' package's tas attribute. The time array series file name, name record, and method record, along with the time series data are set in the `initialize` method.

[13]:
```
# initialize the time array series
rcha.tas.initialize(
    filename="method2.tas",
    tas_array=tas,
    time_series_namerecord="rcharray_1",
    interpolation_methodrecord="LINEAR",
)
```

[14]:
```
try:
    temp_dir.cleanup()
except PermissionError:
    # can occur on windows: https://docs.python.org/3/library/tempfile.html#tempfile.
↪TemporaryDirectory
    pass
```

5.2.5 MODFLOW 6: Working with MODFLOW Scalar Data

This tutorial shows how to view, access, and change the underlying data variables for MODFLOW 6 objects in FloPy. Interaction with a FloPy MODFLOW 6 model is different from other models, such as MODFLOW-2005, MT3D, and SEAWAT, for example.

FloPy stores model data in data objects (`MFDataArray`, `MFDataList`, `MFDataScalar` objects) that are accessible from packages Data can be added to a package by using the appropriate parameters when the package is constructed and through package attributes.

The MODFLOW 6 simulation structure is arranged in the following generalized way:

```
Simulation --> Package --> DATA

Simulation --> Model --> Package (--> Package) --> DATA
```

This tutorial focuses on MODFLOW Data that is a single integer or string, or consists of boolean flag(s). These data are stored by FloPy in a MFScalar object and are referred to as MODFLOW scalar data.

Introduction to MODFLOW Scalar Data

MODFLOW single integer, strings, or boolean flag(s) are stored by FloPy as scalar data in `MFScalar` objects. The different types of scalar data are described below.

1. Single integer values. Examples include `nrow`, `ncol`, `nlay`, and `nper`.
2. Single string values. Examples include `time_units` and `length_units`.
3. Boolean flags. These can be found in the options section of most packages. These include perched, `nogrb`, `print_input`, and `save_flows`.
4. Boolean flags with an additional optional flag. These include `newton under_relaxation` and `xt3d rhs`.

In the following all four types of scalar data will be added to a model. Before adding data to your model first create a simulation (`MFSimulation`) and a model (`MFModel`) object in FloPy.

[1]:
```
# package import
import os
from pathlib import Path
from tempfile import TemporaryDirectory
```

[2]:
```
import numpy as np
```

[3]:
```
import flopy
```

[4]:
```
# set up where simulation workspace will be stored
temp_dir = TemporaryDirectory()
workspace = temp_dir.name
name = "tutorial05_mf6_data"
```

[5]:
```
# create the flopy simulation object
sim = flopy.mf6.MFSimulation(
    sim_name=name, exe_name="mf6", version="mf6", sim_ws=workspace
)
```

[6]:
```
# create the flopy groundwater flow (gwf) model object
model_nam_file = f"{name}.nam"
gwf = flopy.mf6.ModflowGwf(sim, modelname=name, model_nam_file=model_nam_file)
# create the flopy iterative model solver (ims) package object
# (both pname and complexity are scalar data)
ims = flopy.mf6.modflow.mfims.ModflowIms(sim, pname="ims", complexity="SIMPLE")
```

Adding MODFLOW Single Integer and String Values

Single integer and string values can be assigned on construction of the `MFScalar` data object, and can be assigned or changed after construction.

Below, a `TDIS` package is constructed with the `time_units` and `nper` parameters being assigned "DAYS" and "2", respectively.

[7]:
```
# create the FloPy temporal discretization object
tdis = flopy.mf6.modflow.mftdis.ModflowTdis(
    sim,
    pname="tdis",
    time_units="DAYS",
    nper=2,
    perioddata=[(1.0, 1, 1.0), (1.0, 1, 1.0)],
)
```

Next, `time_units` is reassigned a value after construction by using `TDIS`'s `time_units` attribute.

[8]:
```
tdis.time_units = "MONTHS"
```

Setting MODFLOW Boolean Flags

Boolean flags can be assigned a True or False value. In the example below `nogrb` is assigned a value of True and then changed to false.

For this example, first some values are first defined for the discretization package

[9]:
```
nlay = 3
h = 50.0
length = 400.0
n = 10
bot = np.linspace(-h / nlay, -h, nlay)
delrow = delcol = length / (n - 1)
```

Below the discretization package is created. The MODFLOW `nogrb` option assigned a value of True, switching this option on.

[10]:
```
dis = flopy.mf6.modflow.mfgwfdis.ModflowGwfdis(
    gwf,
    pname="dis",
    nogrb=True,
    nlay=nlay,
    nrow=n,
    ncol=n,
    delr=delrow,
    delc=delcol,
    top=0.0,
    botm=bot,
)
```

The `nogrb` option is then switched off by setting the `DIS` package's `nogrb` attribute to False.

[11]:
```
dis.nogrb = False
```

Boolean flags with an additional optional flag can either be specified by:

1. Specifying the entire line as it would be displayed in the package file as a string (`xt3doptions="xt3d rhs"`)
2. Specifying each flag name in a list (`xt3doptions=["xt3d", "rhs"]`)

To turn off both flags use an empty string (`xt3doptions=""`) or an empty list (`xt3doptions=[]`).

First, an `NPF` package is created. `xt3doptions` can either be turned on or off, and if it is on `rhs` can optionally be turned on. `xt3doptions` is set to the string "xt3d rhs", turning both options on.

[12]:
```
# create the node property flow package with xt3doptions as single
npf = flopy.mf6.modflow.mfgwfnpf.ModflowGwfnpf(
    gwf,
    rewet_record="REWET WETFCT 1.0 IWETIT 1 IHDWET 0",
    pname="npf",
    icelltype=1,
    k=1.0,
    save_flows=True,
    xt3doptions="xt3d rhs",
)
```

```
<flopy.mf6.data.mfstructure.MFDataItemStructure object at 0x7fb836c9fb80>
<flopy.mf6.data.mfstructure.MFDataItemStructure object at 0x7fb836c9fbb0>
```

Next, the `rhs` option is turned off by setting `xt3doptions` to the string "xt3d".

[13]:
```
npf.xt3doptions = "xt3d"
```

Finally, both `xt3d` and `rhs` are turned off by setting `xt3doptions` to an empty string.

[14]:
```
npf.xt3doptions = ""
```

Retrieving MODFLOW Scalar Data

MODFLOW scalar data can be retrieved with `get_data`, `repr/str`, or `get_file_entry`.

Retrieval Method	Description
get_data	Returns scalar value
repr/str	Returns string with a header describing how data is stored (internal, external) with a string representation of the data on the next line
get_file_e	Returns string with the scalar keyword (if any) followed by a space and a string representation of the scalar value (if any). This is the format used by the MODFLOW-6 package file. This is the format used by the MODFLOW-6 package file.

The `IMS` package's `complexity` option and the `NPF` package's `xt3doptions` are printed below using the different data retrieval methods highlighted above.

First the complexity data is printed using the `get_data` method.

[15]:
```
print(ims.complexity.get_data())
```

```
simple
```

The xt3doptions data can also be printed with `get_data`.

```
[16]: print(npf.xt3doptions.get_data())
```

```
[]
```

The complexity data is then printed with repr

```
[17]: print(repr(ims.complexity))
```

```
{internal}
('simple')
```

The xt3doptions data is printed with repr

```
[18]: print(str(npf.xt3doptions))
```

```
{internal}
([])
```

The complexity data is printed as it would appear in a MODFLOW 6 file using the `get_file_entry` method.

```
[19]: print(ims.complexity.get_file_entry())
```

```
  COMPLEXITY  simple
```

The xt3doptions data is printed as it would appear in a MODFLOW 6 file using the `get_file_entry` method.

```
[20]: print(npf.xt3doptions.get_file_entry())
```

```
[21]: try:
    temp_dir.cleanup()
except PermissionError:
    # can occur on windows: https://docs.python.org/3/library/tempfile.html#tempfile.
↪TemporaryDirectory
    pass
```

5.2.6 MODFLOW 6: Working with MODFLOW List Data.

This tutorial shows how to view, access, and change the underlying data variables for MODFLOW 6 objects in FloPy. Interaction with a FloPy MODFLOW 6 model is different from other models, such as MODFLOW-2005, MT3D, and SEAWAT, for example.

FloPy stores model data in data objects (`MFDataArray`, `MFDataList`, `MFDataScalar` objects) that are accessible from packages. Data can be added to a package by using the appropriate parameters when the package is constructed and through package attributes.

The MODFLOW 6 simulation structure is arranged in the following generalized way:

```
Simulation --> Package --> DATA

Simulation --> Model --> Package (--> Package) --> DATA
```

This tutorial focuses on MODFLOW Data from the `PackageData`, `ConnectionData`, `StressPeriodData`, and other similar blocks. These blocks contain data with columns, data that fits into a numpy recarray, pandas data frame, or a spreadsheet with column headers. These data are stored by FloPy in a `MFList` or `MFTransientList` object and a referred to as MODFLOW list data.

Introduction to MODFLOW List Data

MODFLOW contains list data that can be conveniently stored in a numpy recarray or a pandas dataframe. These data are either a single or multiple row of data, with each column containing the same data type.

Some MODFLOW list data only contains a single row, like the `OC` package's `head print_format` option and the `NPF` package's `rewet_record`. Other MODFLOW list data can contain multiple rows, like the `MAW` package's `packagedata` and `connectiondata`. FloPy stores both single row and multiple row list data in `MFList` objects.

MODFLOW stress period data can contain lists of data for one or more stress periods. FloPy stores stress period list data in `MFTransientList` objects. Note that not all MODFLOW stress period data is "list" data that fits neatly in a recarray or a panda's dataframe. Some packages including `RCH` and `EVT` have a `READASARRAYS` option that allows stress period data to be inputted as an array. When `READASARRAYS` is selected FloPy stores stress period array data in an `MFTransientArray` object (see tutorial 8).

Examples of using FloPy to store, update, and retrieve different types of MODFLOW list data are given below. The examples start by first creating a simulation (`MFSimulation`) and a model (`MFModel`) object in FloPy.

[1]:
```python
# package import
import os
from pathlib import Path
from tempfile import TemporaryDirectory
```

[2]:
```python
import numpy as np
```

[3]:
```python
import flopy
```

[4]:
```python
# set up where simulation workspace will be stored
temp_dir = TemporaryDirectory()
workspace = temp_dir.name
name = "tutorial06_mf6_data"
```

[5]:
```python
# create the Flopy simulation and tdis objects
sim = flopy.mf6.MFSimulation(
    sim_name=name, exe_name="mf6", version="mf6", sim_ws=workspace
)
tdis = flopy.mf6.modflow.mftdis.ModflowTdis(
    sim,
    pname="tdis",
    time_units="DAYS",
    nper=2,
    perioddata=[(1.0, 1, 1.0), (1.0, 1, 1.0)],
)
```

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```
# create the Flopy groundwater flow (gwf) model object
model_nam_file = f"{name}.nam"
gwf = flopy.mf6.ModflowGwf(sim, modelname=name, model_nam_file=model_nam_file)
# create the flopy iterative model solver (ims) package object
ims = flopy.mf6.modflow.mfims.ModflowIms(sim, pname="ims", complexity="SIMPLE")
# create the discretization package
bot = np.linspace(-50.0 / 3.0, -3.0, 3)
delrow = delcol = 4.0
dis = flopy.mf6.modflow.mfgwfdis.ModflowGwfdis(
    gwf,
    pname="dis",
    nogrb=True,
    nlay=3,
    nrow=10,
    ncol=10,
    delr=delrow,
    delc=delcol,
    top=0.0,
    botm=bot,
)
```

Adding MODFLOW Package Data, Connection Data, and Option Lists

MODFLOW Package data, connection data, and option lists are stored by FloPy as numpy recarrays. FloPy does accept numpy recarrays as input, but does has other supported formats discussed below.

MODFLOW option lists that only contain a single row or data can be either specified by:

1. Specifying a string containing the entire line as it would be displayed in the package file (`rewet_record="REWET WETFCT 1.0 IWETIT 1 IHDWET 0"`)
2. Specifying the data in a tuple within a list (`rewet_record=[("WETFCT", 1.0, "IWETIT", 1, "IHDWET", 0)]`)

In the example below the npf package is created setting the `rewet_record` option to a string of text as would be typed into the package file.

[6]:
```
npf = flopy.mf6.modflow.mfgwfnpf.ModflowGwfnpf(
    gwf,
    rewet_record="REWET WETFCT 1.0 IWETIT 1 IHDWET 0",
    pname="npf",
    icelltype=1,
    k=1.0,
    save_flows=True,
    xt3doptions="xt3d rhs",
)
```

```
<flopy.mf6.data.mfstructure.MFDataItemStructure object at 0x7f01df33d250>
<flopy.mf6.data.mfstructure.MFDataItemStructure object at 0x7f01df33d280>
```

`rewet_record` is then set using the npf package's `rewet_record` property. This time 'rewet_record' is defined using a tuple within a list.

[7]:
```
npf.rewet_record = [("WETFCT", 1.1, "IWETIT", 0, "IHDWET", 1)]
```

MODFLOW multirow lists, like package data and connection data, can be specified:

1. As a list of tuples where each tuple represents a row in the list (stress_period_data = [((1, 2, 3), 20.0), ((1, 7, 3), 25.0)])
2. As a numpy recarray. Building a numpy recarray is more complicated and is beyond the scope of this guide.

In the example below the chd package is created, setting `stress_period_data` as a list of tuples.

We build the chd package using an array of tuples for stress_period_data stress_period_data = [(first_chd_cell, head), (second_chd_cell, head), . . .] Note that the cellid information (layer, row, column) is encapsulated in a tuple.

[8]:
```
stress_period_data = [((1, 8, 8), 100.0), ((1, 9, 9), 105.0)]
# build chd package
chd = flopy.mf6.modflow.mfgwfchd.ModflowGwfchd(
    gwf,
    pname="chd",
    maxbound=len(stress_period_data),
    stress_period_data=stress_period_data,
    save_flows=True,
)
```

Adding Stress Period List Data

MODFLOW stress period data is stored by FloPy as a dictionary of numpy recarrays, where each dictionary key is a zero-based stress period and each dictionary value is a recarray containing the stress period data for that stress period. FloPy keeps this stress period data in a `MFTransientList` object and this data type is referred to as a transient list.

FloPy accepts stress period data as a dictionary of numpy recarrays, but also supports replacing the recarrays with lists of tuples discussed above. Stress period data spanning multiple stress periods must be specified as a dictionary of lists where the dictionary key is the stress period expressed as a zero-based integer.

The example below creates `stress_period_data` for the wel package with the first stress period containing a single well and the second stress period empty. When empty stress period data is entered FloPy writes an empty stress period block to the package file.

First we create wel package with stress_period_data dictionary keys as zero-based integers so key "0" is stress period 1

[9]:
```
stress_period_data = {
    0: [((2, 3, 1), -25.0)],  # stress period 1 well data
    1: [],
}  # stress period 2 well data is empty
```

Then, using the dictionary created above, we build the wel package.

[10]:
```
wel = flopy.mf6.ModflowGwfwel(
    gwf,
    print_input=True,
    print_flows=True,
    stress_period_data=stress_period_data,
    save_flows=False,
    pname="WEL-1",
)
```

Retrieving MODFLOW Package Data, Connection Data, and Option Lists

MODFLOW package data, connection data, and option lists can be retrieved with `get_data`, `array`, `repr/str`, or get_file_entry.

Retrieval Method	Description
get_data	Returns recarray
array	Return recarray
repr/str	Returns string with storage information followed by recarray's repr/str
get_file_entr	Returns string containing data formatted for the MODFLOW-6 package file. Certain zero-based numbers, like layer, row, column, are converted to one-based numbers.

The `NPF` package's `rewet_record` is printed below using the different data retrieval methods highlighted above.

First we use the `get_data` method to get the rewet_record as a recarray.

[11]:
```python
print(npf.rewet_record.get_data())
```

```
[('WETFCT', 1.1, 'IWETIT', 0, 'IHDWET', 1)]
```

Next we use the `array` method, which also returns a recarray.

[12]:
```python
print(npf.rewet_record.array)
```

```
[('WETFCT', 1.1, 'IWETIT', 0, 'IHDWET', 1)]
```

Then we use repr to print a string representation of rewet_record.

[13]:
```python
print(repr(npf.rewet_record))
```

```
{internal}
(rec.array([('WETFCT', 1.1, 'IWETIT', 0, 'IHDWET', 1)],
          dtype=[('wetfct_label', 'O'), ('wetfct', '<f8'), ('iwetit_label', 'O'), (
↪'iwetit', '<i8'), ('ihdwet_label', 'O'), ('ihdwet', '<i8')]))
```

Using str prints a similar string representation of rewet_record.

[14]:
```python
print(str(npf.rewet_record))
```

```
{internal}
([('WETFCT', 1.1, 'IWETIT', 0, 'IHDWET', 1)])
```

Last, using the `get_file_entry` method the data is printed as it would appear in a MODFLOW 6 file.

[15]:
```python
print(npf.rewet_record.get_file_entry())
```

```
  REWET  WETFCT       1.10000000  IWETIT  0  IHDWET  1
```

Retrieving MODFLOW Stress Period List Data

Stress period data can be retrieved with `get_data`, `array`, `repr/str`, or `get_file_entry`.

Retrieval Method	Description
get_data	Returns dictionary of recarrays
array	Return single recarray for all stress periods
repr/str	Returns string with storage information followed by recarray repr/str for each recarray
get_file_entry(key	Returns string containing data formatted for the MODFLOW-6 package file for the stress period specified by key

The `WEL` package's `stress_period_data` is printed below using the different data retrieval methods highlighted above.

First we use the `get_data` method to get the stress period data as a dictionary of recarrays.

[16]:
```
print(wel.stress_period_data.get_data())
```

```
{0: rec.array([((2, 3, 1), -25.)],
          dtype=[('cellid', 'O'), ('q', '<f8')])}
```

Next we use the `array` attribute to get the stress period data as a single recarray.

[17]:
```
print(wel.stress_period_data.array)
```

```
[rec.array([((2, 3, 1), -25.)],
          dtype=[('cellid', 'O'), ('q', '<f8')]), None]
```

repr can be used to generate a string representation of stress period data.

[18]:
```
print(repr(wel.stress_period_data))
```

```
{0: <flopy.mf6.data.mfdataplist.PandasListStorage object at 0x7f01df041100>}
```

str produces a similar string representation of stress period data.

[19]:
```
print(str(wel.stress_period_data))
```

```
{0: <flopy.mf6.data.mfdataplist.PandasListStorage object at 0x7f01df041100>}
```

The `get_file_entry` method prints the stress period data as it would appear in a MODFLOW 6 file.

[20]:
```
print(wel.stress_period_data.get_file_entry(0))
```

```
  3 4 2 -2.50000000E+01
```

[21]:
```
try:
    temp_dir.cleanup()
except PermissionError:
    # can occur on windows: https://docs.python.org/3/library/tempfile.html#tempfile.
↪TemporaryDirectory
    pass
```

5.2.7 MODFLOW 6: Working with MODFLOW Grid Array Data

This tutorial shows how to view, access, and change the underlying data variables for MODFLOW 6 objects in FloPy. Interaction with a FloPy MODFLOW 6 model is different from other models, such as MODFLOW-2005, MT3D, and SEAWAT, for example.

FloPy stores model data in data objects (`MFDataArray`, `MFDataList`, `MFDataScalar` objects) that are accessible from packages. Data can be added to a package by using the appropriate parameters when the package is constructed and through package attributes.

The MODFLOW 6 simulation structure is arranged in the following generalized way:

```
Simulation --> Package --> DATA

Simulation --> Model --> Package (--> Package) --> DATA
```

This tutorial focuses on MODFLOW grid array data from the `GridData` and other similar blocks. These blocks contain data in a one or more dimensional array format organized by dimensions, which can include layer, row, column, and stress period. These data are stored by FloPy in a `MFArray` or `MFTransientArray` object and a referred to as array data.

Introduction to MODFLOW Array Data

MODFLOW array data use the `MFArray` or `MFTransientArray` FloPy classes and are stored in numpy ndarrays. Most MODFLOW array data are two (row, column) or three (layer, row, column) dimensional and represent data on the model grid. Other MODFLOW array data contain data by stress period. The following list summarizes the different types of MODFLOW array data.

- Time-invariant multi-dimensional array data. This includes:
  1. One and two dimensional arrays that do not have a layer dimension. Examples include `top`, `delc`, and `delr`.
  2. Three dimensional arrays that can contain a layer dimension. Examples include `botm`, `idomain`, and `k`.
- Transient arrays that can change with time and therefore contain arrays of data for one or more stress periods. Examples include `irch` and `recharge` in the `RCHA` package.

In the example below a three dimensional ndarray is constructed for the `DIS` package's `botm` array. First, the a simulation and groundwater-flow model are set up.

[1]:
```
# package import
import os
from pathlib import Path
from tempfile import TemporaryDirectory
```

[2]:
```
import numpy as np
```

[3]:
```
import flopy
```

[4]:
```
# set up where simulation workspace will be stored
temp_dir = TemporaryDirectory()
workspace = temp_dir.name
name = "tutorial07_mf6_data"
```

[5]:
```python
# create the FloPy simulation and tdis objects
sim = flopy.mf6.MFSimulation(
    sim_name=name, exe_name="mf6", version="mf6", sim_ws=workspace
)
tdis = flopy.mf6.modflow.mftdis.ModflowTdis(
    sim,
    pname="tdis",
    time_units="DAYS",
    nper=2,
    perioddata=[(1.0, 1, 1.0), (1.0, 1, 1.0)],
)
# create the Flopy groundwater flow (gwf) model object
model_nam_file = f"{name}.nam"
gwf = flopy.mf6.ModflowGwf(sim, modelname=name, model_nam_file=model_nam_file)
# create the flopy iterative model solver (ims) package object
ims = flopy.mf6.modflow.mfims.ModflowIms(sim, pname="ims", complexity="SIMPLE")
```

Then a three-dimensional ndarray of floating point values is created using numpy's `linspace` method.

[6]:
```python
bot = np.linspace(-50.0 / 3.0, -3.0, 3)
delrow = delcol = 4.0
```

The `DIS` package is then created passing the three-dimensional array to the `botm` parameter. The `botm` array defines the model's cell bottom elevations.

[7]:
```python
dis = flopy.mf6.modflow.mfgwfdis.ModflowGwfdis(
    gwf,
    pname="dis",
    nogrb=True,
    nlay=3,
    nrow=10,
    ncol=10,
    delr=delrow,
    delc=delcol,
    top=0.0,
    botm=bot,
)
```

Adding MODFLOW Grid Array Data

MODFLOW grid array data, like the data found in the `NPF` package's `GridData` block, can be specified as:

1. A constant value
2. A n-dimensional list
3. A numpy ndarray

Additionally, layered grid data (generally arrays with a layer dimension) can be specified by layer.

In the example below `icelltype` is specified as constants by layer, `k` is specified as a numpy ndarray, `k22` is specified as an array by layer, and `k33` is specified as a constant.

First `k` is set up as a 3 layer, by 10 row, by 10 column array with all values set to 10.0 using numpy's full method.

[8]:
```python
k = np.full((3, 10, 10), 10.0)
```

Next k22 is set up as a three dimensional list of nested lists. This option can be useful for those that are familiar with python lists but are not familiar with the numpy library.

[9]:
```python
k22_row = []
for row in range(0, 10):
    k22_row.append(8.0)
k22_layer = []
for col in range(0, 10):
    k22_layer.append(k22_row)
k22 = [k22_layer, k22_layer, k22_layer]
```

K33 is set up as a single constant value. Whenever an array has all the same values the easiest and most efficient way to set it up is as a constant value. Constant values also take less space to store.

[10]:
```python
k33 = 1.0
```

The k, k22, and k33 values defined above are then passed in on construction of the npf package.

[11]:
```python
npf = flopy.mf6.ModflowGwfnpf(
    gwf,
    pname="npf",
    save_flows=True,
    icelltype=[1, 1, 1],
    k=k,
    k22=k22,
    k33=k33,
    xt3doptions="xt3d rhs",
    rewet_record="REWET WETFCT 1.0 IWETIT 1 IHDWET 0",
)
```

```
<flopy.mf6.data.mfstructure.MFDataItemStructure object at 0x7f5198b2b790>
<flopy.mf6.data.mfstructure.MFDataItemStructure object at 0x7f5198b2b7c0>
```

Layered Data

When we look at what will be written to the npf input file, we see that the entire npf.k22 array is written as one long array with the number of values equal to nlay * nrow * ncol. And this whole-array specification may be of use in some cases. Often times, however, it is easier to work with each layer separately. An MFArray object, such as npf.k22 can be converted to a layered array as follows.

[12]:
```python
npf.k22.make_layered()
```

By changing npf.k22 to layered, we are then able to manage each layer separately. Before doing so, however, we need to pass in data that can be separated into three layers. An array of the correct size is one option.

[13]:
```python
shp = npf.k22.array.shape
a = np.arange(shp[0] * shp[1] * shp[2]).reshape(shp)
npf.k22.set_data(a)
```

Now that npf.k22 has been set to be layered, if we print information about it, we see that each layer is stored separately, however, npf.k22.array will still return a full three-dimensional array.

[14]:
```python
print(type(npf.k22))
print(npf.k22)
```

```
<class 'flopy.mf6.data.mfdataarray.MFArray'>
Layer_1{internal}
([[ 0  1  2  3  4  5  6  7  8  9]
 [10 11 12 13 14 15 16 17 18 19]
 [20 21 22 23 24 25 26 27 28 29]
 [30 31 32 33 34 35 36 37 38 39]
 [40 41 42 43 44 45 46 47 48 49]
 [50 51 52 53 54 55 56 57 58 59]
 [60 61 62 63 64 65 66 67 68 69]
 [70 71 72 73 74 75 76 77 78 79]
 [80 81 82 83 84 85 86 87 88 89]
 [90 91 92 93 94 95 96 97 98 99]])
Layer_2{internal}
([[100 101 102 103 104 105 106 107 108 109]
 [110 111 112 113 114 115 116 117 118 119]
 [120 121 122 123 124 125 126 127 128 129]
 [130 131 132 133 134 135 136 137 138 139]
 [140 141 142 143 144 145 146 147 148 149]
 [150 151 152 153 154 155 156 157 158 159]
 [160 161 162 163 164 165 166 167 168 169]
 [170 171 172 173 174 175 176 177 178 179]
 [180 181 182 183 184 185 186 187 188 189]
 [190 191 192 193 194 195 196 197 198 199]])
Layer_3{internal}
([[200 201 202 203 204 205 206 207 208 209]
 [210 211 212 213 214 215 216 217 218 219]
 [220 221 222 223 224 225 226 227 228 229]
 [230 231 232 233 234 235 236 237 238 239]
 [240 241 242 243 244 245 246 247 248 249]
 [250 251 252 253 254 255 256 257 258 259]
 [260 261 262 263 264 265 266 267 268 269]
 [270 271 272 273 274 275 276 277 278 279]
 [280 281 282 283 284 285 286 287 288 289]
 [290 291 292 293 294 295 296 297 298 299]])
```

We also see that each layer is printed separately to the npf Package input file, and that the LAYERED keyword is activated:

[15]:
```python
print(npf.k22.get_file_entry())
```

```
  k22  LAYERED
    INTERNAL  FACTOR  1.0
           0.00000000       1.00000000       2.00000000       3.00000000       4.
↪00000000       5.00000000       6.00000000       7.00000000       8.00000000       9.
↪00000000
          10.00000000      11.00000000      12.00000000      13.00000000      14.
↪00000000      15.00000000      16.00000000      17.00000000      18.00000000      19.
↪00000000
          20.00000000      21.00000000      22.00000000      23.00000000      24.
↪00000000      25.00000000      26.00000000      27.00000000      28.00000000      29.
```

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```
↪00000000
        30.00000000     31.00000000     32.00000000     33.00000000     34.
↪00000000     35.00000000     36.00000000     37.00000000     38.00000000     39.
↪00000000
        40.00000000     41.00000000     42.00000000     43.00000000     44.
↪00000000     45.00000000     46.00000000     47.00000000     48.00000000     49.
↪00000000
        50.00000000     51.00000000     52.00000000     53.00000000     54.
↪00000000     55.00000000     56.00000000     57.00000000     58.00000000     59.
↪00000000
        60.00000000     61.00000000     62.00000000     63.00000000     64.
↪00000000     65.00000000     66.00000000     67.00000000     68.00000000     69.
↪00000000
        70.00000000     71.00000000     72.00000000     73.00000000     74.
↪00000000     75.00000000     76.00000000     77.00000000     78.00000000     79.
↪00000000
        80.00000000     81.00000000     82.00000000     83.00000000     84.
↪00000000     85.00000000     86.00000000     87.00000000     88.00000000     89.
↪00000000
        90.00000000     91.00000000     92.00000000     93.00000000     94.
↪00000000     95.00000000     96.00000000     97.00000000     98.00000000     99.
↪00000000
  INTERNAL  FACTOR  1.0
       100.00000000    101.00000000    102.00000000    103.00000000    104.
↪00000000    105.00000000    106.00000000    107.00000000    108.00000000    109.
↪00000000
       110.00000000    111.00000000    112.00000000    113.00000000    114.
↪00000000    115.00000000    116.00000000    117.00000000    118.00000000    119.
↪00000000
       120.00000000    121.00000000    122.00000000    123.00000000    124.
↪00000000    125.00000000    126.00000000    127.00000000    128.00000000    129.
↪00000000
       130.00000000    131.00000000    132.00000000    133.00000000    134.
↪00000000    135.00000000    136.00000000    137.00000000    138.00000000    139.
↪00000000
       140.00000000    141.00000000    142.00000000    143.00000000    144.
↪00000000    145.00000000    146.00000000    147.00000000    148.00000000    149.
↪00000000
       150.00000000    151.00000000    152.00000000    153.00000000    154.
↪00000000    155.00000000    156.00000000    157.00000000    158.00000000    159.
↪00000000
       160.00000000    161.00000000    162.00000000    163.00000000    164.
↪00000000    165.00000000    166.00000000    167.00000000    168.00000000    169.
↪00000000
       170.00000000    171.00000000    172.00000000    173.00000000    174.
↪00000000    175.00000000    176.00000000    177.00000000    178.00000000    179.
↪00000000
       180.00000000    181.00000000    182.00000000    183.00000000    184.
↪00000000    185.00000000    186.00000000    187.00000000    188.00000000    189.
↪00000000
       190.00000000    191.00000000    192.00000000    193.00000000    194.
↪00000000    195.00000000    196.00000000    197.00000000    198.00000000    199.
```

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```
↪00000000
    INTERNAL   FACTOR   1.0
         200.00000000      201.00000000      202.00000000      203.00000000      204.
↪00000000      205.00000000      206.00000000      207.00000000      208.00000000      209.
↪00000000
         210.00000000      211.00000000      212.00000000      213.00000000      214.
↪00000000      215.00000000      216.00000000      217.00000000      218.00000000      219.
↪00000000
         220.00000000      221.00000000      222.00000000      223.00000000      224.
↪00000000      225.00000000      226.00000000      227.00000000      228.00000000      229.
↪00000000
         230.00000000      231.00000000      232.00000000      233.00000000      234.
↪00000000      235.00000000      236.00000000      237.00000000      238.00000000      239.
↪00000000
         240.00000000      241.00000000      242.00000000      243.00000000      244.
↪00000000      245.00000000      246.00000000      247.00000000      248.00000000      249.
↪00000000
         250.00000000      251.00000000      252.00000000      253.00000000      254.
↪00000000      255.00000000      256.00000000      257.00000000      258.00000000      259.
↪00000000
         260.00000000      261.00000000      262.00000000      263.00000000      264.
↪00000000      265.00000000      266.00000000      267.00000000      268.00000000      269.
↪00000000
         270.00000000      271.00000000      272.00000000      273.00000000      274.
↪00000000      275.00000000      276.00000000      277.00000000      278.00000000      279.
↪00000000
         280.00000000      281.00000000      282.00000000      283.00000000      284.
↪00000000      285.00000000      286.00000000      287.00000000      288.00000000      289.
↪00000000
         290.00000000      291.00000000      292.00000000      293.00000000      294.
↪00000000      295.00000000      296.00000000      297.00000000      298.00000000      299.
↪00000000
```

Working with a layered array provides lots of flexibility. For example, constants can be set for some layers, but arrays for others:

[16]:
```
npf.k22.set_data([1, a[2], 200])
print(npf.k22.get_file_entry())
```

```
  k22   LAYERED
    CONSTANT        1.00000000
    INTERNAL   FACTOR   1.0
         200.00000000      201.00000000      202.00000000      203.00000000      204.
↪00000000      205.00000000      206.00000000      207.00000000      208.00000000      209.
↪00000000
         210.00000000      211.00000000      212.00000000      213.00000000      214.
↪00000000      215.00000000      216.00000000      217.00000000      218.00000000      219.
↪00000000
         220.00000000      221.00000000      222.00000000      223.00000000      224.
↪00000000      225.00000000      226.00000000      227.00000000      228.00000000      229.
↪00000000
         230.00000000      231.00000000      232.00000000      233.00000000      234.
```

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```
↪00000000     235.00000000     236.00000000     237.00000000     238.00000000     239.
↪00000000
         240.00000000     241.00000000     242.00000000     243.00000000     244.
↪00000000     245.00000000     246.00000000     247.00000000     248.00000000     249.
↪00000000
         250.00000000     251.00000000     252.00000000     253.00000000     254.
↪00000000     255.00000000     256.00000000     257.00000000     258.00000000     259.
↪00000000
         260.00000000     261.00000000     262.00000000     263.00000000     264.
↪00000000     265.00000000     266.00000000     267.00000000     268.00000000     269.
↪00000000
         270.00000000     271.00000000     272.00000000     273.00000000     274.
↪00000000     275.00000000     276.00000000     277.00000000     278.00000000     279.
↪00000000
         280.00000000     281.00000000     282.00000000     283.00000000     284.
↪00000000     285.00000000     286.00000000     287.00000000     288.00000000     289.
↪00000000
         290.00000000     291.00000000     292.00000000     293.00000000     294.
↪00000000     295.00000000     296.00000000     297.00000000     298.00000000     299.
↪00000000
    CONSTANT     200.00000000
```

To gain full control over an individual layers, layer information can be provided as a dictionary:

[17]:
```
a0 = {"factor": 0.5, "iprn": 1, "data": 100 * np.ones((10, 10))}
a1 = 50
a2 = {"factor": 1.0, "iprn": 14, "data": 30 * np.ones((10, 10))}
npf.k22.set_data([a0, a1, a2])
print(npf.k22.get_file_entry())
```

```
  k22  LAYERED
    INTERNAL  FACTOR  0.5  IPRN  1
         100.00000000     100.00000000     100.00000000     100.00000000     100.
↪00000000     100.00000000     100.00000000     100.00000000     100.00000000     100.
↪00000000
         100.00000000     100.00000000     100.00000000     100.00000000     100.
↪00000000     100.00000000     100.00000000     100.00000000     100.00000000     100.
↪00000000
         100.00000000     100.00000000     100.00000000     100.00000000     100.
↪00000000     100.00000000     100.00000000     100.00000000     100.00000000     100.
↪00000000
         100.00000000     100.00000000     100.00000000     100.00000000     100.
↪00000000     100.00000000     100.00000000     100.00000000     100.00000000     100.
↪00000000
         100.00000000     100.00000000     100.00000000     100.00000000     100.
↪00000000     100.00000000     100.00000000     100.00000000     100.00000000     100.
↪00000000
         100.00000000     100.00000000     100.00000000     100.00000000     100.
↪00000000     100.00000000     100.00000000     100.00000000     100.00000000     100.
↪00000000
         100.00000000     100.00000000     100.00000000     100.00000000     100.
↪00000000     100.00000000     100.00000000     100.00000000     100.00000000     100.
```

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```
↪00000000
         100.00000000      100.00000000      100.00000000      100.00000000      100.
↪00000000      100.00000000      100.00000000      100.00000000      100.00000000      100.
↪00000000
         100.00000000      100.00000000      100.00000000      100.00000000      100.
↪00000000      100.00000000      100.00000000      100.00000000      100.00000000      100.
↪00000000
         100.00000000      100.00000000      100.00000000      100.00000000      100.
↪00000000      100.00000000      100.00000000      100.00000000      100.00000000      100.
↪00000000
    CONSTANT       50.00000000
    INTERNAL   FACTOR   1.0   IPRN   14
          30.00000000       30.00000000       30.00000000       30.00000000       30.
↪00000000       30.00000000       30.00000000       30.00000000       30.00000000       30.
↪00000000
          30.00000000       30.00000000       30.00000000       30.00000000       30.
↪00000000       30.00000000       30.00000000       30.00000000       30.00000000       30.
↪00000000
          30.00000000       30.00000000       30.00000000       30.00000000       30.
↪00000000       30.00000000       30.00000000       30.00000000       30.00000000       30.
↪00000000
          30.00000000       30.00000000       30.00000000       30.00000000       30.
↪00000000       30.00000000       30.00000000       30.00000000       30.00000000       30.
↪00000000
          30.00000000       30.00000000       30.00000000       30.00000000       30.
↪00000000       30.00000000       30.00000000       30.00000000       30.00000000       30.
↪00000000
          30.00000000       30.00000000       30.00000000       30.00000000       30.
↪00000000       30.00000000       30.00000000       30.00000000       30.00000000       30.
↪00000000
          30.00000000       30.00000000       30.00000000       30.00000000       30.
↪00000000       30.00000000       30.00000000       30.00000000       30.00000000       30.
↪00000000
          30.00000000       30.00000000       30.00000000       30.00000000       30.
↪00000000       30.00000000       30.00000000       30.00000000       30.00000000       30.
↪00000000
          30.00000000       30.00000000       30.00000000       30.00000000       30.
↪00000000       30.00000000       30.00000000       30.00000000       30.00000000       30.
↪00000000
          30.00000000       30.00000000       30.00000000       30.00000000       30.
↪00000000       30.00000000       30.00000000       30.00000000       30.00000000       30.
↪00000000
```

Here we say that the FACTOR has been set to 0.5 for the first layer and an alternative print flag is set for the last layer.

Because we are specifying a factor for the top layer, we can also see that the `get_data()` method returns the array without the factor applied

[18]:
```
print(npf.k22.get_data())
```

```
[[[100. 100. 100. 100. 100. 100. 100. 100. 100. 100.]
  [100. 100. 100. 100. 100. 100. 100. 100. 100. 100.]
```

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```
 [100. 100. 100. 100. 100. 100. 100. 100. 100. 100.]
 [100. 100. 100. 100. 100. 100. 100. 100. 100. 100.]
 [100. 100. 100. 100. 100. 100. 100. 100. 100. 100.]
 [100. 100. 100. 100. 100. 100. 100. 100. 100. 100.]
 [100. 100. 100. 100. 100. 100. 100. 100. 100. 100.]
 [100. 100. 100. 100. 100. 100. 100. 100. 100. 100.]
 [100. 100. 100. 100. 100. 100. 100. 100. 100. 100.]
 [100. 100. 100. 100. 100. 100. 100. 100. 100. 100.]]

[[ 50.  50.  50.  50.  50.  50.  50.  50.  50.  50.]
 [ 50.  50.  50.  50.  50.  50.  50.  50.  50.  50.]
 [ 50.  50.  50.  50.  50.  50.  50.  50.  50.  50.]
 [ 50.  50.  50.  50.  50.  50.  50.  50.  50.  50.]
 [ 50.  50.  50.  50.  50.  50.  50.  50.  50.  50.]
 [ 50.  50.  50.  50.  50.  50.  50.  50.  50.  50.]
 [ 50.  50.  50.  50.  50.  50.  50.  50.  50.  50.]
 [ 50.  50.  50.  50.  50.  50.  50.  50.  50.  50.]
 [ 50.  50.  50.  50.  50.  50.  50.  50.  50.  50.]
 [ 50.  50.  50.  50.  50.  50.  50.  50.  50.  50.]]

[[ 30.  30.  30.  30.  30.  30.  30.  30.  30.  30.]
 [ 30.  30.  30.  30.  30.  30.  30.  30.  30.  30.]
 [ 30.  30.  30.  30.  30.  30.  30.  30.  30.  30.]
 [ 30.  30.  30.  30.  30.  30.  30.  30.  30.  30.]
 [ 30.  30.  30.  30.  30.  30.  30.  30.  30.  30.]
 [ 30.  30.  30.  30.  30.  30.  30.  30.  30.  30.]
 [ 30.  30.  30.  30.  30.  30.  30.  30.  30.  30.]
 [ 30.  30.  30.  30.  30.  30.  30.  30.  30.  30.]
 [ 30.  30.  30.  30.  30.  30.  30.  30.  30.  30.]
 [ 30.  30.  30.  30.  30.  30.  30.  30.  30.  30.]]]
```

whereas the `array` property returns the array with the factor applied

[19]:
```
print(npf.k22.array)
```

```
[[[50. 50. 50. 50. 50. 50. 50. 50. 50. 50.]
  [50. 50. 50. 50. 50. 50. 50. 50. 50. 50.]
  [50. 50. 50. 50. 50. 50. 50. 50. 50. 50.]
  [50. 50. 50. 50. 50. 50. 50. 50. 50. 50.]
  [50. 50. 50. 50. 50. 50. 50. 50. 50. 50.]
  [50. 50. 50. 50. 50. 50. 50. 50. 50. 50.]
  [50. 50. 50. 50. 50. 50. 50. 50. 50. 50.]
  [50. 50. 50. 50. 50. 50. 50. 50. 50. 50.]
  [50. 50. 50. 50. 50. 50. 50. 50. 50. 50.]
  [50. 50. 50. 50. 50. 50. 50. 50. 50. 50.]]

 [[50. 50. 50. 50. 50. 50. 50. 50. 50. 50.]
  [50. 50. 50. 50. 50. 50. 50. 50. 50. 50.]
  [50. 50. 50. 50. 50. 50. 50. 50. 50. 50.]
  [50. 50. 50. 50. 50. 50. 50. 50. 50. 50.]
  [50. 50. 50. 50. 50. 50. 50. 50. 50. 50.]
  [50. 50. 50. 50. 50. 50. 50. 50. 50. 50.]
  [50. 50. 50. 50. 50. 50. 50. 50. 50. 50.]
```

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```
  [50. 50. 50. 50. 50. 50. 50. 50. 50. 50.]
  [50. 50. 50. 50. 50. 50. 50. 50. 50. 50.]
  [50. 50. 50. 50. 50. 50. 50. 50. 50. 50.]]

 [[30. 30. 30. 30. 30. 30. 30. 30. 30. 30.]
  [30. 30. 30. 30. 30. 30. 30. 30. 30. 30.]
  [30. 30. 30. 30. 30. 30. 30. 30. 30. 30.]
  [30. 30. 30. 30. 30. 30. 30. 30. 30. 30.]
  [30. 30. 30. 30. 30. 30. 30. 30. 30. 30.]
  [30. 30. 30. 30. 30. 30. 30. 30. 30. 30.]
  [30. 30. 30. 30. 30. 30. 30. 30. 30. 30.]
  [30. 30. 30. 30. 30. 30. 30. 30. 30. 30.]
  [30. 30. 30. 30. 30. 30. 30. 30. 30. 30.]
  [30. 30. 30. 30. 30. 30. 30. 30. 30. 30.]]]
```

Adding MODFLOW Stress Period Array Data

Transient array data spanning multiple stress periods must be specified as a dictionary of arrays, where the dictionary key is the stress period, expressed as a zero-based integer, and the dictionary value is the grid data for that stress period.

In the following example a RCHA package is created. First a dictionary is created that contains recharge for the model's two stress periods. Recharge is specified as a constant value in this example, though it could also be specified as a 3-dimensional ndarray or list of lists.

[20]:
```
rch_sp1 = 0.01
rch_sp2 = 0.03
rch_spd = {0: rch_sp1, 1: rch_sp2}
```

The RCHA package is created and the dictionary constructed above is passed in as the `recharge` parameter.

[21]:
```
rch = flopy.mf6.ModflowGwfrcha(
    gwf, readasarrays=True, pname="rch", print_input=True, recharge=rch_spd
)
```

Retrieving Grid Array Data

Grid data can be retrieved with `get_data`, `array`, `[]`, `repr/str`, or `get_file_entry`.

Retrieval Method	Description
get_data	Returns ndarray of data without multiplier applied, unless the apply_mult parameter is set to True
array	Returns ndarray of data with multiplier applied
[]	Returns a particular layer of data if data is layered, otherwise is an array index
repr/str	Returns string with storage information followed by ndarray repr/str
get_file_entry(	Returns string containing data formatted for the MODFLOW-6 package file. If layer is not specified returns all layers, otherwise returns just the layer specified.

Below the NPF k array is retrieved using the various methods highlighted above.

First, we use the `get_data` method to get k as an ndarray.

[22]:
```
print(npf.k.get_data())
```

```
[[[10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
  [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
  [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
  [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
  [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
  [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
  [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
  [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
  [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
  [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]]

 [[10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
  [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
  [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
  [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
  [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
  [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
  [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
  [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
  [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
  [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]]

 [[10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
  [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
  [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
  [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
  [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
  [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
  [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
  [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
  [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
  [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]]]
```

Next, we use the `array` attribute which also gets k as an ndarray.

[23]:
```
print(npf.k.array)
```

```
[[[10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
  [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
  [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
  [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
  [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
  [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
  [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
  [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
  [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
  [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]]

 [[10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
  [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
  [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
  [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
```

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```
 [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
 [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
 [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
 [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
 [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
 [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]]

[[10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
 [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
 [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
 [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
 [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
 [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
 [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
 [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
 [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
 [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]]]
```

We can also use the `[]` to get a single layer of data as an ndarray.

[24]:
```
print(npf.k[0])
```

```
[[10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
 [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
 [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
 [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
 [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
 [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
 [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
 [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
 [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
 [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]]
```

repr gives a string representation of the data.

[25]:
```
print(repr(npf.k))
```

```
Layer_1{internal}
(array([[10., 10., 10., 10., 10., 10., 10., 10., 10., 10.],
       [10., 10., 10., 10., 10., 10., 10., 10., 10., 10.],
       [10., 10., 10., 10., 10., 10., 10., 10., 10., 10.],
       [10., 10., 10., 10., 10., 10., 10., 10., 10., 10.],
       [10., 10., 10., 10., 10., 10., 10., 10., 10., 10.],
       [10., 10., 10., 10., 10., 10., 10., 10., 10., 10.],
       [10., 10., 10., 10., 10., 10., 10., 10., 10., 10.],
       [10., 10., 10., 10., 10., 10., 10., 10., 10., 10.],
       [10., 10., 10., 10., 10., 10., 10., 10., 10., 10.],
       [10., 10., 10., 10., 10., 10., 10., 10., 10., 10.]]))
Layer_2{internal}
(array([[10., 10., 10., 10., 10., 10., 10., 10., 10., 10.],
       [10., 10., 10., 10., 10., 10., 10., 10., 10., 10.],
       [10., 10., 10., 10., 10., 10., 10., 10., 10., 10.],
       [10., 10., 10., 10., 10., 10., 10., 10., 10., 10.],
```

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```
       [10., 10., 10., 10., 10., 10., 10., 10., 10., 10.],
       [10., 10., 10., 10., 10., 10., 10., 10., 10., 10.],
       [10., 10., 10., 10., 10., 10., 10., 10., 10., 10.],
       [10., 10., 10., 10., 10., 10., 10., 10., 10., 10.],
       [10., 10., 10., 10., 10., 10., 10., 10., 10., 10.],
       [10., 10., 10., 10., 10., 10., 10., 10., 10., 10.]]))
Layer_3{internal}
(array([[10., 10., 10., 10., 10., 10., 10., 10., 10., 10.],
       [10., 10., 10., 10., 10., 10., 10., 10., 10., 10.],
       [10., 10., 10., 10., 10., 10., 10., 10., 10., 10.],
       [10., 10., 10., 10., 10., 10., 10., 10., 10., 10.],
       [10., 10., 10., 10., 10., 10., 10., 10., 10., 10.],
       [10., 10., 10., 10., 10., 10., 10., 10., 10., 10.],
       [10., 10., 10., 10., 10., 10., 10., 10., 10., 10.],
       [10., 10., 10., 10., 10., 10., 10., 10., 10., 10.],
       [10., 10., 10., 10., 10., 10., 10., 10., 10., 10.],
       [10., 10., 10., 10., 10., 10., 10., 10., 10., 10.]]))
```

str gives a similar string representation of the data.

[26]:
```
print(str(npf.k))
```

```
Layer_1{internal}
([[10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
 [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
 [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
 [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
 [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
 [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
 [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
 [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
 [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
 [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]])
Layer_2{internal}
([[10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
 [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
 [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
 [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
 [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
 [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
 [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
 [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
 [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
 [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]])
Layer_3{internal}
([[10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
 [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
 [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
 [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
 [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
 [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
 [10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
```

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```
[10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
[10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]
[10. 10. 10. 10. 10. 10. 10. 10. 10. 10.]])
```

The method `get_file_entry` prints the data as it would appear in a MODFLOW 6 file.

[27]:
```
print(npf.k.get_file_entry())
```

```
  k  LAYERED
    INTERNAL  FACTOR  1.0
          10.00000000      10.00000000      10.00000000      10.00000000      10.
↪00000000      10.00000000      10.00000000      10.00000000      10.00000000      10.
↪00000000
          10.00000000      10.00000000      10.00000000      10.00000000      10.
↪00000000      10.00000000      10.00000000      10.00000000      10.00000000      10.
↪00000000
          10.00000000      10.00000000      10.00000000      10.00000000      10.
↪00000000      10.00000000      10.00000000      10.00000000      10.00000000      10.
↪00000000
          10.00000000      10.00000000      10.00000000      10.00000000      10.
↪00000000      10.00000000      10.00000000      10.00000000      10.00000000      10.
↪00000000
          10.00000000      10.00000000      10.00000000      10.00000000      10.
↪00000000      10.00000000      10.00000000      10.00000000      10.00000000      10.
↪00000000
          10.00000000      10.00000000      10.00000000      10.00000000      10.
↪00000000      10.00000000      10.00000000      10.00000000      10.00000000      10.
↪00000000
          10.00000000      10.00000000      10.00000000      10.00000000      10.
↪00000000      10.00000000      10.00000000      10.00000000      10.00000000      10.
↪00000000
          10.00000000      10.00000000      10.00000000      10.00000000      10.
↪00000000      10.00000000      10.00000000      10.00000000      10.00000000      10.
↪00000000
          10.00000000      10.00000000      10.00000000      10.00000000      10.
↪00000000      10.00000000      10.00000000      10.00000000      10.00000000      10.
↪00000000
          10.00000000      10.00000000      10.00000000      10.00000000      10.
↪00000000      10.00000000      10.00000000      10.00000000      10.00000000      10.
↪00000000
    INTERNAL  FACTOR  1.0
          10.00000000      10.00000000      10.00000000      10.00000000      10.
↪00000000      10.00000000      10.00000000      10.00000000      10.00000000      10.
↪00000000
          10.00000000      10.00000000      10.00000000      10.00000000      10.
↪00000000      10.00000000      10.00000000      10.00000000      10.00000000      10.
↪00000000
          10.00000000      10.00000000      10.00000000      10.00000000      10.
↪00000000      10.00000000      10.00000000      10.00000000      10.00000000      10.
↪00000000
          10.00000000      10.00000000      10.00000000      10.00000000      10.
↪00000000      10.00000000      10.00000000      10.00000000      10.00000000      10.
```

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```
↪00000000
           10.00000000       10.00000000       10.00000000       10.00000000       10.
↪00000000       10.00000000       10.00000000       10.00000000       10.00000000       10.
↪00000000
           10.00000000       10.00000000       10.00000000       10.00000000       10.
↪00000000       10.00000000       10.00000000       10.00000000       10.00000000       10.
↪00000000
           10.00000000       10.00000000       10.00000000       10.00000000       10.
↪00000000       10.00000000       10.00000000       10.00000000       10.00000000       10.
↪00000000
           10.00000000       10.00000000       10.00000000       10.00000000       10.
↪00000000       10.00000000       10.00000000       10.00000000       10.00000000       10.
↪00000000
           10.00000000       10.00000000       10.00000000       10.00000000       10.
↪00000000       10.00000000       10.00000000       10.00000000       10.00000000       10.
↪00000000
           10.00000000       10.00000000       10.00000000       10.00000000       10.
↪00000000       10.00000000       10.00000000       10.00000000       10.00000000       10.
↪00000000
    INTERNAL  FACTOR  1.0
           10.00000000       10.00000000       10.00000000       10.00000000       10.
↪00000000       10.00000000       10.00000000       10.00000000       10.00000000       10.
↪00000000
           10.00000000       10.00000000       10.00000000       10.00000000       10.
↪00000000       10.00000000       10.00000000       10.00000000       10.00000000       10.
↪00000000
           10.00000000       10.00000000       10.00000000       10.00000000       10.
↪00000000       10.00000000       10.00000000       10.00000000       10.00000000       10.
↪00000000
           10.00000000       10.00000000       10.00000000       10.00000000       10.
↪00000000       10.00000000       10.00000000       10.00000000       10.00000000       10.
↪00000000
           10.00000000       10.00000000       10.00000000       10.00000000       10.
↪00000000       10.00000000       10.00000000       10.00000000       10.00000000       10.
↪00000000
           10.00000000       10.00000000       10.00000000       10.00000000       10.
↪00000000       10.00000000       10.00000000       10.00000000       10.00000000       10.
↪00000000
           10.00000000       10.00000000       10.00000000       10.00000000       10.
↪00000000       10.00000000       10.00000000       10.00000000       10.00000000       10.
↪00000000
           10.00000000       10.00000000       10.00000000       10.00000000       10.
↪00000000       10.00000000       10.00000000       10.00000000       10.00000000       10.
↪00000000
           10.00000000       10.00000000       10.00000000       10.00000000       10.
↪00000000       10.00000000       10.00000000       10.00000000       10.00000000       10.
↪00000000
           10.00000000       10.00000000       10.00000000       10.00000000       10.
↪00000000       10.00000000       10.00000000       10.00000000       10.00000000       10.
↪00000000
```

Retrieving MODFLOW Stress Period Array Data

Transient array data can be retrieved with `get_data`, `array`, `repr/str`, or `get_file_entry`.

Retrieval Method	Description
get_data	Returns dictionary of ndarrays without multiplier applied. The dictionary key is the stress period as a zero-based integer.
array	Returns ndarray of data for all stress periods (stress period is an added dimension)
repr/str	Returns string with storage information followed by ndarray repr/str for all stress periods
get_file_entry(la	Returns string containing data formatted for the MODFLOW-6 package file. Use to specify a stress period (zero-based integer).

Below the RCHA `recharge` array is retrieved using the various methods highlighted above.

First, we use the `get_data` method to get the recharge data as a dictionary of ndarrays. The dictionary key is a the stress period (zero based).

```
[28]: print(rch.recharge.get_data())
```

```
{0: array([[0.01, 0.01, 0.01, 0.01, 0.01, 0.01, 0.01, 0.01, 0.01, 0.01],
       [0.01, 0.01, 0.01, 0.01, 0.01, 0.01, 0.01, 0.01, 0.01, 0.01],
       [0.01, 0.01, 0.01, 0.01, 0.01, 0.01, 0.01, 0.01, 0.01, 0.01],
       [0.01, 0.01, 0.01, 0.01, 0.01, 0.01, 0.01, 0.01, 0.01, 0.01],
       [0.01, 0.01, 0.01, 0.01, 0.01, 0.01, 0.01, 0.01, 0.01, 0.01],
       [0.01, 0.01, 0.01, 0.01, 0.01, 0.01, 0.01, 0.01, 0.01, 0.01],
       [0.01, 0.01, 0.01, 0.01, 0.01, 0.01, 0.01, 0.01, 0.01, 0.01],
       [0.01, 0.01, 0.01, 0.01, 0.01, 0.01, 0.01, 0.01, 0.01, 0.01],
       [0.01, 0.01, 0.01, 0.01, 0.01, 0.01, 0.01, 0.01, 0.01, 0.01],
       [0.01, 0.01, 0.01, 0.01, 0.01, 0.01, 0.01, 0.01, 0.01, 0.01]]), 1: array([[0.03,␣
↪0.03, 0.03, 0.03, 0.03, 0.03, 0.03, 0.03, 0.03, 0.03],
       [0.03, 0.03, 0.03, 0.03, 0.03, 0.03, 0.03, 0.03, 0.03, 0.03],
       [0.03, 0.03, 0.03, 0.03, 0.03, 0.03, 0.03, 0.03, 0.03, 0.03],
       [0.03, 0.03, 0.03, 0.03, 0.03, 0.03, 0.03, 0.03, 0.03, 0.03],
       [0.03, 0.03, 0.03, 0.03, 0.03, 0.03, 0.03, 0.03, 0.03, 0.03],
       [0.03, 0.03, 0.03, 0.03, 0.03, 0.03, 0.03, 0.03, 0.03, 0.03],
       [0.03, 0.03, 0.03, 0.03, 0.03, 0.03, 0.03, 0.03, 0.03, 0.03],
       [0.03, 0.03, 0.03, 0.03, 0.03, 0.03, 0.03, 0.03, 0.03, 0.03],
       [0.03, 0.03, 0.03, 0.03, 0.03, 0.03, 0.03, 0.03, 0.03, 0.03],
       [0.03, 0.03, 0.03, 0.03, 0.03, 0.03, 0.03, 0.03, 0.03, 0.03]])}
```

Next, we use the `array` attribute to get the data as an 4-dimensional ndarray.

```
[29]: print(rch.recharge.array)
```

```
[[[[0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01]
   [0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01]
   [0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01]
   [0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01]
   [0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01]
   [0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01]
   [0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01]
   [0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01]
   [0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01]
```

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```
   [0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01]]]


 [[[0.03 0.03 0.03 0.03 0.03 0.03 0.03 0.03 0.03 0.03]
   [0.03 0.03 0.03 0.03 0.03 0.03 0.03 0.03 0.03 0.03]
   [0.03 0.03 0.03 0.03 0.03 0.03 0.03 0.03 0.03 0.03]
   [0.03 0.03 0.03 0.03 0.03 0.03 0.03 0.03 0.03 0.03]
   [0.03 0.03 0.03 0.03 0.03 0.03 0.03 0.03 0.03 0.03]
   [0.03 0.03 0.03 0.03 0.03 0.03 0.03 0.03 0.03 0.03]
   [0.03 0.03 0.03 0.03 0.03 0.03 0.03 0.03 0.03 0.03]
   [0.03 0.03 0.03 0.03 0.03 0.03 0.03 0.03 0.03 0.03]
   [0.03 0.03 0.03 0.03 0.03 0.03 0.03 0.03 0.03 0.03]
   [0.03 0.03 0.03 0.03 0.03 0.03 0.03 0.03 0.03 0.03]]]]
```

repr gives a string representation of the data.

[30]:
```
print(repr(rch.recharge))
```

```
{constant 0.03}
```

str gives a similar representation of the data.

[31]:
```
print(str(rch.recharge))
```

```
{constant 0.03}
```

We can use the `get_file_entry` method to get the data as it would appear in a MODFLOW 6 file for a specific stress period. In this case we are getting the data for stress period 2 (stress periods are treated as 0-based in FloPy).

[32]:
```
print(rch.recharge.get_file_entry(1))
```

```
  recharge
    CONSTANT       0.03000000
```

[33]:
```
try:
    temp_dir.cleanup()
except PermissionError:
    # can occur on windows: https://docs.python.org/3/library/tempfile.html#tempfile.
↪TemporaryDirectory
    pass
```

5.2.8 MODFLOW 6: Data Storage Information and Performance Optimization

This tutorial shows the different options for storing MODFLOW data in FloPy. Interaction with a FloPy MODFLOW 6 model is different from other models, such as MODFLOW-2005, MT3D, and SEAWAT, for example.

FloPy stores model data in data objects (`MFDataArray`, `MFDataList`, `MFDataScalar` objects) that are accessible from packages. Data can be added to a package by using the appropriate parameters when the package is constructed and through package attributes.

The MODFLOW 6 simulation structure is arranged in the following generalized way:

```
Simulation --> Package --> DATA

Simulation --> Model --> Package (--> Package) --> DATA
```

This tutorial focuses on the different storage options for MODFLOW data and how to optimize data storage read/write speed.

Introduction to Data Storage Information

MODFLOW array and list data can either be stored internally or externally in text or binary files. Additionally array data can have a factor applied to them and can have a format flag/code to define how these data will be formatted. This data storage information is specified within a python dictionary. The python dictionary must contain a "data" key where the data is stored and supports several other keys that determine how and where the data is stored.

The following code sets up a basic simulation with a groundwater flow model. for the example below.

[1]:
```python
# package import
import os
from pathlib import Path
from tempfile import TemporaryDirectory
```

[2]:
```python
import numpy as np
```

[3]:
```python
import flopy
```

[4]:
```python
# set up where simulation workspace will be stored
temp_dir = TemporaryDirectory()
workspace = temp_dir.name
name = "tutorial08_mf6_data"
```

[5]:
```python
# create the FloPy simulation and tdis objects
sim = flopy.mf6.MFSimulation(
    sim_name=name, exe_name="mf6", version="mf6", sim_ws=workspace
)
tdis = flopy.mf6.modflow.mftdis.ModflowTdis(
    sim,
    pname="tdis",
    time_units="DAYS",
    nper=2,
    perioddata=[(1.0, 1, 1.0), (1.0, 1, 1.0)],
)
# create the Flopy groundwater flow (gwf) model object
```

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```
model_nam_file = f"{name}.nam"
gwf = flopy.mf6.ModflowGwf(sim, modelname=name, model_nam_file=model_nam_file)
# create the flopy iterative model solver (ims) package object
ims = flopy.mf6.modflow.mfims.ModflowIms(sim, pname="ims", complexity="SIMPLE")
# create the discretization package
bot = np.linspace(-50.0 / 3.0, -3.0, 3)
delrow = delcol = 4.0
dis = flopy.mf6.modflow.mfgwfdis.ModflowGwfdis(
    gwf,
    pname="dis",
    nogrb=True,
    nlay=3,
    nrow=10,
    ncol=10,
    delr=delrow,
    delc=delcol,
    top=0.0,
    botm=bot,
)
```

Setting up a Data Storage Information Dictionary

To store data externally add a `filename` key to the dictionary whose value is the file where you want to store the data. Add a `binary` key with value True to make the file a binary file. Add a `prn` key whose value is a format code to set the format code for the data. For array data add a `factor` key whose value is a positive floating point number to add a factor/multiplier for the array.

Below a dictionary is created that defines how a `k33` array will be stored. The dictionary specifies that the `k33` array be stored in the binary file k33.txt with a factor of 1.0 applied to the array and a print code of 1. The `k33` array data is constructed as a numpy array.

[6]:
```
k33_values = np.full((3, 10, 10), 1.1)
k33 = {
    "filename": "k33.txt",
    "factor": 1.0,
    "data": k33_values,
    "iprn": 1,
    "binary": "True",
}
```

The `NPF` package is then created with the `k33` array in an external binary file. This binary file is created when the simulation method `write_simulation` is called.

[7]:
```
npf = flopy.mf6.ModflowGwfnpf(
    gwf,
    pname="npf",
    save_flows=True,
    icelltype=[1, 1, 1],
    k=10.0,
    k22=5.0,
    k33=k33,
    xt3doptions="xt3d rhs",
```

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```
    rewet_record="REWET WETFCT 1.0 IWETIT 1 IHDWET 0",
)
```

```
<flopy.mf6.data.mfstructure.MFDataItemStructure object at 0x7fd996dfd2b0>
<flopy.mf6.data.mfstructure.MFDataItemStructure object at 0x7fd996dfd2e0>
```

External files can be set for specific layers of data. If we want to store the bottom elevations for the third model layer to an external file, then the dictionary that we pass in for the third layer can be given a "filename" key.

[8]:
```
a0 = {"factor": 0.5, "iprn": 1, "data": np.ones((10, 10))}
a1 = -100
a2 = {
    "filename": "dis.botm.3.txt",
    "factor": 2.0,
    "iprn": 1,
    "data": -100 * np.ones((10, 10)),
}
```

A list containing data for the three specified layers is then passed in to the `botm` object's `set_record` method.

[9]:
```
dis.botm.set_record([a0, a1, a2])
print(dis.botm.get_file_entry())
```

```
  botm  LAYERED
    INTERNAL  FACTOR  0.5  IPRN  1
               1.00000000        1.00000000        1.00000000        1.00000000        1.
↪00000000        1.00000000        1.00000000        1.00000000        1.00000000        1.
↪00000000
               1.00000000        1.00000000        1.00000000        1.00000000        1.
↪00000000        1.00000000        1.00000000        1.00000000        1.00000000        1.
↪00000000
               1.00000000        1.00000000        1.00000000        1.00000000        1.
↪00000000        1.00000000        1.00000000        1.00000000        1.00000000        1.
↪00000000
               1.00000000        1.00000000        1.00000000        1.00000000        1.
↪00000000        1.00000000        1.00000000        1.00000000        1.00000000        1.
↪00000000
               1.00000000        1.00000000        1.00000000        1.00000000        1.
↪00000000        1.00000000        1.00000000        1.00000000        1.00000000        1.
↪00000000
               1.00000000        1.00000000        1.00000000        1.00000000        1.
↪00000000        1.00000000        1.00000000        1.00000000        1.00000000        1.
↪00000000
               1.00000000        1.00000000        1.00000000        1.00000000        1.
↪00000000        1.00000000        1.00000000        1.00000000        1.00000000        1.
↪00000000
               1.00000000        1.00000000        1.00000000        1.00000000        1.
↪00000000        1.00000000        1.00000000        1.00000000        1.00000000        1.
↪00000000
               1.00000000        1.00000000        1.00000000        1.00000000        1.
↪00000000        1.00000000        1.00000000        1.00000000        1.00000000        1.
↪00000000
               1.00000000        1.00000000        1.00000000        1.00000000        1.
```

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```
↪00000000       1.00000000       1.00000000       1.00000000       1.00000000       1.
↪00000000
    CONSTANT    -100.00000000
    OPEN/CLOSE  'dis.botm.3.txt'  FACTOR  2.0  IPRN  1
```

The botm data and its attributes (filename, binary, factor, iprn) can be retrieved as a dictionary of dictionaries using get_record.

[10]:
```
botm_record = dis.botm.get_record()
print("botm layer 1 record:")
print(botm_record[0])
print("\nbotm layer 2 record:")
print(botm_record[1])
print("\nbotm layer 3 record:")
print(botm_record[2])
```

```
botm layer 1 record:
{'factor': 0.5, 'iprn': 1, 'data': array([[1., 1., 1., 1., 1., 1., 1., 1., 1., 1.],
       [1., 1., 1., 1., 1., 1., 1., 1., 1., 1.],
       [1., 1., 1., 1., 1., 1., 1., 1., 1., 1.],
       [1., 1., 1., 1., 1., 1., 1., 1., 1., 1.],
       [1., 1., 1., 1., 1., 1., 1., 1., 1., 1.],
       [1., 1., 1., 1., 1., 1., 1., 1., 1., 1.],
       [1., 1., 1., 1., 1., 1., 1., 1., 1., 1.],
       [1., 1., 1., 1., 1., 1., 1., 1., 1., 1.],
       [1., 1., 1., 1., 1., 1., 1., 1., 1., 1.],
       [1., 1., 1., 1., 1., 1., 1., 1., 1., 1.]])}

botm layer 2 record:
{'factor': 1.0, 'iprn': None, 'data': array([[-100., -100., -100., -100., -100., -100., -
↪100., -100., -100.,
        -100.],
       [-100., -100., -100., -100., -100., -100., -100., -100., -100.,
        -100.],
       [-100., -100., -100., -100., -100., -100., -100., -100., -100.,
        -100.],
       [-100., -100., -100., -100., -100., -100., -100., -100., -100.,
        -100.],
       [-100., -100., -100., -100., -100., -100., -100., -100., -100.,
        -100.],
       [-100., -100., -100., -100., -100., -100., -100., -100., -100.,
        -100.],
       [-100., -100., -100., -100., -100., -100., -100., -100., -100.,
        -100.],
       [-100., -100., -100., -100., -100., -100., -100., -100., -100.,
        -100.],
       [-100., -100., -100., -100., -100., -100., -100., -100., -100.,
        -100.],
       [-100., -100., -100., -100., -100., -100., -100., -100., -100.,
        -100.]])}

botm layer 3 record:
```

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```
{'filename': 'dis.botm.3.txt', 'binary': False, 'factor': 2.0, 'iprn': 1, 'data':␣
↪array([[-100., -100., -100., -100., -100., -100., -100., -100., -100.,
        -100.],
       [-100., -100., -100., -100., -100., -100., -100., -100., -100.,
        -100.],
       [-100., -100., -100., -100., -100., -100., -100., -100., -100.,
        -100.],
       [-100., -100., -100., -100., -100., -100., -100., -100., -100.,
        -100.],
       [-100., -100., -100., -100., -100., -100., -100., -100., -100.,
        -100.],
       [-100., -100., -100., -100., -100., -100., -100., -100., -100.,
        -100.],
       [-100., -100., -100., -100., -100., -100., -100., -100., -100.,
        -100.],
       [-100., -100., -100., -100., -100., -100., -100., -100., -100.,
        -100.],
       [-100., -100., -100., -100., -100., -100., -100., -100., -100.,
        -100.],
       [-100., -100., -100., -100., -100., -100., -100., -100., -100.,
        -100.]])}
```

The botm record retrieved can be modified and then saved with set_record. For example, the array data's "factor" can be modified and saved.

[11]:
```
botm_record[0]["factor"] = 0.6
dis.botm.set_record(botm_record)
```

The updated value can then be retrieved.

[12]:
```
botm_record = dis.botm.get_record()
print(f"botm layer 1 factor:  {botm_record[0]['factor']}")
```

```
botm layer 1 factor:  0.6
```

The get_record and set_record methods can also be used with list data to get and set the data and its "filename" and "binary" attributes. This is demonstrated with the wel package. First, a wel package is constructed.

[13]:
```
welspdict = {
    0: {"filename": "well_sp1.txt", "data": [[(0, 0, 0), 0.25]]},
    1: [[(0, 0, 0), 0.1]],
}
wel = flopy.mf6.ModflowGwfwel(
    gwf,
    print_input=True,
    print_flows=True,
    stress_period_data=welspdict,
    save_flows=False,
)
```

The wel stress period data and associated "filename" and "binary" attributes can be retrieved with get_record.

```
[14]: spd_record = wel.stress_period_data.get_record()
print("Stress period 1 record:")
print(spd_record[0])
print("\nStress period 2 record:")
print(spd_record[1])
```

```
Stress period 1 record:
{'filename': 'well_sp1.txt', 'binary': False, 'data': rec.array([((0, 0, 0), 0.25)],
          dtype=[('cellid', 'O'), ('q', '<f8')])}

Stress period 2 record:
{'data': rec.array([((0, 0, 0), 0.1)],
          dtype=[('cellid', 'O'), ('q', '<f8')]), 'binary': False}
```

The wel data and associated attributes can be changed by modifying the record and then saving it with the set_record method.

```
[15]: spd_record[0]["filename"] = "well_package_sp1.txt"
spd_record[0]["binary"] = True
spd_record[1]["filename"] = "well_package_sp2.bin"
wel.stress_period_data.set_record(spd_record)
```

The changes can be verified by calling get_record again.

```
[16]: spd_record = wel.stress_period_data.get_record()
print(f"New filename for stress period 1:  {spd_record[0]['filename']}")
print(f"New binary flag for stress period 1:  {spd_record[0]['binary']}")
print(f"New filename for stress period 2:  {spd_record[1]['filename']}")
```

```
New filename for stress period 1:  well_package_sp1.txt
New binary flag for stress period 1:  True
New filename for stress period 2:  well_package_sp2.bin
```

Optimizing FloPy Performance

By default FloPy will perform a number of verification checks on your data when FloPy loads or saves that data. For large datasets turning these verification checks off can significantly improve FloPy's performance. Additionally, storing files externally can help minimize the amount of data FloPy reads/writes when loading and saving a simulation. The following steps will help you optimize FloPy's performance for large datasets.

1) Turn off FloPy verification checks and FloPy's option to automatically update "maxbound". This can be turned off on an existing simulation by either individually turning off each of these settings.

```
[17]: sim.simulation_data.auto_set_sizes = False
sim.simulation_data.verify_data = False
sim.write_simulation()
```

```
writing simulation...
  writing simulation name file...
  writing simulation tdis package...
  writing solution package ims...
  writing model tutorial08_mf6_data...
    writing model name file...
    writing package dis...
```

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```
    writing package npf...
    writing package wel_0...
```

or by setting lazy_io to True.

[18]:
```
sim.simulation_data.lazy_io = True
sim.write_simulation()
```

```
writing simulation...
  writing simulation name file...
  writing simulation tdis package...
  writing solution package ims...
  writing model tutorial08_mf6_data...
    writing model name file...
    writing package dis...
    writing package npf...
    writing package wel_0...
```

These options can also be turned off when loading an existing simulation or creating a new simulation by setting lazy_io to True.

[19]:
```
sim2 = flopy.mf6.MFSimulation.load(
    sim_ws=workspace,
    lazy_io=True,
)
```

```
loading simulation...
  loading simulation name file...
  loading tdis package...
  loading model gwf6...
    loading package dis...
    loading package npf...
    loading package wel...
  loading solution package tutorial08_mf6_data...
```

[20]:
```
sim3 = flopy.mf6.MFSimulation(lazy_io=True)
```

2) Whenever possible save large datasets to external binary files. Binary files are more compact and the data will be read and written significantly faster. See MODFLOW-6 documentation for which packages and data support binary files.

[21]:
```
# store all well period data in external binary files
spd_record[0]["binary"] = True
spd_record[1]["binary"] = True
wel.stress_period_data.set_record(spd_record)
```

3) For datasets that do not support binary files, save them to external text files. When loading a simulation, FloPy will always parse MODFLOW-6 package files, but will not parse external text files when auto_set_sizes and verify data are both set to False. Additionally, if write_simulation is later called, external files will not be re-written unless either the data or the file path has changed.

[22]:
```
# store lak period data in external text files
period = {
```

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```
    0: {"filename": "lak_sp1.txt", "data": [(0, "STAGE", 10.0)]},
    1: {"filename": "lak_sp2.txt", "data": [(0, "STAGE", 15.0)]},
}
lakpd = [(0, -2.0, 1)]
lakecn = [(0, 0, (0, 1, 0), "HORIZONTAL", 1.0, -5.0, 0.0, 10.0, 10.0)]
lak = flopy.mf6.ModflowGwflak(
    gwf,
    pname="lak-1",
    nlakes=1,
    noutlets=0,
    ntables=0,
    packagedata=lakpd,
    connectiondata=lakecn,
    perioddata=period,
)
```

[23]:
```
try:
    temp_dir.cleanup()
except PermissionError:
    # can occur on windows: https://docs.python.org/3/library/tempfile.html#tempfile.
↪TemporaryDirectory
    pass
```

5.2.9 MODFLOW 6: Multiple Models - How to create multiple models in a simulation

This tutorial shows a simulation using two models, demonstrating how to use exchanges and exchange subpackages.

Introduction to Multiple Models

MODFLOW-6 simulations can contain multiple models, which can be linked through the groundwater exchange package, which can contain mover and ghost node correction subpackages.

The following code sets up a basic simulation.

[1]:
```
# package import
from pathlib import Path
from tempfile import TemporaryDirectory
```

[2]:
```
import flopy
```

[3]:
```
# set up where simulation workspace will be stored
temp_dir = TemporaryDirectory()
workspace = temp_dir.name
name = "tutorial09_mf6_data"
```

[4]:
```
# create the FloPy simulation and tdis objects
sim = flopy.mf6.MFSimulation(
    sim_name=name, exe_name="mf6", version="mf6", sim_ws=workspace
)
```

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```
tdis = flopy.mf6.modflow.mftdis.ModflowTdis(
    sim,
    pname="tdis",
    time_units="DAYS",
    nper=2,
    perioddata=[(1.0, 1, 1.0), (1.0, 1, 1.0)],
)
```

Groundwater Flow Model Setup

We will start by setting up two groundwater flow models that are part of the same simulation.

[5]:
```
# set up first groundwater flow model
name_1 = "ex_1_mod_1"
model_nam_file = f"{name_1}.nam"
gwf = flopy.mf6.ModflowGwf(
    sim, modelname=name_1, model_nam_file=model_nam_file
)
# create the discretization package
bot = [-10.0, -50.0, -200.0]
delrow = delcol = 4.0
nlay = 3
nrow = 10
ncol = 10
dis = flopy.mf6.modflow.mfgwfdis.ModflowGwfdis(
    gwf,
    pname="dis-1",
    nogrb=True,
    nlay=nlay,
    nrow=nrow,
    ncol=ncol,
    delr=delrow,
    delc=delcol,
    top=0.0,
    botm=bot,
)
# create npf package
npf = flopy.mf6.ModflowGwfnpf(
    gwf,
    pname="npf-1",
    save_flows=True,
    icelltype=[1, 1, 1],
    k=10.0,
    k33=5.0,
    xt3doptions="xt3d rhs",
    # rewet_record="REWET WETFCT 1.0 IWETIT 1 IHDWET 0",
)
# create ic package
ic_package = flopy.mf6.modflow.mfgwfic.ModflowGwfic(gwf, strt=0.0)
```

[6]:
```
# create ghb package
ghb_spd = {0: [((0, 0, 0), -1.0, 1000.0)]}
ghb = flopy.mf6.modflow.mfgwfghb.ModflowGwfghb(
    gwf,
    print_input=True,
    print_flows=True,
    pname="ghb-1",
    maxbound=1,
    stress_period_data=ghb_spd,
)
```

[7]:
```
# create wel package
welspd = {0: [((0, 5, ncol - 1), -100.0)]}
wel = flopy.mf6.ModflowGwfwel(
    gwf,
    print_input=True,
    print_flows=True,
    mover=True,
    stress_period_data=welspd,
    save_flows=False,
    pname="WEL-1",
)
```

[8]:
```
# set up second groundwater flow model with a finer grid
name_1 = "ex_1_mod_2"
model_nam_file = f"{name_1}.nam"
gwf_2 = flopy.mf6.ModflowGwf(
    sim, modelname=name_1, model_nam_file=model_nam_file
)
# create the flopy iterative model solver (ims) package object
# by default flopy will register both models with the ims package.
ims = flopy.mf6.modflow.mfims.ModflowIms(
    sim, pname="ims", complexity="SIMPLE", linear_acceleration="BICGSTAB"
)
# no need to create a new ims package.  flopy will automatically register
# create the discretization package
bot = [-10.0, -50.0, -200.0]
dis_2 = flopy.mf6.modflow.mfgwfdis.ModflowGwfdis(
    gwf_2,
    pname="dis-2",
    nogrb=True,
    nlay=nlay,
    nrow=nrow * 2,
    ncol=ncol * 2,
    delr=delrow / 2.0,
    delc=delcol / 2.0,
    top=0.0,
    botm=bot,
)
# create npf package
npf_2 = flopy.mf6.ModflowGwfnpf(
    gwf_2,
```

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```
    pname="npf-2",
    save_flows=True,
    icelltype=[1, 1, 1],
    k=10.0,
    k33=5.0,
    xt3doptions="xt3d rhs",
    # rewet_record="REWET WETFCT 1.0 IWETIT 1 IHDWET 0",
)
# create ic package
ic_package_2 = flopy.mf6.modflow.mfgwfic.ModflowGwfic(gwf_2, strt=0.0)
```

[9]:
```
# create ghb package
ghb_spd = {0: [((0, 0, 19), -10.0, 1000.0)]}
ghb_2 = flopy.mf6.modflow.mfgwfghb.ModflowGwfghb(
    gwf_2,
    print_input=True,
    print_flows=True,
    pname="ghb-2",
    maxbound=1,
    stress_period_data=ghb_spd,
)
```

[10]:
```
# create lak package
lakpd = [(0, -2.0, 1)]
lakecn = [(0, 0, (0, 5, 0), "HORIZONTAL", 1.0, -5.0, 0.0, 10.0, 10.0)]
lak_2 = flopy.mf6.ModflowGwflak(
    gwf_2,
    pname="lak-2",
    print_input=True,
    mover=True,
    nlakes=1,
    noutlets=0,
    ntables=0,
    packagedata=lakpd,
    connectiondata=lakecn,
)
```

Connecting the Flow Models

The two groundwater flow models created above are now part of the same simulation, but they are not connected. To connect them we will use the gwfgwf package and two of its subpackages, gnc and mvr.

Use exchangedata to define how the two models are connected. In this example we are connecting the right edge of the first model to the left edge of the second model. The second model is 2x the discretization, so each cell in the first model is connected to two cells in the second model.

[11]:
```
gwfgwf_data = []
row_2 = 0
for row in range(0, nrow):
    gwfgwf_data.append([(0, ncol - 1, row), (0, 0, row_2), 1, 2.03, 1.01, 2.0])
    row_2 += 1
```

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```
    gwfgwf_data.append([(0, ncol - 1, row), (0, 0, row_2), 1, 2.03, 1.01, 2.0])
    row_2 += 1
```

[12]:
```
# create the gwfgwf package
gwfgwf = flopy.mf6.ModflowGwfgwf(
    sim,
    exgtype="GWF6-GWF6",
    nexg=len(gwfgwf_data),
    exgmnamea=gwf.name,
    exgmnameb=gwf_2.name,
    exchangedata=gwfgwf_data,
    filename="mod1_mod2.gwfgwf",
)
```

Due to the two model's different cell sizes, the cell centers of the first model do not align with the cell centers in the second model. To correct for this we will use the ghost node correction package (gnc).

[13]:
```
gnc_data = []
col_2 = 0
weight_close = 1.0 / 1.25
weight_far = 0.25 / 1.25
for col in range(0, ncol):
    if col == 0:
        gnc_data.append(
            (
                (0, nrow - 1, col),
                (0, 0, col_2),
                (0, nrow - 1, col),
                (0, nrow - 1, 0),
                1.00,
                0.0,
            )
        )
    else:
        gnc_data.append(
            (
                (0, nrow - 1, col),
                (0, 0, col_2),
                (0, nrow - 1, col),
                (0, nrow - 1, col - 1),
                weight_close,
                weight_far,
            )
        )
    col_2 += 1
    if col == ncol - 1:
        gnc_data.append(
            (
                (0, nrow - 1, col),
                (0, 0, col_2),
                (0, nrow - 1, col),
                (0, nrow - 1, 0),
```

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```
                1.00,
                0.0,
            )
        )
    else:
        gnc_data.append(
            (
                (0, nrow - 1, col),
                (0, 0, col_2),
                (0, nrow - 1, col),
                (0, nrow - 1, col + 1),
                weight_close,
                weight_far,
            )
        )
    col_2 += 1
```

[14]:
```
# set up gnc package
fname = "gwfgwf.input.gnc"
gwfgwf.gnc.initialize(
    filename=fname,
    print_input=True,
    print_flows=True,
    numgnc=ncol * 2,
    numalphaj=2,
    gncdata=gnc_data,
)
```

The extraction well at the right-hand side of the first model is pumping the water it extracts into a nearby lake at the left-hand side of the second model. Using the mover (mvr) package, water extracted from the first model's wel package is moved to the second model's lak package.

[15]:
```
package_data = [(gwf.name, "WEL-1"), (gwf_2.name, "lak-2")]
period_data = [(gwf.name, "WEL-1", 0, gwf_2.name, "lak-2", 0, "FACTOR", 1.0)]
fname = "gwfgwf.input.mvr"
gwfgwf.mvr.initialize(
    filename=fname,
    modelnames=True,
    print_input=True,
    print_flows=True,
    maxpackages=2,
    maxmvr=1,
    packages=package_data,
    perioddata=period_data,
)
```

[16]:
```
sim.write_simulation()
sim.run_simulation()
```

```
writing simulation...
  writing simulation name file...
  writing simulation tdis package...
```

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```
  writing solution package ims...
  writing package mod1_mod2.gwfgwf...
  writing package gwfgwf.input.gnc...
  writing package gwfgwf.input.mvr...
  writing model ex_1_mod_1...
    writing model name file...
    writing package dis-1...
    writing package npf-1...
    writing package ic...
    writing package ghb-1...
    writing package wel-1...
INFORMATION: maxbound in ('gwf6', 'wel', 'dimensions') changed to 1 based on size of␣
↪stress_period_data
  writing model ex_1_mod_2...
    writing model name file...
    writing package dis-2...
    writing package npf-2...
    writing package ic...
    writing package ghb-2...
    writing package lak-2...
FloPy is using the following executable to run the model: ../../home/runner/.local/bin/
↪modflow/mf6
                                   MODFLOW 6
                U.S. GEOLOGICAL SURVEY MODULAR HYDROLOGIC MODEL
                            VERSION 6.4.2 06/28/2023

   MODFLOW 6 compiled Jul 05 2023 20:29:14 with Intel(R) Fortran Intel(R) 64
   Compiler Classic for applications running on Intel(R) 64, Version 2021.7.0
                             Build 20220726_000000

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 Run start date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:26:15

 Writing simulation list file: mfsim.lst
 Using Simulation name file: mfsim.nam

    Solving:  Stress period:     1    Time step:     1
    Solving:  Stress period:     2    Time step:     1
```

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```
Run end date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:26:15
Elapsed run time:  0.131 Seconds

Normal termination of simulation.
```

[16]:
```
(True, [])
```

[17]:
```python
try:
    temp_dir.cleanup()
except PermissionError:
    # can occur on windows: https://docs.python.org/3/library/tempfile.html#tempfile.
↪TemporaryDirectory
    pass
```

5.2.10 Observations, time series and time array series

This code sets up a simulation and creates some data for the simulation.

[1]:
```python
import os
import sys
from tempfile import TemporaryDirectory

import numpy as np

try:
    import flopy
except:
    fpth = os.path.abspath(os.path.join("..", ".."))
    sys.path.append(fpth)
    import flopy

# init paths
exe_name = "mf6"

# temporary directory
temp_dir = TemporaryDirectory()
sim_path = os.path.join(temp_dir.name, "obs_ts_tas_ex")
# make the directory if it does not exist
if not os.path.isdir(sim_path):
    os.makedirs(sim_path, exist_ok=True)

# init paths
test_ex_name = "child_pkgs_test"
model_name = "child_pkgs"

print(sys.version)
print(f"numpy version: {np.__version__}")
print(f"flopy version: {flopy.__version__}")
```

```
3.8.18 (default, Aug 28 2023, 08:27:22)
[GCC 11.4.0]
```

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```
numpy version: 1.24.4
flopy version: 3.5.0
```

[2]:
```
# create simulation
sim = flopy.mf6.MFSimulation(
    sim_name=test_ex_name, version="mf6", exe_name="mf6", sim_ws=sim_path
)

tdis_rc = [(1.0, 1, 1.0), (10.0, 120, 1.0), (10.0, 120, 1.0), (10.0, 120, 1.0)]
tdis_package = flopy.mf6.modflow.mftdis.ModflowTdis(
    sim, time_units="DAYS", nper=4, perioddata=tdis_rc
)
model = flopy.mf6.ModflowGwf(
    sim, modelname=model_name, model_nam_file=f"{model_name}.nam"
)
ims_package = flopy.mf6.modflow.mfims.ModflowIms(
    sim,
    print_option="SUMMARY",
    complexity="SIMPLE",
    outer_hclose=0.0001,
    outer_maximum=500,
    under_relaxation="NONE",
    inner_maximum=100,
    inner_hclose=0.0001,
    rcloserecord=0.001,
    linear_acceleration="CG",
    scaling_method="NONE",
    reordering_method="NONE",
    relaxation_factor=0.97,
)
sim.register_ims_package(ims_package, [model.name])
bot_data = [-100 for x in range(150)]
dis_package = flopy.mf6.modflow.mfgwfdis.ModflowGwfdis(
    model,
    nlay=3,
    nrow=15,
    ncol=10,
    delr=500.0,
    delc=500.0,
    top=50.0,
    botm=[5.0, -10.0, {"factor": 1.0, "data": bot_data}],
    filename=f"{model_name}.dis",
)
ic_package = flopy.mf6.modflow.mfgwfic.ModflowGwfic(
    model, strt=50.0, filename=f"{model_name}.ic"
)
npf_package = flopy.mf6.modflow.mfgwfnpf.ModflowGwfnpf(
    model,
    save_flows=True,
    icelltype=[1, 0, 0],
    k=[5.0, 0.1, 4.0],
    k33=[0.5, 0.005, 0.1],
```

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```
)
oc_package = flopy.mf6.modflow.mfgwfoc.ModflowGwfoc(
    model,
    budget_filerecord="child_pkgs.cbc",
    head_filerecord="child_pkgs.hds",
    headprintrecord=["COLUMNS", 10, "WIDTH", 15, "DIGITS", 6, "GENERAL"],
    saverecord=[("HEAD", "ALL"), ("BUDGET", "ALL")],
    printrecord=[("HEAD", "FIRST"), ("HEAD", "LAST"), ("BUDGET", "LAST")],
)
sto_package = flopy.mf6.modflow.mfgwfsto.ModflowGwfsto(
    model,
    save_flows=True,
    iconvert=1,
    ss=0.000001,
    sy=0.2,
    steady_state={0: True},
    transient={1: True},
)
```

Observations

Observations can be set for any package through the package.obs object, and each package.obs object has several attributes that can be set:

package.obs.filename : str Name of observations file to create. The default is packagename + '.obs', e.g. mymodel.ghb.obs.

package.obs.continuous : dict A dictionary that has file names as keys and a list of observations as the dictionary values. Default should probably be None. package.obs.observations = {'fname1': [(obsname, obstype, cellid), …], 'fname2': [(obsname, obstype, cellid), …]}

package.obs.digits : int Number of digits to write the observation values. Default is 10.

package.obs.print_input : bool Flag indicating whether or not observations are written to listing file.

Method 1: Pass obs to package constructor

[3]:
```
# build ghb stress period data
ghb_spd = {}
ghb_period = []
for layer, cond in zip(range(1, 3), [15.0, 1500.0]):
    for row in range(0, 15):
        ghb_period.append(((layer, row, 9), 1.0, cond, "Estuary-L2"))
ghb_spd[0] = ghb_period

# build obs data
ghb_obs = {
    ("ghb_obs.csv", "binary"): [
        ("ghb-2-6-10", "GHB", (1, 5, 9)),
        ("ghb-3-6-10", "GHB", (2, 5, 9)),
    ],
```

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```
    "ghb_flows.csv": [
        ("Estuary2", "GHB", "Estuary-L2"),
        ("Estuary3", "GHB", "Estuary-L3"),
    ],
}
# build ghb package
ghb = flopy.mf6.modflow.mfgwfghb.ModflowGwfghb(
    model,
    print_input=True,
    print_flows=True,
    save_flows=True,
    boundnames=True,
    observations=ghb_obs,
    pname="ghb",
    maxbound=30,
    stress_period_data=ghb_spd,
)
ghb.obs.print_input = True

sim.write_simulation()
success, buff = sim.run_simulation(silent=True, report=True)
if success:
    for line in buff:
        print(line)
else:
    raise ValueError("Failed to run.")

# clean up for next example
model.remove_package("ghb")
```

```
writing simulation...
  writing simulation name file...
  writing simulation tdis package...
  writing solution package ims_-1...
  writing model child_pkgs...
    writing model name file...
    writing package dis...
    writing package ic...
    writing package npf...
    writing package oc...
    writing package sto...
    writing package ghb...
    writing package obs_0...
                                   MODFLOW 6
                U.S. GEOLOGICAL SURVEY MODULAR HYDROLOGIC MODEL
                            VERSION 6.4.2 06/28/2023

   MODFLOW 6 compiled Jul 05 2023 20:29:14 with Intel(R) Fortran Intel(R) 64
   Compiler Classic for applications running on Intel(R) 64, Version 2021.7.0
                             Build 20220726_000000

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 Run start date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:26:17

 Writing simulation list file: mfsim.lst
 Using Simulation name file: mfsim.nam

    Solving:  Stress period:     1    Time step:     1
    Solving:  Stress period:     2    Time step:     1
    Solving:  Stress period:     2    Time step:     2
    Solving:  Stress period:     2    Time step:     3
    Solving:  Stress period:     2    Time step:     4
    Solving:  Stress period:     2    Time step:     5
    Solving:  Stress period:     2    Time step:     6
    Solving:  Stress period:     2    Time step:     7
    Solving:  Stress period:     2    Time step:     8
    Solving:  Stress period:     2    Time step:     9
    Solving:  Stress period:     2    Time step:    10
    Solving:  Stress period:     2    Time step:    11
    Solving:  Stress period:     2    Time step:    12
    Solving:  Stress period:     2    Time step:    13
    Solving:  Stress period:     2    Time step:    14
    Solving:  Stress period:     2    Time step:    15
    Solving:  Stress period:     2    Time step:    16
    Solving:  Stress period:     2    Time step:    17
    Solving:  Stress period:     2    Time step:    18
    Solving:  Stress period:     2    Time step:    19
    Solving:  Stress period:     2    Time step:    20
    Solving:  Stress period:     2    Time step:    21
    Solving:  Stress period:     2    Time step:    22
    Solving:  Stress period:     2    Time step:    23
    Solving:  Stress period:     2    Time step:    24
    Solving:  Stress period:     2    Time step:    25
    Solving:  Stress period:     2    Time step:    26
    Solving:  Stress period:     2    Time step:    27
    Solving:  Stress period:     2    Time step:    28
    Solving:  Stress period:     2    Time step:    29
    Solving:  Stress period:     2    Time step:    30
    Solving:  Stress period:     2    Time step:    31
    Solving:  Stress period:     2    Time step:    32
    Solving:  Stress period:     2    Time step:    33
```

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```
    Solving:  Stress period:     2    Time step:    34
    Solving:  Stress period:     2    Time step:    35
    Solving:  Stress period:     2    Time step:    36
    Solving:  Stress period:     2    Time step:    37
    Solving:  Stress period:     2    Time step:    38
    Solving:  Stress period:     2    Time step:    39
    Solving:  Stress period:     2    Time step:    40
    Solving:  Stress period:     2    Time step:    41
    Solving:  Stress period:     2    Time step:    42
    Solving:  Stress period:     2    Time step:    43
    Solving:  Stress period:     2    Time step:    44
    Solving:  Stress period:     2    Time step:    45
    Solving:  Stress period:     2    Time step:    46
    Solving:  Stress period:     2    Time step:    47
    Solving:  Stress period:     2    Time step:    48
    Solving:  Stress period:     2    Time step:    49
    Solving:  Stress period:     2    Time step:    50
    Solving:  Stress period:     2    Time step:    51
    Solving:  Stress period:     2    Time step:    52
    Solving:  Stress period:     2    Time step:    53
    Solving:  Stress period:     2    Time step:    54
    Solving:  Stress period:     2    Time step:    55
    Solving:  Stress period:     2    Time step:    56
    Solving:  Stress period:     2    Time step:    57
    Solving:  Stress period:     2    Time step:    58
    Solving:  Stress period:     2    Time step:    59
    Solving:  Stress period:     2    Time step:    60
    Solving:  Stress period:     2    Time step:    61
    Solving:  Stress period:     2    Time step:    62
    Solving:  Stress period:     2    Time step:    63
    Solving:  Stress period:     2    Time step:    64
    Solving:  Stress period:     2    Time step:    65
    Solving:  Stress period:     2    Time step:    66
    Solving:  Stress period:     2    Time step:    67
    Solving:  Stress period:     2    Time step:    68
    Solving:  Stress period:     2    Time step:    69
    Solving:  Stress period:     2    Time step:    70
    Solving:  Stress period:     2    Time step:    71
    Solving:  Stress period:     2    Time step:    72
    Solving:  Stress period:     2    Time step:    73
    Solving:  Stress period:     2    Time step:    74
    Solving:  Stress period:     2    Time step:    75
    Solving:  Stress period:     2    Time step:    76
    Solving:  Stress period:     2    Time step:    77
    Solving:  Stress period:     2    Time step:    78
    Solving:  Stress period:     2    Time step:    79
    Solving:  Stress period:     2    Time step:    80
    Solving:  Stress period:     2    Time step:    81
    Solving:  Stress period:     2    Time step:    82
    Solving:  Stress period:     2    Time step:    83
    Solving:  Stress period:     2    Time step:    84
    Solving:  Stress period:     2    Time step:    85
```

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```
    Solving:  Stress period:     2    Time step:    86
    Solving:  Stress period:     2    Time step:    87
    Solving:  Stress period:     2    Time step:    88
    Solving:  Stress period:     2    Time step:    89
    Solving:  Stress period:     2    Time step:    90
    Solving:  Stress period:     2    Time step:    91
    Solving:  Stress period:     2    Time step:    92
    Solving:  Stress period:     2    Time step:    93
    Solving:  Stress period:     2    Time step:    94
    Solving:  Stress period:     2    Time step:    95
    Solving:  Stress period:     2    Time step:    96
    Solving:  Stress period:     2    Time step:    97
    Solving:  Stress period:     2    Time step:    98
    Solving:  Stress period:     2    Time step:    99
    Solving:  Stress period:     2    Time step:   100
    Solving:  Stress period:     2    Time step:   101
    Solving:  Stress period:     2    Time step:   102
    Solving:  Stress period:     2    Time step:   103
    Solving:  Stress period:     2    Time step:   104
    Solving:  Stress period:     2    Time step:   105
    Solving:  Stress period:     2    Time step:   106
    Solving:  Stress period:     2    Time step:   107
    Solving:  Stress period:     2    Time step:   108
    Solving:  Stress period:     2    Time step:   109
    Solving:  Stress period:     2    Time step:   110
    Solving:  Stress period:     2    Time step:   111
    Solving:  Stress period:     2    Time step:   112
    Solving:  Stress period:     2    Time step:   113
    Solving:  Stress period:     2    Time step:   114
    Solving:  Stress period:     2    Time step:   115
    Solving:  Stress period:     2    Time step:   116
    Solving:  Stress period:     2    Time step:   117
    Solving:  Stress period:     2    Time step:   118
    Solving:  Stress period:     2    Time step:   119
    Solving:  Stress period:     2    Time step:   120
    Solving:  Stress period:     3    Time step:     1
    Solving:  Stress period:     3    Time step:     2
    Solving:  Stress period:     3    Time step:     3
    Solving:  Stress period:     3    Time step:     4
    Solving:  Stress period:     3    Time step:     5
    Solving:  Stress period:     3    Time step:     6
    Solving:  Stress period:     3    Time step:     7
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    Solving:  Stress period:     3    Time step:    14
    Solving:  Stress period:     3    Time step:    15
    Solving:  Stress period:     3    Time step:    16
    Solving:  Stress period:     3    Time step:    17
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    Solving:  Stress period:     3    Time step:    18
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    Solving:  Stress period:     3    Time step:    67
    Solving:  Stress period:     3    Time step:    68
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    Solving:  Stress period:     3    Time step:   118
    Solving:  Stress period:     3    Time step:   119
    Solving:  Stress period:     3    Time step:   120
    Solving:  Stress period:     4    Time step:     1
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    Solving:  Stress period:     4    Time step:     2
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    Solving:  Stress period:     4    Time step:   104
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    Solving:  Stress period:     4    Time step:   106
    Solving:  Stress period:     4    Time step:   107
    Solving:  Stress period:     4    Time step:   108
    Solving:  Stress period:     4    Time step:   109
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    Solving:  Stress period:     4    Time step:   111
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    Solving:  Stress period:     4    Time step:   115
    Solving:  Stress period:     4    Time step:   116
    Solving:  Stress period:     4    Time step:   117
    Solving:  Stress period:     4    Time step:   118
    Solving:  Stress period:     4    Time step:   119
    Solving:  Stress period:     4    Time step:   120

 Run end date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:26:18
 Elapsed run time:  0.259 Seconds


WARNING REPORT:

  1. NONLINEAR BLOCK VARIABLE 'OUTER_HCLOSE' IN FILE 'child_pkgs_test.ims'
     WAS DEPRECATED IN VERSION 6.1.1. SETTING OUTER_DVCLOSE TO OUTER_HCLOSE
     VALUE.
  2. LINEAR BLOCK VARIABLE 'INNER_HCLOSE' IN FILE 'child_pkgs_test.ims' WAS
     DEPRECATED IN VERSION 6.1.1. SETTING INNER_DVCLOSE TO INNER_HCLOSE VALUE.
 Normal termination of simulation.
```

Method 2: Initialize obs through ghb.obs.initialize

[4]:
```python
# build ghb stress period data
ghb_spd = {}
ghb_period = []
for layer, cond in zip(range(1, 3), [15.0, 1500.0]):
    for row in range(0, 15):
        ghb_period.append(((layer, row, 9), 1.0, cond, "Estuary-L2"))
ghb_spd[0] = ghb_period

# build ghb package
ghb = flopy.mf6.modflow.mfgwfghb.ModflowGwfghb(
    model,
    print_input=True,
    print_flows=True,
    save_flows=True,
    boundnames=True,
    maxbound=30,
    stress_period_data=ghb_spd,
    pname="ghb",
)
```

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```
# build obs data
ghb_obs = {
    ("ghb_obs.csv", "binary"): [
        ("ghb-2-6-10", "GHB", (1, 5, 9)),
        ("ghb-3-6-10", "GHB", (2, 5, 9)),
    ],
    "ghb_flows.csv": [
        ("Estuary2", "GHB", "Estuary-L2"),
        ("Estuary3", "GHB", "Estuary-L3"),
    ],
}

# initialize obs package
ghb.obs.initialize(
    filename="child_pkgs_test.ghb.obs",
    digits=9,
    print_input=True,
    continuous=ghb_obs,
)

sim.write_simulation()
success, buff = sim.run_simulation(silent=True, report=True)
if success:
    for line in buff:
        print(line)
else:
    raise ValueError("Failed to run.")

# clean up for next example
model.remove_package("ghb")
```

```
writing simulation...
  writing simulation name file...
  writing simulation tdis package...
  writing solution package ims_-1...
  writing model child_pkgs...
    writing model name file...
    writing package dis...
    writing package ic...
    writing package npf...
    writing package oc...
    writing package sto...
    writing package ghb...
    writing package obs_0...
                                   MODFLOW 6
                U.S. GEOLOGICAL SURVEY MODULAR HYDROLOGIC MODEL
                            VERSION 6.4.2 06/28/2023

   MODFLOW 6 compiled Jul 05 2023 20:29:14 with Intel(R) Fortran Intel(R) 64
   Compiler Classic for applications running on Intel(R) 64, Version 2021.7.0
                             Build 20220726_000000
```

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```
This software has been approved for release by the U.S. Geological
Survey (USGS). Although the software has been subjected to rigorous
review, the USGS reserves the right to update the software as needed
pursuant to further analysis and review. No warranty, expressed or
implied, is made by the USGS or the U.S. Government as to the
functionality of the software and related material nor shall the
fact of release constitute any such warranty. Furthermore, the
software is released on condition that neither the USGS nor the U.S.
Government shall be held liable for any damages resulting from its
authorized or unauthorized use. Also refer to the USGS Water
Resources Software User Rights Notice for complete use, copyright,
and distribution information.


 Run start date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:26:18

 Writing simulation list file: mfsim.lst
 Using Simulation name file: mfsim.nam

    Solving:  Stress period:     1    Time step:     1
    Solving:  Stress period:     2    Time step:     1
    Solving:  Stress period:     2    Time step:     2
    Solving:  Stress period:     2    Time step:     3
    Solving:  Stress period:     2    Time step:     4
    Solving:  Stress period:     2    Time step:     5
    Solving:  Stress period:     2    Time step:     6
    Solving:  Stress period:     2    Time step:     7
    Solving:  Stress period:     2    Time step:     8
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    Solving:  Stress period:     3    Time step:     1
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    Solving:  Stress period:     3    Time step:     3
    Solving:  Stress period:     3    Time step:     4
    Solving:  Stress period:     3    Time step:     5
    Solving:  Stress period:     3    Time step:     6
    Solving:  Stress period:     3    Time step:     7
    Solving:  Stress period:     3    Time step:     8
    Solving:  Stress period:     3    Time step:     9
    Solving:  Stress period:     3    Time step:    10
    Solving:  Stress period:     3    Time step:    11
    Solving:  Stress period:     3    Time step:    12
    Solving:  Stress period:     3    Time step:    13
    Solving:  Stress period:     3    Time step:    14
    Solving:  Stress period:     3    Time step:    15
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    Solving:  Stress period:     3    Time step:    16
    Solving:  Stress period:     3    Time step:    17
    Solving:  Stress period:     3    Time step:    18
    Solving:  Stress period:     3    Time step:    19
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    Solving:  Stress period:     3    Time step:    63
    Solving:  Stress period:     3    Time step:    64
    Solving:  Stress period:     3    Time step:    65
    Solving:  Stress period:     3    Time step:    66
    Solving:  Stress period:     3    Time step:    67
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    Solving:  Stress period:     3    Time step:    68
    Solving:  Stress period:     3    Time step:    69
    Solving:  Stress period:     3    Time step:    70
    Solving:  Stress period:     3    Time step:    71
    Solving:  Stress period:     3    Time step:    72
    Solving:  Stress period:     3    Time step:    73
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    Solving:  Stress period:     3    Time step:   116
    Solving:  Stress period:     3    Time step:   117
    Solving:  Stress period:     3    Time step:   118
    Solving:  Stress period:     3    Time step:   119
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    Solving:  Stress period:     3    Time step:   120
    Solving:  Stress period:     4    Time step:     1
    Solving:  Stress period:     4    Time step:     2
    Solving:  Stress period:     4    Time step:     3
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    Solving:  Stress period:     4    Time step:    51
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    Solving:  Stress period:     4    Time step:    52
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    Solving:  Stress period:     4    Time step:    66
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    Solving:  Stress period:     4    Time step:    68
    Solving:  Stress period:     4    Time step:    69
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    Solving:  Stress period:     4    Time step:   100
    Solving:  Stress period:     4    Time step:   101
    Solving:  Stress period:     4    Time step:   102
    Solving:  Stress period:     4    Time step:   103
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    Solving:  Stress period:     4    Time step:   104
    Solving:  Stress period:     4    Time step:   105
    Solving:  Stress period:     4    Time step:   106
    Solving:  Stress period:     4    Time step:   107
    Solving:  Stress period:     4    Time step:   108
    Solving:  Stress period:     4    Time step:   109
    Solving:  Stress period:     4    Time step:   110
    Solving:  Stress period:     4    Time step:   111
    Solving:  Stress period:     4    Time step:   112
    Solving:  Stress period:     4    Time step:   113
    Solving:  Stress period:     4    Time step:   114
    Solving:  Stress period:     4    Time step:   115
    Solving:  Stress period:     4    Time step:   116
    Solving:  Stress period:     4    Time step:   117
    Solving:  Stress period:     4    Time step:   118
    Solving:  Stress period:     4    Time step:   119
    Solving:  Stress period:     4    Time step:   120

 Run end date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:26:18
 Elapsed run time:  0.259 Seconds


WARNING REPORT:

  1. NONLINEAR BLOCK VARIABLE 'OUTER_HCLOSE' IN FILE 'child_pkgs_test.ims'
     WAS DEPRECATED IN VERSION 6.1.1. SETTING OUTER_DVCLOSE TO OUTER_HCLOSE
     VALUE.
  2. LINEAR BLOCK VARIABLE 'INNER_HCLOSE' IN FILE 'child_pkgs_test.ims' WAS
     DEPRECATED IN VERSION 6.1.1. SETTING INNER_DVCLOSE TO INNER_HCLOSE VALUE.
 Normal termination of simulation.
```

Method 3: Pass observations a dictionary of anything that could be passed to ghb.obs.initialize

[5]:
```python
# build ghb stress period data
ghb_spd = {}
ghb_period = []
for layer, cond in zip(range(1, 3), [15.0, 1500.0]):
    for row in range(0, 15):
        ghb_period.append(((layer, row, 9), 1.0, cond, "Estuary-L2"))
ghb_spd[0] = ghb_period

# build obs data
ghb_obs = {
    ("ghb_obs.csv", "binary"): [
        ("ghb-2-6-10", "GHB", (1, 5, 9)),
        ("ghb-3-6-10", "GHB", (2, 5, 9)),
    ],
    "ghb_flows.csv": [
        ("Estuary2", "GHB", "Estuary-L2"),
        ("Estuary3", "GHB", "Estuary-L3"),
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```
    ],
}
# append additional obs attributes to obs dictionary
ghb_obs["digits"] = 7
ghb_obs["print_input"] = False
ghb_obs["filename"] = "method_3.obs"

# build ghb package
ghb_package = flopy.mf6.modflow.mfgwfghb.ModflowGwfghb(
    model,
    print_input=True,
    print_flows=True,
    save_flows=True,
    boundnames=True,
    observations=ghb_obs,
    pname="ghb",
    maxbound=30,
    stress_period_data=ghb_spd,
)

sim.write_simulation()
success, buff = sim.run_simulation(silent=True, report=True)
if success:
    for line in buff:
        print(line)
else:
    raise ValueError("Failed to run.")

# clean up for next example
model.remove_package("ghb")
```

```
writing simulation...
  writing simulation name file...
  writing simulation tdis package...
  writing solution package ims_-1...
  writing model child_pkgs...
    writing model name file...
    writing package dis...
    writing package ic...
    writing package npf...
    writing package oc...
    writing package sto...
    writing package ghb...
    writing package obs_0...
                                   MODFLOW 6
                U.S. GEOLOGICAL SURVEY MODULAR HYDROLOGIC MODEL
                            VERSION 6.4.2 06/28/2023

   MODFLOW 6 compiled Jul 05 2023 20:29:14 with Intel(R) Fortran Intel(R) 64
   Compiler Classic for applications running on Intel(R) 64, Version 2021.7.0
                             Build 20220726_000000
```

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```
This software has been approved for release by the U.S. Geological
Survey (USGS). Although the software has been subjected to rigorous
review, the USGS reserves the right to update the software as needed
pursuant to further analysis and review. No warranty, expressed or
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functionality of the software and related material nor shall the
fact of release constitute any such warranty. Furthermore, the
software is released on condition that neither the USGS nor the U.S.
Government shall be held liable for any damages resulting from its
authorized or unauthorized use. Also refer to the USGS Water
Resources Software User Rights Notice for complete use, copyright,
and distribution information.


 Run start date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:26:18

 Writing simulation list file: mfsim.lst
 Using Simulation name file: mfsim.nam

    Solving:  Stress period:     1    Time step:     1
    Solving:  Stress period:     2    Time step:     1
    Solving:  Stress period:     2    Time step:     2
    Solving:  Stress period:     2    Time step:     3
    Solving:  Stress period:     2    Time step:     4
    Solving:  Stress period:     2    Time step:     5
    Solving:  Stress period:     2    Time step:     6
    Solving:  Stress period:     2    Time step:     7
    Solving:  Stress period:     2    Time step:     8
    Solving:  Stress period:     2    Time step:     9
    Solving:  Stress period:     2    Time step:    10
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    Solving:  Stress period:     2    Time step:    12
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    Solving:  Stress period:     2    Time step:    33
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    Solving:  Stress period:     2    Time step:    85
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    Solving:  Stress period:     2    Time step:   117
    Solving:  Stress period:     2    Time step:   118
    Solving:  Stress period:     2    Time step:   119
    Solving:  Stress period:     2    Time step:   120
    Solving:  Stress period:     3    Time step:     1
    Solving:  Stress period:     3    Time step:     2
    Solving:  Stress period:     3    Time step:     3
    Solving:  Stress period:     3    Time step:     4
    Solving:  Stress period:     3    Time step:     5
    Solving:  Stress period:     3    Time step:     6
    Solving:  Stress period:     3    Time step:     7
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    Solving:  Stress period:     3    Time step:     9
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    Solving:  Stress period:     3    Time step:    11
    Solving:  Stress period:     3    Time step:    12
    Solving:  Stress period:     3    Time step:    13
    Solving:  Stress period:     3    Time step:    14
    Solving:  Stress period:     3    Time step:    15
    Solving:  Stress period:     3    Time step:    16
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    Solving:  Stress period:     3    Time step:    17
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    Solving:  Stress period:     3    Time step:    66
    Solving:  Stress period:     3    Time step:    67
    Solving:  Stress period:     3    Time step:    68
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    Solving:  Stress period:     3    Time step:    69
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    Solving:  Stress period:     3    Time step:    71
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    Solving:  Stress period:     3    Time step:   119
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    Solving:  Stress period:     4    Time step:     1
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    Solving:  Stress period:     4    Time step:   101
    Solving:  Stress period:     4    Time step:   102
    Solving:  Stress period:     4    Time step:   103
    Solving:  Stress period:     4    Time step:   104
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```
    Solving:  Stress period:     4    Time step:   105
    Solving:  Stress period:     4    Time step:   106
    Solving:  Stress period:     4    Time step:   107
    Solving:  Stress period:     4    Time step:   108
    Solving:  Stress period:     4    Time step:   109
    Solving:  Stress period:     4    Time step:   110
    Solving:  Stress period:     4    Time step:   111
    Solving:  Stress period:     4    Time step:   112
    Solving:  Stress period:     4    Time step:   113
    Solving:  Stress period:     4    Time step:   114
    Solving:  Stress period:     4    Time step:   115
    Solving:  Stress period:     4    Time step:   116
    Solving:  Stress period:     4    Time step:   117
    Solving:  Stress period:     4    Time step:   118
    Solving:  Stress period:     4    Time step:   119
    Solving:  Stress period:     4    Time step:   120

 Run end date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:26:18
 Elapsed run time:  0.251 Seconds


WARNING REPORT:

  1. NONLINEAR BLOCK VARIABLE 'OUTER_HCLOSE' IN FILE 'child_pkgs_test.ims'
     WAS DEPRECATED IN VERSION 6.1.1. SETTING OUTER_DVCLOSE TO OUTER_HCLOSE
     VALUE.
  2. LINEAR BLOCK VARIABLE 'INNER_HCLOSE' IN FILE 'child_pkgs_test.ims' WAS
     DEPRECATED IN VERSION 6.1.1. SETTING INNER_DVCLOSE TO INNER_HCLOSE VALUE.
 Normal termination of simulation.
```

Time Series

Time series can be set for any package through the package.ts object, and each package.ts object has several attributes that can be set:

package.ts.filename : str Name of time series file to create. The default is packagename + '.ts', e.g. mymodel.ghb.ts.

package.ts.timeseries : recarray Array containing the time series information. timeseries = [(t, np.sin(t)) for t in np.linspace(0, 100., 10)]

package.ts.time_series_namerecord : str or list (of strings) List of names of the time series data columns. Default is to use names from timeseries.dtype.names[1:].

package.ts.interpolation_methodrecord_single : str Interpolation method. Must be only one time series record. If there are multiple time series records, then the methods attribute must be used. Default is 'linear'.

package.ts.interpolation_methodrecord : list (of strings) List of interpolation methods to use for each time series data column. Method must be either 'stepwise', 'linear', or 'linearend'.

package.ts.sfacrecord_single : float Scale factor to multiply the time series data column. Can only be used if there is one time series data column.

package.ts.sfacrecord : list (of floats) Scale factors to multiply the time series data columns.

Method 1: Pass time series to package constructor

[6]:
```
# build ghb stress period data
ghb_spd_ts = {}
ghb_period = []
for layer, cond in zip(range(1, 3), [15.0, 1500.0]):
    for row in range(0, 15):
        ghb_period.append(((layer, row, 9), "tides", cond, "Estuary-L2"))
ghb_spd_ts[0] = ghb_period

# build ts data
ts_data = []
for n in range(0, 365):
    ts_data.append((float(n / 11.73), float(n / 60.0)))

# build obs data
ghb_obs = {
    ("ghb_obs.csv", "binary"): [
        ("ghb-2-6-10", "GHB", (1, 5, 9)),
        ("ghb-3-6-10", "GHB", (2, 5, 9)),
    ],
    "ghb_flows.csv": [
        ("Estuary2", "GHB", "Estuary-L2"),
        ("Estuary3", "GHB", "Estuary-L3"),
    ],
}
# build ghb package
ghb = flopy.mf6.modflow.mfgwfghb.ModflowGwfghb(
    model,
    print_input=True,
    print_flows=True,
    save_flows=True,
    boundnames=True,
    timeseries=ts_data,
    pname="ghb",
    maxbound=30,
    stress_period_data=ghb_spd_ts,
)

# set required time series attributes
ghb.ts.time_series_namerecord = "tides"
ghb.ts.interpolation_methodrecord = "stepwise"

sim.write_simulation()
success, buff = sim.run_simulation(silent=True, report=True)
if success:
    for line in buff:
        print(line)
else:
    raise ValueError("Failed to run.")

# clean up for next example
model.remove_package("ghb")
```

```
WARNING: Unable to resolve dimension of ('ts', 'timeseries', 'timeseries', 'ts_array')␣
↪based on shape "time_series_names".
WARNING: Unable to resolve dimension of ('ts', 'timeseries', 'timeseries', 'ts_array')␣
↪based on shape "time_series_names".
WARNING: Unable to resolve dimension of ('ts', 'timeseries', 'timeseries', 'ts_array')␣
↪based on shape "time_series_names".
writing simulation...
  writing simulation name file...
  writing simulation tdis package...
  writing solution package ims_-1...
  writing model child_pkgs...
    writing model name file...
    writing package dis...
    writing package ic...
    writing package npf...
    writing package oc...
    writing package sto...
    writing package ghb...
    writing package ts_0...
                                   MODFLOW 6
                U.S. GEOLOGICAL SURVEY MODULAR HYDROLOGIC MODEL
                            VERSION 6.4.2 06/28/2023

   MODFLOW 6 compiled Jul 05 2023 20:29:14 with Intel(R) Fortran Intel(R) 64
   Compiler Classic for applications running on Intel(R) 64, Version 2021.7.0
                             Build 20220726_000000

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Resources Software User Rights Notice for complete use, copyright,
and distribution information.


 Run start date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:26:18

 Writing simulation list file: mfsim.lst
 Using Simulation name file: mfsim.nam

    Solving:  Stress period:     1    Time step:     1
    Solving:  Stress period:     2    Time step:     1
    Solving:  Stress period:     2    Time step:     2
    Solving:  Stress period:     2    Time step:     3
    Solving:  Stress period:     2    Time step:     4
    Solving:  Stress period:     2    Time step:     5
    Solving:  Stress period:     2    Time step:     6
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    Solving:  Stress period:     2    Time step:     7
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    Solving:  Stress period:     2    Time step:    86
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    Solving:  Stress period:     2    Time step:    88
    Solving:  Stress period:     2    Time step:    89
    Solving:  Stress period:     2    Time step:    90
    Solving:  Stress period:     2    Time step:    91
    Solving:  Stress period:     2    Time step:    92
    Solving:  Stress period:     2    Time step:    93
    Solving:  Stress period:     2    Time step:    94
    Solving:  Stress period:     2    Time step:    95
    Solving:  Stress period:     2    Time step:    96
    Solving:  Stress period:     2    Time step:    97
    Solving:  Stress period:     2    Time step:    98
    Solving:  Stress period:     2    Time step:    99
    Solving:  Stress period:     2    Time step:   100
    Solving:  Stress period:     2    Time step:   101
    Solving:  Stress period:     2    Time step:   102
    Solving:  Stress period:     2    Time step:   103
    Solving:  Stress period:     2    Time step:   104
    Solving:  Stress period:     2    Time step:   105
    Solving:  Stress period:     2    Time step:   106
    Solving:  Stress period:     2    Time step:   107
    Solving:  Stress period:     2    Time step:   108
    Solving:  Stress period:     2    Time step:   109
    Solving:  Stress period:     2    Time step:   110
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    Solving:  Stress period:     2    Time step:   111
    Solving:  Stress period:     2    Time step:   112
    Solving:  Stress period:     2    Time step:   113
    Solving:  Stress period:     2    Time step:   114
    Solving:  Stress period:     2    Time step:   115
    Solving:  Stress period:     2    Time step:   116
    Solving:  Stress period:     2    Time step:   117
    Solving:  Stress period:     2    Time step:   118
    Solving:  Stress period:     2    Time step:   119
    Solving:  Stress period:     2    Time step:   120
    Solving:  Stress period:     3    Time step:     1
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    Solving:  Stress period:     3    Time step:     9
    Solving:  Stress period:     3    Time step:    10
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    Solving:  Stress period:     3    Time step:    38
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    Solving:  Stress period:     3    Time step:    40
    Solving:  Stress period:     3    Time step:    41
    Solving:  Stress period:     3    Time step:    42
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    Solving:  Stress period:     3    Time step:    43
    Solving:  Stress period:     3    Time step:    44
    Solving:  Stress period:     3    Time step:    45
    Solving:  Stress period:     3    Time step:    46
    Solving:  Stress period:     3    Time step:    47
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    Solving:  Stress period:     3    Time step:    56
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    Solving:  Stress period:     3    Time step:    62
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    Solving:  Stress period:     3    Time step:    92
    Solving:  Stress period:     3    Time step:    93
    Solving:  Stress period:     3    Time step:    94
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    Solving:  Stress period:     3    Time step:    95
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    Solving:  Stress period:     4    Time step:    27
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    Solving:  Stress period:     4    Time step:    76
    Solving:  Stress period:     4    Time step:    77
    Solving:  Stress period:     4    Time step:    78
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    Solving:  Stress period:     4    Time step:    79
    Solving:  Stress period:     4    Time step:    80
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    Solving:  Stress period:     4    Time step:    97
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    Solving:  Stress period:     4    Time step:   104
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    Solving:  Stress period:     4    Time step:   106
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    Solving:  Stress period:     4    Time step:   109
    Solving:  Stress period:     4    Time step:   110
    Solving:  Stress period:     4    Time step:   111
    Solving:  Stress period:     4    Time step:   112
    Solving:  Stress period:     4    Time step:   113
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    Solving:  Stress period:     4    Time step:   115
    Solving:  Stress period:     4    Time step:   116
    Solving:  Stress period:     4    Time step:   117
    Solving:  Stress period:     4    Time step:   118
    Solving:  Stress period:     4    Time step:   119
    Solving:  Stress period:     4    Time step:   120

 Run end date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:26:19
 Elapsed run time:  0.381 Seconds


WARNING REPORT:

  1. NONLINEAR BLOCK VARIABLE 'OUTER_HCLOSE' IN FILE 'child_pkgs_test.ims'
     WAS DEPRECATED IN VERSION 6.1.1. SETTING OUTER_DVCLOSE TO OUTER_HCLOSE
     VALUE.
```

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```
 2. LINEAR BLOCK VARIABLE 'INNER_HCLOSE' IN FILE 'child_pkgs_test.ims' WAS
    DEPRECATED IN VERSION 6.1.1. SETTING INNER_DVCLOSE TO INNER_HCLOSE VALUE.
Normal termination of simulation.
```

Method 2: Initialize time series through ghb.ts.initialize

[7]:
```python
# build ghb stress period data
ghb_spd_ts = {}
ghb_period = []
for layer, cond in zip(range(1, 3), [15.0, 1500.0]):
    for row in range(0, 15):
        ghb_period.append(((layer, row, 9), "tides", cond, "Estuary-L2"))
ghb_spd_ts[0] = ghb_period

# build ts data
ts_data = []
for n in range(0, 365):
    ts_data.append((float(n / 11.73), float(n / 60.0)))

# build obs data
ghb_obs = {
    ("ghb_obs.csv", "binary"): [
        ("ghb-2-6-10", "GHB", (1, 5, 9)),
        ("ghb-3-6-10", "GHB", (2, 5, 9)),
    ],
    "ghb_flows.csv": [
        ("Estuary2", "GHB", "Estuary-L2"),
        ("Estuary3", "GHB", "Estuary-L3"),
    ],
}
# build ghb package
ghb = flopy.mf6.modflow.mfgwfghb.ModflowGwfghb(
    model,
    print_input=True,
    print_flows=True,
    save_flows=True,
    boundnames=True,
    pname="ghb",
    maxbound=30,
    stress_period_data=ghb_spd_ts,
)
# initialize time series
ghb.ts.initialize(
    filename="method2.ts",
    timeseries=ts_data,
    time_series_namerecord="tides",
    interpolation_methodrecord="linearend",
    sfacrecord=1.1,
)
```

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```
sim.write_simulation()
success, buff = sim.run_simulation(silent=True, report=True)
if success:
    for line in buff:
        print(line)
else:
    raise ValueError("Failed to run.")

# clean up for next example
model.remove_package("ghb")
```

```
WARNING: Unable to resolve dimension of ('ts', 'attributes', 'sfacrecord_single',
↪'sfacval') based on shape "time_series_name".
WARNING: Unable to resolve dimension of ('ts', 'attributes', 'sfacrecord_single',
↪'sfacval') based on shape "time_series_name".
writing simulation...
  writing simulation name file...
  writing simulation tdis package...
  writing solution package ims_-1...
  writing model child_pkgs...
    writing model name file...
    writing package dis...
    writing package ic...
    writing package npf...
    writing package oc...
    writing package sto...
    writing package ghb...
    writing package ts_0...
WARNING: Unable to resolve dimension of ('ts', 'attributes', 'sfacrecord_single',
↪'sfacval') based on shape "time_series_name".
                                   MODFLOW 6
                U.S. GEOLOGICAL SURVEY MODULAR HYDROLOGIC MODEL
                            VERSION 6.4.2 06/28/2023

   MODFLOW 6 compiled Jul 05 2023 20:29:14 with Intel(R) Fortran Intel(R) 64
   Compiler Classic for applications running on Intel(R) 64, Version 2021.7.0
                             Build 20220726_000000

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Resources Software User Rights Notice for complete use, copyright,
and distribution information.
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```
Run start date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:26:19

Writing simulation list file: mfsim.lst
Using Simulation name file: mfsim.nam

   Solving:  Stress period:     1    Time step:     1
   Solving:  Stress period:     2    Time step:     1
   Solving:  Stress period:     2    Time step:     2
   Solving:  Stress period:     2    Time step:     3
   Solving:  Stress period:     2    Time step:     4
   Solving:  Stress period:     2    Time step:     5
   Solving:  Stress period:     2    Time step:     6
   Solving:  Stress period:     2    Time step:     7
   Solving:  Stress period:     2    Time step:     8
   Solving:  Stress period:     2    Time step:     9
   Solving:  Stress period:     2    Time step:    10
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    Solving:  Stress period:     2    Time step:    47
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    Solving:  Stress period:     2    Time step:    71
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    Solving:  Stress period:     2    Time step:    73
    Solving:  Stress period:     2    Time step:    74
    Solving:  Stress period:     2    Time step:    75
    Solving:  Stress period:     2    Time step:    76
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    Solving:  Stress period:     2    Time step:    79
    Solving:  Stress period:     2    Time step:    80
    Solving:  Stress period:     2    Time step:    81
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    Solving:  Stress period:     2    Time step:    83
    Solving:  Stress period:     2    Time step:    84
    Solving:  Stress period:     2    Time step:    85
    Solving:  Stress period:     2    Time step:    86
    Solving:  Stress period:     2    Time step:    87
    Solving:  Stress period:     2    Time step:    88
    Solving:  Stress period:     2    Time step:    89
    Solving:  Stress period:     2    Time step:    90
    Solving:  Stress period:     2    Time step:    91
    Solving:  Stress period:     2    Time step:    92
    Solving:  Stress period:     2    Time step:    93
    Solving:  Stress period:     2    Time step:    94
    Solving:  Stress period:     2    Time step:    95
    Solving:  Stress period:     2    Time step:    96
    Solving:  Stress period:     2    Time step:    97
    Solving:  Stress period:     2    Time step:    98
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    Solving:  Stress period:     2    Time step:    99
    Solving:  Stress period:     2    Time step:   100
    Solving:  Stress period:     2    Time step:   101
    Solving:  Stress period:     2    Time step:   102
    Solving:  Stress period:     2    Time step:   103
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    Solving:  Stress period:     2    Time step:   105
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    Solving:  Stress period:     2    Time step:   107
    Solving:  Stress period:     2    Time step:   108
    Solving:  Stress period:     2    Time step:   109
    Solving:  Stress period:     2    Time step:   110
    Solving:  Stress period:     2    Time step:   111
    Solving:  Stress period:     2    Time step:   112
    Solving:  Stress period:     2    Time step:   113
    Solving:  Stress period:     2    Time step:   114
    Solving:  Stress period:     2    Time step:   115
    Solving:  Stress period:     2    Time step:   116
    Solving:  Stress period:     2    Time step:   117
    Solving:  Stress period:     2    Time step:   118
    Solving:  Stress period:     2    Time step:   119
    Solving:  Stress period:     2    Time step:   120
    Solving:  Stress period:     3    Time step:     1
    Solving:  Stress period:     3    Time step:     2
    Solving:  Stress period:     3    Time step:     3
    Solving:  Stress period:     3    Time step:     4
    Solving:  Stress period:     3    Time step:     5
    Solving:  Stress period:     3    Time step:     6
    Solving:  Stress period:     3    Time step:     7
    Solving:  Stress period:     3    Time step:     8
    Solving:  Stress period:     3    Time step:     9
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    Solving:  Stress period:     3    Time step:    27
    Solving:  Stress period:     3    Time step:    28
    Solving:  Stress period:     3    Time step:    29
    Solving:  Stress period:     3    Time step:    30
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    Solving:  Stress period:     3    Time step:    31
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    Solving:  Stress period:     3    Time step:    81
    Solving:  Stress period:     3    Time step:    82
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    Solving:  Stress period:     3    Time step:    83
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    Solving:  Stress period:     4    Time step:    11
    Solving:  Stress period:     4    Time step:    12
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    Solving:  Stress period:     4    Time step:    15
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    Solving:  Stress period:     4    Time step:    19
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    Solving:  Stress period:     4    Time step:    65
    Solving:  Stress period:     4    Time step:    66
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    Solving:  Stress period:     4    Time step:    67
    Solving:  Stress period:     4    Time step:    68
    Solving:  Stress period:     4    Time step:    69
    Solving:  Stress period:     4    Time step:    70
    Solving:  Stress period:     4    Time step:    71
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    Solving:  Stress period:     4    Time step:   104
    Solving:  Stress period:     4    Time step:   105
    Solving:  Stress period:     4    Time step:   106
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    Solving:  Stress period:     4    Time step:   111
    Solving:  Stress period:     4    Time step:   112
    Solving:  Stress period:     4    Time step:   113
    Solving:  Stress period:     4    Time step:   114
    Solving:  Stress period:     4    Time step:   115
    Solving:  Stress period:     4    Time step:   116
    Solving:  Stress period:     4    Time step:   117
    Solving:  Stress period:     4    Time step:   118
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```
    Solving:  Stress period:     4    Time step:   119
    Solving:  Stress period:     4    Time step:   120

 Run end date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:26:19
 Elapsed run time:  0.443 Seconds


WARNING REPORT:

  1. NONLINEAR BLOCK VARIABLE 'OUTER_HCLOSE' IN FILE 'child_pkgs_test.ims'
     WAS DEPRECATED IN VERSION 6.1.1. SETTING OUTER_DVCLOSE TO OUTER_HCLOSE
     VALUE.
  2. LINEAR BLOCK VARIABLE 'INNER_HCLOSE' IN FILE 'child_pkgs_test.ims' WAS
     DEPRECATED IN VERSION 6.1.1. SETTING INNER_DVCLOSE TO INNER_HCLOSE VALUE.
 Normal termination of simulation.
```

Method 3: Pass timeseries a dictionary of anything that could be passed to ghb.ts.initialize

[8]:
```python
# build ghb stress period data
ghb_spd_ts = {}
ghb_period = []
for layer, cond in zip(range(1, 3), [15.0, 1500.0]):
    for row in range(0, 15):
        ghb_period.append(((layer, row, 9), "tides", cond, "Estuary-L2"))
ghb_spd_ts[0] = ghb_period

# build ts data
ts_data = []
for n in range(0, 365):
    ts_data.append((float(n / 11.73), float(n / 60.0)))
ts_dict = {
    "timeseries": ts_data,
    "time_series_namerecord": "tides",
    "interpolation_methodrecord": "linear",
    "filename": "method3.ts",
}
# build obs data
ghb_obs = {
    ("ghb_obs.csv", "binary"): [
        ("ghb-2-6-10", "GHB", (1, 5, 9)),
        ("ghb-3-6-10", "GHB", (2, 5, 9)),
    ],
    "ghb_flows.csv": [
        ("Estuary2", "GHB", "Estuary-L2"),
        ("Estuary3", "GHB", "Estuary-L3"),
    ],
}
# build ghb package
ghb = flopy.mf6.modflow.mfgwfghb.ModflowGwfghb(
    model,
```

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```
    print_input=True,
    print_flows=True,
    save_flows=True,
    boundnames=True,
    pname="ghb",
    timeseries=ts_dict,
    maxbound=30,
    stress_period_data=ghb_spd_ts,
)

sim.write_simulation()
success, buff = sim.run_simulation(silent=True, report=True)
if success:
    for line in buff:
        print(line)
else:
    raise ValueError("Failed to run.")

# clean up for next example
model.remove_package("ghb")
```

```
writing simulation...
  writing simulation name file...
  writing simulation tdis package...
  writing solution package ims_-1...
  writing model child_pkgs...
    writing model name file...
    writing package dis...
    writing package ic...
    writing package npf...
    writing package oc...
    writing package sto...
    writing package ghb...
    writing package ts_0...
                                   MODFLOW 6
                U.S. GEOLOGICAL SURVEY MODULAR HYDROLOGIC MODEL
                            VERSION 6.4.2 06/28/2023

   MODFLOW 6 compiled Jul 05 2023 20:29:14 with Intel(R) Fortran Intel(R) 64
   Compiler Classic for applications running on Intel(R) 64, Version 2021.7.0
                             Build 20220726_000000

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authorized or unauthorized use. Also refer to the USGS Water
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```
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and distribution information.


 Run start date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:26:19

 Writing simulation list file: mfsim.lst
 Using Simulation name file: mfsim.nam

    Solving:  Stress period:     1    Time step:     1
    Solving:  Stress period:     2    Time step:     1
    Solving:  Stress period:     2    Time step:     2
    Solving:  Stress period:     2    Time step:     3
    Solving:  Stress period:     2    Time step:     4
    Solving:  Stress period:     2    Time step:     5
    Solving:  Stress period:     2    Time step:     6
    Solving:  Stress period:     2    Time step:     7
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    Solving:  Stress period:     2    Time step:    42
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    Solving:  Stress period:     2    Time step:    43
    Solving:  Stress period:     2    Time step:    44
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    Solving:  Stress period:     2    Time step:    62
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    Solving:  Stress period:     2    Time step:    68
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    Solving:  Stress period:     2    Time step:    73
    Solving:  Stress period:     2    Time step:    74
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    Solving:  Stress period:     2    Time step:    78
    Solving:  Stress period:     2    Time step:    79
    Solving:  Stress period:     2    Time step:    80
    Solving:  Stress period:     2    Time step:    81
    Solving:  Stress period:     2    Time step:    82
    Solving:  Stress period:     2    Time step:    83
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    Solving:  Stress period:     2    Time step:    86
    Solving:  Stress period:     2    Time step:    87
    Solving:  Stress period:     2    Time step:    88
    Solving:  Stress period:     2    Time step:    89
    Solving:  Stress period:     2    Time step:    90
    Solving:  Stress period:     2    Time step:    91
    Solving:  Stress period:     2    Time step:    92
    Solving:  Stress period:     2    Time step:    93
    Solving:  Stress period:     2    Time step:    94
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    Solving:  Stress period:     2    Time step:    95
    Solving:  Stress period:     2    Time step:    96
    Solving:  Stress period:     2    Time step:    97
    Solving:  Stress period:     2    Time step:    98
    Solving:  Stress period:     2    Time step:    99
    Solving:  Stress period:     2    Time step:   100
    Solving:  Stress period:     2    Time step:   101
    Solving:  Stress period:     2    Time step:   102
    Solving:  Stress period:     2    Time step:   103
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    Solving:  Stress period:     2    Time step:   105
    Solving:  Stress period:     2    Time step:   106
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    Solving:  Stress period:     2    Time step:   109
    Solving:  Stress period:     2    Time step:   110
    Solving:  Stress period:     2    Time step:   111
    Solving:  Stress period:     2    Time step:   112
    Solving:  Stress period:     2    Time step:   113
    Solving:  Stress period:     2    Time step:   114
    Solving:  Stress period:     2    Time step:   115
    Solving:  Stress period:     2    Time step:   116
    Solving:  Stress period:     2    Time step:   117
    Solving:  Stress period:     2    Time step:   118
    Solving:  Stress period:     2    Time step:   119
    Solving:  Stress period:     2    Time step:   120
    Solving:  Stress period:     3    Time step:     1
    Solving:  Stress period:     3    Time step:     2
    Solving:  Stress period:     3    Time step:     3
    Solving:  Stress period:     3    Time step:     4
    Solving:  Stress period:     3    Time step:     5
    Solving:  Stress period:     3    Time step:     6
    Solving:  Stress period:     3    Time step:     7
    Solving:  Stress period:     3    Time step:     8
    Solving:  Stress period:     3    Time step:     9
    Solving:  Stress period:     3    Time step:    10
    Solving:  Stress period:     3    Time step:    11
    Solving:  Stress period:     3    Time step:    12
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    Solving:  Stress period:     3    Time step:    14
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    Solving:  Stress period:     3    Time step:    19
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    Solving:  Stress period:     3    Time step:    23
    Solving:  Stress period:     3    Time step:    24
    Solving:  Stress period:     3    Time step:    25
    Solving:  Stress period:     3    Time step:    26
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    Solving:  Stress period:     3    Time step:    27
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    Solving:  Stress period:     3    Time step:    29
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    Solving:  Stress period:     3    Time step:    45
    Solving:  Stress period:     3    Time step:    46
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    Solving:  Stress period:     3    Time step:    77
    Solving:  Stress period:     3    Time step:    78
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    Solving:  Stress period:     3    Time step:    79
    Solving:  Stress period:     3    Time step:    80
    Solving:  Stress period:     3    Time step:    81
    Solving:  Stress period:     3    Time step:    82
    Solving:  Stress period:     3    Time step:    83
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    Solving:  Stress period:     4    Time step:     1
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    Solving:  Stress period:     4    Time step:    11
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    Solving:  Stress period:     4    Time step:    61
    Solving:  Stress period:     4    Time step:    62
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    Solving:  Stress period:     4    Time step:    63
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    Solving:  Stress period:     4    Time step:   106
    Solving:  Stress period:     4    Time step:   107
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    Solving:  Stress period:     4    Time step:   110
    Solving:  Stress period:     4    Time step:   111
    Solving:  Stress period:     4    Time step:   112
    Solving:  Stress period:     4    Time step:   113
    Solving:  Stress period:     4    Time step:   114
```

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```
    Solving:  Stress period:     4    Time step:   115
    Solving:  Stress period:     4    Time step:   116
    Solving:  Stress period:     4    Time step:   117
    Solving:  Stress period:     4    Time step:   118
    Solving:  Stress period:     4    Time step:   119
    Solving:  Stress period:     4    Time step:   120

 Run end date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:26:20
 Elapsed run time:  0.386 Seconds


WARNING REPORT:

  1. NONLINEAR BLOCK VARIABLE 'OUTER_HCLOSE' IN FILE 'child_pkgs_test.ims'
     WAS DEPRECATED IN VERSION 6.1.1. SETTING OUTER_DVCLOSE TO OUTER_HCLOSE
     VALUE.
  2. LINEAR BLOCK VARIABLE 'INNER_HCLOSE' IN FILE 'child_pkgs_test.ims' WAS
     DEPRECATED IN VERSION 6.1.1. SETTING INNER_DVCLOSE TO INNER_HCLOSE VALUE.
 Normal termination of simulation.
```

Multiple time series packages

[9]:
```
# build ghb stress period data
ghb_spd_ts = {}
ghb_period = []
for layer, cond in zip(range(1, 3), [15.0, 1500.0]):
    for row in range(0, 15):
        if row < 10:
            ghb_period.append(((layer, row, 9), "tides", cond, "Estuary-L2"))
        else:
            ghb_period.append(((layer, row, 9), "wl", cond, "Estuary-L2"))
ghb_spd_ts[0] = ghb_period

# build ts data
ts_data = []
for n in range(0, 365):
    ts_data.append((float(n / 11.73), float(n / 60.0)))
ts_data2 = []
for n in range(0, 365):
    ts_data2.append((float(0.0 + (n / 11.73)), 2 * float(n / 60.0)))
ts_data3 = []
for n in range(0, 365):
    ts_data3.append((float(0.0 + (n / 11.73)), 1.5 * float(n / 60.0)))

# build obs data
ghb_obs = {
    ("ghb_obs.csv", "binary"): [
        ("ghb-2-6-10", "GHB", (1, 5, 9)),
        ("ghb-3-6-10", "GHB", (2, 5, 9)),
    ],
```

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```
    "ghb_flows.csv": [
        ("Estuary2", "GHB", "Estuary-L2"),
        ("Estuary3", "GHB", "Estuary-L3"),
    ],
}
# build ghb package
ghb = flopy.mf6.modflow.mfgwfghb.ModflowGwfghb(
    model,
    print_input=True,
    print_flows=True,
    save_flows=True,
    boundnames=True,
    pname="ghb",
    maxbound=30,
    stress_period_data=ghb_spd_ts,
)

# initialize time series
ghb.ts.initialize(
    filename="tides.ts",
    timeseries=ts_data,
    time_series_namerecord="tides",
    interpolation_methodrecord="linearend",
    sfacrecord=1.1,
)
# append additional time series
ghb.ts.append_package(
    filename="wls.ts",
    timeseries=ts_data2,
    time_series_namerecord="wl",
    interpolation_methodrecord="stepwise",
    sfacrecord=1.2,
)
# append additional time series
ghb.ts.append_package(
    filename="wls2.ts",
    timeseries=ts_data3,
    time_series_namerecord="wl2",
    interpolation_methodrecord="stepwise",
    sfacrecord=1.3,
)

# retreive information from each time series
print(
    "{} is using {} interpolation".format(
        ghb.ts[0].filename,
        ghb.ts[0].interpolation_methodrecord.get_data()[0][0],
    )
)
print(
    "{} is using {} interpolation".format(
        ghb.ts[1].filename,
```

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```
        ghb.ts[1].interpolation_methodrecord.get_data()[0][0],
    )
)
print(
    "{} is using {} interpolation".format(
        ghb.ts[2].filename,
        ghb.ts[2].interpolation_methodrecord.get_data()[0][0],
    )
)

sim.write_simulation()
success, buff = sim.run_simulation(silent=True, report=True)
if success:
    for line in buff:
        print(line)
else:
    raise ValueError("Failed to run.")
```

```
WARNING: Unable to resolve dimension of ('ts', 'attributes', 'sfacrecord_single',
↪'sfacval') based on shape "time_series_name".
WARNING: Unable to resolve dimension of ('ts', 'attributes', 'sfacrecord_single',
↪'sfacval') based on shape "time_series_name".
WARNING: Unable to resolve dimension of ('ts', 'attributes', 'sfacrecord_single',
↪'sfacval') based on shape "time_series_name".
WARNING: Unable to resolve dimension of ('ts', 'attributes', 'sfacrecord_single',
↪'sfacval') based on shape "time_series_name".
WARNING: Unable to resolve dimension of ('ts', 'attributes', 'sfacrecord_single',
↪'sfacval') based on shape "time_series_name".
WARNING: Unable to resolve dimension of ('ts', 'attributes', 'sfacrecord_single',
↪'sfacval') based on shape "time_series_name".
tides.ts is using linearend interpolation
wls.ts is using stepwise interpolation
wls2.ts is using stepwise interpolation
writing simulation...
  writing simulation name file...
  writing simulation tdis package...
  writing solution package ims_-1...
  writing model child_pkgs...
    writing model name file...
    writing package dis...
    writing package ic...
    writing package npf...
    writing package oc...
    writing package sto...
    writing package ghb...
    writing package ts_0...
WARNING: Unable to resolve dimension of ('ts', 'attributes', 'sfacrecord_single',
↪'sfacval') based on shape "time_series_name".
    writing package ts_1...
WARNING: Unable to resolve dimension of ('ts', 'attributes', 'sfacrecord_single',
↪'sfacval') based on shape "time_series_name".
    writing package ts_2...
```

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```
WARNING: Unable to resolve dimension of ('ts', 'attributes', 'sfacrecord_single',
↪'sfacval') based on shape "time_series_name".
                                   MODFLOW 6
                U.S. GEOLOGICAL SURVEY MODULAR HYDROLOGIC MODEL
                            VERSION 6.4.2 06/28/2023

   MODFLOW 6 compiled Jul 05 2023 20:29:14 with Intel(R) Fortran Intel(R) 64
   Compiler Classic for applications running on Intel(R) 64, Version 2021.7.0
                             Build 20220726_000000

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Resources Software User Rights Notice for complete use, copyright,
and distribution information.


 Run start date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:26:20

 Writing simulation list file: mfsim.lst
 Using Simulation name file: mfsim.nam

    Solving:  Stress period:     1    Time step:     1
    Solving:  Stress period:     2    Time step:     1
    Solving:  Stress period:     2    Time step:     2
    Solving:  Stress period:     2    Time step:     3
    Solving:  Stress period:     2    Time step:     4
    Solving:  Stress period:     2    Time step:     5
    Solving:  Stress period:     2    Time step:     6
    Solving:  Stress period:     2    Time step:     7
    Solving:  Stress period:     2    Time step:     8
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    Solving:  Stress period:     2    Time step:    10
    Solving:  Stress period:     2    Time step:    11
    Solving:  Stress period:     2    Time step:    12
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    Solving:  Stress period:     2    Time step:    18
    Solving:  Stress period:     2    Time step:    19
    Solving:  Stress period:     2    Time step:    20
    Solving:  Stress period:     2    Time step:    21
    Solving:  Stress period:     2    Time step:    22
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    Solving:  Stress period:     2    Time step:    23
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    Solving:  Stress period:     2    Time step:    70
    Solving:  Stress period:     2    Time step:    71
    Solving:  Stress period:     2    Time step:    72
    Solving:  Stress period:     2    Time step:    73
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    Solving:  Stress period:     2    Time step:    75
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    Solving:  Stress period:     3    Time step:     4
    Solving:  Stress period:     3    Time step:     5
    Solving:  Stress period:     3    Time step:     6
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    Solving:  Stress period:     3    Time step:   111
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    Solving:  Stress period:     4    Time step:   118
    Solving:  Stress period:     4    Time step:   119
    Solving:  Stress period:     4    Time step:   120

 Run end date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:26:20
 Elapsed run time:  0.427 Seconds


WARNING REPORT:

  1. NONLINEAR BLOCK VARIABLE 'OUTER_HCLOSE' IN FILE 'child_pkgs_test.ims'
     WAS DEPRECATED IN VERSION 6.1.1. SETTING OUTER_DVCLOSE TO OUTER_HCLOSE
     VALUE.
  2. LINEAR BLOCK VARIABLE 'INNER_HCLOSE' IN FILE 'child_pkgs_test.ims' WAS
     DEPRECATED IN VERSION 6.1.1. SETTING INNER_DVCLOSE TO INNER_HCLOSE VALUE.
 Normal termination of simulation.
```

Time Array Series

Time array series can be set for any package through the package.tas object, and each package.tas object has several attributes that can be set:

package.tas.filename : str Name of time series file to create. The default is packagename + '.tas', e.g. mymodel.rcha.tas.

package.tas.tas_array : {double:[double]} Array containing the time array series information for specific times. tas_array = {0.0: 0.0001, 200.0: [0.01, 0.02...]}

package.tas.time_series_namerecord : str Name by which a package references a particular time-array series. The name must be unique among all time-array series used in a package

package.tas.interpolation_methodrecord : list (of strings) List of interpolation methods to use for time array series. Method must be either 'stepwise' or 'linear'.

package.tas.sfacrecord_single : float Scale factor to multiply the time array series data column. Can only be used if there is one time series data column.

Method 1: Pass time array series to package constructor

[10]:
```
tas = {0.0: 0.000002, 200.0: 0.0000001}
# create recharge package with time array series data
# flopy will generate a warning that there is not yet a time series name
# record for recharray_1
rcha = flopy.mf6.modflow.mfgwfrcha.ModflowGwfrcha(
    model, timearrayseries=tas, recharge="TIMEARRAYSERIES rcharray_1"
)
# finish defining the time array series properties
rcha.tas.time_series_namerecord = "rcharray_1"
rcha.tas.interpolation_methodrecord = "LINEAR"

sim.write_simulation()
success, buff = sim.run_simulation(silent=True, report=True)
if success:
    for line in buff:
        print(line)
else:
    raise ValueError("Failed to run.")

# clean up for next example
model.remove_package("rcha")
```

```
WARNING: Time array series name rcharray_1 not found in any time series file
writing simulation...
  writing simulation name file...
  writing simulation tdis package...
  writing solution package ims_-1...
  writing model child_pkgs...
    writing model name file...
    writing package dis...
    writing package ic...
    writing package npf...
    writing package oc...
    writing package sto...
    writing package ghb...
    writing package ts_0...
WARNING: Unable to resolve dimension of ('ts', 'attributes', 'sfacrecord_single',
↪'sfacval') based on shape "time_series_name".
    writing package ts_1...
WARNING: Unable to resolve dimension of ('ts', 'attributes', 'sfacrecord_single',
↪'sfacval') based on shape "time_series_name".
    writing package ts_2...
WARNING: Unable to resolve dimension of ('ts', 'attributes', 'sfacrecord_single',
↪'sfacval') based on shape "time_series_name".
    writing package rcha_0...
```

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```
    writing package tas_0...
                                   MODFLOW 6
                U.S. GEOLOGICAL SURVEY MODULAR HYDROLOGIC MODEL
                            VERSION 6.4.2 06/28/2023

   MODFLOW 6 compiled Jul 05 2023 20:29:14 with Intel(R) Fortran Intel(R) 64
   Compiler Classic for applications running on Intel(R) 64, Version 2021.7.0
                             Build 20220726_000000

This software has been approved for release by the U.S. Geological
Survey (USGS). Although the software has been subjected to rigorous
review, the USGS reserves the right to update the software as needed
pursuant to further analysis and review. No warranty, expressed or
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authorized or unauthorized use. Also refer to the USGS Water
Resources Software User Rights Notice for complete use, copyright,
and distribution information.


 Run start date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:26:20

 Writing simulation list file: mfsim.lst
 Using Simulation name file: mfsim.nam

    Solving:  Stress period:     1    Time step:     1
    Solving:  Stress period:     2    Time step:     1
    Solving:  Stress period:     2    Time step:     2
    Solving:  Stress period:     2    Time step:     3
    Solving:  Stress period:     2    Time step:     4
    Solving:  Stress period:     2    Time step:     5
    Solving:  Stress period:     2    Time step:     6
    Solving:  Stress period:     2    Time step:     7
    Solving:  Stress period:     2    Time step:     8
    Solving:  Stress period:     2    Time step:     9
    Solving:  Stress period:     2    Time step:    10
    Solving:  Stress period:     2    Time step:    11
    Solving:  Stress period:     2    Time step:    12
    Solving:  Stress period:     2    Time step:    13
    Solving:  Stress period:     2    Time step:    14
    Solving:  Stress period:     2    Time step:    15
    Solving:  Stress period:     2    Time step:    16
    Solving:  Stress period:     2    Time step:    17
    Solving:  Stress period:     2    Time step:    18
    Solving:  Stress period:     2    Time step:    19
    Solving:  Stress period:     2    Time step:    20
    Solving:  Stress period:     2    Time step:    21
    Solving:  Stress period:     2    Time step:    22
    Solving:  Stress period:     2    Time step:    23
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    Solving:  Stress period:     2    Time step:    24
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    Solving:  Stress period:     2    Time step:    68
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    Solving:  Stress period:     2    Time step:    70
    Solving:  Stress period:     2    Time step:    71
    Solving:  Stress period:     2    Time step:    72
    Solving:  Stress period:     2    Time step:    73
    Solving:  Stress period:     2    Time step:    74
    Solving:  Stress period:     2    Time step:    75
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    Solving:  Stress period:     2    Time step:    76
    Solving:  Stress period:     2    Time step:    77
    Solving:  Stress period:     2    Time step:    78
    Solving:  Stress period:     2    Time step:    79
    Solving:  Stress period:     2    Time step:    80
    Solving:  Stress period:     2    Time step:    81
    Solving:  Stress period:     2    Time step:    82
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    Solving:  Stress period:     2    Time step:    86
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    Solving:  Stress period:     2    Time step:    89
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    Solving:  Stress period:     2    Time step:   118
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    Solving:  Stress period:     2    Time step:   120
    Solving:  Stress period:     3    Time step:     1
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    Solving:  Stress period:     3    Time step:     3
    Solving:  Stress period:     3    Time step:     4
    Solving:  Stress period:     3    Time step:     5
    Solving:  Stress period:     3    Time step:     6
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    Solving:  Stress period:     3    Time step:     8
    Solving:  Stress period:     3    Time step:     9
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    Solving:  Stress period:     3    Time step:    24
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    Solving:  Stress period:     3    Time step:    58
    Solving:  Stress period:     3    Time step:    59
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    Solving:  Stress period:     3    Time step:    60
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    Solving:  Stress period:     3    Time step:   112
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    Solving:  Stress period:     4    Time step:    44
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    Solving:  Stress period:     4    Time step:    96
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    Solving:  Stress period:     4    Time step:   117
    Solving:  Stress period:     4    Time step:   118
    Solving:  Stress period:     4    Time step:   119
    Solving:  Stress period:     4    Time step:   120

 Run end date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:26:21
 Elapsed run time:  0.445 Seconds


WARNING REPORT:

  1. NONLINEAR BLOCK VARIABLE 'OUTER_HCLOSE' IN FILE 'child_pkgs_test.ims'
     WAS DEPRECATED IN VERSION 6.1.1. SETTING OUTER_DVCLOSE TO OUTER_HCLOSE
     VALUE.
  2. LINEAR BLOCK VARIABLE 'INNER_HCLOSE' IN FILE 'child_pkgs_test.ims' WAS
     DEPRECATED IN VERSION 6.1.1. SETTING INNER_DVCLOSE TO INNER_HCLOSE VALUE.
 Normal termination of simulation.
```

Method 2: Initialize time array series through rcha.tas.initialize

[11]:
```python
# create recharge package with recharge pointing to a time array series
# not yet defined. flopy will generate a warning that there is not yet a
# time series name record for recharray_1
rcha = flopy.mf6.modflow.mfgwfrcha.ModflowGwfrcha(
    model, recharge="TIMEARRAYSERIES rcharray_1"
)
rch_array = 0.000002 * np.ones((15, 10))
rch_array[0, 0] = 0.0001
tas = {0.0: rch_array, 200.0: 0.0000001}
```

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```
# initialize the time array series
rcha.tas.initialize(
    filename="method2.tas",
    tas_array=tas,
    time_series_namerecord="rcharray_1",
    interpolation_methodrecord="LINEAR",
)

sim.write_simulation()
success, buff = sim.run_simulation(silent=True, report=True)
if success:
    for line in buff:
        print(line)
else:
    raise ValueError("Failed to run.")

# clean up for next example
model.remove_package("rcha")
```

```
WARNING: Time array series name rcharray_1 not found in any time series file
writing simulation...
  writing simulation name file...
  writing simulation tdis package...
  writing solution package ims_-1...
  writing model child_pkgs...
    writing model name file...
    writing package dis...
    writing package ic...
    writing package npf...
    writing package oc...
    writing package sto...
    writing package ghb...
    writing package ts_0...
WARNING: Unable to resolve dimension of ('ts', 'attributes', 'sfacrecord_single',
↪'sfacval') based on shape "time_series_name".
    writing package ts_1...
WARNING: Unable to resolve dimension of ('ts', 'attributes', 'sfacrecord_single',
↪'sfacval') based on shape "time_series_name".
    writing package ts_2...
WARNING: Unable to resolve dimension of ('ts', 'attributes', 'sfacrecord_single',
↪'sfacval') based on shape "time_series_name".
    writing package rcha_0...
    writing package tas_0...
                                   MODFLOW 6
                U.S. GEOLOGICAL SURVEY MODULAR HYDROLOGIC MODEL
                            VERSION 6.4.2 06/28/2023

   MODFLOW 6 compiled Jul 05 2023 20:29:14 with Intel(R) Fortran Intel(R) 64
   Compiler Classic for applications running on Intel(R) 64, Version 2021.7.0
                             Build 20220726_000000

This software has been approved for release by the U.S. Geological
```

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```
Survey (USGS). Although the software has been subjected to rigorous
review, the USGS reserves the right to update the software as needed
pursuant to further analysis and review. No warranty, expressed or
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Resources Software User Rights Notice for complete use, copyright,
and distribution information.


 Run start date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:26:21

 Writing simulation list file: mfsim.lst
 Using Simulation name file: mfsim.nam

    Solving:  Stress period:     1    Time step:     1
    Solving:  Stress period:     2    Time step:     1
    Solving:  Stress period:     2    Time step:     2
    Solving:  Stress period:     2    Time step:     3
    Solving:  Stress period:     2    Time step:     4
    Solving:  Stress period:     2    Time step:     5
    Solving:  Stress period:     2    Time step:     6
    Solving:  Stress period:     2    Time step:     7
    Solving:  Stress period:     2    Time step:     8
    Solving:  Stress period:     2    Time step:     9
    Solving:  Stress period:     2    Time step:    10
    Solving:  Stress period:     2    Time step:    11
    Solving:  Stress period:     2    Time step:    12
    Solving:  Stress period:     2    Time step:    13
    Solving:  Stress period:     2    Time step:    14
    Solving:  Stress period:     2    Time step:    15
    Solving:  Stress period:     2    Time step:    16
    Solving:  Stress period:     2    Time step:    17
    Solving:  Stress period:     2    Time step:    18
    Solving:  Stress period:     2    Time step:    19
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    Solving:  Stress period:     2    Time step:    21
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    Solving:  Stress period:     2    Time step:    31
    Solving:  Stress period:     2    Time step:    32
    Solving:  Stress period:     2    Time step:    33
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    Solving:  Stress period:     2    Time step:    34
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    Solving:  Stress period:     2    Time step:    36
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    Solving:  Stress period:     2    Time step:    38
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    Solving:  Stress period:     2    Time step:    81
    Solving:  Stress period:     2    Time step:    82
    Solving:  Stress period:     2    Time step:    83
    Solving:  Stress period:     2    Time step:    84
    Solving:  Stress period:     2    Time step:    85
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    Solving:  Stress period:     2    Time step:    86
    Solving:  Stress period:     2    Time step:    87
    Solving:  Stress period:     2    Time step:    88
    Solving:  Stress period:     2    Time step:    89
    Solving:  Stress period:     2    Time step:    90
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    Solving:  Stress period:     2    Time step:   118
    Solving:  Stress period:     2    Time step:   119
    Solving:  Stress period:     2    Time step:   120
    Solving:  Stress period:     3    Time step:     1
    Solving:  Stress period:     3    Time step:     2
    Solving:  Stress period:     3    Time step:     3
    Solving:  Stress period:     3    Time step:     4
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    Solving:  Stress period:     3    Time step:    16
    Solving:  Stress period:     3    Time step:    17
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    Solving:  Stress period:     3    Time step:    18
    Solving:  Stress period:     3    Time step:    19
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    Solving:  Stress period:     3    Time step:    70
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    Solving:  Stress period:     3    Time step:   118
    Solving:  Stress period:     3    Time step:   119
    Solving:  Stress period:     3    Time step:   120
    Solving:  Stress period:     4    Time step:     1
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    Solving:  Stress period:     4    Time step:     2
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    Solving:  Stress period:     4    Time step:    54
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    Solving:  Stress period:     4    Time step:   102
    Solving:  Stress period:     4    Time step:   103
    Solving:  Stress period:     4    Time step:   104
    Solving:  Stress period:     4    Time step:   105
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    Solving:  Stress period:     4    Time step:   106
    Solving:  Stress period:     4    Time step:   107
    Solving:  Stress period:     4    Time step:   108
    Solving:  Stress period:     4    Time step:   109
    Solving:  Stress period:     4    Time step:   110
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    Solving:  Stress period:     4    Time step:   112
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    Solving:  Stress period:     4    Time step:   114
    Solving:  Stress period:     4    Time step:   115
    Solving:  Stress period:     4    Time step:   116
    Solving:  Stress period:     4    Time step:   117
    Solving:  Stress period:     4    Time step:   118
    Solving:  Stress period:     4    Time step:   119
    Solving:  Stress period:     4    Time step:   120

 Run end date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:26:21
 Elapsed run time:  0.461 Seconds


WARNING REPORT:

  1. NONLINEAR BLOCK VARIABLE 'OUTER_HCLOSE' IN FILE 'child_pkgs_test.ims'
     WAS DEPRECATED IN VERSION 6.1.1. SETTING OUTER_DVCLOSE TO OUTER_HCLOSE
     VALUE.
  2. LINEAR BLOCK VARIABLE 'INNER_HCLOSE' IN FILE 'child_pkgs_test.ims' WAS
     DEPRECATED IN VERSION 6.1.1. SETTING INNER_DVCLOSE TO INNER_HCLOSE VALUE.
 Normal termination of simulation.
```

Method 3: Pass timearrayseries a dictionary of anything that could be passed to rcha.tas.initialize

[12]:
```
rch_array = 0.0000001 * np.ones((15, 10))
rch_array[0, 0] = 0.0001
tas = {
    0.0: 0.000002,
    200.0: rch_array,
    "filename": "method3.tas",
    "time_series_namerecord": "rcharray_1",
    "interpolation_methodrecord": "LINEAR",
}
rcha = flopy.mf6.modflow.mfgwfrcha.ModflowGwfrcha(
    model, timearrayseries=tas, recharge="TIMEARRAYSERIES rcharray_1"
)

sim.write_simulation()
success, buff = sim.run_simulation(silent=True, report=True)
if success:
    for line in buff:
        print(line)
else:
```

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```
    raise ValueError("Failed to run.")

# clean up for next example
model.remove_package("rcha")
```

```
writing simulation...
  writing simulation name file...
  writing simulation tdis package...
  writing solution package ims_-1...
  writing model child_pkgs...
    writing model name file...
    writing package dis...
    writing package ic...
    writing package npf...
    writing package oc...
    writing package sto...
    writing package ghb...
    writing package ts_0...
WARNING: Unable to resolve dimension of ('ts', 'attributes', 'sfacrecord_single',
↪'sfacval') based on shape "time_series_name".
    writing package ts_1...
WARNING: Unable to resolve dimension of ('ts', 'attributes', 'sfacrecord_single',
↪'sfacval') based on shape "time_series_name".
    writing package ts_2...
WARNING: Unable to resolve dimension of ('ts', 'attributes', 'sfacrecord_single',
↪'sfacval') based on shape "time_series_name".
    writing package rcha_0...
    writing package tas_0...
                                   MODFLOW 6
                U.S. GEOLOGICAL SURVEY MODULAR HYDROLOGIC MODEL
                            VERSION 6.4.2 06/28/2023

   MODFLOW 6 compiled Jul 05 2023 20:29:14 with Intel(R) Fortran Intel(R) 64
   Compiler Classic for applications running on Intel(R) 64, Version 2021.7.0
                             Build 20220726_000000

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Survey (USGS). Although the software has been subjected to rigorous
review, the USGS reserves the right to update the software as needed
pursuant to further analysis and review. No warranty, expressed or
implied, is made by the USGS or the U.S. Government as to the
functionality of the software and related material nor shall the
fact of release constitute any such warranty. Furthermore, the
software is released on condition that neither the USGS nor the U.S.
Government shall be held liable for any damages resulting from its
authorized or unauthorized use. Also refer to the USGS Water
Resources Software User Rights Notice for complete use, copyright,
and distribution information.


 Run start date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:26:21
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Writing simulation list file: mfsim.lst
Using Simulation name file: mfsim.nam

   Solving:  Stress period:     1    Time step:     1
   Solving:  Stress period:     2    Time step:     1
   Solving:  Stress period:     2    Time step:     2
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   Solving:  Stress period:     2    Time step:    12
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   Solving:  Stress period:     2    Time step:    18
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   Solving:  Stress period:     2    Time step:    46
   Solving:  Stress period:     2    Time step:    47
   Solving:  Stress period:     2    Time step:    48
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    Solving:  Stress period:     4    Time step:   120
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```
 Run end date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:26:22
 Elapsed run time:  0.436 Seconds


WARNING REPORT:

  1. NONLINEAR BLOCK VARIABLE 'OUTER_HCLOSE' IN FILE 'child_pkgs_test.ims'
     WAS DEPRECATED IN VERSION 6.1.1. SETTING OUTER_DVCLOSE TO OUTER_HCLOSE
     VALUE.
  2. LINEAR BLOCK VARIABLE 'INNER_HCLOSE' IN FILE 'child_pkgs_test.ims' WAS
     DEPRECATED IN VERSION 6.1.1. SETTING INNER_DVCLOSE TO INNER_HCLOSE VALUE.
 Normal termination of simulation.
```

5.2.11 Working with the Multi-node Well (MNW2) Package

[1]:
```
import os
```

[2]:
```
import sys
from tempfile import TemporaryDirectory

import numpy as np

try:
    import pandas as pd
except:
    pass

# run installed version of flopy or add local path
try:
    import flopy
except:
    fpth = os.path.abspath(os.path.join("..", ".."))
    sys.path.append(fpth)
    import flopy

print(sys.version)
print(f"numpy version: {np.__version__}")
try:
    print(f"pandas version: {pd.__version__}")
except:
    pass
print(f"flopy version: {flopy.__version__}")
```

```
3.8.18 (default, Aug 28 2023, 08:27:22)
[GCC 11.4.0]
numpy version: 1.24.4
pandas version: 2.0.3
flopy version: 3.5.0
```

Make an MNW2 package from scratch

[3]:
```
# temporary directory
temp_dir = TemporaryDirectory()
model_ws = temp_dir.name

m = flopy.modflow.Modflow("mnw2example", model_ws=model_ws)
dis = flopy.modflow.ModflowDis(
    nrow=5, ncol=5, nlay=3, nper=3, top=10, botm=0, model=m
)
```

MNW2 information by node

(this could be prepared externally from well reconds and read in from a csv or excel file) * this table has two multi-node wells, the first (well1) consisting of two nodes that are manually specified (where the variable **rw** is specified by node) * node that some variables that are constant for the whole well are also included (losstype, zpump, etc.)

[4]:
```
node_data = pd.DataFrame(
    [
        [1, 1, 9.5, 7.1, "well1", "skin", -1, 0, 0, 0, 1.0, 2.0, 5.0, 6.2],
        [1, 1, 7.1, 5.1, "well1", "skin", -1, 0, 0, 0, 0.5, 2.0, 5.0, 6.2],
        [3, 3, 9.1, 3.7, "well2", "skin", -1, 0, 0, 0, 1.0, 2.0, 5.0, 4.1],
    ],
    columns=[
        "i",
        "j",
        "ztop",
        "zbotm",
        "wellid",
        "losstype",
        "pumploc",
        "qlimit",
        "ppflag",
        "pumpcap",
        "rw",
        "rskin",
        "kskin",
        "zpump",
    ],
)
node_data
```

[4]:
```
   i  j  ztop  zbotm wellid losstype  pumploc  qlimit  ppflag  pumpcap   rw  \
0  1  1   9.5    7.1  well1     skin       -1       0       0        0  1.0
1  1  1   7.1    5.1  well1     skin       -1       0       0        0  0.5
2  3  3   9.1    3.7  well2     skin       -1       0       0        0  1.0

   rskin  kskin  zpump
0    2.0    5.0    6.2
1    2.0    5.0    6.2
2    2.0    5.0    4.1
```

convert the DataFrame to a recarray for compatibility with flopy

[5]:
```
node_data = node_data.to_records()
node_data
```

[5]:
```
rec.array([(0, 1, 1, 9.5, 7.1, 'well1', 'skin', -1, 0, 0, 0, 1. , 2., 5., 6.2),
           (1, 1, 1, 7.1, 5.1, 'well1', 'skin', -1, 0, 0, 0, 0.5, 2., 5., 6.2),
           (2, 3, 3, 9.1, 3.7, 'well2', 'skin', -1, 0, 0, 0, 1. , 2., 5., 4.1)],
          dtype=[('index', '<i8'), ('i', '<i8'), ('j', '<i8'), ('ztop', '<f8'), ('zbotm',
↪ '<f8'), ('wellid', 'O'), ('losstype', 'O'), ('pumploc', '<i8'), ('qlimit', '<i8'), (
↪'ppflag', '<i8'), ('pumpcap', '<i8'), ('rw', '<f8'), ('rskin', '<f8'), ('kskin', '<f8
↪'), ('zpump', '<f8')])
```

Stress period information

(could also be developed externally)

[6]:
```
stress_period_data = pd.DataFrame(
    [
        [0, "well1", 0],
        [1, "well1", 100.0],
        [0, "well2", 0],
        [1, "well2", 1000.0],
    ],
    columns=["per", "wellid", "qdes"],
)
stress_period_data
```

[6]:

	per	wellid	qdes
0	0	well1	0.0
1	1	well1	100.0
2	0	well2	0.0
3	1	well2	1000.0

[7]:
```
pers = stress_period_data.groupby("per")
stress_period_data = {i: pers.get_group(i).to_records() for i in [0, 1]}
stress_period_data
```

[7]:
```
{0: rec.array([(0, 0, 'well1', 0.), (2, 0, 'well2', 0.)],
           dtype=[('index', '<i8'), ('per', '<i8'), ('wellid', 'O'), ('qdes', '<f8')]),
 1: rec.array([(1, 1, 'well1',  100.), (3, 1, 'well2', 1000.)],
           dtype=[('index', '<i8'), ('per', '<i8'), ('wellid', 'O'), ('qdes', '<f8')])}
```

Make `ModflowMnw2` package object

- note that extraneous columns in node_data and stress_period_data are ignored
- if itmp is positive, it must equal the number of active wells being specified in `stress_period_data`, otherwise the package class will raise an error.

[8]:
```
mnw2 = flopy.modflow.ModflowMnw2(
    model=m,
    mnwmax=2,
    node_data=node_data,
    stress_period_data=stress_period_data,
    itmp=[2, 2, -1],  # reuse second per pumping for last stress period
)
```

[9]:
```
# "nodtot" is computed automatically
mnw2.nodtot
```

[9]:
```
3
```

[10]:
```
pd.DataFrame(mnw2.node_data)
```

[10]:
```
   k  i  j  ztop  zbotm wellid losstype  pumploc  qlimit  ppflag  ...  hlim  \
0  0  1  1   9.5    7.1  well1     skin       -1       0       0  ...   0.0
1  0  1  1   7.1    5.1  well1     skin       -1       0       0  ...   0.0
2  0  3  3   9.1    3.7  well2     skin       -1       0       0  ...   0.0

   qcut  qfrcmn  qfrcmx  hlift  liftq0  liftqmax  hwtol  liftn   qn
0     0     0.0     0.0    0.0     0.0       0.0    0.0    0.0  0.0
1     0     0.0     0.0    0.0     0.0       0.0    0.0    0.0  0.0
2     0     0.0     0.0    0.0     0.0       0.0    0.0    0.0  0.0

[3 rows x 33 columns]
```

[11]:
```
pd.DataFrame(mnw2.stress_period_data[0])
```

[11]:
```
   k  i  j wellid  qdes  capmult  cprime  hlim  qcut  qfrcmn  qfrcmx
0  0  1  1  well1   0.0        0     0.0   0.0     0     0.0     0.0
1  0  3  3  well2   0.0        0     0.0   0.0     0     0.0     0.0
```

[12]:
```
pd.DataFrame(mnw2.stress_period_data[1])
```

[12]:
```
   k  i  j wellid    qdes  capmult  cprime  hlim  qcut  qfrcmn  qfrcmx
0  0  1  1  well1   100.0        0     0.0   0.0     0     0.0     0.0
1  0  3  3  well2  1000.0        0     0.0   0.0     0     0.0     0.0
```

[13]:
```
tmp = flopy.modflow.ModflowMnw2(
    model=m,
    itmp=[1, 1, -1],  # reuse second per pumping for last stress period
)
```

```
/opt/hostedtoolcache/Python/3.8.18/x64/lib/python3.8/site-packages/flopy/mbase.py:658:
↪UserWarning: Unit 34 of package MNW2 already in use.
  warn(
/opt/hostedtoolcache/Python/3.8.18/x64/lib/python3.8/site-packages/flopy/mbase.py:667:
```

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```
↪UserWarning: Two packages of the same type, Replacing existing 'MNW2' package.
  warn(
```

empty `node_data` and `stress_period_data` tables can also be generated by the package class, and then filled

[14]:
```
node_data = tmp.get_empty_node_data(3)
node_data
```

[14]:
```
rec.array([(0, 0, 0, 0., 0., 0, 0, 0, 0, 0, 0, 0., 0., 0., 0., 0., 0., 0., 0., 0, 0, 0,␣
↪0., 0., 0, 0., 0., 0., 0., 0., 0., 0., 0.),
           (0, 0, 0, 0., 0., 0, 0, 0, 0, 0, 0, 0., 0., 0., 0., 0., 0., 0., 0., 0, 0, 0,␣
↪0., 0., 0, 0., 0., 0., 0., 0., 0., 0., 0.),
           (0, 0, 0, 0., 0., 0, 0, 0, 0, 0, 0, 0., 0., 0., 0., 0., 0., 0., 0., 0, 0, 0,␣
↪0., 0., 0, 0., 0., 0., 0., 0., 0., 0., 0.)],
          dtype=[('k', '<i8'), ('i', '<i8'), ('j', '<i8'), ('ztop', '<f4'), ('zbotm', '
↪<f4'), ('wellid', 'O'), ('losstype', 'O'), ('pumploc', '<i8'), ('qlimit', '<i8'), (
↪'ppflag', '<i8'), ('pumpcap', '<i8'), ('rw', '<f4'), ('rskin', '<f4'), ('kskin', '<f4
↪'), ('B', '<f4'), ('C', '<f4'), ('P', '<f4'), ('cwc', '<f4'), ('pp', '<f4'), ('pumplay
↪', '<i8'), ('pumprow', '<i8'), ('pumpcol', '<i8'), ('zpump', '<f4'), ('hlim', '<f4'), (
↪'qcut', '<i8'), ('qfrcmn', '<f4'), ('qfrcmx', '<f4'), ('hlift', '<f4'), ('liftq0', '<f4
↪'), ('liftqmax', '<f4'), ('hwtol', '<f4'), ('liftn', '<f4'), ('qn', '<f4')])
```

Mnw objects

at the base of the flopy mnw2 module is the **Mnw** object class, which describes a single multi-node well. A list or dict of **Mnw** objects can be used to build a package (using the example above):

```
flopy.modflow.ModflowMnw2(model=m, mnwmax=2,
                 mnw=<dict or list of Mnw objects>,
                 itmp=[1, 1, -1], # reuse second per pumping for last stress period
                 )
```

or if node_data and stress_period_data are supplied, the **Mnw** objects are created on initialization of the ModflowMnw2 class instance, and assigned to the `.mnw` attribute, as items in a dictionary keyed by `wellid`.

[15]:
```
mnw2.mnw
```

[15]:
```
{'well1': <flopy.modflow.mfmnw2.Mnw at 0x7fe87f7295e0>,
 'well2': <flopy.modflow.mfmnw2.Mnw at 0x7fe87f729460>}
```

[16]:
```
mnw2.mnw["well1"].rw
```

[16]:
```
[1.0, 0.5]
```

Note that Mnw object attributes for variables that vary by node are lists (e.g. `rw` above)

Each Mnw object has its own `node_data` and `stress_period_data`

[17]:
```
pd.DataFrame(mnw2.mnw["well1"].node_data)
```

[17]:
```
   k  i  j  ztop  zbotm wellid losstype  pumploc  qlimit  ppflag  ...  hlim  \
0  0  1  1   9.5    7.1  well1     skin       -1       0       0  ...   0.0
1  0  1  1   7.1    5.1  well1     skin       -1       0       0  ...   0.0

   qcut  qfrcmn  qfrcmx  hlift  liftq0  liftqmax  hwtol  liftn   qn
0     0     0.0     0.0    0.0     0.0       0.0    0.0    0.0  0.0
1     0     0.0     0.0    0.0     0.0       0.0    0.0    0.0  0.0

[2 rows x 33 columns]
```

Instead of a dict keyed by stress period, Mnw.stress_period_data is a recarray with pumping data listed by stress period for that well

- note that data for period 2, where `itmp` < 1, is shown (was copied from s.p. 1 during construction of the **Mnw** object)

[18]:
```
pd.DataFrame(mnw2.mnw["well2"].stress_period_data)
```

[18]:
```
   k  i  j  per    qdes  capmult  cprime  hlim  qcut  qfrcmn  qfrcmx
0  0  3  3    0     0.0        0     0.0   0.0     0     0.0     0.0
1  0  3  3    1  1000.0        0     0.0   0.0     0     0.0     0.0
2  0  3  3    1  1000.0        0     0.0   0.0     0     0.0     0.0
```

Build the same package using only the `Mnw` objects

[19]:
```
mnw2fromobj = flopy.modflow.ModflowMnw2(
    model=m,
    mnwmax=2,
    mnw=mnw2.mnw,
    itmp=[2, 2, -1],  # reuse second per pumping for last stress period
)
```

```
/opt/hostedtoolcache/Python/3.8.18/x64/lib/python3.8/site-packages/flopy/mbase.py:658:␣
↪UserWarning: Unit 34 of package MNW2 already in use.
  warn(
/opt/hostedtoolcache/Python/3.8.18/x64/lib/python3.8/site-packages/flopy/mbase.py:667:␣
↪UserWarning: Two packages of the same type, Replacing existing 'MNW2' package.
  warn(
```

[20]:
```
pd.DataFrame(mnw2fromobj.node_data)
```

[20]:
```
   k  i  j  ztop  zbotm wellid losstype  pumploc  qlimit  ppflag  ...  hlim  \
0  0  1  1   9.5    7.1  well1     skin       -1       0       0  ...   0.0
1  0  1  1   7.1    5.1  well1     skin       -1       0       0  ...   0.0
2  0  3  3   9.1    3.7  well2     skin       -1       0       0  ...   0.0

   qcut  qfrcmn  qfrcmx  hlift  liftq0  liftqmax  hwtol  liftn   qn
```

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```
0      0      0.0     0.0     0.0     0.0       0.0     0.0     0.0   0.0
1      0      0.0     0.0     0.0     0.0       0.0     0.0     0.0   0.0
2      0      0.0     0.0     0.0     0.0       0.0     0.0     0.0   0.0

[3 rows x 33 columns]
```

[21]:
```python
pd.DataFrame(mnw2fromobj.stress_period_data[0])
```

[21]:
```
   k  i  j wellid  qdes  capmult  cprime  hlim  qcut  qfrcmn  qfrcmx
0  0  1  1  well1   0.0        0     0.0   0.0     0     0.0     0.0
1  0  3  3  well2   0.0        0     0.0   0.0     0     0.0     0.0
```

[22]:
```python
pd.DataFrame(mnw2fromobj.stress_period_data[1])
```

[22]:
```
   k  i  j wellid    qdes  capmult  cprime  hlim  qcut  qfrcmn  qfrcmx
0  0  1  1  well1   100.0        0     0.0   0.0     0     0.0     0.0
1  0  3  3  well2  1000.0        0     0.0   0.0     0     0.0     0.0
```

By default, the `node_data` and `stress_period_data` tables attached to the `ModflowMnw2` package class are definitive

- on writing of the package output (`mnw2.write_file()`), the **Mnw** objects are regenerated from the tables. This setting is controlled by the default argument `use_tables=True`. To write the package file using the **Mnw** objects (ignoring the tables), use `mnw2.write_file(use_tables=False)`.

[23]:
```python
per1 = flopy.modflow.ModflowMnw2.get_empty_stress_period_data(itmp=2)
per1
```

[23]:
```
rec.array([(0, 0, 0, 0, 0., 0, 0., 0., 0, 0., 0.),
           (0, 0, 0, 0, 0., 0, 0., 0., 0, 0., 0.)],
          dtype=[('k', '<i8'), ('i', '<i8'), ('j', '<i8'), ('wellid', 'O'), ('qdes', '<f4
↪'), ('capmult', '<i8'), ('cprime', '<f4'), ('hlim', '<f4'), ('qcut', '<i8'), ('qfrcmn',
↪ '<f4'), ('qfrcmx', '<f4')])
```

Write an MNW2 package file and inspect the results

[24]:
```python
mnw2.write_file(os.path.join(model_ws, "test.mnw2"))
```

[25]:
```python
junk = [
    print(l.strip("\n"))
    for l in open(os.path.join(model_ws, "test.mnw2")).readlines()
]
```

```
# MNW2 package for MODFLOW-2005 generated by Flopy 3.5.0
2 0 0
well1 -2
            skin -1 0 0 0
              -1.0000000E+00     2.0000000E+00     5.0000000E+00
               9.5000000E+00     7.0999999E+00 2 2     1.0000000E+00
               7.0999999E+00     5.0999999E+00 2 2     5.0000000E-01
```

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```
               6.1999998E+00
well2 -1
            skin -1 0 0 0
               1.0000000E+00    2.0000000E+00    5.0000000E+00
               9.1000004E+00    3.7000000E+00 4 4
               4.0999999E+00
2  Stress Period 1
well1    0.0000000E+00
well2    0.0000000E+00
2  Stress Period 2
well1    1.0000000E+02
well2    1.0000000E+03
-1  Stress Period 3
```

Load some example MNW2 packages

[26]:
```
path = os.path.join("..", "..", "examples", "data", "mnw2_examples")
m = flopy.modflow.Modflow("MNW2-Fig28", model_ws=model_ws)
dis = flopy.modflow.ModflowDis.load(os.path.join(path, "MNW2-Fig28.dis"), m)
```

[27]:
```
m.get_package_list()
```

[27]:
```
['DIS']
```

[28]:
```
mnw2pth = os.path.join(path, "MNW2-Fig28.mnw2")
mnw2 = flopy.modflow.ModflowMnw2.load(mnw2pth, m)
```

[29]:
```
pd.DataFrame(mnw2.node_data)
```

[29]:
```
   k   i   j  ztop  zbotm  wellid losstype  pumploc  qlimit  ppflag  ... \
0  0  29  40  -5.0  -65.0  well-a     skin        0       1       0  ...

   hlim  qcut  qfrcmn  qfrcmx  hlift  liftq0  liftqmax  hwtol  liftn   qn
0  -7.5    -1     0.1    0.15    0.0     0.0       0.0    0.0    0.0  0.0

[1 rows x 33 columns]
```

[30]:
```
pd.DataFrame(mnw2.stress_period_data[0])
```

[30]:
```
   k   i   j  wellid  qdes  capmult  cprime  hlim  qcut  qfrcmn  qfrcmx
0  0  29  40  well-a   0.0        0     0.0   0.0     0     0.0     0.0
```

[31]:
```
mnw2.mnw
```

[31]:
```
{'well-a': <flopy.modflow.mfmnw2.Mnw at 0x7fe84dea8af0>}
```

[32]:
```
pd.DataFrame(mnw2.mnw["well-a"].stress_period_data)
```

[32]:
```
   k   i   j  per     qdes  capmult  cprime  hlim  qcut  qfrcmn  qfrcmx
0  0  29  40    0      0.0        0     0.0   0.0     0     0.0     0.0
1  0  29  40    1 -10000.0        0     0.0   0.0     0     0.0     0.0
2  0  29  40    2 -10000.0        0     0.0   0.0     0     0.0     0.0
```

[33]:
```
path = os.path.join("..", "..", "examples", "data", "mnw2_examples")
m = flopy.modflow.Modflow("br", model_ws=model_ws)
mnw2 = flopy.modflow.ModflowMnw2.load(
    os.path.join(path, "BadRiver_cal.mnw2"), m
)
```

[34]:
```
df = pd.DataFrame(mnw2.node_data)
df.loc[:, df.sum(axis=0) != 0]
```

[34]:
```
      i    j         ztop        zbotm            wellid losstype  pumploc  \
0   294  503   181.630005   161.630005         br_birch1     skin       -1
1   295  503   179.119995   159.119995         br_birch2     skin       -1
2   175  342   400.220001   312.220001   br_diaperville1     skin       -1
3   174  342   399.119995   312.119995   br_diaperville2     skin       -1
4   248  454   565.200012   555.200012        br_franks1     skin       -1
5   249  453   564.419983   554.419983        br_franks2     skin       -1
6   180  396   453.959991   447.959991        br_odanah1     skin       -1
7   181  395   450.559998   444.559998        br_odanah2     skin       -1
8   181  395   380.489990   371.489990        br_odanah3     skin       -1
9   180  396   450.739990   444.739990        br_odanah4     skin       -1
10  170  350   475.410004   472.410004      br_oldschool     skin       -1
11  172  312   377.410004   348.410004        br_recycle     skin       -1
12  216  412   562.200012   542.200012         br_unspec     skin       -1
13  516  424  1079.910034  1072.910034         cfsp_ncp1     skin       -1
14  515  424  1077.900024  1074.900024         cfsp_ncp2     skin       -1
15  539  415  1093.010010  1003.010010           cfsp_of     skin       -1
16  360    2   706.330017   699.330017    hayward_bait_n     skin       -1
17  360    6   705.289978   698.289978   hayward_bait_ne     skin       -1
18  362    4   696.979980   689.979980   hayward_bait_of     skin       -1
19  456  699  1352.050049  1342.050049         ironbelt2     skin       -1
20  456  699  1350.439941  1343.439941         ironbelt3     skin       -1
21  599  414  1198.839966  1188.839966           mellen2     skin       -1
22  576  408  1151.599976  1131.599976           mellen3     skin       -1
23  253  149   622.179993   602.179993         milestone     skin       -1
24  208  148   520.119995   500.119995               nsp     skin       -1
25   80  162   535.299988    30.299999         washburn1     skin       -1
26   91  143   541.280029   -67.720001         washburn2     skin       -1

     rw  rskin  kskin        zpump
0   1.0    2.0   10.0   162.630005
1   1.0    2.0   10.0   160.119995
2   1.0    2.0   10.0   313.220001
3   1.0    2.0   10.0   313.119995
4   1.0    2.0   10.0   556.200012
5   1.0    2.0   10.0   555.419983
6   1.0    2.0   10.0   448.959991
7   1.0    2.0   10.0   445.559998
8   1.0    2.0   10.0   372.489990
9   1.0    2.0   10.0   445.739990
10  1.0    2.0   10.0   473.410004
11  1.0    2.0   10.0   349.410004
12  1.0    2.0   10.0   543.200012
13  1.0    2.0   10.0  1073.910034
```

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```
14  1.0    2.0   10.0  1075.900024
15  1.0    2.0   10.0  1004.010010
16  1.0    2.0   10.0   700.330017
17  1.0    2.0   10.0   699.289978
18  1.0    2.0   10.0   690.979980
19  1.0    2.0   10.0  1343.050049
20  1.0    2.0   10.0  1344.439941
21  1.0    2.0   10.0  1189.839966
22  1.0    2.0   10.0  1132.599976
23  1.0    2.0   10.0   603.179993
24  1.0    2.0   10.0   501.119995
25  1.0    2.0   10.0    31.299999
26  1.0    2.0   10.0   -66.720001
```

[35]:
```
try:
    # ignore PermissionError on Windows
    temp_dir.cleanup()
except:
    pass
```

5.2.12 Accessing MODFLOW 6 Output

This tutorial shows how to access output from MODFLOW 6 models and packages by using the built in `.output` attribute on any MODFLOW 6 model or package object

[1]:
```
import os
from pathlib import Path
from tempfile import TemporaryDirectory
```

[2]:
```
import numpy as np
```

[3]:
```
# ## Package import
import flopy
```

Load a simple demonstration model

[4]:
```
exe_name = "mf6"
project_root_path = Path.cwd().parent.parent
ws = os.path.abspath(os.path.dirname(""))
sim_ws = str(
    project_root_path / "examples" / "data" / "mf6" / "test001e_UZF_3lay"
)
```

[5]:
```
# load the model
sim = flopy.mf6.MFSimulation.load(
    sim_ws=sim_ws,
    exe_name=exe_name,
    verbosity_level=0,
```

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```
)
# change the simulation path, rewrite the files, and run the model
temp_dir = TemporaryDirectory()
sim_ws = temp_dir.name
sim.set_sim_path(sim_ws)
sim.write_simulation(silent=True)
sim.run_simulation(silent=True)
```

[5]:
```
(True, [])
```

Get output using the `.output` attribute

The output attribute dynamically generates methods for each package based on the available output options within that package. A list of all available outputs are:

head()	Method to get the `HeadFile` object for the model. Accessed from the model object or the OC package object
budget()	Method to get the `CellBudgetFile` object for the model. Accessed from the model object or the OC package object
budgetcsv()	Method to get the MODFLOW-6 budget csv as a `CsvFile` object. Valid for model, oc, and advanced packages such as MAW, UZF, LAK
zonebudget()	Method to get the `ZoneBudget6` object for the model. Accessed from the model object or the OC package object
obs()	Method to get observation file data in the form of a `MF6Obs` object. Accessed from any package that allows observations.
csv()	Method to get csv output data in the form of a `CsvFile` object. Example files are inner and outer iteration files from IMS
package_convergence	Method to get csv based package convergence information from packages such as SFR, LAK, UZF, and MAW. Returns a `CsvFile` object
stage()	Method to get binary stage file output from the SFR and LAK packages
concentration()	Method to get the binary concentration file output from a groundwater transport model. Accessed from the model object or the OC package object
cim()	Method to get immobile concentration output from the CIM package
density()	Method to get density file output from the BUY package

Get head file and cell budget file outputs

The head file output and cell budget file output can be loaded from either the model object or the OC package object.

[6]:
```
ml = sim.get_model("gwf_1")
```

[7]:
```
bud = ml.output.budget()
bud.get_data(idx=0, full3D=True)
```

[7]:
```
[array([[[ 0.,  0.,  0.,  0., -0.,  0.,  0.,  0., -0.,  0.,  0.,  0.,
          -0.,  0.,  0.,  0., -0.,  0.,  0.,  0., -0.,  0.,  0.,  0.,
          -0.,  0.,  0.,  0., -0.,  0.,  0.,  0., -0.,  0.,  0.,  0.,
          -0.,  0.,  0., -0.,  0.,  0.,  0., -0., -0.,  0.,  0.,  0.,
          -0., -0.,  0.,  0.,  0., -0., -0.,  0.,  0.,  0., -0., -0.,
           0.,  0.,  0., -0., -0.,  0.,  0.,  0., -0., -0.,  0.,  0.,
```

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```
            0., -0., -0.,  0.,  0.,  0., -0., -0.,  0.,  0.,  0., -0.,
           -0.,  0.,  0., -0.,  0.,  0., -0., -0.,  0.,  0., -0., -0.,
            0.,  0., -0., -0.,  0.,  0., -0., -0.,  0.,  0., -0., -0.,
            0.,  0., -0., -0.,  0.,  0., -0., -0.,  0.,  0., -0., -0.,
            0.,  0., -0., -0.]]])]
```

```
[8]: budcsv = ml.output.budgetcsv()
     budcsv.data
```

```
[8]: rec.array([(2.00e+00, 0.00000000e+00,  0.        , 0.,  0.        , 0., 0., 0.        ,␣
     ↪  0.        , 0.        , 0., 0., 0.,  0.        ,  0.        ,  0.00000000e+00),
            (4.00e+00, 0.00000000e+00,  0.        , 0.,  0.        , 0., 0., 0.        ,␣
     ↪  0.        , 0.        , 0., 0., 0.,  0.        ,  0.        ,  0.00000000e+00),
            (6.00e+00, 0.00000000e+00,  0.        , 0.,  0.        , 0., 0., 0.        ,␣
     ↪  0.        , 0.        , 0., 0., 0.,  0.        ,  0.        ,  0.00000000e+00),
            (8.00e+00, 0.00000000e+00,  0.        , 0.,  0.        , 0., 0., 0.        ,␣
     ↪  0.        , 0.        , 0., 0., 0.,  0.        ,  0.        ,  0.00000000e+00),
            (1.00e+01, 0.00000000e+00,  0.        , 0.,  0.        , 0., 0., 0.        ,␣
     ↪  0.        , 0.        , 0., 0., 0.,  0.        ,  0.        ,  0.00000000e+00),
            (1.20e+01, 0.00000000e+00,  0.        , 0.,  0.        , 0., 0., 0.        ,␣
     ↪  0.        , 0.        , 0., 0., 0.,  0.        ,  0.        ,  0.00000000e+00),
            (1.40e+01, 0.00000000e+00,  0.        , 0.,  0.        , 0., 0., 0.        ,␣
     ↪  0.        , 0.        , 0., 0., 0.,  0.        ,  0.        ,  0.00000000e+00),
            (1.60e+01, 0.00000000e+00,  0.        , 0.,  0.        , 0., 0., 0.        ,␣
     ↪  0.        , 0.        , 0., 0., 0.,  0.        ,  0.        ,  0.00000000e+00),
            (1.80e+01, 0.00000000e+00,  0.        , 0.,  0.        , 0., 0., 0.        ,␣
     ↪  0.        , 0.        , 0., 0., 0.,  0.        ,  0.        ,  0.00000000e+00),
            (2.00e+01, 0.00000000e+00,  0.        , 0.,  0.        , 0., 0., 0.        ,␣
     ↪  0.        , 0.        , 0., 0., 0.,  0.        ,  0.        ,  0.00000000e+00),
            (2.20e+01, 0.00000000e+00,  0.        , 0.,  0.        , 0., 0., 0.        ,␣
     ↪  0.        , 0.        , 0., 0., 0.,  0.        ,  0.        ,  0.00000000e+00),
            (2.40e+01, 0.00000000e+00,  0.        , 0.,  0.        , 0., 0., 0.        ,␣
     ↪  0.        , 0.        , 0., 0., 0.,  0.        ,  0.        ,  0.00000000e+00),
            (2.60e+01, 0.00000000e+00,  0.        , 0.,  0.        , 0., 0., 0.        ,␣
     ↪  0.        , 0.        , 0., 0., 0.,  0.        ,  0.        ,  0.00000000e+00),
            (2.80e+01, 0.00000000e+00,  0.        , 0.,  0.        , 0., 0., 0.        ,␣
     ↪  0.        , 0.        , 0., 0., 0.,  0.        ,  0.        ,  0.00000000e+00),
            (3.00e+01, 0.00000000e+00,  0.        , 0.,  0.        , 0., 0., 0.        ,␣
     ↪  0.        , 0.        , 0., 0., 0.,  0.        ,  0.        ,  0.00000000e+00),
            (3.20e+01, 0.00000000e+00,  0.        , 0.,  0.        , 0., 0., 0.        ,␣
     ↪  0.        , 0.        , 0., 0., 0.,  0.        ,  0.        ,  0.00000000e+00),
            (3.40e+01, 0.00000000e+00,  0.        , 0.,  0.        , 0., 0., 0.        ,␣
     ↪  0.        , 0.        , 0., 0., 0.,  0.        ,  0.        ,  0.00000000e+00),
            (3.60e+01, 0.00000000e+00,  0.        , 0.,  0.        , 0., 0., 0.        ,␣
     ↪  0.        , 0.        , 0., 0., 0.,  0.        ,  0.        ,  0.00000000e+00),
            (3.80e+01, 0.00000000e+00,  0.        , 0.,  0.        , 0., 0., 0.        ,␣
     ↪  0.        , 0.        , 0., 0., 0.,  0.        ,  0.        ,  0.00000000e+00),
            (4.00e+01, 0.00000000e+00,  0.        , 0.,  0.        , 0., 0., 0.        ,␣
     ↪  0.        , 0.        , 0., 0., 0.,  0.        ,  0.        ,  0.00000000e+00),
            (4.20e+01, 0.00000000e+00,  0.        , 0.,  0.        , 0., 0., 0.        ,␣
     ↪  0.        , 0.        , 0., 0., 0.,  0.        ,  0.        ,  0.00000000e+00),
            (4.40e+01, 0.00000000e+00,  0.        , 0.,  0.        , 0., 0., 0.        ,␣
```

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```
↪   0.        ,  0.          , 0., 0., 0.,   0.         ,   0.          ,  0.00000000e+00),
           (4.60e+01, 0.00000000e+00,  0.         , 0.,   0.          , 0., 0., 0.          ,␣
↪   0.        ,  0.          , 0., 0., 0.,   0.         ,   0.          ,  0.00000000e+00),
           (4.80e+01, 0.00000000e+00,  0.         , 0.,   0.          , 0., 0., 0.          ,␣
↪   0.        ,  0.          , 0., 0., 0.,   0.         ,   0.          ,  0.00000000e+00),
           (5.00e+01, 0.00000000e+00,  0.         , 0.,   0.          , 0., 0., 0.          ,␣
↪   0.        ,  0.          , 0., 0., 0.,   0.         ,   0.          ,  0.00000000e+00),
           (5.20e+01, 0.00000000e+00,  0.         , 0.,   0.          , 0., 0., 0.          ,␣
↪   0.        ,  0.          , 0., 0., 0.,   0.         ,   0.          ,  0.00000000e+00),
           (5.40e+01, 0.00000000e+00,  0.         , 0.,   0.          , 0., 0., 0.          ,␣
↪   0.        ,  0.          , 0., 0., 0.,   0.         ,   0.          ,  0.00000000e+00),
           (5.60e+01, 0.00000000e+00,  0.         , 0.,   0.          , 0., 0., 0.          ,␣
↪   0.        ,  0.          , 0., 0., 0.,   0.         ,   0.          ,  0.00000000e+00),
           (5.80e+01, 0.00000000e+00,  0.         , 0.,   0.          , 0., 0., 0.          ,␣
↪   0.        ,  0.          , 0., 0., 0.,   0.         ,   0.          ,  0.00000000e+00),
           (6.00e+01, 0.00000000e+00,  0.         , 0.,   0.          , 0., 0., 0.          ,␣
↪   0.        ,  0.          , 0., 0., 0.,   0.         ,   0.          ,  0.00000000e+00),
           (1.10e+02, 0.00000000e+00,  0.         , 0.,   0.          , 0., 0., 0.          ,␣
↪   0.        ,  0.          , 0., 0., 0.,   0.         ,   0.          ,  0.00000000e+00),
           (1.60e+02, 0.00000000e+00,  0.         , 0.,   0.          , 0., 0., 0.          ,␣
↪   0.        ,  0.          , 0., 0., 0.,   0.         ,   0.          ,  0.00000000e+00),
           (2.10e+02, 0.00000000e+00,  0.         , 0.,   0.          , 0., 0., 0.          ,␣
↪   0.        ,  0.          , 0., 0., 0.,   0.         ,   0.          ,  0.00000000e+00),
           (2.60e+02, 0.00000000e+00,  0.         , 0.,   0.          , 0., 0., 0.          ,␣
↪   0.        ,  0.          , 0., 0., 0.,   0.         ,   0.          ,  0.00000000e+00),
           (3.10e+02, 0.00000000e+00,  0.         , 0.,   0.          , 0., 0., 0.          ,␣
↪   0.        ,  0.          , 0., 0., 0.,   0.         ,   0.          ,  0.00000000e+00),
           (3.60e+02, 0.00000000e+00,  0.         , 0.,   0.          , 0., 0., 0.          ,␣
↪   0.        ,  0.          , 0., 0., 0.,   0.         ,   0.          ,  0.00000000e+00),
           (4.10e+02, 0.00000000e+00,  0.         , 0.,   0.          , 0., 0., 0.          ,␣
↪   0.        ,  0.          , 0., 0., 0.,   0.         ,   0.          ,  0.00000000e+00),
           (4.60e+02, 0.00000000e+00,  0.         , 0.,   0.          , 0., 0., 0.          ,␣
↪   0.        ,  0.          , 0., 0., 0.,   0.         ,   0.          ,  0.00000000e+00),
           (5.10e+02, 0.00000000e+00,  0.         , 0.,   0.          , 0., 0., 0.          ,␣
↪   0.        ,  0.          , 0., 0., 0.,   0.         ,   0.          ,  0.00000000e+00),
           (5.60e+02, 0.00000000e+00,  0.         , 0.,   0.          , 0., 0., 0.          ,␣
↪   0.        ,  0.          , 0., 0., 0.,   0.         ,   0.          ,  0.00000000e+00),
           (6.00e+02, 0.00000000e+00,  0.         , 0.,   0.          , 0., 0., 0.          ,␣
↪   0.        ,  0.          , 0., 0., 0.,   0.         ,   0.          ,  0.00000000e+00),
           (6.40e+02, 0.00000000e+00,  0.         , 0.,   0.          , 0., 0., 0.          ,␣
↪   0.        ,  0.          , 0., 0., 0.,   0.         ,   0.          ,  0.00000000e+00),
           (6.80e+02, 0.00000000e+00,  0.         , 0.,   0.          , 0., 0., 0.          ,␣
↪   0.        ,  0.          , 0., 0., 0.,   0.         ,   0.          ,  0.00000000e+00),
           (7.20e+02, 0.00000000e+00,  0.         , 0.,   0.          , 0., 0., 0.          ,␣
↪   0.        ,  0.          , 0., 0., 0.,   0.         ,   0.          ,  0.00000000e+00),
           (7.60e+02, 0.00000000e+00,  0.         , 0.,   0.          , 0., 0., 0.          ,␣
↪   0.        ,  0.          , 0., 0., 0.,   0.         ,   0.          ,  0.00000000e+00),
           (8.00e+02, 0.00000000e+00,  0.         , 0.,   0.          , 0., 0., 0.          ,␣
↪   0.        ,  0.          , 0., 0., 0.,   0.         ,   0.          ,  0.00000000e+00),
           (8.40e+02, 0.00000000e+00,  0.         , 0.,   0.          , 0., 0., 0.          ,␣
↪   0.        ,  0.          , 0., 0., 0.,   0.         ,   0.          ,  0.00000000e+00),
           (8.80e+02, 0.00000000e+00,  0.         , 0.,   0.          , 0., 0., 0.          ,␣
```

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```
→ 0.          , 0.          , 0., 0., 0.,    0.          ,  0.          ,  0.00000000e+00),
           (9.20e+02, 0.00000000e+00,  0.          , 0.,  0.          , 0., 0., 0.          ,␣
→ 0.          , 0.          , 0., 0., 0.,    0.          ,  0.          ,  0.00000000e+00),
           (9.60e+02, 0.00000000e+00,  0.          , 0.,  0.          , 0., 0., 0.          ,␣
→ 0.          , 0.          , 0., 0., 0.,    0.          ,  0.          ,  0.00000000e+00),
           (1.00e+03, 0.00000000e+00,  0.          , 0.,  0.          , 0., 0., 0.          ,␣
→ 0.          , 0.          , 0., 0., 0.,    0.          ,  0.          ,  0.00000000e+00),
           (1.04e+03, 0.00000000e+00,  0.          , 0.,  0.          , 0., 0., 0.          ,␣
→ 0.          , 0.          , 0., 0., 0.,    0.          ,  0.          ,  0.00000000e+00),
           (1.08e+03, 0.00000000e+00,  0.          , 0.,  0.          , 0., 0., 0.          ,␣
→ 0.          , 0.          , 0., 0., 0.,    0.          ,  0.          ,  0.00000000e+00),
           (1.12e+03, 0.00000000e+00,  0.          , 0.,  0.          , 0., 0., 0.          ,␣
→ 0.          , 0.          , 0., 0., 0.,    0.          ,  0.          ,  0.00000000e+00),
           (1.16e+03, 0.00000000e+00,  0.          , 0.,  0.          , 0., 0., 0.          ,␣
→ 0.          , 0.          , 0., 0., 0.,    0.          ,  0.          ,  0.00000000e+00),
           (1.20e+03, 0.00000000e+00,  0.          , 0.,  0.          , 0., 0., 0.          ,␣
→ 0.          , 0.          , 0., 0., 0.,    0.          ,  0.          ,  0.00000000e+00),
           (1.24e+03, 0.00000000e+00,  0.          , 0.,  0.          , 0., 0., 0.          ,␣
→ 0.          , 0.          , 0., 0., 0.,    0.          ,  0.          ,  0.00000000e+00),
           (1.28e+03, 0.00000000e+00,  0.          , 0.,  0.          , 0., 0., 0.          ,␣
→ 0.          , 0.          , 0., 0., 0.,    0.          ,  0.          ,  0.00000000e+00),
           (1.32e+03, 0.00000000e+00,  0.          , 0.,  0.          , 0., 0., 0.          ,␣
→ 0.          , 0.          , 0., 0., 0.,    0.          ,  0.          ,  0.00000000e+00),
           (1.36e+03, 0.00000000e+00,  0.          , 0.,  0.          , 0., 0., 0.          ,␣
→ 0.          , 0.          , 0., 0., 0.,    0.          ,  0.          ,  0.00000000e+00),
           (1.40e+03, 0.00000000e+00,  0.          , 0.,  0.          , 0., 0., 0.          ,␣
→ 0.          , 0.          , 0., 0., 0.,    0.          ,  0.          ,  0.00000000e+00),
           (1.44e+03, 0.00000000e+00,  0.          , 0.,  0.          , 0., 0., 0.          ,␣
→ 0.          , 0.          , 0., 0., 0.,    0.          ,  0.          ,  0.00000000e+00),
           (1.48e+03, 0.00000000e+00,  0.          , 0.,  0.          , 0., 0., 0.          ,␣
→ 0.          , 0.          , 0., 0., 0.,    0.          ,  0.          ,  0.00000000e+00),
           (1.52e+03, 0.00000000e+00,  0.          , 0., 128.0217841 , 0., 0., 0.02722978,␣
→108.61508013, 19.37931792, 0., 0., 0., 128.0217841 , 128.02162783,  1.22061576e-04),
           (1.56e+03, 0.00000000e+00,  0.          , 0., 138.99381474, 0., 0., 0.02616677,␣
→103.79225125, 35.17524461, 0., 0., 0., 138.99381474, 138.99366263,  1.09439391e-04),
           (1.60e+03, 0.00000000e+00,  0.          , 0., 136.4972012 , 0., 0., 0.0225728 ,␣
→ 89.06987566, 47.4046209 , 0., 0., 0., 136.4972012 , 136.49706937,  9.65814295e-05),
           (1.64e+03, 0.00000000e+00,  0.          , 0., 134.35958704, 0., 0., 0.01957412,␣
→ 76.88688611, 57.45301299, 0., 0., 0., 134.35958704, 134.35947321,  8.47152128e-05),
           (1.68e+03, 0.00000000e+00,  0.          , 0., 131.24481479, 0., 0., 0.01672315,␣
→ 65.43186869, 65.79613475, 0., 0., 0., 131.24481479, 131.24472659,  6.72047136e-05),
           (1.72e+03, 0.00000000e+00,  0.          , 0., 123.13434058, 0., 0., 0.01312794,␣
→ 51.19484895, 71.92589496, 0., 0., 0., 123.13434058, 123.13387185,  3.80661214e-04),
           (1.76e+03, 0.00000000e+00,  0.          , 0., 114.00353442, 0., 0., 0.0097074 ,␣
→ 37.75854966, 76.23496189, 0., 0., 0., 114.00353442, 114.00321895,  2.76719717e-04),
           (1.80e+03, 0.00000000e+00,  0.          , 0., 110.11487407, 0., 0., 0.0078339 ,␣
→ 30.41322044, 79.693573  , 0., 0., 0., 110.11487407, 110.11462734,  2.24068325e-04),
           (1.84e+03, 0.00000000e+00,  0.          , 0., 105.40602911, 0., 0., 0.00594997,␣
→ 23.06535254, 82.33456504, 0., 0., 0., 105.40602911, 105.40586755,  1.53273477e-04),
           (1.88e+03, 0.00000000e+00,  0.          , 0.,  95.08914871, 0., 0., 0.00307764,␣
→ 11.90628617, 83.17970019, 0., 0., 0.,  95.08914871,  95.089064  ,  8.90844871e-05),
           (1.92e+03, 0.00000000e+00,  0.          , 0.,  94.69475504, 0., 0., 0.00271043,␣
```

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↪ 10.48542653, 84.20654512, 0., 0., 0.,  94.69475504,  94.69468209,  7.70440756e-05),
         (1.96e+03, 0.00000000e+00,  0.         , 0.,  89.77312957, 0., 0., 0.00134165,␣
↪  5.18451079, 84.58703172, 0., 0., 0.,  89.77312957,  89.77288416,  2.73360282e-04),
         (2.00e+03, 3.28550762e-05,  0.12927097, 0.,  85.77949492, 0., 0., 0.00037754,␣
↪  1.45488492, 84.45346195, 0., 0., 0.,  85.90879875,  85.90872441,  8.65285791e-05),
         (2.04e+03, 1.11673220e-03,  4.33428447, 0.,  79.06662935, 0., 0., 0.         ,␣
↪  0.         , 83.40218928, 0., 0., 0.,  83.40203055,  83.40218928, -1.90324298e-04),
         (2.08e+03, 9.50436281e-04,  3.6847171 , 0.,  79.01606345, 0., 0., 0.         ,␣
↪  0.         , 82.70187216, 0., 0., 0.,  82.70173099,  82.70187216, -1.70697486e-04),
         (2.12e+03, 8.09420799e-04,  3.13589527, 0.,  79.07017251, 0., 0., 0.         ,␣
↪  0.         , 82.20700075, 0., 0., 0.,  82.2068772 ,  82.20700075, -1.50282359e-04),
         (2.16e+03, 1.74634716e-03,  6.76514808, 0.,  74.44436606, 0., 0., 0.         ,␣
↪  0.         , 81.21149171, 0., 0., 0.,  81.21126049,  81.21149171, -2.84711568e-04),
         (2.20e+03, 2.91726961e-03, 11.31295605, 0.,  67.97128273, 0., 0., 0.         ,␣
↪  0.         , 79.28753204, 0., 0., 0.,  79.28715604,  79.28753204, -4.74219376e-04),
         (2.24e+03, 3.18846934e-03, 12.36643397, 0.,  65.05084871, 0., 0., 0.         ,␣
↪  0.         , 77.42085884, 0., 0., 0.,  77.42047115,  77.42085884, -5.00756338e-04),
         (2.28e+03, 3.08245610e-03, 11.96212155, 0.,  63.67724795, 0., 0., 0.         ,␣
↪  0.         , 75.64282768, 0., 0., 0.,  75.64245196,  75.64282768, -4.96712518e-04),
         (2.32e+03, 2.66394411e-03, 10.34112384, 0.,  63.8844137 , 0., 0., 0.         ,␣
↪  0.         , 74.22852942, 0., 0., 0.,  74.22820148,  74.22852942, -4.41794671e-04),
         (2.36e+03, 2.31518433e-03,  8.99067397, 0.,  64.05458652, 0., 0., 0.         ,␣
↪  0.         , 73.04786211, 0., 0., 0.,  73.04757567,  73.04786211, -3.92124078e-04),
         (2.40e+03, 2.17404830e-03,  8.44571365, 0.,  63.52276663, 0., 0., 0.         ,␣
↪  0.         , 71.97090718, 0., 0., 0.,  71.97065433,  71.97090718, -3.51328184e-04),
         (2.44e+03, 2.81993508e-03, 10.96537535, 0.,  59.39318153, 0., 0., 0.         ,␣
↪  0.         , 70.36169271, 0., 0., 0.,  70.36137682,  70.36169271, -4.48957261e-04),
         (2.48e+03, 2.99544059e-03, 11.65308129, 0.,  57.07292771, 0., 0., 0.         ,␣
↪  0.         , 68.72930656, 0., 0., 0.,  68.72900444,  68.72930656, -4.39583720e-04),
         (2.52e+03, 4.00001313e-03, 15.57599202, 0.,  50.80019371, 0., 0., 0.         ,␣
↪  0.         , 66.38055059, 0., 0., 0.,  66.38018574,  66.38055059, -5.49633887e-04),
         (2.56e+03, 3.81480656e-03, 14.86546946, 0.,  49.32928447, 0., 0., 0.         ,␣
↪  0.         , 64.19891797, 0., 0., 0.,  64.19856873,  64.19891797, -5.43997899e-04)],
        dtype=[('totim', '<f8'), ('STO-SS(STORAGE)_IN', '<f8'), ('STO-SY(STORAGE)_IN',
↪'<f8'), ('CHD(CHD-1)_IN', '<f8'), ('UZF-GWRCH(UZF-1)_IN', '<f8'), ('UZF-GWD(UZF-1)_IN',
↪ '<f8'), ('UZF-GWET(UZF-1)_IN', '<f8'), ('STO-SS(STORAGE)_OUT', '<f8'), ('STO-
↪SY(STORAGE)_OUT', '<f8'), ('CHD(CHD-1)_OUT', '<f8'), ('UZF-GWRCH(UZF-1)_OUT', '<f8'), (
↪'UZF-GWD(UZF-1)_OUT', '<f8'), ('UZF-GWET(UZF-1)_OUT', '<f8'), ('TOTAL_IN', '<f8'), (
↪'TOTAL_OUT', '<f8'), ('PERCENT_DIFFERENCE', '<f8')])
```

[9]:
```
hds = ml.output.head()
hds.get_data()
```

[9]:
```
array([[[-25.        , -24.93660487, -24.88816332, -24.85548043,
         -24.83902108, -24.83902108, -24.85548043, -24.88816332,
         -24.93660487, -25.        ]],

       [[-25.        , -24.93660487, -24.88816332, -24.85548043,
         -24.83902108, -24.83902108, -24.85548043, -24.88816332,
         -24.93660487, -25.        ]],

       [[-25.        , -24.93660487, -24.88816332, -24.85548043,
```

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```
-24.83902108, -24.83902108, -24.85548043, -24.88816332,
         -24.93660487, -25.        ]]])
```

[10]:
```
bud = ml.oc.output.budget()
bud.get_data(idx=0, full3D=True)
```

[10]:
```
[array([[[ 0.,  0.,  0.,  0., -0.,  0.,  0.,  0., -0.,  0.,  0.,  0.,
          -0.,  0.,  0.,  0., -0.,  0.,  0.,  0., -0.,  0.,  0.,  0.,
          -0.,  0.,  0.,  0., -0.,  0.,  0.,  0., -0.,  0.,  0.,  0.,
          -0.,  0.,  0., -0.,  0.,  0.,  0., -0., -0.,  0.,  0.,  0.,
          -0., -0.,  0.,  0.,  0., -0., -0.,  0.,  0.,  0., -0., -0.,
           0.,  0.,  0., -0., -0.,  0.,  0.,  0., -0., -0.,  0.,  0.,
           0., -0., -0.,  0.,  0.,  0., -0., -0.,  0.,  0.,  0., -0.,
          -0.,  0.,  0., -0.,  0.,  0., -0., -0.,  0.,  0., -0., -0.,
           0.,  0., -0., -0.,  0.,  0., -0., -0.,  0.,  0., -0., -0.,
           0.,  0., -0., -0.,  0.,  0., -0., -0.,  0.,  0., -0., -0.,
           0.,  0., -0., -0.]]])]
```

[11]:
```
hds = ml.oc.output.head()
hds.get_data()
```

[11]:
```
array([[[-25.        , -24.93660487, -24.88816332, -24.85548043,
         -24.83902108, -24.83902108, -24.85548043, -24.88816332,
         -24.93660487, -25.        ]],

       [[-25.        , -24.93660487, -24.88816332, -24.85548043,
         -24.83902108, -24.83902108, -24.85548043, -24.88816332,
         -24.93660487, -25.        ]],

       [[-25.        , -24.93660487, -24.88816332, -24.85548043,
         -24.83902108, -24.83902108, -24.85548043, -24.88816332,
         -24.93660487, -25.        ]]])
```

Get output associated with a specific package

The .output attribute is tied to the package object and allows the user to get the output types specified in the MODFLOW 6 package. Here is an example with a UZF package that has UZF budget file output, budgetcsv file output, package convergence output, and observation data.

[12]:
```
uzf = ml.uzf
uzf_bud = uzf.output.budget()
uzf_bud.get_data(idx=0)
```

[12]:
```
[rec.array([( 1,  9,  0., 100000.), ( 9,  1, -0., 100000.),
            ( 2, 10,  0., 100000.), (10,  2, -0., 100000.),
            ( 3, 11,  0., 100000.), (11,  3, -0., 100000.),
            ( 4, 12,  0., 100000.), (12,  4, -0., 100000.),
            ( 5, 13,  0., 100000.), (13,  5, -0., 100000.),
            ( 6, 14,  0., 100000.), (14,  6, -0., 100000.),
            ( 7, 15,  0., 100000.), (15,  7, -0., 100000.),
            ( 8, 16,  0., 100000.), (16,  8, -0., 100000.),
            ( 9, 17,  0., 100000.), (17,  9, -0., 100000.),
```

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```
            (10, 18,  0., 100000.), (18, 10, -0., 100000.),
            (11, 19,  0., 100000.), (19, 11, -0., 100000.),
            (12, 20,  0., 100000.), (20, 12, -0., 100000.),
            (13, 21,  0., 100000.), (21, 13, -0., 100000.),
            (14, 22,  0., 100000.), (22, 14, -0., 100000.),
            (15, 23,  0., 100000.), (23, 15, -0., 100000.),
            (16, 24,  0., 100000.), (24, 16, -0., 100000.)],
           dtype=[('node', '<i4'), ('node2', '<i4'), ('q', '<f8'), ('FLOW-AREA', '<f8
→')])]
```

[13]:
```
uzf_budcsv = uzf.output.budgetcsv()
uzf_budcsv.data
```

[13]:
```
rec.array([(2.00e+00, 0., 8000., 0., 0., 0.00000000e+00,   0.         , 0., 0., 0.
→01124365, 7999.98875635, 8000.        , 8000.         ,  3.41060513e-14),
           (4.00e+00, 0., 8000., 0., 0., 0.00000000e+00,   0.         , 0., 0., 0.
→02248729, 7999.97751271, 8000.        , 8000.         , -2.27373675e-14),
           (6.00e+00, 0., 8000., 0., 0., 0.00000000e+00,   0.         , 0., 0., 0.
→03373091, 7999.96626909, 8000.        , 8000.         ,  6.82121026e-14),
           (8.00e+00, 0., 8000., 0., 0., 0.00000000e+00,   0.         , 0., 0., 0.
→04497452, 7999.95502458, 8000.        , 7999.9999991 ,  1.12417183e-08),
           (1.00e+01, 0., 8000., 0., 0., 0.00000000e+00,   0.         , 0., 0., 0.
→10119265, 7999.89880735, 8000.        , 8000.         ,  1.13686838e-13),
           (1.20e+01, 0., 8000., 0., 0., 0.00000000e+00,   0.         , 0., 0., 0.
→15741054, 7999.84258946, 8000.        , 8000.         , -1.13686838e-14),
           (1.40e+01, 0., 8000., 0., 0., 0.00000000e+00,   0.         , 0., 0., 0.
→21362819, 7999.78637181, 8000.        , 8000.         ,  6.82121026e-14),
           (1.60e+01, 0., 8000., 0., 0., 0.00000000e+00,   0.         , 0., 0., 0.
→26984561, 7999.73015439, 8000.        , 8000.         , -5.68434189e-14),
           (1.80e+01, 0., 8000., 0., 0., 0.00000000e+00,   0.         , 0., 0., 0.
→32606279, 7999.67393721, 8000.        , 8000.         , -2.38742359e-13),
           (2.00e+01, 0., 8000., 0., 0., 0.00000000e+00,   0.         , 0., 0., 0.
→38227973, 7999.61772027, 8000.        , 8000.         ,  6.82121026e-14),
           (2.20e+01, 0., 8000., 0., 0., 0.00000000e+00,   0.         , 0., 0., 0.
→43849643, 7999.56150357, 8000.        , 8000.         ,  2.04636308e-13),
           (2.40e+01, 0., 8000., 0., 0., 0.00000000e+00,   0.         , 0., 0., 0.
→13492205, 7999.86507795, 8000.        , 8000.         , -9.09494702e-14),
           (2.60e+01, 0., 8000., 0., 0., 0.00000000e+00,   0.         , 0., 0., 0.
→19113979, 7999.80886021, 8000.        , 8000.         , -3.63797881e-13),
           (2.80e+01, 0., 8000., 0., 0., 0.00000000e+00,   0.         , 0., 0., 0.2473573␣
→, 7999.7526427 , 8000.        , 8000.         ,  4.66116035e-13),
           (3.00e+01, 0., 8000., 0., 0., 0.00000000e+00,   0.         , 0., 0., 0.3035747␣
→, 7999.6964253 , 8000.        , 8000.         , -9.09494702e-14),
           (3.20e+01, 0., 8000., 0., 0., 0.00000000e+00,   0.         , 0., 0., 0.
→35979212, 7999.64020788, 8000.        , 8000.         , -7.95807864e-14),
           (3.40e+01, 0., 8000., 0., 0., 0.00000000e+00,   0.         , 0., 0., 0.4160093␣
→, 7999.5839907 , 8000.        , 8000.         , -9.09494702e-14),
           (3.60e+01, 0., 8000., 0., 0., 0.00000000e+00,   0.         , 0., 0., 0.
→47222624, 7999.52777376, 8000.        , 8000.         , -7.95807864e-14),
           (3.80e+01, 0., 8000., 0., 0., 0.00000000e+00,   0.         , 0., 0., 0.
→52844295, 7999.47155705, 8000.        , 8000.         , -9.09494702e-14),
           (4.00e+01, 0., 8000., 0., 0., 0.00000000e+00,   0.         , 0., 0., 0.
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↪22486856, 7999.77513144, 8000.        , 8000.        ,  7.27595761e-13),
           (4.20e+01, 0., 8000., 0., 0., 0.00000000e+00,  0.         , 0., 0., 0.
↪28108631, 7999.71891369, 8000.        , 8000.        ,  2.04636308e-13),
           (4.40e+01, 0., 8000., 0., 0., 0.00000000e+00,  0.         , 0., 0., 0.
↪33475407, 7999.66524593, 8000.        , 8000.        , -1.02318154e-13),
           (4.60e+01, 0., 8000., 0., 0., 0.00000000e+00,  0.         , 0., 0., 0.
↪38480503, 7999.61519497, 8000.        , 8000.        , -5.11590770e-13),
           (4.80e+01, 0., 8000., 0., 0., 0.00000000e+00,  0.         , 0., 0., 0.
↪43407536, 7999.56558735, 8000.        , 7999.99966271,  4.21615857e-06),
           (5.00e+01, 0., 8000., 0., 0., 1.18939114e-01,  0.         , 0., 0., 0.
↪48208139, 7999.63685772, 8000.11893911, 8000.11893911,  4.54740590e-13),
           (5.20e+01, 0., 8000., 0., 0., 2.40000000e-01,  0.         , 0., 0., 0.
↪62375028, 7999.61624972, 8000.24      , 8000.24      ,  4.54733709e-14),
           (5.40e+01, 0., 8000., 0., 0., 2.40000000e-01,  0.         , 0., 0., 0.
↪64056589, 7999.59943411, 8000.24      , 8000.24      , -1.13683427e-13),
           (5.60e+01, 0., 8000., 0., 0., 0.00000000e+00,  0.         , 0., 0., 0.
↪32744504, 7999.67255496, 8000.        , 8000.        , -2.16004992e-13),
           (5.80e+01, 0., 8000., 0., 0., 0.00000000e+00,  0.         , 0., 0., 0.
↪36195984, 7999.63804016, 8000.        , 8000.        ,  1.93267624e-13),
           (6.00e+01, 0., 8000., 0., 0., 0.00000000e+00,  0.         , 0., 0., 0.
↪39268212, 7999.60731788, 8000.        , 8000.        ,  4.66116035e-13),
           (1.10e+02, 0.,    0., 0., 0., 3.78724873e+03,  0.         , 0., 0., 0.
↪41882422, 3786.82970478, 3787.24873018, 3787.24852899,  5.31225330e-06),
           (1.60e+02, 0.,    0., 0., 0., 6.28239222e+02,  0.         , 0., 0., 0.
↪51502761,  627.69903841,  628.23922183,  628.21406602,  4.00425715e-03),
           (2.10e+02, 0.,    0., 0., 0., 3.79980452e+02,  0.         , 0., 0., 0.
↪56814228,  379.36208201,  379.98045151,  379.9302243 ,  1.32192414e-02),
           (2.60e+02, 0.,    0., 0., 0., 1.22681840e+02,  0.         , 0., 0., 0.
↪60336166,  122.00319618,  122.68183971,  122.60655784,  6.13823347e-02),
           (3.10e+02, 0.,    0., 0., 0., 1.22634110e+02,  0.         , 0., 0., 0.
↪58736429,  121.9464052 ,  122.63410992,  122.53376948,  8.18544694e-02),
           (3.60e+02, 0.,    0., 0., 0., 1.22586380e+02,  0.         , 0., 0., 0.
↪58904253,  121.8719518 ,  122.58638012,  122.46099433,  1.02335961e-01),
           (4.10e+02, 0.,    0., 0., 0., 1.22538650e+02,  0.         , 0., 0., 0.
↪57596753,  121.81226742,  122.53865033,  122.38823496,  1.22824712e-01),
           (4.60e+02, 0.,    0., 0., 0., 1.22490921e+02,  0.         , 0., 0., 0.
↪56435326,  121.75113567,  122.49092053,  122.31548892,  1.43322724e-01),
           (5.10e+02, 0.,    0., 0., 0., 1.22443191e+02,  0.         , 0., 0., 0.
↪55419916,  121.68855904,  122.44319073,  122.2427582 ,  1.63828398e-01),
           (5.60e+02, 0.,    0., 0., 0., 1.22395461e+02,  0.         , 0., 0., 0.
↪56040475,  121.60963737,  122.39546094,  122.17004212,  1.84342282e-01),
           (6.00e+02, 0.,    0., 0., 0., 1.74018709e+01,  0.         , 0., 0., 0.
↪55999969,   16.82414951,   17.4018709 ,   17.3841492 ,  1.01889790e-01),
           (6.40e+02, 0.,    0., 0., 0., 1.51944083e+02,  0.         , 0., 0., 0.
↪55144142,  151.39263928,  151.94408282,  151.9440807 ,  1.39256758e-06),
           (6.80e+02, 0.,    0., 0., 0., 2.72064073e+02,  0.         , 0., 0., 0.
↪54288289,  271.52105105,  272.06407257,  272.06393394,  5.09554104e-05),
           (7.20e+02, 0.,    0., 0., 0., 2.43435052e+02,  0.         , 0., 0., 0.
↪53432434,  242.90043095,  243.43505167,  243.43475529,  1.21747747e-04),
           (7.60e+02, 0.,    0., 0., 0., 2.24436380e+02,  0.         , 0., 0., 0.
↪52576579,  223.91019007,  224.43638039,  224.43595586,  1.89152075e-04),
           (8.00e+02, 0.,    0., 0., 0., 1.92144820e+02,  0.         , 0., 0., 0.
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↪51720724,  191.62706411,  192.14481959,  192.14427135,  2.85328186e-04),
           (8.40e+02, 0.,    0., 0., 0., 1.89295138e+02,   0.          , 0., 0., 0.
↪50864868,  188.7858185 ,  189.29513782,  189.29446718,  3.54282046e-04),
           (8.80e+02, 0.,    0., 0., 0., 1.59711534e+02,   0.          , 0., 0., 0.
↪50009013,  159.2106566 ,  159.71153439,  159.71074673,  4.93175545e-04),
           (9.20e+02, 0.,    0., 0., 0., 1.54912199e+02,   0.          , 0., 0., 0.
↪49153158,  154.41976469,  154.91219927,  154.91129626,  5.82916597e-04),
           (9.60e+02, 0.,    0., 0., 0., 1.53348712e+02,   0.          , 0., 0., 0.
↪48297303,  152.8647234 ,  153.34871173,  153.34769643,  6.62088144e-04),
           (1.00e+03, 0.,    0., 0., 0., 1.22470337e+02,   0.          , 0., 0., 0.
↪47441447,  121.99480078,  122.47033704,  122.46921525,  9.15973800e-04),
           (1.04e+03, 0.,    0., 0., 0., 1.22428683e+02,   0.          , 0., 0., 0.
↪46585592,  121.9616002 ,  122.42868329,  122.42745612,  1.00236285e-03),
           (1.08e+03, 0.,    0., 0., 0., 1.22381264e+02,   0.          , 0., 0., 0.
↪45729737,  121.92263707,  122.38126375,  122.37993444,  1.08621048e-03),
           (1.12e+03, 0.,    0., 0., 0., 1.22333850e+02,   0.          , 0., 0., 0.
↪44873881,  121.88368331,  122.33385014,  122.33242212,  1.16731720e-03),
           (1.16e+03, 0.,    0., 0., 0., 1.22274162e+02,   0.          , 0., 0., 0.
↪44018026,  121.83245857,  122.27416212,  122.27263883,  1.24580486e-03),
           (1.20e+03, 0.,    0., 0., 0., 1.22222909e+02,   0.          , 0., 0., 0.
↪43162171,  121.78967189,  122.22290873,  122.2212936 ,  1.32147141e-03),
           (1.24e+03, 0.,    0., 0., 0., 1.22175517e+02,   0.          , 0., 0., 0.
↪42306316,  121.75075005,  122.17551675,  122.17381321,  1.39435034e-03),
           (1.28e+03, 0.,    0., 0., 0., 1.22128131e+02,   0.          , 0., 0., 0.4145046␣
↪,  121.71183756,  122.12813069,  122.12634217,  1.46447817e-03),
           (1.32e+03, 0.,    0., 0., 0., 1.22080751e+02,   0.          , 0., 0., 0.
↪40594605,  121.67293442,  122.08075056,  122.07888047,  1.53185243e-03),
           (1.36e+03, 0.,    0., 0., 0., 1.22022484e+02,   0.          , 0., 0., 0.3973875␣
↪,  121.62314831,  122.02248402,  122.0205358 ,  1.59661237e-03),
           (1.40e+03, 0.,    0., 0., 0., 1.21761590e+02,   0.          , 0., 0., 0.
↪38882895,  121.3707379 ,  121.76158975,  121.75956685,  1.66137130e-03),
           (1.44e+03, 0.,    0., 0., 0., 1.15127548e+02,   0.          , 0., 0., 0.
↪38027039,  114.74518428,  115.1275483 ,  115.12545468,  1.81853759e-03),
           (1.48e+03, 0.,    0., 0., 0., 1.06834995e+02,   0.          , 0., 0., 0.
↪37171184,  106.46112218,  106.83499475,  106.83283402,  2.02250892e-03),
           (1.52e+03, 0.,    0., 0., 0., 1.28387162e+02, 128.0217841 , 0., 0., 0.
↪36315329,    0.          ,  128.3871623 ,  128.38493739,  1.73299045e-03),
           (1.56e+03, 0.,    0., 0., 0., 1.39350694e+02, 138.99381474, 0., 0., 0.
↪35459473,    0.          ,  139.35069441,  139.34840947,  1.63971258e-03),
           (1.60e+03, 0.,    0., 0., 0., 1.36845580e+02, 136.4972012 , 0., 0., 0.
↪34603618,    0.          ,  136.84557981,  136.84323738,  1.71174694e-03),
           (1.64e+03, 0.,    0., 0., 0., 1.34699461e+02, 134.35958704, 0., 0., 0.
↪33747763,    0.          ,  134.69946073,  134.69706466,  1.77884019e-03),
           (1.68e+03, 0.,    0., 0., 0., 1.31576180e+02, 131.24481479, 0., 0., 0.
↪32891908,    0.          ,  131.57617996,  131.57373387,  1.85908572e-03),
           (1.72e+03, 0.,    0., 0., 0., 1.23457194e+02, 123.13434058, 0., 0., 0.
↪32036052,    0.          ,  123.45719445,  123.4547011 ,  2.01962857e-03),
           (1.76e+03, 0.,    0., 0., 0., 1.14317874e+02, 114.00353442, 0., 0., 0.
↪31180197,    0.          ,  114.31787365,  114.31533639,  2.21950275e-03),
           (1.80e+03, 0.,    0., 0., 0., 1.10420694e+02, 110.11487407, 0., 0., 0.
↪30324342,    0.          ,  110.42069432,  110.41811749,  2.33367700e-03),
           (1.84e+03, 0.,    0., 0., 0., 1.05703327e+02, 105.40602911, 0., 0., 0.
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↪29468487,    0.        ,  105.7033274 ,  105.70071398,  2.47244563e-03),
           (1.88e+03, 0.,    0., 0., 0., 9.53779221e+01,  95.08914871, 0., 0., 0.
↪28612631,    0.        ,  95.37792207,   95.37527503,  2.77535835e-03),
           (1.92e+03, 0.,    0., 0., 0., 9.49750001e+01,  94.69475504, 0., 0., 0.
↪27756776,    0.        ,  94.97500009,   94.9723228 ,  2.81897970e-03),
           (1.96e+03, 0.,    0., 0., 0., 9.00448429e+01,  89.77312957, 0., 0., 0.
↪26900921,    0.        ,  90.0448429 ,   90.04213878,  3.00312769e-03),
           (2.00e+03, 0.,    0., 0., 0., 8.60426727e+01,  85.77949492, 0., 0., 0.
↪26045065,    0.        ,  86.04267268,   86.03994557,  3.16952968e-03),
           (2.04e+03, 0.,    0., 0., 0., 7.93212676e+01,  79.06662935, 0., 0., 0.2518921␣
↪,    0.        ,  79.3212676 ,   79.31852145,  3.46212104e-03),
           (2.08e+03, 0.,    0., 0., 0., 7.92621596e+01,  79.01606345, 0., 0., 0.
↪24333355,    0.        ,  79.26215964,   79.259397  ,  3.48550200e-03),
           (2.12e+03, 0.,    0., 0., 0., 7.93077233e+01,  79.07017251, 0., 0., 0.234775 ␣
↪,    0.        ,  79.30772334,   79.30494751,  3.50012862e-03),
           (2.16e+03, 0.,    0., 0., 0., 7.46733681e+01,  74.44436606, 0., 0., 0.
↪22621644,    0.        ,  74.67336811,   74.67058251,  3.73045242e-03),
           (2.20e+03, 0.,    0., 0., 0., 6.81917326e+01,  67.97128273, 0., 0., 0.
↪21765789,    0.        ,  68.19173259,   68.18894062,  4.09438250e-03),
           (2.24e+03, 0.,    0., 0., 0., 6.52627430e+01,  65.05084871, 0., 0., 0.
↪20909934,    0.        ,  65.26274298,   65.25994805,  4.28268329e-03),
           (2.28e+03, 0.,    0., 0., 0., 6.38805832e+01,  63.67724795, 0., 0., 0.
↪20054079,    0.        ,  63.88058323,   63.87778874,  4.37465570e-03),
           (2.32e+03, 0.,    0., 0., 0., 6.40791861e+01,  63.8844137 , 0., 0., 0.
↪19198223,    0.        ,  64.07918605,   64.07639593,  4.35427472e-03),
           (2.36e+03, 0.,    0., 0., 0., 6.42407922e+01,  64.05458652, 0., 0., 0.
↪18342368,    0.        ,  64.2407922 ,   64.2380102 ,  4.33067676e-03),
           (2.40e+03, 0.,    0., 0., 0., 6.37004030e+01,  63.52276663, 0., 0., 0.
↪17486513,    0.        ,  63.70040299,   63.69763176,  4.35050707e-03),
           (2.44e+03, 0.,    0., 0., 0., 5.95622453e+01,  59.39318153, 0., 0., 0.
↪16630658,    0.        ,  59.56224528,   59.55948811,  4.62916709e-03),
           (2.48e+03, 0.,    0., 0., 0., 5.72334154e+01,  57.07292771, 0., 0., 0.
↪15774802,    0.        ,  57.23341545,   57.23067573,  4.78702424e-03),
           (2.52e+03, 0.,    0., 0., 0., 5.09521020e+01,  50.80019371, 0., 0., 0.
↪14918947,    0.        ,  50.95210203,   50.94938318,  5.33623414e-03),
           (2.56e+03, 0.,    0., 0., 0., 4.94726100e+01,  49.32928447, 0., 0., 0.
↪14063092,    0.        ,  49.47260998,   49.46991539,  5.44677831e-03)],
          dtype=[('totim', '<f8'), ('GWF_IN', '<f8'), ('INFILTRATION_IN', '<f8'), ('REJ-
↪INF_IN', '<f8'), ('UZET_IN', '<f8'), ('STORAGE_IN', '<f8'), ('GWF_OUT', '<f8'), (
↪'INFILTRATION_OUT', '<f8'), ('REJ-INF_OUT', '<f8'), ('UZET_OUT', '<f8'), ('STORAGE_OUT
↪', '<f8'), ('TOTAL_IN', '<f8'), ('TOTAL_OUT', '<f8'), ('PERCENT_DIFFERENCE', '<f8')])
```

[14]:
```
uzf_conv = uzf.output.package_convergence()
if uzf_conv is not None:
    uzf_conv.data[0:10]
```

[15]:
```
uzf_obs = uzf.output.obs()
uzf_obs.data[0:10]
```

[15]:
```
rec.array([( 2., 0.05, 0.05, 0.), ( 4., 0.05, 0.05, 0.),
           ( 6., 0.05, 0.05, 0.), ( 8., 0.05, 0.05, 0.),
           (10., 0.05, 0.05, 0.), (12., 0.05, 0.05, 0.),
```

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```
          (14., 0.05, 0.05, 0.), (16., 0.05, 0.05, 0.),
          (18., 0.05, 0.05, 0.), (20., 0.05, 0.05, 0.)],
         dtype=[('totim', '<f8'), ('ID3_DPTH=8.0', '<f8'), ('ID3_DPTH=24.0', '<f8'), (
↪'ID3_RCH', '<f8')])
```

Check which output types are available in a package

The `.output` attribute also has a `methods()` function that returns a list of available output functions for a given package. Here are a couple of examples

[16]:
```
print("UZF package: ", uzf.output.methods())
print("Model object: ", ml.output.methods())
print("OC package: ", ml.oc.output.methods())
print("DIS package: ", ml.dis.output.methods())
```

```
UZF package:  ['zonebudget()', 'budget()', 'budgetcsv()', 'package_convergence()', 'obs()
↪']
Model object:  ['list()', 'zonebudget()', 'budget()', 'budgetcsv()', 'head()']
OC package:  ['list()', 'zonebudget()', 'budget()', 'budgetcsv()', 'head()']
DIS package:  None
```

Managing multiple observation and csv file outputs in the same package

For many packages, multiple observation output files can be used. The `obs()` and `csv()` functions allow the user to specify a observation file or csv file name. If no name is specified, the `obs()` and `csv()` methods will return the first file that is listed in the package.

[17]:
```
output = ml.obs[0].output
obs_names = output.obs_names
output.obs(f=obs_names[0]).data[0:10]
```

[17]:
```
rec.array([( 2., 0.05, 0.05, 0.), ( 4., 0.05, 0.05, 0.),
          ( 6., 0.05, 0.05, 0.), ( 8., 0.05, 0.05, 0.),
          (10., 0.05, 0.05, 0.), (12., 0.05, 0.05, 0.),
          (14., 0.05, 0.05, 0.), (16., 0.05, 0.05, 0.),
          (18., 0.05, 0.05, 0.), (20., 0.05, 0.05, 0.)],
         dtype=[('totim', '<f8'), ('ID3_DPTH=8.0', '<f8'), ('ID3_DPTH=24.0', '<f8'), (
↪'ID3_RCH', '<f8')])
```

Creating and running ZoneBudget for MF6

For the model and many packages, zonebudget can be run on the cell budget file. The `.output` method allows the user to easily build a ZoneBudget6 instance, then run the model, and view output. First we'll build a layered zone array, then build and run zonebudget

[18]:
```
zarr = np.ones(ml.modelgrid.shape, dtype=int)
for i in range(1, 4):
    zarr[i - 1] *= i
```

[19]:
```
zonbud = ml.output.zonebudget(zarr)
zonbud.change_model_ws(sim_ws)
zonbud.write_input()
zonbud.run_model()
```

```
FloPy is using the following executable to run the model: ../../home/runner/.local/bin/
↪modflow/zbud6
                              ZONEBUDGET Version 6
                             U.S. GEOLOGICAL SURVEY
                            VERSION 6.4.2 06/28/2023
...

Normal Termination
```

[19]:
```
(True, [])
```

[20]:
```
df = zonbud.get_dataframes(net=True)
df = df.reset_index()
df
```

[20]:
```
      totim    name  ZONE_1        ZONE_2        ZONE_3
0       2.0  ZONE_0     0.0  0.000000e+00  0.000000e+00
1       2.0  ZONE_1     0.0  0.000000e+00  0.000000e+00
2       2.0  ZONE_2     0.0  0.000000e+00  0.000000e+00
3       2.0  ZONE_3     0.0  0.000000e+00  0.000000e+00
4       4.0  ZONE_0     0.0  0.000000e+00  0.000000e+00
..      ...     ...     ...           ...           ...
355  2520.0  ZONE_3     0.0  0.000000e+00  0.000000e+00
356  2560.0  ZONE_0     0.0  0.000000e+00  0.000000e+00
357  2560.0  ZONE_1     0.0  0.000000e+00  0.000000e+00
358  2560.0  ZONE_2     0.0  0.000000e+00 -5.684342e-10
359  2560.0  ZONE_3     0.0  5.684342e-10  0.000000e+00

[360 rows x 5 columns]
```

[21]:
```
try:
    temp_dir.cleanup()
except:
    # prevent windows permission error
    pass
```

5.2.13 SFR2 package loading and querying

[1]:
```
import os
```

[2]:
```
import sys

# run installed version of flopy or add local path
try:
    import flopy
except:
    fpth = os.path.abspath(os.path.join("..", ".."))
```

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```
    sys.path.append(fpth)
    import flopy

print(sys.version)
print(f"flopy version: {flopy.__version__}")
```

```
3.8.18 (default, Aug 28 2023, 08:27:22)
[GCC 11.4.0]
flopy version: 3.5.0
```

Create a model instance

```
[3]: m = flopy.modflow.Modflow()
```

Read the SFR2 file

```
[4]: f = os.path.join(
         "..", "..", "examples", "data", "mf2005_test", "testsfr2_tab_ICALC2.sfr"
     )
     stuff = open(f).readlines()
     stuff
```

```
[4]: ['# SFR2 Package input file for hypothetical test simulation\n',
      '# Test of SFR2 Package; revised October 1, 2011\n',
      '# Example for using keyword options\n',
      '# Stress period inflow rates are now specified in testsfr2_tab.tab TRANSROUTE\n',
      'REACHINPUT \n',
      'TABFILES 1 50\n',
      ' 100  1  0  0  1.0  0.00001 -1 0 5 20 5 20  0  1  0.7 0.0001     Item 1: NSTRM NSS␣
     ↪NSFRPAR NPARSEG CONST DLEAK ISTCB1 ISTCB2 {ISFROPT} {NSTRAIL} {ISUZN} {NSFRSETS}\n',
      '       1      4       1      1      1    200.0 \n',
      '       1      4       2      1      2    200.0 \n',
      '       1      4       3      1      3    200.0 \n',
      '       1      4       4      1      4    200.0 \n',
      '       1      4       5      1      5    200.0 \n',
      '       1      4       6      1      6    200.0 \n',
      '       1      4       7      1      7    200.0 \n',
      '       1      4       8      1      8    200.0 \n',
      '       1      4       9      1      9    200.0 \n',
      '       1      4      10      1     10    200.0 \n',
      '       1      4      11      1     11    200.0 \n',
      '       1      4      12      1     12    200.0 \n',
      '       1      4      13      1     13    200.0 \n',
      '       1      4      14      1     14    200.0 \n',
      '       1      4      15      1     15    200.0 \n',
      '       1      4      16      1     16    200.0 \n',
      '       1      4      17      1     17    200.0 \n',
      '       1      4      18      1     18    200.0 \n',
      '       1      4      19      1     19    200.0 \n',
      '       1      4      20      1     20    200.0 \n',
      '       1      4      21      1     21    200.0  \n',
      '       1      4      22      1     22    200.0  \n',
      '       1      4      23      1     23    200.0  \n',
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'        1      4      24      1      24    200.0   \n',
'        1      4      25      1      25    200.0   \n',
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'        1      4      27      1      27    200.0 \n',
'        1      4      28      1      28    200.0 \n',
'        1      4      29      1      29    200.0 \n',
'        1      4      30      1      30    200.0 \n',
'        1      4      31      1      31    200.0   \n',
'        1      4      32      1      32    200.0   \n',
'        1      4      33      1      33    200.0   \n',
'        1      4      34      1      34    200.0   \n',
'        1      4      35      1      35    200.0   \n',
'        1      4      36      1      36    200.0   \n',
'        1      4      37      1      37    200.0   \n',
'        1      4      38      1      38    200.0   \n',
'        1      4      39      1      39    200.0   \n',
'        1      4      40      1      40    200.0   \n',
'        1      4      41      1      41    200.0   \n',
'        1      4      42      1      42    200.0   \n',
'        1      4      43      1      43    200.0   \n',
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'        1      4      46      1      46    200.0 \n',
'        1      4      47      1      47    200.0 \n',
'        1      4      48      1      48    200.0 \n',
'        1      4      49      1      49    200.0 \n',
'        1      4      50      1      50    200.0 \n',
'        1      4      51      1      51    200.0   \n',
'        1      4      52      1      52    200.0   \n',
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'        1      4      56      1      56    200.0   \n',
'        1      4      57      1      57    200.0   \n',
'        1      4      58      1      58    200.0   \n',
'        1      4      59      1      59    200.0   \n',
'        1      4      60      1      60    200.0   \n',
'        1      4      61      1      61    200.0   \n',
'        1      4      62      1      62    200.0   \n',
'        1      4      63      1      63    200.0   \n',
'        1      4      64      1      64    200.0   \n',
'        1      4      65      1      65    200.0   \n',
'        1      4      66      1      66    200.0 \n',
'        1      4      67      1      67    200.0 \n',
'        1      4      68      1      68    200.0 \n',
'        1      4      69      1      69    200.0 \n',
'        1      4      70      1      70    200.0 \n',
'        1      4      71      1      71    200.0   \n',
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'        1      4      73      1      73    200.0   \n',
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'        1      4     100      1     100   200.0 \n',
'1  0  0 0                                 Item 5: stress period 1\n',
'   1 2 0 0  .3 0.0   0.0  0.0 0.030 .04              Item 6a:\n',
'  .00000035 0.5  140.  .3  .1  3.5  6.0e-6           Item 6b:\n',
'  .00000035 0.5  110.  .3  .1  3.5  6.0e-6           Item 6c:\n',
'0. 2. 4. 6. 8. 10. 12. 14.                           Item 6d:\n',
'6.0 4.5 3.5 0. 0.3 3.5 4.5 6.                        Item 6d:\n',
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```
 '\n',
 '3\n',
 '\n',
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 '4\n',
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 '5\n',
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 '6\n',
 '\n',
 '\n',
 ' \n',
 '7\n',
 '\n',
 '\n',
 '\n',
 '8\n',
 '\n',
 '\n',
 '\n',
 '9\n',
 '\n',
 '\n',
 '\n',
 '0\n',
 '\n',
 '\n',
 '\n',
 ' ']
```

Load the SFR2 file

[5]:
```
sfr = flopy.modflow.ModflowSfr2.load(f, m, nper=50)
```

[6]:
```
sfr.segment_data.keys()
```

[6]:
```
dict_keys([0])
```

Query the reach data in the SFR2 file

[7]:
```
sfr.reach_data
```

[7]:
```
rec.array([(0, 0, 3,  0, 1,   1, 200., 0., 0., 0., 0., 0., 0., 0., 0.,   1, 0),
           (0, 0, 3,  1, 1,   2, 200., 0., 0., 0., 0., 0., 0., 0., 0.,   2, 0),
           (0, 0, 3,  2, 1,   3, 200., 0., 0., 0., 0., 0., 0., 0., 0.,   3, 0),
           (0, 0, 3,  3, 1,   4, 200., 0., 0., 0., 0., 0., 0., 0., 0.,   4, 0),
           (0, 0, 3,  4, 1,   5, 200., 0., 0., 0., 0., 0., 0., 0., 0.,   5, 0),
           (0, 0, 3,  5, 1,   6, 200., 0., 0., 0., 0., 0., 0., 0., 0.,   6, 0),
```

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```
            (0, 0, 3,  6, 1,   7, 200., 0., 0., 0., 0., 0., 0., 0., 0.,   7, 0),
            (0, 0, 3,  7, 1,   8, 200., 0., 0., 0., 0., 0., 0., 0., 0.,   8, 0),
            (0, 0, 3,  8, 1,   9, 200., 0., 0., 0., 0., 0., 0., 0., 0.,   9, 0),
            (0, 0, 3,  9, 1,  10, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  10, 0),
            (0, 0, 3, 10, 1,  11, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  11, 0),
            (0, 0, 3, 11, 1,  12, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  12, 0),
            (0, 0, 3, 12, 1,  13, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  13, 0),
            (0, 0, 3, 13, 1,  14, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  14, 0),
            (0, 0, 3, 14, 1,  15, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  15, 0),
            (0, 0, 3, 15, 1,  16, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  16, 0),
            (0, 0, 3, 16, 1,  17, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  17, 0),
            (0, 0, 3, 17, 1,  18, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  18, 0),
            (0, 0, 3, 18, 1,  19, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  19, 0),
            (0, 0, 3, 19, 1,  20, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  20, 0),
            (0, 0, 3, 20, 1,  21, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  21, 0),
            (0, 0, 3, 21, 1,  22, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  22, 0),
            (0, 0, 3, 22, 1,  23, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  23, 0),
            (0, 0, 3, 23, 1,  24, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  24, 0),
            (0, 0, 3, 24, 1,  25, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  25, 0),
            (0, 0, 3, 25, 1,  26, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  26, 0),
            (0, 0, 3, 26, 1,  27, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  27, 0),
            (0, 0, 3, 27, 1,  28, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  28, 0),
            (0, 0, 3, 28, 1,  29, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  29, 0),
            (0, 0, 3, 29, 1,  30, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  30, 0),
            (0, 0, 3, 30, 1,  31, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  31, 0),
            (0, 0, 3, 31, 1,  32, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  32, 0),
            (0, 0, 3, 32, 1,  33, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  33, 0),
            (0, 0, 3, 33, 1,  34, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  34, 0),
            (0, 0, 3, 34, 1,  35, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  35, 0),
            (0, 0, 3, 35, 1,  36, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  36, 0),
            (0, 0, 3, 36, 1,  37, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  37, 0),
            (0, 0, 3, 37, 1,  38, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  38, 0),
            (0, 0, 3, 38, 1,  39, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  39, 0),
            (0, 0, 3, 39, 1,  40, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  40, 0),
            (0, 0, 3, 40, 1,  41, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  41, 0),
            (0, 0, 3, 41, 1,  42, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  42, 0),
            (0, 0, 3, 42, 1,  43, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  43, 0),
            (0, 0, 3, 43, 1,  44, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  44, 0),
            (0, 0, 3, 44, 1,  45, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  45, 0),
            (0, 0, 3, 45, 1,  46, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  46, 0),
            (0, 0, 3, 46, 1,  47, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  47, 0),
            (0, 0, 3, 47, 1,  48, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  48, 0),
            (0, 0, 3, 48, 1,  49, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  49, 0),
            (0, 0, 3, 49, 1,  50, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  50, 0),
            (0, 0, 3, 50, 1,  51, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  51, 0),
            (0, 0, 3, 51, 1,  52, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  52, 0),
            (0, 0, 3, 52, 1,  53, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  53, 0),
            (0, 0, 3, 53, 1,  54, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  54, 0),
            (0, 0, 3, 54, 1,  55, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  55, 0),
            (0, 0, 3, 55, 1,  56, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  56, 0),
            (0, 0, 3, 56, 1,  57, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  57, 0),
            (0, 0, 3, 57, 1,  58, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  58, 0),
```

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```
            (0, 0, 3, 58, 1,  59, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  59, 0),
            (0, 0, 3, 59, 1,  60, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  60, 0),
            (0, 0, 3, 60, 1,  61, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  61, 0),
            (0, 0, 3, 61, 1,  62, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  62, 0),
            (0, 0, 3, 62, 1,  63, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  63, 0),
            (0, 0, 3, 63, 1,  64, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  64, 0),
            (0, 0, 3, 64, 1,  65, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  65, 0),
            (0, 0, 3, 65, 1,  66, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  66, 0),
            (0, 0, 3, 66, 1,  67, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  67, 0),
            (0, 0, 3, 67, 1,  68, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  68, 0),
            (0, 0, 3, 68, 1,  69, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  69, 0),
            (0, 0, 3, 69, 1,  70, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  70, 0),
            (0, 0, 3, 70, 1,  71, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  71, 0),
            (0, 0, 3, 71, 1,  72, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  72, 0),
            (0, 0, 3, 72, 1,  73, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  73, 0),
            (0, 0, 3, 73, 1,  74, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  74, 0),
            (0, 0, 3, 74, 1,  75, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  75, 0),
            (0, 0, 3, 75, 1,  76, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  76, 0),
            (0, 0, 3, 76, 1,  77, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  77, 0),
            (0, 0, 3, 77, 1,  78, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  78, 0),
            (0, 0, 3, 78, 1,  79, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  79, 0),
            (0, 0, 3, 79, 1,  80, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  80, 0),
            (0, 0, 3, 80, 1,  81, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  81, 0),
            (0, 0, 3, 81, 1,  82, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  82, 0),
            (0, 0, 3, 82, 1,  83, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  83, 0),
            (0, 0, 3, 83, 1,  84, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  84, 0),
            (0, 0, 3, 84, 1,  85, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  85, 0),
            (0, 0, 3, 85, 1,  86, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  86, 0),
            (0, 0, 3, 86, 1,  87, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  87, 0),
            (0, 0, 3, 87, 1,  88, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  88, 0),
            (0, 0, 3, 88, 1,  89, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  89, 0),
            (0, 0, 3, 89, 1,  90, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  90, 0),
            (0, 0, 3, 90, 1,  91, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  91, 0),
            (0, 0, 3, 91, 1,  92, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  92, 0),
            (0, 0, 3, 92, 1,  93, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  93, 0),
            (0, 0, 3, 93, 1,  94, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  94, 0),
            (0, 0, 3, 94, 1,  95, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  95, 0),
            (0, 0, 3, 95, 1,  96, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  96, 0),
            (0, 0, 3, 96, 1,  97, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  97, 0),
            (0, 0, 3, 97, 1,  98, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  98, 0),
            (0, 0, 3, 98, 1,  99, 200., 0., 0., 0., 0., 0., 0., 0., 0.,  99, 0),
            (0, 0, 3, 99, 1, 100, 200., 0., 0., 0., 0., 0., 0., 0., 0., 100, 0)],
           dtype=[('node', '<i8'), ('k', '<i8'), ('i', '<i8'), ('j', '<i8'), ('iseg', '<i8
↪'), ('ireach', '<i8'), ('rchlen', '<f4'), ('strtop', '<f4'), ('slope', '<f4'), (
↪'strthick', '<f4'), ('strhc1', '<f4'), ('thts', '<f4'), ('thti', '<f4'), ('eps', '<f4
↪'), ('uhc', '<f4'), ('reachID', '<i8'), ('outreach', '<i8')])
```

Query the channel flow data in the SFR2 file

[8]:
```
sfr.channel_flow_data
```

[8]:
```
{}
```

Query the channel geometry data in the SFR2 file

[9]:
```
sfr.channel_geometry_data
```

[9]:
```
{0: {1: [[0.0, 2.0, 4.0, 6.0, 8.0, 10.0, 12.0, 14.0],
   [6.0, 4.5, 3.5, 0.0, 0.3, 3.5, 4.5, 6.0]]}}
```

Query dataset 5 data in the SFR2 file

[10]:
```
sfr.dataset_5
```

[10]:
```
{0: [1, 0, 0, 0],
 1: [-1, 0, 0, 0],
 2: [-1, 0, 0, 0],
 3: [-1, 0, 0, 0],
 4: [-1, 0, 0, 0],
 5: [-1, 0, 0, 0],
 6: [-1, 0, 0, 0],
 7: [-1, 0, 0, 0],
 8: [-1, 0, 0, 0],
 9: [-1, 0, 0, 0],
 10: [-1, 0, 0, 0],
 11: [-1, 0, 0, 0],
 12: [-1, 0, 0, 0],
 13: [-1, 0, 0, 0],
 14: [-1, 0, 0, 0],
 15: [-1, 0, 0, 0],
 16: [-1, 0, 0, 0],
 17: [-1, 0, 0, 0],
 18: [-1, 0, 0, 0],
 19: [-1, 0, 0, 0],
 20: [-1, 0, 0, 0],
 21: [-1, 0, 0, 0],
 22: [-1, 0, 0, 0],
 23: [-1, 0, 0, 0],
 24: [-1, 0, 0, 0],
 25: [-1, 0, 0, 0],
 26: [-1, 0, 0, 0],
 27: [-1, 0, 0, 0],
 28: [-1, 0, 0, 0],
 29: [-1, 0, 0, 0],
 30: [-1, 0, 0, 0],
 31: [-1, 0, 0, 0],
 32: [-1, 0, 0, 0],
 33: [-1, 0, 0, 0],
 34: [-1, 0, 0, 0],
 35: [-1, 0, 0, 0],
 36: [-1, 0, 0, 0],
 37: [-1, 0, 0, 0],
 38: [-1, 0, 0, 0],
 39: [-1, 0, 0, 0],
 40: [-1, 0, 0, 0],
 41: [-1, 0, 0, 0],
 42: [-1, 0, 0, 0],
 43: [-1, 0, 0, 0],
```

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```
44: [-1, 0, 0, 0],
45: [-1, 0, 0, 0],
46: [-1, 0, 0, 0],
47: [-1, 0, 0, 0],
48: [-1, 0, 0, 0],
49: [-1, 0, 0, 0]}
```

Query the TABFILES dictionary in the SFR2 object to determine the TABFILES data in the SFR2 file

[11]:
```
sfr.tabfiles_dict
```

[11]:
```
{1: {'numval': 50, 'inuit': 55}}
```

[12]:
```
sfr.tabfiles
```

[12]:
```
True
```

5.2.14 Unconfined steady-state flow model

This tutorial demonstrates a simple MODFLOW 6 model with FloPy.

Getting Started

[1]:
```
from pathlib import Path
from tempfile import TemporaryDirectory
```

[2]:
```
import matplotlib.pyplot as plt
import numpy as np
```

[3]:
```
import flopy
```

We are creating a square model with a specified head equal to `h1` along the edge of the model in layer 1. A well is located in the center of the upper-left quadrant in layer 10. First, set the name of the model and the parameters of the model: the number of layers `Nlay`, the number of rows and columns `N`, lengths of the sides of the model `L`, aquifer thickness `H`, hydraulic conductivity `k`, and the well pumping rate `q`.

[4]:
```
h1 = 100
Nlay = 10
N = 101
L = 400.0
H = 50.0
k = 1.0
q = -1000.0
```

Create the Flopy Model Objects

One big difference between MODFLOW 6 and previous MODFLOW versions is that MODFLOW 6 is based on the concept of a simulation. A simulation consists of the following:

- Temporal discretization (`TDIS`)
- One or more models
- Zero or more exchanges (instructions for how models are coupled)
- Solutions

For this simple example, the simulation consists of the temporal discretization (`TDIS`) package, a groundwater flow (`GWF`) model, and an iterative model solution (`IMS`), which controls how the GWF model is solved.

Create a temporary workspace, then the FloPy simulation object

[5]:
```
temp_dir = TemporaryDirectory()
workspace = Path(temp_dir.name)
name = "tutorial01_mf6"
sim = flopy.mf6.MFSimulation(
    sim_name=name, exe_name="mf6", version="mf6", sim_ws=workspace
)
```

Create the Flopy `TDIS` object

[6]:
```
tdis = flopy.mf6.ModflowTdis(
    sim, pname="tdis", time_units="DAYS", nper=1, perioddata=[(1.0, 1, 1.0)]
)
```

Create the Flopy `IMS` Package object

[7]:
```
ims = flopy.mf6.ModflowIms(
    sim,
    pname="ims",
    complexity="SIMPLE",
    linear_acceleration="BICGSTAB",
)
```

Create the Flopy groundwater flow (gwf) model object

[8]:
```
model_nam_file = f"{name}.nam"
gwf = flopy.mf6.ModflowGwf(
    sim,
    modelname=name,
    model_nam_file=model_nam_file,
    save_flows=True,
    newtonoptions="NEWTON UNDER_RELAXATION",
)
```

Now that the overall simulation is set up, we can focus on building the groundwater flow model. The groundwater flow model will be built by adding packages to it that describe the model characteristics.

Create the discretization (DIS) Package

Define the discretization of the model. All layers are given equal thickness. The `bot` array is build from `H` and the `Nlay` values to indicate top and bottom of each layer, and `delrow` and `delcol` are computed from model size `L` and number of cells `N`. Once these are all computed, the Discretization file is built.

[9]:
```
bot = np.linspace(-H / Nlay, -H, Nlay)
delrow = delcol = L / (N - 1)
dis = flopy.mf6.ModflowGwfdis(
    gwf,
    nlay=Nlay,
    nrow=N,
    ncol=N,
    delr=delrow,
    delc=delcol,
    top=0.0,
    botm=bot,
)
```

Create the initial conditions (IC) Package

[10]:
```
start = h1 * np.ones((Nlay, N, N))
ic = flopy.mf6.ModflowGwfic(gwf, pname="ic", strt=start)
```

Create the node property flow (NPF) Package

[11]:
```
npf = flopy.mf6.ModflowGwfnpf(
    gwf,
    icelltype=1,
    k=k,
)
```

Create the constant head (CHD) Package

List information is created a bit differently for MODFLOW 6 than for other MODFLOW versions. The cellid (layer, row, column, for a regular grid) can be entered as a tuple as the first entry. Remember that these must be zero-based indices!

[12]:
```
chd_rec = []
layer = 0
for row_col in range(0, N):
    chd_rec.append(((layer, row_col, 0), h1))
    chd_rec.append(((layer, row_col, N - 1), h1))
    if row_col != 0 and row_col != N - 1:
```

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```
        chd_rec.append(((layer, 0, row_col), h1))
        chd_rec.append(((layer, N - 1, row_col), h1))
chd = flopy.mf6.ModflowGwfchd(
    gwf,
    stress_period_data=chd_rec,
)
```

The CHD Package stored the constant heads in a structured array, also called a `numpy.recarray`. We can get a pointer to the recarray for the first stress period (iper = 0) as follows.

[13]:
```
iper = 0
ra = chd.stress_period_data.get_data(key=iper)
ra
```

[13]:
```
rec.array([((0, 0, 0), 100), ((0, 0, 100), 100), ((0, 1, 0), 100),
           ((0, 1, 100), 100), ((0, 0, 1), 100), ((0, 100, 1), 100),
           ((0, 2, 0), 100), ((0, 2, 100), 100), ((0, 0, 2), 100),
           ((0, 100, 2), 100), ((0, 3, 0), 100), ((0, 3, 100), 100),
           ((0, 0, 3), 100), ((0, 100, 3), 100), ((0, 4, 0), 100),
           ((0, 4, 100), 100), ((0, 0, 4), 100), ((0, 100, 4), 100),
           ((0, 5, 0), 100), ((0, 5, 100), 100), ((0, 0, 5), 100),
           ((0, 100, 5), 100), ((0, 6, 0), 100), ((0, 6, 100), 100),
           ((0, 0, 6), 100), ((0, 100, 6), 100), ((0, 7, 0), 100),
           ((0, 7, 100), 100), ((0, 0, 7), 100), ((0, 100, 7), 100),
           ((0, 8, 0), 100), ((0, 8, 100), 100), ((0, 0, 8), 100),
           ((0, 100, 8), 100), ((0, 9, 0), 100), ((0, 9, 100), 100),
           ((0, 0, 9), 100), ((0, 100, 9), 100), ((0, 10, 0), 100),
           ((0, 10, 100), 100), ((0, 0, 10), 100), ((0, 100, 10), 100),
           ((0, 11, 0), 100), ((0, 11, 100), 100), ((0, 0, 11), 100),
           ((0, 100, 11), 100), ((0, 12, 0), 100), ((0, 12, 100), 100),
           ((0, 0, 12), 100), ((0, 100, 12), 100), ((0, 13, 0), 100),
           ((0, 13, 100), 100), ((0, 0, 13), 100), ((0, 100, 13), 100),
           ((0, 14, 0), 100), ((0, 14, 100), 100), ((0, 0, 14), 100),
           ((0, 100, 14), 100), ((0, 15, 0), 100), ((0, 15, 100), 100),
           ((0, 0, 15), 100), ((0, 100, 15), 100), ((0, 16, 0), 100),
           ((0, 16, 100), 100), ((0, 0, 16), 100), ((0, 100, 16), 100),
           ((0, 17, 0), 100), ((0, 17, 100), 100), ((0, 0, 17), 100),
           ((0, 100, 17), 100), ((0, 18, 0), 100), ((0, 18, 100), 100),
           ((0, 0, 18), 100), ((0, 100, 18), 100), ((0, 19, 0), 100),
           ((0, 19, 100), 100), ((0, 0, 19), 100), ((0, 100, 19), 100),
           ((0, 20, 0), 100), ((0, 20, 100), 100), ((0, 0, 20), 100),
           ((0, 100, 20), 100), ((0, 21, 0), 100), ((0, 21, 100), 100),
           ((0, 0, 21), 100), ((0, 100, 21), 100), ((0, 22, 0), 100),
           ((0, 22, 100), 100), ((0, 0, 22), 100), ((0, 100, 22), 100),
           ((0, 23, 0), 100), ((0, 23, 100), 100), ((0, 0, 23), 100),
           ((0, 100, 23), 100), ((0, 24, 0), 100), ((0, 24, 100), 100),
           ((0, 0, 24), 100), ((0, 100, 24), 100), ((0, 25, 0), 100),
           ((0, 25, 100), 100), ((0, 0, 25), 100), ((0, 100, 25), 100),
           ((0, 26, 0), 100), ((0, 26, 100), 100), ((0, 0, 26), 100),
           ((0, 100, 26), 100), ((0, 27, 0), 100), ((0, 27, 100), 100),
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        ((0, 0, 99), 100), ((0, 100, 99), 100), ((0, 100, 0), 100),
        ((0, 100, 100), 100)],
       dtype=[('cellid', 'O'), ('head', '<i8')])
```

Create the well (WEL) Package

Add a well in model layer 10.

[14]:
```
wel_rec = [(Nlay - 1, int(N / 4), int(N / 4), q)]
wel = flopy.mf6.ModflowGwfwel(
    gwf,
    stress_period_data=wel_rec,
)
```

Create the output control (OC) Package

Save heads and budget output to binary files and print heads to the model listing file at the end of the stress period.

[15]:
```
headfile = f"{name}.hds"
head_filerecord = [headfile]
budgetfile = f"{name}.cbb"
budget_filerecord = [budgetfile]
saverecord = [("HEAD", "ALL"), ("BUDGET", "ALL")]
printrecord = [("HEAD", "LAST")]
oc = flopy.mf6.ModflowGwfoc(
    gwf,
    saverecord=saverecord,
    head_filerecord=head_filerecord,
    budget_filerecord=budget_filerecord,
    printrecord=printrecord,
)
```

Create the MODFLOW 6 Input Files and Run the Model

Once all the flopy objects are created, it is very easy to create all of the input files and run the model.

Write the datasets

[16]:
```
sim.write_simulation()
```

```
writing simulation...
  writing simulation name file...
  writing simulation tdis package...
  writing solution package ims...
  writing model tutorial01_mf6...
    writing model name file...
    writing package dis...
    writing package ic...
    writing package npf...
    writing package chd_0...
INFORMATION: maxbound in ('gwf6', 'chd', 'dimensions') changed to 400 based on size of␣
↪stress_period_data
    writing package wel_0...
INFORMATION: maxbound in ('gwf6', 'wel', 'dimensions') changed to 1 based on size of␣
```

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```
↪stress_period_data
    writing package oc...
```

Run the Simulation

We can also run the simulation from python, but only if the MODFLOW 6 executable is available. The executable can be made available by putting the executable in a folder that is listed in the system path variable. Another option is to just put a copy of the executable in the simulation folder, though this should generally be avoided. A final option is to provide a full path to the executable when the simulation is constructed. This would be done by specifying exe_name with the full path.

[17]:
```python
success, buff = sim.run_simulation()
assert success, "MODFLOW 6 did not terminate normally."
```

```
FloPy is using the following executable to run the model: ../../home/runner/.local/bin/
↪modflow/mf6
                                   MODFLOW 6
                U.S. GEOLOGICAL SURVEY MODULAR HYDROLOGIC MODEL
                            VERSION 6.4.2 06/28/2023

   MODFLOW 6 compiled Jul 05 2023 20:29:14 with Intel(R) Fortran Intel(R) 64
   Compiler Classic for applications running on Intel(R) 64, Version 2021.7.0
                             Build 20220726_000000

This software has been approved for release by the U.S. Geological
Survey (USGS). Although the software has been subjected to rigorous
review, the USGS reserves the right to update the software as needed
pursuant to further analysis and review. No warranty, expressed or
implied, is made by the USGS or the U.S. Government as to the
functionality of the software and related material nor shall the
fact of release constitute any such warranty. Furthermore, the
software is released on condition that neither the USGS nor the U.S.
Government shall be held liable for any damages resulting from its
authorized or unauthorized use. Also refer to the USGS Water
Resources Software User Rights Notice for complete use, copyright,
and distribution information.


 Run start date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:26:34

 Writing simulation list file: mfsim.lst
 Using Simulation name file: mfsim.nam

    Solving:  Stress period:     1    Time step:     1

 Run end date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:26:36
 Elapsed run time:  1.863 Seconds

 Normal termination of simulation.
```

Post-Process Head Results

First, a link to the heads file is created with using the `.output.head()` method on the groundwater flow model. The link and the `get_data` method are used with the step number and period number for which we want to retrieve data. A three-dimensional array is returned of size `nlay, nrow, ncol`. Matplotlib contouring functions are used to make contours of the layers or a cross-section.

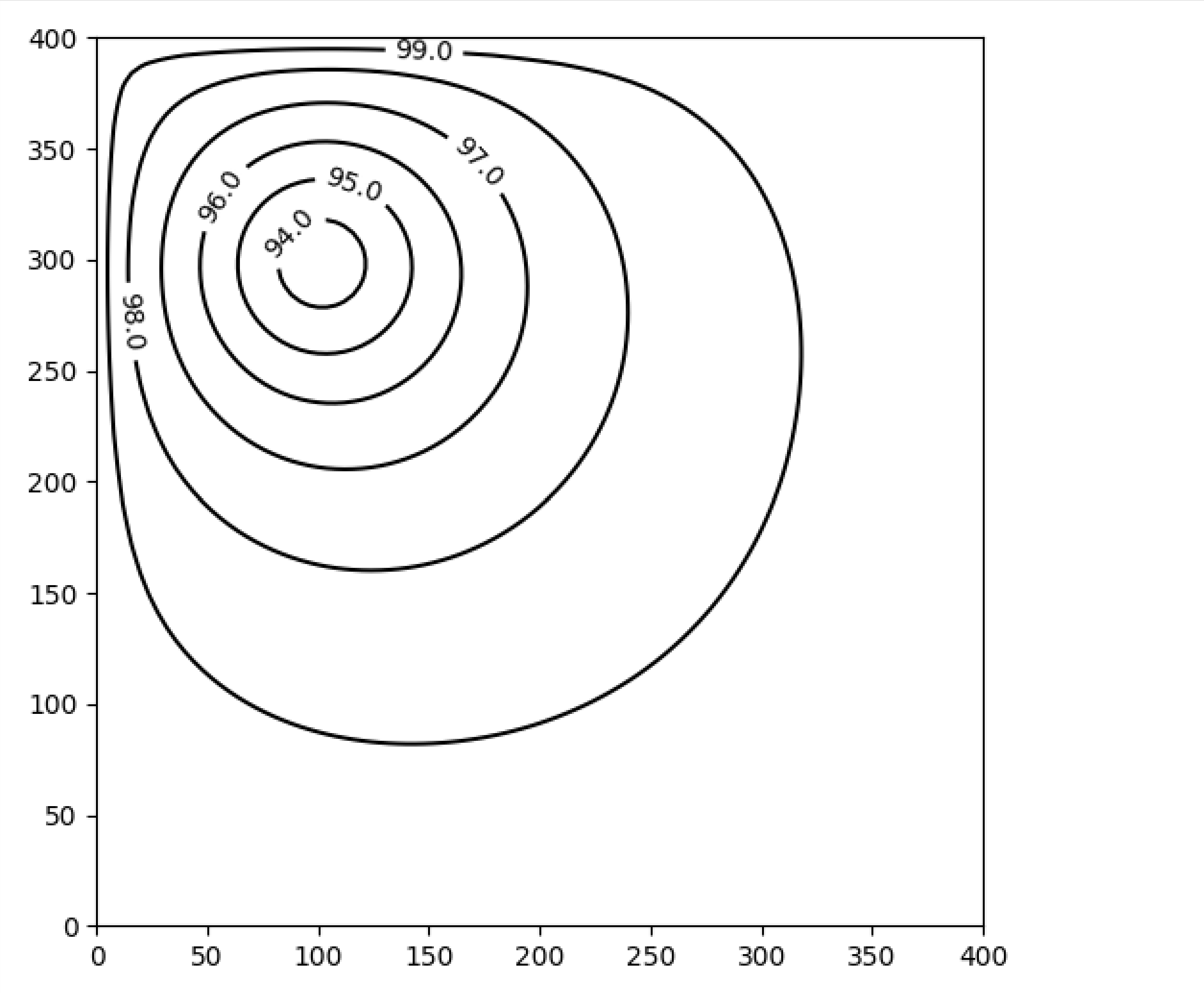
Read the binary head file and plot the results. We can use the Flopy `.output.head()` method on the groundwater flow model object (`gwf`). Also set a few variables that will be used for plotting.

[18]:
```
h = gwf.output.head().get_data(kstpkper=(0, 0))
x = y = np.linspace(0, L, N)
y = y[::-1]
vmin, vmax = 90.0, 100.0
contour_intervals = np.arange(90, 100.1, 1.0)
```

Plot a Map of Layer 1

[19]:
```
fig = plt.figure(figsize=(6, 6))
ax = fig.add_subplot(1, 1, 1, aspect="equal")
c = ax.contour(x, y, h[0], contour_intervals, colors="black")
plt.clabel(c, fmt="%2.1f")
```

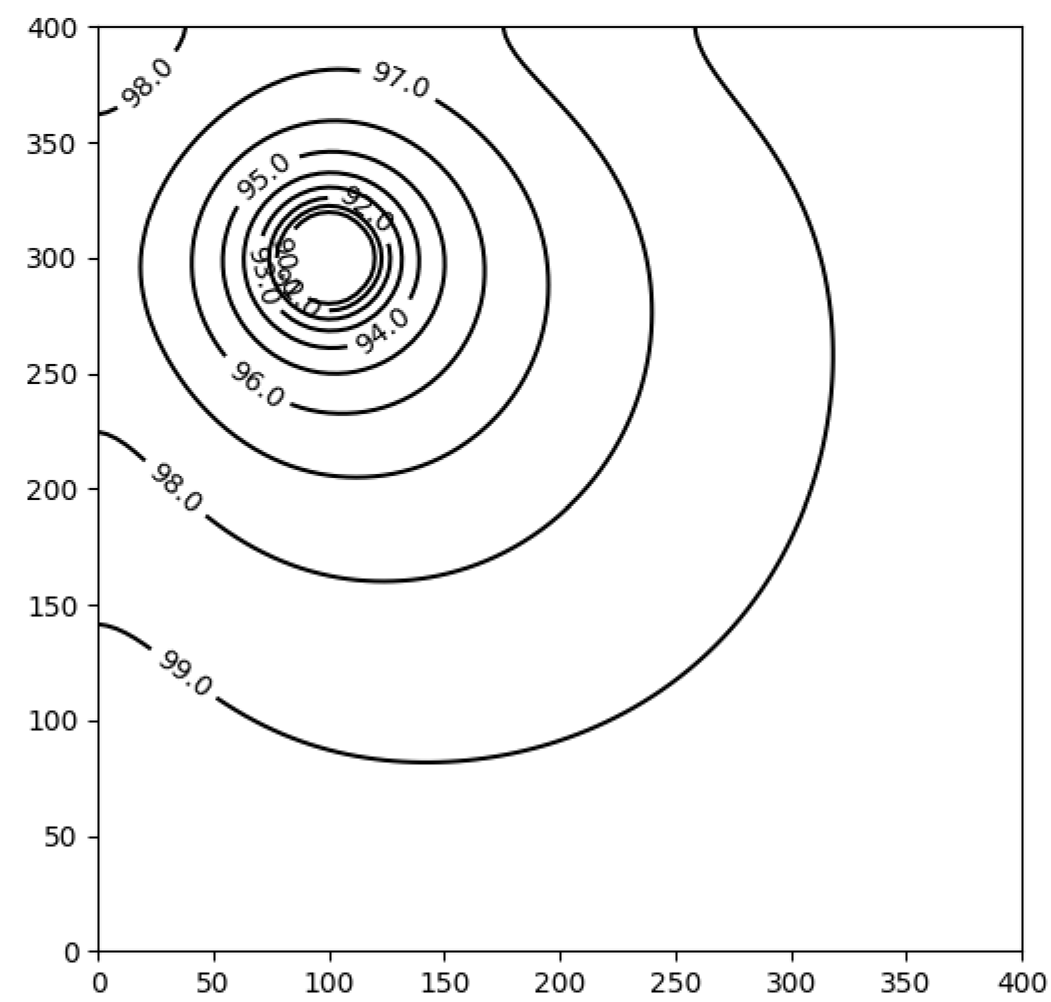
[19]:
```
<a list of 6 text.Text objects>
```



Plot a Map of Layer 10

[20]:
```
x = y = np.linspace(0, L, N)
y = y[::-1]
fig = plt.figure(figsize=(6, 6))
ax = fig.add_subplot(1, 1, 1, aspect="equal")
c = ax.contour(x, y, h[-1], contour_intervals, colors="black")
plt.clabel(c, fmt="%1.1f")
```

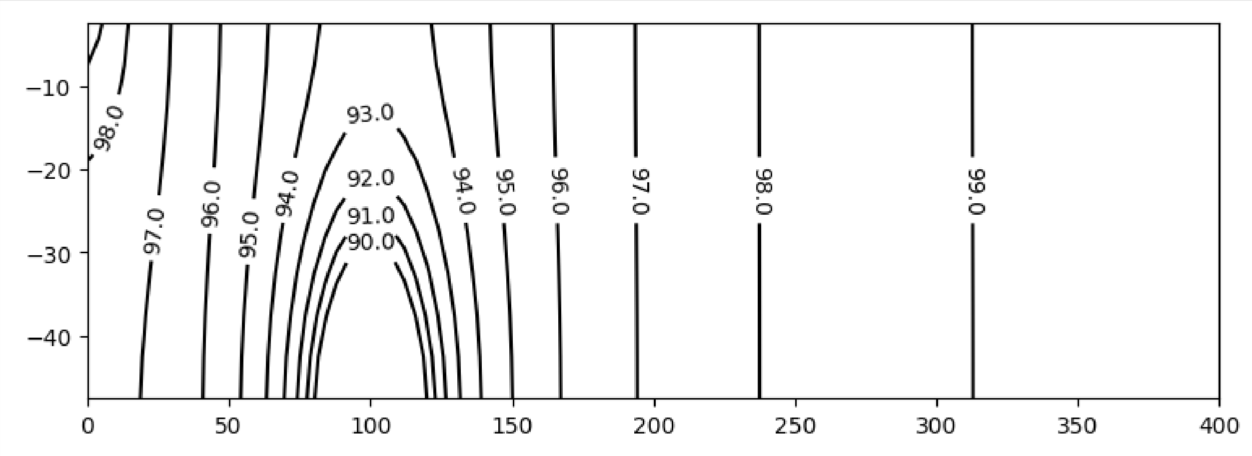
[20]:
```
<a list of 11 text.Text objects>
```



Plot a Cross-section along row 25

[21]:
```
z = np.linspace(-H / Nlay / 2, -H + H / Nlay / 2, Nlay)
fig = plt.figure(figsize=(9, 3))
ax = fig.add_subplot(1, 1, 1, aspect="auto")
c = ax.contour(x, z, h[:, int(N / 4), :], contour_intervals, colors="black")
plt.clabel(c, fmt="%1.1f")
```

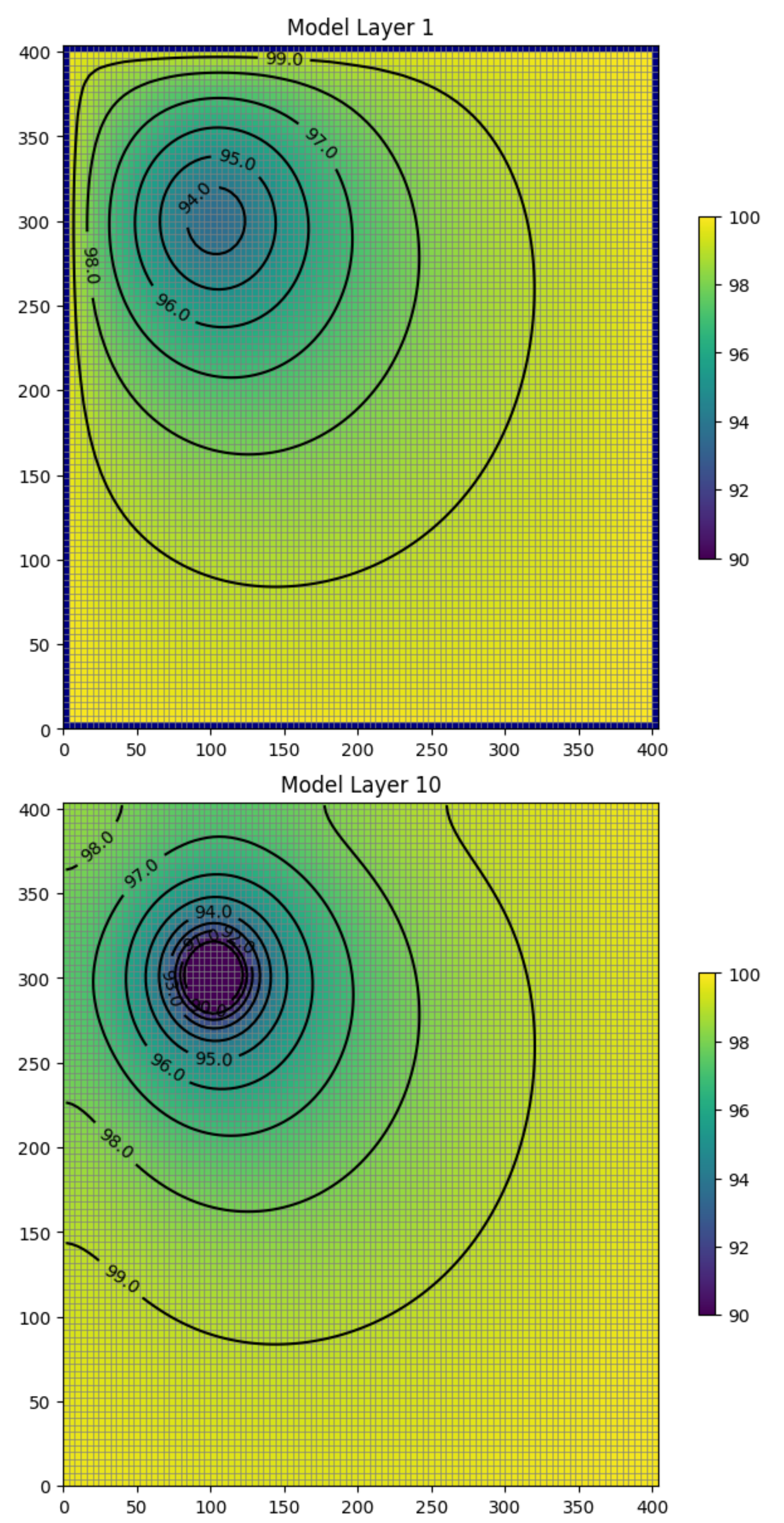
[21]:
```
<a list of 15 text.Text objects>
```



Use the FloPy `PlotMapView()` capabilities for MODFLOW 6

Plot a Map of heads in Layers 1 and 10

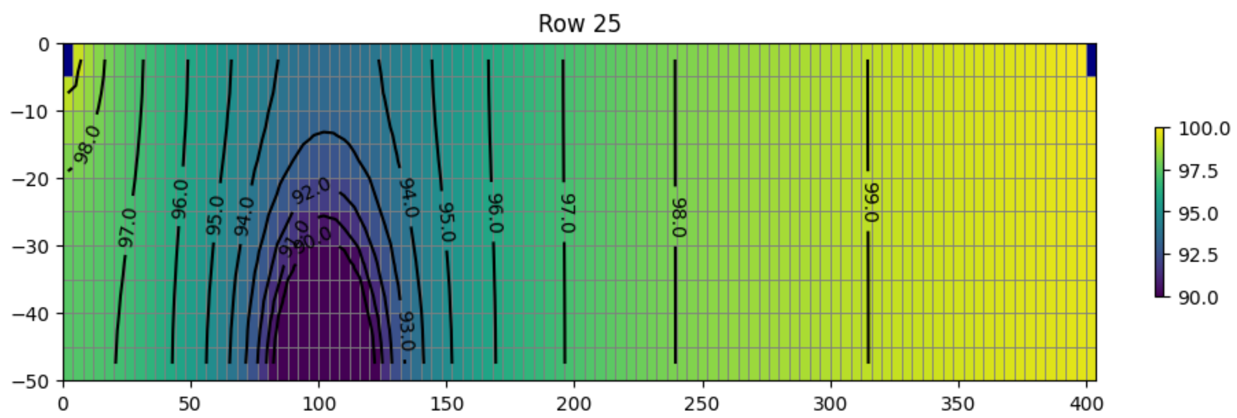
[22]:
```python
fig, axes = plt.subplots(2, 1, figsize=(6, 12), constrained_layout=True)
# first subplot
ax = axes[0]
ax.set_title("Model Layer 1")
modelmap = flopy.plot.PlotMapView(model=gwf, ax=ax)
pa = modelmap.plot_array(h, vmin=vmin, vmax=vmax)
quadmesh = modelmap.plot_bc("CHD")
linecollection = modelmap.plot_grid(lw=0.5, color="0.5")
contours = modelmap.contour_array(
    h,
    levels=contour_intervals,
    colors="black",
)
ax.clabel(contours, fmt="%2.1f")
cb = plt.colorbar(pa, shrink=0.5, ax=ax)
# second subplot
ax = axes[1]
ax.set_title(f"Model Layer {Nlay}")
modelmap = flopy.plot.PlotMapView(model=gwf, ax=ax, layer=Nlay - 1)
linecollection = modelmap.plot_grid(lw=0.5, color="0.5")
pa = modelmap.plot_array(h, vmin=vmin, vmax=vmax)
quadmesh = modelmap.plot_bc("CHD")
contours = modelmap.contour_array(
    h,
    levels=contour_intervals,
    colors="black",
)
ax.clabel(contours, fmt="%2.1f")
cb = plt.colorbar(pa, shrink=0.5, ax=ax)
```


Model Layer 1
Model Layer 10
99.0
97.0
95.0
94.0
98.0
96.0
100
98
96
94
92
90

Use the FloPy `PlotCrossSection()` capabilities for MODFLOW 6

Plot a cross-section of heads along row 25

[23]:
```
fig, ax = plt.subplots(1, 1, figsize=(9, 3), constrained_layout=True)
# first subplot
ax.set_title("Row 25")
modelmap = flopy.plot.PlotCrossSection(
    model=gwf,
    ax=ax,
    line={"row": int(N / 4)},
)
pa = modelmap.plot_array(h, vmin=vmin, vmax=vmax)
quadmesh = modelmap.plot_bc("CHD")
linecollection = modelmap.plot_grid(lw=0.5, color="0.5")
contours = modelmap.contour_array(
    h,
    levels=contour_intervals,
    colors="black",
)
ax.clabel(contours, fmt="%2.1f")
cb = plt.colorbar(pa, shrink=0.5, ax=ax)
```



Determine the Flow Residual

The `FLOW-JA-FACE` cell-by-cell budget data can be processed to determine the flow residual for each cell in a MODFLOW 6 model. The diagonal position for each row in the `FLOW-JA-FACE` cell-by-cell budget data contains the flow residual for each cell and can be extracted using the `flopy.mf6.utils.get_residuals()` function.

First extract the `FLOW-JA-FACE` array from the cell-by-cell budget file

[24]:
```
flowja = gwf.oc.output.budget().get_data(text="FLOW-JA-FACE", kstpkper=(0, 0))[
    0
]
```

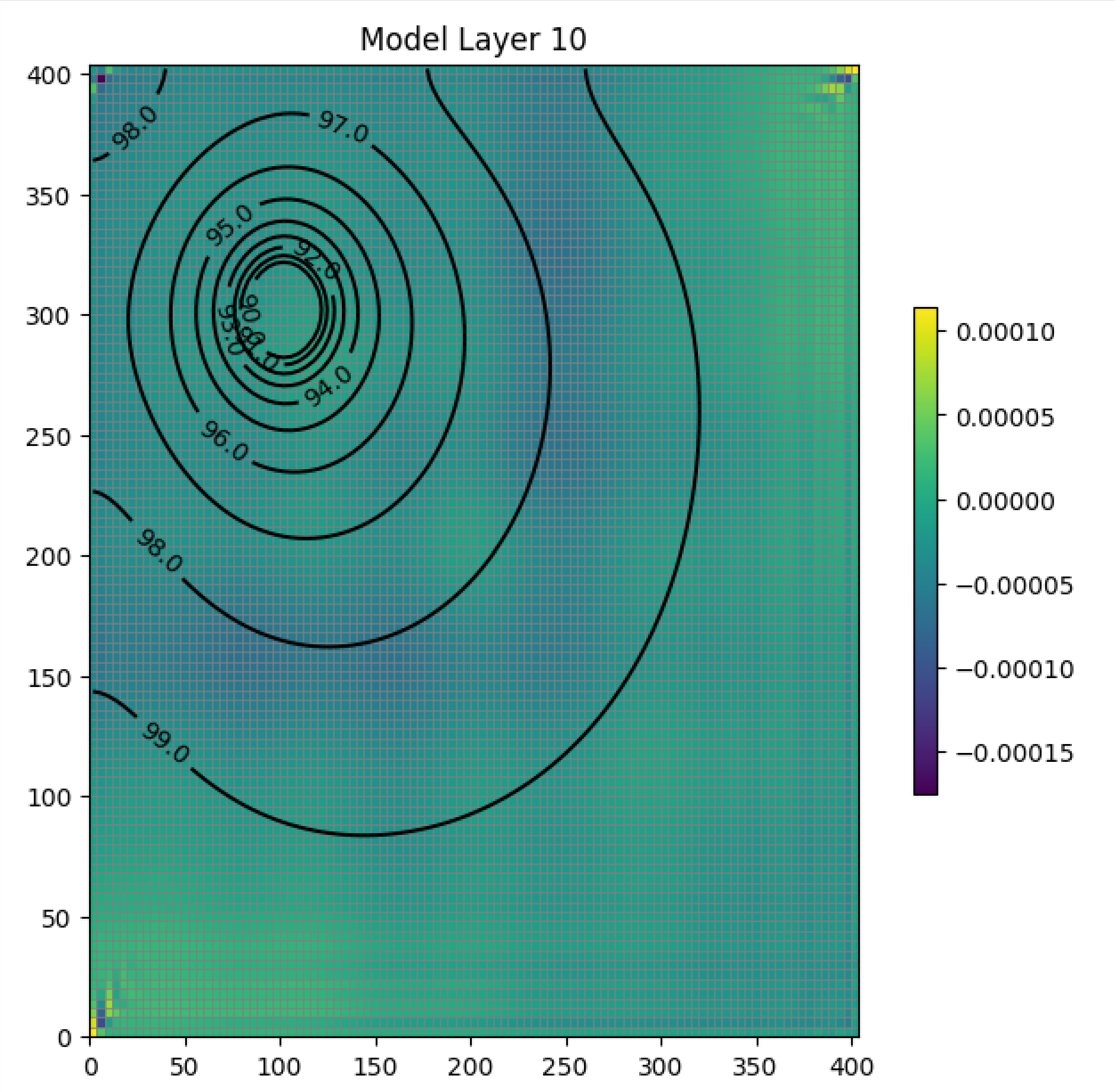
Next extract the flow residual. The MODFLOW 6 binary grid file is passed into the function because it contains the ia array that defines the location of the diagonal position in the `FLOW-JA-FACE` array.

[25]:
```
grb_file = workspace / f"{name}.dis.grb"
residual = flopy.mf6.utils.get_residuals(flowja, grb_file=grb_file)
```

Plot a Map of the flow error in Layer 10

[26]:
```
fig, ax = plt.subplots(1, 1, figsize=(6, 6), constrained_layout=True)
ax.set_title("Model Layer 10")
modelmap = flopy.plot.PlotMapView(model=gwf, ax=ax, layer=Nlay - 1)
pa = modelmap.plot_array(residual)
quadmesh = modelmap.plot_bc("CHD")
linecollection = modelmap.plot_grid(lw=0.5, color="0.5")
contours = modelmap.contour_array(
    h,
    levels=contour_intervals,
    colors="black",
)
ax.clabel(contours, fmt="%2.1f")
plt.colorbar(pa, shrink=0.5)
```

[26]:
```
<matplotlib.colorbar.Colorbar at 0x7f7f036830d0>
```



Clean up the temporary directory

[27]:
```python
try:
    temp_dir.cleanup()
except PermissionError:
    # can occur on windows: https://docs.python.org/3/library/tempfile.html#tempfile.
↪TemporaryDirectory
    pass
```

5.3 MODFLOW-2005

5.3.1 MODFLOW-2005 Basic stress packages

Flopy has a new way to enter boundary conditions for some MODFLOW packages. These changes are substantial. Boundary conditions can now be entered as a list of boundaries, as a numpy recarray, or as a dictionary. These different styles are described in this notebook.

Flopy also now requires zero-based input. This means that **all boundaries are entered in zero-based layer, row, and column indices**. This means that older Flopy scripts will need to be modified to account for this change. If you are familiar with Python, this should be natural, but if not, then it may take some time to get used to zero-based numbering. Flopy users submit all information in zero-based form, and Flopy converts this to the one-based form required by MODFLOW.

The following MODFLOW-2005 packages are affected by this change:

- Well
- Drain
- River
- General-Head Boundary
- Time-Variant Constant Head

This notebook explains the different ways to enter these types of boundary conditions.

[1]:
```
# begin by importing flopy
import os
import sys
from tempfile import TemporaryDirectory

import numpy as np

# run installed version of flopy or add local path
try:
    import flopy
except:
    fpth = os.path.abspath(os.path.join("..", ".."))
    sys.path.append(fpth)
    import flopy

# temporary directory
temp_dir = TemporaryDirectory()
workspace = os.path.join(temp_dir.name)

print(sys.version)
print(f"numpy version: {np.__version__}")
print(f"flopy version: {flopy.__version__}")
```

```
3.8.18 (default, Aug 28 2023, 08:27:22)
[GCC 11.4.0]
numpy version: 1.24.4
flopy version: 3.5.0
```

List of Boundaries

Boundary condition information is passed to a package constructor as stress_period_data. In its simplest form, stress_period_data can be a list of individual boundaries, which themselves are lists. The following shows a simple example for a MODFLOW River Package boundary:

[2]:
```
stress_period_data = [
    [
        2,
        3,
        4,
        10.7,
        5000.0,
        -5.7,
    ],  # layer, row, column, stage, conductance, river bottom
    [
        2,
        3,
        5,
        10.7,
        5000.0,
        -5.7,
    ],  # layer, row, column, stage, conductance, river bottom
    [
        2,
        3,
        6,
        10.7,
        5000.0,
        -5.7,
    ],  # layer, row, column, stage, conductance, river bottom
]
m = flopy.modflow.Modflow(modelname="test", model_ws=workspace)
riv = flopy.modflow.ModflowRiv(m, stress_period_data=stress_period_data)
m.write_input()
```

If we look at the River Package created here, you see that the layer, row, and column numbers have been increased by one.

[3]:
```
!head -n 10 '../../examples/data/test.riv'
```

```
head: cannot open '../../examples/data/test.riv' for reading: No such file or directory
```

If this model had more than one stress period, then Flopy will assume that this boundary condition information applies until the end of the simulation

[4]:
```
m = flopy.modflow.Modflow(modelname="test", model_ws=workspace)
dis = flopy.modflow.ModflowDis(m, nper=3)
riv = flopy.modflow.ModflowRiv(m, stress_period_data=stress_period_data)
m.write_input()
!head -n 10 '../../examples/data/test.riv'
```

```
head: cannot open '../../examples/data/test.riv' for reading: No such file or directory
```

Recarray of Boundaries

Numpy allows the use of recarrays, which are numpy arrays in which each column of the array may be given a different type. Boundary conditions can be entered as recarrays. Information on the structure of the recarray for a boundary condition package can be obtained from that particular package. The structure of the recarray is contained in the dtype.

[5]:
```
riv_dtype = flopy.modflow.ModflowRiv.get_default_dtype()
print(riv_dtype)
```

```
[('k', '<i8'), ('i', '<i8'), ('j', '<i8'), ('stage', '<f4'), ('cond', '<f4'), ('rbot', '
↪<f4')]
```

Now that we know the structure of the recarray that we want to create, we can create a new one as follows.

[6]:
```
stress_period_data = np.zeros((3), dtype=riv_dtype)
stress_period_data = stress_period_data.view(np.recarray)
print("stress_period_data: ", stress_period_data)
print("type is: ", type(stress_period_data))
```

```
stress_period_data:  [(0, 0, 0, 0., 0., 0.) (0, 0, 0, 0., 0., 0.) (0, 0, 0, 0., 0., 0.)]
type is:  <class 'numpy.recarray'>
```

We can then fill the recarray with our boundary conditions.

[7]:
```
stress_period_data[0] = (2, 3, 4, 10.7, 5000.0, -5.7)
stress_period_data[1] = (2, 3, 5, 10.7, 5000.0, -5.7)
stress_period_data[2] = (2, 3, 6, 10.7, 5000.0, -5.7)
print(stress_period_data)
```

```
[(2, 3, 4, 10.7, 5000., -5.7) (2, 3, 5, 10.7, 5000., -5.7)
 (2, 3, 6, 10.7, 5000., -5.7)]
```

[8]:
```
m = flopy.modflow.Modflow(modelname="test", model_ws=workspace)
riv = flopy.modflow.ModflowRiv(m, stress_period_data=stress_period_data)
m.write_input()
!head -n 10 '../../examples/data/test.riv'
```

```
head: cannot open '../../examples/data/test.riv' for reading: No such file or directory
```

As before, if we have multiple stress periods, then this recarray will apply to all of them.

[9]:
```
m = flopy.modflow.Modflow(modelname="test", model_ws=workspace)
dis = flopy.modflow.ModflowDis(m, nper=3)
riv = flopy.modflow.ModflowRiv(m, stress_period_data=stress_period_data)
m.write_input()
!head -n 10 '../../examples/data/test.riv'
```

```
head: cannot open '../../examples/data/test.riv' for reading: No such file or directory
```

Dictionary of Boundaries

The power of the new functionality in Flopy3 is the ability to specify a dictionary for stress_period_data. If specified as a dictionary, the key is the stress period number (**as a zero-based number**), and the value is either a nested list, an integer value of 0 or -1, or a recarray for that stress period.

Let's say that we want to use the following schedule for our rivers: 0. No rivers in stress period zero 1. Rivers specified by a list in stress period 1 2. No rivers 3. No rivers 4. No rivers 5. Rivers specified by a recarray 6. Same recarray rivers 7. Same recarray rivers 8. Same recarray rivers

[10]:
```
sp1 = [
    [
        2,
        3,
        4,
        10.7,
        5000.0,
        -5.7,
    ],  # layer, row, column, stage, conductance, river bottom
    [
        2,
        3,
        5,
        10.7,
        5000.0,
        -5.7,
    ],  # layer, row, column, stage, conductance, river bottom
    [
        2,
        3,
        6,
        10.7,
        5000.0,
        -5.7,
    ],  # layer, row, column, stage, conductance, river bottom
]
print(sp1)
```

```
[[2, 3, 4, 10.7, 5000.0, -5.7], [2, 3, 5, 10.7, 5000.0, -5.7], [2, 3, 6, 10.7, 5000.0, -
↪5.7]]
```

[11]:
```
riv_dtype = flopy.modflow.ModflowRiv.get_default_dtype()
sp5 = np.zeros((3), dtype=riv_dtype)
sp5 = sp5.view(np.recarray)
sp5[0] = (2, 3, 4, 20.7, 5000.0, -5.7)
sp5[1] = (2, 3, 5, 20.7, 5000.0, -5.7)
sp5[2] = (2, 3, 6, 20.7, 5000.0, -5.7)
print(sp5)
```

```
[(2, 3, 4, 20.7, 5000., -5.7) (2, 3, 5, 20.7, 5000., -5.7)
 (2, 3, 6, 20.7, 5000., -5.7)]
```

[12]:
```
sp_dict = {0: 0, 1: sp1, 2: 0, 5: sp5}
m = flopy.modflow.Modflow(modelname="test", model_ws=workspace)
```

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```
dis = flopy.modflow.ModflowDis(m, nper=8)
riv = flopy.modflow.ModflowRiv(m, stress_period_data=sp_dict)
m.write_input()
!head -n 10 '../../examples/data/test.riv'
```

```
head: cannot open '../../examples/data/test.riv' for reading: No such file or directory
```

MODFLOW Auxiliary Variables

Flopy works with MODFLOW auxiliary variables by allowing the recarray to contain additional columns of information. The auxiliary variables must be specified as package options as shown in the example below.

In this example, we also add a string in the last column of the list in order to name each boundary condition. In this case, however, we do not include boundname as an auxiliary variable as MODFLOW would try to read it as a floating point number.

[13]:
```
# create an empty array with an iface auxiliary variable at the end
riva_dtype = [
    ("k", "<i8"),
    ("i", "<i8"),
    ("j", "<i8"),
    ("stage", "<f4"),
    ("cond", "<f4"),
    ("rbot", "<f4"),
    ("iface", "<i4"),
    ("boundname", object),
]
riva_dtype = np.dtype(riva_dtype)
stress_period_data = np.zeros((3), dtype=riva_dtype)
stress_period_data = stress_period_data.view(np.recarray)
print("stress_period_data: ", stress_period_data)
print("type is: ", type(stress_period_data))
```

```
stress_period_data:  [(0, 0, 0, 0., 0., 0., 0, 0) (0, 0, 0, 0., 0., 0., 0, 0)
 (0, 0, 0, 0., 0., 0., 0, 0)]
type is:  <class 'numpy.recarray'>
```

[14]:
```
stress_period_data[0] = (2, 3, 4, 10.7, 5000.0, -5.7, 1, "riv1")
stress_period_data[1] = (2, 3, 5, 10.7, 5000.0, -5.7, 2, "riv2")
stress_period_data[2] = (2, 3, 6, 10.7, 5000.0, -5.7, 3, "riv3")
print(stress_period_data)
```

```
[(2, 3, 4, 10.7, 5000., -5.7, 1, 'riv1')
 (2, 3, 5, 10.7, 5000., -5.7, 2, 'riv2')
 (2, 3, 6, 10.7, 5000., -5.7, 3, 'riv3')]
```

[15]:
```
m = flopy.modflow.Modflow(modelname="test", model_ws=workspace)
riv = flopy.modflow.ModflowRiv(
    m,
    stress_period_data=stress_period_data,
    dtype=riva_dtype,
    options=["aux iface"],
```

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```
)
m.write_input()
!head -n 10 '../../examples/data/test.riv'
```

```
head: cannot open '../../examples/data/test.riv' for reading: No such file or directory
```

Working with Unstructured Grids

Flopy can create an unstructured grid boundary condition package for MODFLOW-USG. This can be done by specifying a custom dtype for the recarray. The following shows an example of how that can be done.

[16]:
```
# create an empty array based on nodenumber instead of layer, row, and column
rivu_dtype = [
    ("nodenumber", "<i8"),
    ("stage", "<f4"),
    ("cond", "<f4"),
    ("rbot", "<f4"),
]
rivu_dtype = np.dtype(rivu_dtype)
stress_period_data = np.zeros((3), dtype=rivu_dtype)
stress_period_data = stress_period_data.view(np.recarray)
print("stress_period_data: ", stress_period_data)
print("type is: ", type(stress_period_data))
```

```
stress_period_data:  [(0, 0., 0., 0.) (0, 0., 0., 0.) (0, 0., 0., 0.)]
type is:  <class 'numpy.recarray'>
```

[17]:
```
stress_period_data[0] = (77, 10.7, 5000.0, -5.7)
stress_period_data[1] = (245, 10.7, 5000.0, -5.7)
stress_period_data[2] = (450034, 10.7, 5000.0, -5.7)
print(stress_period_data)
```

```
[(    77, 10.7, 5000., -5.7) (   245, 10.7, 5000., -5.7)
 (450034, 10.7, 5000., -5.7)]
```

[18]:
```
m = flopy.modflow.Modflow(modelname="test", model_ws=workspace)
riv = flopy.modflow.ModflowRiv(
    m, stress_period_data=stress_period_data, dtype=rivu_dtype
)
m.write_input()
!head -n 10 '../../examples/data/test.riv'
```

```
head: cannot open '../../examples/data/test.riv' for reading: No such file or directory
```

Combining two boundary condition packages

[19]:
```
ml = flopy.modflow.Modflow(modelname="test", model_ws=workspace)
dis = flopy.modflow.ModflowDis(ml, 10, 10, 10, 10)
sp_data1 = {3: [1, 1, 1, 1.0], 5: [1, 2, 4, 4.0]}
wel1 = flopy.modflow.ModflowWel(ml, stress_period_data=sp_data1)
ml.write_input()
!head -n 10 '../../examples/data/test.wel'
```

```
head: cannot open '../../examples/data/test.wel' for reading: No such file or directory
```

[20]:
```
sp_data2 = {0: [1, 1, 3, 3.0], 8: [9, 2, 4, 4.0]}
wel2 = flopy.modflow.ModflowWel(ml, stress_period_data=sp_data2)
ml.write_input()
!head -n 10 '../../examples/data/test.wel'
```

```
head: cannot open '../../examples/data/test.wel' for reading: No such file or directory
```

```
/opt/hostedtoolcache/Python/3.8.18/x64/lib/python3.8/site-packages/flopy/mbase.py:658:
↪UserWarning: Unit 20 of package WEL already in use.
  warn(
/opt/hostedtoolcache/Python/3.8.18/x64/lib/python3.8/site-packages/flopy/mbase.py:667:
↪UserWarning: Two packages of the same type, Replacing existing 'WEL' package.
  warn(
```

Now we create a third wel package, using the `MfList.append()` method:

[21]:
```
wel3 = flopy.modflow.ModflowWel(
    ml,
    stress_period_data=wel2.stress_period_data.append(wel1.stress_period_data),
)
ml.write_input()
!head -n 10 '../../examples/data/test.wel'
```

```
head: cannot open '../../examples/data/test.wel' for reading: No such file or directory
```

5.3.2 Error checking for MODFLOW-2005 models

[1]:
```
import os
import sys
from tempfile import TemporaryDirectory

# run installed version of flopy or add local path
try:
    import flopy
except:
    fpth = os.path.abspath(os.path.join("..", ".."))
    sys.path.append(fpth)
    import flopy

print(sys.version)
print(f"flopy version: {flopy.__version__}")
```

```
3.8.18 (default, Aug 28 2023, 08:27:22)
[GCC 11.4.0]
flopy version: 3.5.0
```

Set the working directory

```
[2]: path = os.path.join("..", "..", "examples", "data", "mf2005_test")
```

Load example dataset and change the model work space

```
[3]: m = flopy.modflow.Modflow.load("test1ss.nam", model_ws=path)
temp_dir = TemporaryDirectory()
workspace = temp_dir.name
m.change_model_ws(workspace)
```

By default, the checker performs a model-level check when a set of model files are loaded, unless load is called with `check=False`. The load check only produces screen output if load is called with `verbose=True`. Checks are also performed at the package level when an individual package is loaded

The `check()` method

Each model and each package has a `check()` method. The check method has three arguments:

```
[4]: help(m.check)
```

```
Help on method check in module flopy.mbase:

check(f: Union[str, os.PathLike, NoneType] = None, verbose=True, level=1) method of␣
↪flopy.modflow.mf.Modflow instance
    Check model data for common errors.

    Parameters
    ----------
    f : str or PathLike, optional, default None
        String defining file name or file handle for summary file
        of check method output. If a string is passed a file handle
        is created. If f is None, check method does not write
        results to a summary file. (default is None)
    verbose : bool
        Boolean flag used to determine if check method results are
        written to the screen
    level : int
        Check method analysis level. If level=0, summary checks are
        performed. If level=1, full checks are performed.

    Returns
    -------
    None

    Examples
```

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```
--------

>>> import flopy
>>> m = flopy.modflow.Modflow.load('model.nam')
>>> m.check()
```

The check class

By default, check is called at the model level without a summary output file, but with `verbose=True` and `level=1`. The check methods return an instance of the **check** class, which is housed with the flopy utilities.

[5]:
```
chk = m.check()
```

```
test1ss MODEL DATA VALIDATION SUMMARY:
  3 Warnings:
    OC package: action(s) defined in OC stress_period_data ignored as they are not part␣
↪the stress periods defined by DIS
    RCH package: Mean R/T ratio < checker warning threshold of 2e-08 for 1 stress periods
    RCH package: Variable NRCHOP set to value other than 3

  Checks that passed:
    Unit number conflicts
    Compatible solver package
    DIS package: zero or negative thickness
    DIS package: thin cells (less than checker threshold of 1.0)
    DIS package: nan values in top array
    DIS package: nan values in bottom array
    BAS6 package: isolated cells in ibound array
    BAS6 package: Not a number
    LPF package: zero or negative horizontal hydraulic conductivity values
    LPF package: negative horizontal anisotropy values
    LPF package: vertical hydraulic conductivity values below checker threshold of 1e-11
    LPF package: vertical hydraulic conductivity values above checker threshold of␣
↪100000.0
    LPF package: horizontal hydraulic conductivity values below checker threshold of 1e-
↪11
    LPF package: horizontal hydraulic conductivity values above checker threshold of␣
↪100000.0
    GHB package: BC indices valid
    GHB package: not a number (Nan) entries
    GHB package: BC in inactive cells
    GHB package: BC elevation below cell bottom
```

Summary array

Most of the attributes and methods in **check** are intended to be used by the `check()` methods. The central attribute of **check** is the summary array:

[6]:
```
chk.summary_array
```

[6]:
```
rec.array([('Warning', 'OC', 0, 0, 0, 0.0000000e+00, '\r    OC package: action(s)␣
↪defined in OC stress_period_data ignored as they are not part the stress periods␣
↪defined by DIS'),
           ('Warning', 'RCH', 0, 0, 0, 1.1785914e-09, '\r    RCH package: Mean R/T ratio
↪< checker warning threshold of 2e-08 for 1 stress periods'),
           ('Warning', 'RCH', 0, 0, 0, 1.0000000e+00, '\r    RCH package: Variable␣
↪NRCHOP set to value other than 3')],
          dtype=[('type', 'O'), ('package', 'O'), ('k', '<i8'), ('i', '<i8'), ('j', '<i8
↪'), ('value', '<f8'), ('desc', 'O')])
```

This is a numpy record array that summarizes errors and warnings found by the checker. The package, layer-row-column location of the error, the offending value, and a description of the error are provided. In the checker, errors and warnings are loosely defined as follows: #### Errors:

either input that would cause MODFLOW to crash, or inputs that almost certainly mis-represent the intended conceptual model.

Warnings:

inputs that are potentially problematic, but may be intentional.

each package-level check produces a **check** instance with a summary array. The model level checks combine the summary arrays from the packages into a master summary array. At the model and the package levels, the summary array is used to generate the screen output shown above. At either level, the summary array can be written to a csv file by supply a filename to the `f` argument. Specifying `level=2` prints the summary array to the screen.

[7]:
```
m.check(level=2)
```

```
Errors and/or Warnings encountered.
Errors and/or Warnings encountered.

test1ss MODEL DATA VALIDATION SUMMARY:
  3 Warnings:
    OC package: action(s) defined in OC stress_period_data ignored as they are not part␣
↪the stress periods defined by DIS
    RCH package: Mean R/T ratio < checker warning threshold of 2e-08 for 1 stress periods
    RCH package: Variable NRCHOP set to value other than 3

  Checks that passed:
    Unit number conflicts
    Compatible solver package
    DIS package: zero or negative thickness
    DIS package: thin cells (less than checker threshold of 1.0)
    DIS package: nan values in top array
    DIS package: nan values in bottom array
    BAS6 package: isolated cells in ibound array
    BAS6 package: Not a number
    LPF package: zero or negative horizontal hydraulic conductivity values
```

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```
    LPF package: negative horizontal anisotropy values
    LPF package: vertical hydraulic conductivity values below checker threshold of 1e-11
    LPF package: vertical hydraulic conductivity values above checker threshold of␣
↪100000.0
    LPF package: horizontal hydraulic conductivity values below checker threshold of 1e-
↪11
    LPF package: horizontal hydraulic conductivity values above checker threshold of␣
↪100000.0
    GHB package: BC indices valid
    GHB package: not a number (Nan) entries
    GHB package: BC in inactive cells
    GHB package: BC elevation below cell bottom

DETAILED SUMMARY:
type    package k       i       j       value   desc
Warning OC      0       0       0       0.00e+00        OC package: action(s) defined in␣
↪OC stress_period_data ignored as they are not part the stress periods defined by DIS
Warning RCH     0       0       0       1.18e-09        RCH package: Mean R/T ratio <␣
↪checker warning threshold of 2e-08 for 1 stress periods
Warning RCH     0       0       0       1.00e+00        RCH package: Variable NRCHOP set␣
↪to value other than 3
```

[7]:
```
<flopy.utils.check.check at 0x7f2a384afa30>
```

example of package level check and summary file

[8]:
```
m.rch.check()
```

```
RCH PACKAGE DATA VALIDATION:
  2 Warnings:
    Mean R/T ratio < checker warning threshold of 2e-08 for 1 stress periods
    Variable NRCHOP set to value other than 3
```

[8]:
```
<flopy.utils.check.check at 0x7f2a384afc70>
```

example of summary output file

[9]:
```
m.check(f=os.path.join(workspace, "checksummary.csv"))
```

```
test1ss MODEL DATA VALIDATION SUMMARY:
  3 Warnings:
    OC package: action(s) defined in OC stress_period_data ignored as they are not part␣
↪the stress periods defined by DIS
    RCH package: Mean R/T ratio < checker warning threshold of 2e-08 for 1 stress periods
    RCH package: Variable NRCHOP set to value other than 3
  see ../../../../../../../tmp/tmpi_an_c4v/checksummary.csv for details.

  Checks that passed:
```

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```
    Unit number conflicts
    Compatible solver package
    DIS package: zero or negative thickness
    DIS package: thin cells (less than checker threshold of 1.0)
    DIS package: nan values in top array
    DIS package: nan values in bottom array
    BAS6 package: isolated cells in ibound array
    BAS6 package: Not a number
    LPF package: zero or negative horizontal hydraulic conductivity values
    LPF package: negative horizontal anisotropy values
    LPF package: vertical hydraulic conductivity values below checker threshold of 1e-11
    LPF package: vertical hydraulic conductivity values above checker threshold of␣
↪100000.0
    LPF package: horizontal hydraulic conductivity values below checker threshold of 1e-
↪11
    LPF package: horizontal hydraulic conductivity values above checker threshold of␣
↪100000.0
    GHB package: BC indices valid
    GHB package: not a number (Nan) entries
    GHB package: BC in inactive cells
    GHB package: BC elevation below cell bottom
```

[9]:
```
<flopy.utils.check.check at 0x7f2a09d87ac0>
```

[10]:
```python
summary_pth = os.path.join(workspace, "checksummary.csv")

try:
    import pandas as pd

    df = pd.read_csv(summary_pth)
except:
    df = open(summary_pth).readlines()
df
```

[10]:
```
      type package  k  i  j  value  \
0  Warning      OC  0  0  0    0.0
1  Warning     RCH  0  0  0    0.0
2  Warning     RCH  0  0  0    1.0

                                                desc
0  action(s) defined in OC stress_period_data ign...
1  Mean R/T ratio < checker warning threshold of ...
2          Variable NRCHOP set to value other than 3
```

checking on `write_input()`

checking is also performed by default when `write_input()` is called at the package or model level. Checking on write is performed with the same `verbose` setting as specified for the model. However, if errors or warnings are encountered and `level=1` (default) or higher, a screen message notifies the user of the errors.

By default, the checks performed on `load()` and `write_input()` save results to a summary file, which is named after the packge or the model.

[11]:
```
m.write_input()
```

5.3.3 Loading MODFLOW-2005 models

This tutorial demonstrates how to load models from disk.

First import `flopy`.

[1]:
```
import os
import sys

try:
    import flopy
except:
    fpth = os.path.abspath(os.path.join("..", ".."))
    sys.path.append(fpth)
    import flopy

print(sys.version)
print(f"flopy version: {flopy.__version__}")
```

```
3.8.18 (default, Aug 28 2023, 08:27:22)
[GCC 11.4.0]
flopy version: 3.5.0
```

The `load()` method

To load a MODFLOW 2005 model, use the `Modflow.load()` method. The method's first argument is the path or name of the model namefile. Other parameters include:

- `model_ws`: the model workspace
- `verbose`: whether to write diagnostic information useful for troubleshooting
- `check`: whether to check for model configuration errors

[2]:
```
model_ws = os.path.join("..", "..", "examples", "data", "mf2005_test")
ml = flopy.modflow.Modflow.load(
    "bcf2ss.nam",
    model_ws=model_ws,
    verbose=True,
    version="mf2005",
    check=False,
)
```

```
Creating new model with name: bcf2ss
--------------------------------------------------

Parsing the namefile --> /home/runner/work/flopy/flopy/.docs/Notebooks/../../examples/
↪data/mf2005_test/bcf2ss.nam
could not set filehandle to bcf2ss.lst

--------------------------------------------------
External unit dictionary:
{7: filename:/home/runner/work/flopy/flopy/.docs/Notebooks/../../examples/data/mf2005_
↪test/bcf2ss.lst, filetype:LIST, 8: filename:/home/runner/work/flopy/flopy/.docs/
↪Notebooks/../../examples/data/mf2005_test/bcf2ss.ba6, filetype:BAS6, 11: filename:/
↪home/runner/work/flopy/flopy/.docs/Notebooks/../../examples/data/mf2005_test/bcf2ss.
↪bc6, filetype:BCF6, 12: filename:/home/runner/work/flopy/flopy/.docs/Notebooks/../../
↪examples/data/mf2005_test/bcf2ss.wel, filetype:WEL, 14: filename:/home/runner/work/
↪flopy/flopy/.docs/Notebooks/../../examples/data/mf2005_test/bcf2ss.riv, filetype:RIV,␣
↪18: filename:/home/runner/work/flopy/flopy/.docs/Notebooks/../../examples/data/mf2005_
↪test/bcf2ss.rch, filetype:RCH, 19: filename:/home/runner/work/flopy/flopy/.docs/
↪Notebooks/../../examples/data/mf2005_test/bcf2ss.pcg, filetype:PCG, 20: filename:/home/
↪runner/work/flopy/flopy/.docs/Notebooks/../../examples/data/mf2005_test/bcf2ss.oc,␣
↪filetype:OC, 10: filename:/home/runner/work/flopy/flopy/.docs/Notebooks/../../examples/
↪data/mf2005_test/bcf2ss.dis, filetype:DIS}
--------------------------------------------------

ModflowBas6 free format:True

loading dis package file...
   Loading dis package with:
      2 layers, 10 rows, 15 columns, and 2 stress periods
   loading laycbd...
   loading delr...
   loading delc...
   loading top...
   loading botm...
      for 2 layers and 1 confining beds
   loading stress period data...
       for 2 stress periods
adding Package:  DIS
   DIS  package load...success
   LIST package load...skipped
loading bas6 package file...
adding Package:  BAS6
   BAS6 package load...success
loading bcf package file...
   loading ipakcb, HDRY, IWDFLG, WETFCT, IWETIT, IHDWET...
   loading LAYCON...
   loading TRPY...
   loading hy layer   1...
   loading vcont layer   1...
   loading sf2 layer   1...
   loading tran layer   2...
Adding bcf2ss.cbc (unit=30) to the output list.
```

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```
adding Package:  BCF6
   BCF6 package load...success
loading wel package file...
   loading <class 'flopy.modflow.mfwel.ModflowWel'> for kper     1
   loading <class 'flopy.modflow.mfwel.ModflowWel'> for kper     2
adding Package:  WEL
   WEL  package load...success
loading riv package file...
   loading <class 'flopy.modflow.mfriv.ModflowRiv'> for kper     1
   loading <class 'flopy.modflow.mfriv.ModflowRiv'> for kper     2
adding Package:  RIV
   RIV  package load...success
loading rch package file...
   loading rech stress period   1...
adding Package:  RCH
   RCH  package load...success
loading pcg package file...
   explicit ihcofadd in file
adding Package:  PCG
   PCG  package load...success
loading oc package file...
head file name will be generated by flopy
drawdown file name will be generated by flopy
adding Package:  OC
   OC   package load...success

WARNING:
    External file unit 30 does not exist in ext_unit_dict.

WARNING:
    External file unit 50 does not exist in ext_unit_dict.

WARNING:
    External file unit 0 does not exist in ext_unit_dict.

   The following 8 packages were successfully loaded.
      bcf2ss.dis
      bcf2ss.ba6
      bcf2ss.bc6
      bcf2ss.wel
      bcf2ss.riv
      bcf2ss.rch
      bcf2ss.pcg
      bcf2ss.oc
   The following 1 packages were not loaded.
      bcf2ss.lst
```

Auxiliary variables

Below we load a model containig auxiliary variables, then access them.

[3]:
```
model_ws = os.path.join("..", "..", "examples", "data", "mp6")
ml = flopy.modflow.Modflow.load(
    "EXAMPLE.nam",
    model_ws=model_ws,
    verbose=False,
    version="mf2005",
    check=False,
)
```

Auxiliary IFACE data are in the river package. Retrieve it from the model object.

[4]:
```
riv = ml.riv.stress_period_data[0]
```

Confirm that the `iface` auxiliary data have been read by looking at the `dtype`.

[5]:
```
riv.dtype
```

[5]:
```
dtype((numpy.record, [('k', '<i8'), ('i', '<i8'), ('j', '<i8'), ('stage', '<f4'), ('cond
↪', '<f4'), ('rbot', '<f4'), ('iface', '<f4')]))
```

The `iface` data is accessible from the recarray.

[6]:
```
riv["iface"]
```

[6]:
```
array([6., 6., 6., 6., 6., 6., 6., 6., 6., 6., 6., 6., 6., 6., 6., 6., 6.,
       6., 6., 6., 6., 6., 6., 6., 6.], dtype=float32)
```

5.3.4 MODFLOW Tutorial 1: Confined Steady-State Flow Model

This tutorial demonstrates use of FloPy to develop a simple MODFLOW-2005 model.

[1]:
```
# ## Getting Started
#
# If FloPy has been properly installed, then it can be imported as follows:
from pathlib import Path
from tempfile import TemporaryDirectory
```

[2]:
```
import numpy as np
```

[3]:
```
import flopy
```

Now that we can import flopy, we begin creating our simple MODFLOW model. numpy is imported to create arrays of model data.

Creating the MODFLOW Model

One of the nice things about creating models in python is that it is very easy to change one or two things and completely change the grid resolution for your model. So in this example, we will design our python script so that the number of layers, columns, and rows can be easily changed.

We can create a very simple MODFLOW model that has a basic package (BAS), discretization input file (DIS), layer-property flow (LPF) package, output control (OC), and preconditioned conjugate gradient (PCG) solver. Each one of these has its own input file, which will be created automatically by flopy, provided that we pass flopy the correct information.

Discretization

We start by creating a temporary workspace, then a flopy model object.

[4]:
```
temp_dir = TemporaryDirectory()
workspace = Path(temp_dir.name)
name = "tutorial01_mf"
mf = flopy.modflow.Modflow(name, exe_name="mf2005", model_ws=workspace)
```

Next, let's proceed by defining our model domain and creating a MODFLOW grid to span the domain.

[5]:
```
Lx = 1000.0
Ly = 1000.0
ztop = 0.0
zbot = -50.0
nlay = 1
nrow = 10
ncol = 10
delr = Lx / ncol
delc = Ly / nrow
delv = (ztop - zbot) / nlay
botm = np.linspace(ztop, zbot, nlay + 1)
```

With this information, we can now create the flopy discretization object by entering the following:

[6]:
```
dis = flopy.modflow.ModflowDis(
    mf, nlay, nrow, ncol, delr=delr, delc=delc, top=ztop, botm=botm[1:]
)
```

Basic Package

Next we can create a flopy object that represents the MODFLOW Basic Package. For this simple model, we will assign constant head values of 10. and 0. to the first and last model columns (in all layers), respectively. The python code for doing this is:

[7]:
```
ibound = np.ones((nlay, nrow, ncol), dtype=np.int32)
ibound[:, :, 0] = -1
ibound[:, :, -1] = -1
strt = np.ones((nlay, nrow, ncol), dtype=np.float32)
strt[:, :, 0] = 10.0
```

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```
strt[:, :, -1] = 0.0
bas = flopy.modflow.ModflowBas(mf, ibound=ibound, strt=strt)
```

Layer-Property Flow Package

Constant values of 10. are assigned for the horizontal and vertical hydraulic conductivity:

[8]:
```
lpf = flopy.modflow.ModflowLpf(mf, hk=10.0, vka=10.0, ipakcb=53)
```

Because we did not specify a value for laytyp, Flopy will use the default value of 0, which means that this model will be confined.

Output Control

Here we can use the default OC settings by specifying the following:

[9]:
```
spd = {(0, 0): ["print head", "print budget", "save head", "save budget"]}
oc = flopy.modflow.ModflowOc(mf, stress_period_data=spd, compact=True)
```

The stress period dictionary is used to set what output is saved for the corresponding stress period and time step. In this case, the tuple `(0, 0)` means that stress period 1 and time step 1 for MODFLOW will have output saved. Head and budgets will be printed and head and budget information will be saved.

Preconditioned Conjugate Gradient Package

The default settings used by flopy will be used by specifying the following commands:

[10]:
```
pcg = flopy.modflow.ModflowPcg(mf)
```

Writing the MODFLOW Data Files

The MODFLOW input data files are written by simply issuing the following:

[11]:
```
mf.write_input()
```

Running the Model

Flopy can also be used to run the model. The model object (`mf` in this example) has an attached method that will run the model. For this to work, the MODFLOW program must be located somewhere within the system path, or within the working directory. In this example, we have specified that the name of the executable program is 'mf2005'. Issue the following to run the model:

[12]:
```
success, buff = mf.run_model()
assert success, "MODFLOW did not terminate normally."
```

```
FloPy is using the following executable to run the model: ../../home/runner/.local/bin/
↪modflow/mf2005

                                  MODFLOW-2005
    U.S. GEOLOGICAL SURVEY MODULAR FINITE-DIFFERENCE GROUND-WATER FLOW MODEL
                             Version 1.12.00 2/3/2017

 Using NAME file: tutorial01_mf.nam
 Run start date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:26:50

 Solving:  Stress period:     1    Time step:     1    Ground-Water Flow Eqn.
 Run end date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:26:50
 Elapsed run time:  0.001 Seconds

  Normal termination of simulation
```

Here we have used run_model, and we could also have specified values for the optional keywords silent, pause, and report.

Post-Processing the Results

Now that we have successfully built and run our MODFLOW model, we can look at the results. MODFLOW writes the simulated heads to a binary data output file. We cannot look at these heads with a text editor, but flopy has a binary utility that can be used to read the heads. The following statements will read the binary head file and create a plot of simulated heads for layer 1:

[13]:
```python
import matplotlib.pyplot as plt
```

[14]:
```python
import flopy.utils.binaryfile as bf
```

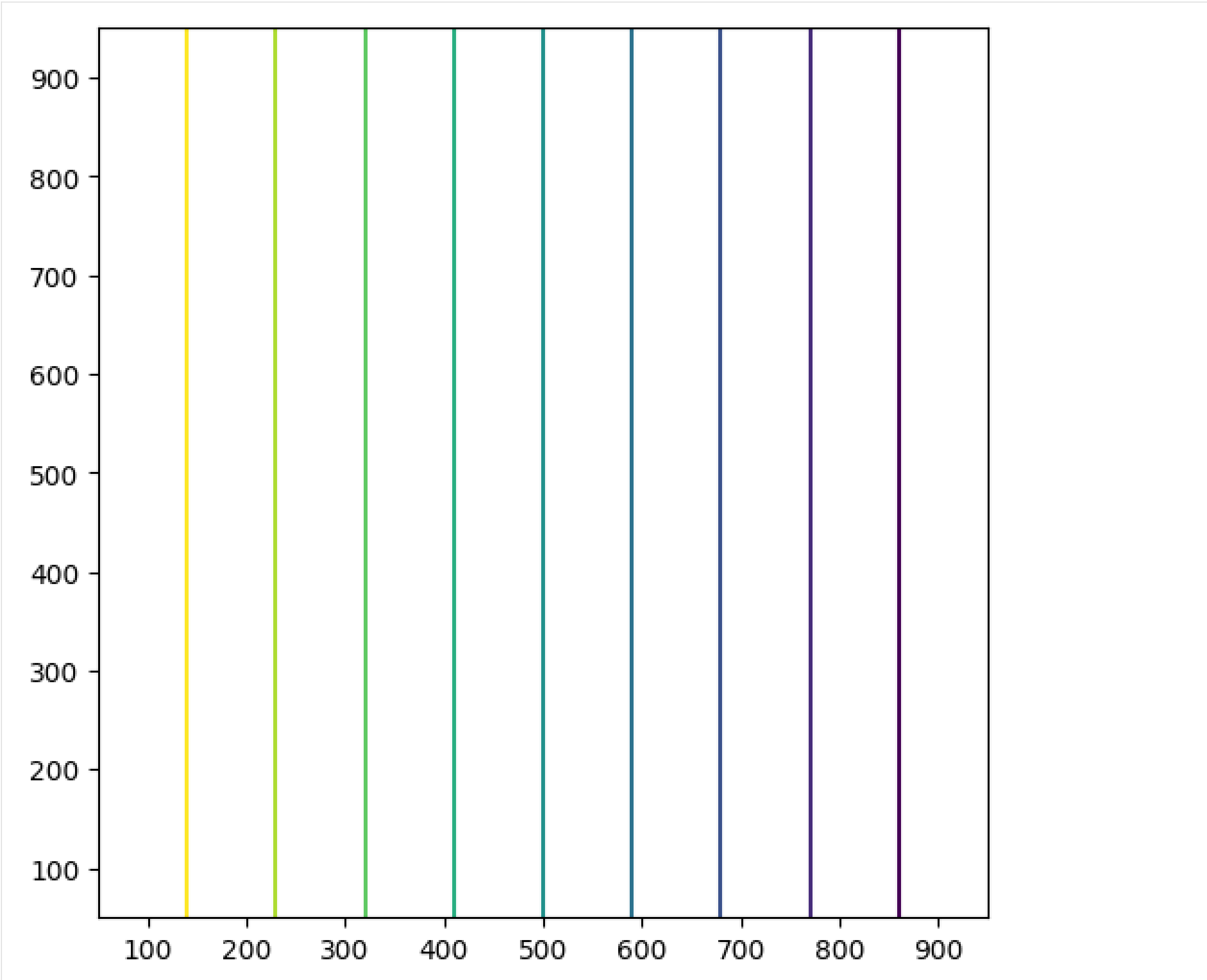
Extract the heads

[15]:
```python
hds = bf.HeadFile(Path(workspace) / f"{name}.hds")
head = hds.get_data(totim=1.0)
```

Contour the heads

[16]:
```python
extent = (delr / 2.0, Lx - delr / 2.0, Ly - delc / 2.0, delc / 2.0)
fig = plt.figure(figsize=(6, 6))
ax = fig.add_subplot(1, 1, 1, aspect="equal")
ax.contour(head[0, :, :], levels=np.arange(1, 10, 1), extent=extent)
```

[16]:
```
<matplotlib.contour.QuadContourSet at 0x7f294986cb20>
```



Flopy also has some pre-canned plotting capabilities can can be accessed using the `PlotMapView()` class. The following code shows how to use the plotmapview class to plot boundary conditions (`IBOUND`), plot the grid, plot head contours, and plot vectors:

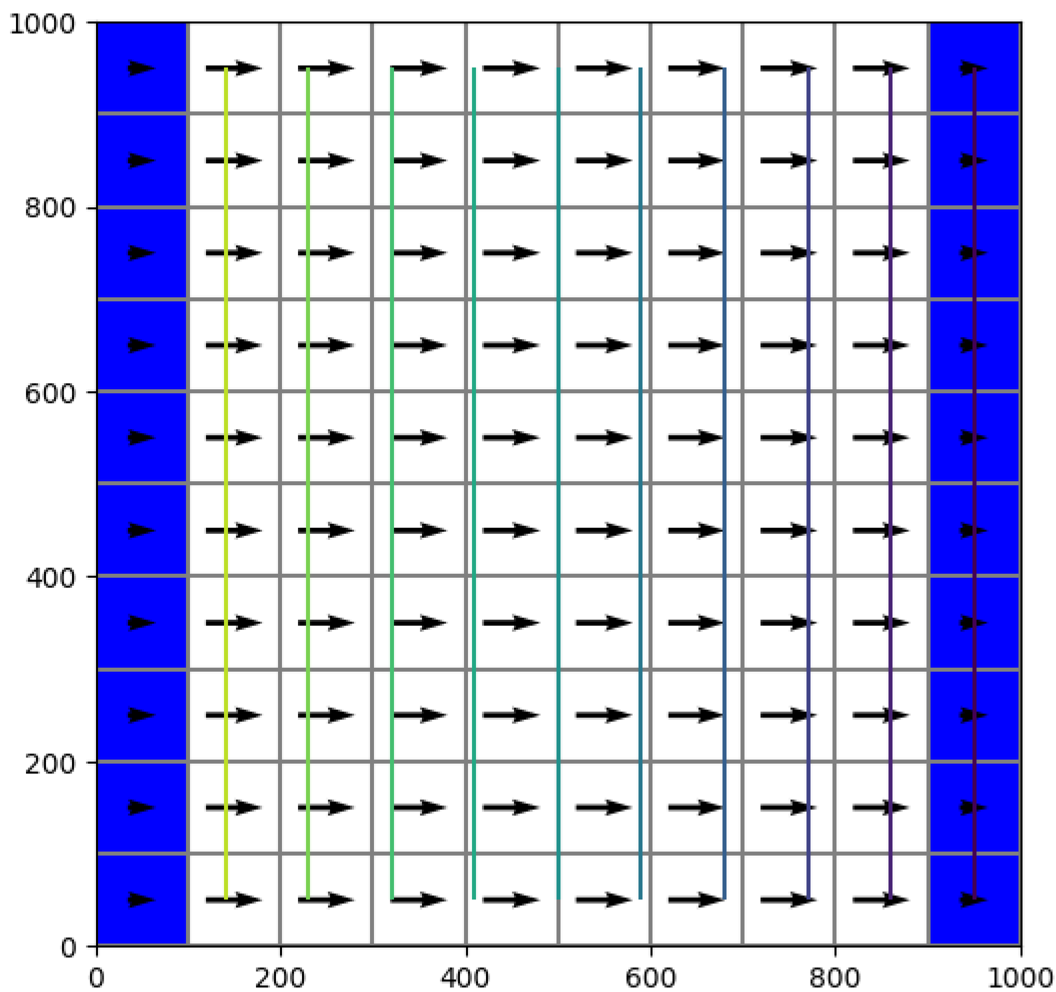
[17]:
```
# Extract the heads
hds = bf.HeadFile(Path(workspace) / f"{name}.hds")
times = hds.get_times()
head = hds.get_data(totim=times[-1])
```

Extract the cell-by-cell flows

[18]:
```
cbb = bf.CellBudgetFile(Path(workspace) / f"{name}.cbc")
kstpkper_list = cbb.get_kstpkper()
frf = cbb.get_data(text="FLOW RIGHT FACE", totim=times[-1])[0]
fff = cbb.get_data(text="FLOW FRONT FACE", totim=times[-1])[0]
qx, qy, qz = flopy.utils.postprocessing.get_specific_discharge(
    (frf, fff, None), mf, head
)
```

Create the figure

[19]:
```
fig = plt.figure(figsize=(6, 6))
ax = fig.add_subplot(1, 1, 1, aspect="equal")
modelmap = flopy.plot.PlotMapView(model=mf, layer=0, ax=ax)
qm = modelmap.plot_ibound()
lc = modelmap.plot_grid()
cs = modelmap.contour_array(head, levels=np.linspace(0, 10, 11))
quiver = modelmap.plot_vector(qx, qy)
```



Clean up the temporary workspace

[20]:
```
try:
    temp_dir.cleanup()
except:
    # prevent windows permission error
    pass
```

5.3.5 MODFLOW Tutorial 2: Unconfined Transient Flow Model

In this example, we will convert the tutorial 1 model into an unconfined, transient flow model with time varying boundaries. Instead of using constant heads for the left and right boundaries (by setting ibound to -1), we will use general head boundaries. We will have the model consider the following conditions:

- Initial conditions – head is 10.0 everywhere
- Period 1 (1 day) – steady state with left and right GHB stage = 10.
- Period 2 (100 days) – left GHB with stage = 10., right GHB with stage set to 0.
- Period 3 (100 days) – pumping well at model center with rate = -500., left and right GHB = 10., and 0.

We will start with selected model commands from the previous tutorial.

[1]:
```
# ## Getting Started
#
# As shown in the previous MODFLOW tutorial, import flopy.
from pathlib import Path
from tempfile import TemporaryDirectory
```

[2]:
```
import numpy as np
```

[3]:
```
import flopy
```

Creating the MODFLOW Model

Define the Model Extent, Grid Resolution, and Characteristics

Assign the model information

[4]:
```
Lx = 1000.0
Ly = 1000.0
ztop = 10.0
zbot = -50.0
nlay = 1
nrow = 10
ncol = 10
delr = Lx / ncol
delc = Ly / nrow
delv = (ztop - zbot) / nlay
botm = np.linspace(ztop, zbot, nlay + 1)
hk = 1.0
vka = 1.0
sy = 0.1
ss = 1.0e-4
laytyp = 1
```

Variables for the BAS package Note that changes from the MODFLOW tutorial 1

[5]:
```
ibound = np.ones((nlay, nrow, ncol), dtype=np.int32)
strt = 10.0 * np.ones((nlay, nrow, ncol), dtype=np.float32)
```

Define the Stress Periods

To create a model with multiple stress periods, we need to define nper, perlen, nstp, and steady. This is done in the following block in a manner that allows us to pass these variable directly to the discretization object:

[6]:
```
nper = 3
perlen = [1, 100, 100]
nstp = [1, 100, 100]
steady = [True, False, False]
```

Create Time-Invariant Flopy Objects

With this information, we can now create the static flopy objects that do not change with time:

[7]:
```
temp_dir = TemporaryDirectory()
workspace = temp_dir.name
name = "tutorial02_mf"
mf = flopy.modflow.Modflow(name, exe_name="mf2005", model_ws=workspace)
dis = flopy.modflow.ModflowDis(
    mf,
    nlay,
    nrow,
    ncol,
    delr=delr,
    delc=delc,
    top=ztop,
    botm=botm[1:],
    nper=nper,
    perlen=perlen,
    nstp=nstp,
    steady=steady,
)
bas = flopy.modflow.ModflowBas(mf, ibound=ibound, strt=strt)
lpf = flopy.modflow.ModflowLpf(
    mf, hk=hk, vka=vka, sy=sy, ss=ss, laytyp=laytyp, ipakcb=53
)
pcg = flopy.modflow.ModflowPcg(mf)
```

Transient General-Head Boundary Package

At this point, our model is ready to add our transient boundary packages. First, we will create the GHB object, which is of the following type: `flopy.modflow.ModflowGhb()`.

The key to creating Flopy transient boundary packages is recognizing that the boundary data is stored in a dictionary with key values equal to the zero-based stress period number and values equal to the boundary conditions for that stress period. For a GHB the values can be a two-dimensional nested list of `[layer, row, column, stage, conductance]`.

[8]:
```
stageleft = 10.0
stageright = 10.0
bound_sp1 = []
```

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```
for il in range(nlay):
    condleft = hk * (stageleft - zbot) * delc
    condright = hk * (stageright - zbot) * delc
    for ir in range(nrow):
        bound_sp1.append([il, ir, 0, stageleft, condleft])
        bound_sp1.append([il, ir, ncol - 1, stageright, condright])
print("Adding ", len(bound_sp1), "GHBs for stress period 1.")
```

```
Adding  20 GHBs for stress period 1.
```

[9]:
```
# Make list for stress period 2
stageleft = 10.0
stageright = 0.0
condleft = hk * (stageleft - zbot) * delc
condright = hk * (stageright - zbot) * delc
bound_sp2 = []
for il in range(nlay):
    for ir in range(nrow):
        bound_sp2.append([il, ir, 0, stageleft, condleft])
        bound_sp2.append([il, ir, ncol - 1, stageright, condright])
print("Adding ", len(bound_sp2), "GHBs for stress period 2.")
```

```
Adding  20 GHBs for stress period 2.
```

[10]:
```
# We do not need to add a dictionary entry for stress period 3.
# Flopy will automatically take the list from stress period 2 and apply it
# to the end of the simulation
stress_period_data = {0: bound_sp1, 1: bound_sp2}
```

[11]:
```
# Create the flopy ghb object
ghb = flopy.modflow.ModflowGhb(mf, stress_period_data=stress_period_data)
```

Transient Well Package

Now we can create the well package object, which is of the type, `flopy.modflow.ModflowWel()`.

[12]:
```
# Create the well package
# Remember to use zero-based layer, row, column indices!
pumping_rate = -500.0
wel_sp1 = [[0, nrow / 2 - 1, ncol / 2 - 1, 0.0]]
wel_sp2 = [[0, nrow / 2 - 1, ncol / 2 - 1, 0.0]]
wel_sp3 = [[0, nrow / 2 - 1, ncol / 2 - 1, pumping_rate]]
stress_period_data = {0: wel_sp1, 1: wel_sp2, 2: wel_sp3}
wel = flopy.modflow.ModflowWel(mf, stress_period_data=stress_period_data)
```

Output Control

Here we create the output control package object, which is of the type `flopy.modflow.ModflowOc()`.

[13]:
```
stress_period_data = {}
for kper in range(nper):
    for kstp in range(nstp[kper]):
        stress_period_data[(kper, kstp)] = [
            "save head",
            "save drawdown",
            "save budget",
            "print head",
            "print budget",
        ]
oc = flopy.modflow.ModflowOc(
    mf, stress_period_data=stress_period_data, compact=True
)
```

Running the Model

Run the model with the run_model method, which returns a success flag and the stream of output. With run_model, we have some finer control, that allows us to suppress the output.

[14]:
```
# Write the model input files
mf.write_input()
```

[15]:
```
# Run the model
success, mfoutput = mf.run_model(silent=True, pause=False)
assert success, "MODFLOW did not terminate normally."
```

Post-Processing the Results

Once again, we can read heads from the MODFLOW binary output file, using the `flopy.utils.binaryfile()` module. Included with the HeadFile object are several methods that we will use here:

- `get_times()` will return a list of times contained in the binary head file
- `get_data()` will return a three-dimensional head array for the specified time
- `get_ts()` will return a time series array `[ntimes, headval]` for the specified cell

Using these methods, we can create head plots and hydrographs from the model results.

[16]:
```
# Imports
import matplotlib.pyplot as plt
```

[17]:
```
import flopy.utils.binaryfile as bf
```

[18]:
```
# Create the headfile and budget file objects
headobj = bf.HeadFile(Path(workspace) / f"{name}.hds")
times = headobj.get_times()
cbb = bf.CellBudgetFile(Path(workspace) / f"{name}.cbc")
```

[19]:
```
# Setup contour parameters
levels = np.linspace(0, 10, 11)
extent = (delr / 2.0, Lx - delr / 2.0, delc / 2.0, Ly - delc / 2.0)
print("Levels: ", levels)
print("Extent: ", extent)
```

```
Levels:  [ 0.  1.  2.  3.  4.  5.  6.  7.  8.  9. 10.]
Extent:  (50.0, 950.0, 50.0, 950.0)
```

[20]:
```
# Well point for plotting
wpt = (450.0, 550.0)
```

Create a figure with maps for three times

[21]:
```
# Make the plots
fig = plt.figure(figsize=(5, 15))
mytimes = [1.0, 101.0, 201.0]
for iplot, time in enumerate(mytimes):
    print("*****Processing time: ", time)
    head = headobj.get_data(totim=time)
    # Print statistics
    print("Head statistics")
    print("  min: ", head.min())
    print("  max: ", head.max())
    print("  std: ", head.std())

    # Extract flow right face and flow front face
    frf = cbb.get_data(text="FLOW RIGHT FACE", totim=time)[0]
    fff = cbb.get_data(text="FLOW FRONT FACE", totim=time)[0]

    # Create a map for this time
    ax = fig.add_subplot(len(mytimes), 1, iplot + 1, aspect="equal")
    ax.set_title(f"stress period {iplot + 1}")

    pmv = flopy.plot.PlotMapView(model=mf, layer=0, ax=ax)
    qm = pmv.plot_ibound()
    lc = pmv.plot_grid()
    qm = pmv.plot_bc("GHB", alpha=0.5)
    if head.min() != head.max():
        cs = pmv.contour_array(head, levels=levels)
        plt.clabel(cs, inline=1, fontsize=10, fmt="%1.1f")
        quiver = pmv.plot_vector(frf, fff)

    mfc = "None"
    if (iplot + 1) == len(mytimes):
        mfc = "black"
    ax.plot(
        wpt[0],
        wpt[1],
        lw=0,
        marker="o",
        markersize=8,
        markeredgewidth=0.5,
```

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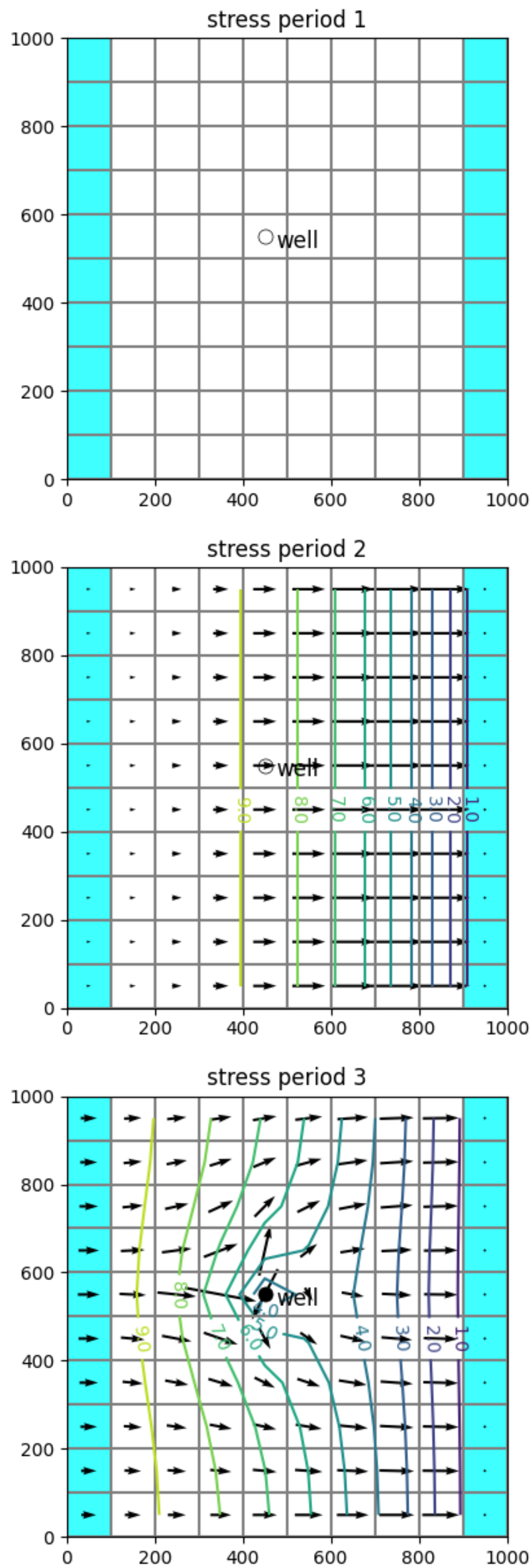
```
        markeredgecolor="black",
        markerfacecolor=mfc,
        zorder=9,
    )
    ax.text(wpt[0] + 25, wpt[1] - 25, "well", size=12, zorder=12)
```

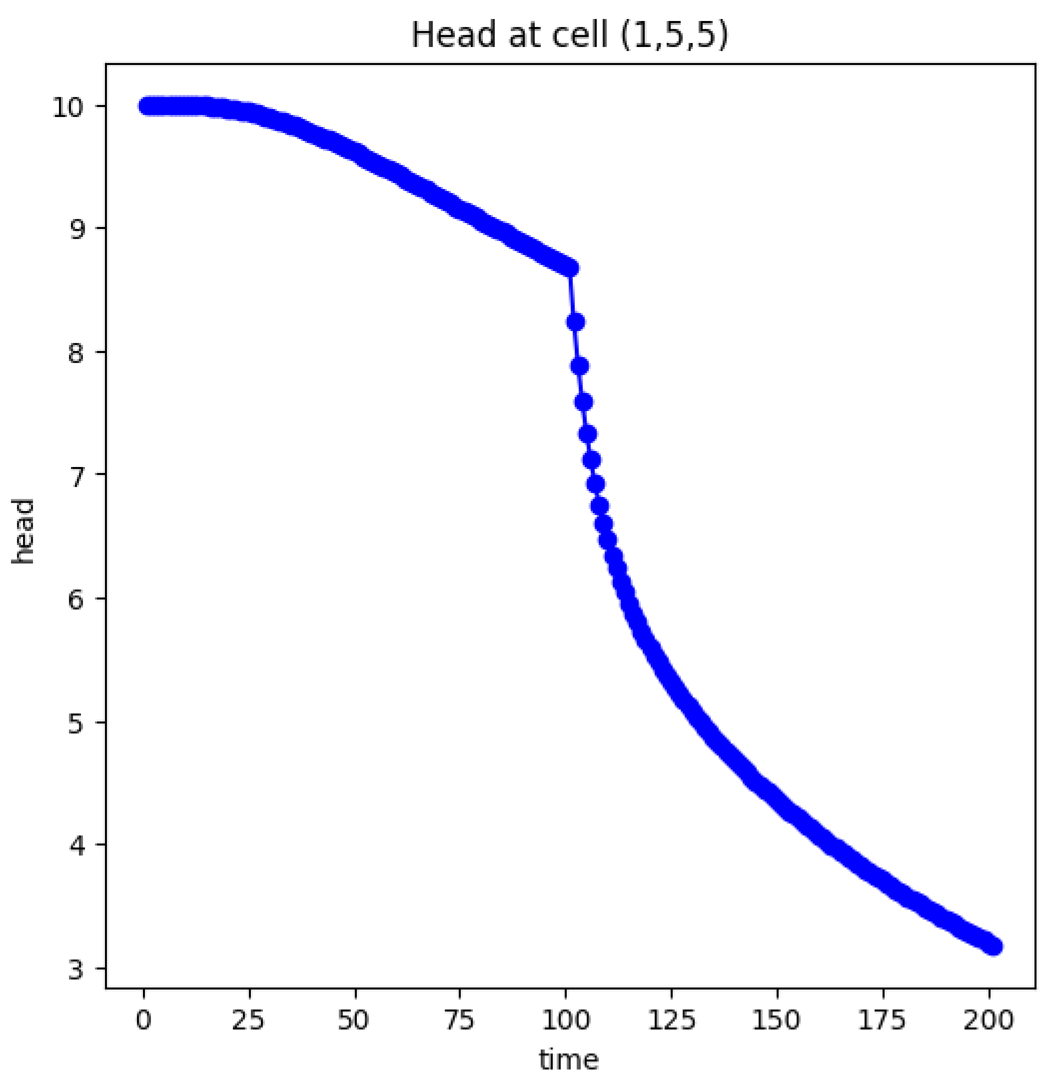
```
*****Processing time:  1.0
Head statistics
  min:  10.0
  max:  10.0
  std:  0.0
*****Processing time:  101.0
Head statistics
  min:  0.025931068
  max:  9.998436
  std:  3.2574987
*****Processing time:  201.0
Head statistics
  min:  0.016297927
  max:  9.994038
  std:  3.1544707
```


stress period 1
well
stress period 2
well
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
stress period 3
well
9.0
8.0
7.0
4.0
3.0
2.0
1.0
0
200
400
600
800
1000

Create a hydrograph

[22]:
```
# Plot the head versus time
idx = (0, int(nrow / 2) - 1, int(ncol / 2) - 1)
ts = headobj.get_ts(idx)
fig = plt.figure(figsize=(6, 6))
ax = fig.add_subplot(1, 1, 1)
ttl = f"Head at cell ({idx[0] + 1},{idx[1] + 1},{idx[2] + 1})"
ax.set_title(ttl)
ax.set_xlabel("time")
ax.set_ylabel("head")
ax.plot(ts[:, 0], ts[:, 1], "bo-")
```

[22]:
```
[<matplotlib.lines.Line2D at 0x7f878b9d9be0>]
```



[23]:
```
try:
    temp_dir.cleanup()
except:
    # prevent windows permission error
```

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```
    pass
```

5.4 MODFLOW-LGR

5.4.1 Local grid refinement (LGR) utility

FloPy has a utility for creating and managing a parent grid and a child grid. Both grids must regular MODFLOW grids consisting of layers, rows, and columns. The term Local Grid Refinement (LGR) is used to denote this configuration. With the current version, only one child grid is supported; however, the utility could be used multiple times to create multiple child models. Those child models could also be used with the utility to create grandchildren models, though it is unclear if there would be benefit to constructing models with this configuration.

The FloPy LGR utility is designed to work primarily with MODFLOW 6 as MODFLOW 6 can be used to run multiple groundwater models in the same simulation. These models can be tightly coupled at their interfaces. This LGR approach is based on the idea of creating multiple model instances, each with their own input and output. This approach is different from using an unstructured grid to represent a single mesh with local refinements in areas of interest.

First set the path and import the required packages. The flopy path doesn't have to be set if you install flopy from a binary installer. If you want to run this notebook, you have to set the path to your own flopy path.

[1]:
```
import os
import sys
from tempfile import TemporaryDirectory

import matplotlib as mpl
import matplotlib.pyplot as plt
import numpy as np

import flopy
from flopy.utils.lgrutil import Lgr

# temporary directory
temp_dir = TemporaryDirectory()
workspace = os.path.join(temp_dir.name, "mf6lgr")
# make sure workspace directory exists
if not os.path.isdir(workspace):
    os.makedirs(workspace, exist_ok=True)

print(sys.version)
print(f"numpy version: {np.__version__}")
print(f"matplotlib version: {mpl.__version__}")
print(f"flopy version: {flopy.__version__}")
```

```
3.8.18 (default, Aug 28 2023, 08:27:22)
[GCC 11.4.0]
numpy version: 1.24.4
matplotlib version: 3.7.4
flopy version: 3.5.0
```

LGR basics

The LGR Utility works by defining the parent grid. Then cells within the parent grid are marked as being replaced by a child grid with a specified level of refinement. The terminology and variable descriptions here are based on concepts developed for the MODFLOW-LGR program.

[2]:
```
# set up the parent grid information
xoffp = 0.0
yoffp = 0.0
nlayp = 3
nrowp = 25
ncolp = 45
dx = 100.0
dy = 100.0
dz = 20.0
delrp = dx * np.ones(ncolp, dtype=float)
delcp = dy * np.ones(nrowp, dtype=float)
topp = dz * np.ones((nrowp, ncolp), dtype=float)
botmp = np.empty((nlayp, nrowp, ncolp), dtype=float)
for k in range(nlayp):
    botmp[k] = -(k + 1) * dz
```

[3]:
```
# Define relation of child to parent using
# these parent indices to show where child is active
istart = int(nrowp / 3)
istop = int(nrowp * 2 / 3) + 1
jstart = int(ncolp / 3)
jstop = int(ncolp * 2 / 3) + 1
kstart = 0
kstop = 1 + 1

# idomainp has a 1 where parent is active and 0 where child is active
idomainp = np.ones((nlayp, nrowp, ncolp), dtype=int)
idomainp[kstart:kstop, istart:istop, jstart:jstop] = 0

# Set the number of child layers per parent layer (list of length parent nlay)
# The following will result in 4 child layers that span model layers
# 1 and 2 of the parent grid.  Vertical dimension of child cells will be half
# of the parent vertical dimension.
ncppl = np.array(nlayp * [2], dtype=int)
ncppl[kstop:] = 0
print(f"ncppl: {ncppl}")

# Set the number of child cells per parent cell
ncpp = 5

# Create the Lgr utility object, which contains methods for connecting a
# parent and child model in a MODFLOW 6 simulation
lgr = Lgr(
    nlayp,
    nrowp,
    ncolp,
    delrp,
```

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```
    delcp,
    topp,
    botmp,
    idomainp,
    ncpp=ncpp,
    ncppl=ncppl,
    xllp=xoffp,
    yllp=yoffp,
)
```

```
ncppl: [2 2 0]
```

[4]:
```
# information about the parent and child models
# can be accessed using simple grid objects returned
# on the fly by lgr.parent and lgr.child
print("Parent grid information")
parent = lgr.parent
print(f"parent nlay: {parent.nlay}")
print(f"parent nrow: {parent.nrow}")
print(f"parent ncol: {parent.ncol}")
print(f"parent delr[0]: {parent.delr[0]}")
print(f"parent delc[0]: {parent.delc[0]}")
print(f"parent top[0, 0]: {parent.top[0, 0]}")
print(f"parent botm[:, 0, 0]: {parent.botm[:, 0, 0]}")

print("\nChild grid information")
child = lgr.child
print(f"child nlay: {child.nlay}")
print(f"child nrow: {child.nrow}")
print(f"child ncol: {child.ncol}")
print(f"child delr[0]: {child.delr[0]}")
print(f"child delc[0]: {child.delc[0]}")
print(f"child top[0, 0]: {child.top[0, 0]}")
print(f"child botm[:, 0, 0]: {child.botm[:, 0, 0]}")
```

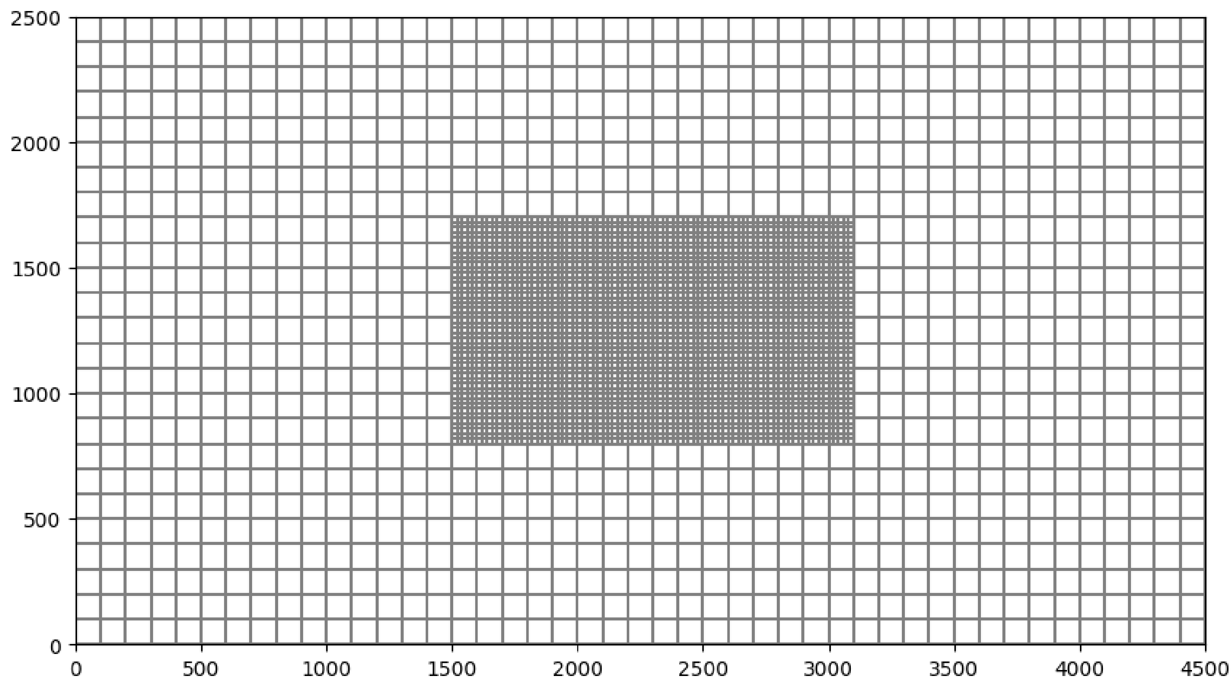
```
Parent grid information
parent nlay: 3
parent nrow: 25
parent ncol: 45
parent delr[0]: 100.0
parent delc[0]: 100.0
parent top[0, 0]: 20.0
parent botm[:, 0, 0]: [-20. -40. -60.]

Child grid information
child nlay: 4
child nrow: 45
child ncol: 80
child delr[0]: 20.0
child delc[0]: 20.0
child top[0, 0]: 20.0
child botm[:, 0, 0]: [  0. -20. -30. -40.]
```

[5]:
```
# from the Lgr object, it is possible to ask for a flopy modelgrid object
# for the parent and child.  These objects are created on the fly and
# can be used to plot the grids prior to creating the MODFLOW 6 simulation
mgp = lgr.parent.modelgrid
mgc = lgr.child.modelgrid

fig = plt.figure(figsize=(10, 10))
ax = fig.add_subplot(1, 1, aspect="equal")
mgc.plot(ax=ax)
mgp.plot(ax=ax)
```

[5]:
```
<matplotlib.collections.LineCollection at 0x7ff8049a2520>
```



Simple example model

For this example, we reproduce the simple model shown on the front page of the flopy GitHub repository. In this adaptation, we insert a finer, locally refined grid in the middle of the domain, but we tightly couple the parent and child models.

[6]:
```
# set up the parent grid information
xoffp = 0.0
yoffp = 0.0
nlayp = 5
nrowp = 5
ncolp = 5
dx = 100.0
dy = 100.0
dz = 100.0
delrp = dx * np.ones(ncolp, dtype=float)
delcp = dy * np.ones(nrowp, dtype=float)
```

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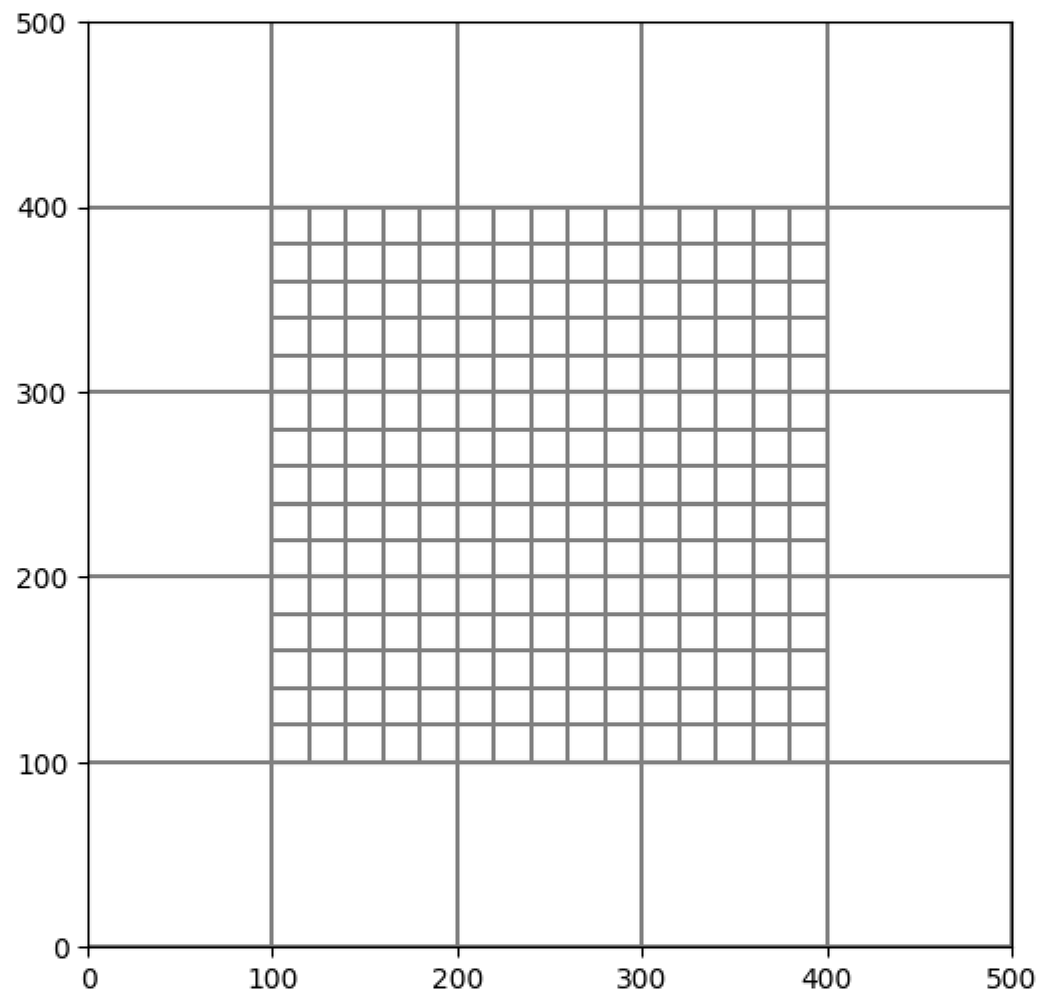
```
topp = dz * np.ones((nrowp, ncolp), dtype=float)
botmp = np.empty((nlayp, nrowp, ncolp), dtype=float)
for k in range(nlayp):
    botmp[k] = -(k + 1) * dz

# Define relation of child to parent
# idomainp has a 1 where parent is active and 0 where child is active
idomainp = np.ones((nlayp, nrowp, ncolp), dtype=int)
idomainp[:, 1:4, 1:4] = 0

# Set the number of child cells per parent cell
ncpp = 5

# Set the number of child layers per parent layer (list of cell parent nlay)
ncppl = [1, 1, 1, 1, 1]

# Create the Lgr utility object, which contains methods for connecting a
# parent and child model in a MODFLOW 6 simulation
lgr = Lgr(
    nlayp,
    nrowp,
    ncolp,
    delrp,
    delcp,
    topp,
    botmp,
    idomainp,
    ncpp=ncpp,
    ncppl=ncppl,
    xllp=xoffp,
    yllp=yoffp,
)

# from the Lgr object, it is possible to ask for a flopy modelgrid object
# for the parent and child.  These objects are created on the fly and
# can be used to plot the grids prior to creating the MODFLOW 6 simulation
mgp = lgr.parent.modelgrid
mgc = lgr.child.modelgrid
```

[7]:
```
# plot the child and parent grids, which can be
# done easily using the flopy modelgrid objects
fig = plt.figure(figsize=(6, 6))
ax = fig.add_subplot(1, 1, 1, aspect="equal")
mgc.plot(ax=ax)
mgp.plot(ax=ax)
```

[7]:
```
<matplotlib.collections.LineCollection at 0x7ff804875b20>
```



Build the MODFLOW 6 Model

Now that we have the grid, we can setup and run the MODFLOW 6 model.

[8]:
```
# set up the MODFLOW 6 simulation
ws = os.path.join(workspace, "ex1")
simname = "lgr"
pname = "parent"
cname = "child"
sim = flopy.mf6.MFSimulation(sim_name=simname, sim_ws=ws, exe_name="mf6")
tdis = flopy.mf6.ModflowTdis(sim)

# Because we will use the xt3d option for coupling the models
# we need use to the asymmetric BICGSTAB linear solver
ims = flopy.mf6.ModflowIms(sim, linear_acceleration="BICGSTAB")

# retrieve the exchange data from the lgr object
exchangedata = lgr.get_exchange_data(angldegx=True, cdist=True)
```

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```
nexg = len(exchangedata)

# When creating the exchange, which couples the child and parent
# models, use the xt3d option, which is an alternative to the
# ghost-node correction.  This xt3d option was added as a new
# capability for the gwt-gwt and gwf-gwf exchanges in MODFLOW version 6.3.0.
exg = flopy.mf6.ModflowGwfgwf(
    sim,
    exgtype="GWF6-GWF6",
    xt3d=True,
    auxiliary=["angldegx", "cdist"],
    exgmnamea=pname,
    exgmnameb=cname,
    nexg=nexg,
    exchangedata=exchangedata,
)

# Set up the parent model and use the lgr.parent object to
# help provide the necessary information.
lgrp = lgr.parent
gwfp = flopy.mf6.ModflowGwf(sim, modelname=pname, save_flows=True)
dis = flopy.mf6.ModflowGwfdis(gwfp, **lgrp.get_gridprops_dis6())
ic = flopy.mf6.ModflowGwfic(gwfp)
npf = flopy.mf6.ModflowGwfnpf(gwfp, save_specific_discharge=True)
chdspd = [[(0, 0, 0), 1.0], [(0, lgrp.nrow - 1, lgrp.ncol - 1), 0.0]]
chd = flopy.mf6.ModflowGwfchd(gwfp, stress_period_data=chdspd)
oc = flopy.mf6.ModflowGwfoc(
    gwfp,
    budget_filerecord=f"{pname}.bud",
    head_filerecord=f"{pname}.hds",
    saverecord=[("HEAD", "ALL"), ("BUDGET", "ALL")],
)

# Set up the child model and use the lgr.child object to
# help provide the necessary information.
lgrc = lgr.child
gwfc = flopy.mf6.ModflowGwf(sim, modelname=cname, save_flows=True)
dis = flopy.mf6.ModflowGwfdis(gwfc, **lgrc.get_gridprops_dis6())
ic = flopy.mf6.ModflowGwfic(gwfc)
npf = flopy.mf6.ModflowGwfnpf(gwfc, save_specific_discharge=True)
oc = flopy.mf6.ModflowGwfoc(
    gwfc,
    budget_filerecord=f"{cname}.bud",
    head_filerecord=f"{cname}.hds",
    saverecord=[("HEAD", "ALL"), ("BUDGET", "ALL")],
)

sim.write_simulation()
success, buff = sim.run_simulation(silent=True, report=True)
if success:
    for line in buff:
        print(line)
```

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```
else:
    raise ValueError("Failed to run.")
```

```
writing simulation...
  writing simulation name file...
  writing simulation tdis package...
  writing solution package ims_-1...
  writing package lgr.gwfgwf...
  writing model parent...
    writing model name file...
    writing package dis...
    writing package ic...
    writing package npf...
    writing package chd_0...
INFORMATION: maxbound in ('gwf6', 'chd', 'dimensions') changed to 2 based on size of␣
↪stress_period_data
    writing package oc...
  writing model child...
    writing model name file...
    writing package dis...
    writing package ic...
    writing package npf...
    writing package oc...
                                   MODFLOW 6
                U.S. GEOLOGICAL SURVEY MODULAR HYDROLOGIC MODEL
                            VERSION 6.4.2 06/28/2023

   MODFLOW 6 compiled Jul 05 2023 20:29:14 with Intel(R) Fortran Intel(R) 64
   Compiler Classic for applications running on Intel(R) 64, Version 2021.7.0
                             Build 20220726_000000

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 Run start date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:29:34

 Writing simulation list file: mfsim.lst
 Using Simulation name file: mfsim.nam

    Solving:  Stress period:     1    Time step:     1
```

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```
Run end date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:29:34
Elapsed run time:  0.088 Seconds

Normal termination of simulation.
```

[9]:
```
# load and store the head arrays from the parent and child models
head = [gwfp.output.head().get_data(), gwfc.output.head().get_data()]

# load and store the specific discharge results for the parent and child models
bud = gwfp.output.budget()
spdis = bud.get_data(text="DATA-SPDIS")[0]
spdisp = flopy.utils.postprocessing.get_specific_discharge(spdis, gwfp)
bud = gwfc.output.budget()
spdis = bud.get_data(text="DATA-SPDIS")[0]
spdisc = flopy.utils.postprocessing.get_specific_discharge(spdis, gwfc)
```

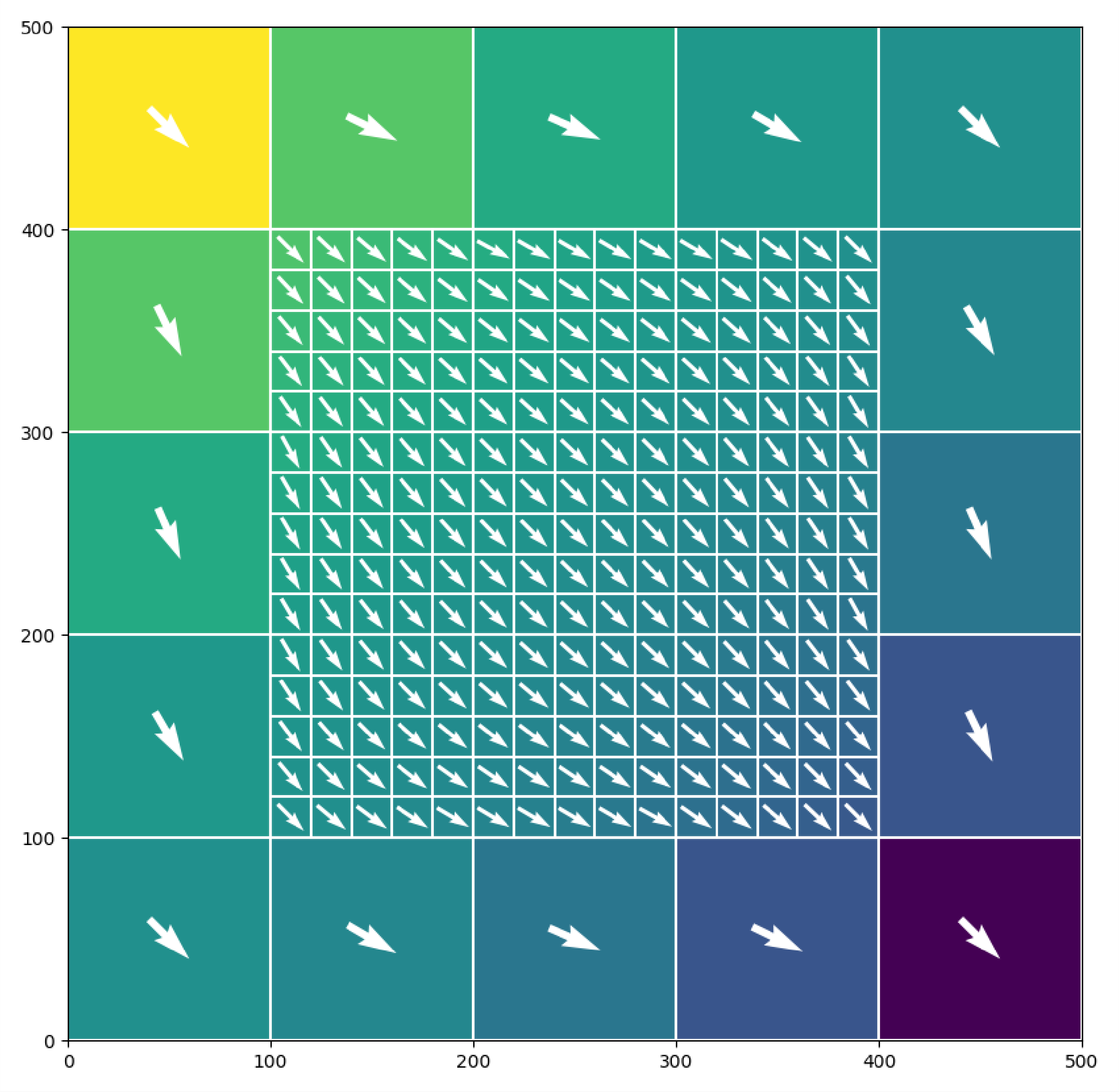
[10]:
```
# plot the results from both the parent and child models
# on the same figure
f = plt.figure(figsize=(10, 10))
ax = plt.subplot(1, 1, 1, aspect="equal")
pmvp = flopy.plot.PlotMapView(gwfp, ax=ax)
pmvc = flopy.plot.PlotMapView(gwfc, ax=ax, extent=pmvp.extent)

pmvp.plot_array(head[0], vmin=0.0, vmax=1.0)
pmvc.plot_array(head[1], vmin=0.0, vmax=1.0)

pmvp.plot_grid(colors="white")
pmvc.plot_grid(colors="white")

pmvp.plot_vector(spdisp[0], spdisp[1], normalize=True, color="white")
pmvc.plot_vector(spdisc[0], spdisc[1], normalize=True, color="white")
```

[10]:
```
<matplotlib.quiver.Quiver at 0x7ff811ffc8b0>
```



Coupled flow and transport model

For this example, we simulate coupled flow and transport for a LGR configuration.

[11]:
```
# set up the parent grid information
xoffp = 0.0
yoffp = 0.0
nlayp = 3
nrowp = 25
ncolp = 45
dx = 10.0
dy = 10.0
```

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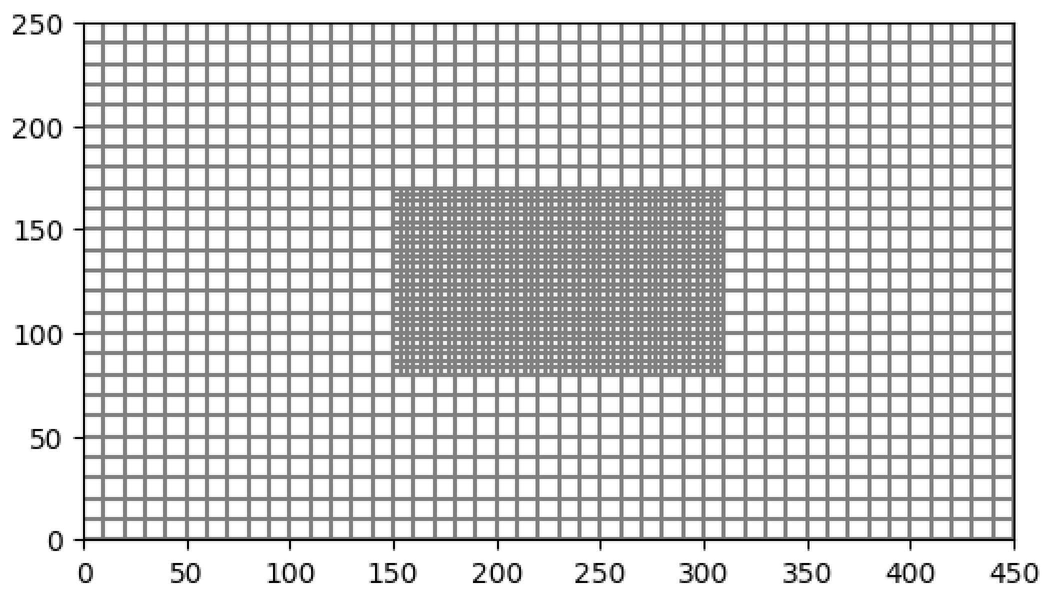
```
dz = 20.0
delrp = dx * np.ones(ncolp, dtype=float)
delcp = dy * np.ones(nrowp, dtype=float)
topp = dz * np.ones((nrowp, ncolp), dtype=float)
botmp = np.empty((nlayp, nrowp, ncolp), dtype=float)
for k in range(nlayp):
    botmp[k] = -(k + 1) * dz

# Define relation of child to parent using
# these parent indices to show where child is active
istart = int(nrowp / 3)
istop = int(nrowp * 2 / 3) + 1
jstart = int(ncolp / 3)
jstop = int(ncolp * 2 / 3) + 1
kstart = 0
kstop = 1 + 1

# idomainp has a 1 where parent is active and 0 where child is active
idomainp = np.ones((nlayp, nrowp, ncolp), dtype=int)
idomainp[kstart:kstop, istart:istop, jstart:jstop] = 0

# Set the number of child layers per parent layer
ncppl = np.array(nlayp * [1], dtype=int)
ncppl[kstop:] = 0
print(f"ncppl: {ncppl}")

# Set the number of child cells per parent cell
ncpp = 3

# Create the Lgr utility object, which contains methods for connecting a
# parent and child model in a MODFLOW 6 simulation
lgr = Lgr(
    nlayp,
    nrowp,
    ncolp,
    delrp,
    delcp,
    topp,
    botmp,
    idomainp,
    ncpp=ncpp,
    ncppl=ncppl,
    xllp=xoffp,
    yllp=yoffp,
)

# from the Lgr object, it is possible to ask for a flopy modelgrid object
# for the parent and child.  These objects are created on the fly and
# can be used to plot the grids prior to creating the MODFLOW 6 simulation
mgp = lgr.parent.modelgrid
mgc = lgr.child.modelgrid
```

```
ncppl: [1 1 0]
```

[12]:
```python
# plot the child and parent grids, which can be
# done easily using the flopy modelgrid objects
fig = plt.figure(figsize=(6, 6))
ax = fig.add_subplot(1, 1, 1, aspect="equal")
mgc.plot(ax=ax)
mgp.plot(ax=ax)
```

[12]:
```
<matplotlib.collections.LineCollection at 0x7ff811fa4df0>
```



Build the MODFLOW 6 Model

Now that we have the grid, we can setup and run the MODFLOW 6 model.

[13]:
```python
# set up the MODFLOW 6 simulation
ws = os.path.join(workspace, "ex2")
simname = "lgr"
sim = flopy.mf6.MFSimulation(sim_name=simname, sim_ws=ws, exe_name="mf6")
tdis = flopy.mf6.ModflowTdis(sim, perioddata=[(50 * 365.0, 10, 1.0)])

pname = "parent-flow"
cname = "child-flow"

# Because we will use the xt3d option for coupling the models
# we need use to the asymmetric BICGSTAB linear solver
ims_flow = flopy.mf6.ModflowIms(
    sim, linear_acceleration="BICGSTAB", filename="flow.ims"
)

# retrieve the exchange data from the lgr object
exchangedata = lgr.get_exchange_data(angldegx=True, cdist=True)
```

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```
nexg = len(exchangedata)

# When creating the exchange, which couples the child and parent
# models, use the xt3d option, which is an alternative to the
# ghost-node correction.  This xt3d option was added as a new
# capability for the gwt-gwt and gwf-gwf exchanges in MODFLOW version 6.3.0.
exg = flopy.mf6.ModflowGwfgwf(
    sim,
    exgtype="GWF6-GWF6",
    xt3d=True,
    auxiliary=["angldegx", "cdist"],
    exgmnamea=pname,
    exgmnameb=cname,
    nexg=nexg,
    exchangedata=exchangedata,
)

# Set up the parent model and use the lgr.parent object to
# help provide the necessary information.
lgrp = lgr.parent
gwfp = flopy.mf6.ModflowGwf(sim, modelname=pname, save_flows=True)
dis = flopy.mf6.ModflowGwfdis(gwfp, **lgrp.get_gridprops_dis6())
ic = flopy.mf6.ModflowGwfic(gwfp)
npf = flopy.mf6.ModflowGwfnpf(gwfp, save_specific_discharge=True)
chdspd = [[(0, 0, 0), 1.0], [(0, lgrp.nrow - 1, lgrp.ncol - 1), 0.0]]
chd = flopy.mf6.ModflowGwfchd(gwfp, stress_period_data=chdspd)
oc = flopy.mf6.ModflowGwfoc(
    gwfp,
    budget_filerecord=f"{pname}.bud",
    head_filerecord=f"{pname}.hds",
    saverecord=[("HEAD", "ALL"), ("BUDGET", "ALL")],
)

# Set up the child model and use the lgr.child object to
# help provide the necessary information.
lgrc = lgr.child
gwfc = flopy.mf6.ModflowGwf(sim, modelname=cname, save_flows=True)
dis = flopy.mf6.ModflowGwfdis(gwfc, **lgrc.get_gridprops_dis6())
ic = flopy.mf6.ModflowGwfic(gwfc)
npf = flopy.mf6.ModflowGwfnpf(gwfc, save_specific_discharge=True)
oc = flopy.mf6.ModflowGwfoc(
    gwfc,
    budget_filerecord=f"{cname}.bud",
    head_filerecord=f"{cname}.hds",
    saverecord=[("HEAD", "ALL"), ("BUDGET", "ALL")],
)
```

[14]:
```
# now set up transport model
include_transport = True
if include_transport:
    pname = "parent-tran"
    cname = "child-tran"
```

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```
# retrieve the exchange data from the lgr object
exchangedata = lgr.get_exchange_data(angldegx=True, cdist=True)
nexg = len(exchangedata)

# When creating the exchange, which couples the child and parent
# models, use the xt3d option, which is an alternative to the
# ghost-node correction.  This xt3d option was added as a new
# capability for the gwt-gwt and gwf-gwf exchanges in MODFLOW version 6.3.0.
exg = flopy.mf6.ModflowGwtgwt(
    sim,
    exgtype="GWT6-GWT6",
    gwfmodelname1=gwfp.name,
    gwfmodelname2=gwfc.name,
    # xt3d=True,
    auxiliary=["angldegx", "cdist"],
    exgmnamea=pname,
    exgmnameb=cname,
    nexg=nexg,
    exchangedata=exchangedata,
)

# Set up the parent model and use the lgr.parent object to
# help provide the necessary information.
lgrp = lgr.parent
gwtp = flopy.mf6.ModflowGwt(sim, modelname=pname, save_flows=True)
dis = flopy.mf6.ModflowGwtdis(gwtp, **lgrp.get_gridprops_dis6())
mst = flopy.mf6.ModflowGwtmst(gwtp, porosity=0.2)
ic = flopy.mf6.ModflowGwtic(gwtp)
adv = flopy.mf6.ModflowGwtadv(gwtp)
dsp = flopy.mf6.ModflowGwtdsp(gwtp, alh=1.0, ath1=0.1)
ssm = flopy.mf6.ModflowGwtssm(gwtp)
oc = flopy.mf6.ModflowGwtoc(
    gwtp,
    budget_filerecord=f"{pname}.bud",
    concentration_filerecord=f"{pname}.ucn",
    saverecord=[("CONCENTRATION", "ALL"), ("BUDGET", "ALL")],
)

# Set up the child model and use the lgr.child object to
# help provide the necessary information.
lgrc = lgr.child
gwtc = flopy.mf6.ModflowGwt(sim, modelname=cname, save_flows=True)
dis = flopy.mf6.ModflowGwtdis(gwtc, **lgrc.get_gridprops_dis6())
mst = flopy.mf6.ModflowGwtmst(gwtc, porosity=0.2)
ic = flopy.mf6.ModflowGwtic(gwtc)
adv = flopy.mf6.ModflowGwtadv(gwtc)
dsp = flopy.mf6.ModflowGwtdsp(gwtc, alh=1.0, ath1=0.1)
# ssm = flopy.mf6.ModflowGwtssm(gwtc)
cncspd = {0: [[(0, int(lgrc.nrow / 2), int(lgrc.ncol / 2)), 1000.0]]}
cnc = flopy.mf6.ModflowGwtcnc(gwtc, stress_period_data=cncspd)
oc = flopy.mf6.ModflowGwtoc(
```

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```
        gwtc,
        budget_filerecord=f"{cname}.bud",
        concentration_filerecord=f"{cname}.ucn",
        saverecord=[("CONCENTRATION", "ALL"), ("BUDGET", "ALL")],
        printrecord=[("CONCENTRATION", "LAST"), ("BUDGET", "ALL")],
    )

    ims_tran = flopy.mf6.ModflowIms(
        sim, linear_acceleration="BICGSTAB", filename="tran.ims"
    )
    sim.register_ims_package(ims_tran, [gwtp.name, gwtc.name])

    # couple flow and transport models
    gwfgwt_p = flopy.mf6.ModflowGwfgwt(
        sim,
        exgtype="GWF6-GWT6",
        exgmnamea=gwfp.name,
        exgmnameb=gwtp.name,
        filename="gwfp_gwtp.gwfgwt",
    )
    gwfgwt_c = flopy.mf6.ModflowGwfgwt(
        sim,
        exgtype="GWF6-GWT6",
        exgmnamea=gwfc.name,
        exgmnameb=gwtc.name,
        filename="gwfc_gwtc.gwfgwt",
    )
```

[15]:
```
# write and run simulation
sim.write_simulation(silent=True)
success, buff = sim.run_simulation(silent=True, report=True)
assert success, "Model did not run to completion."
```

[16]:
```
# load and store the head arrays from the parent and child models
head = [gwfp.output.head().get_data(), gwfc.output.head().get_data()]
conc = [
    gwtp.output.concentration().get_data(),
    gwtc.output.concentration().get_data(),
]

# load and store the specific discharge results for the parent and child models
bud = gwfp.output.budget()
spdis = bud.get_data(text="DATA-SPDIS")[0]
spdisp = flopy.utils.postprocessing.get_specific_discharge(spdis, gwfp)
bud = gwfc.output.budget()
spdis = bud.get_data(text="DATA-SPDIS")[0]
spdisc = flopy.utils.postprocessing.get_specific_discharge(spdis, gwfc)
```

[17]:
```
# plot the results from both the parent and child models
# on the same figure
f = plt.figure(figsize=(12, 10))
```

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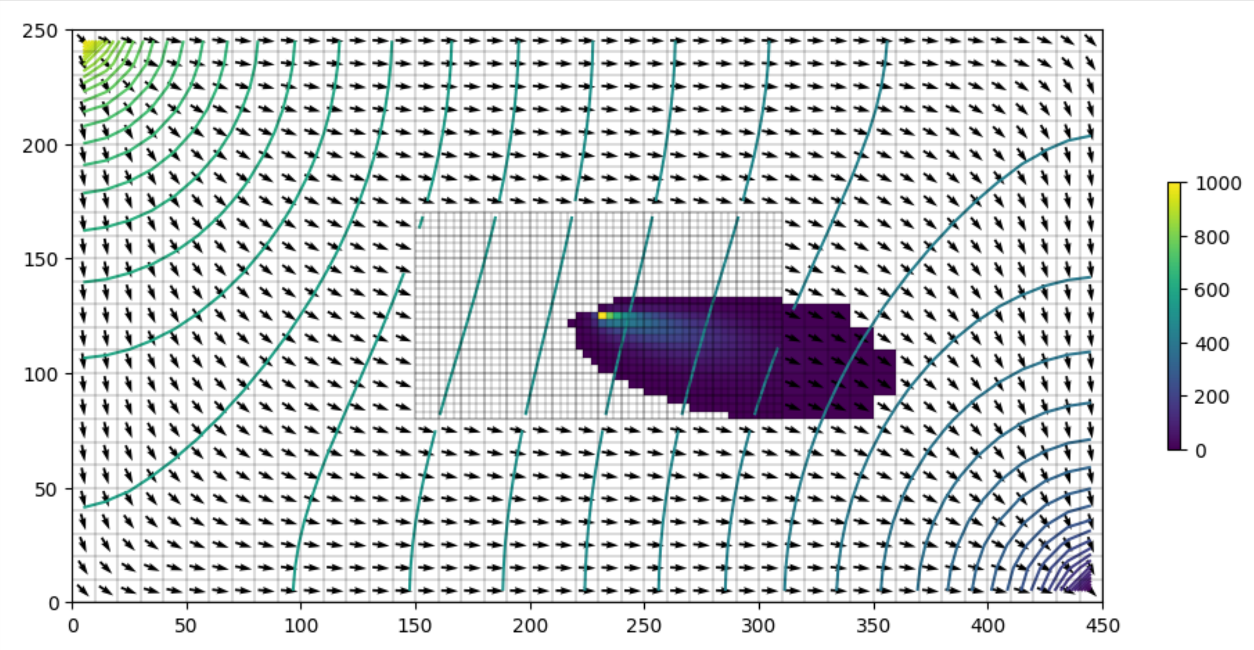
```
ax = plt.subplot(1, 1, 1, aspect="equal")
pmvp = flopy.plot.PlotMapView(gwfp, ax=ax)
pmvc = flopy.plot.PlotMapView(gwfc, ax=ax, extent=pmvp.extent)

# color flood head
# pmvp.plot_array(head[0], vmin=0., vmax=1., masked_values=[1.e30])
# pmvc.plot_array(head[1], vmin=0., vmax=1.)

# contour head
cs = pmvp.contour_array(
    head[0], levels=np.linspace(0, 1), masked_values=[1.0e30]
)
cs = pmvc.contour_array(
    head[1], levels=np.linspace(0, 1), masked_values=[1.0e30]
)

# color flood concentrations
a1 = conc[0]
a2 = conc[1]
a1 = np.ma.masked_where(a1 < 1.0, a1)
a2 = np.ma.masked_where(a2 < 1.0, a2)
vmin = 0.0
vmax = 1000.0
pmvp.plot_array(a1, vmin=vmin, vmax=vmax, masked_values=[1.0e30])
pa = pmvc.plot_array(a2, vmin=vmin, vmax=vmax)
plt.colorbar(pa, shrink=0.25)

# draw parent and child grids
pmvp.plot_grid(colors="black", linewidths=0.2)
pmvc.plot_grid(colors="black", linewidths=0.2)

# plot vectors
qv = pmvp.plot_vector(spdisp[0], spdisp[1], normalize=True, color="black")
# qv = pmvc.plot_vector(spdisc[0], spdisc[1], normalize=True, color="white")
```



[18]:
```
try:
    # ignore PermissionError on Windows
    temp_dir.cleanup()
except:
    pass
```

5.5 MODFLOW-NWT

5.5.1 Working with MODFLOW-NWT v 1.1 option blocks

In MODFLOW-NWT an option block is present for the WEL file, UZF file, and SFR file. This block takes keyword arguments that are supplied in an option line in other versions of MODFLOW.

The `OptionBlock` class was created to provide combatibility with the MODFLOW-NWT option block and allow the user to easily edit values within the option block

[1]:
```
import os
import sys
from tempfile import TemporaryDirectory

try:
    import flopy
except:
    fpth = os.path.abspath(os.path.join("..", ".."))
    sys.path.append(fpth)
    import flopy

from flopy.utils import OptionBlock
```

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```
print(sys.version)
print(f"flopy version: {flopy.__version__}")
```

```
3.8.18 (default, Aug 28 2023, 08:27:22)
[GCC 11.4.0]
flopy version: 3.5.0
```

[2]:
```
load_ws = os.path.join("..", "..", "examples", "data", "options", "sagehen")

# temporary directory
temp_dir = TemporaryDirectory()
model_ws = os.path.join(temp_dir.name, "nwt_options", "output")
```

Loading a MODFLOW-NWT model that has option block options

It is critical to set the `version` flag in `flopy.modflow.Modflow.load()` to `version='mfnwt'`

We are going to load a modified version of the Sagehen test problem from GSFLOW to illustrate compatibility

[3]:
```
mfexe = "mfnwt"

ml = flopy.modflow.Modflow.load(
    "sagehen.nam", model_ws=load_ws, exe_name=mfexe, version="mfnwt"
)
ml.change_model_ws(new_pth=model_ws)
ml.write_input()
```

```
   loading iuzfbnd array...
   loading vks array...
   loading eps array...
   loading thts array...
stress period 1:
   loading finf array...
stress period 2:

creating model workspace...
   ../../../../../../../tmp/tmp70vm3j9j/nwt_options/output
```

Let's look at the options attribute of the UZF object

The `uzf.options` attribute is an `OptionBlock` object. The representation of this object is the option block that will be written to output, which allows the user to easily check to make sure the block has the options they want.

[4]:
```
uzf = ml.get_package("UZF")
uzf.options
```

[4]:
```
OPTIONS
NOSURFLEAK
ETSQUARE 0.2
SAVEFINF
END
```

The `OptionBlock` object also has attributes which correspond to the option names listed in the online guide to modflow

The user can call and edit the options within the option block

[5]:
```
print(uzf.options.nosurfleak)
print(uzf.options.savefinf)
```

```
True
True
```

[6]:
```
uzf.options.etsquare = False
uzf.options
```

[6]:
```
OPTIONS
NOSURFLEAK
SAVEFINF
END
```

[7]:
```
uzf.options.etsquare = True
uzf.options
```

[7]:
```
OPTIONS
NOSURFLEAK
ETSQUARE 0.2
SAVEFINF
END
```

The user can also see the single line representation of the options

[8]:
```
uzf.options.single_line_options
```

[8]:
```
'NOSURFLEAK ETSQUARE 0.2 SAVEFINF'
```

And the user can easily change to single line options writing

[9]:
```
uzf.options.block = False

# write out only the uzf file
uzf_name = "uzf_opt.uzf"
uzf.write_file(os.path.join(model_ws, uzf_name))
```

Now let's examine the first few lines of the new UZF file

[10]:
```
f = open(os.path.join(model_ws, uzf_name))
for ix, line in enumerate(f):
    if ix == 3:
        break
    else:
        print(line)
```

```
# UZF package for MODFLOW-NWT generated by Flopy 3.5.0

```

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```
NOSURFLEAK ETSQUARE 0.2 SAVEFINF

         3         1         0         0         0         0        15       100      ␣
↪4   1.000000E+00 #NUZTOP IUZFOPT IRUNFLG IETFLG ipakcb IUZFCB2 NTRAIL NSETS NUZGAGES
```

And let's load the new UZF file

[11]:
```python
uzf2 = flopy.modflow.ModflowUzf1.load(
    os.path.join(model_ws, uzf_name), ml, check=False
)
```

```
   loading iuzfbnd array...
   loading vks array...
   loading eps array...
   loading thts array...
stress period 1:
   loading finf array...
stress period 2:
```

```
/opt/hostedtoolcache/Python/3.8.18/x64/lib/python3.8/site-packages/flopy/mbase.py:667:␣
↪UserWarning: Two packages of the same type, Replacing existing 'UZF' package.
  warn(
```

Now we can look at the options object, and check if it's block or line format

`block=False` indicates that options will be written as line format

[12]:
```python
print(uzf2.options)
print(uzf2.options.block)
```

```
OPTIONS
NOSURFLEAK
ETSQUARE 0.2
SAVEFINF
END

False
```

Finally we can convert back to block format

[13]:
```python
uzf2.options.block = True
uzf2.write_file(os.path.join(model_ws, uzf_name))
ml.remove_package("UZF")

uzf3 = flopy.modflow.ModflowUzf1.load(
    os.path.join(model_ws, uzf_name), ml, check=False
)
print("\n")
print(uzf3.options)
print(uzf3.options.block)
```

```
   loading iuzfbnd array...
   loading vks array...
   loading eps array...
   loading thts array...
stress period 1:
   loading finf array...
stress period 2:


OPTIONS
NOSURFLEAK
ETSQUARE 0.2
SAVEFINF
END

True
```

We can also look at the WEL object

[14]:
```
wel = ml.get_package("WEL")
wel.options
```

[14]:
```
OPTIONS
SPECIFY 0.1 90
END
```

Let's write this out as a single line option block and examine the first few lines

[15]:
```
wel_name = "wel_opt.wel"
wel.options.block = False

wel.write_file(os.path.join(model_ws, wel_name))


f = open(os.path.join(model_ws, wel_name))
for ix, line in enumerate(f):
    if ix == 4:
        break
    else:
        print(line)
```

```
# WEL package for MODFLOW-NWT generated by Flopy 3.5.0

         5         0 NOPRINT

SPECIFY 0.1 90

         5         0 # stress period 1
```

And we can load the new single line options WEL file and confirm that it is being read as an option line

[16]:
```
ml.remove_package("WEL")
wel2 = flopy.modflow.ModflowWel.load(
    os.path.join(model_ws, wel_name), ml, nper=ml.nper, check=False
)

wel2.options
wel2.options.block
```

[16]:
```
False
```

Building an OptionBlock from scratch

The user can also build an `OptionBlock` object from scratch to add to a `ModflowSfr2`, `ModflowUzf1`, or `ModflowWel` file.

The `OptionBlock` class has two required parameters and one optional parameter

`option_line`: a one line, string based representation of the options

`package`: a modflow package object

`block`: boolean flag for line based or block based options

[17]:
```
opt_line = "specify 0.1 20"
options = OptionBlock(opt_line, flopy.modflow.ModflowWel, block=True)
options
```

[17]:
```
OPTIONS
SPECIFY 0.1 20
END
```

from here we can set the noprint flag by using `options.noprint`

[18]:
```
options.noprint = True
```

and the user can also add auxillary variables by using `options.auxillary`

[19]:
```
options.auxillary = ["aux", "iface"]
```

Now we can create a new wel file using this `OptionBlock`

and write it to output

[20]:
```
wel3 = flopy.modflow.ModflowWel(
    ml,
    stress_period_data=wel.stress_period_data,
    options=options,
    unitnumber=99,
)

wel3.write_file(os.path.join(model_ws, wel_name))
```

```
/opt/hostedtoolcache/Python/3.8.18/x64/lib/python3.8/site-packages/flopy/mbase.py:667:␣
↪UserWarning: Two packages of the same type, Replacing existing 'WEL' package.
  warn(
```

And now let's examine the first few lines of the file

[21]:
```
f = open(os.path.join(model_ws, wel_name))
for ix, line in enumerate(f):
    if ix == 8:
        break
    else:
        print(line)
```

```
# WEL package for MODFLOW-NWT generated by Flopy 3.5.0

OPTIONS

SPECIFY 0.1 20

END

         5          0 NOPRINT AUX IFACE

         5          0 # stress period 1

         1         35         12             20.0

         1         36         13             21.0
```

We can see that everything that the OptionBlock class writes out options in the correct location.

The user can also switch the options over to option line style and write out the output too!

[22]:
```
wel3.options.block = False
wel3.write_file(os.path.join(model_ws, wel_name))

f = open(os.path.join(model_ws, wel_name))
for ix, line in enumerate(f):
    if ix == 6:
        break
    else:
        print(line)
```

```
# WEL package for MODFLOW-NWT generated by Flopy 3.5.0

         5          0 NOPRINT AUX IFACE

SPECIFY 0.1 20

         5          0 # stress period 1

         1         35         12             20.0

         1         36         13             21.0
```

[23]:
```
try:
    # ignore PermissionError on Windows
    temp_dir.cleanup()
except:
    pass
```

5.6 MT3DMS

5.6.1 MT3D-USGS: Transport with the SFR/LAK/UZF Packages (SFT/LKT/UZT), and chemical reactions (RCT)

A more comprehensive demonstration of setting up an MT3D-USGS model that uses all of the new packages included in the first release of MT3D-USGS. Also includes RCT.

Problem Description:

- 300 row x 300 col x 3 layer x 2 stress period model
- Flow model uses SFR, LAK, and UZF with connections between all three
- Transport model simulates streamflow transport (SFT), with connection to a single lake (LKT)
- Transport model simulates overland runoff and spring discharge (UZT) to surface water network

Start by importing some libraries:

[1]:
```
import os
import sys
from tempfile import TemporaryDirectory

import matplotlib as mpl
import matplotlib.pyplot as plt
import numpy as np
import pandas as pd

# run installed version of flopy or add local path
try:
    import flopy
except:
    fpth = os.path.abspath(os.path.join("..", ".."))
    sys.path.append(fpth)
    import flopy

print(sys.version)
print(f"numpy version: {np.__version__}")
print(f"matplotlib version: {mpl.__version__}")
print(f"flopy version: {flopy.__version__}")
```

```
3.8.18 (default, Aug 28 2023, 08:27:22)
[GCC 11.4.0]
numpy version: 1.24.4
```

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```
matplotlib version: 3.7.4
flopy version: 3.5.0
```

Create a MODFLOW model and store it, in this case in the variable 'mf'. The modelname will be the name given to all MODFLOW files. The exe_name should be the name of the MODFLOW executable. In this case, we want to use version: 'mfnwt' for MODFLOW-NWT

[2]:
```
# temporary directory
temp_dir = TemporaryDirectory()
model_ws = temp_dir.name

modelpth = os.path.join(model_ws, "no3")
modelname = "no3"
mfexe = "mfnwt"
mtexe = "mt3dusgs"

# Make sure modelpth directory exists
if not os.path.isdir(modelpth):
    os.makedirs(modelpth, exist_ok=True)

# Instantiate MODFLOW object in flopy
mf = flopy.modflow.Modflow(
    modelname=modelname, exe_name=mfexe, model_ws=modelpth, version="mfnwt"
)
```

Set up model discretization

[3]:
```
Lx = 90000.0
Ly = 90000.0
nrow = 300
ncol = 300
nlay = 3

delr = Lx / ncol
delc = Ly / nrow

xmax = ncol * delr
ymax = nrow * delc

X, Y = np.meshgrid(
    np.linspace(delr / 2, xmax - delr / 2, ncol),
    np.linspace(ymax - delc / 2, 0 + delc / 2, nrow),
)
```

Instantiate output control (oc) package for MODFLOW-NWT

[4]:
```
oc = flopy.modflow.ModflowOc(mf)
```

Instantiate solver package for MODFLOW-NWT

[5]:
```
# Newton-Raphson Solver: Create a flopy nwt package object

headtol = 1.0e-4
fluxtol = 5
maxiterout = 5000
thickfact = 1e-06
linmeth = 2
iprnwt = 1
ibotav = 1

nwt = flopy.modflow.ModflowNwt(
    mf,
    headtol=headtol,
    fluxtol=fluxtol,
    maxiterout=maxiterout,
    thickfact=thickfact,
    linmeth=linmeth,
    iprnwt=iprnwt,
    ibotav=ibotav,
    options="SIMPLE",
)
```

Instantiate discretization (DIS) package for MODFLOW-NWT

[6]:
```
elv_pth = os.path.join(
    "..",
    "..",
    "examples",
    "data",
    "mt3d_example_sft_lkt_uzt",
    "dis_arrays",
    "grnd_elv.txt",
)

# Top of Layer 1 elevation determined using GW Vistas and stored locally
grndElv = np.loadtxt(elv_pth)

# Bottom of layer 1 elevation also determined from use of GUI and stored locally
bt1_pth = os.path.join(
    "..",
    "..",
    "examples",
    "data",
```

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```
    "mt3d_example_sft_lkt_uzt",
    "dis_arrays",
    "bot1.txt",
)
bot1Elv = np.loadtxt(bt1_pth)

bot2Elv = np.ones(bot1Elv.shape) * 100
bot3Elv = np.zeros(bot2Elv.shape)

botm = [bot1Elv, bot2Elv, bot3Elv]
botm = np.array(botm)
Steady = [False, False]
nstp = [1, 1]
tsmult = [1.0, 1.0]

# Stress periods
perlen = [9131.25, 9131.25]

# Create the discretization object
# itmuni = 4 (days); lenuni = 1 (feet)
dis = flopy.modflow.ModflowDis(
    mf,
    nlay,
    nrow,
    ncol,
    nper=2,
    delr=delr,
    delc=delc,
    top=grndElv,
    botm=botm,
    laycbd=0,
    itmuni=4,
    lenuni=1,
    steady=Steady,
    nstp=nstp,
    tsmult=tsmult,
    perlen=perlen,
)
```

Instantiate upstream weighting (UPW) flow package for MODFLOW-NWT

[7]:
```
# UPW must be instantiated after DIS.  Otherwise, during the mf.write_input() procedures,
# flopy will crash.

# First line of UPW input is: IUPWCB HDRY NPUPW IPHDRY
hdry = -1.00e30
iphdry = 0

# Next variables are: LAYTYP, LAYAVG, CHANI, LAYVKA, LAYWET
laytyp = [1, 3, 3]  # >0: convertible
```

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```
layavg = 0  #  0: harmonic mean
chani = 1.0  # >0: CHANI is the horizontal anisotropy for the entire layer
layvka = 0  # =0: indicates VKA is vertical hydraulic conductivity
laywet = 0  # Always set equal to zero in UPW package
hk = 20
# hani = 1           # Not needed because CHANI > 1
vka = 0.5  # Is equal to vert. K b/c LAYVKA = 0
ss = 0.00001
sy = 0.20

upw = flopy.modflow.ModflowUpw(
    mf,
    laytyp=laytyp,
    layavg=layavg,
    chani=chani,
    layvka=layvka,
    laywet=laywet,
    ipakcb=53,
    hdry=hdry,
    iphdry=iphdry,
    hk=hk,
    vka=vka,
    ss=ss,
    sy=sy,
)
```

Instantiate basic (BAS or BA6) package for MODFLOW-NWT

[8]:
```
ibnd1_pth = os.path.join(
    "..",
    "..",
    "examples",
    "data",
    "mt3d_example_sft_lkt_uzt",
    "bas_arrays",
    "ibnd_lay1.txt",
)
ibnd1 = np.loadtxt(ibnd1_pth)
ibnd2 = np.ones(ibnd1.shape)
ibnd3 = np.ones(ibnd2.shape)

ibnd = [ibnd1, ibnd2, ibnd3]
ibnd = np.array(ibnd)

StHd1_pth = os.path.join(
    "..",
    "..",
    "examples",
    "data",
    "mt3d_example_sft_lkt_uzt",
```

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```
    "bas_arrays",
    "strthd1.txt",
)
StHd1 = np.loadtxt(StHd1_pth)

StHd2_pth = os.path.join(
    "..",
    "..",
    "examples",
    "data",
    "mt3d_example_sft_lkt_uzt",
    "bas_arrays",
    "strthd2.txt",
)
StHd2 = np.loadtxt(StHd2_pth)

StHd3_pth = os.path.join(
    "..",
    "..",
    "examples",
    "data",
    "mt3d_example_sft_lkt_uzt",
    "bas_arrays",
    "strthd3.txt",
)
StHd3 = np.loadtxt(StHd3_pth)

strtElev = [StHd1, StHd2, StHd3]
strtElev = np.array(strtElev)

hdry = 999.0

bas = flopy.modflow.ModflowBas(mf, ibound=ibnd, hnoflo=hdry, strt=strtElev)
```

Instantiate general head boundary (GHB) package for MODFLOW-NWT

[9]:
```
# GHB boundaries are located along the top (north) and bottom (south)
# edges of the domain, all 3 layers.

elev_stpt_row1 = 308.82281
elev_stpt_row300 = 239.13811
elev_slp = (308.82281 - 298.83649) / (ncol - 1)

sp = []
for k in [0, 1, 2]:  # These indices need to be adjusted for 0-based moronicism
    for i in [
        0,
        299,
    ]:  # These indices need to be adjusted for 0-based silliness
        for j in np.arange(
```

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```
            0, 300, 1
        ):  # These indices need to be adjusted for 0-based foolishness
            # Skipping cells not satisfying the conditions below
            if (i == 1 and (j < 27 or j > 31)) or (
                i == 299 and (j < 26 or j > 31)
            ):
                if i % 2 == 0:
                    sp.append(
                        [
                            k,
                            i,
                            j,
                            elev_stpt_row1 - (elev_slp * (j - 1)),
                            11.3636,
                        ]
                    )
                else:
                    sp.append(
                        [
                            k,
                            i,
                            j,
                            elev_stpt_row300 - (elev_slp * (j - 1)),
                            11.3636,
                        ]
                    )


for k in [0, 1, 2]:
    for j in np.arange(26, 32, 1):
        sp.append([k, 299, j, 238.20, 3409.0801])

ghb = flopy.modflow.ModflowGhb(mf, stress_period_data=sp)
```

Instantiate streamflow routing (SFR2) package for MODFLOW-NWT

[10]:
```
# Read pre-prepared reach data into numpy recarrays using numpy.genfromtxt()
# Remember that the cell indices stored in the pre-prepared NO3_ReachInput.csv file are␣
↪based on 0-based indexing.
# Flopy will convert to 1-based when it writes the files

rpth = os.path.join(
    "..",
    "..",
    "examples",
    "data",
    "mt3d_example_sft_lkt_uzt",
    "sfr_data",
    "no3_reachinput.csv",
)
```

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```
reach_data = np.genfromtxt(rpth, delimiter=",", names=True)
reach_data

# Read pre-prepared segment data into numpy recarrays using numpy.genfromtxt()

spth = os.path.join(
    "..",
    "..",
    "examples",
    "data",
    "mt3d_example_sft_lkt_uzt",
    "sfr_data",
    "no3_segmentdata.csv",
)
ss_segment_data = np.genfromtxt(spth, delimiter=",", names=True)
segment_data = {0: ss_segment_data, 1: ss_segment_data}
segment_data[0][0:1]["width1"]

nstrm = len(reach_data)
nss = len(segment_data[0])
nsfrpar = 0
const = 128390.4  # constant for manning's equation, units of cfs
dleak = 0.0001
ipakcb = 53  # flag for writing SFR output to cell-by-cell budget (on unit 53)
istcb2 = 37  # flag for writing SFR output to text file
isfropt = 1
dataset_5 = {
    0: [nss, 0, 0],
    1: [-1, 0, 0],
}  # dataset 5 (see online guide) (ITMP, IRDFLG, IPTFLG)

# Input arguments generally follow the variable names defined in the Online Guide to␣
↪MODFLOW
sfr = flopy.modflow.ModflowSfr2(
    mf,
    nstrm=nstrm,
    nss=nss,
    const=const,
    dleak=dleak,
    ipakcb=ipakcb,
    istcb2=istcb2,
    isfropt=isfropt,
    reachinput=True,
    reach_data=reach_data,
    segment_data=segment_data,
    dataset_5=dataset_5,
    unit_number=15,
)
```

Instantiate Lake (LAK) package for MODFLOW-NWT

[11]:
```python
# Read pre-prepared lake arrays
LakArr_pth = os.path.join(
    "..",
    "..",
    "examples",
    "data",
    "mt3d_example_sft_lkt_uzt",
    "lak_arrays",
    "lakarr1.txt",
)
LakArr_lyr1 = np.loadtxt(LakArr_pth)
LakArr_lyr2 = np.zeros(LakArr_lyr1.shape)
LakArr_lyr3 = np.zeros(LakArr_lyr2.shape)

LakArr = [LakArr_lyr1, LakArr_lyr2, LakArr_lyr3]
LakArr = np.array(LakArr)

nlakes = int(np.max(LakArr))
ipakcb = ipakcb  # From above
theta = -1.0  # Implicit
nssitr = 10  # Maximum number of iterations for Newton’s method
sscncr = 1.000e-03  # Convergence criterion for equilibrium lake stage solution
surfdep = 2.000e00  # Height of small topological variations in lake-bottom
stages = 268.00  # Initial stage of each lake at the beginning of the run

# ITMP  > 0, read lake definition data
# ITMP1  0, read new recharge, evaporation, runoff, and withdrawal data for each lake
# LWRT  > 0, suppresses printout from the lake package

bdlknc_lyr1 = LakArr_lyr1.copy()
bdlknc_lyr2 = LakArr_lyr1.copy()
bdlknc_lyr3 = np.zeros(LakArr_lyr1.shape)

# Need to expand bdlknc_lyr1 non-zero values by 1 in either direction
# (left/right and up/down)
for i in np.arange(0, LakArr_lyr1.shape[0]):
    for j in np.arange(0, LakArr_lyr1.shape[1]):
        im1 = i - 1
        ip1 = i + 1
        jm1 = j - 1
        jp1 = j + 1

        if im1 >= 0:
            if LakArr_lyr1[i, j] == 1 and LakArr_lyr1[im1, j] == 0:
                bdlknc_lyr1[im1, j] = 1

        if ip1 < LakArr_lyr1.shape[0]:
            if LakArr_lyr1[i, j] == 1 and LakArr_lyr1[ip1, j] == 0:
                bdlknc_lyr1[ip1, j] = 1
```

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```
        if jm1 >= 0:
            if LakArr_lyr1[i, j] == 1 and LakArr_lyr1[i, jm1] == 0:
                bdlknc_lyr1[i, jm1] = 1

        if jp1 < LakArr_lyr1.shape[1]:
            if LakArr_lyr1[i, j] == 1 and LakArr_lyr1[i, jp1] == 0:
                bdlknc_lyr1[i, jp1] = 1


bdlknc = [bdlknc_lyr1, bdlknc_lyr2, bdlknc_lyr3]
bdlknc = np.array(bdlknc)

flux_data = {0: [[0.0073, 0.0073, 0.0, 0.0]], 1: [[0.0073, 0.0073, 0.0, 0.0]]}

lak = flopy.modflow.ModflowLak(
    mf,
    nlakes=nlakes,
    ipakcb=ipakcb,
    theta=theta,
    nssitr=nssitr,
    sscncr=sscncr,
    surfdep=surfdep,
    stages=stages,
    lakarr=LakArr,
    bdlknc=bdlknc,
    flux_data=flux_data,
    unit_number=16,
)
```

Instantiate gage package for use with MODFLOW-NWT package

[12]:
```
gages = [
    [1, 225, 90, 3],
    [2, 68, 91, 3],
    [3, 33, 92, 3],
    [4, 165, 93, 3],
    [5, 123, 94, 3],
    [6, 77, 95, 3],
    [7, 173, 96, 3],
    [8, 328, 97, 3],
    [9, 115, 98, 3],
    [-1, -101, 1],
]

# gages = [[1,38,61,1],[2,67,62,1], [3,176,63,1], [4,152,64,1], [5,186,65,1], [6,31,66,
↪1]]
files = [
    "no3.gag",
    "seg1_gag.out",
    "seg2_gag.out",
```

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```
    "seg3_gag.out",
    "seg4_gag.out",
    "seg5_gag.out",
    "seg6_gag.out",
    "seg7_gag.out",
    "seg8_gag.out",
    "seg9_gag.out",
    "lak1_gag.out",
]

numgage = len(gages)
gage = flopy.modflow.ModflowGage(
    mf, numgage=numgage, gage_data=gages, filenames=files
)
```

Instantiate Unsaturated-Zone Flow (UZF) package for MODFLOW-NWT

[13]:
```
nuztop = 2
iuzfopt = 2
irunflg = 1
ietflg = 0
iuzfcb = 52
iuzfcb2 = 0
ntrail2 = 20
nsets2 = 20
nuzgag = 2
surfdep = 2.0

eps = 3.0
thts = 0.30
thti = 0.13079

fname_uzbnd = os.path.join(
    "..",
    "..",
    "examples",
    "data",
    "mt3d_example_sft_lkt_uzt",
    "uzf_arrays",
    "iuzbnd.txt",
)
fname_runbnd = os.path.join(
    "..",
    "..",
    "examples",
    "data",
    "mt3d_example_sft_lkt_uzt",
    "uzf_arrays",
    "irunbnd.txt",
)
```

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```
iuzfbnd = np.loadtxt(fname_uzbnd)
irunbnd = np.loadtxt(fname_runbnd)

uzgag = [[106, 160, 121, 3], [1, 1, -122, 1]]

finf = {0: 1.8250e-03, 1: 1.8250e-03}

uzf = flopy.modflow.ModflowUzf1(
    mf,
    nuztop=nuztop,
    iuzfopt=iuzfopt,
    irunflg=irunflg,
    ietflg=ietflg,
    ipakcb=iuzfcb,
    iuzfcb2=iuzfcb2,
    ntrail2=ntrail2,
    nsets=nsets2,
    surfdep=surfdep,
    uzgag=uzgag,
    iuzfbnd=1,
    irunbnd=0,
    vks=1.0e-6,
    eps=3.5,
    thts=0.35,
    thtr=0.15,
    thti=0.20,
)
```

Instantiate Drain (DRN) package for MODFLOW-NWT

[14]:
```
fname_drnElv = os.path.join(
    "..",
    "..",
    "examples",
    "data",
    "mt3d_example_sft_lkt_uzt",
    "drn_arrays",
    "elv.txt",
)
fname_drnCond = os.path.join(
    "..",
    "..",
    "examples",
    "data",
    "mt3d_example_sft_lkt_uzt",
    "drn_arrays",
    "cond.txt",
)
```

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```
drnElv = np.loadtxt(fname_drnElv)
drnCond = np.loadtxt(fname_drnCond)

drnElv_lst = pd.DataFrame(
    {
        "lay": 1,
        "row": np.nonzero(drnElv)[0] + 1,
        "col": np.nonzero(drnElv)[1] + 1,
        "elv": drnElv[np.nonzero(drnElv)],
        "cond": drnCond[np.nonzero(drnCond)],
    },
    columns=["lay", "row", "col", "elv", "cond"],
)

# Convert the DataFrame into a list of lists for the drn constructor
stress_period_data = drnElv_lst.values.tolist()

# Create a dictionary, 1 entry for each of the two stress periods.
stress_period_data = {0: stress_period_data, 1: stress_period_data}

drn = flopy.modflow.ModflowDrn(
    mf, ipakcb=ipakcb, stress_period_data=stress_period_data
)
```

Instantiate linkage with mass transport routing (LMT) package for MODFLOW-NWT (generates linker file)

[15]:
```
lmt = flopy.modflow.ModflowLmt(
    mf,
    output_file_name="NO3.ftl",
    output_file_header="extended",
    output_file_format="formatted",
    package_flows=["all"],
)
```

Now work on MT3D-USGS file creation

[16]:
```
# Start by setting up MT3D-USGS class and pass in MODFLOW-NWT object for setting up a␣
↪number of the BTN arrays

mt = flopy.mt3d.Mt3dms(
    modflowmodel=mf,
    modelname=modelname,
    model_ws=modelpth,
    version="mt3d-usgs",
    namefile_ext="mtnam",
    exe_name=mtexe,
    ftlfilename="no3.ftl",
```

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```
    ftlfree=True,
)
```

Instantiate basic transport (BTN) package for MT3D-USGS

[17]:
```
ncomp = 1
lunit = "FT"
sconc = 0.0
prsity = 0.3
cinact = -1.0
thkmin = 0.000001
nprs = -2
nprobs = 10
nprmas = 10
dt0 = 0.1
nstp = 1
mxstrn = 500
ttsmult = 1.2
ttsmax = 100

# These observations need to be entered with 0-based indexing
obs = [[0, 104, 158], [1, 104, 158], [2, 104, 158]]

btn = flopy.mt3d.Mt3dBtn(
    mt,
    MFStyleArr=True,
    DRYCell=True,
    lunit=lunit,
    sconc=sconc,
    ncomp=ncomp,
    prsity=prsity,
    cinact=cinact,
    obs=obs,
    thkmin=thkmin,
    nprs=nprs,
    nprobs=nprobs,
    chkmas=True,
    nprmas=nprmas,
    dt0=dt0,
    nstp=nstp,
    mxstrn=mxstrn,
    ttsmult=ttsmult,
    ttsmax=ttsmax,
)
```

Instantiate advection (ADV) package for MT3D-USGS

[18]:
```
mixelm = 0
percel = 1.0000
mxpart = 5000
nadvfd = 1  # (1 = Upstream weighting)

adv = flopy.mt3d.Mt3dAdv(
    mt, mixelm=mixelm, percel=percel, mxpart=mxpart, nadvfd=nadvfd
)
```

Instantiate generalized conjugate gradient solver (GCG) package for MT3D-USGS

[19]:
```
mxiter = 1
iter1 = 50
isolve = 3
ncrs = 0
accl = 1.000000
cclose = 1.00e-06
iprgcg = 5

gcg = flopy.mt3d.Mt3dGcg(
    mt,
    mxiter=mxiter,
    iter1=iter1,
    isolve=isolve,
    ncrs=ncrs,
    accl=accl,
    cclose=cclose,
    iprgcg=iprgcg,
)
```

Instantiate dispersion (DSP) package for MT3D-USGS

[20]:
```
al = 0.1  # longitudinal dispersivity
trpt = 0.1  # ratio of the horizontal transverse dispersivity to 'AL'
trpv = 0.1  # ratio of the vertical transverse dispersitvity to 'AL'
dmcoef = 1.0000e-10

dsp = flopy.mt3d.Mt3dDsp(
    mt, al=al, trpt=trpt, trpv=trpv, dmcoef=dmcoef, multiDiff=True
)
```

Instantiate source-sink mixing (SSM) package for MT3D-USGS

[21]:
```python
# no user-specified concentrations associated with boundary conditions

mxss = 11199

ssm = flopy.mt3d.Mt3dSsm(mt, mxss=mxss)
```

Instantiate reaction (RCT) package for MT3D-USGS

[22]:
```python
isothm = 0
ireact = 1
irctop = 2
igetsc = 0
ireaction = 0

rc1 = 6.3258e-04  # first-order reaction rate for the dissolved phase
rc2 = 0.0  # Decay on Soil Layer

rct = flopy.mt3d.Mt3dRct(
    mt, isothm=isothm, ireact=ireact, igetsc=igetsc, rc1=rc1, rc2=rc2
)
```

Instantiate streamflow transport (SFT) package for MT3D-USGS

[23]:
```python
nsfinit = len(reach_data)
mxsfbc = len(reach_data)
icbcsf = 0
ioutobs = 92
isfsolv = 1
wimp = 0.5
wups = 1.0
cclosesf = 1.0e-6
mxitersf = 10
crntsf = 1.0
iprtxmd = 0
coldsf = 0
dispsf = 0
obs_sf = [225, 293, 326, 491, 614, 691, 864, 1192, 1307]
sf_stress_period_data = {0: [0, 0, 0], 1: [0, 0, 0], 2: [0, 0, 0]}

gage_output = [None, None, "no3.sftobs"]

sft = flopy.mt3d.Mt3dSft(
    mt,
    nsfinit=nsfinit,
    mxsfbc=mxsfbc,
    icbcsf=icbcsf,
    ioutobs=ioutobs,
```

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```
    isfsolv=isfsolv,
    wimp=wimp,
    wups=wups,
    cclosesf=cclosesf,
    mxitersf=mxitersf,
    crntsf=crntsf,
    iprtxmd=iprtxmd,
    coldsf=coldsf,
    dispsf=dispsf,
    nobssf=len(obs_sf),
    obs_sf=obs_sf,
    sf_stress_period_data=sf_stress_period_data,
    filenames=gage_output,
)
```

Instantiate unsaturated-zone transport (UZT) package for MT3D-USGS

[24]:
```
mxuzcon = np.count_nonzero(irunbnd)
icbcuz = 45
iet = 0
wc = np.ones((nlay, nrow, ncol)) * 0.29
sdh = np.ones((nlay, nrow, ncol))

uzt = flopy.mt3d.Mt3dUzt(
    mt,
    mxuzcon=mxuzcon,
    icbcuz=icbcuz,
    iet=iet,
    iuzfbnd=iuzfbnd,
    sdh=sdh,
    cuzinf=1.4158e-03,
    filenames="no3",
)
```

Instantiate lake transport (LKT) package for MT3D-USGS

[25]:
```
nlkinit = 1
mxlkbc = 720
icbclk = 81
ietlak = 1
coldlak = 1

lkt_flux_data = {0: [[0, 1, 0.01667]], 1: [[0, 1, 0.02667]]}

lkt = flopy.mt3d.Mt3dLkt(
    mt,
    nlkinit=nlkinit,
    mxlkbc=mxlkbc,
```

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```
    icbclk=icbclk,
    ietlak=ietlak,
    coldlak=coldlak,
    lk_stress_period_data=lkt_flux_data,
)
```

Write the MT3D-USGS input files for inspecting and running

[26]:
```
mf.write_input()
mt.write_input()

# mf.run_model()
# mt.run_model()
```

5.6.2 Using FloPy to simplify the use of the MT3DMS SSM package

A multi-component transport demonstration

[1]:
```
import os
import sys
from tempfile import TemporaryDirectory

import numpy as np

# run installed version of flopy or add local path
try:
    import flopy
except:
    fpth = os.path.abspath(os.path.join("..", ".."))
    sys.path.append(fpth)
    import flopy

print(sys.version)
print(f"numpy version: {np.__version__}")
print(f"flopy version: {flopy.__version__}")
```

```
3.8.18 (default, Aug 28 2023, 08:27:22)
[GCC 11.4.0]
numpy version: 1.24.4
flopy version: 3.5.0
```

First, we will create a simple model structure

[2]:
```
nlay, nrow, ncol = 10, 10, 10
perlen = np.zeros((10), dtype=float) + 10
nper = len(perlen)

ibound = np.ones((nlay, nrow, ncol), dtype=int)
```

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```
botm = np.arange(-1, -11, -1)
top = 0.0
```

Create the MODFLOW packages

[3]:
```
# temporary directory
temp_dir = TemporaryDirectory()
model_ws = temp_dir.name

modelname = "ssmex"
mf = flopy.modflow.Modflow(modelname, model_ws=model_ws)
dis = flopy.modflow.ModflowDis(
    mf,
    nlay=nlay,
    nrow=nrow,
    ncol=ncol,
    perlen=perlen,
    nper=nper,
    botm=botm,
    top=top,
    steady=False,
)
bas = flopy.modflow.ModflowBas(mf, ibound=ibound, strt=top)
lpf = flopy.modflow.ModflowLpf(mf, hk=100, vka=100, ss=0.00001, sy=0.1)
oc = flopy.modflow.ModflowOc(mf)
pcg = flopy.modflow.ModflowPcg(mf)
rch = flopy.modflow.ModflowRch(mf)
```

We'll track the cell locations for the SSM data using the MODFLOW boundary conditions.

Get a dictionary (dict) that has the SSM itype for each of the boundary types.

[4]:
```
itype = flopy.mt3d.Mt3dSsm.itype_dict()
print(itype)
print(flopy.mt3d.Mt3dSsm.get_default_dtype())
ssm_data = {}
```

```
{'CHD': 1, 'BAS6': 1, 'PBC': 1, 'WEL': 2, 'DRN': 3, 'RIV': 4, 'GHB': 5, 'MAS': 15, 'CC':␣
↪-1}
[('k', '<i8'), ('i', '<i8'), ('j', '<i8'), ('css', '<f4'), ('itype', '<i8')]
```

Add a general head boundary (ghb). The general head boundary head (bhead) is 0.1 for the first 5 stress periods with a component 1 (comp_1) concentration of 1.0 and a component 2 (comp_2) concentration of 100.0. Then bhead is increased to 0.25 and comp_1 concentration is reduced to 0.5 and comp_2 concentration is increased to 200.0

[5]:
```
ghb_data = {}
print(flopy.modflow.ModflowGhb.get_default_dtype())
ghb_data[0] = [(4, 4, 4, 0.1, 1.5)]
ssm_data[0] = [(4, 4, 4, 1.0, itype["GHB"], 1.0, 100.0)]
ghb_data[5] = [(4, 4, 4, 0.25, 1.5)]
ssm_data[5] = [(4, 4, 4, 0.5, itype["GHB"], 0.5, 200.0)]
```

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```
for k in range(nlay):
    for i in range(nrow):
        ghb_data[0].append((k, i, 0, 0.0, 100.0))
        ssm_data[0].append((k, i, 0, 0.0, itype["GHB"], 0.0, 0.0))

ghb_data[5] = [(4, 4, 4, 0.25, 1.5)]
ssm_data[5] = [(4, 4, 4, 0.5, itype["GHB"], 0.5, 200.0)]
for k in range(nlay):
    for i in range(nrow):
        ghb_data[5].append((k, i, 0, -0.5, 100.0))
        ssm_data[5].append((k, i, 0, 0.0, itype["GHB"], 0.0, 0.0))
```

```
[('k', '<i8'), ('i', '<i8'), ('j', '<i8'), ('bhead', '<f4'), ('cond', '<f4')]
```

Add an injection `well`. The injection rate (`flux`) is 10.0 with a comp_1 concentration of 10.0 and a comp_2 concentration of 0.0 for all stress periods. WARNING: since we changed the `SSM` data in stress period 6, we need to add the well to the ssm_data for stress period 6.

[6]:
```
wel_data = {}
print(flopy.modflow.ModflowWel.get_default_dtype())
wel_data[0] = [(0, 4, 8, 10.0)]
ssm_data[0].append((0, 4, 8, 10.0, itype["WEL"], 10.0, 0.0))
ssm_data[5].append((0, 4, 8, 10.0, itype["WEL"], 10.0, 0.0))
```

```
[('k', '<i8'), ('i', '<i8'), ('j', '<i8'), ('flux', '<f4')]
```

Add the `GHB` and `WEL` packages to the `mf` `MODFLOW` object instance.

[7]:
```
ghb = flopy.modflow.ModflowGhb(mf, stress_period_data=ghb_data)
wel = flopy.modflow.ModflowWel(mf, stress_period_data=wel_data)
```

Create the `MT3DMS` packages

[8]:
```
mt = flopy.mt3d.Mt3dms(modflowmodel=mf, modelname=modelname, model_ws=model_ws)
btn = flopy.mt3d.Mt3dBtn(mt, sconc=0, ncomp=2, sconc2=50.0)
adv = flopy.mt3d.Mt3dAdv(mt)
ssm = flopy.mt3d.Mt3dSsm(mt, stress_period_data=ssm_data)
gcg = flopy.mt3d.Mt3dGcg(mt)
```

```
found 'rch' in modflow model, resetting crch to 0.0
SSM: setting crch for component 2 to zero. kwarg name crch2
```

Let’s verify that `stress_period_data` has the right `dtype`

[9]:
```
print(ssm.stress_period_data.dtype)
```

```
[('k', '<i8'), ('i', '<i8'), ('j', '<i8'), ('css', '<f4'), ('itype', '<i8'), ('cssm(01)',
↪ '<f4'), ('cssm(02)', '<f4')]
```

Create the SEAWAT packages

[10]:
```
swt = flopy.seawat.Seawat(
    modflowmodel=mf,
    mt3dmodel=mt,
    modelname=modelname,
    namefile_ext="nam_swt",
    model_ws=model_ws,
)
vdf = flopy.seawat.SeawatVdf(swt, mtdnconc=0, iwtable=0, indense=-1)
```

[11]:
```
mf.write_input()
mt.write_input()
swt.write_input()
```

And finally, modify the vdf package to fix indense.

[12]:
```
fname = f"{modelname}.vdf"
f = open(os.path.join(model_ws, fname))
lines = f.readlines()
f.close()
f = open(os.path.join(model_ws, fname), "w")
for line in lines:
    f.write(line)
for kper in range(nper):
    f.write("-1\n")
f.close()
```

[13]:
```
try:
    # ignore PermissionError on Windows
    temp_dir.cleanup()
except:
    pass
```

5.6.3 SEAWAT Tutorial 1: Henry Saltwater Intrusion Problem

In this tutorial, we will use Flopy to create, run, and post process the Henry saltwater intrusion problem using SEAWAT Version 4.

[1]:
```
# ## Getting Started
from pathlib import Path
from tempfile import TemporaryDirectory
```

[2]:
```
import numpy as np
```

[3]:
```
import flopy
```

Input variables for the Henry Problem

[4]:
```
Lx = 2.0
Lz = 1.0
nlay = 50
nrow = 1
ncol = 100
delr = Lx / ncol
delc = 1.0
delv = Lz / nlay
henry_top = 1.0
henry_botm = np.linspace(henry_top - delv, 0.0, nlay)
qinflow = 5.702  # m3/day
dmcoef = 0.57024  # m2/day  Could also try 1.62925 as another case of the Henry problem
hk = 864.0  # m/day
```

Create the basic MODFLOW model structure

[5]:
```
temp_dir = TemporaryDirectory()
workspace = temp_dir.name
name = "seawat_henry"
swt = flopy.seawat.Seawat(name, exe_name="swtv4", model_ws=workspace)
print(swt.namefile)
```

```
seawat_henry.nam
```

save cell fluxes to unit 53

[6]:
```
ipakcb = 53
```

Add DIS package to the MODFLOW model

[7]:
```
dis = flopy.modflow.ModflowDis(
    swt,
    nlay,
    nrow,
    ncol,
    nper=1,
    delr=delr,
    delc=delc,
    laycbd=0,
    top=henry_top,
    botm=henry_botm,
    perlen=1.5,
    nstp=15,
)
```

[8]:
```
# Variables for the BAS package
ibound = np.ones((nlay, nrow, ncol), dtype=np.int32)
ibound[:, :, -1] = -1
```

Add BAS package to the MODFLOW model

[9]:
```
bas = flopy.modflow.ModflowBas(swt, ibound, 0)
```

Add LPF package to the MODFLOW model

[10]:
```
lpf = flopy.modflow.ModflowLpf(swt, hk=hk, vka=hk, ipakcb=ipakcb)
```

Add PCG Package to the MODFLOW model

[11]:
```
pcg = flopy.modflow.ModflowPcg(swt, hclose=1.0e-8)
```

Add OC package to the MODFLOW model

[12]:
```
oc = flopy.modflow.ModflowOc(
    swt,
    stress_period_data={(0, 0): ["save head", "save budget"]},
    compact=True,
)
```

Create WEL and SSM data

[13]:
```
itype = flopy.mt3d.Mt3dSsm.itype_dict()
wel_data = {}
ssm_data = {}
wel_sp1 = []
ssm_sp1 = []
for k in range(nlay):
    wel_sp1.append([k, 0, 0, qinflow / nlay])
    ssm_sp1.append([k, 0, 0, 0.0, itype["WEL"]])
    ssm_sp1.append([k, 0, ncol - 1, 35.0, itype["BAS6"]])
wel_data[0] = wel_sp1
ssm_data[0] = ssm_sp1
wel = flopy.modflow.ModflowWel(swt, stress_period_data=wel_data, ipakcb=ipakcb)
```

Create the basic MT3DMS model structure

[14]:
```
btn = flopy.mt3d.Mt3dBtn(
    swt,
    nprs=-5,
    prsity=0.35,
    sconc=35.0,
    ifmtcn=0,
    chkmas=False,
    nprobs=10,
    nprmas=10,
    dt0=0.001,
)
adv = flopy.mt3d.Mt3dAdv(swt, mixelm=0)
dsp = flopy.mt3d.Mt3dDsp(swt, al=0.0, trpt=1.0, trpv=1.0, dmcoef=dmcoef)
gcg = flopy.mt3d.Mt3dGcg(swt, iter1=500, mxiter=1, isolve=1, cclose=1e-7)
ssm = flopy.mt3d.Mt3dSsm(swt, stress_period_data=ssm_data)
```

Create the SEAWAT model structure

[15]:
```
vdf = flopy.seawat.SeawatVdf(
    swt,
    iwtable=0,
    densemin=0,
    densemax=0,
    denseref=1000.0,
    denseslp=0.7143,
    firstdt=1e-3,
)
```

Write the input files

[16]:
```
swt.write_input()
```

Run the model

[17]:
```
success, buff = swt.run_model(silent=True, report=True)
assert success, "SEAWAT did not terminate normally."
```

Post-process the results

[18]:
```
import numpy as np
```

[19]:
```
import flopy.utils.binaryfile as bf
```

Load the concentration data

[20]:
```
ucnobj = bf.UcnFile(Path(workspace) / "MT3D001.UCN", model=swt)
times = ucnobj.get_times()
concentration = ucnobj.get_data(totim=times[-1])
```

Load the cell-by-cell flow data

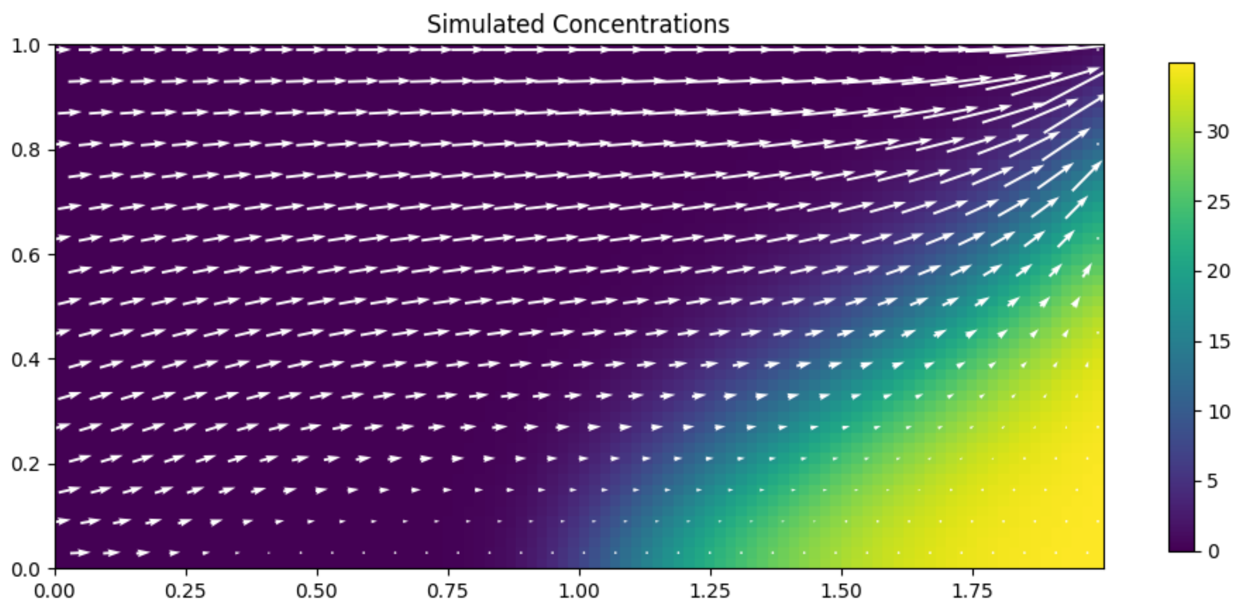
[21]:
```
cbbobj = bf.CellBudgetFile(Path(workspace) / f"{name}.cbc")
times = cbbobj.get_times()
qx = cbbobj.get_data(text="flow right face", totim=times[-1])[0]
qy = np.zeros((nlay, nrow, ncol), dtype=float)
qz = cbbobj.get_data(text="flow lower face", totim=times[-1])[0]
```

Create a plot with concentrations and flow vectors

[22]:
```
import matplotlib.pyplot as plt
```

[23]:
```
fig = plt.figure(figsize=(12, 9))
ax = fig.add_subplot(1, 1, 1, aspect="equal")
pmv = flopy.plot.PlotCrossSection(model=swt, ax=ax, line={"row": 0})
arr = pmv.plot_array(concentration)
pmv.plot_vector(qx, qy, -qz, color="white", kstep=3, hstep=3)
plt.colorbar(arr, shrink=0.5, ax=ax)
ax.set_title("Simulated Concentrations")
```

[23]:
```
Text(0.5, 1.0, 'Simulated Concentrations')
```



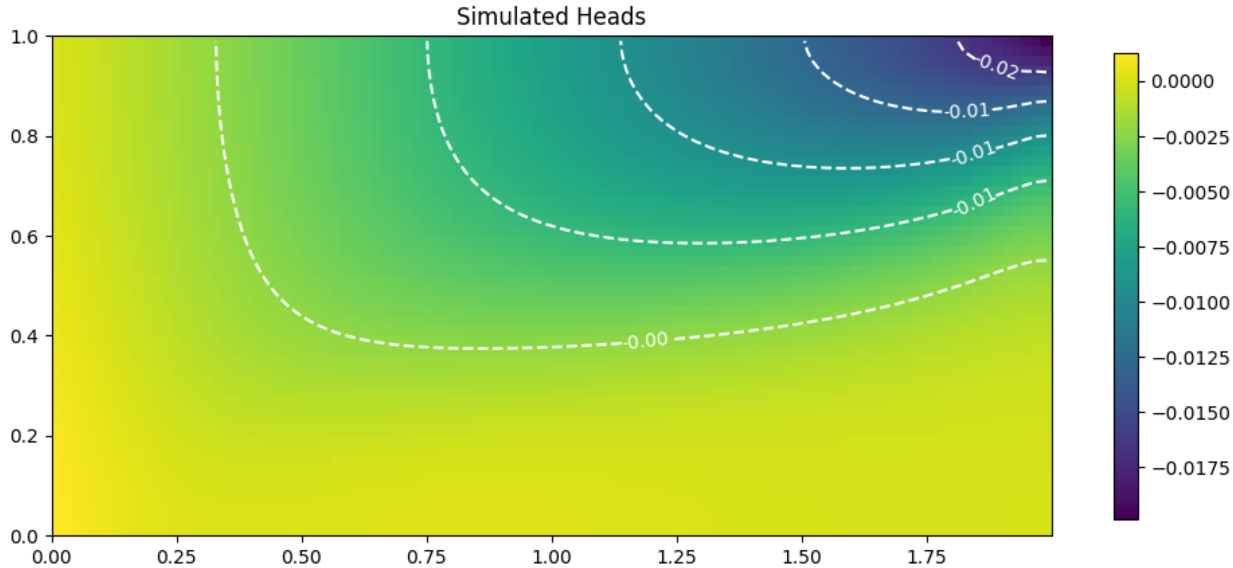
Load the head data

[24]:
```
headobj = bf.HeadFile(Path(workspace) / f"{name}.hds")
times = headobj.get_times()
head = headobj.get_data(totim=times[-1])
```

Create a plot with heads

[25]:
```
fig = plt.figure(figsize=(12, 9))
ax = fig.add_subplot(1, 1, 1, aspect="equal")
pmv = flopy.plot.PlotCrossSection(model=swt, ax=ax, line={"row": 0})
arr = pmv.plot_array(head)
contours = pmv.contour_array(head, colors="white")
ax.clabel(contours, fmt="%2.2f")
plt.colorbar(arr, shrink=0.5, ax=ax)
ax.set_title("Simulated Heads")
```

```
[25]: Text(0.5, 1.0, 'Simulated Heads')
```




```
[26]: try:
          temp_dir.cleanup()
      except:
          # prevent windows permission error
          pass
```

5.7 PEST

5.7.1 Support for PEST

This notebook demonstrates the current parameter estimation functionality that is available with FloPy. The capability to write a simple template file for PEST is the only capability implemented so far. The plan is to develop functionality for creating PEST instruction files as well as the PEST control file.

```
[1]: import os
     import sys
     from tempfile import TemporaryDirectory

     import numpy as np

     # run installed version of flopy or add local path
     try:
         import flopy
     except:
         fpth = os.path.abspath(os.path.join("..", ".."))
         sys.path.append(fpth)
         import flopy

     print(sys.version)
```

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```
print(f"numpy version: {np.__version__}")
print(f"flopy version: {flopy.__version__}")
```

```
3.8.18 (default, Aug 28 2023, 08:27:22)
[GCC 11.4.0]
numpy version: 1.24.4
flopy version: 3.5.0
```

This notebook will work with a simple model using the dimensions below

[2]:
```
# temporary directory
temp_dir = TemporaryDirectory()
workspace = temp_dir.name

# Define the model dimensions
nlay = 3
nrow = 20
ncol = 20

# Create the flopy model object and add the dis and lpf packages
m = flopy.modflow.Modflow(modelname="mymodel", model_ws=workspace)
dis = flopy.modflow.ModflowDis(m, nlay, nrow, ncol)
lpf = flopy.modflow.ModflowLpf(m, hk=10.0)
```

Simple One Parameter Example

In order to create a PEST template file, we first need to define a parameter. For example, let's say we want to parameterize hydraulic conductivity, which is a static variable in flopy and MODFLOW. As a first step, let's define a parameter called HK_LAYER_1 and assign it to all of layer 1. We will not parameterize hydraulic conductivity for layers 2 and 3 and instead leave HK at its value of 10. (as assigned in the block above this one). We can do this as follows.

[3]:
```
mfpackage = "lpf"
partype = "hk"
parname = "HK_LAYER_1"
idx = np.empty((nlay, nrow, ncol), dtype=bool)
idx[0] = True
idx[1:] = False

# The span variable defines how the parameter spans the package
span = {"idx": idx}

# These parameters have not affect yet, but may in the future
startvalue = 10.0
lbound = 0.001
ubound = 1000.0
transform = "log"

p = flopy.pest.Params(
    mfpackage, partype, parname, startvalue, lbound, ubound, span
)
```

At this point, we have enough information to the write a PEST template file for the LPF package. We can do this using the following statement:

[4]:
```
tw = flopy.pest.TemplateWriter(m, [p])
tw.write_template()
```

```
The following packages will be parameterized: ['LPF']
```

At this point, the lpf template file will have been created. The following block will print the template file.

[5]:
```
lines = open(os.path.join(workspace, "mymodel.lpf.tpl")).readlines()
for l in lines:
    print(l.strip())
```

```
ptf ~
# LPF package for MODFLOW-2005 generated by Flopy 3.5.0
0    -1E+30         0
0         0         0
0         0         0
1.000000E+00   1.000000E+00   1.000000E+00
0         0         0
0         0         0
CONSTANT ~ HK_LAYER_1  ~    #hk Layer 1
CONSTANT    1.000000E+00                           #vka1
CONSTANT 10.0    #hk Layer 2
CONSTANT    1.000000E+00                           #vka2
CONSTANT 10.0    #hk Layer 3
CONSTANT    1.000000E+00                           #vka3
```

The span variable will also accept 'layers', in which the parameter applies to the list of layers, as shown next. When 'layers' is specified in the span dictionary, then the original hk value of 10. remains in the array, and the multiplier is specified on the array control line.

[6]:
```
mfpackage = "lpf"
partype = "hk"
parname = "HK_LAYER_1-3"

# Span indicates that the hk parameter applies as a multiplier to layers 0 and 2␣
↪(MODFLOW layers 1 and 3)
span = {"layers": [0, 2]}

# These parameters have not affect yet, but may in the future
startvalue = 10.0
lbound = 0.001
ubound = 1000.0
transform = "log"

p = flopy.pest.Params(
    mfpackage, partype, parname, startvalue, lbound, ubound, span
)
tw = flopy.pest.templatewriter.TemplateWriter(m, [p])
tw.write_template()
```

```
The following packages will be parameterized: ['LPF']
```

```
[7]: lines = open(os.path.join(workspace, "mymodel.lpf.tpl")).readlines()
     for l in lines:
         print(l.strip())
```

```
ptf ~
# LPF package for MODFLOW-2005 generated by Flopy 3.5.0
0    -1E+30         0
0         0         0
0         0         0
1.000000E+00   1.000000E+00   1.000000E+00
0         0         0
0         0         0
INTERNAL ~ HK_LAYER_1-3  ~ (FREE) -1      #hk Layer 1
10.0            10.0            10.0            10.0            10.0            10.0            10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0            10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0            10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0            10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0            10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0            10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0            10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0            10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0            10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0            10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0            10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0            10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0            10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0            10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0            10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0            10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0            10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0            10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0            10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0            10.0            10.0            10.0            10.0
```

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```
10.0            10.0            10.0            10.0            10.0            10.0            ␣
↪        10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0            ␣
↪        10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0            ␣
↪        10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0            ␣
↪        10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0            ␣
↪        10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0            ␣
↪        10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0            ␣
↪        10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0            ␣
↪        10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0            ␣
↪        10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0            ␣
↪        10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0            ␣
↪        10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0            ␣
↪        10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0            ␣
↪        10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0            ␣
↪        10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0            ␣
↪        10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0            ␣
↪        10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0            ␣
↪        10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0            ␣
↪        10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0            ␣
↪        10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0            ␣
↪        10.0            10.0            10.0            10.0
CONSTANT    1.000000E+00                        #vka1
CONSTANT 10.0    #hk Layer 2
CONSTANT    1.000000E+00                        #vka2
INTERNAL ~ HK_LAYER_1-3  ~ (FREE) -1       #hk Layer 3
10.0            10.0            10.0            10.0            10.0            10.0            ␣
↪        10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0            ␣
↪        10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0            ␣
↪        10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0            ␣
↪        10.0            10.0            10.0            10.0
```

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```
10.0            10.0            10.0            10.0            10.0            10.0            ␣
↪        10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0            ␣
↪        10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0            ␣
↪        10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0            ␣
↪        10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0            ␣
↪        10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0            ␣
↪        10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0            ␣
↪        10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0            ␣
↪        10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0            ␣
↪        10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0            ␣
↪        10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0            ␣
↪        10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0            ␣
↪        10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0            ␣
↪        10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0            ␣
↪        10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0            ␣
↪        10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0            ␣
↪        10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0            ␣
↪        10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0            ␣
↪        10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0            ␣
↪        10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0            ␣
↪        10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0            ␣
↪        10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0            ␣
↪        10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0            ␣
↪        10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0            ␣
↪        10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0            ␣
↪        10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0            ␣
↪        10.0            10.0            10.0            10.0
```

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```
10.0            10.0            10.0            10.0            10.0            10.0    ␣
↪       10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0    ␣
↪       10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0    ␣
↪       10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0    ␣
↪       10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0    ␣
↪       10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0    ␣
↪       10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0    ␣
↪       10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0    ␣
↪       10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0    ␣
↪       10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0    ␣
↪       10.0            10.0            10.0            10.0
CONSTANT    1.000000E+00                          #vka3
```

Multiple Parameter Zoned Approach

The params module has a helper function called zonearray2params that will take a zone array and some other information and create a list of parameters, which can then be passed to the template writer. This next example shows how to create a slightly more complicated LPF template file in which both HK and VKA are parameterized.

[8]:
```python
# Create a zone array
zonearray = np.ones((nlay, nrow, ncol), dtype=int)
zonearray[0, 10:, 7:] = 2
zonearray[0, 15:, 9:] = 3
zonearray[1] = 4
```

[9]:
```python
# Create a list of parameters for HK
mfpackage = "lpf"
parzones = [2, 3, 4]
parvals = [56.777, 78.999, 99.0]
lbound = 5
ubound = 500
transform = "log"
plisthk = flopy.pest.zonearray2params(
    mfpackage, "hk", parzones, lbound, ubound, parvals, transform, zonearray
)
```

In this case, Flopy will create three parameters: hk_2, hk_3, and hk_4, which will apply to the horizontal hydraulic conductivity for cells in zones 2, 3, and 4, respectively. Only those zone numbers listed in parzones will be parameterized. For example, many cells in zonearray have a value of 1. Those cells will not be parameterized. Instead, their hydraulic conductivity values will remain fixed at the value that was specified when the Flopy LPF package was created.

[10]:
```
# Create a list of parameters for VKA
parzones = [1, 2]
parvals = [0.001, 0.0005]
zonearray = np.ones((nlay, nrow, ncol), dtype=int)
zonearray[1] = 2
plistvk = flopy.pest.zonearray2params(
    mfpackage, "vka", parzones, lbound, ubound, parvals, transform, zonearray
)
```

[11]:
```
# Combine the HK and VKA parameters together
plist = plisthk + plistvk
for p in plist:
    print(p.name, p.mfpackage, p.startvalue)
```

```
hk_2 lpf 56.777
hk_3 lpf 78.999
hk_4 lpf 99.0
vka_1 lpf 0.001
vka_2 lpf 0.0005
```

[12]:
```
# Write the template file
tw = flopy.pest.templatewriter.TemplateWriter(m, plist)
tw.write_template()
```

```
The following packages will be parameterized: ['LPF']
```

[13]:
```
# Print contents of template file
lines = open(os.path.join(workspace, "mymodel.lpf.tpl")).readlines()
for l in lines:
    print(l.strip())
```

```
ptf ~
# LPF package for MODFLOW-2005 generated by Flopy 3.5.0
0    -1E+30         0
0         0         0
0         0         0
1.000000E+00   1.000000E+00   1.000000E+00
0         0         0
0         0         0
INTERNAL 1.0 (FREE) -1      #hk Layer 1
10.0            10.0            10.0            10.0            10.0            10.0    ␣
↪        10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0    ␣
↪        10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0    ␣
↪        10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0    ␣
↪        10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0    ␣
↪        10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0    ␣
↪        10.0            10.0            10.0            10.0
```

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```
10.0            10.0            10.0            10.0            10.0            10.0    ␣
↪        10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0    ␣
↪        10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0    ␣
↪        10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0    ␣
↪        10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0    ␣
↪        10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0    ␣
↪        10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0    ␣
↪        10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0    ␣
↪        10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0    ␣
↪        10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0    ␣
↪        10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0    ␣
↪        10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0    ␣
↪        10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0    ␣
↪        10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0    ␣
↪        10.0            10.0            10.0            10.0
10.0            10.0            10.0            10.0            10.0            10.0    ␣
↪        10.0 ~    hk_2      ~ ~    hk_2      ~ ~    hk_2      ~
~    hk_2      ~ ~    hk_2      ~ ~    hk_2      ~ ~    hk_2      ~ ~    hk_2      ~ ~    hk_
↪2      ~ ~    hk_2      ~ ~    hk_2      ~ ~    hk_2      ~ ~    hk_2      ~
10.0            10.0            10.0            10.0            10.0            10.0    ␣
↪        10.0 ~    hk_2      ~ ~    hk_2      ~ ~    hk_2      ~
~    hk_2      ~ ~    hk_2      ~ ~    hk_2      ~ ~    hk_2      ~ ~    hk_2      ~ ~    hk_
↪2      ~ ~    hk_2      ~ ~    hk_2      ~ ~    hk_2      ~ ~    hk_2      ~
10.0            10.0            10.0            10.0            10.0            10.0    ␣
↪        10.0 ~    hk_2      ~ ~    hk_2      ~ ~    hk_2      ~
~    hk_2      ~ ~    hk_2      ~ ~    hk_2      ~ ~    hk_2      ~ ~    hk_2      ~ ~    hk_
↪2      ~ ~    hk_2      ~ ~    hk_2      ~ ~    hk_2      ~ ~    hk_2      ~
10.0            10.0            10.0            10.0            10.0            10.0    ␣
↪        10.0 ~    hk_2      ~ ~    hk_2      ~ ~    hk_2      ~
~    hk_2      ~ ~    hk_2      ~ ~    hk_2      ~ ~    hk_2      ~ ~    hk_2      ~ ~    hk_
↪2      ~ ~    hk_2      ~ ~    hk_2      ~ ~    hk_2      ~ ~    hk_2      ~
10.0            10.0            10.0            10.0            10.0            10.0    ␣
↪        10.0 ~    hk_2      ~ ~    hk_2      ~ ~    hk_2      ~
~    hk_2      ~ ~    hk_2      ~ ~    hk_2      ~ ~    hk_2      ~ ~    hk_2      ~ ~    hk_
↪2      ~ ~    hk_2      ~ ~    hk_2      ~ ~    hk_2      ~ ~    hk_2      ~
10.0            10.0            10.0            10.0            10.0            10.0    ␣
↪        10.0 ~    hk_2      ~ ~    hk_2      ~ ~    hk_3      ~
~    hk_3      ~ ~    hk_3      ~ ~    hk_3      ~ ~    hk_3      ~ ~    hk_3      ~ ~    hk_
↪3      ~ ~    hk_3      ~ ~    hk_3      ~ ~    hk_3      ~ ~    hk_3      ~
```

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```
10.0            10.0            10.0            10.0            10.0            10.0    ␣
↪        10.0 ~    hk_2     ~ ~    hk_2     ~ ~    hk_3     ~
~    hk_3     ~ ~    hk_3     ~ ~    hk_3     ~ ~    hk_3     ~ ~    hk_3     ~ ~    hk_
↪3     ~ ~    hk_3     ~ ~    hk_3     ~ ~    hk_3     ~ ~    hk_3     ~
10.0            10.0            10.0            10.0            10.0            10.0    ␣
↪        10.0 ~    hk_2     ~ ~    hk_2     ~ ~    hk_3     ~
~    hk_3     ~ ~    hk_3     ~ ~    hk_3     ~ ~    hk_3     ~ ~    hk_3     ~ ~    hk_
↪3     ~ ~    hk_3     ~ ~    hk_3     ~ ~    hk_3     ~ ~    hk_3     ~
10.0            10.0            10.0            10.0            10.0            10.0    ␣
↪        10.0 ~    hk_2     ~ ~    hk_2     ~ ~    hk_3     ~
~    hk_3     ~ ~    hk_3     ~ ~    hk_3     ~ ~    hk_3     ~ ~    hk_3     ~ ~    hk_
↪3     ~ ~    hk_3     ~ ~    hk_3     ~ ~    hk_3     ~ ~    hk_3     ~
10.0            10.0            10.0            10.0            10.0            10.0    ␣
↪        10.0 ~    hk_2     ~ ~    hk_2     ~ ~    hk_3     ~
~    hk_3     ~ ~    hk_3     ~ ~    hk_3     ~ ~    hk_3     ~ ~    hk_3     ~ ~    hk_
↪3     ~ ~    hk_3     ~ ~    hk_3     ~ ~    hk_3     ~ ~    hk_3     ~
CONSTANT ~    vka_1    ~    #vka1
CONSTANT ~    hk_4     ~    #hk Layer 2
CONSTANT ~    vka_2    ~    #vka2
CONSTANT 10.0    #hk Layer 3
CONSTANT ~    vka_1    ~    #vka3
```

Two-Dimensional Transient Arrays

Flopy supports parameterization of transient two dimensional arrays, like recharge. This is similar to the approach for three dimensional static arrays, but there are some important differences in how span is specified. The parameter span here is also a dictionary, and it must contain a 'kper' key, which corresponds to a list of stress periods (zero based, of course) for which the parameter applies. The span dictionary must also contain an 'idx' key. If span['idx'] is None, then the parameter is a multiplier for those stress periods. If span['idx'] is a tuple (iarray, jarray), where iarray and jarray are a list of array indices, or a boolean array of shape (nrow, ncol), then the parameter applies only to the cells specified in idx.

[14]:
```python
# Define the model dimensions (made smaller for easier viewing)
nlay = 3
nrow = 5
ncol = 5
nper = 3

# Create the flopy model object and add the dis and lpf packages
m = flopy.modflow.Modflow(modelname="mymodel", model_ws=workspace)
dis = flopy.modflow.ModflowDis(m, nlay, nrow, ncol, nper=nper)
lpf = flopy.modflow.ModflowLpf(m, hk=10.0)
rch = flopy.modflow.ModflowRch(m, rech={0: 0.001, 2: 0.003})
```

Next, we create the parameters

[15]:
```python
plist = []
```

[16]:
```python
# Create a multiplier parameter for recharge
mfpackage = "rch"
partype = "rech"
```

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```
parname = "RECH_MULT"
startvalue = None
lbound = None
ubound = None
transform = None

# For a recharge multiplier, span['idx'] must be None
idx = None
span = {"kpers": [0, 1, 2], "idx": idx}
p = flopy.pest.Params(
    mfpackage, partype, parname, startvalue, lbound, ubound, span
)
plist.append(p)
```

[17]:
```
# Write the template file
tw = flopy.pest.TemplateWriter(m, plist)
tw.write_template()
```

```
The following packages will be parameterized: ['RCH']
```

[18]:
```
# Print the results
lines = open(os.path.join(workspace, "mymodel.rch.tpl")).readlines()
for l in lines:
    print(l.strip())
```

```
ptf ~
# RCH package for MODFLOW-2005 generated by Flopy 3.5.0
3         0
1        -1 # Stress period 1
INTERNAL ~    RECH_MULT    ~ (FREE) -1      #rech_1
0.001          0.001          0.001          0.001          0.001
0.001          0.001          0.001          0.001          0.001
0.001          0.001          0.001          0.001          0.001
0.001          0.001          0.001          0.001          0.001
0.001          0.001          0.001          0.001          0.001
1        -1 # Stress period 2
INTERNAL ~    RECH_MULT    ~ (FREE) -1      #rech_1
0.001          0.001          0.001          0.001          0.001
0.001          0.001          0.001          0.001          0.001
0.001          0.001          0.001          0.001          0.001
0.001          0.001          0.001          0.001          0.001
0.001          0.001          0.001          0.001          0.001
1        -1 # Stress period 3
INTERNAL ~    RECH_MULT    ~ (FREE) -1      #rech_3
0.003          0.003          0.003          0.003          0.003
0.003          0.003          0.003          0.003          0.003
0.003          0.003          0.003          0.003          0.003
0.003          0.003          0.003          0.003          0.003
0.003          0.003          0.003          0.003          0.003
```

Multiplier parameters can also be combined with index parameters as follows.

[19]:
```python
plist = []

# Create a multiplier parameter for recharge
mfpackage = "rch"
partype = "rech"
parname = "RECH_MULT"
startvalue = None
lbound = None
ubound = None
transform = None

# For a recharge multiplier, span['idx'] must be None
span = {"kpers": [1, 2], "idx": None}
p = flopy.pest.Params(
    mfpackage, partype, parname, startvalue, lbound, ubound, span
)
plist.append(p)
```

[20]:
```python
# Now create an index parameter
mfpackage = "rch"
partype = "rech"
parname = "RECH_ZONE"
startvalue = None
lbound = None
ubound = None
transform = None

# For a recharge index parameter, span['idx'] must be a boolean array or tuple of array␣
↪indices
idx = np.empty((nrow, ncol), dtype=bool)
idx[0:3, 0:3] = True
span = {"kpers": [1], "idx": idx}
p = flopy.pest.Params(
    mfpackage, partype, parname, startvalue, lbound, ubound, span
)
plist.append(p)
```

[21]:
```python
# Write the template file
tw = flopy.pest.templatewriter.TemplateWriter(m, plist)
tw.write_template()

# Print the results
lines = open(os.path.join(workspace, "mymodel.rch.tpl")).readlines()
for l in lines:
    print(l.strip())
```

```
The following packages will be parameterized: ['RCH']

ptf ~
# RCH package for MODFLOW-2005 generated by Flopy 3.5.0
3         0
1        -1 # Stress period 1
CONSTANT    1.000000E-03                           #rech_1
```

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```
1         -1 # Stress period 2
INTERNAL ~    RECH_MULT    ~ (FREE) -1      #rech_1
~  RECH_ZONE  ~ ~  RECH_ZONE  ~ ~  RECH_ZONE  ~          0.001          0.001
~  RECH_ZONE  ~ ~  RECH_ZONE  ~ ~  RECH_ZONE  ~          0.001          0.001
~  RECH_ZONE  ~ ~  RECH_ZONE  ~ ~  RECH_ZONE  ~          0.001          0.001
0.001          0.001          0.001          0.001          0.001
0.001          0.001          0.001          0.001          0.001
1         -1 # Stress period 3
INTERNAL ~    RECH_MULT    ~ (FREE) -1      #rech_3
0.003          0.003          0.003          0.003          0.003
0.003          0.003          0.003          0.003          0.003
0.003          0.003          0.003          0.003          0.003
0.003          0.003          0.003          0.003          0.003
0.003          0.003          0.003          0.003          0.003
```

[22]:
```
try:
    # ignore PermissionError on Windows
    temp_dir.cleanup()
except:
    pass
```

CHAPTER

SIX

EXAMPLES GALLERY

The following examples illustrate the functionality of Flopy. After the tutorials, the examples are the best resource for learning the underlying capabilities of FloPy.

6.1 Preprocessing and Discretization

6.1.1 Triangular mesh example

First set the path and import the required packages. The flopy path doesn't have to be set if you install flopy from a binary installer. If you want to run this notebook, you have to set the path to your own flopy path.

[1]:
```
import os
import sys
from pathlib import Path
from tempfile import TemporaryDirectory

import matplotlib as mpl
import matplotlib.pyplot as plt
import numpy as np

import flopy

temp_dir = TemporaryDirectory()
workspace = Path(temp_dir.name)

print(sys.version)
print(f"numpy version: {np.__version__}")
print(f"matplotlib version: {mpl.__version__}")
print(f"flopy version: {flopy.__version__}")
```

```
3.8.18 (default, Aug 28 2023, 08:27:22)
[GCC 11.4.0]
numpy version: 1.24.4
matplotlib version: 3.7.4
flopy version: 3.5.0
```

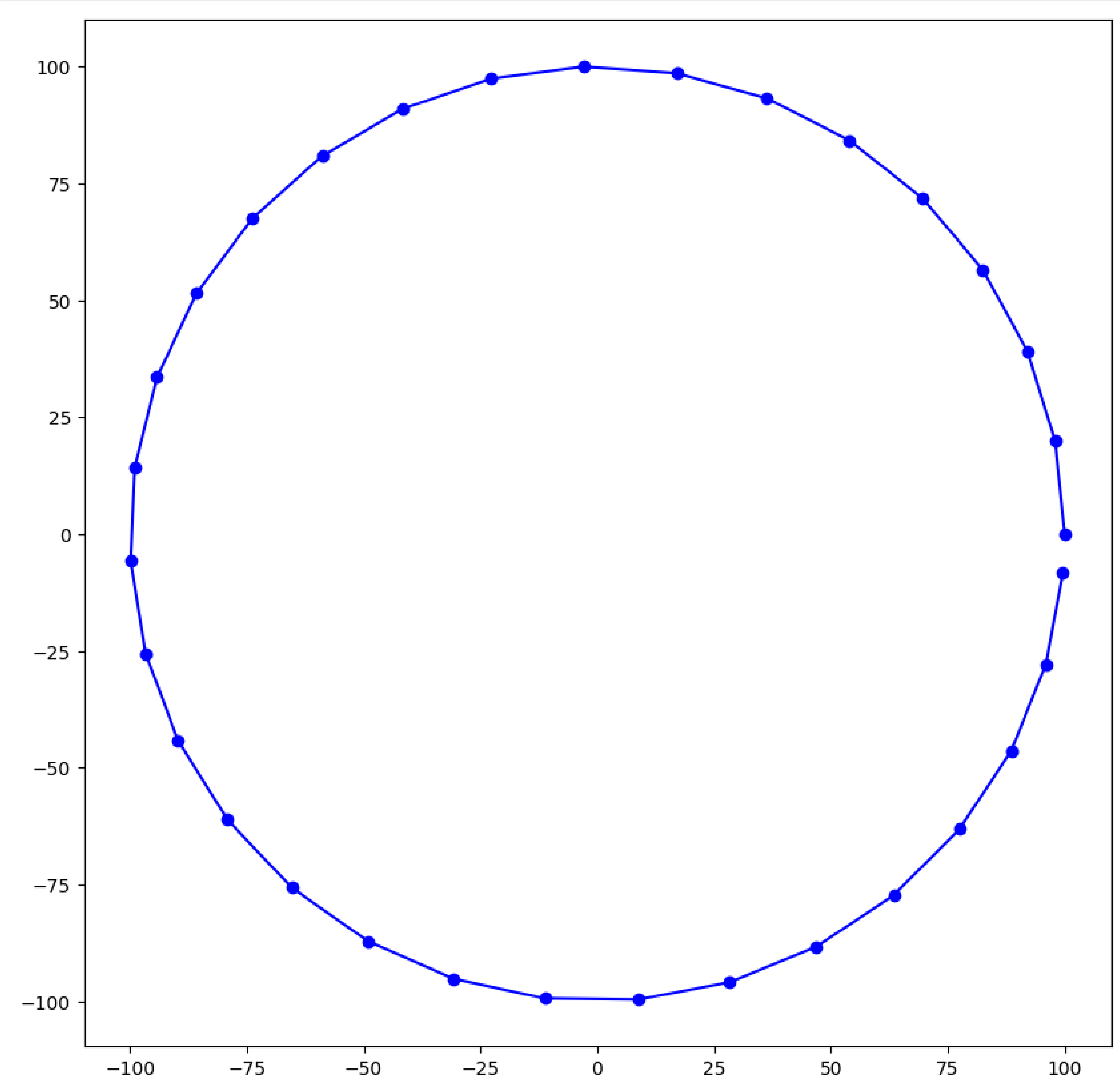
Creating Meshes with the Triangle Class

The Flopy Triangle class at (flopy.utils.triangle.Triangle) can be used to generate triangular meshes using the Triangle program (https://www.cs.cmu.edu/~quake/triangle.html). The Triangle class is a thin wrapper that builds input files for the Triangle program, reads Triangle output, and makes plots of the mesh. To use the Triangle class, the user must have an executable copy of the triangle program somewhere on their system.

Let's start by making a simple triangular mesh of a circle using the Flopy Triangle class and the triangle program.

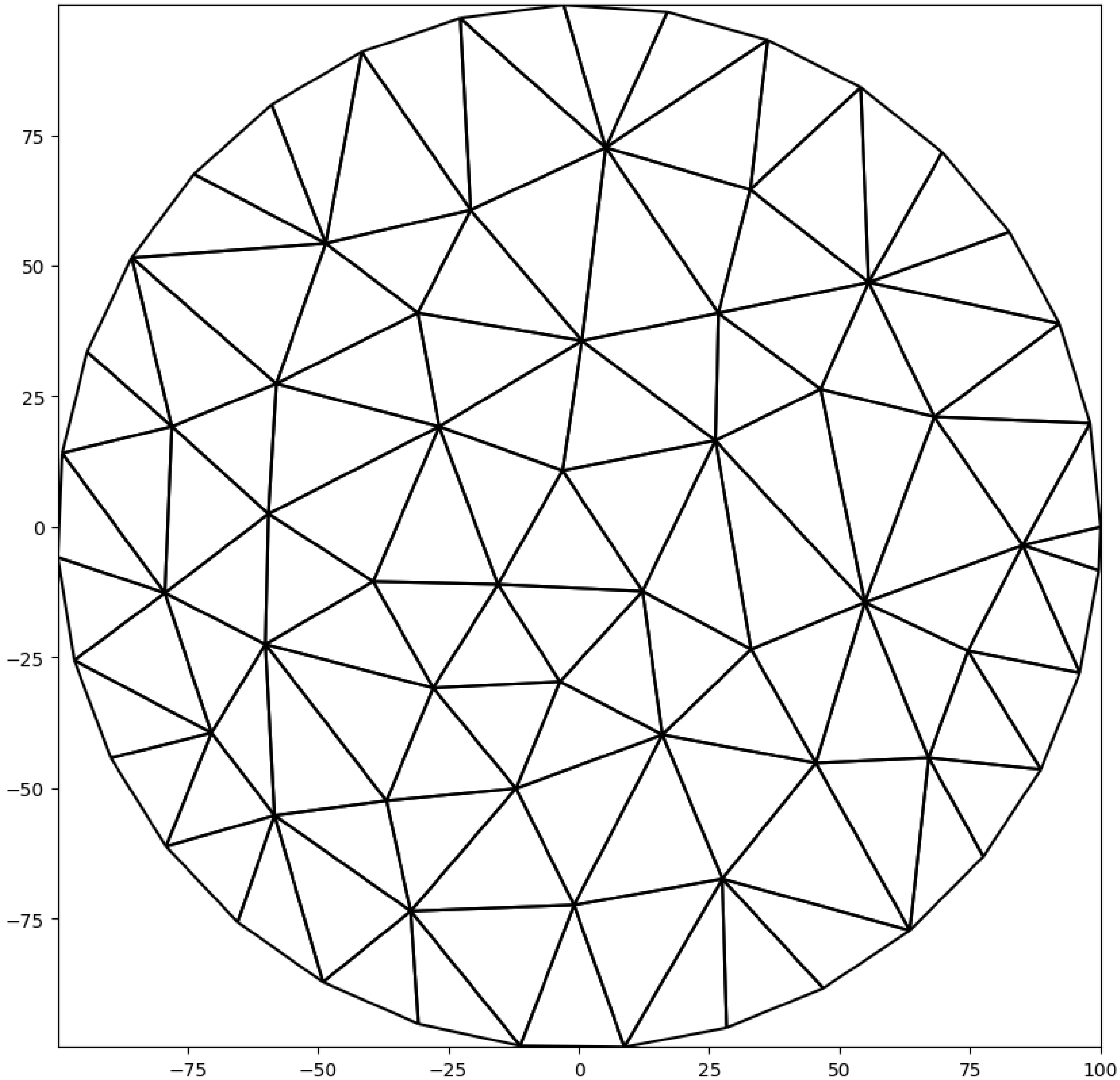
[2]:
```
# we start by creating a polygon (circle_poly), which is a list of
# (x,y) points that define the circle
theta = np.arange(0.0, 2 * np.pi, 0.2)
radius = 100.0
x = radius * np.cos(theta)
y = radius * np.sin(theta)
circle_poly = [(x, y) for x, y in zip(x, y)]
fig = plt.figure(figsize=(10, 10))
ax = plt.subplot(1, 1, 1, aspect="equal")
ax.plot(x, y, "bo-")
```

[2]:
```
[<matplotlib.lines.Line2D at 0x7ff0b89719d0>]
```



[3]:
```python
from flopy.utils.triangle import Triangle

# We can then use the Triangle class and Triangle program
# to make the mesh, as follows.
tri = Triangle(maximum_area=500, angle=30, model_ws=workspace)
tri.add_polygon(circle_poly)
tri.build(verbose=False)
fig = plt.figure(figsize=(10, 10))
ax = plt.subplot(1, 1, 1, aspect="equal")
pc = tri.plot(ax=ax)
```

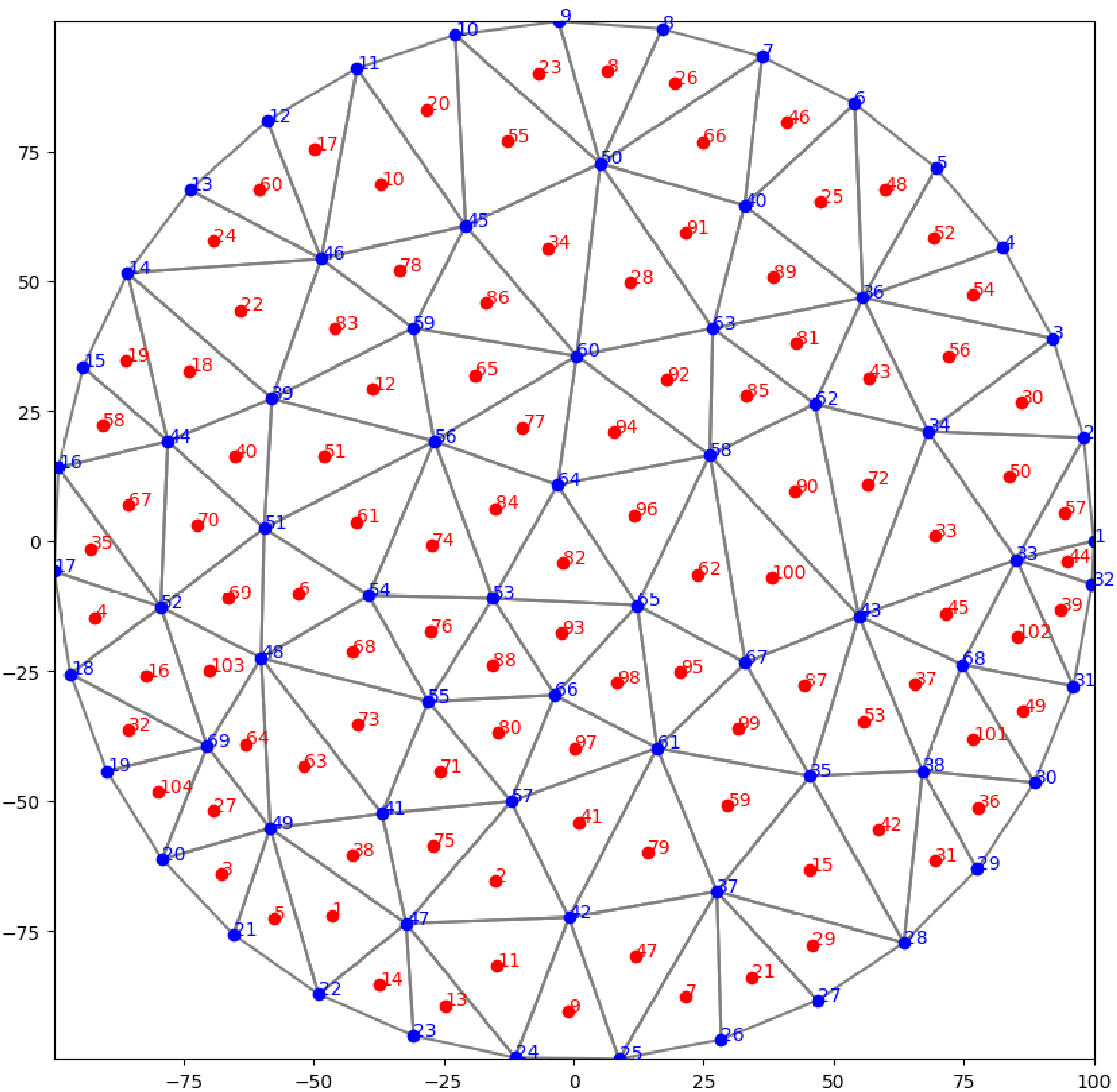


The Triangle class creates a .node and a .poly file as input for the Triangle program. The Triangle class then reads four output files from the Triangle program into numpy structured arrays. These four structured arrays are stored with the object as follows.

[4]:
```
print(tri.node.dtype)
print(tri.ele.dtype)
print(tri.neigh.dtype)
print(tri.edge.dtype)
```

```
[('ivert', '<i8'), ('x', '<f8'), ('y', '<f8'), ('boundary_marker', '<i8')]
[('icell', '<i8'), ('iv1', '<i8'), ('iv2', '<i8'), ('iv3', '<i8')]
[('icell', '<i8'), ('neighbor1', '<i8'), ('neighbor2', '<i8'), ('neighbor3', '<i8')]
[('iedge', '<i8'), ('endpoint1', '<i8'), ('endpoint2', '<i8'), ('boundary_marker', '<i8
↪')]
```

[5]:
```python
# We can also plot the cells and vertices and label them,
# but this really only works for coarse meshes
fig = plt.figure(figsize=(10, 10))
ax = plt.subplot(1, 1, 1, aspect="equal")
tri.plot(ax=ax, edgecolor="gray")
tri.plot_vertices(ax=ax, marker="o", color="blue")
tri.label_vertices(ax=ax, fontsize=10, color="blue")
tri.plot_centroids(ax=ax, marker="o", color="red")
tri.label_cells(ax=ax, fontsize=10, color="red")
```



[6]:
```python
# What about a hole?
theta = np.arange(0.0, 2 * np.pi, 0.2)
radius = 30.0
x = radius * np.cos(theta) + 25.0
```

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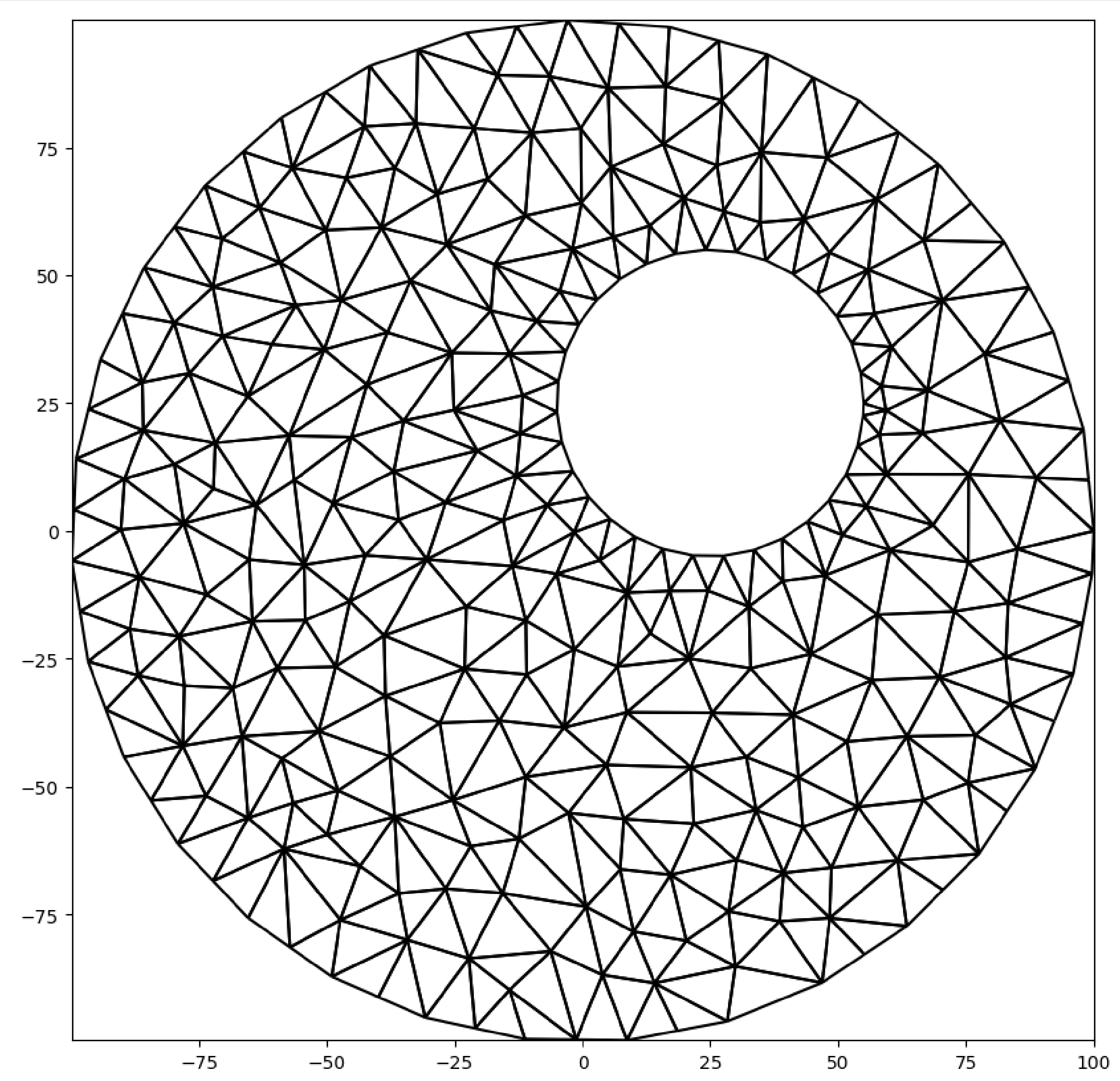
```
y = radius * np.sin(theta) + 25.0
inner_circle_poly = [(x, y) for x, y in zip(x, y)]

# The hole is created by passing in another polygon and
# then passing a point inside the hole polygon with the
# add_hole() method.
tri = Triangle(maximum_area=100, angle=30, model_ws=workspace)
tri.add_polygon(circle_poly)
tri.add_polygon(inner_circle_poly)
tri.add_hole((25, 25))
tri.build(verbose=False)
fig = plt.figure(figsize=(10, 10))
ax = plt.subplot(1, 1, 1, aspect="equal")
tri.plot(ax=ax)
```

[6]:
```
<matplotlib.collections.LineCollection at 0x7ff0c5d29d60>
```



Specifying Regions with Different Triangle Sizes

Different parts of the domain can be assigned different levels of refinement by adding multiple polygons and then identifying the different polygons as regions with different maximum triangle areas.

[7]:
```
active_domain = [(0, 0), (100, 0), (100, 100), (0, 100)]
area1 = [(10, 10), (40, 10), (40, 40), (10, 40)]
area2 = [(60, 60), (80, 60), (80, 80), (60, 80)]
tri = Triangle(angle=30, model_ws=workspace)
tri.add_polygon(active_domain)
tri.add_polygon(area1)
tri.add_polygon(area2)
tri.add_region((1, 1), 0, maximum_area=100)  # point inside active domain
```

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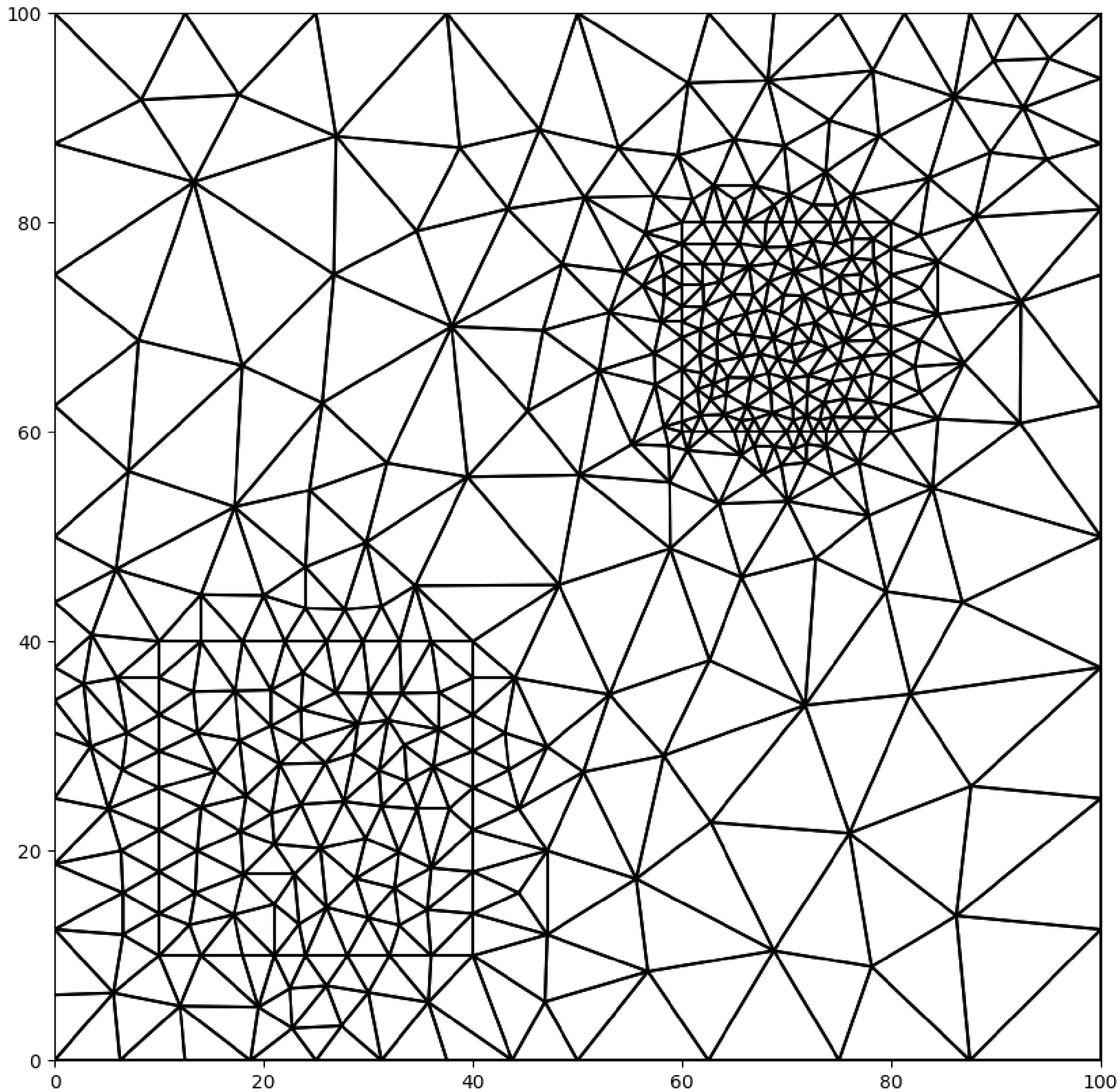
```
tri.add_region((11, 11), 1, maximum_area=10)  # point inside area1
tri.add_region((61, 61), 2, maximum_area=3)  # point inside area2
tri.build(verbose=False)
fig = plt.figure(figsize=(10, 10))
ax = plt.subplot(1, 1, 1, aspect="equal")
tri.plot(ax=ax)
```

[7]: <matplotlib.collections.LineCollection at 0x7ff0c5b52460>



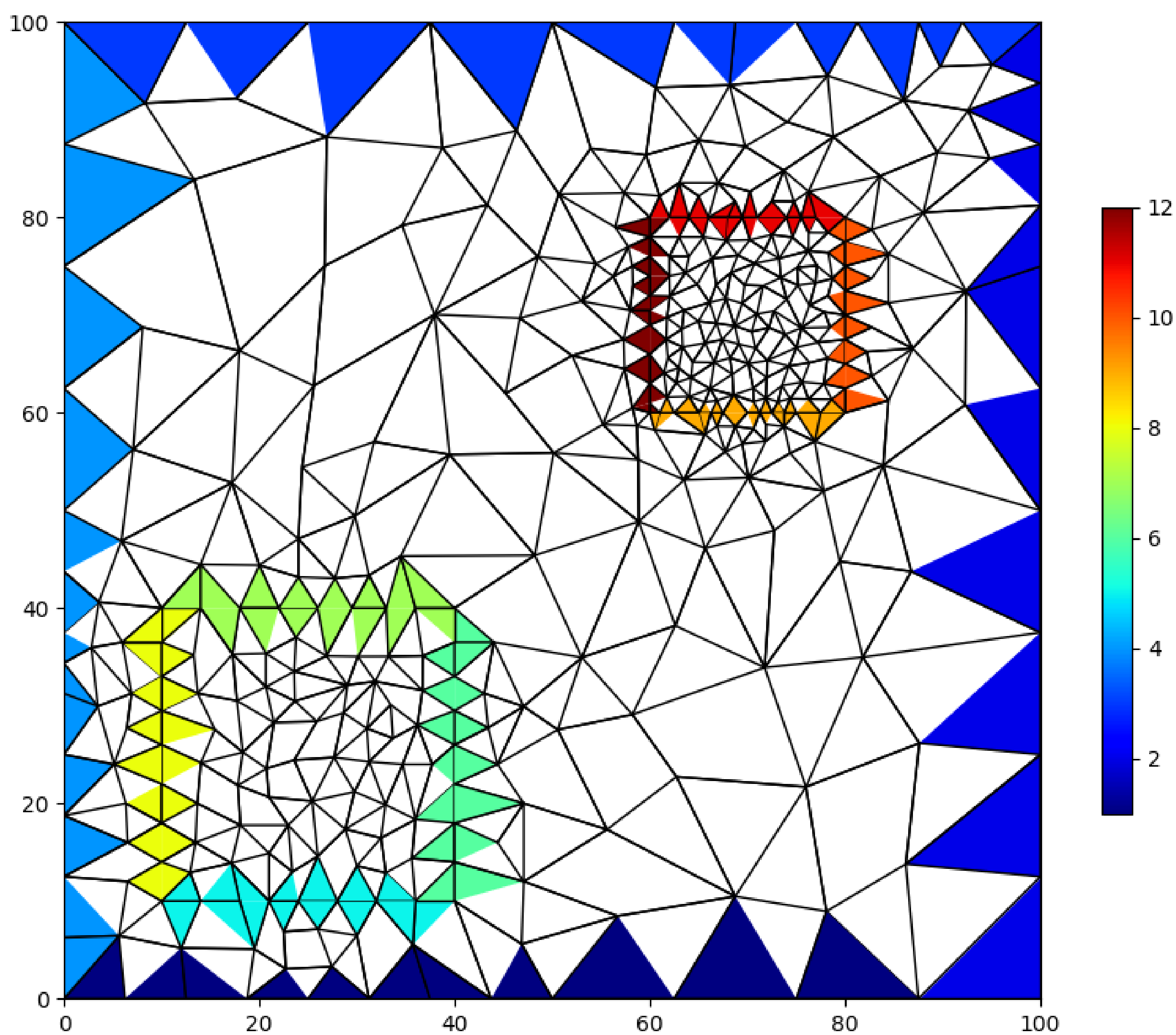
Identifying Boundary Cells

The Triangle class has some limited capabilities for identifying the cells on polygone boundaries. In the example above, three polygons were added to the Triangle class. An integer boundary marker is automatically calculated and assigned by the Triangle class. Boundary marker 1 corresponds to the first line segment of the first polygon added. So in this case, boundary marker 1 corresponds to cells along the line `[(0, 0), (100, 0)]`. Boundary marker 2 corresponds to the next line segment, which is along the right face of the domain.

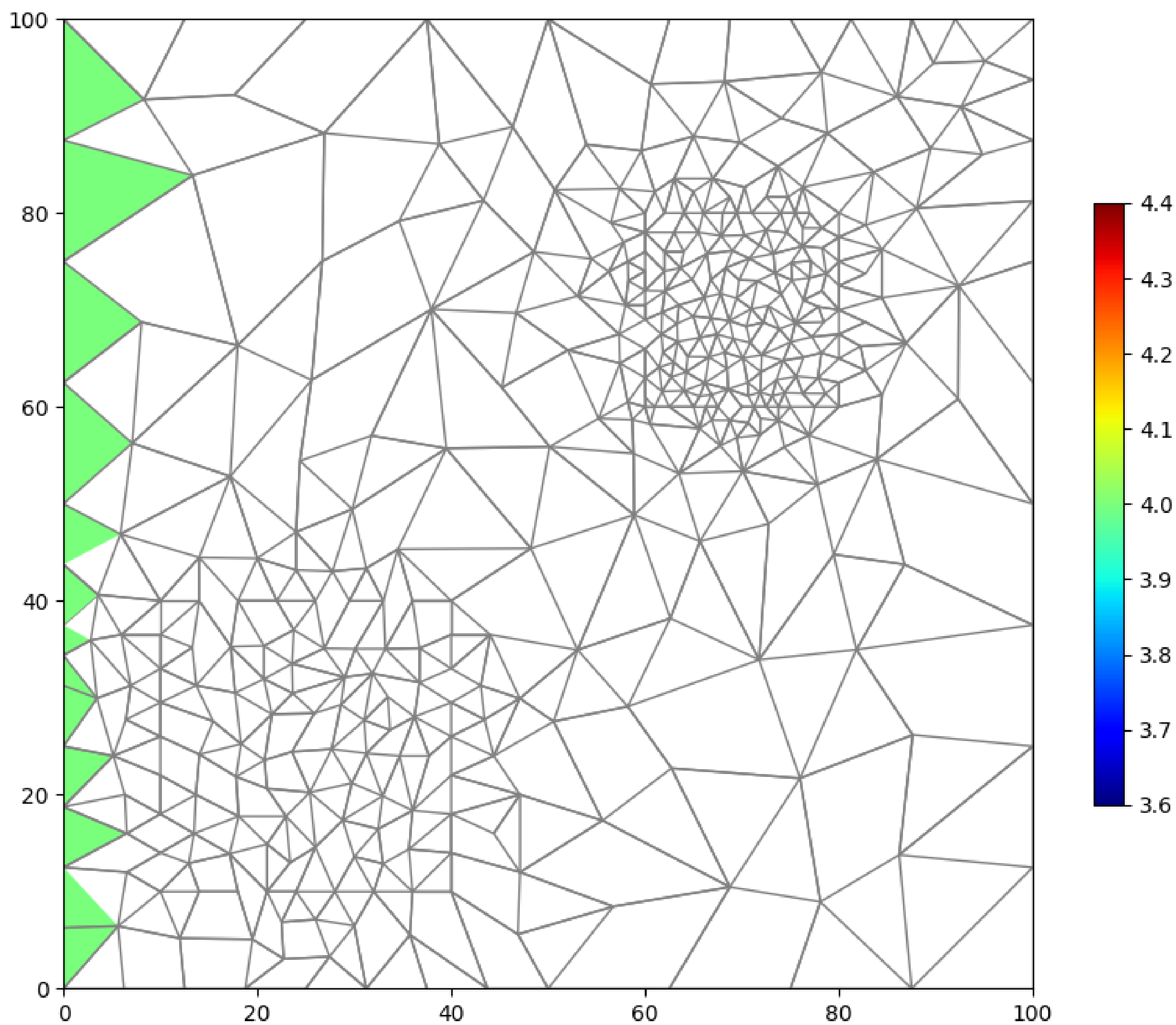
Triangle has a method for getting back an integer array for the mesh that has a boundary marker id for each cell. Values of zero indicate that the cell does not touch a boundary.

[8]:
```
# this shows all the boundary cells
ibd = tri.get_boundary_marker_array()
ibd = np.ma.masked_equal(ibd, 0)
fig = plt.figure(figsize=(10, 10))
ax = plt.subplot(1, 1, 1, aspect="equal")
pc = tri.plot(a=ibd, cmap="jet")
plt.colorbar(pc, shrink=0.5)
```

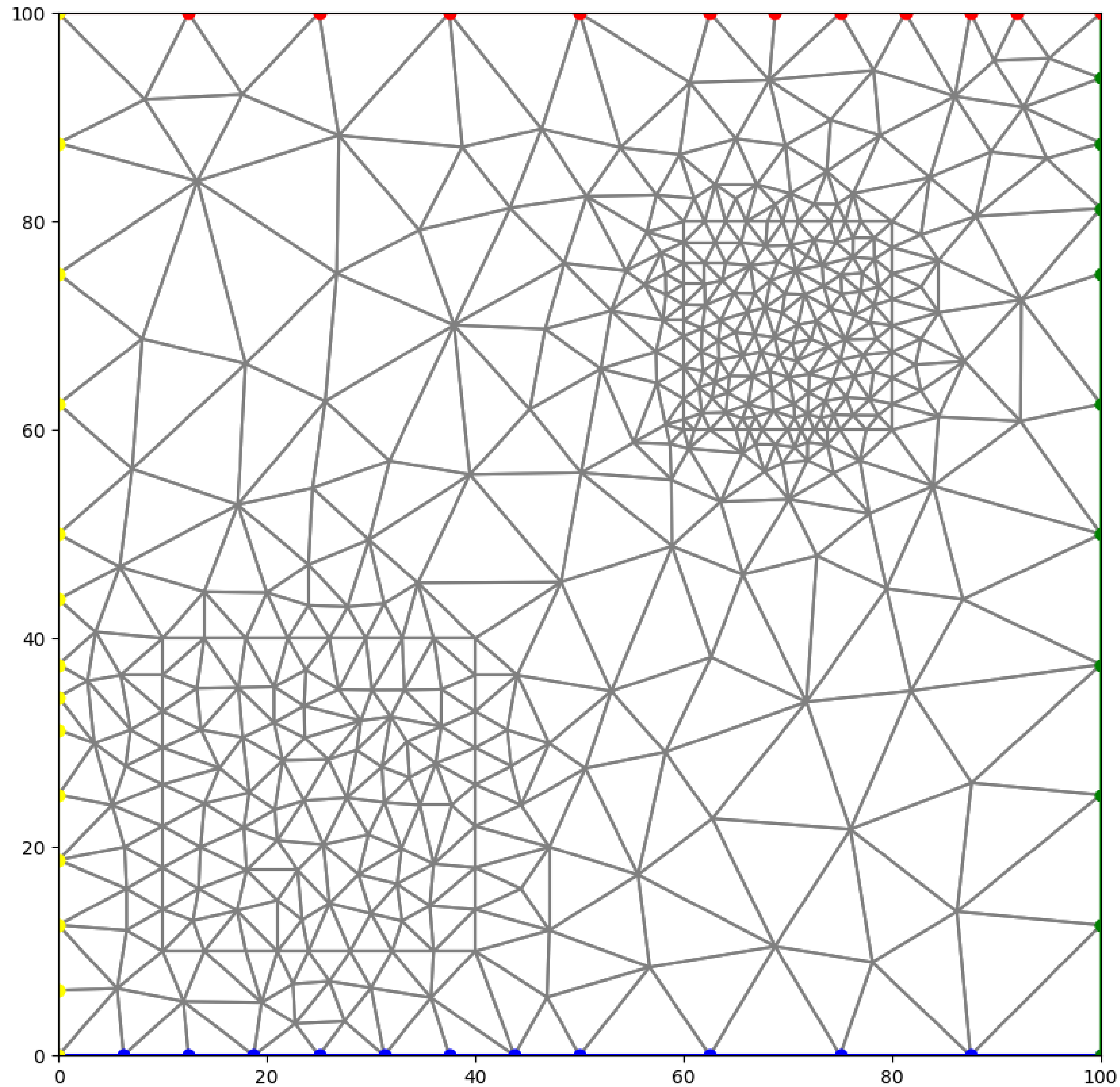
[8]:
```
<matplotlib.colorbar.Colorbar at 0x7ff0c5dd1070>
```



[9]:
```
# we could plot just one group of boundary cells
# this shows all the boundary cells
ibd = tri.get_boundary_marker_array()
ibd = np.ma.masked_not_equal(ibd, 4)
fig = plt.figure(figsize=(10, 10))
ax = plt.subplot(1, 1, 1, aspect="equal")
pc = tri.plot(a=ibd, cmap="jet", edgecolor="gray")
cb = plt.colorbar(pc, shrink=0.5)
```



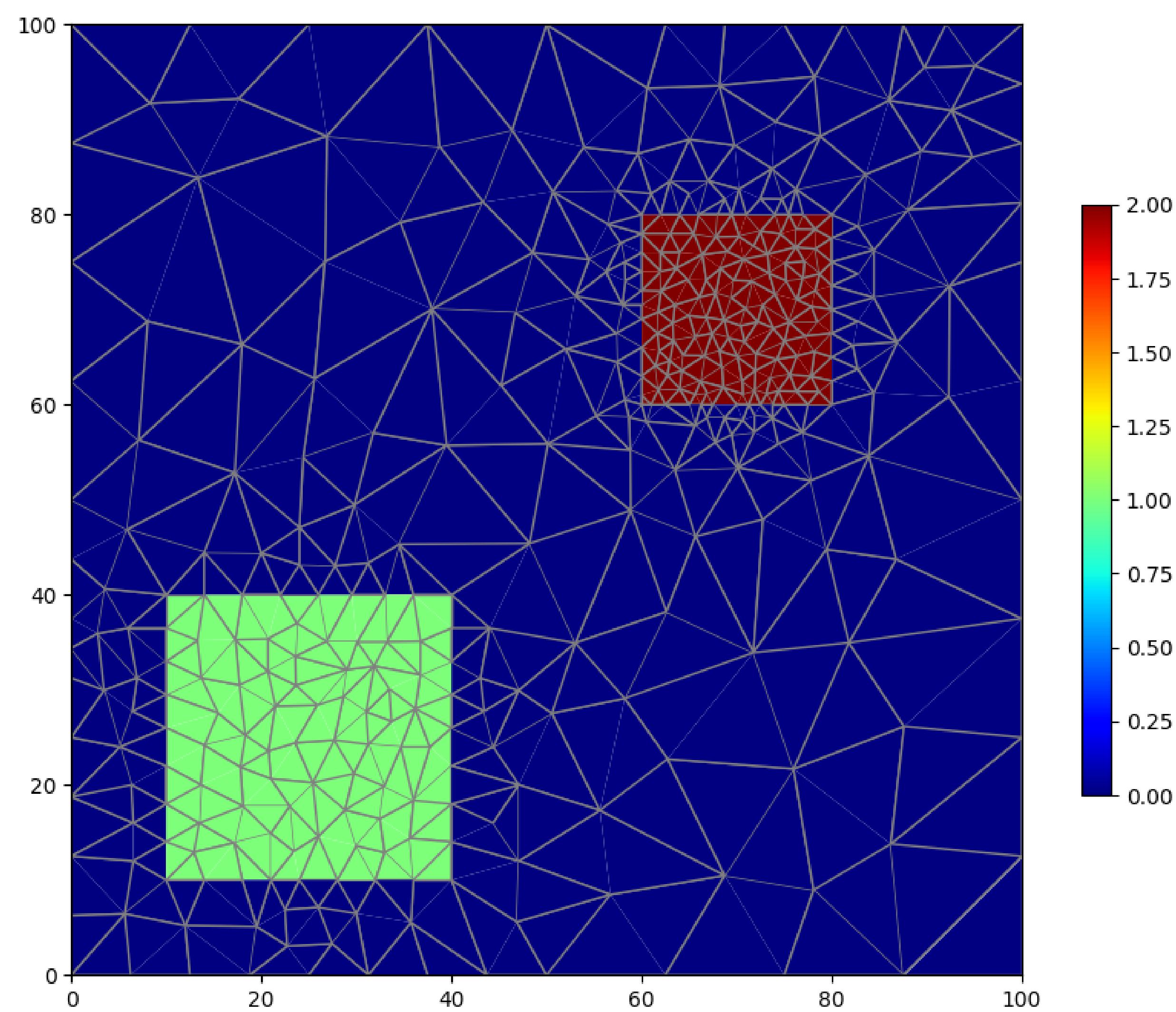
[10]:
```
# we can also plot the lines that comprise the boundaries
fig = plt.figure(figsize=(10, 10))
ax = plt.subplot(1, 1, 1, aspect="equal")
tri.plot(ax=ax, edgecolor="gray")
for ibm in [1, 2, 3, 4]:
    colors = ["blue", "green", "red", "yellow"]
    tri.plot_boundary(ibm, ax, marker="o", color=colors[ibm - 1])
```



Cell Attributes

If regions (using the add_region() method) are used and an attribute value is provided, it is possible to determine the cells that are within each region.

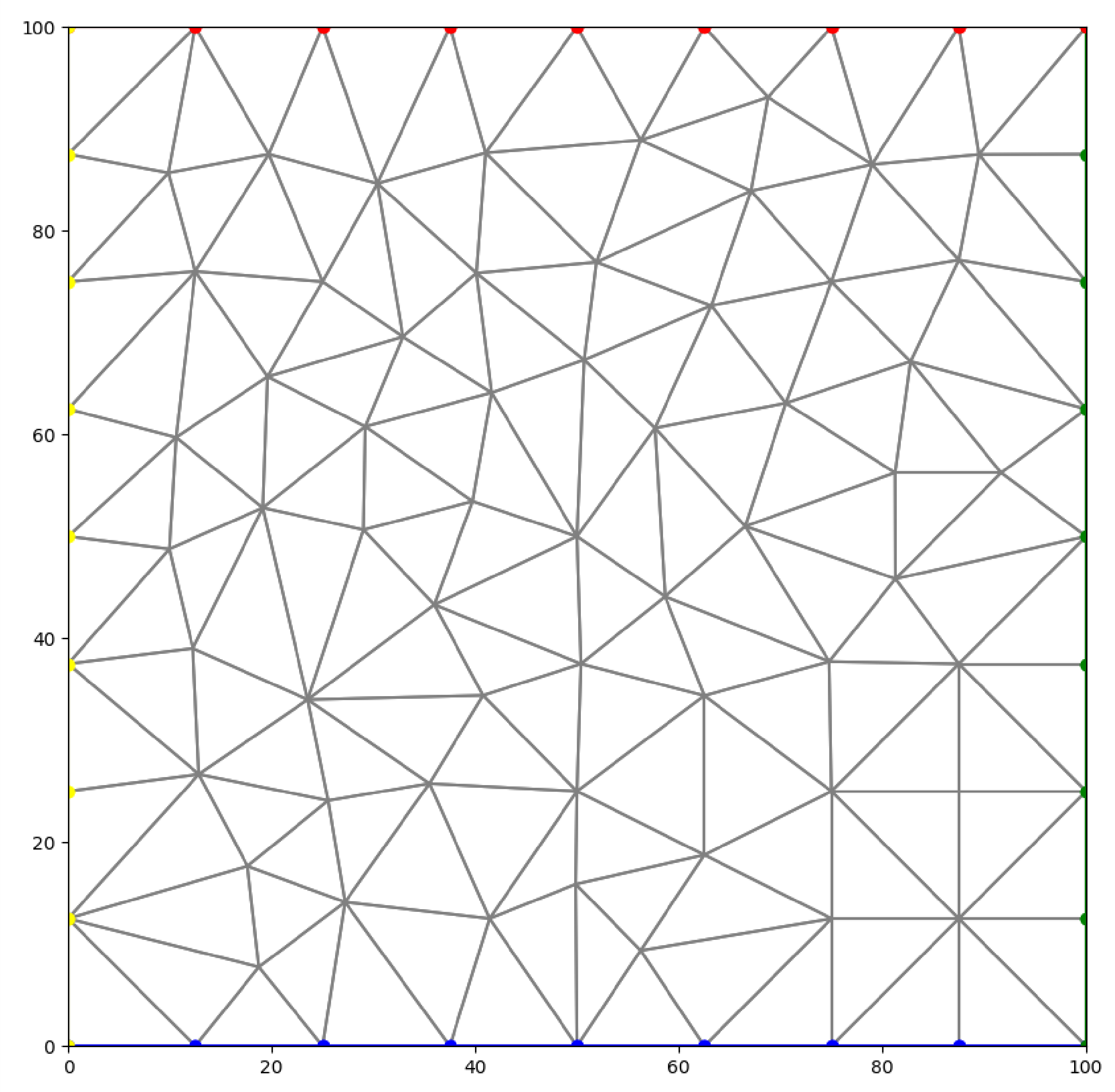
[11]:
```
attribute_array = tri.get_attribute_array()
fig = plt.figure(figsize=(10, 10))
ax = plt.subplot(1, 1, 1, aspect="equal")
pc = tri.plot(a=attribute_array, cmap="jet", edgecolor="gray")
cb = plt.colorbar(pc, shrink=0.5)
```



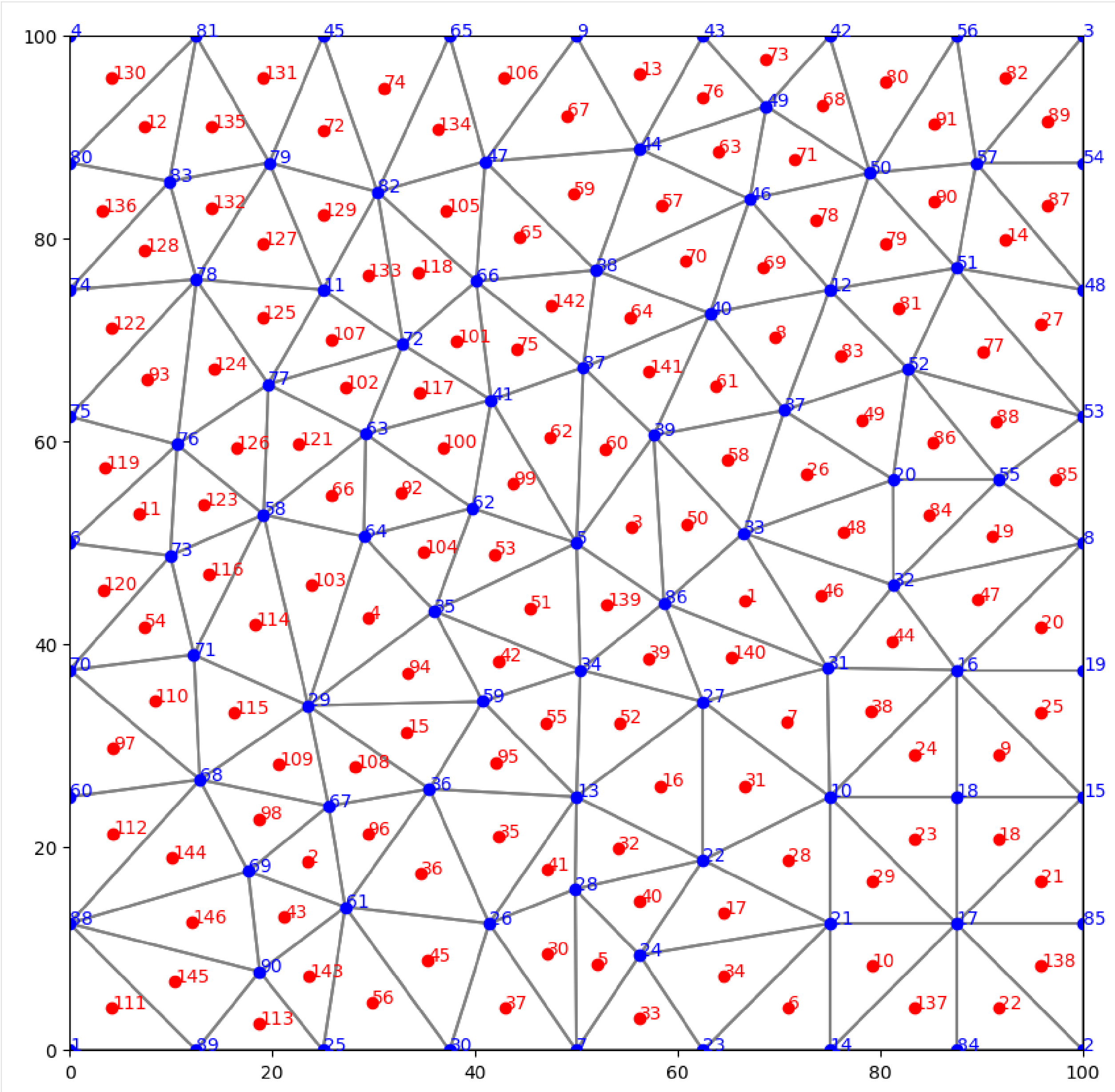
Building a Simple MODFLOW 6 Model

We can use the functionality described so far to build a simple MODFLOW 6 model using Flopy. For demonstration purposes, we'll create a very coarse triangular mesh and impose constant head boundaries on the left and right sides. We will simulate flow as steady state.

[12]:
```python
active_domain = [(0, 0), (100, 0), (100, 100), (0, 100)]
tri = Triangle(angle=30, maximum_area=100, model_ws=workspace)
tri.add_polygon(active_domain)
tri.build()
fig = plt.figure(figsize=(10, 10))
ax = plt.subplot(1, 1, 1, aspect="equal")
tri.plot(edgecolor="gray")
for ibm in [1, 2, 3, 4]:
    colors = ["blue", "green", "red", "yellow"]
    tri.plot_boundary(ibm, ax, marker="o", color=colors[ibm - 1])
```



[13]:
```
fig = plt.figure(figsize=(10, 10))
ax = plt.subplot(1, 1, 1, aspect="equal")
tri.plot(ax=ax, edgecolor="gray")
tri.plot_vertices(ax=ax, marker="o", color="blue")
tri.label_vertices(ax=ax, fontsize=10, color="blue")
tri.plot_centroids(ax=ax, marker="o", color="red")
tri.label_cells(ax=ax, fontsize=10, color="red")
```



[14]:
```python
name = "mf"
sim = flopy.mf6.MFSimulation(
    sim_name=name, version="mf6", exe_name="mf6", sim_ws=workspace
)
tdis = flopy.mf6.ModflowTdis(
    sim, time_units="DAYS", perioddata=[[1.0, 1, 1.0]]
)
gwf = flopy.mf6.ModflowGwf(sim, modelname=name, save_flows=True)
ims = flopy.mf6.ModflowIms(
    sim,
    print_option="SUMMARY",
    complexity="complex",
    outer_hclose=1.0e-8,
```

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```
    inner_hclose=1.0e-8,
)
cell2d = tri.get_cell2d()
vertices = tri.get_vertices()
xcyc = tri.get_xcyc()
nlay = 1
ncpl = tri.ncpl
nvert = tri.nvert
top = 1.0
botm = [0.0]
dis = flopy.mf6.ModflowGwfdisv(
    gwf,
    nlay=nlay,
    ncpl=ncpl,
    nvert=nvert,
    top=top,
    botm=botm,
    vertices=vertices,
    cell2d=cell2d,
)
npf = flopy.mf6.ModflowGwfnpf(
    gwf, xt3doptions=[(True)], save_specific_discharge=None
)
ic = flopy.mf6.ModflowGwfic(gwf)


def chdhead(x):
    return x * 10.0 / 100.0


chdlist = []
leftcells = tri.get_edge_cells(4)
rightcells = tri.get_edge_cells(2)
for icpl in leftcells + rightcells:
    h = chdhead(xcyc[icpl, 0])
    chdlist.append([(0, icpl), h])
chd = flopy.mf6.ModflowGwfchd(gwf, stress_period_data=chdlist)
oc = flopy.mf6.ModflowGwfoc(
    gwf,
    budget_filerecord=f"{name}.cbc",
    head_filerecord=f"{name}.hds",
    saverecord=[("HEAD", "LAST"), ("BUDGET", "LAST")],
    printrecord=[("HEAD", "LAST"), ("BUDGET", "LAST")],
)
sim.write_simulation()
success, buff = sim.run_simulation(report=True)
```

```
WARNING: Unable to resolve dimension of ('gwf6', 'disv', 'cell2d', 'cell2d', 'icvert')␣
↪based on shape "ncvert".
writing simulation...
  writing simulation name file...
  writing simulation tdis package...
```

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```
  writing solution package ims_-1...
  writing model mf...
    writing model name file...
    writing package disv...
    writing package npf...
    writing package ic...
    writing package chd_0...
INFORMATION: maxbound in ('gwf6', 'chd', 'dimensions') changed to 16 based on size of␣
↪stress_period_data
    writing package oc...
FloPy is using the following executable to run the model: ../../home/runner/.local/bin/
↪modflow/mf6
                                   MODFLOW 6
                U.S. GEOLOGICAL SURVEY MODULAR HYDROLOGIC MODEL
                            VERSION 6.4.2 06/28/2023

   MODFLOW 6 compiled Jul 05 2023 20:29:14 with Intel(R) Fortran Intel(R) 64
   Compiler Classic for applications running on Intel(R) 64, Version 2021.7.0
                             Build 20220726_000000

This software has been approved for release by the U.S. Geological
Survey (USGS). Although the software has been subjected to rigorous
review, the USGS reserves the right to update the software as needed
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Resources Software User Rights Notice for complete use, copyright,
and distribution information.


 Run start date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:27:27

 Writing simulation list file: mfsim.lst
 Using Simulation name file: mfsim.nam

    Solving:  Stress period:     1    Time step:     1

 Run end date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:27:27
 Elapsed run time:  0.016 Seconds


WARNING REPORT:

  1. NONLINEAR BLOCK VARIABLE 'OUTER_HCLOSE' IN FILE 'mf.ims' WAS DEPRECATED
     IN VERSION 6.1.1. SETTING OUTER_DVCLOSE TO OUTER_HCLOSE VALUE.
  2. LINEAR BLOCK VARIABLE 'INNER_HCLOSE' IN FILE 'mf.ims' WAS DEPRECATED IN
     VERSION 6.1.1. SETTING INNER_DVCLOSE TO INNER_HCLOSE VALUE.
 Normal termination of simulation.
```
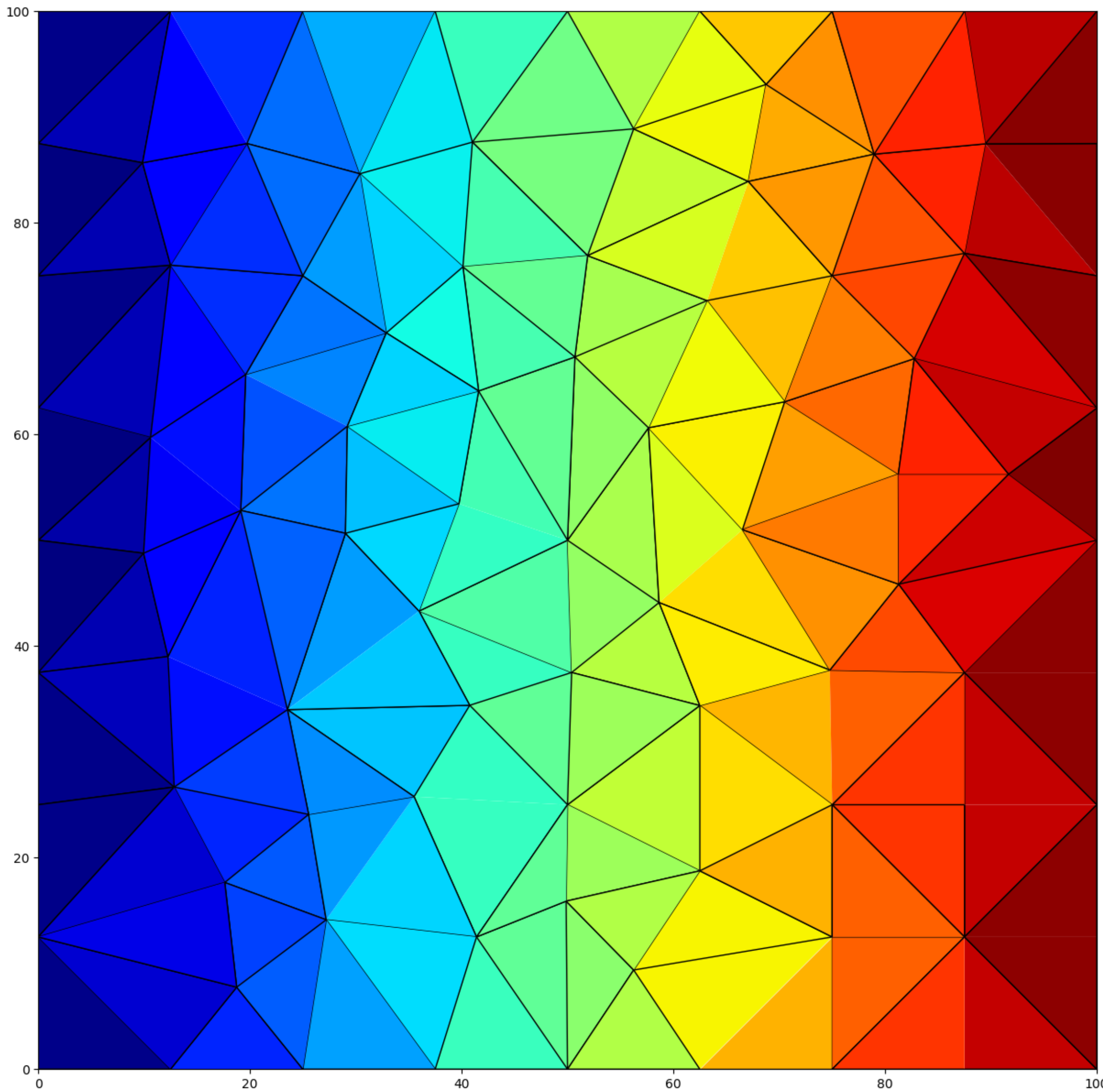

[15]:
```
fname = workspace / f"{name}.hds"
hdobj = flopy.utils.HeadFile(fname, precision="double")
head = hdobj.get_data()
fname = workspace / f"{name}.cbc"
bdobj = flopy.utils.CellBudgetFile(fname, precision="double", verbose=False)
# qxqy = bdobj.get_data(text='DATA-SPDIS')[0]

fig = plt.figure(figsize=(15, 15))
ax = plt.subplot(1, 1, 1, aspect="equal")
tri.plot(ax=ax, a=head[0, 0, :], cmap="jet")
```

[15]:
```
<matplotlib.collections.PathCollection at 0x7ff0c593f4c0>
```



Clean up the temporary workspace.

[16]:
```python
try:
    # ignore PermissionError on Windows
    temp_dir.cleanup()
except:
    pass
```

6.1.2 Voronoi Grid and MODFLOW 6 Flow and Transport Example

First set the path and import the required packages. The flopy path doesn't have to be set if you install flopy from a binary installer. If you want to run this notebook, you have to set the path to your own flopy path.

[1]:
```python
import os
import sys
from pathlib import Path
from tempfile import TemporaryDirectory

import matplotlib as mpl
import matplotlib.pyplot as plt
import numpy as np
from shapely.geometry import LineString, Point

import flopy
from flopy.discretization import VertexGrid
from flopy.utils.triangle import Triangle as Triangle
from flopy.utils.voronoi import VoronoiGrid

temp_dir = TemporaryDirectory()
workspace = Path(temp_dir.name)

print(sys.version)
print(f"numpy version: {np.__version__}")
print(f"matplotlib version: {mpl.__version__}")
print(f"flopy version: {flopy.__version__}")
```

```
3.8.18 (default, Aug 28 2023, 08:27:22)
[GCC 11.4.0]
numpy version: 1.24.4
matplotlib version: 3.7.4
flopy version: 3.5.0
```

Use Triangle to Generate Points for Voronoi Grid

[2]:
```python
# set domain extents
xmin = 0.0
xmax = 2000.0
ymin = 0.0
ymax = 1000.0

# set minimum angle
angle_min = 30
```

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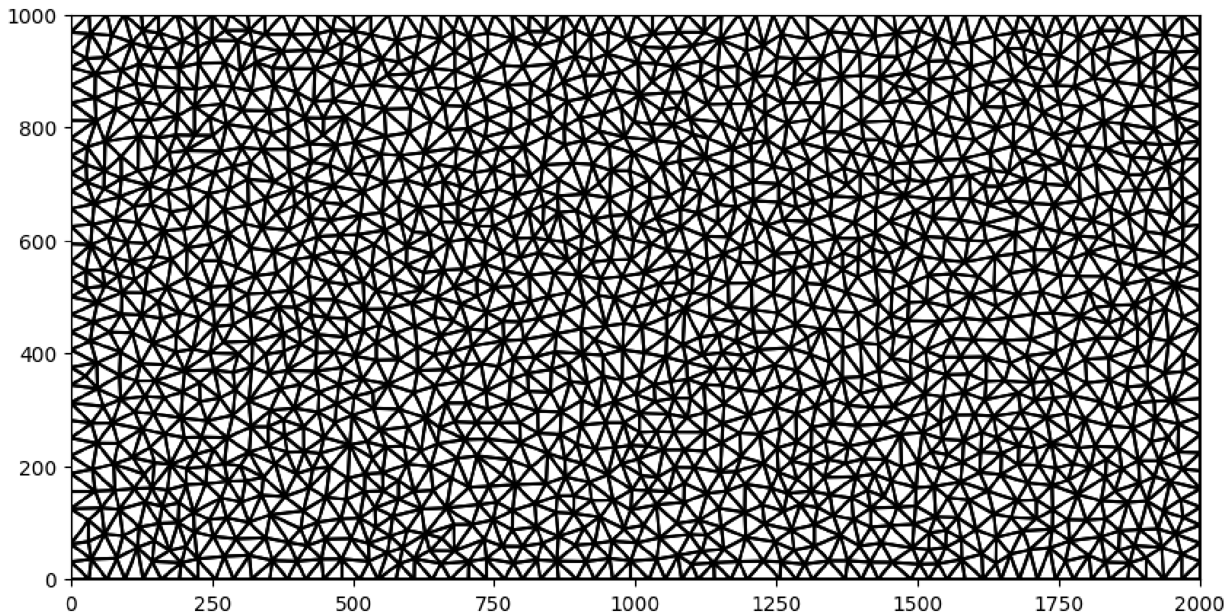
```
# set maximum area
area_max = 1000.0

delr = area_max**0.5
ncol = xmax / delr
nrow = ymax / delr
nodes = ncol * nrow
print("equivalent delr: ", delr)
print("equivalent nodes, ncol, nrow: ", int(nodes), ncol, nrow)
```

```
equivalent delr:  31.622776601683793
equivalent nodes, ncol, nrow:  2000 63.245553203367585 31.622776601683793
```

[3]:
```
tri = Triangle(maximum_area=area_max, angle=angle_min, model_ws=workspace)
poly = np.array(((xmin, ymin), (xmax, ymin), (xmax, ymax), (xmin, ymax)))
tri.add_polygon(poly)
tri.build(verbose=False)

fig = plt.figure(figsize=(10, 10))
ax = plt.subplot(1, 1, 1, aspect="equal")
pc = tri.plot(ax=ax)
```

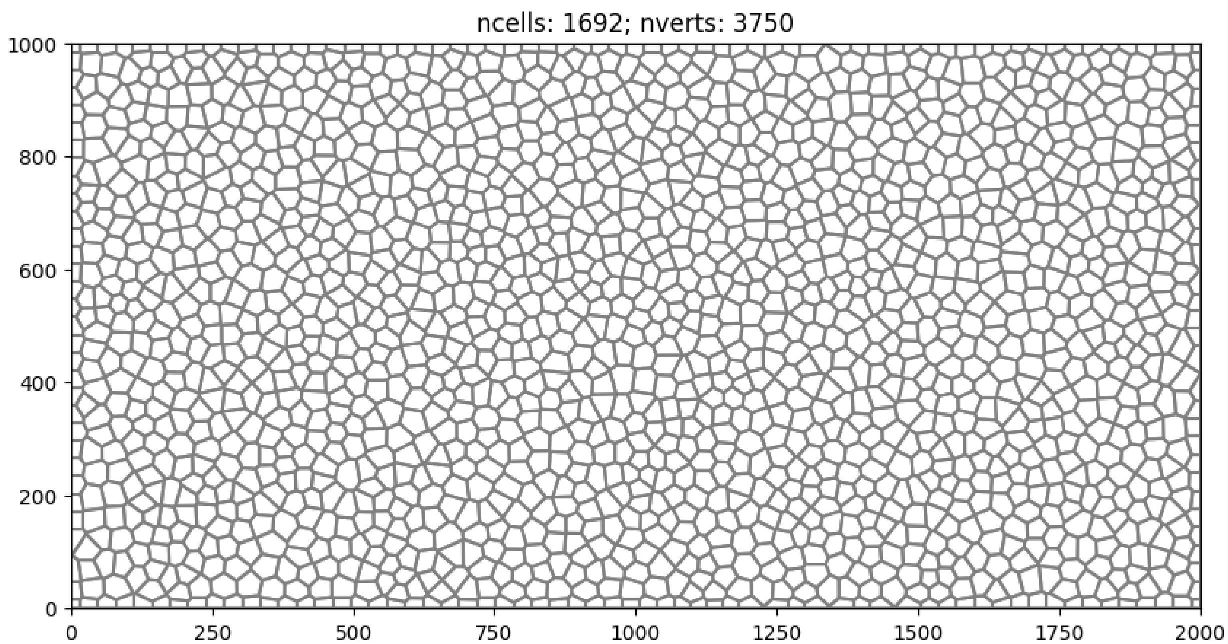


Create and Plot FloPy Voronoi Grid

The Flopy VoronoiGrid class can be used to generate voronoi grids using the scipy.spatial.Voronoi class. The VoronoiGrid class is a thin wrapper that makes sure edge cells are closed and provides methods for obtaining the information needed to make FloPy MODFLOW models. It works by passing in the flopy Triangle object generated in the previous cell.

[4]:
```
voronoi_grid = VoronoiGrid(tri)
fig = plt.figure(figsize=(10, 10))
ax = plt.subplot(1, 1, 1, aspect="equal")
voronoi_grid.plot(ax=ax, facecolor="none")
```

[4]:
```
<Axes: title={'center': 'ncells: 1692; nverts: 3750'}>
```



Use the VertexGrid Representation to Identify Boundary Cells

[5]:
```
gridprops = voronoi_grid.get_gridprops_vertexgrid()
vgrid = flopy.discretization.VertexGrid(**gridprops, nlay=1)
ibd = np.zeros(vgrid.ncpl, dtype=int)
gi = flopy.utils.GridIntersect(vgrid)

# identify cells on left edge
line = LineString([(xmin, ymin), (xmin, ymax)])
cells0 = gi.intersect(line)["cellids"]
cells0 = np.array(list(cells0))
ibd[cells0] = 1

# identify cells on right edge
line = LineString([(xmax, ymin), (xmax, ymax)])
cells1 = gi.intersect(line)["cellids"]
cells1 = np.array(list(cells1))
```

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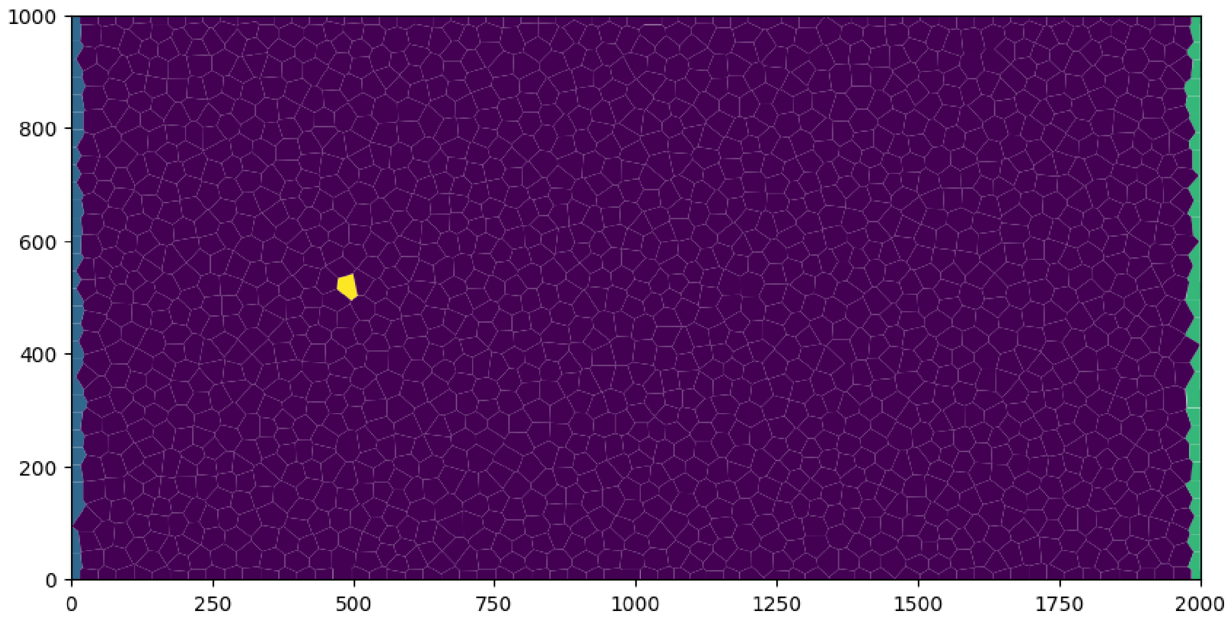
```
ibd[cells1] = 2

# identify cell for a constant concentration condition
point = Point((500, 500))
cells2 = gi.intersect(point)["cellids"]
cells2 = np.array(list(cells2))
ibd[cells2] = 3

if True:
    fig = plt.figure(figsize=(10, 10))
    ax = plt.subplot(1, 1, 1, aspect="equal")
    pmv = flopy.plot.PlotMapView(modelgrid=vgrid)
    pmv.plot_array(ibd)
```



Create Run and Post Process a MODFLOW 6 Flow Model

[6]:
```
name = "mf"
sim_ws = os.path.join(workspace, "flow")
sim = flopy.mf6.MFSimulation(
    sim_name=name, version="mf6", exe_name="mf6", sim_ws=sim_ws
)
tdis = flopy.mf6.ModflowTdis(
    sim, time_units="DAYS", perioddata=[[1.0, 1, 1.0]]
)
gwf = flopy.mf6.ModflowGwf(sim, modelname=name, save_flows=True)
ims = flopy.mf6.ModflowIms(
    sim,
    print_option="SUMMARY",
    complexity="complex",
    outer_dvclose=1.0e-8,
```

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```
    inner_dvclose=1.0e-8,
)
disv_gridprops = voronoi_grid.get_disv_gridprops()
nlay = 1
top = 1.0
botm = [0.0]
disv = flopy.mf6.ModflowGwfdisv(
    gwf, nlay=nlay, **disv_gridprops, top=top, botm=botm
)
npf = flopy.mf6.ModflowGwfnpf(
    gwf,
    xt3doptions=[(True)],
    k=10.0,
    save_saturation=True,
    save_specific_discharge=True,
)
ic = flopy.mf6.ModflowGwfic(gwf)

chdlist = []
for icpl in cells0:
    chdlist.append([(0, icpl), 1.0])
for icpl in cells1:
    chdlist.append([(0, icpl), 0.0])
chd = flopy.mf6.ModflowGwfchd(gwf, stress_period_data=chdlist)
oc = flopy.mf6.ModflowGwfoc(
    gwf,
    budget_filerecord=f"{name}.bud",
    head_filerecord=f"{name}.hds",
    saverecord=[("HEAD", "ALL"), ("BUDGET", "ALL")],
    printrecord=[("HEAD", "LAST"), ("BUDGET", "LAST")],
)
sim.write_simulation()
success, buff = sim.run_simulation(report=True, silent=True)

head = gwf.output.head().get_data()
bdobj = gwf.output.budget()
spdis = bdobj.get_data(text="DATA-SPDIS")[0]

fig = plt.figure(figsize=(15, 15))
ax = plt.subplot(1, 1, 1, aspect="equal")
pmv = flopy.plot.PlotMapView(gwf)
pmv.plot_array(head, cmap="jet", alpha=0.5)
pmv.plot_vector(spdis["qx"], spdis["qy"], alpha=0.25)
```

```
WARNING: Unable to resolve dimension of ('gwf6', 'disv', 'cell2d', 'cell2d', 'icvert')␣
↪based on shape "ncvert".
writing simulation...
  writing simulation name file...
  writing simulation tdis package...
  writing solution package ims_-1...
  writing model mf...
    writing model name file...
```

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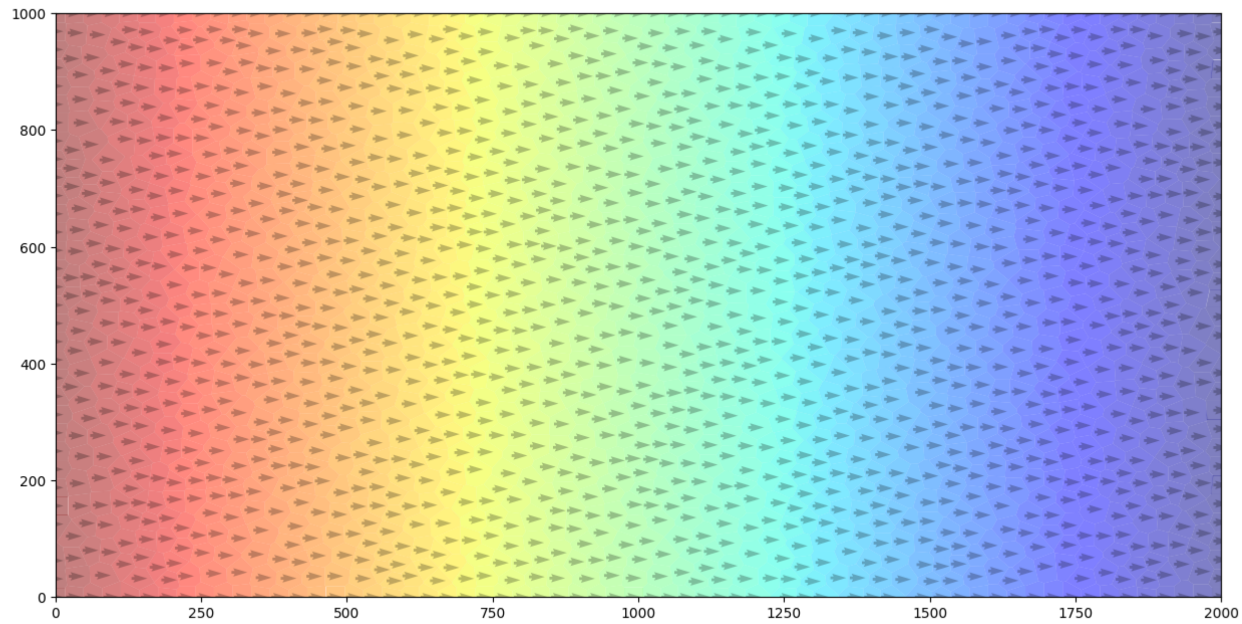
```
    writing package disv...
    writing package npf...
    writing package ic...
    writing package chd_0...
INFORMATION: maxbound in ('gwf6', 'chd', 'dimensions') changed to 62 based on size of␣
↪stress_period_data
    writing package oc...
```

[6]:

```
<matplotlib.quiver.Quiver at 0x7f5111efb160>
```



Create Run and Post Process a MODFLOW 6 Transport Model

[7]:

```python
name = "mf"
sim_ws = os.path.join(workspace, "transport")
sim = flopy.mf6.MFSimulation(
    sim_name=name, version="mf6", exe_name="mf6", sim_ws=sim_ws
)
tdis = flopy.mf6.ModflowTdis(
    sim, time_units="DAYS", perioddata=[[100 * 365.0, 100, 1.0]]
)
gwt = flopy.mf6.ModflowGwt(sim, modelname=name, save_flows=True)
ims = flopy.mf6.ModflowIms(
    sim,
    print_option="SUMMARY",
    complexity="simple",
    linear_acceleration="bicgstab",
    outer_dvclose=1.0e-6,
    inner_dvclose=1.0e-6,
)
disv_gridprops = voronoi_grid.get_disv_gridprops()
nlay = 1
```

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```
top = 1.0
botm = [0.0]
disv = flopy.mf6.ModflowGwtdisv(
    gwt, nlay=nlay, **disv_gridprops, top=top, botm=botm
)
ic = flopy.mf6.ModflowGwtic(gwt, strt=0.0)
sto = flopy.mf6.ModflowGwtmst(gwt, porosity=0.2)
adv = flopy.mf6.ModflowGwtadv(gwt, scheme="TVD")
dsp = flopy.mf6.ModflowGwtdsp(gwt, alh=5.0, ath1=0.5)
sourcerecarray = [()]
ssm = flopy.mf6.ModflowGwtssm(gwt, sources=sourcerecarray)
cnclist = [
    [(0, cells2[0]), 1.0],
]
cnc = flopy.mf6.ModflowGwtcnc(
    gwt, maxbound=len(cnclist), stress_period_data=cnclist, pname="CNC-1"
)
pd = [
    ("GWFHEAD", "../flow/mf.hds"),
    ("GWFBUDGET", "../flow/mf.bud"),
]
fmi = flopy.mf6.ModflowGwtfmi(gwt, packagedata=pd)
oc = flopy.mf6.ModflowGwtoc(
    gwt,
    budget_filerecord=f"{name}.cbc",
    concentration_filerecord=f"{name}.ucn",
    saverecord=[("CONCENTRATION", "ALL"), ("BUDGET", "ALL")],
)

sim.write_simulation()
success, buff = sim.run_simulation(report=True, silent=True)

conc = gwt.output.concentration().get_data()

fig = plt.figure(figsize=(10, 10))
ax = plt.subplot(1, 1, 1, aspect="equal")
pmv = flopy.plot.PlotMapView(gwf)
c = pmv.plot_array(conc, cmap="jet")
pmv.contour_array(conc, levels=(0.0001, 0.001, 0.01, 0.1), colors="y")
plt.colorbar(c, shrink=0.5)
```

```
WARNING: Unable to resolve dimension of ('gwt6', 'disv', 'cell2d', 'cell2d', 'icvert')␣
↪based on shape "ncvert".
writing simulation...
  writing simulation name file...
  writing simulation tdis package...
  writing solution package ims_-1...
  writing model mf...
    writing model name file...
    writing package disv...
    writing package ic...
    writing package mst...
```

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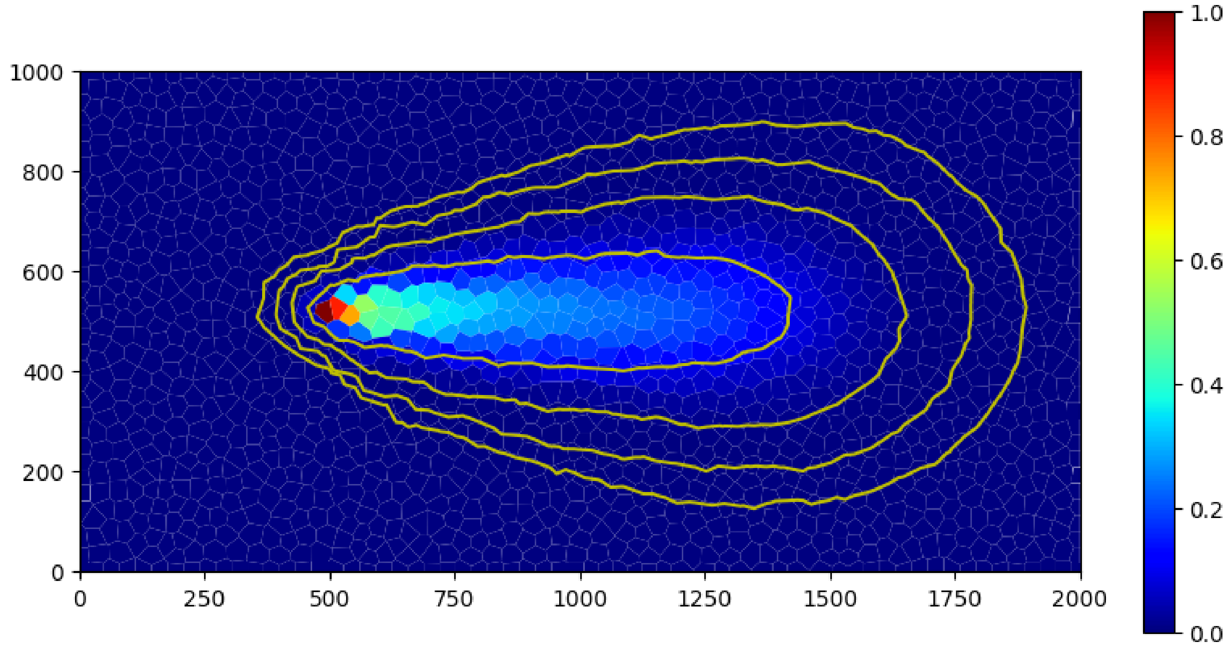
```
    writing package adv...
    writing package dsp...
    writing package ssm...
    writing package cnc-1...
    writing package fmi...
    writing package oc...
```

[7]: <matplotlib.colorbar.Colorbar at 0x7f510dc40a90>



Building Voronoi Grid Examples

Irregular Domain Boundary

[8]:
```python
domain = [
    [1831.381546, 6335.543757],
    [4337.733475, 6851.136153],
    [6428.747084, 6707.916043],
    [8662.980804, 6493.085878],
    [9350.437333, 5891.561415],
    [9235.861245, 4717.156511],
    [8963.743036, 3685.971717],
    [8691.624826, 2783.685023],
    [8047.13433, 2038.94045],
    [7416.965845, 578.0953252],
    [6414.425073, 105.4689614],
    [5354.596258, 205.7230386],
    [4624.173696, 363.2651598],
    [3363.836725, 563.7733141],
    [1330.11116, 1809.788273],
```

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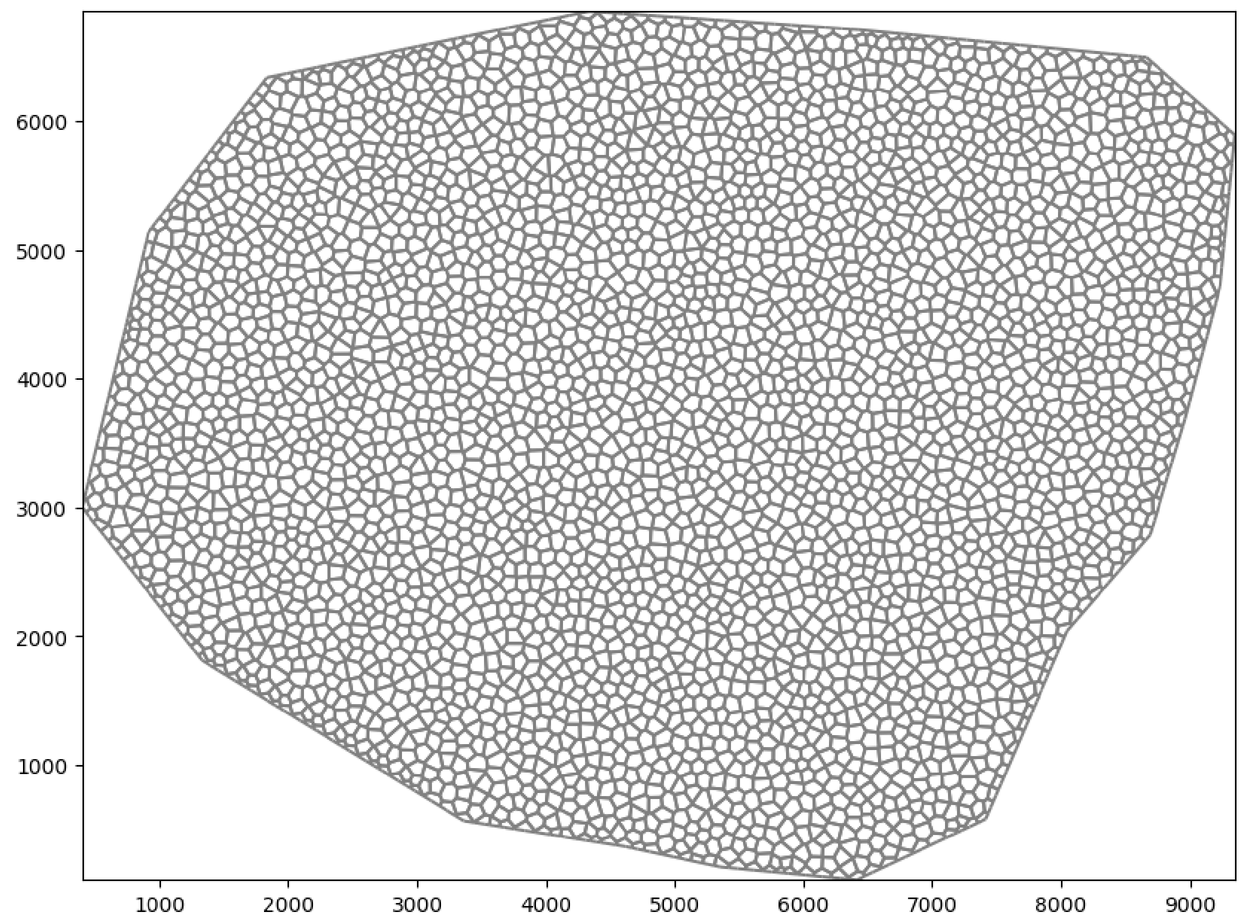
```
    [399.1804436, 2998.515188],
    [914.7728404, 5132.494831],
]
area_max = 100.0**2
tri = Triangle(maximum_area=area_max, angle=30, model_ws=workspace)
poly = np.array(domain)
tri.add_polygon(poly)
tri.build(verbose=False)

vor = VoronoiGrid(tri)
gridprops = vor.get_gridprops_vertexgrid()
voronoi_grid = VertexGrid(**gridprops, nlay=1)

fig = plt.figure(figsize=(10, 10))
ax = fig.add_subplot()
ax.set_aspect("equal")
voronoi_grid.plot(ax=ax)
```

[8]:

```
<matplotlib.collections.LineCollection at 0x7f510dc2b430>
```



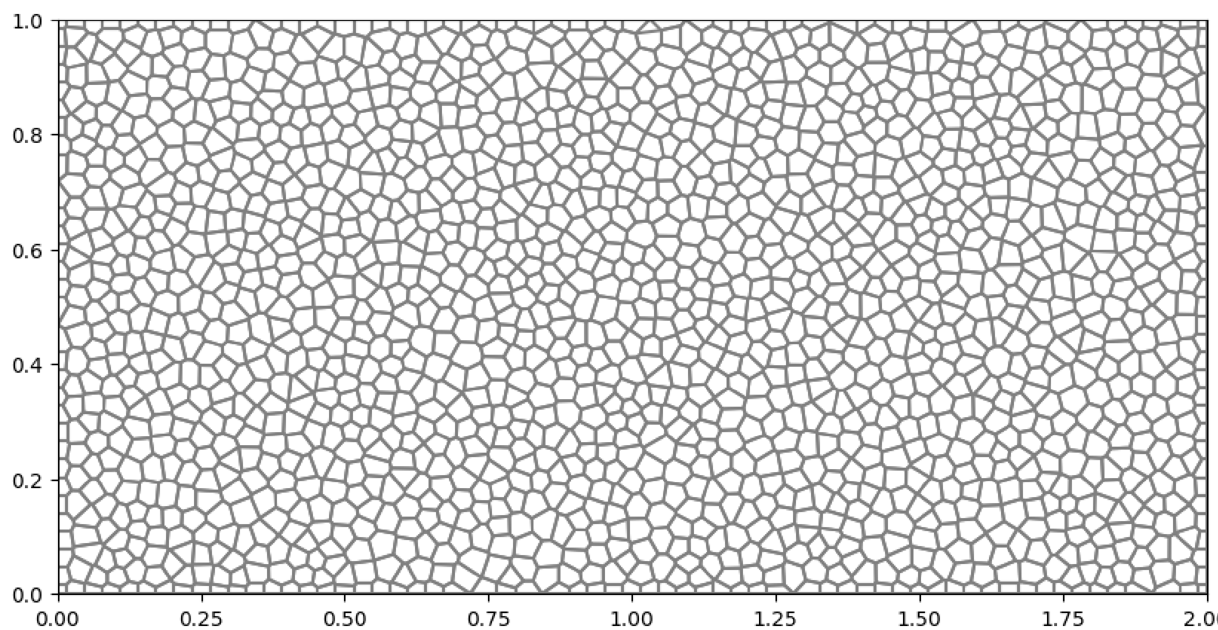
Simple Rectangular Domain

[9]:
```
xmin = 0.0
xmax = 2.0
ymin = 0.0
ymax = 1.0
area_max = 0.001
tri = Triangle(maximum_area=area_max, angle=30, model_ws=workspace)
poly = np.array(((xmin, ymin), (xmax, ymin), (xmax, ymax), (xmin, ymax)))
tri.add_polygon(poly)
tri.build(verbose=False)

vor = VoronoiGrid(tri)
gridprops = vor.get_gridprops_vertexgrid()
voronoi_grid = VertexGrid(**gridprops, nlay=1)

fig = plt.figure(figsize=(10, 10))
ax = fig.add_subplot()
ax.set_aspect("equal")
voronoi_grid.plot(ax=ax)
```

[9]:
```
<matplotlib.collections.LineCollection at 0x7f50edc96130>
```



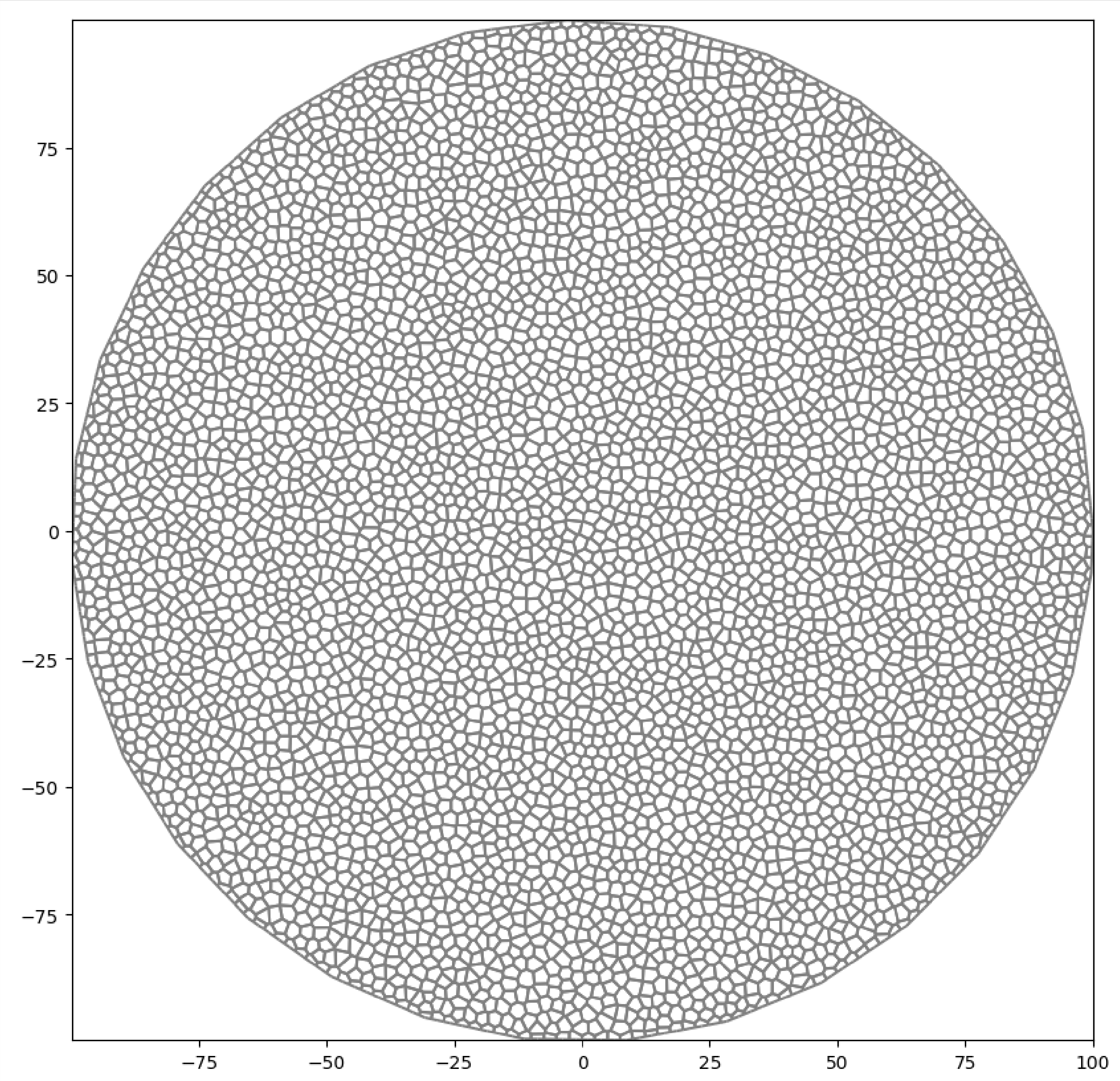
Circular Grid

[10]:
```
theta = np.arange(0.0, 2 * np.pi, 0.2)
radius = 100.0
x = radius * np.cos(theta)
y = radius * np.sin(theta)
circle_poly = [(x, y) for x, y in zip(x, y)]
tri = Triangle(maximum_area=5, angle=30, model_ws=workspace)
tri.add_polygon(circle_poly)
tri.build(verbose=False)

vor = VoronoiGrid(tri)
gridprops = vor.get_gridprops_vertexgrid()
voronoi_grid = VertexGrid(**gridprops, nlay=1)

fig = plt.figure(figsize=(10, 10))
ax = fig.add_subplot()
ax.set_aspect("equal")
voronoi_grid.plot(ax=ax)
```

[10]:
```
<matplotlib.collections.LineCollection at 0x7f510d11fa90>
```



Circular Grid with Hole

[11]:
```
theta = np.arange(0.0, 2 * np.pi, 0.2)
radius = 30.0
x = radius * np.cos(theta) + 25.0
y = radius * np.sin(theta) + 25.0
inner_circle_poly = [(x, y) for x, y in zip(x, y)]

tri = Triangle(maximum_area=10, angle=30, model_ws=workspace)
tri.add_polygon(circle_poly)
tri.add_polygon(inner_circle_poly)
tri.add_hole((25, 25))
```

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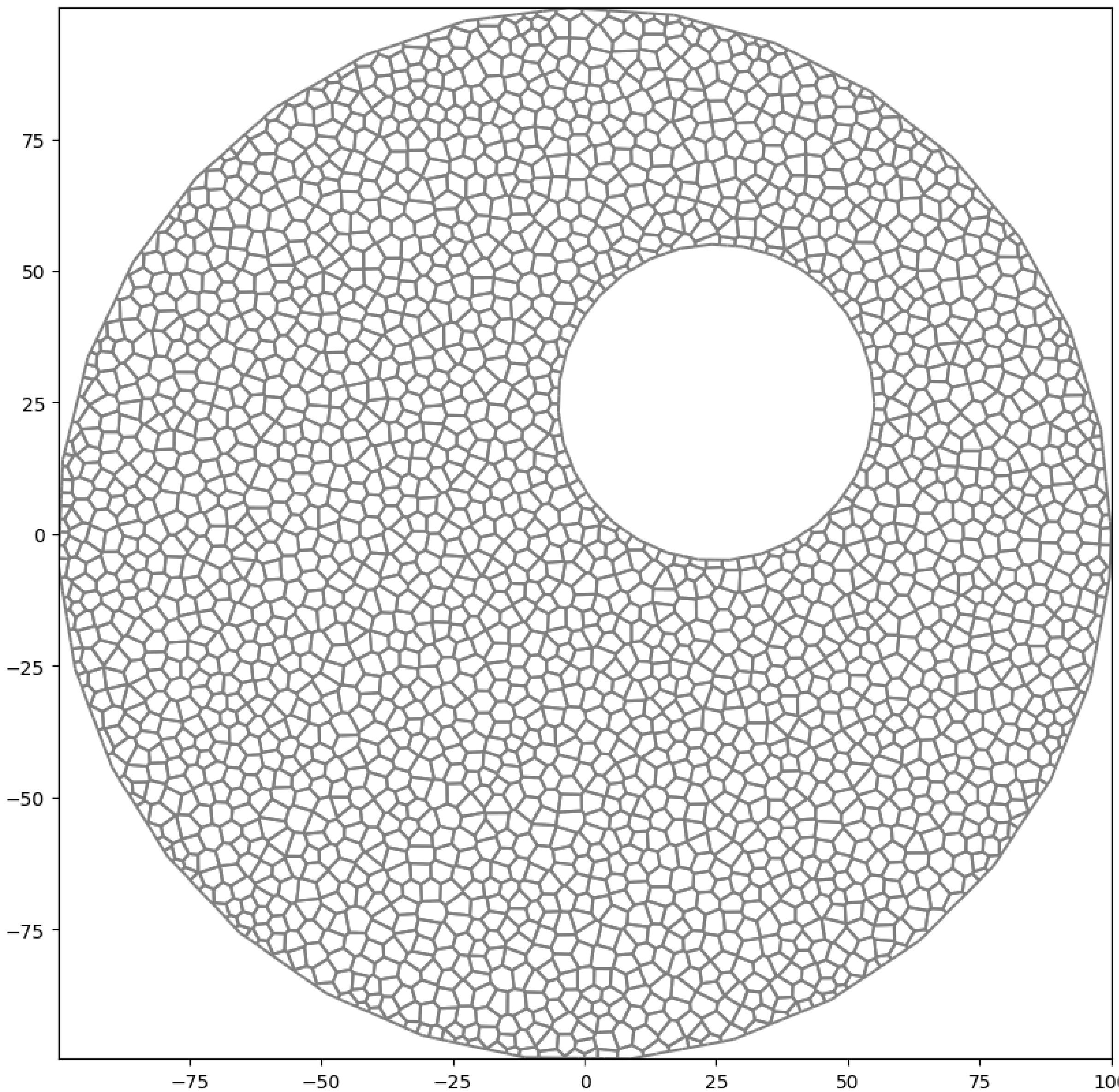
```
tri.build(verbose=False)

vor = VoronoiGrid(tri)
gridprops = vor.get_gridprops_vertexgrid()
voronoi_grid = VertexGrid(**gridprops, nlay=1)

fig = plt.figure(figsize=(10, 10))
ax = fig.add_subplot()
ax.set_aspect("equal")
voronoi_grid.plot(ax=ax)
```

[11]:
```
<matplotlib.collections.LineCollection at 0x7f5104720e20>
```



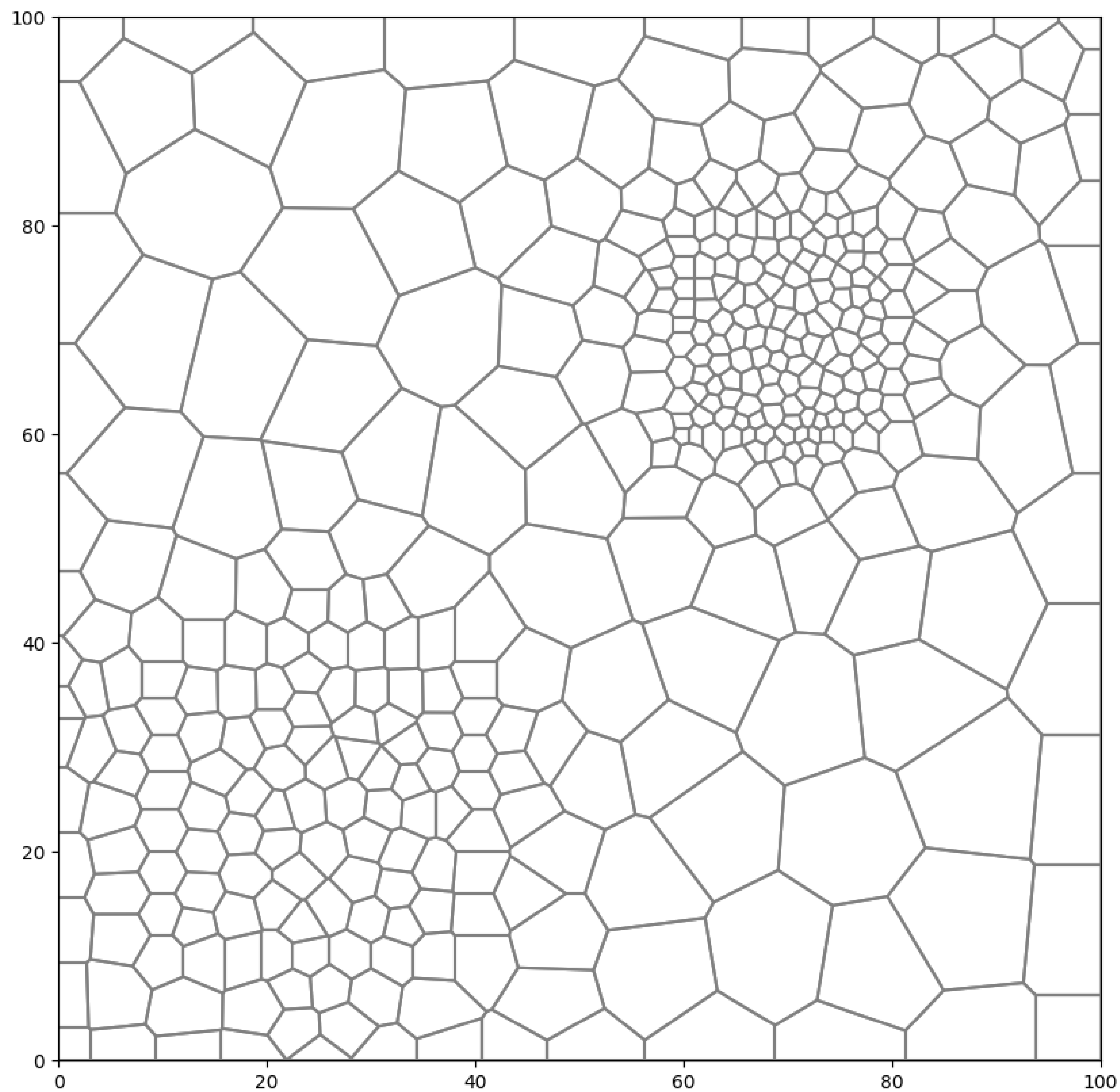
Regions with Different Refinement

[12]:
```
active_domain = [(0, 0), (100, 0), (100, 100), (0, 100)]
area1 = [(10, 10), (40, 10), (40, 40), (10, 40)]
area2 = [(60, 60), (80, 60), (80, 80), (60, 80)]
tri = Triangle(angle=30, model_ws=workspace)
tri.add_polygon(active_domain)
tri.add_polygon(area1)
tri.add_polygon(area2)
tri.add_region((1, 1), 0, maximum_area=100)  # point inside active domain
tri.add_region((11, 11), 1, maximum_area=10)  # point inside area1
tri.add_region((61, 61), 2, maximum_area=3)  # point inside area2
tri.build(verbose=False)

vor = VoronoiGrid(tri)
gridprops = vor.get_gridprops_vertexgrid()
voronoi_grid = VertexGrid(**gridprops, nlay=1)

fig = plt.figure(figsize=(10, 10))
ax = fig.add_subplot()
ax.set_aspect("equal")
voronoi_grid.plot(ax=ax)
```

[12]:
```
<matplotlib.collections.LineCollection at 0x7f510db91610>
```



Regions with Different Refinement and Hole

[13]:
```
active_domain = [(0, 0), (100, 0), (100, 100), (0, 100)]
area1 = [(10, 10), (40, 10), (40, 40), (10, 40)]
area2 = [(70, 70), (90, 70), (90, 90), (70, 90)]

tri = Triangle(angle=30, model_ws=workspace)

# requirement that active_domain is first polygon to be added
tri.add_polygon(active_domain)

# requirement that any holes be added next
```
(continues on next page)

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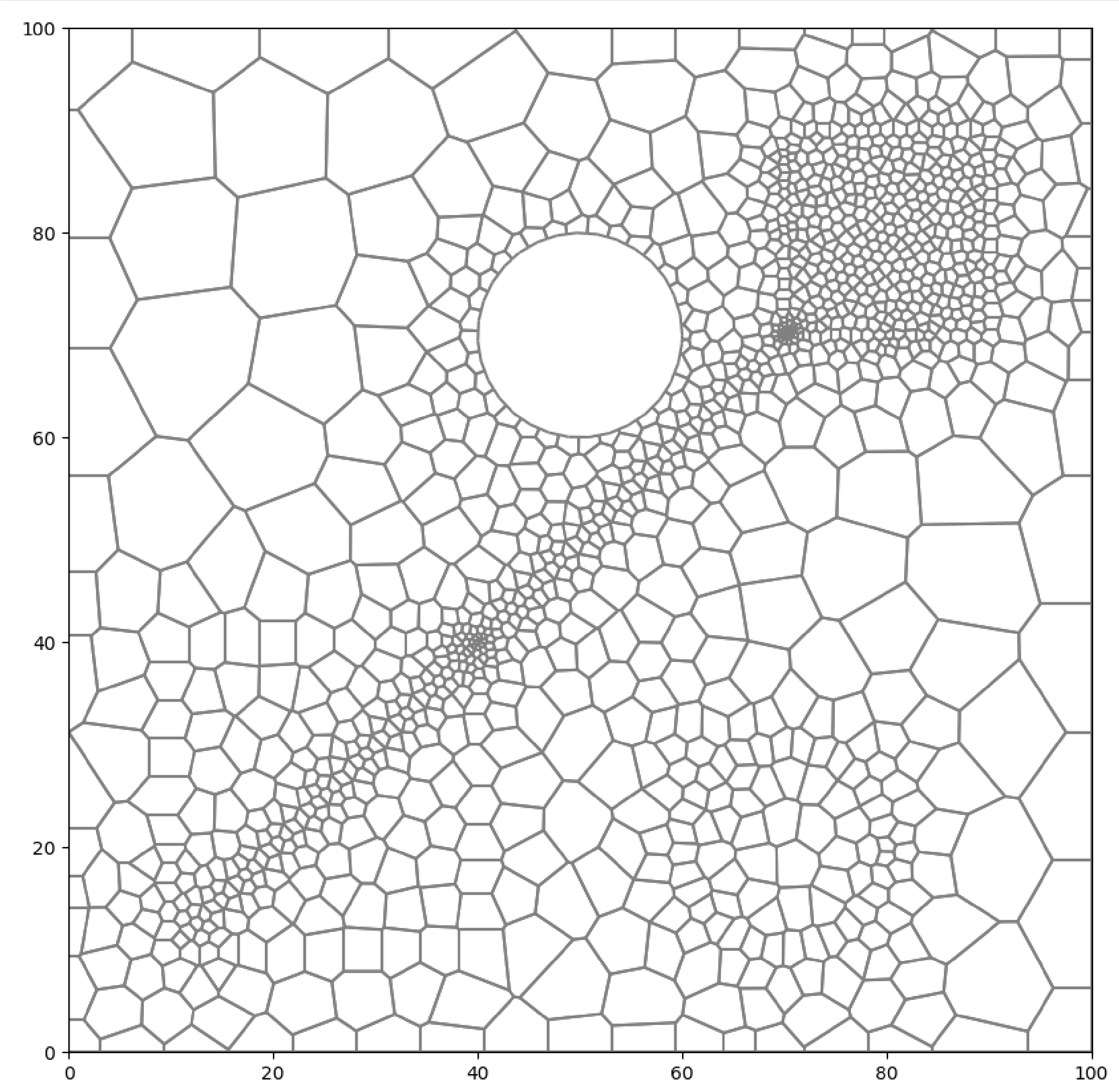
```
theta = np.arange(0.0, 2 * np.pi, 0.2)
radius = 10.0
x = radius * np.cos(theta) + 50.0
y = radius * np.sin(theta) + 70.0
circle_poly0 = [(x, y) for x, y in zip(x, y)]
tri.add_polygon(circle_poly0)
tri.add_hole((50, 70))

# Add a polygon to force cells to conform to it
theta = np.arange(0.0, 2 * np.pi, 0.2)
radius = 10.0
x = radius * np.cos(theta) + 70.0
y = radius * np.sin(theta) + 20.0
circle_poly1 = [(x, y) for x, y in zip(x, y)]
tri.add_polygon(circle_poly1)
# tri.add_hole((70, 20))

# add line through domain to force conforming cells
line = [(x, x) for x in np.linspace(11, 89, 100)]
tri.add_polygon(line)


# then regions and other polygons should follow
tri.add_polygon(area1)
tri.add_polygon(area2)
tri.add_region((1, 1), 0, maximum_area=100)  # point inside active domain
tri.add_region((11, 11), 1, maximum_area=10)  # point inside area1
tri.add_region((70, 70), 2, maximum_area=1)  # point inside area2

tri.build(verbose=False)

vor = VoronoiGrid(tri)
gridprops = vor.get_gridprops_vertexgrid()
voronoi_grid = VertexGrid(**gridprops, nlay=1)

fig = plt.figure(figsize=(10, 10))
ax = fig.add_subplot()
ax.set_aspect("equal")
voronoi_grid.plot(ax=ax)
```

[13]:
```
<matplotlib.collections.LineCollection at 0x7f510449b970>
```



[14]:
```
try:
    # ignore PermissionError on Windows
    temp_dir.cleanup()
except:
    pass
```

6.1.3 Intersecting model grids with shapes

Note: This feature requires the shapely package (which is an optional FloPy dependency).

This notebook shows the grid intersection functionality in flopy. The intersection methods are available through the `GridIntersect` object. A flopy modelgrid is passed to instantiate the object. Then the modelgrid can be intersected with Points, LineStrings and Polygons and their Multi variants.

Table of Contents

Import packages

[1]:
```
import os
import sys

import matplotlib as mpl
import matplotlib.pyplot as plt
import numpy as np
import shapely
from shapely.geometry import (
    LineString,
    MultiLineString,
    MultiPoint,
    MultiPolygon,
    Point,
    Polygon,
)

import flopy
import flopy.discretization as fgrid
import flopy.plot as fplot
from flopy.utils import GridIntersect

print(sys.version)
print(f"numpy version: {np.__version__}")
print(f"matplotlib version: {mpl.__version__}")
print(f"flopy version: {flopy.__version__}")
print(f"shapely version: {shapely.__version__}")
```

```
3.8.18 (default, Aug 28 2023, 08:27:22)
[GCC 11.4.0]
numpy version: 1.24.4
matplotlib version: 3.7.4
flopy version: 3.5.0
shapely version: 2.0.2
```

GridIntersect Class

The GridIntersect class is constructed by passing a flopy modelgrid object to the constructor. There are options users can select to change how the intersection is calculated.

- `method`: derived from model grid type or defined by the user: can be either `"vertex"` or `"structured"`. If `"structured"` is passed, the intersections are performed using structured methods. These methods use information about the regular grid to limit the search space for intersection calculations. Note that `method="vertex"` also works for structured grids.
- `rtree`: either `True` (default) or `False`, only read when `method="vertex"`. When True, an STR-tree is built, which allows for fast spatial queries. Building the STR-tree does take some time however. Setting the option to False avoids building the STR-tree but requires the intersection calculation to loop through all grid cells.

In general the "vertex" option is robust and fast and is therefore recommended in most situations. In some rare cases building the STR-tree might not be worth the time, in which case it can be avoided by passing `rtree=False`. If you are working with a structured grid, then the `method="structured"` can speed up intersection operations in some situations (e.g. for (multi)points) with the added advantage of not having to build an STR-tree.

The important methods in the GridIntersect object are:

- `intersects()`: returns cellids for gridcells that intersect a shape (accepts shapely geometry objects, flopy geometry object, shapefile.Shape objects, and geojson objects)
- `intersect()`: for intersecting the modelgrid with point, linestrings, and polygon geometries (accepts shapely geometry objects, flopy geometry object, shapefile.Shape objects, and geojson objects)
- `plot_point()`: for plotting point intersection results
- `plot_linestring()`: for plotting linestring intersection results
- `plot_polygon()`: for plotting polygon intersection results

In the following sections examples of intersections are shown for structured and vertex grids for different types of shapes (Polygon, LineString and Point).

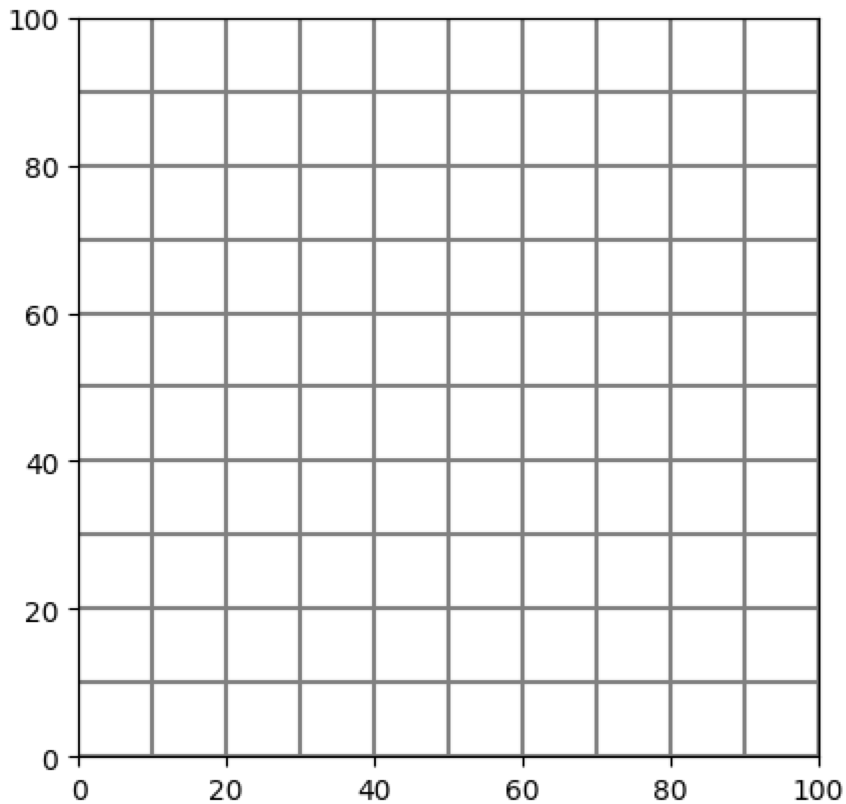
Rectangular regular grid

[2]:
```python
delc = 10 * np.ones(10, dtype=float)
delr = 10 * np.ones(10, dtype=float)
```

[3]:
```python
xoff = 0.0
yoff = 0.0
angrot = 0.0
sgr = fgrid.StructuredGrid(
    delc, delr, top=None, botm=None, xoff=xoff, yoff=yoff, angrot=angrot
)
```

[4]:
```
sgr.plot()
```

[4]:
```
<matplotlib.collections.LineCollection at 0x7f693186ffa0>
```



Polygon with regular grid

Polygon to intersect with:

[5]:
```
p = Polygon(
    shell=[
        (15, 15),
        (20, 50),
        (35, 80.0),
        (80, 50),
        (80, 40),
        (40, 5),
        (15, 12),
    ],
    holes=[[(25, 25), (25, 45), (45, 45), (45, 25)]],
)
```

Create the GridIntersect class for our modelgrid. The `method` kwarg is passed to force GridIntersect to use the `"vertex"` intersection methods.

[6]:
```
ix = GridIntersect(sgr, method="vertex")
```

Do the intersect operation for a polygon

[7]:
```
result = ix.intersect(p)
```

The results are returned as a numpy.recarray containing several fields based on the intersection performed. An explanation of the data in each of the possible fields is given below: - **cellids**: contains the cell ids of the intersected grid cells - **vertices**: contains the vertices of the intersected shape - **areas**: contains the area of the polygon in that grid cell (only for polygons) - **lengths**: contains the length of the linestring in that grid cell (only for linestrings) - **ixshapes**: contains the shapely object representing the intersected shape (useful for plotting the result)

Looking at the first few entries of the results of the polygon intersection (convert to pandas.DataFrame for prettier formatting)

[8]:
```
result[:5]
# pd.DataFrame(result)  # recommended for prettier formatting and working with result
```

[8]:
```
rec.array([((2, 3), <POLYGON ((35 80, 40 76.667, 40 70, 30 70, 35 80))>,  66.66666667),
           ((2, 4), <POLYGON ((50 70, 40 70, 40 76.667, 50 70))>,  33.33333333),
           ((3, 2), <POLYGON ((30 70, 30 60, 25 60, 30 70))>,  25.        ),
           ((3, 3), <POLYGON ((40 70, 40 60, 30 60, 30 70, 40 70))>, 100.        ),
           ((3, 4), <POLYGON ((50 70, 50 60, 40 60, 40 70, 50 70))>, 100.        )],
          dtype=[('cellids', 'O'), ('ixshapes', 'O'), ('areas', '<f8')])
```

The cellids can be easily obtained

[9]:
```
result.cellids
```

[9]:
```
array([(2, 3), (2, 4), (3, 2), (3, 3), (3, 4), (3, 5), (3, 6), (4, 2),
       (4, 3), (4, 4), (4, 5), (4, 6), (4, 7), (5, 1), (5, 2), (5, 3),
       (5, 4), (5, 5), (5, 6), (5, 7), (6, 1), (6, 2), (6, 4), (6, 5),
       (6, 6), (6, 7), (7, 1), (7, 2), (7, 3), (7, 4), (7, 5), (7, 6),
       (8, 1), (8, 2), (8, 3), (8, 4), (8, 5), (9, 2), (9, 3), (9, 4)],
      dtype=object)
```

Or the areas

[10]:
```
result.areas
```

[10]:
```
array([ 66.66666667,  33.33333333,  25.        , 100.        ,
       100.        ,  66.66666667,   8.33333333,  75.        ,
       100.        , 100.        , 100.        ,  91.66666667,
        33.33333333,   7.14285714,  75.        ,  50.        ,
        75.        , 100.        , 100.        , 100.        ,
        21.42857143,  50.        ,  50.        , 100.        ,
        99.10714286,  43.75      ,  35.71428571,  75.        ,
        50.        ,  75.        ,  96.42857143,  32.14285714,
        41.71428571,  99.35714286, 100.        ,  91.96428571,
        22.32142857,   8.64285714,  36.        ,  14.28571429])
```

If a user is only interested in which cells the shape intersects (and not the areas or the actual shape of the intersected object) with there is also the `intersects()` method. This method works for all types of shapely geometries.

[11]:
```
ix.intersects(p)
```

[11]:
```
rec.array([((8, 1),), ((7, 2),), ((7, 1),), ((6, 1),), ((6, 2),),
           ((9, 4),), ((9, 2),), ((9, 3),), ((8, 2),), ((8, 3),),
           ((8, 4),), ((7, 3),), ((7, 4),), ((6, 4),), ((5, 1),),
```

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```
          ((4, 1),), ((4, 2),), ((3, 2),), ((5, 2),), ((5, 3),),
          ((5, 4),), ((4, 3),), ((4, 4),), ((3, 4),), ((3, 3),),
          ((2, 4),), ((2, 3),), ((2, 2),), ((1, 3),), ((8, 5),),
          ((7, 5),), ((7, 6),), ((6, 5),), ((6, 6),), ((6, 7),),
          ((6, 8),), ((5, 5),), ((5, 7),), ((5, 6),), ((4, 6),),
          ((4, 5),), ((3, 6),), ((3, 5),), ((2, 5),), ((5, 8),),
          ((4, 8),), ((4, 7),)],
         dtype=[('cellids', 'O')])
```

The results of an intersection can be visualized with the plotting methods in the `GridIntersect` object: - `plot_polygon` - `plot_linestring` - `plot_point`

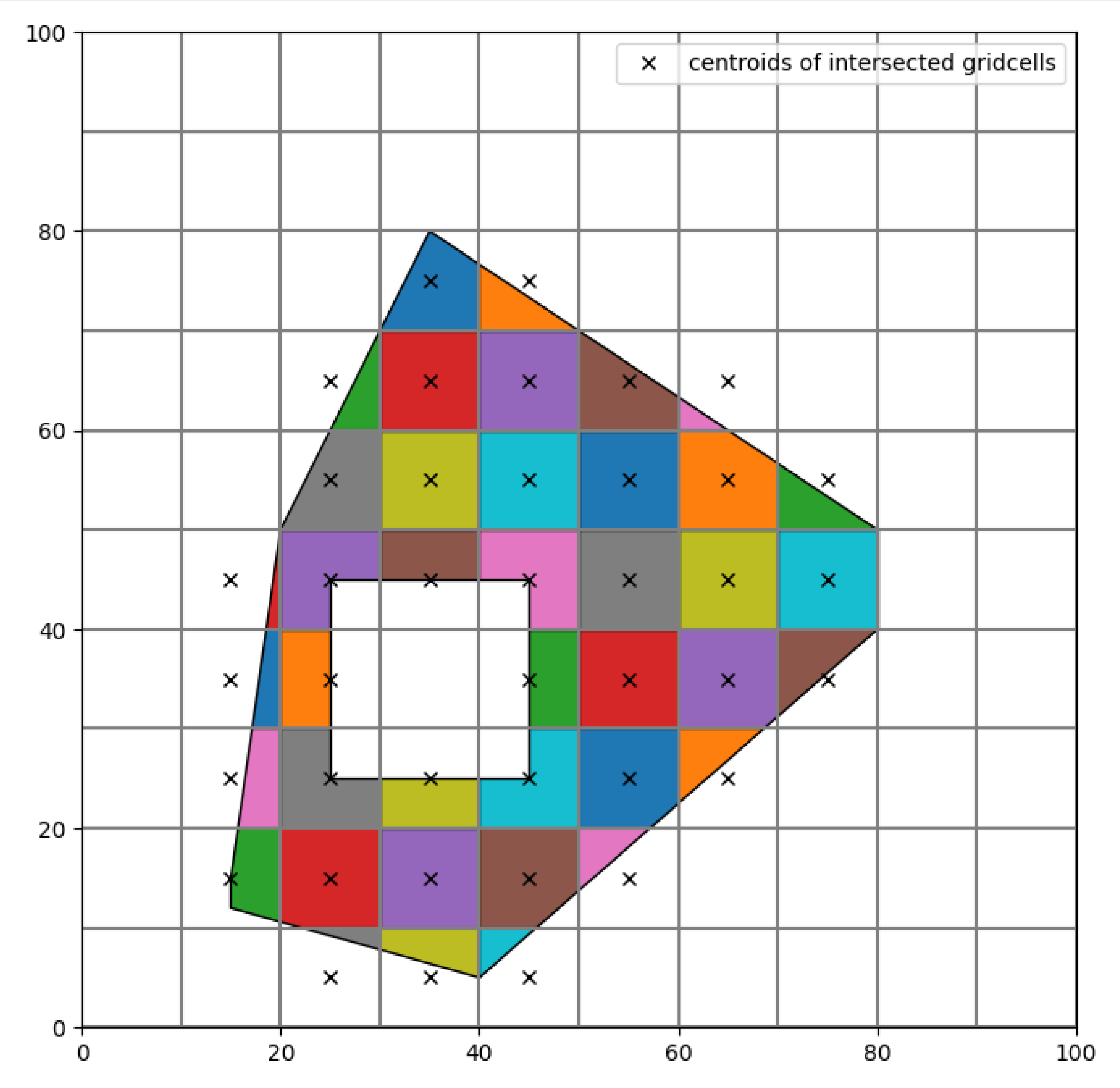
[12]:
```
# create a figure and plot the grid
fig, ax = plt.subplots(1, 1, figsize=(8, 8))
sgr.plot(ax=ax)

# the intersection object contains some helpful plotting commands
ix.plot_polygon(result, ax=ax)

# add black x at cell centers
for irow, icol in result.cellids:
    (h2,) = ax.plot(
        sgr.xcellcenters[0, icol],
        sgr.ycellcenters[irow, 0],
        "kx",
        label="centroids of intersected gridcells",
    )

# add legend
ax.legend([h2], [i.get_label() for i in [h2]], loc="best")
```

[12]:
```
<matplotlib.legend.Legend at 0x7f692f489f40>
```



The `intersect()` method contains several keyword arguments that specifically deal with polygons:

- `contains_centroid`: only store intersection result if cell centroid is contained within polygon
- `min_area_fraction`: minimal intersecting cell area (expressed as a fraction of the total cell area) to include cells in intersection result

Two examples showing the usage of these keyword arguments are shown below.

Example with `contains_centroid` set to True, only cells in which centroid is within the intersected polygon are stored. Note the difference with the previous result.

[13]:
```
# contains_centroid example

result2 = ix.intersect(p, contains_centroid=True)
```

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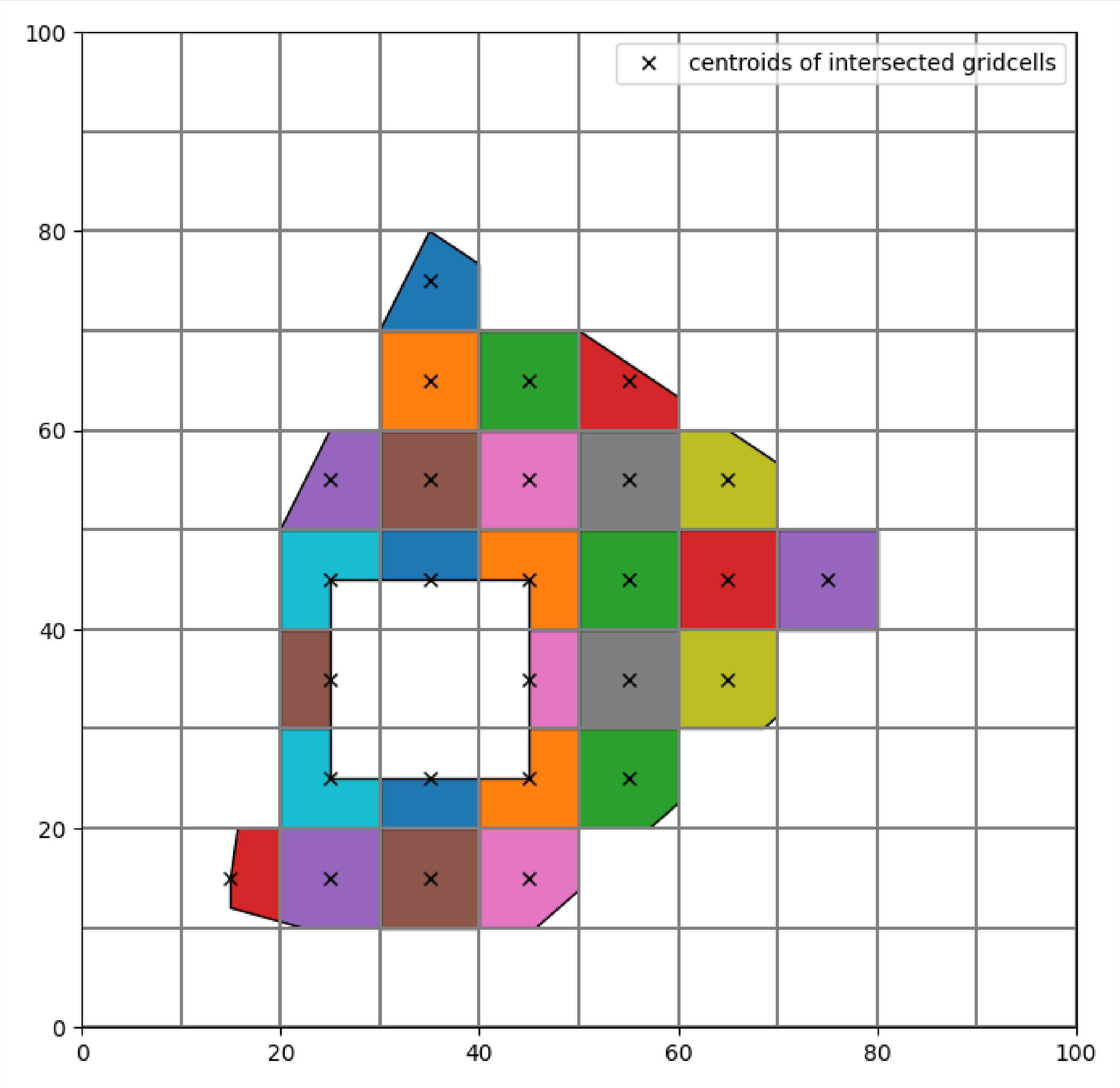
```
# create a figure and plot the grid
fig, ax = plt.subplots(1, 1, figsize=(8, 8))
sgr.plot(ax=ax)

# the intersection object contains some helpful plotting commands
ix.plot_polygon(result2, ax=ax)

# add black x at cell centers
for irow, icol in result2.cellids:
    (h2,) = ax.plot(
        sgr.xcellcenters[0, icol],
        sgr.ycellcenters[irow, 0],
        "kx",
        label="centroids of intersected gridcells",
    )

# add legend
ax.legend([h2], [i.get_label() for i in [h2]], loc="best")
```

[13]:
```
<matplotlib.legend.Legend at 0x7f692f3d2af0>
```



Example with `min_area_threshold` set to 0.35, the intersection result in a cell should cover 35% or more of the cell area.

[14]:
```
# min_area_threshold example

result3 = ix.intersect(p, min_area_fraction=0.35)

# create a figure and plot the grid
fig, ax = plt.subplots(1, 1, figsize=(8, 8))
sgr.plot(ax=ax)

# the intersection object contains some helpful plotting commands
ix.plot_polygon(result3, ax=ax)
```

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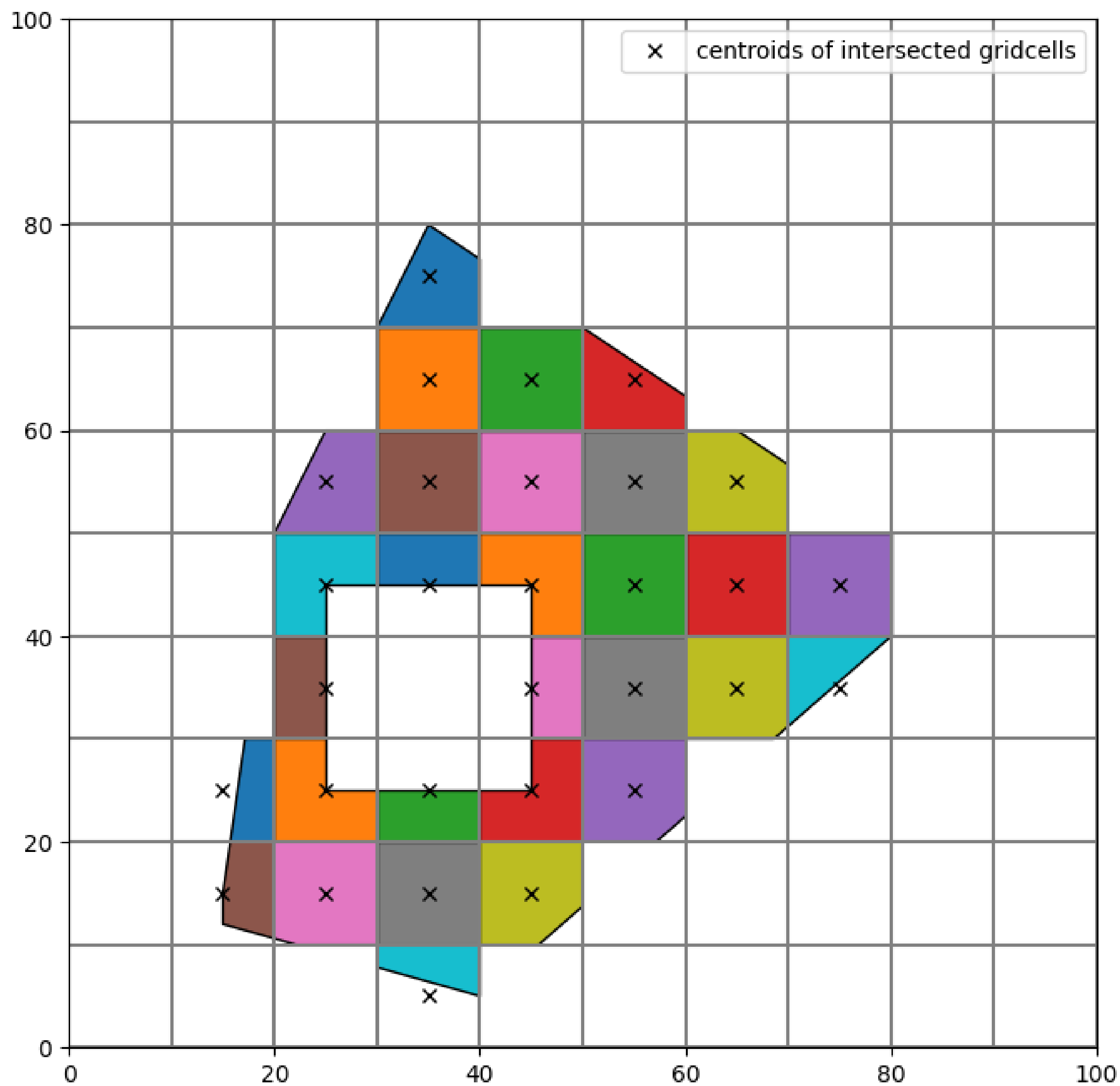
```
# add black x at cell centers
for irow, icol in result3.cellids:
    (h2,) = ax.plot(
        sgr.xcellcenters[0, icol],
        sgr.ycellcenters[irow, 0],
        "kx",
        label="centroids of intersected gridcells",
    )

# add legend
ax.legend([h2], [i.get_label() for i in [h2]], loc="best")
```

[14]: <matplotlib.legend.Legend at 0x7f692f31ca90>



Alternatively, the intersection can be calculated using special methods optimized for structured grids. Access these methods by instantiating the GridIntersect class with the `method="structured"` keyword argument.

[15]:
```
ixs = GridIntersect(sgr, method="structured")
result4 = ixs.intersect(p)
```

The result is the same as before:

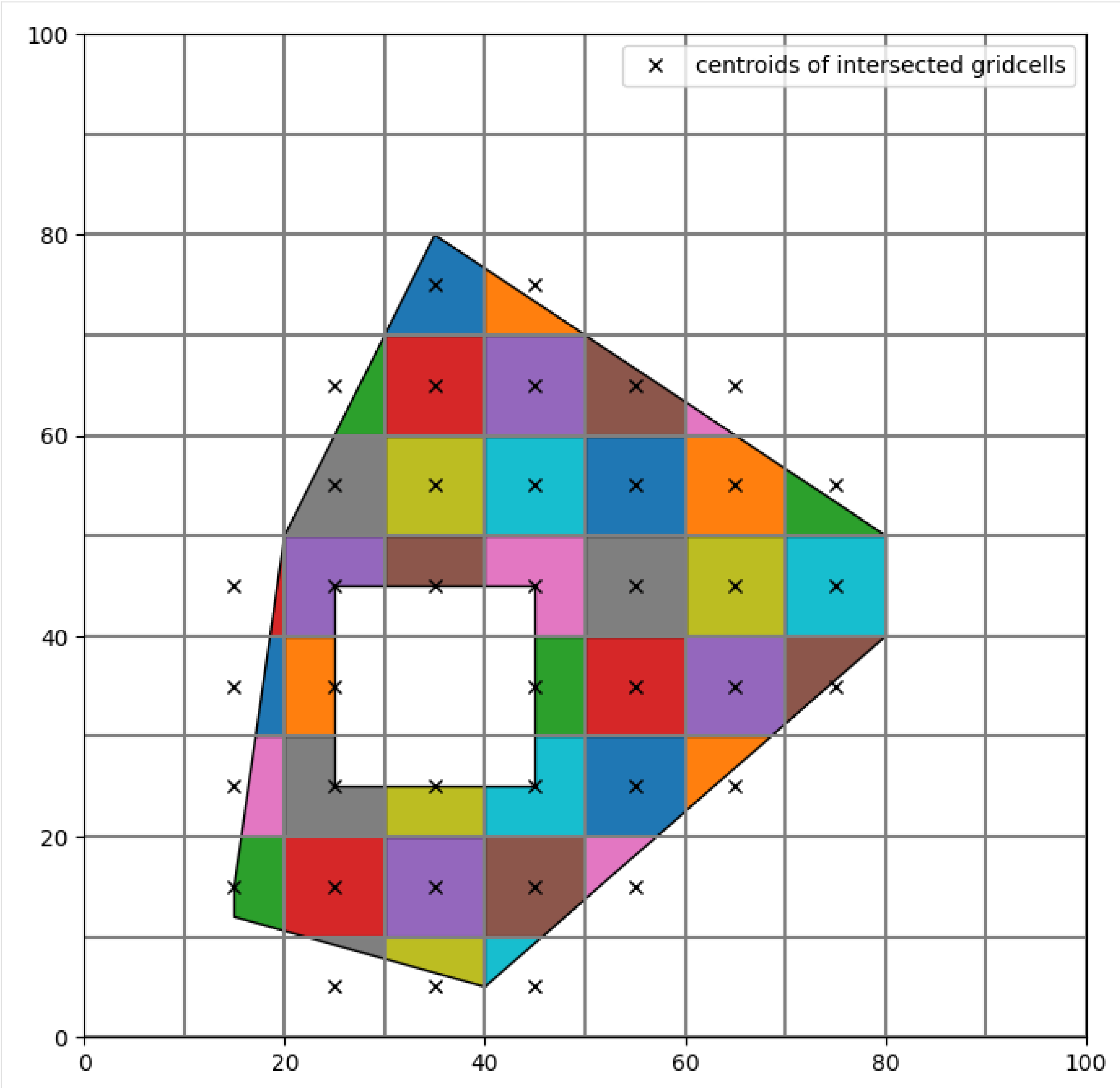
[16]:
```
# create a figure and plot the grid
fig, ax = plt.subplots(1, 1, figsize=(8, 8))
sgr.plot(ax=ax)

# the intersection object contains some helpful plotting commands
ix.plot_polygon(result4, ax=ax)

# add black x at cell centers
for irow, icol in result4.cellids:
    (h2,) = ax.plot(
        sgr.xcellcenters[0, icol],
        sgr.ycellcenters[irow, 0],
        "kx",
        label="centroids of intersected gridcells",
    )

# add legend
ax.legend([h2], [i.get_label() for i in [h2]], loc="best")
```

[16]:
```
<matplotlib.legend.Legend at 0x7f692f250ee0>
```



Polyline with regular grid

MultiLineString to intersect with:

[17]:
```
ls1 = LineString([(95, 105), (30, 50)])
ls2 = LineString([(30, 50), (90, 22)])
ls3 = LineString([(90, 22), (0, 0)])
mls = MultiLineString(lines=[ls1, ls2, ls3])
```

[18]:
```
result = ix.intersect(mls)
```

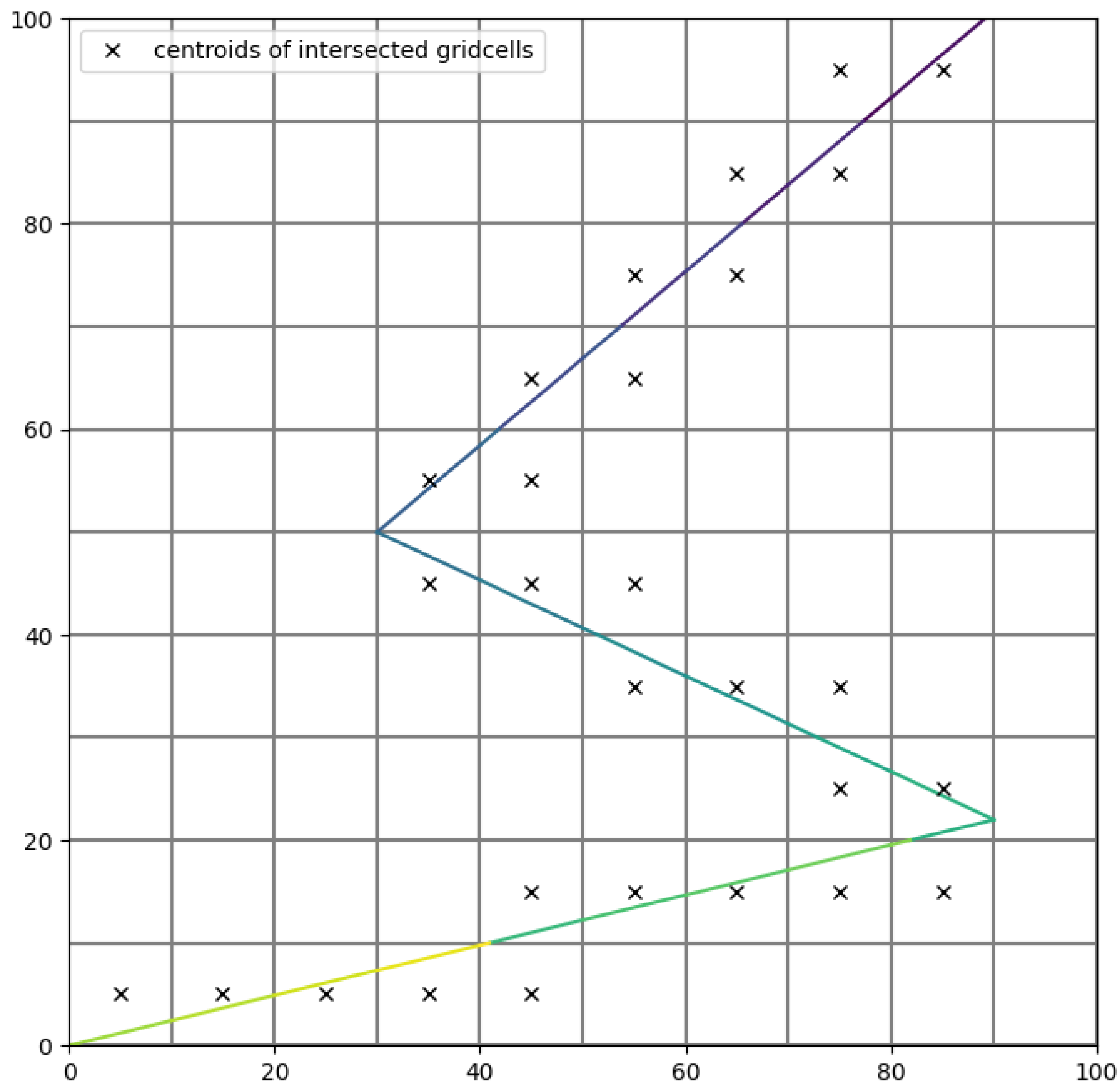
Plot the result

[19]:
```
fig, ax = plt.subplots(1, 1, figsize=(8, 8))
sgr.plot(ax=ax)
ix.plot_linestring(result, ax=ax, cmap="viridis")

for irow, icol in result.cellids:
    (h2,) = ax.plot(
        sgr.xcellcenters[0, icol],
        sgr.ycellcenters[irow, 0],
        "kx",
        label="centroids of intersected gridcells",
    )

ax.legend([h2], [i.get_label() for i in [h2]], loc="best")
```

[19]:
```
<matplotlib.legend.Legend at 0x7f692ef85ca0>
```



Same as before, the intersect for structured grids can also be performed with a different method optimized for structured grids

[20]:
```
ixs = GridIntersect(sgr, method="structured")
```

[21]:
```
result2 = ixs.intersect(mls)

# ordering is different so compare sets to check equality
check = len(set(result2.cellids) - set(result.cellids)) == 0
print(
    "Intersection result with method='structured' and "
    f"method='vertex' are equal: {check}"
)
```

```
Intersection result with method='structured' and method='vertex' are equal: True
```

MultiPoint with regular grid

MultiPoint to intersect with

[22]:
```
mp = MultiPoint(
    points=[
        Point(50.0, 0.0),
        Point(45.0, 45.0),
        Point(10.0, 10.0),
        Point(150.0, 100.0),
    ]
)
```

For points and linestrings there is a keyword argument `return_all_intersections` which will return multiple intersection results for points or (parts of) linestrings on cell boundaries. As an example, the difference is shown with the MultiPoint intersection. Note the number of red "+" symbols indicating the centroids of intersected cells, in the bottom left case, there are 4 results because the point lies exactly on the intersection between 4 grid cells.

[23]:
```
result = ix.intersect(mp)
result_all = ix.intersect(mp, return_all_intersections=True)
```

[24]:
```
fig, ax = plt.subplots(1, 1, figsize=(8, 8))
sgr.plot(ax=ax)
ix.plot_point(result, ax=ax, s=50, color="C0")
ix.plot_point(result_all, ax=ax, s=50, marker=".", color="C3")

for irow, icol in result.cellids:
    (h2,) = ax.plot(
        sgr.xcellcenters[0, icol],
        sgr.ycellcenters[irow, 0],
        "kx",
        ms=15,
        label="centroids of intersected cells",
    )

for irow, icol in result_all.cellids:
```

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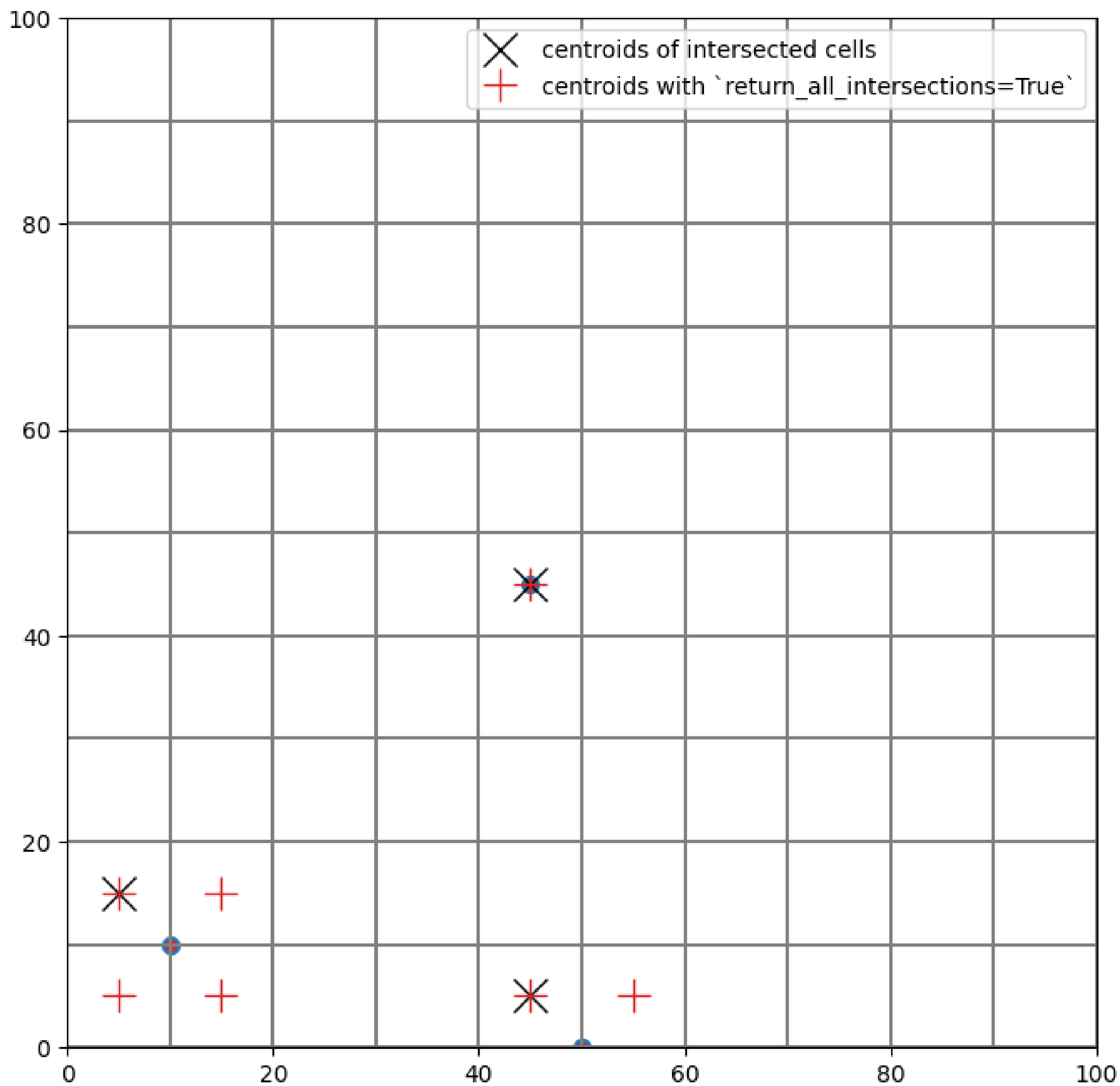
```
    (h3,) = ax.plot(
        sgr.xcellcenters[0, icol],
        sgr.ycellcenters[irow, 0],
        "C3+",
        ms=15,
        label="centroids with `return_all_intersections=True`",
    )

ax.legend([h2, h3], [i.get_label() for i in [h2, h3]], loc="best")
```

```
[24]: <matplotlib.legend.Legend at 0x7f692ee2d820>
```



Same as before, the intersect for structured grids can also be performed with a different method written specifically for structured grids.

[25]:
```
ixs = GridIntersect(sgr, method="structured")
```

[26]:
```
result2 = ixs.intersect(mp, return_all_intersections=False)

# ordering is different so compare sets to check equality
check = len(set(result2.cellids) - set(result.cellids)) == 0
print(
    "Intersection result with method='structured' and "
    f"method='vertex' are equal: {check}"
)
```

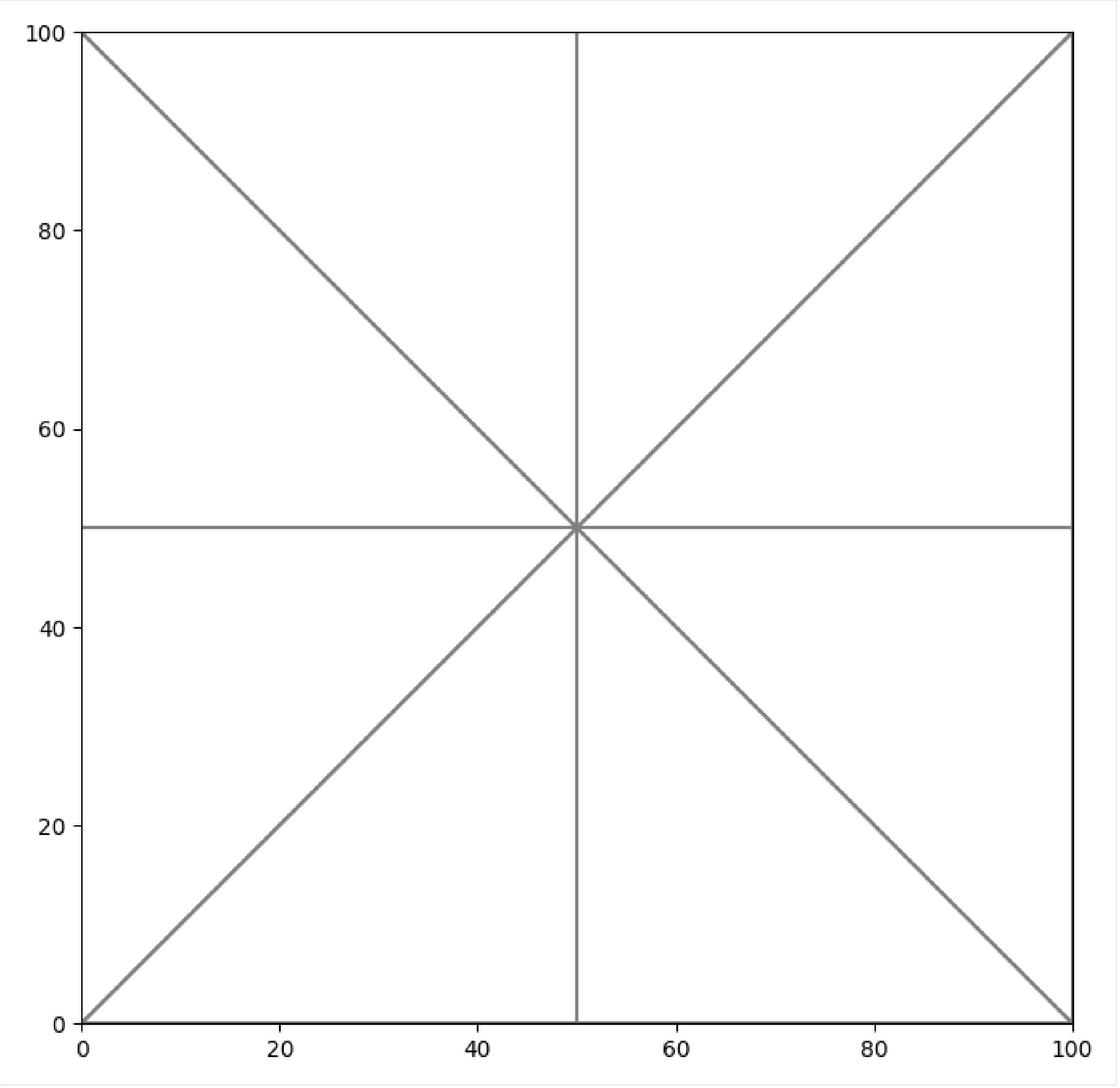
```
Intersection result with method='structured' and method='vertex' are equal: True
```

Vertex Grid

[27]:
```
cell2d = [
    [0, 83.33333333333333, 66.66666666666667, 3, 4, 2, 7],
    [1, 16.666666666666668, 33.333333333333336, 3, 4, 0, 5],
    [2, 33.333333333333336, 83.33333333333333, 3, 1, 8, 4],
    [3, 16.666666666666668, 66.66666666666667, 3, 5, 1, 4],
    [4, 33.333333333333336, 16.666666666666668, 3, 6, 0, 4],
    [5, 66.66666666666667, 16.666666666666668, 3, 4, 3, 6],
    [6, 83.33333333333333, 33.333333333333336, 3, 7, 3, 4],
    [7, 66.66666666666667, 83.33333333333333, 3, 8, 2, 4],
]
vertices = [
    [0, 0.0, 0.0],
    [1, 0.0, 100.0],
    [2, 100.0, 100.0],
    [3, 100.0, 0.0],
    [4, 50.0, 50.0],
    [5, 0.0, 50.0],
    [6, 50.0, 0.0],
    [7, 100.0, 50.0],
    [8, 50.0, 100.0],
]
tgr = fgrid.VertexGrid(vertices, cell2d)
```

[28]:
```
fig, ax = plt.subplots(1, 1, figsize=(8, 8))
pmv = fplot.PlotMapView(modelgrid=tgr)
pmv.plot_grid(ax=ax)
```

[28]:
```
<matplotlib.collections.LineCollection at 0x7f692ed68fd0>
```



Polygon with triangular grid

[29]:
```
ix2 = GridIntersect(tgr)
```

[30]:
```
result = ix2.intersect(p)
```

[31]:
```
fig, ax = plt.subplots(1, 1, figsize=(8, 8))
pmv = fplot.PlotMapView(ax=ax, modelgrid=tgr)
pmv.plot_grid()
ix.plot_polygon(result, ax=ax)

# only cells that intersect with shape
```

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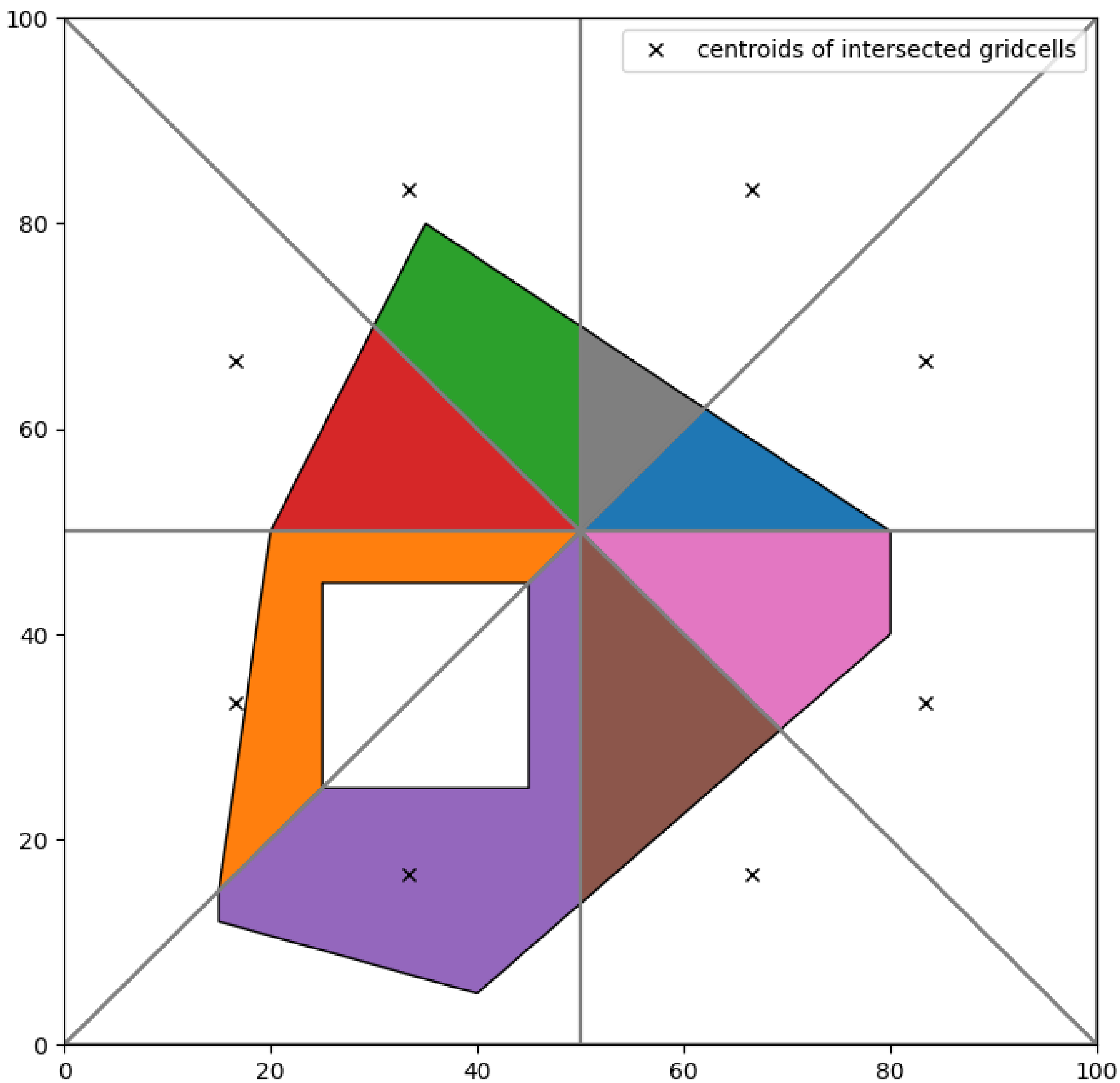
```
for cellid in result.cellids:
    (h2,) = ax.plot(
        tgr.xcellcenters[cellid],
        tgr.ycellcenters[cellid],
        "kx",
        label="centroids of intersected gridcells",
    )

ax.legend([h2], [i.get_label() for i in [h2]], loc="best")
```

[31]:

```
<matplotlib.legend.Legend at 0x7f692ed2c760>
```



LineString with triangular grid

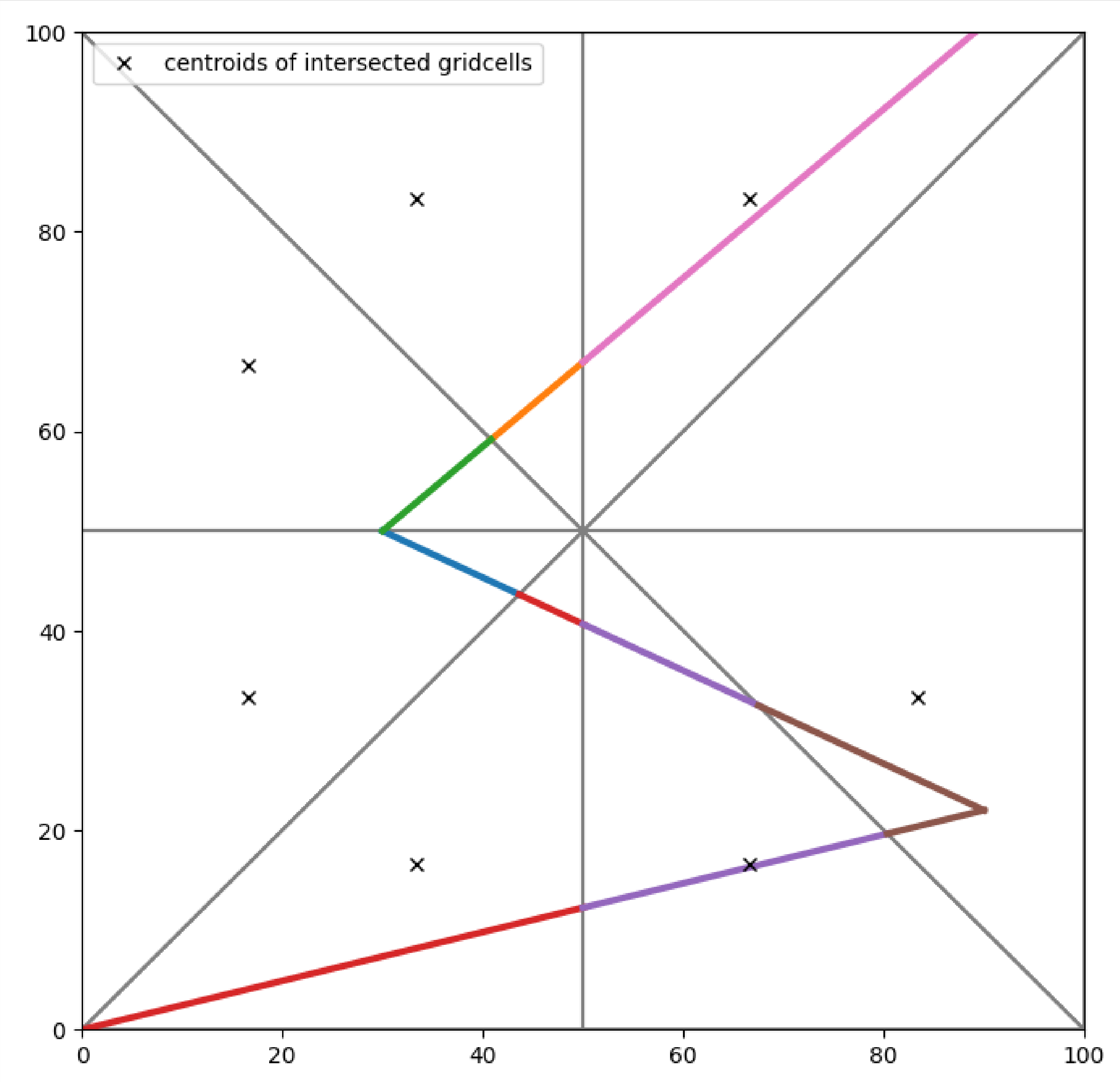
[32]:
```
result = ix2.intersect(mls)
```

[33]:
```
fig, ax = plt.subplots(1, 1, figsize=(8, 8))
pmv = fplot.PlotMapView(ax=ax, modelgrid=tgr)
pmv.plot_grid()
ix2.plot_linestring(result, ax=ax, lw=3)

for cellid in result.cellids:
    (h2,) = ax.plot(
        tgr.xcellcenters[cellid],
        tgr.ycellcenters[cellid],
        "kx",
        label="centroids of intersected gridcells",
    )

ax.legend([h2], [i.get_label() for i in [h2]], loc="best")
```

[33]:
```
<matplotlib.legend.Legend at 0x7f692ed1f730>
```



MultiPoint with triangular grid

[34]:
```
result = ix2.intersect(mp)
result_all = ix2.intersect(mp, return_all_intersections=True)
```

[35]:
```
fig, ax = plt.subplots(1, 1, figsize=(8, 8))
pmv = fplot.PlotMapView(ax=ax, modelgrid=tgr)
pmv.plot_grid()
ix2.plot_point(result, ax=ax, color="k", zorder=5, s=80)

for cellid in result.cellids:
    (h2,) = ax.plot(
```

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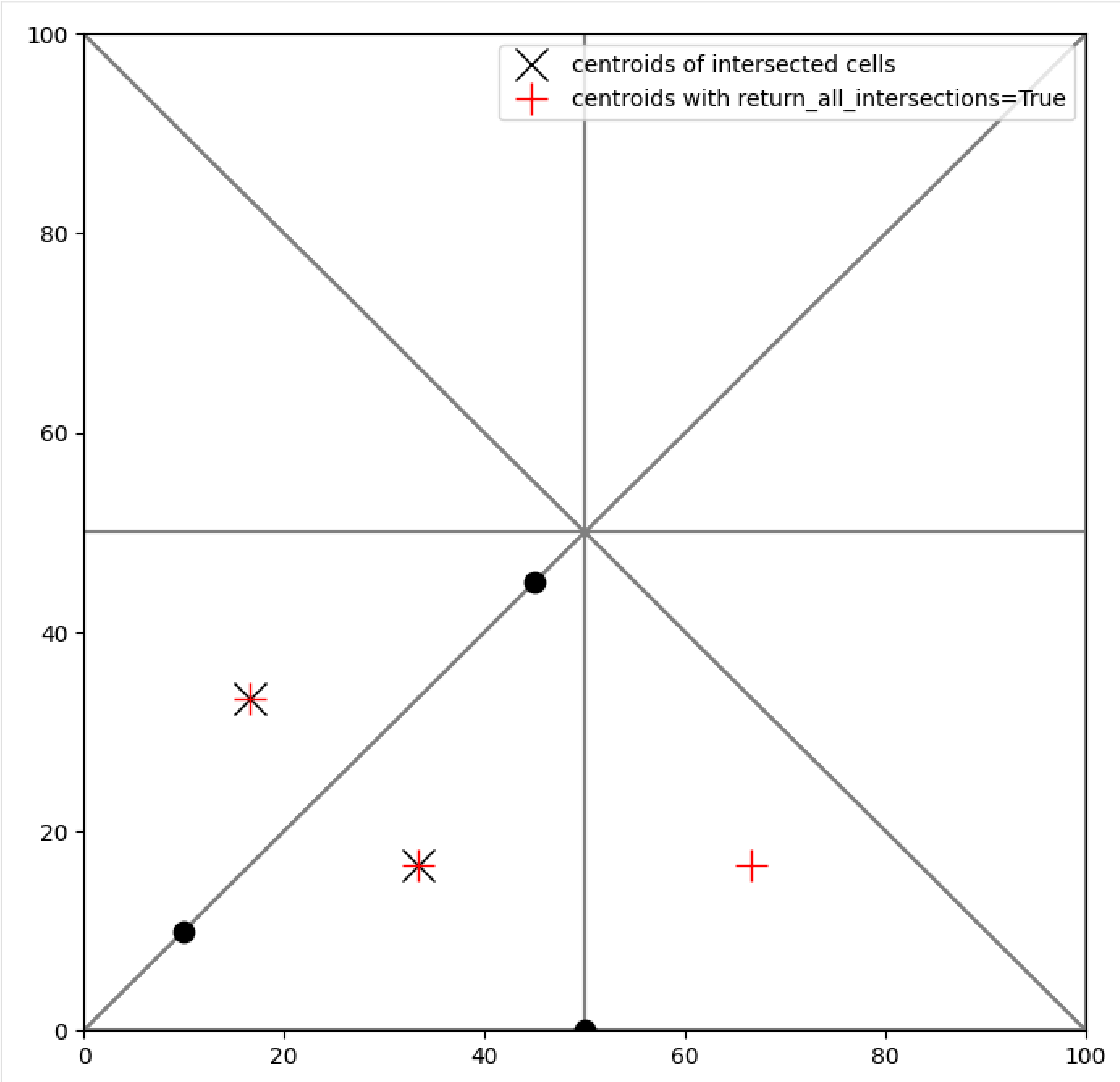
```
        tgr.xcellcenters[cellid],
        tgr.ycellcenters[cellid],
        "kx",
        ms=15,
        label="centroids of intersected cells",
    )
for cellid in result_all.cellids:
    (h3,) = ax.plot(
        tgr.xcellcenters[cellid],
        tgr.ycellcenters[cellid],
        "r+",
        ms=15,
        label="centroids with return_all_intersections=True",
    )

ax.legend([h2, h3], [i.get_label() for i in [h2, h3]], loc="best")
```

[35]:
```
<matplotlib.legend.Legend at 0x7f692cc480a0>
```



6.1.4 Creating Layered Quadtree Grids with GRIDGEN

FloPy has a module that can be used to drive the GRIDGEN program. This notebook shows how it works.

Import Modules and Locate Gridgen Executable

[1]:
```
import os
import shutil
import sys
from tempfile import TemporaryDirectory

import matplotlib as mpl
import matplotlib.pyplot as plt
import numpy as np

# run installed version of flopy or add local path
try:
    import flopy
except:
    fpth = os.path.abspath(os.path.join("..", ".."))
    sys.path.append(fpth)
    import flopy

from flopy.utils import flopy_io
from flopy.utils.gridgen import Gridgen

print(sys.version)
print(f"numpy version: {np.__version__}")
print(f"matplotlib version: {mpl.__version__}")
print(f"flopy version: {flopy.__version__}")
```

```
3.8.18 (default, Aug 28 2023, 08:27:22)
[GCC 11.4.0]
numpy version: 1.24.4
matplotlib version: 3.7.4
flopy version: 3.5.0
```

The Flopy GRIDGEN module requires that the gridgen executable can be called using subprocess **(i.e., gridgen is in your path)**.

[2]:
```
gridgen_exe = flopy.which("gridgen")
if gridgen_exe is None:
    msg = (
        "Warning, gridgen is not in your path. "
        "When you create the griden object you will need to "
        "provide a full path to the gridgen binary executable."
    )
    print(msg)
else:
    print(
        f"gridgen executable was found at: {flopy_io.relpath_safe(gridgen_exe)}"
    )
```

```
gridgen executable was found at: ../../../../../.local/bin/modflow/gridgen
```

[3]:
```
# temporary directory
temp_dir = TemporaryDirectory()
model_ws = temp_dir.name
```

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```
gridgen_ws = os.path.join(model_ws, "gridgen")
if not os.path.exists(gridgen_ws):
    os.makedirs(gridgen_ws, exist_ok=True)
print(f"Model workspace is : {flopy_io.scrub_login(model_ws)}")
print(f"Gridgen workspace is : {flopy_io.scrub_login(gridgen_ws)}")
```

```
Model workspace is : /tmp/tmppwo1ndd9
Gridgen workspace is : /tmp/tmppwo1ndd9/gridgen
```

Basic Gridgen Operations

Setup Base MODFLOW Grid

GRIDGEN works off of a base MODFLOW grid. The following information defines the basegrid.

[4]:
```
Lx = 100.0
Ly = 100.0
nlay = 2
nrow = 51
ncol = 51
delr = Lx / ncol
delc = Ly / nrow
h0 = 10
h1 = 5
top = h0
botm = np.zeros((nlay, nrow, ncol), dtype=np.float32)
botm[1, :, :] = -10.0
```

[5]:
```
ms = flopy.modflow.Modflow(rotation=-20.0)
dis = flopy.modflow.ModflowDis(
    ms,
    nlay=nlay,
    nrow=nrow,
    ncol=ncol,
    delr=delr,
    delc=delc,
    top=top,
    botm=botm,
)
```

Create the Gridgen Object

[6]:
```
g = Gridgen(ms.modelgrid, model_ws=gridgen_ws)
```

Add an Optional Active Domain

Cells outside of the active domain will be clipped and not numbered as part of the final grid. If this step is not performed, then all cells will be included in the final grid.

[7]:
```
# setup the active domain
adshp = os.path.join(gridgen_ws, "ad0")
adpoly = [[[(0, 0), (0, 60), (40, 80), (60, 0), (0, 0)]]]
# g.add_active_domain(adpoly, range(nlay))
```

Refine the Grid

[8]:
```
x = Lx * np.random.random(10)
y = Ly * np.random.random(10)
wells = list(zip(x, y))
g.add_refinement_features(wells, "point", 3, range(nlay))
rf0shp = os.path.join(gridgen_ws, "rf0")
```

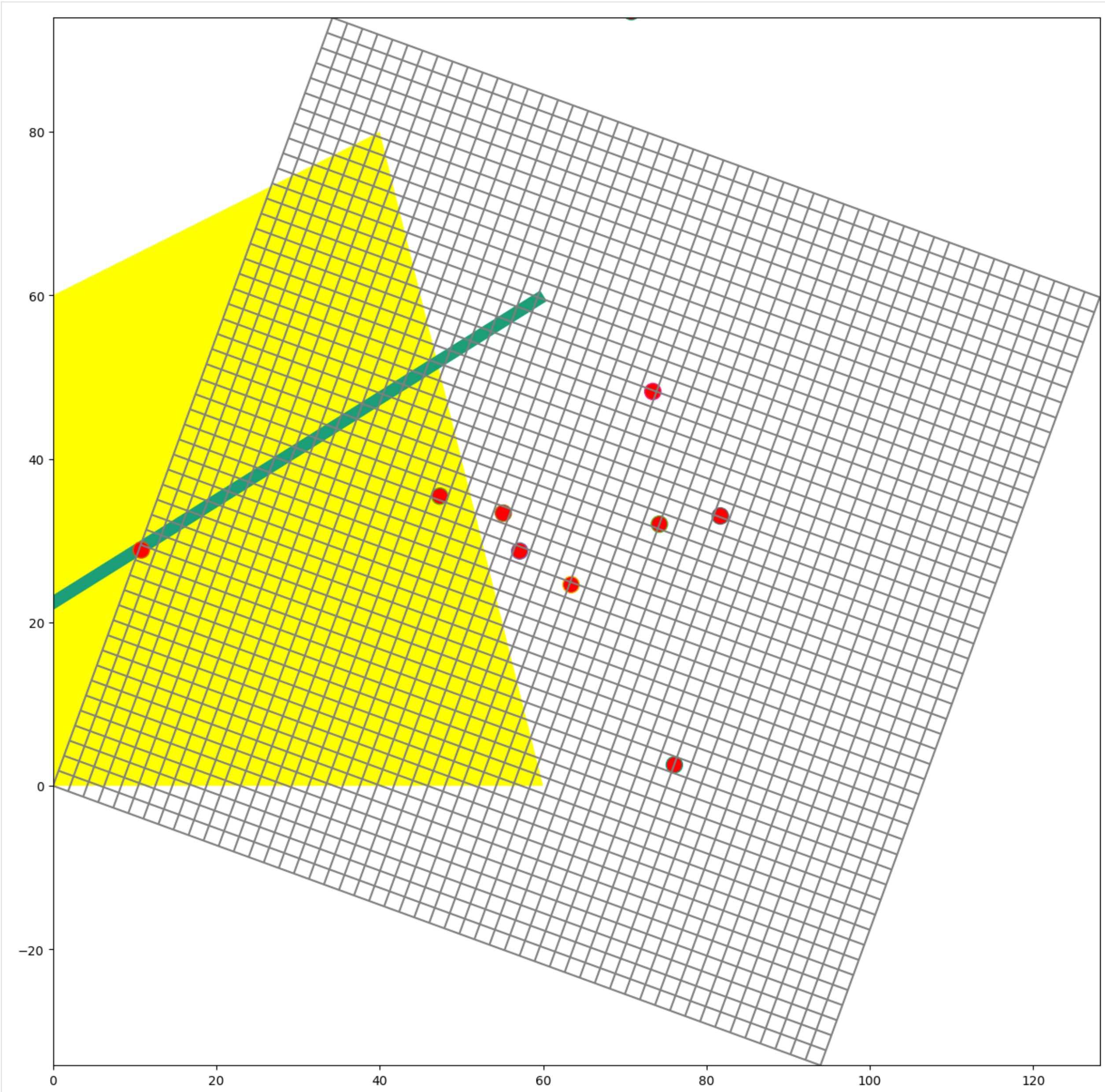
[9]:
```
river = [[(-20, 10), (60, 60)]]
g.add_refinement_features(river, "line", 3, range(nlay))
rf1shp = os.path.join(gridgen_ws, "rf1")
```

[10]:
```
g.add_refinement_features(adpoly, "polygon", 1, range(nlay))
rf2shp = os.path.join(gridgen_ws, "rf2")
```

Plot the Gridgen Input

[11]:
```
fig = plt.figure(figsize=(15, 15))
ax = fig.add_subplot(1, 1, 1, aspect="equal")
mm = flopy.plot.PlotMapView(model=ms)
mm.plot_grid()
flopy.plot.plot_shapefile(rf2shp, ax=ax, facecolor="yellow", edgecolor="none")
flopy.plot.plot_shapefile(rf1shp, ax=ax, linewidth=10)
flopy.plot.plot_shapefile(rf0shp, ax=ax, facecolor="red", radius=1)
```

[11]:
```
<matplotlib.collections.PatchCollection at 0x7f758ed66fd0>
```



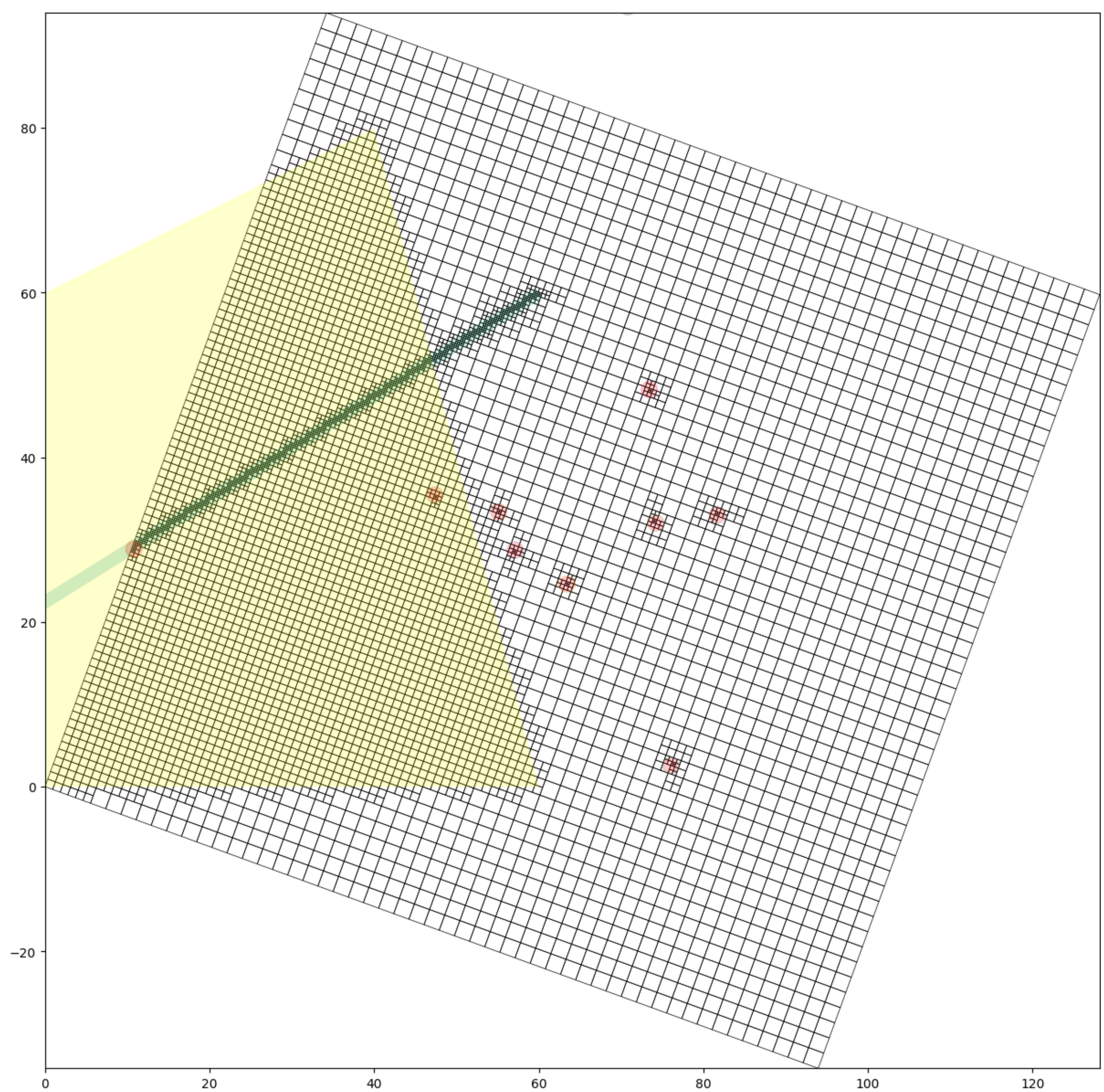
Build the Grid

[12]:
```
g.build(verbose=False)
```

Plot the Grid

[13]:
```
fig = plt.figure(figsize=(15, 15))
ax = fig.add_subplot(1, 1, 1, aspect="equal")
g.plot(ax, linewidth=0.5)
flopy.plot.plot_shapefile(
    rf2shp, ax=ax, facecolor="yellow", edgecolor="none", alpha=0.2
)
flopy.plot.plot_shapefile(rf1shp, ax=ax, linewidth=10, alpha=0.2)
flopy.plot.plot_shapefile(rf0shp, ax=ax, facecolor="red", radius=1, alpha=0.2)
```

[13]:
```
<matplotlib.collections.PatchCollection at 0x7f75833bb880>
```



Create a Flopy ModflowDisu Object

[14]:
```
mu = flopy.mfusg.MfUsg(model_ws=gridgen_ws, modelname="mfusg")
disu = g.get_disu(mu)
disu.write_file()
# print(disu)
```

Intersect Features with the Grid

[15]:
```
adpoly_intersect = g.intersect(adpoly, "polygon", 0)
print(adpoly_intersect.dtype.names)
print(adpoly_intersect)
print(adpoly_intersect.nodenumber)
```

```
('nodenumber', 'polyid', 'totalarea', 'SHAPEID')
[( 322, 0, 0.961169 , 0) ( 382, 0, 0.961169 , 0) ( 325, 0, 0.961169 , 0)
 ... (6042, 0, 0.0977309, 0) (6044, 0, 0.348072 , 0)
 (6045, 0, 0.0428516, 0)]
[ 322  382  325 ... 6042 6044 6045]
```

[16]:
```
well_intersect = g.intersect(wells, "point", 0)
print(well_intersect.dtype.names)
print(well_intersect)
print(well_intersect.nodenumber)
```

```
('nodenumber', 'pointid', 'SHAPEID')
[(4549, 1, 1) (4281, 2, 2) (3091, 3, 3) (1288, 4, 4) (2739, 5, 5)
 (2298, 6, 6) (3280, 7, 7) (2764, 8, 8) (1994, 9, 9)]
[4549 4281 3091 1288 2739 2298 3280 2764 1994]
```

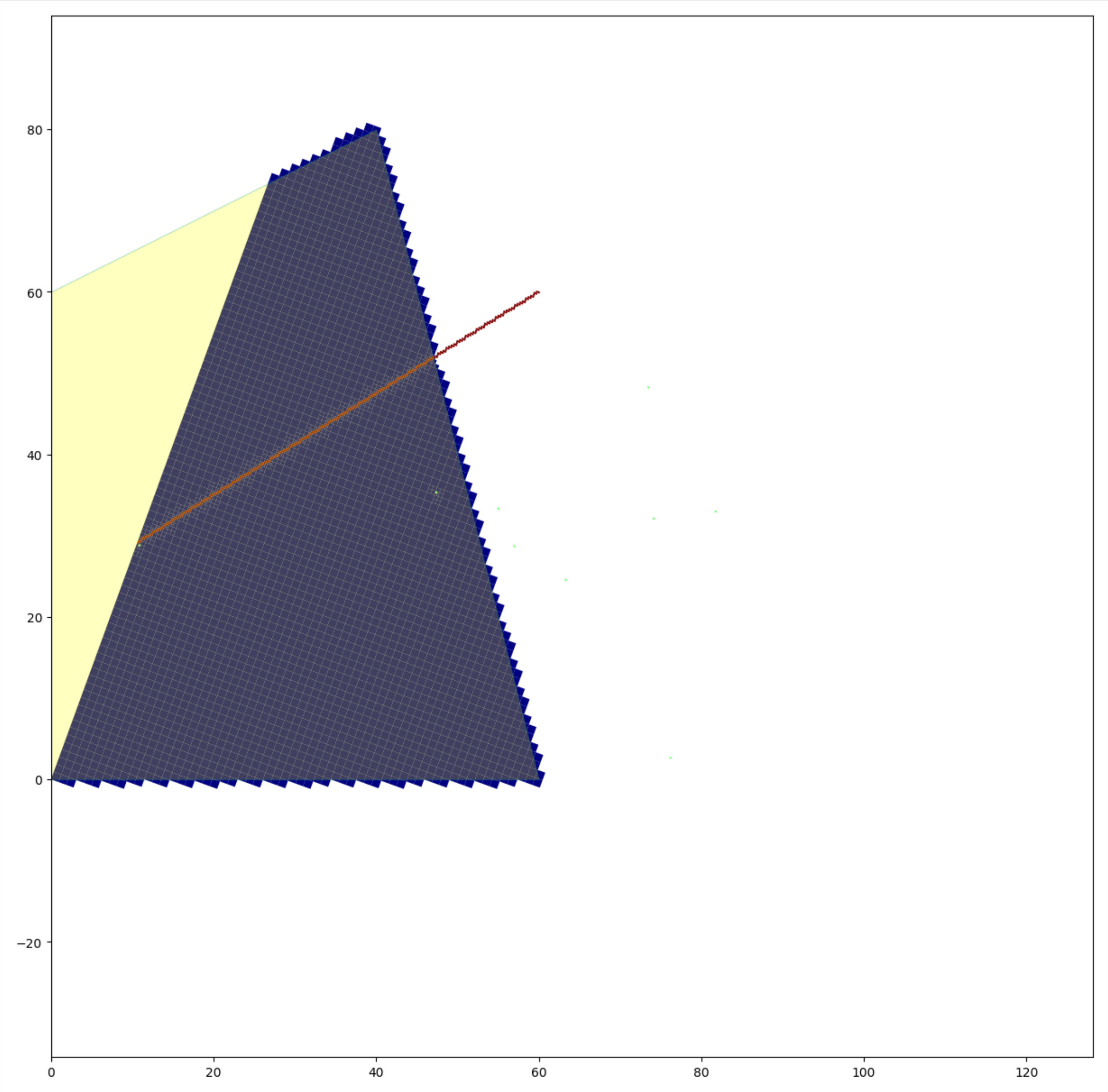
[17]:
```
river_intersect = g.intersect(river, "line", 0)
print(river_intersect.dtype.names)
# print(river_intersect)
# print(river_intersect.nodenumber)
```

```
('nodenumber', 'arcid', 'length', 'starting_distance', 'ending_distance', 'SHAPEID')
```

Plot Intersected Features

[18]:
```
a = np.zeros((g.nodes), dtype=int)
a[adpoly_intersect.nodenumber] = 1
a[well_intersect.nodenumber] = 2
a[river_intersect.nodenumber] = 3
fig = plt.figure(figsize=(15, 15))
ax = fig.add_subplot(1, 1, 1, aspect="equal")
g.plot(ax, a=a, masked_values=[0], edgecolor="none", cmap="jet")
flopy.plot.plot_shapefile(rf2shp, ax=ax, facecolor="yellow", alpha=0.25)
```

[18]:
```
<matplotlib.collections.PatchCollection at 0x7f75973fe430>
```



Use Gridgen to Build MODFLOW 6 DISV Model

In this section, we will reproduce the MODFLOW 6 Quick Start example that is shown on the main page of the flopy repository (https://github.com/modflowpy/flopy).

A main idea for DISV in MODFLOW 6 is that each layer much have the same spatial grid. Gridgen allows the creation of a grid that has a different number of cells within each layer. This type of grid cannot be used with the DISV Package. To make sure that the resulting grid is the same for each layer, refinement should be added to all layers when using the flopy Gridgen wrapper.

[19]:
```
from shapely.geometry import Polygon
```

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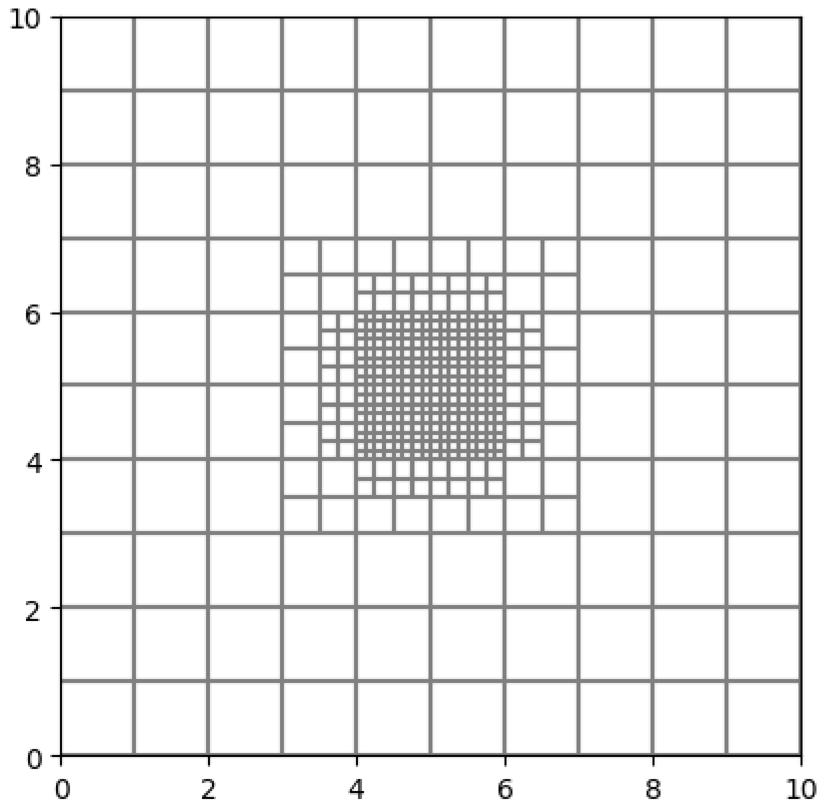
```
name = "dummy"
nlay = 3
nrow = 10
ncol = 10
delr = delc = 1.0
top = 1
bot = 0
dz = (top - bot) / nlay
botm = [top - k * dz for k in range(1, nlay + 1)]

# Create a dummy model and regular grid to use as the base grid for gridgen
sim = flopy.mf6.MFSimulation(sim_name=name, sim_ws=gridgen_ws, exe_name="mf6")
gwf = flopy.mf6.ModflowGwf(sim, modelname=name)

dis = flopy.mf6.ModflowGwfdis(
    gwf,
    nlay=nlay,
    nrow=nrow,
    ncol=ncol,
    delr=delr,
    delc=delc,
    top=top,
    botm=botm,
)

# Create and build the gridgen model with a refined area in the middle
g = Gridgen(gwf.modelgrid, model_ws=gridgen_ws)
polys = [Polygon([(4, 4), (6, 4), (6, 6), (4, 6)])]
g.add_refinement_features(polys, "polygon", 3, range(nlay))
g.build()
```

[20]:

```
# Create and plot a flopy VertexGrid object
# Note that this is not necessary, because it can
# be created automatically after the disv package
# is added to the gwf model (gwf.modelgrid should exist)
gridprops_vg = g.get_gridprops_vertexgrid()
vgrid = flopy.discretization.VertexGrid(**gridprops_vg)
vgrid.plot()
```

[20]:

```
<matplotlib.collections.LineCollection at 0x7f7588a0c670>
```



[21]:
```
# retrieve a dictionary of arguments to be passed
# directly into the flopy disv constructor
disv_gridprops = g.get_gridprops_disv()
disv_gridprops.keys()
```

[21]:
```
dict_keys(['nlay', 'ncpl', 'top', 'botm', 'nvert', 'vertices', 'cell2d'])
```

[22]:
```
# find the cell numbers for constant heads
chdspd = []
ilay = 0
for x, y, head in [(0, 10, 1.0), (10, 0, 0.0)]:
    ra = g.intersect([(x, y)], "point", ilay)
    ic = ra["nodenumber"][0]
    chdspd.append([(ilay, ic), head])
chdspd
```

[22]:
```
[[(0, 0), 1.0], [(0, 435), 0.0]]
```

[23]:
```
# build uun and post-process the MODFLOW 6 model
ws = os.path.join(model_ws, "gridgen_disv")
name = "mymodel"
sim = flopy.mf6.MFSimulation(
    sim_name=name, sim_ws=ws, exe_name="mf6", verbosity_level=0
)
tdis = flopy.mf6.ModflowTdis(sim)
ims = flopy.mf6.ModflowIms(sim, linear_acceleration="bicgstab")
```

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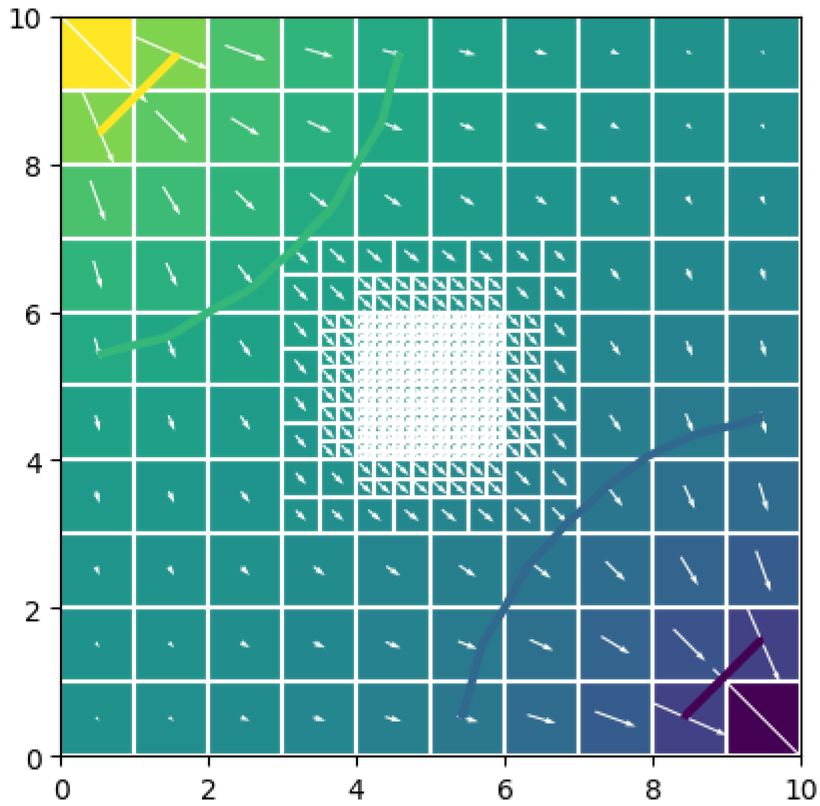
```
gwf = flopy.mf6.ModflowGwf(sim, modelname=name, save_flows=True)
disv = flopy.mf6.ModflowGwfdisv(gwf, **disv_gridprops)
ic = flopy.mf6.ModflowGwfic(gwf)
npf = flopy.mf6.ModflowGwfnpf(
    gwf, xt3doptions=True, save_specific_discharge=True
)
chd = flopy.mf6.ModflowGwfchd(gwf, stress_period_data=chdspd)
budget_file = f"{name}.bud"
head_file = f"{name}.hds"
oc = flopy.mf6.ModflowGwfoc(
    gwf,
    budget_filerecord=budget_file,
    head_filerecord=head_file,
    saverecord=[("HEAD", "ALL"), ("BUDGET", "ALL")],
)
sim.write_simulation()
sim.run_simulation(silent=True)
head = gwf.output.head().get_data()
bud = gwf.output.budget()
spdis = bud.get_data(text="DATA-SPDIS")[0]

pmv = flopy.plot.PlotMapView(gwf)
pmv.plot_array(head)
pmv.plot_grid(colors="white")
pmv.contour_array(head, levels=[0.2, 0.4, 0.6, 0.8], linewidths=3.0)
pmv.plot_vector(spdis["qx"], spdis["qy"], color="white")
```

[23]:

```
<matplotlib.quiver.Quiver at 0x7f75830eaa00>
```



Use Gridgen to Build MODFLOW 6 DISU Model

In this section, we will reproduce the MODFLOW 6 Quick Start example that is shown on the main page of the flopy repository (https://github.com/modflowpy/flopy).

DISU is the most general grid form that can be used with MODFLOW 6. It does not have the requirement that each layer must use the same grid

[24]:
```
from shapely.geometry import Polygon

name = "dummy"
nlay = 3
nrow = 10
ncol = 10
delr = delc = 1.0
top = 1
bot = 0
dz = (top - bot) / nlay
botm = [top - k * dz for k in range(1, nlay + 1)]

# Create a dummy model and regular grid to use as the base grid for gridgen
sim = flopy.mf6.MFSimulation(sim_name=name, sim_ws=gridgen_ws, exe_name="mf6")
gwf = flopy.mf6.ModflowGwf(sim, modelname=name)

dis = flopy.mf6.ModflowGwfdis(
```
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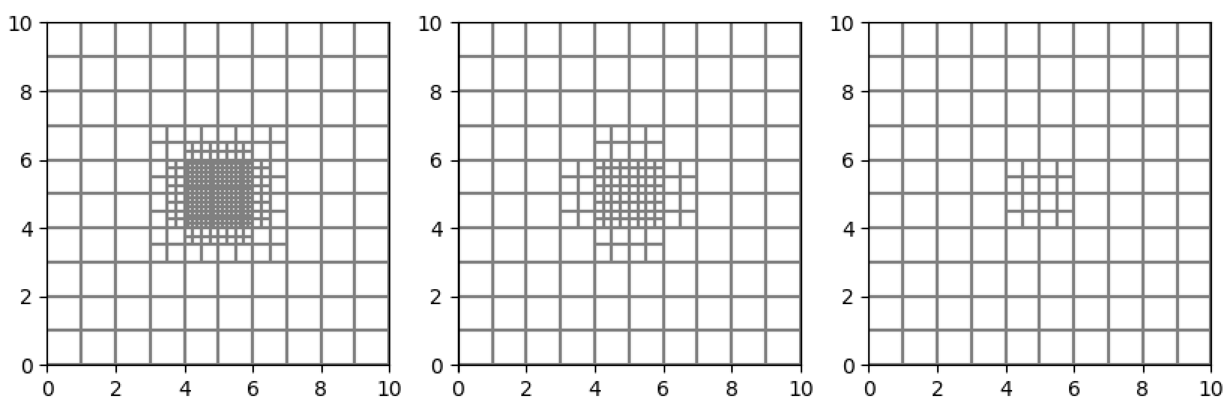
```
    gwf,
    nlay=nlay,
    nrow=nrow,
    ncol=ncol,
    delr=delr,
    delc=delc,
    top=top,
    botm=botm,
)

# Create and build the gridgen model with a refined area in the middle
g = Gridgen(gwf.modelgrid, model_ws=gridgen_ws)
polys = [Polygon([(4, 4), (6, 4), (6, 6), (4, 6)])]
g.add_refinement_features(polys, "polygon", 3, layers=[0])
g.build()
```

[25]:
```
# retrieve a dictionary of arguments to be passed
# directly into the flopy disu constructor
disu_gridprops = g.get_gridprops_disu6()
disu_gridprops.keys()
```

[25]:
```
dict_keys(['nodes', 'top', 'bot', 'area', 'iac', 'nja', 'ja', 'cl12', 'ihc', 'hwva',
↪'angldegx', 'nvert', 'vertices', 'cell2d'])
```

[26]:
```
# Create and plot a flopy UnstructuredGrid object
gridprops_ug = g.get_gridprops_unstructuredgrid()
ugrid = flopy.discretization.UnstructuredGrid(**gridprops_ug)

f = plt.figure(figsize=(10, 10))
for ilay in range(g.nlay):
    ax = plt.subplot(1, g.nlay, ilay + 1)
    ugrid.plot(layer=ilay, ax=ax)
```



[27]:
```
# find the cell numbers for constant heads
chdspd = []
for x, y, head in [(0, 10, 1.0), (10, 0, 0.0)]:
    ra = g.intersect([(x, y)], "point", 0)
    ic = ra["nodenumber"][0]
```

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```
    chdspd.append([(ic,), head])
chdspd
```

[27]:
```
[[(0,), 1.0], [(435,), 0.0]]
```

[28]:
```
# build run and post-process the MODFLOW 6 model
ws = os.path.join(model_ws, "gridgen_disu")
name = "mymodel"
sim = flopy.mf6.MFSimulation(
    sim_name=name, sim_ws=ws, exe_name="mf6", verbosity_level=1
)
tdis = flopy.mf6.ModflowTdis(sim)
ims = flopy.mf6.ModflowIms(sim, linear_acceleration="bicgstab")
gwf = flopy.mf6.ModflowGwf(sim, modelname=name, save_flows=True)
disu = flopy.mf6.ModflowGwfdisu(gwf, **disu_gridprops)
ic = flopy.mf6.ModflowGwfic(gwf)
npf = flopy.mf6.ModflowGwfnpf(
    gwf, xt3doptions=True, save_specific_discharge=True
)
chd = flopy.mf6.ModflowGwfchd(gwf, stress_period_data=chdspd)
budget_file = f"{name}.bud"
head_file = f"{name}.hds"
oc = flopy.mf6.ModflowGwfoc(
    gwf,
    budget_filerecord=budget_file,
    head_filerecord=head_file,
    saverecord=[("HEAD", "ALL"), ("BUDGET", "ALL")],
)
sim.write_simulation()
sim.run_simulation(silent=True)
head = gwf.output.head().get_data()
bud = gwf.output.budget()
spdis = bud.get_data(text="DATA-SPDIS")[0]

gwf.modelgrid.set_coord_info(angrot=15)

f = plt.figure(figsize=(10, 10))
vmin = head.min()
vmax = head.max()
for ilay in range(gwf.modelgrid.nlay):
    ax = plt.subplot(1, g.nlay, ilay + 1)
    pmv = flopy.plot.PlotMapView(gwf, layer=ilay, ax=ax)
    ax.set_aspect("equal")
    pmv.plot_array(head.flatten(), cmap="jet", vmin=vmin, vmax=vmax)
    pmv.plot_grid(colors="k", alpha=0.1)
    pmv.contour_array(
        head, levels=[0.2, 0.4, 0.6, 0.8], linewidths=3.0, vmin=vmin, vmax=vmax
    )
    ax.set_title(f"Layer {ilay + 1}")
    pmv.plot_vector(spdis["qx"], spdis["qy"], color="white")
```

```
WARNING: Unable to resolve dimension of ('gwf6', 'disu', 'cell2d', 'cell2d', 'icvert')␣
↪based on shape "ncvert".
```

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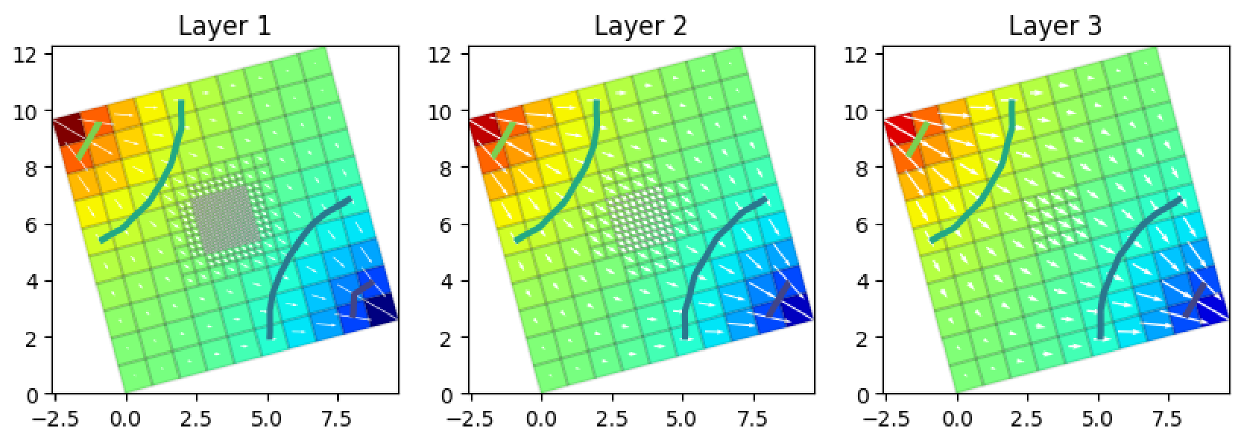
```
writing simulation...
  writing simulation name file...
  writing simulation tdis package...
  writing solution package ims_-1...
  writing model mymodel...
    writing model name file...
    writing package disu...
    writing package ic...
    writing package npf...
    writing package chd_0...
INFORMATION: maxbound in ('gwf6', 'chd', 'dimensions') changed to 2 based on size of
↪stress_period_data
    writing package oc...
```



Use Gridgen to Build MODFLOW-USG DISU Model

In this section, we will reproduce the MODFLOW 6 Quick Start example that is shown on the main page of the flopy repository (https://github.com/modflowpy/flopy).

In this last example, MODFLOW-USG will be used to simulate the problem.

[29]:
```
# build run and post-process the MODFLOW 6 model
ws = os.path.join(model_ws, "gridgen_mfusg")
name = "mymodel"

chdspd = []
for x, y, head in [(0, 10, 1.0), (10, 0, 0.0)]:
    ra = g.intersect([(x, y)], "point", 0)
    ic = ra["nodenumber"][0]
    chdspd.append([ic, head, head])

gridprops = g.get_gridprops_disu5()

# create the mfusg modoel
m = flopy.mfusg.MfUsg(
    modelname=name,
    model_ws=ws,
```

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```
    version="mfusg",
    exe_name="mfusg",
    structured=False,
)
disu = flopy.mfusg.MfUsgDisU(m, **gridprops)
bas = flopy.modflow.ModflowBas(m)
lpf = flopy.mfusg.MfUsgLpf(m)
chd = flopy.modflow.ModflowChd(m, stress_period_data=chdspd)
sms = flopy.mfusg.MfUsgSms(m)
oc = flopy.modflow.ModflowOc(m)
m.write_input()
success, buff = m.run_model(silent=True, report=True)
if success:
    for line in buff:
        print(line)
else:
    raise ValueError("Failed to run.")

# head is returned as a list of head arrays for each layer
head_file = os.path.join(ws, f"{name}.hds")
head = flopy.utils.HeadUFile(head_file).get_data()

# MODFLOW-USG does not have vertices, so we need to create
# and unstructured grid and then assign it to the model. This
# will allow plotting and other features to work properly.
gridprops_ug = g.get_gridprops_unstructuredgrid()
ugrid = flopy.discretization.UnstructuredGrid(**gridprops_ug)
m.modelgrid = ugrid

f = plt.figure(figsize=(10, 10))
vmin = 0.0
vmax = 1.0
for ilay in range(disu.nlay):
    ax = plt.subplot(1, g.nlay, ilay + 1)
    pmv = flopy.plot.PlotMapView(m, layer=ilay, ax=ax)
    ax.set_aspect("equal")
    pmv.plot_array(head[ilay], cmap="jet", vmin=vmin, vmax=vmax)
    pmv.plot_grid(colors="k", alpha=0.1)
    pmv.contour_array(head[ilay], levels=[0.2, 0.4, 0.6, 0.8], linewidths=3.0)
    ax.set_title(f"Layer {ilay + 1}")
```

```
                                  MODFLOW-USG
    U.S. GEOLOGICAL SURVEY MODULAR FINITE-DIFFERENCE GROUNDWATER FLOW MODEL
                             Version 1.5.00 02/27/2019

 Using NAME file: mymodel.nam
 Run start date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:29:02

 Solving:  Stress period:     1    Time step:     1    Groundwater Flow Eqn.
 Run end date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:29:02
 Elapsed run time:  0.003 Seconds
```

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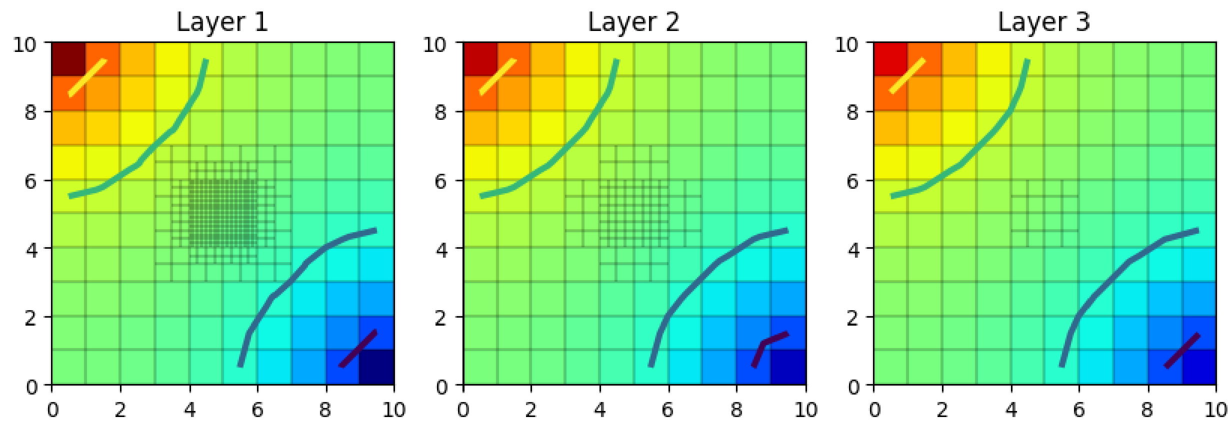
```
Normal termination of simulation
```



[30]:
```
try:
    # ignore PermissionError on Windows
    temp_dir.cleanup()
except:
    pass
```

6.1.5 ModelGrid classes demo

The three modelgrid classes `StructuredGrid`, `VertexGrid`, and `UnstructuredGrid` will be demonstrated in this notebook.

All three classes behave similarly, as they inherit their base functionality from the same "parent" object. Even through they behave similarly, there are also some differences between the three classes based upon the specific grid type.

This notebook will cover:

1) **How to access the modelgrid object from a model and common usages for the modelgrid**
2) **How to build modelgrid objects from scratch**
3) **Useful methods and features**

[1]:
```
import os
import shutil
```

[2]:
```
import sys
from tempfile import TemporaryDirectory

import matplotlib as mpl
import matplotlib.pyplot as plt
import numpy as np

# run installed version of flopy or add local path
```

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```
try:
    import flopy
except:
    fpth = os.path.abspath(os.path.join("..", ".."))
    sys.path.append(fpth)
    import flopy

import flopy.utils.binaryfile as bf
from flopy.discretization import StructuredGrid, UnstructuredGrid, VertexGrid

print(sys.version)
print(f"numpy version: {np.__version__}")
print(f"matplotlib version: {mpl.__version__}")
print(f"flopy version: {flopy.__version__}")
```

```
3.8.18 (default, Aug 28 2023, 08:27:22)
[GCC 11.4.0]
numpy version: 1.24.4
matplotlib version: 3.7.4
flopy version: 3.5.0
```

[3]:
```
# set the names of our modflow executables
# assumes that the executable is in users path statement
mf6_exe = "mf6"
gridgen_exe = "gridgen"
```

[4]:
```
# set paths to each of our model types for this example notebook
spth = os.path.join(
    "..", "..", "examples", "data", "freyberg_multilayer_transient"
)
spth6 = os.path.join("..", "..", "examples", "data", "mf6-freyberg")
vpth = os.path.join("..", "..", "examples", "data")
upth = os.path.join("..", "..", "examples", "data")
u_data_ws = os.path.join("..", "..", "examples", "data", "unstructured")

# temporary workspace
temp_dir = TemporaryDirectory()
gridgen_ws = temp_dir.name
```

Accessing the modelgrid and common usage

How to access the modelgrid object from a model

FloPy model objects have a built in method that dynamically assembles a modelgrid from model discretization information. Therefore, if the user updates their DIS file, when they call the `modelgrid` property the new discretization information will be included within it.

Modflow-2005 example

[5]:
```
# Load a modflow-2005 model
ml = flopy.modflow.Modflow.load("freyberg.nam", model_ws=spth)

# access the modelgrid object
modelgrid = ml.modelgrid

print(type(modelgrid))
```

```
<class 'flopy.discretization.structuredgrid.StructuredGrid'>
```

Spaitial refernce information that is stored in the NAM file, such as:

`xll` : geographic location of lower left model corner x-coordinate `yll` : geographic location of lower left model corner y-coordinate `rotation` : modelgrid rotation in degrees `epsg` : epsg code of modelgrid coordinate system `proj4_str` : proj4 projection information

can be automatcally read in and applied to the modelgrid. FloPy will also write this information out when the user saves their model to file.

This information can be seen by printing the modelgrid

[6]:
```
print(modelgrid)
```

```
xll:622241.1904510253; yll:3343617.741737109; rotation:15.0; crs:EPSG:32614; units:
↪meters; lenuni:2
```

Modflow-6 example

Modflow-6 models also have modelgrid objects attached to them. These grids function in the way. Here is an example.

[7]:
```
# load a modflow-6 simulation
sim = flopy.mf6.MFSimulation.load(sim_ws=spth6, verbosity_level=0)

# get a model object from the simulation
ml = sim.get_model("freyberg")

# access the modelgrid
modelgrid1 = ml.modelgrid

print(type(modelgrid1))
print(modelgrid1)
```

```
<class 'flopy.discretization.structuredgrid.StructuredGrid'>
xll:0.0; yll:0.0; rotation:0.0; units:meters; lenuni:2
```

Note how there is no spatial reference information associated with this modelgrid. This is because, there it was not specified in the name file. In the following section, the notebook will show how to access this information from a modelgrid and how to set this information in a modelgrid object.

Accessing and setting modelgrid reference information

Accessing modelgrid reference information

There are properties attached to the modelgrid that allows the user to access reference information:

- `xoffset` : returns the x-coordinate for the modelgrid's lower left corner
- `yoffset` : returns the y-coordinate for the modelgrid's lower left corner
- `angrot` : returns the rotation of the modelgrid in degrees
- `epsg` : returns the modelgrid epsg code
- `proj4` : returns the modelgrid proj4_str information

[8]:
```python
xoff = modelgrid.xoffset
yoff = modelgrid.yoffset
angrot = modelgrid.angrot
epsg = modelgrid.epsg
proj4 = modelgrid.proj4

print(
    f"xoff: {xoff}\nyoff: {yoff}\nangrot: {angrot}\nepsg: {epsg}\nproj4: {proj4}"
)
```

```
xoff: 622241.1904510253
yoff: 3343617.741737109
angrot: 15.0
epsg: 32614
proj4: +proj=utm +zone=14 +datum=WGS84 +units=m +no_defs +type=crs
```

```
/opt/hostedtoolcache/Python/3.8.18/x64/lib/python3.8/site-packages/pyproj/crs/crs.py:
↪1286: UserWarning: You will likely lose important projection information when␣
↪converting to a PROJ string from another format. See: https://proj.org/faq.html#what-
↪is-the-best-format-for-describing-coordinate-reference-systems
  proj = self._crs.to_proj4(version=version)
```

Setting modelgrid reference information

The `set_coord_info()` method allows the user to set some or all of the modelgrid's coordinate reference information. Here is an example using the modflow6 modelgrid:

[9]:
```python
# show the coordinate info before setting it
print(f"Before: {modelgrid1}\n")

# set reference infromation
modelgrid1.set_coord_info(xoff=xoff, yoff=yoff, angrot=angrot, crs=epsg)

print(f"After: {modelgrid1}")
```

```
Before: xll:0.0; yll:0.0; rotation:0.0; units:meters; lenuni:2

After: xll:622241.1904510253; yll:3343617.741737109; rotation:15.0; crs:EPSG:32614;␣
↪units:meters; lenuni:2
```

The user can also set individual parts of the coordinate information if they do not want to supply all of the fields

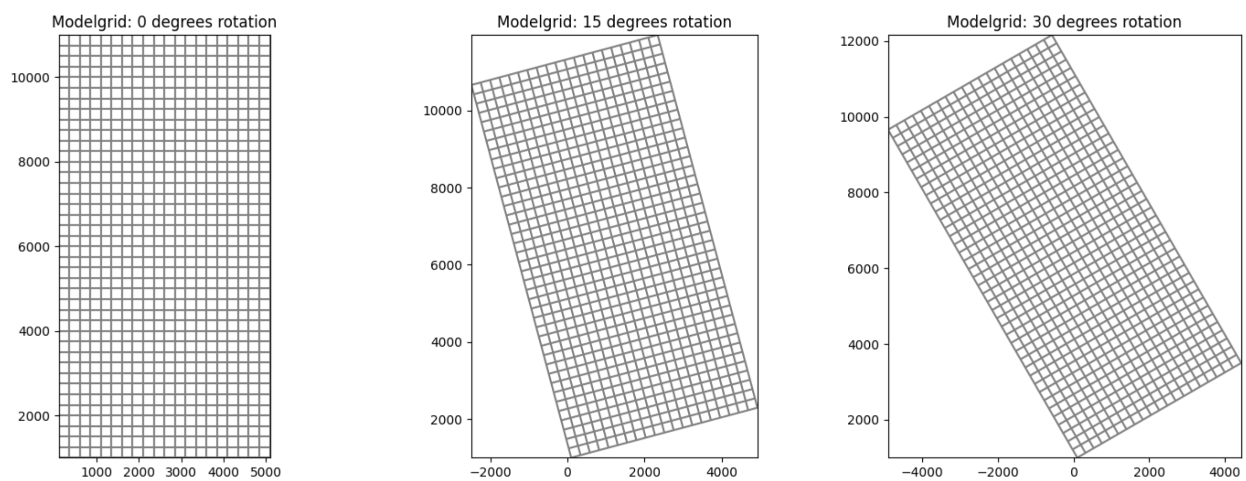
[10]:
```python
# change the offsets and rotation of the modelgrid
angrot = 55
xll = 100
yll = 1000
modelgrid1.set_coord_info(xoff=xll, yoff=yll, angrot=angrot)

print(modelgrid1)
```

```
xll:100; yll:1000; rotation:55; crs:EPSG:32614; units:meters; lenuni:2
```

Using the modelgrid with plotting routines

FloPy's plotting routines accept a model or modelgrid object to determine cell locations for plotting. Here is an example of plotting with the modelgrid object

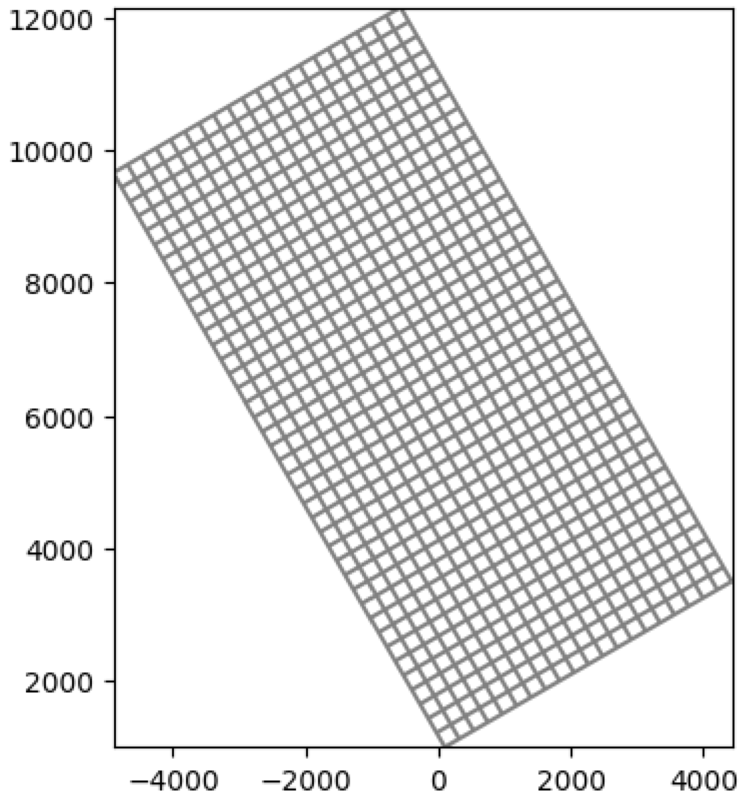
[11]:
```python
fig, axs = plt.subplots(
    nrows=1, ncols=3, figsize=(18, 6), subplot_kw={"aspect": "equal"}
)

rotation = [0, 15, 30]

for ix, ax in enumerate(axs):
    modelgrid1.set_coord_info(angrot=rotation[ix])
    pmv = flopy.plot.PlotMapView(modelgrid=modelgrid1, ax=ax)
    pmv.plot_grid()
    ax.set_title(f"Modelgrid: {rotation[ix]} degrees rotation")
```



The grid lines can also be plotted directly from the modelgrid object

[12]:
```
modelgrid1.plot()
```

[12]:
```
<matplotlib.collections.LineCollection at 0x7fb0ddf14580>
```



Building modelgrid objects from scratch

`StructuredGrid` example

The `StructuredGrid` class can accept a number of parameters, however for a minimal working `StructuredGrid` the user only needs to provide:

- `delc` : Array of cell widths along columns
- `delr` : Array of cell widths along rows

Other optional, but useful parameters the user can supply include: - `top` : Array of model Top elevations - `botm` : Array of layer Botm elevations - `idomain` : An ibound or idomain array that specifies active and inactive cells - `lenuni` : Model length unit integer - `crs` : either an epsg integer code of model coordinate system, a proj4 string or pyproj CRS instance - `prjfile` : path to ".prj" projection file that describes the model coordinate system - `xoff` : x-coordinate of the lower-left corner of the modelgrid - `yoff` : y-coordinate of the lower-left corner of the modelgrid - `angrot` : model grid rotation - `nlay` : number of model layers - `nrow` : number of model rows - `ncol` : number of model columns - `laycbd` : array of length, nlay indicating if Quasi-3D confining layers exist

In this example, some of the more common parameters are used to create a ``StructuredGrid``

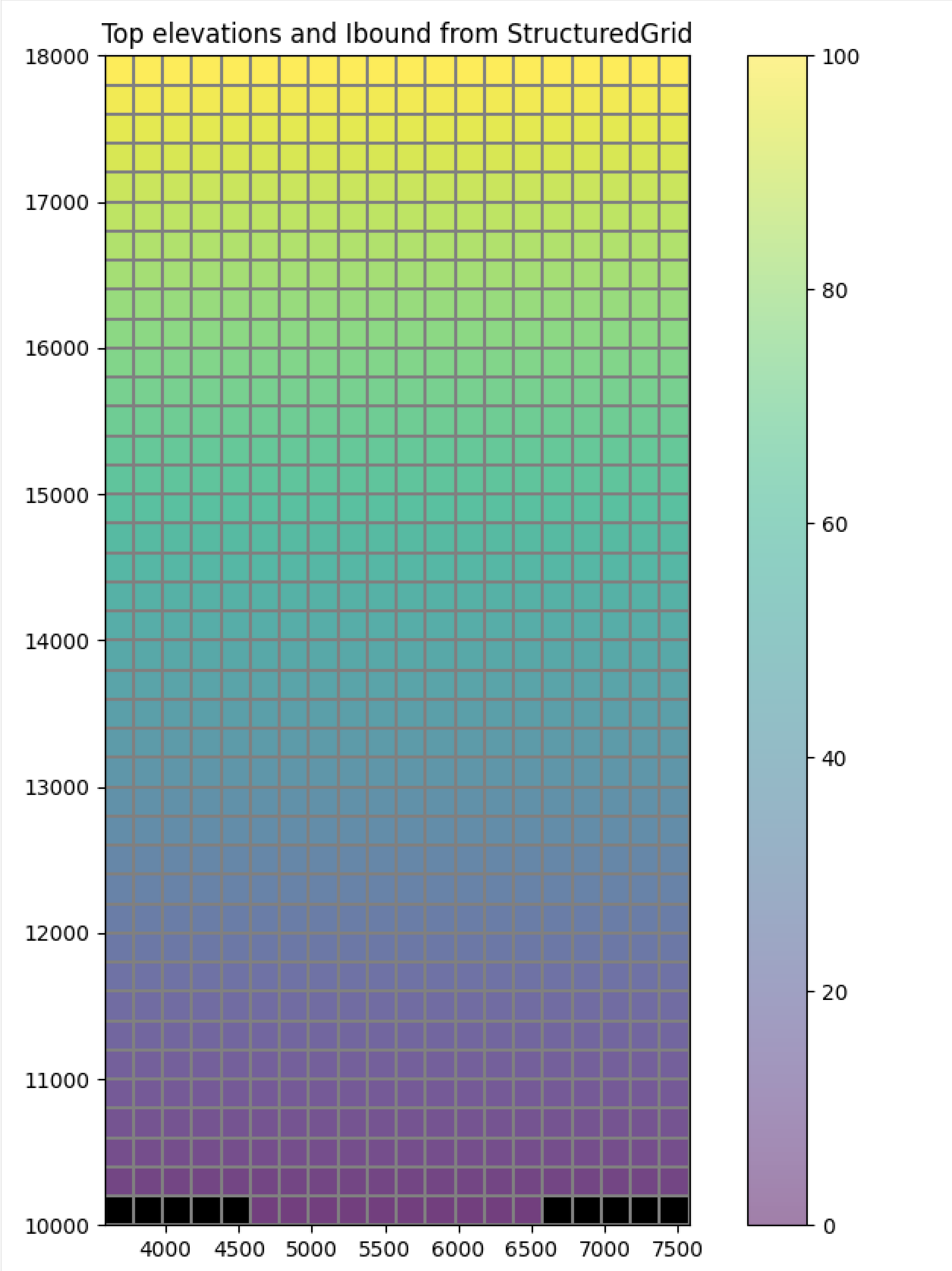
[13]:
```
xll = 3579
yll = 10000
rotation = 0

nrow = 40
ncol = 20
nlay = 1
Lx = 4000
Ly = 8000

# create delr and delc arrays
delr = np.ones((ncol,)) * (Lx / ncol)
delc = np.ones((nrow,)) * (Ly / nrow)

# create a sloped top and bottom
slope = np.linspace(100, 0, nrow)
slope.shape = (1, nrow)

top = np.ones((nrow, ncol)) * slope.T
botm = np.ones((nlay, nrow, ncol)) * (top - 100)

# create an ibound array
ibound = np.ones((nrow, ncol), dtype=int)
ibound[-1, 0:5] = 0
ibound[-1, 15:] = 0


modelgrid = StructuredGrid(
    delr=delr,
    delc=delc,
    top=top,
    botm=botm,
    idomain=ibound,
    nlay=nlay,
    xoff=xll,
    yoff=yll,
    angrot=rotation,
)
modelgrid
```

[13]:
```
xll:3579; yll:10000; rotation:0; units:undefined; lenuni:0
```

Plot some of the modelgrid information

[14]:
```
fig, ax = plt.subplots(figsize=(10, 10))

pmv = flopy.plot.PlotMapView(modelgrid=modelgrid)
pc = pmv.plot_array(modelgrid.top, alpha=0.5)
pmv.plot_grid()
pmv.plot_ibound()

plt.colorbar(pc)
ax.set_title("Top elevations and Ibound from StructuredGrid")
```

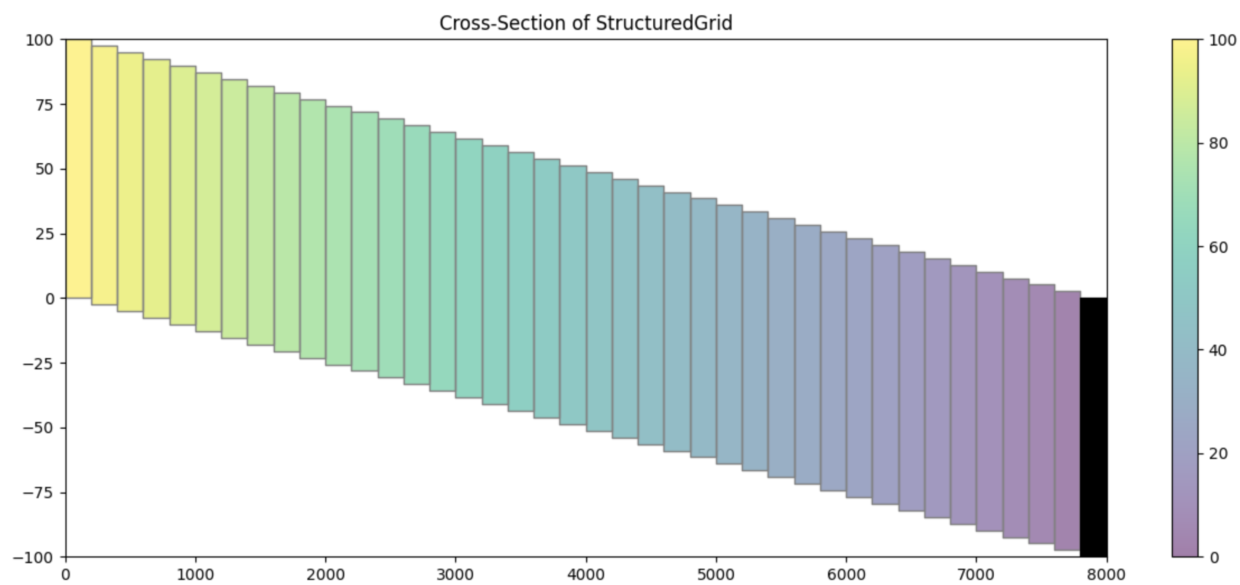
[14]:
```
Text(0.5, 1.0, 'Top elevations and Ibound from StructuredGrid')
```


Top elevations and Ibound from StructuredGrid
18000
17000
16000
15000
14000
13000
12000
11000
10000
4000
4500
5000
5500
6000
6500
7000
7500
100
80
60
40
20
0

Plot a CrossSection of the structured grid

[15]:
```
col = 4

figure, ax = plt.subplots(figsize=(15, 6))

xc = flopy.plot.PlotCrossSection(modelgrid=modelgrid, line={"column": col})
pc = xc.plot_array(modelgrid.top, alpha=0.5)
xc.plot_grid()
xc.plot_ibound()

plt.colorbar(pc)
plt.title("Cross-Section of StructuredGrid")
```

[15]:
```
Text(0.5, 1.0, 'Cross-Section of StructuredGrid')
```



`VertexGrid` example

Before building the `VertexGrid` class we must first develop a grid. This example uses the `Gridgen` class and executable to produce the same grid as the MODFLOW 6 Quick Start example that is shown on the main page of the flopy repository (https://github.com/modflowpy/flopy).

NOTE: The `Gridgen` class requires that either a path to the executable is provided, that the executable exists in the same directory as the script, or that the executable is in the machine's PATH variables to run properly.

[16]:
```
from flopy.utils.geometry import Polygon
```

[17]:
```
from flopy.utils.gridgen import Gridgen

name = "dummy"
nlay = 3
nrow = 10
ncol = 10
```

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```
delr = delc = 1.0
top = 1
bot = 0
dz = (top - bot) / nlay
botm = [top - k * dz for k in range(1, nlay + 1)]

# Create a dummy model and regular grid to use as the base grid for gridgen
sim = flopy.mf6.MFSimulation(sim_name=name, sim_ws=gridgen_ws, exe_name="mf6")
gwf = flopy.mf6.ModflowGwf(sim, modelname=name)

dis = flopy.mf6.ModflowGwfdis(
    gwf,
    nlay=nlay,
    nrow=nrow,
    ncol=ncol,
    delr=delr,
    delc=delc,
    top=top,
    botm=botm,
)

# Create and build the gridgen model with a refined area in the middle
g = Gridgen(gwf.modelgrid, model_ws=gridgen_ws)
polys = [Polygon([(4, 4), (6, 4), (6, 6), (4, 6), (4, 4)])]
g.add_refinement_features(polys, "polygon", 3, range(nlay))
g.build()
```

[18]:
```
# get the vertex grid properties from gridgen and examine them
gridprops = g.get_gridprops_vertexgrid()
gridprops.keys()
```

[18]:
```
dict_keys(['nlay', 'ncpl', 'top', 'botm', 'vertices', 'cell2d'])
```

Building the `VertexGrid`

`VertexGrid` has many similar parameters as the previous `StructuredGrid` example. For a minimal working modelgrid, `VertexGrid` requires:

- `vertices` : list of vertex number, xvertex, yvertex that make up the grid
- `cell2d` : list containing node number, xcenter, ycenter, and vertex numbers (from vertices)

Other optional, but useful parameters include:

- `top` : Array of model Top elevations
- `botm` : Array of layer Botm elevations
- `idomain` : An ibound or idomain array that specifies active and inactive cells
- `lenuni` : Model length unit integer
- `crs` : either an epsg integer code of model coordinate system, a proj4 string or pyproj CRS instance
- `prjfile` : path to ".prj" projection file that describes the model coordinate system

- `xoff` : x-coordinate of the lower-left corner of the modelgrid
- `yoff` : y-coordinate of the lower-left corner of the modelgrid
- `angrot` : model grid rotation
- `nlay` : number of model layers
- `ncpl` : number of cells per model layer

In this example, some of the more common parameters are used to create a ``VertexGrid``

[19]:
```python
vertices = gridprops["vertices"]
cell2d = gridprops["cell2d"]
top = gridprops["top"]
botm = gridprops["botm"]
nlay = gridprops["nlay"]
ncpl = gridprops["ncpl"]
idomain = np.ones((nlay, ncpl), dtype=int)

modelgrid = VertexGrid(
    vertices=vertices,
    cell2d=cell2d,
    top=top,
    idomain=idomain,
    botm=botm,
    nlay=nlay,
    ncpl=ncpl,
)
print(modelgrid)
```

```
xll:0.0; yll:0.0; rotation:0.0; units:undefined; lenuni:0
```

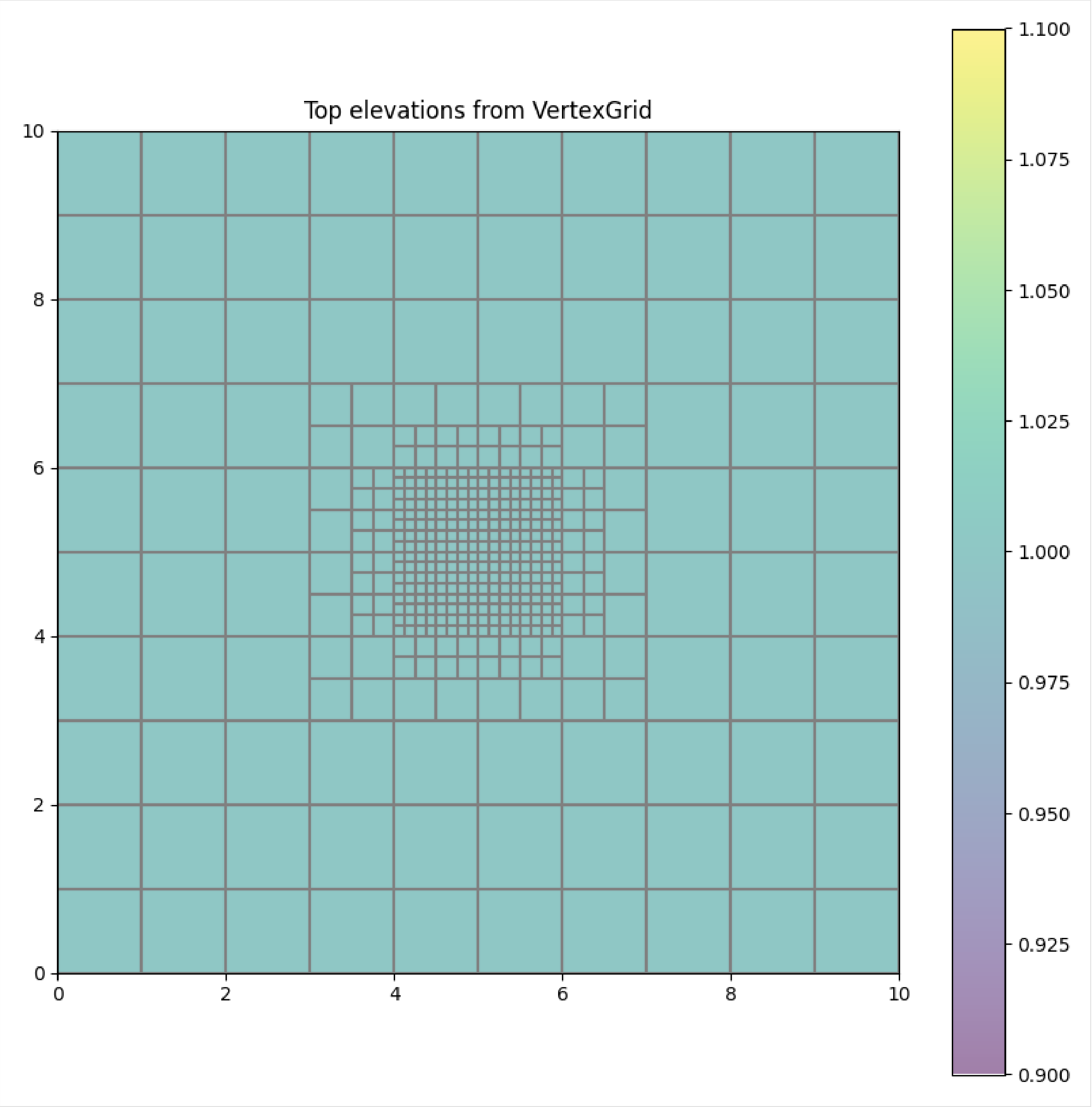
Plot some of the modelgrid information

[20]:
```python
fig, ax = plt.subplots(figsize=(10, 10))

pmv = flopy.plot.PlotMapView(modelgrid=modelgrid)
pc = pmv.plot_array(modelgrid.top, alpha=0.5)
pmv.plot_grid()
pmv.plot_ibound()

plt.colorbar(pc)
ax.set_title("Top elevations from VertexGrid")
```

[20]:
```
Text(0.5, 1.0, 'Top elevations from VertexGrid')
```



Plot a CrossSection of the vertex grid

[21]:
```
line = [(4.45, 0), (4.45, 10)]

figure, ax = plt.subplots(figsize=(15, 6))

xc = flopy.plot.PlotCrossSection(modelgrid=modelgrid, line={"line": line})
pc = xc.plot_array(modelgrid.botm, alpha=0.5)
xc.plot_grid()
xc.plot_ibound()
```

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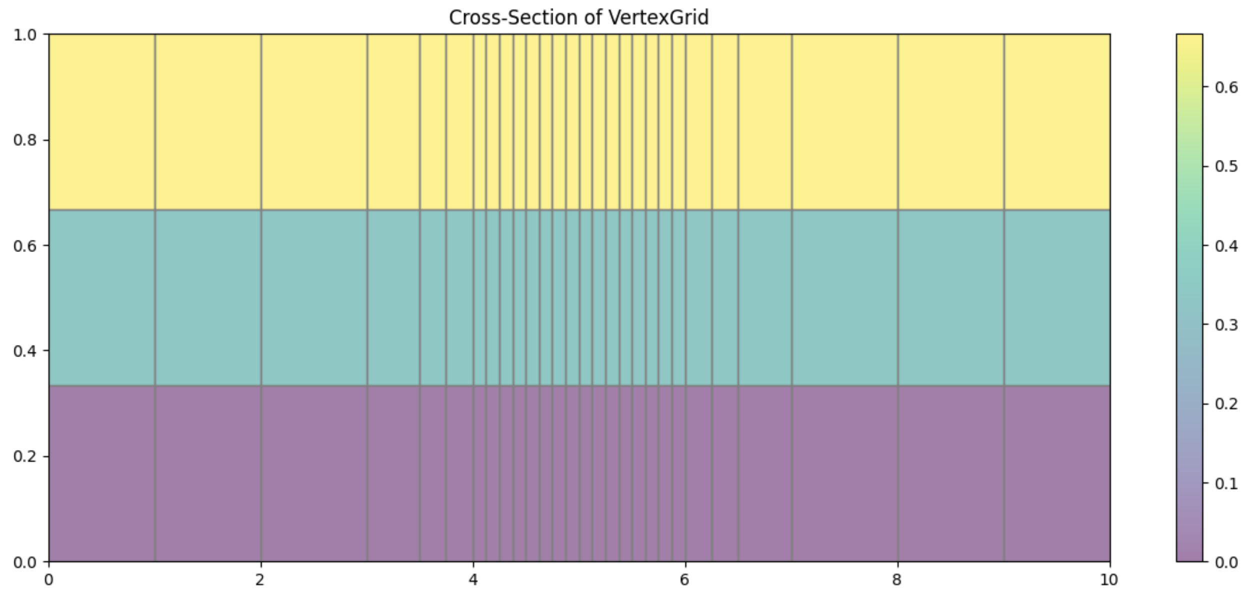
```
plt.colorbar(pc)
plt.title("Cross-Section of VertexGrid")
```

[21]: Text(0.5, 1.0, 'Cross-Section of VertexGrid')



UnstructuredGrid example

Before building an `UnstructuredGrid` we must first develop a grid. This example loads saved grid information from data files to create an `UnstructuredGrid`.

Note: `Gridgen` can also be used to develop an unstructured grid and examples of how to do this can be found in the notebook flopy3_gridgen.ipynb

[22]:
```
# simple functions to load vertices and indice lists
def load_verts(fname):
    verts = np.genfromtxt(
        fname, dtype=[int, float, float], names=["iv", "x", "y"]
    )
    verts["iv"] -= 1  # zero based
    return verts


def load_iverts(fname):
    f = open(fname)
    iverts = []
    xc = []
    yc = []
    for line in f:
        ll = line.strip().split()
        iverts.append([int(i) - 1 for i in ll[4:]])
        xc.append(float(ll[1]))
```

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```
        yc.append(float(ll[2]))
    return iverts, np.array(xc), np.array(yc)
```

Building the `UnstructuredGrid`

`UnstructuredGrid` has many similar parameters as the previous `VertexGrid` example. For a minimal working, but "incomplete" modelgrid, `UnstructuredGrid` requires:

- `vertices` : list of vertex number, xvertex, yvertex that make up the grid
- `iverts` : list of vertex numbers that make up each cell
- `xcenters` : list of x center coordinates for all cells in the grid if the grid varies by layer or for all cells in a layer if the same grid is used for all layers
- `ycenters` : list of y center coordinates for all cells in the grid if the grid varies by layer or for all cells in a layer if the same grid is used for all layers

For a "complete" `UnstructuredGrid` these parameters must be provided in addition to the ones listed above:

- `top` : Array of model Top elevations
- `botm` : Array of layer Botm elevations

Other optional, but useful parameters include:

- `idomain` : An ibound or idomain array that specifies active and inactive cells
- `lenuni` : Model length unit integer
- `ncpl` : one dimensional array of number of cells per model layer
- `crs` : either an epsg integer code of model coordinate system, a proj4 string or pyproj CRS instance
- `prjfile` : path to ".prj" projection file that describes the model coordinate system
- `xoff` : x-coordinate of the lower-left corner of the modelgrid
- `yoff` : y-coordinate of the lower-left corner of the modelgrid
- `angrot` : model grid rotation

In this example, some of the more common parameters are used to create a ``UnstructuredGrid``

[23]:
```
# load vertices
fname = os.path.join(u_data_ws, "ugrid_verts.dat")
verts = load_verts(fname)

# load the index list into iverts, xc, and yc
fname = os.path.join(u_data_ws, "ugrid_iverts.dat")
iverts, xc, yc = load_iverts(fname)

# create a 3 layer model grid
ncpl = np.array(3 * [len(iverts)])
nnodes = np.sum(ncpl)

top = np.ones(nnodes)
```

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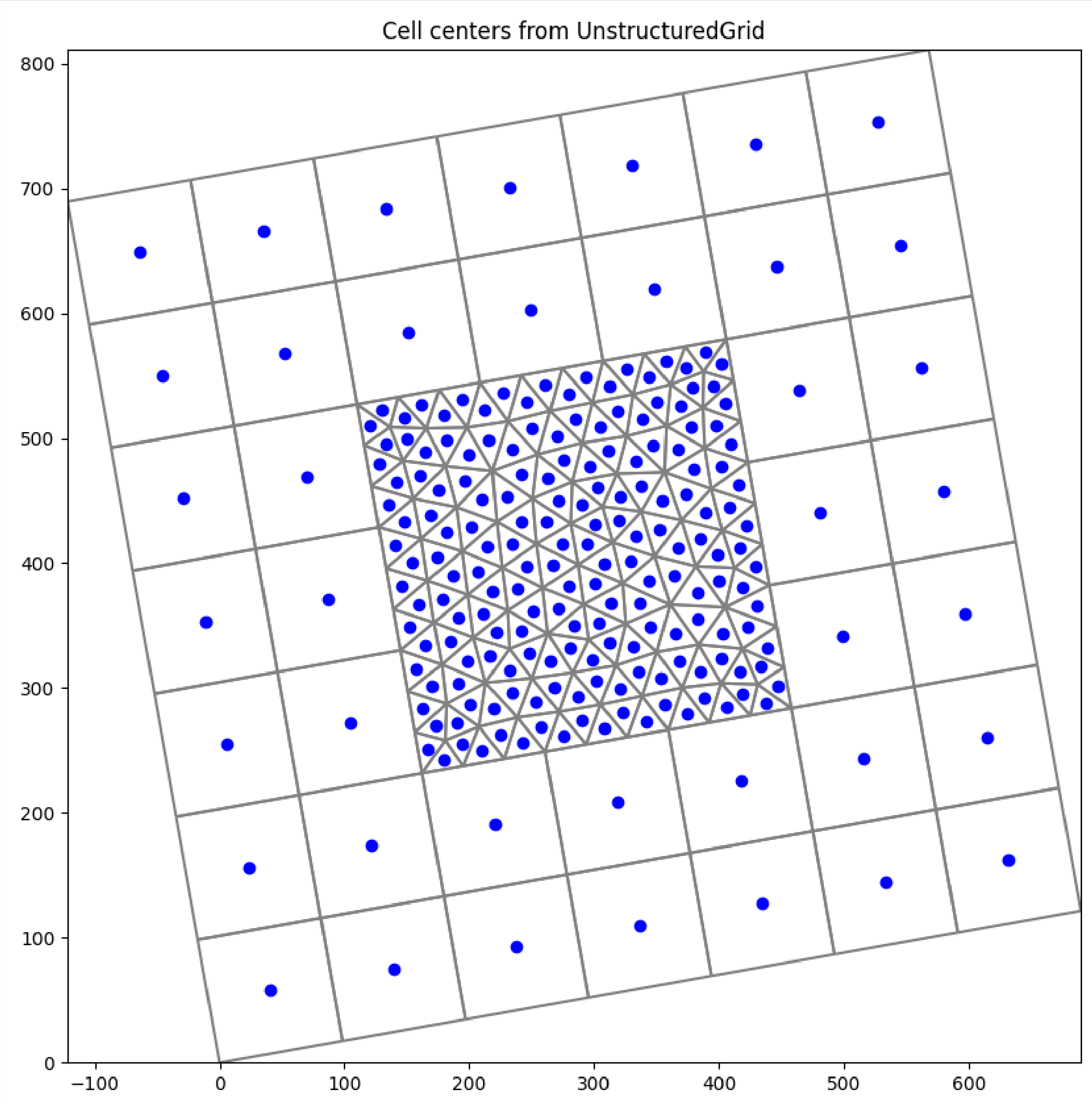
```
botm = np.ones(nnodes)

# set top and botm elevations
i0 = 0
i1 = ncpl[0]
elevs = [100, 0, -100, -200]
for ix, cpl in enumerate(ncpl):
    top[i0:i1] *= elevs[ix]
    botm[i0:i1] *= elevs[ix + 1]
    i0 += cpl
    i1 += cpl

# create the modelgrid
modelgrid = UnstructuredGrid(
    vertices=verts,
    iverts=iverts,
    xcenters=xc,
    ycenters=yc,
    top=top,
    botm=botm,
    ncpl=ncpl,
)
```

Plot some of the modelgrid information

[24]:
```
# rotate the modelgrid for the fun of it
modelgrid.set_coord_info(angrot=10)

fig, ax = plt.subplots(figsize=(10, 10))

pmv = flopy.plot.PlotMapView(modelgrid=modelgrid)
pmv.plot_grid()

# plot cell centers
plt.plot(modelgrid.xcellcenters, modelgrid.ycellcenters, "bo")

ax.set_title("Cell centers from UnstructuredGrid")
```

[24]:
```
Text(0.5, 1.0, 'Cell centers from UnstructuredGrid')
```



Plot a CrossSection of the unstructured grid

[25]:
```
line = [(350, 0), (300, 800)]

figure, ax = plt.subplots(figsize=(15, 6))

# note geographic_coords=True should be set for unstructured grid cross-sections
xc = flopy.plot.PlotCrossSection(
    modelgrid=modelgrid, line={"line": line}, geographic_coords=True
)
```

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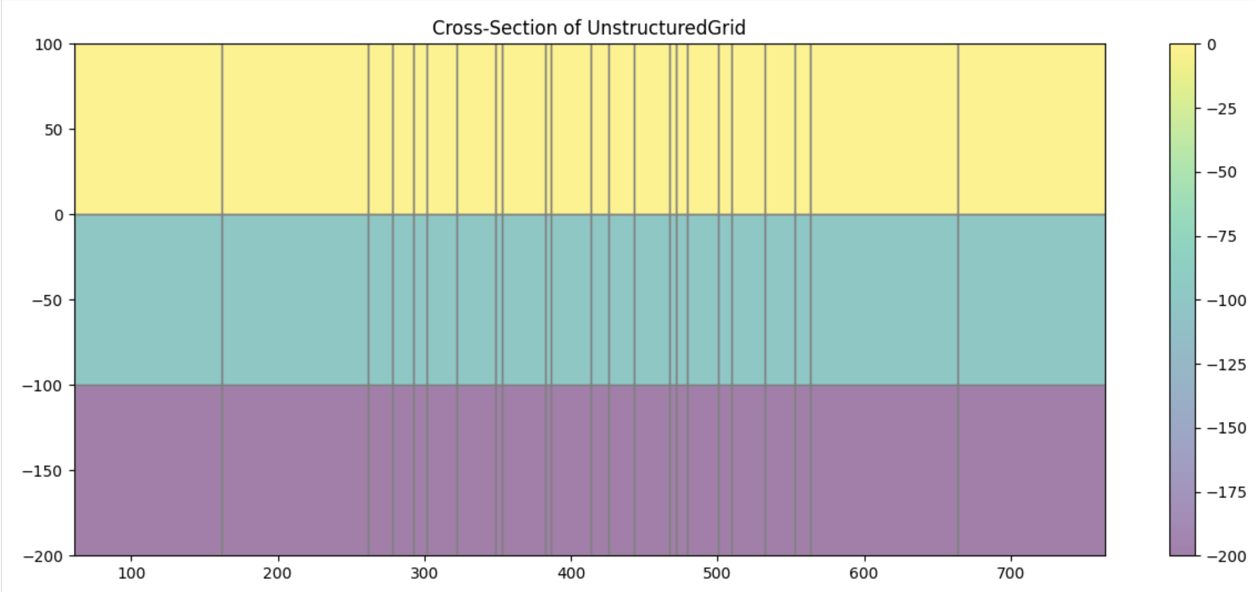
```
pc = xc.plot_array(modelgrid.botm, alpha=0.5)
xc.plot_grid()

plt.colorbar(pc)
plt.title("Cross-Section of UnstructuredGrid")
```

[25]:
```
Text(0.5, 1.0, 'Cross-Section of UnstructuredGrid')
```



Useful methods and properties of the modelgrid classes

Many of the useful methods and features of the modelgrid classes will be presented in this section of the Notebook. The modelgrid classes have a large number of common properties and methods that we will explore. Let's first load a model and look at all of the common features.

[26]:
```
# load a modflow-6 freyberg simulation
sim = flopy.mf6.MFSimulation.load(
    sim_ws=spth6, verbosity_level=0, exe_name=mf6_exe
)

# get a model object from the simulation
ml = sim.get_model("freyberg")

# access the modelgrid
modelgrid = ml.modelgrid

# and set the coordinate info
modelgrid.set_coord_info(
    xoff=622241.1904510253,
    yoff=3343617.741737109,
    angrot=15.0,
    crs="+proj=utm +zone=14 +ellps=WGS84 +datum=WGS84 +units=m +no_defs",
)
```

Common properties

There are many common (shared) properties that are present in `StructuredGrid`, `VertexGrid`, and `UnstructuredGrid`:

Grid info properties

- `is_valid` : returns True if modelgrid is valid
- `is_complete` : returns True if modelgrid has all basic information and `top`, `botm`, and `idomain` have been set
- `grid_type` : returns a string representation of the grid type ("structured", "vertex", or "unstructured")
- `units` : returns a string representation of model units
- `lenuni` : returns an integer representation of model units
- `extent` : returns the modelgrid extent as (xmin, xmax, ymin, ymax)

[27]:
```
# print grid info properties
if modelgrid.is_valid and modelgrid.is_complete:
    print(f"{modelgrid.grid_type} modelgrid is valid and complete\n")

print(f"lenuni: {modelgrid.lenuni}, units: {modelgrid.units}\n")

print(
    "lower left corner: ({0}, {2}), upper right corner: ({1}, {3})".format(
        *modelgrid.extent
    )
)
```

```
structured modelgrid is valid and complete

lenuni: 2, units: meters

lower left corner: (619653.0, 3343617.741737109), upper right corner: (627070.8195824706,
↪ 3354571.0952255125)
```

Spatial reference properties

- `xoffset` : returns the current xoffset of the modelgrid
- `yoffset` : returns the current yoffset of the modelgrid
- `angrot` : returns the angle of rotation of the modelgrid in degrees
- `angrot_radians` : returns the angle of rotation of the modelgrid in radians
- `epsg` : returns the modelgrid epsg code if it is set
- `proj4` : returns the modelgrid proj4 string if it is set
- `prjfile` : returns the path to the modelgrid projection file if it is set

[28]:
```
# Access and print some of these properties
print(f"xoffset: {modelgrid.xoffset}, yoffset: {modelgrid.yoffset}\n")
print(
```

(continues on next page)

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```
    f"rotation (deg): {modelgrid.angrot:.1f}, (rad): {modelgrid.angrot_radians:.4f}\n"
)
print(f"proj4_str: {modelgrid.proj4}")
```

```
xoffset: 622241.1904510253, yoffset: 3343617.741737109

rotation (deg): 15.0, (rad): 0.2618

proj4_str: +proj=utm +zone=14 +datum=WGS84 +units=m +no_defs +type=crs
```

```
/opt/hostedtoolcache/Python/3.8.18/x64/lib/python3.8/site-packages/pyproj/crs/crs.py:
↪1286: UserWarning: You will likely lose important projection information when␣
↪converting to a PROJ string from another format. See: https://proj.org/faq.html#what-
↪is-the-best-format-for-describing-coordinate-reference-systems
  proj = self._crs.to_proj4(version=version)
```

Model discretization properties

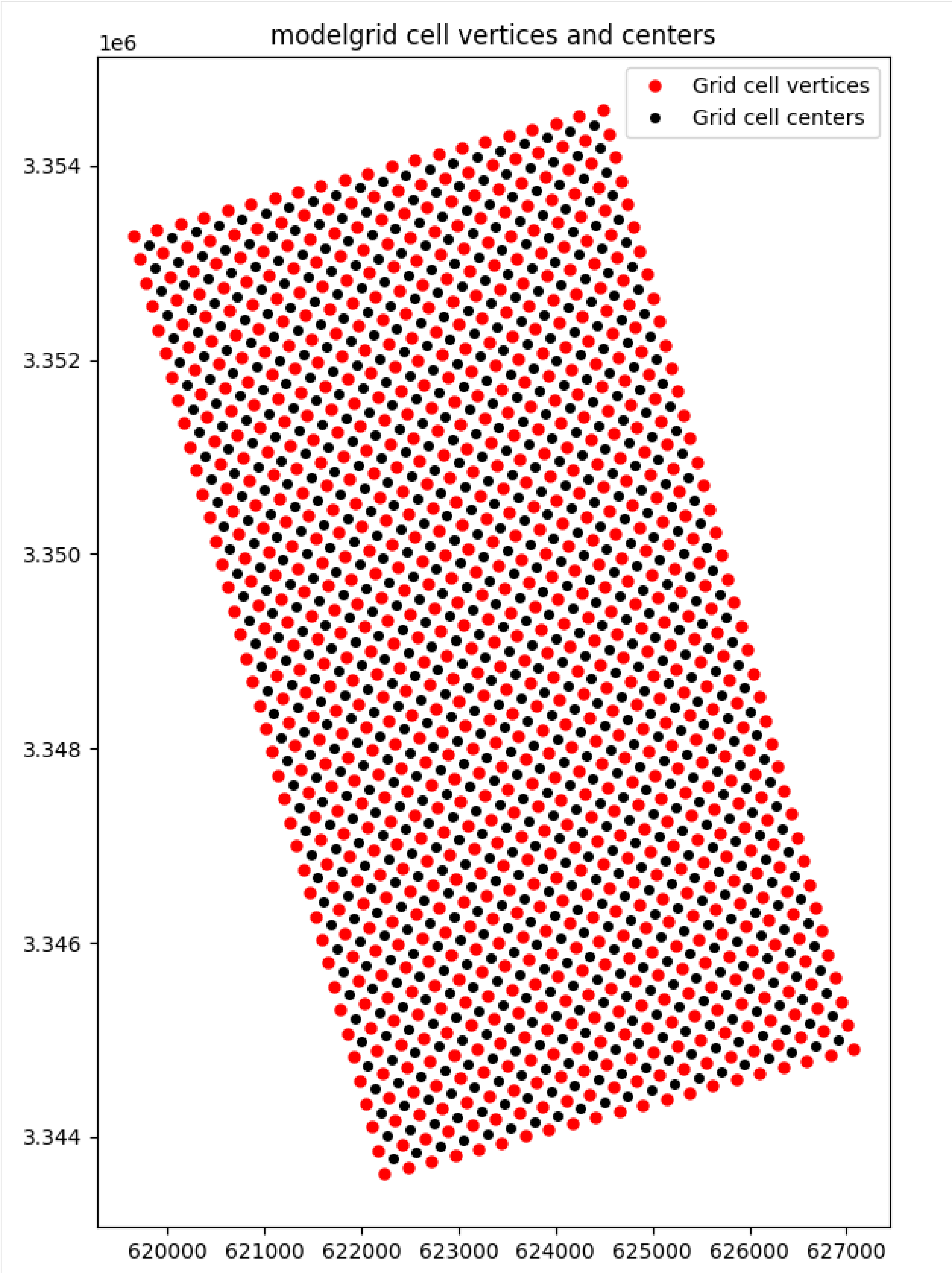
- `shape` : returns the shape of the modelgrid (tuple)
- `ncpl` : returns the number of cells per layer
- `nnodes` : returns the number of cells in the model
- `top` : returns an array of the top elevation of the model or for unstructured grids the top elevation of all cells
- `botm` : retuns an array of the botm elevations of model cells
- `cell_thickness` : returns an array of model cell thickness
- `idomain` : retruns the idomain array associated with the model
- `xvertices` : returns an array of x-vertices for model cells
- `yvertices` : returns an array of y-vertices for model cells
- `zvertices` : returns an array of z-vertices for model cells
- `xcellcenters` : returns an array of x-vertices for model cell centers
- `ycellcenters` : returns an array of y-vertices for model cell centers
- `verts` : returns a list of vertex number, x-coordinate, y-coordinate
- `iverts` : returns a list of cell number, vertex numbers for each cell

[29]:
```
# look at some model discretization information

print(f"Grid shape: {modelgrid.shape}\n")
print(f"number of cells per layer: {modelgrid.ncpl}\n")
print(f"number of cells in model: {modelgrid.nnodes}")
```

```
Grid shape: (1, 40, 20)

number of cells per layer: 800

number of cells in model: 800
```

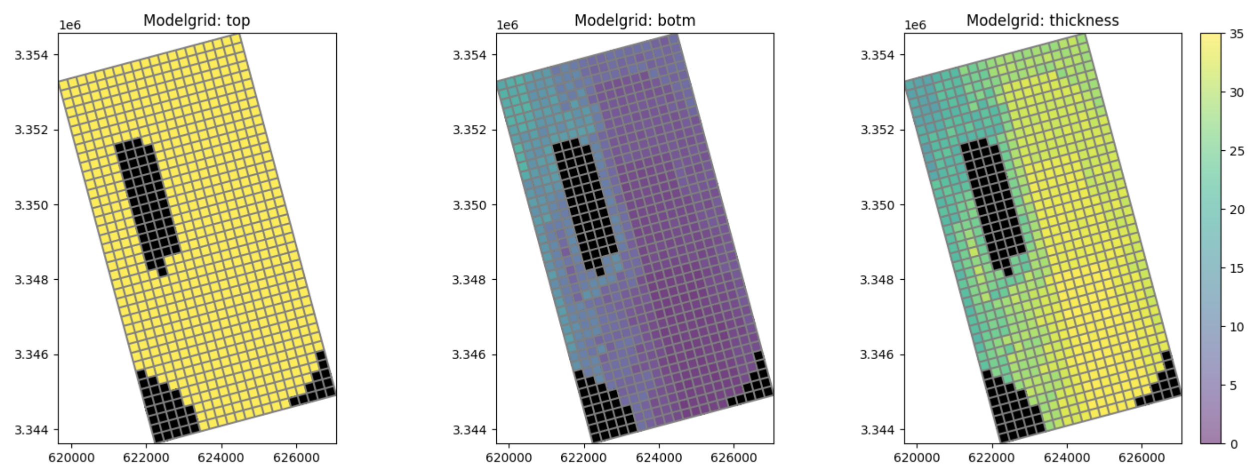
```
[30]: # plot the model cell vertices and cell centers
fig, ax = plt.subplots(figsize=(10, 10), subplot_kw={"aspect": "equal"})

ax.plot(
    np.ravel(modelgrid.xvertices),
    np.ravel(modelgrid.yvertices),
    "ro",
    label="Grid cell vertices",
    ms=5,
)
ax.plot(
    np.ravel(modelgrid.xcellcenters),
    np.ravel(modelgrid.ycellcenters),
    "ko",
    label="Grid cell centers",
    ms=4,
)
plt.legend(
    loc=0,
)
plt.title("modelgrid cell vertices and centers")
```

```
[30]: Text(0.5, 1.0, 'modelgrid cell vertices and centers')
```


modelgrid cell vertices and centers
1e6
Grid cell vertices
Grid cell centers
3.354
3.352
3.350
3.348
3.346
3.344
620000
621000
622000
623000
624000
625000
626000
627000

[31]:
```
# plot layer 1 top, botm, and thickness with ibound overlain
fig, axs = plt.subplots(
    nrows=1, ncols=3, figsize=(18, 6), subplot_kw={"aspect": "equal"}
)

arrays = [modelgrid.top, modelgrid.botm, modelgrid.cell_thickness]

labels = ["top", "botm", "thickness"]

# plot arrays
for ix, ax in enumerate(axs):
    pmv = flopy.plot.PlotMapView(modelgrid=modelgrid, ax=ax)
    pc = pmv.plot_array(
        arrays[ix], masked_values=[1e30], vmin=0, vmax=35, alpha=0.5
    )
    pmv.plot_grid()
    pmv.plot_inactive()
    ax.set_title(f"Modelgrid: {labels[ix]}")

plt.colorbar(pc)
```

[31]:
```
<matplotlib.colorbar.Colorbar at 0x7fb0f96accd0>
```



Common methods

There are also many common (shared) methods that are present in `StructuredGrid`, `VertexGrid`, and `UnstructuredGrid`:

Overview of methods

- `set_coord_info()` : Method to set coordinate reference information for the modelgrid
- `get_coords()` : Method to convert model coordinates to real-world coordinates based on coordinate reference information
- `get_local_coords()` : Method to convert real-world coordinates to model coordinates based on coordinate reference information
- `intersect()` : Method to get the cellid (`StructuredGrid`=(row, column) OR `VertexGrid` & `UnstrucuturedGrid`=node number) from either model coordinates or from real-world coordinates
- `saturated_thickness()` : Method to get the saturated thickness
- `write_shapefile()` : Method to write a shapefile of the grid with just the cellid attributes

set_coord_info()

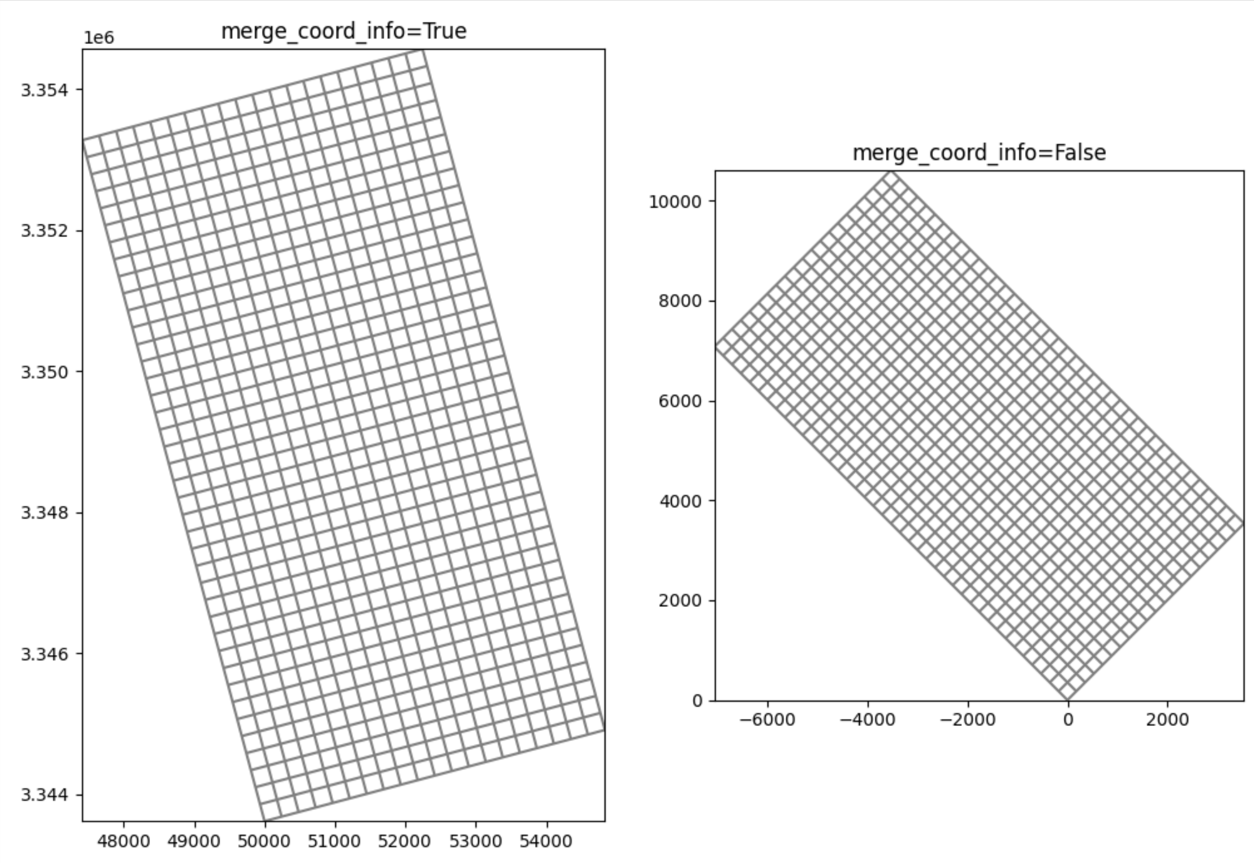
Method to set coordinate reference information for the modelgrid. This method accepts the following optional parameters:

- `xoff` : lower-left corner of modelgrid x-coordinate location
- `yoff` : lower-left corner of modelgrid y-coordinate location
- `angrot` : rotation of model grid in degrees
- `crs` : either an epsg integer code of model coordinate system, a proj4 string or pyproj CRS instance
- `prjfile` : path to ".prj" projection file that describes the model coordinate system
- `merge_coord_info` : boolean flag to either merge changes with the existing coordinate info or clear existing coordinate info before applying changes.

[32]:
```python
fig, ax = plt.subplots(
    nrows=1, ncols=2, figsize=(12, 8), subplot_kw={"aspect": "equal"}
)

# example usage with merge_coord_info=True
modelgrid.set_coord_info(xoff=50000)
print(modelgrid)
modelgrid.plot(ax=ax[0])
ax[0].set_title("merge_coord_info=True")

# example usage with merge_coord_info=False
modelgrid.set_coord_info(angrot=45, merge_coord_info=False)
print(modelgrid)
modelgrid.plot(ax=ax[1])
ax[1].set_title("merge_coord_info=False")
```

```
xll:50000; yll:3343617.741737109; rotation:15.0; crs:EPSG:32614; units:meters; lenuni:2
xll:0.0; yll:0.0; rotation:45; proj4_str:+proj=utm +zone=14 +datum=WGS84 +units=m +no_
↪defs +type=crs; units:meters; lenuni:2
```

[32]:
```
Text(0.5, 1.0, 'merge_coord_info=False')
```



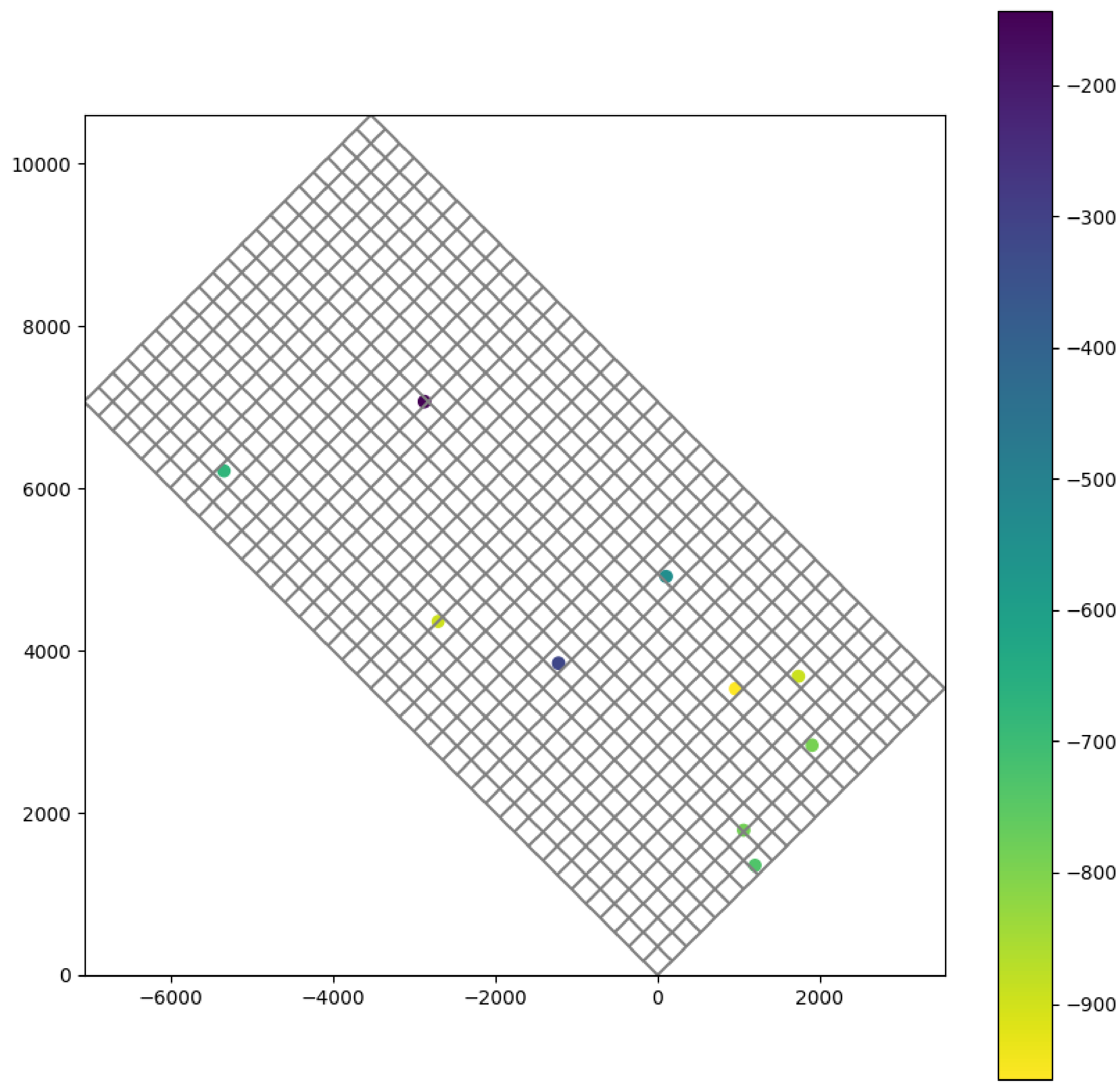
get_coords()

Method to convert model coordinates to real-world coordinates based on coordinate reference information. Input parameters include:

- `x` : float, list, or array of x coordinate values
- `y` : float, list, or array of y coordinate values

[33]:
```
# create some synthetic pumping data
x = modelgrid.xoffset + np.random.rand(10) * 4000
y = modelgrid.yoffset + np.random.rand(10) * 10000
q = np.random.rand(10) * -1000

# get "real-world coordinates"
rw_coords = modelgrid.get_coords(x, y)

fig, ax = plt.subplots(figsize=(10, 10), subplot_kw={"aspect": "equal"})

pmv = flopy.plot.PlotMapView(modelgrid=modelgrid, ax=ax)
pmv.plot_grid()

s = ax.scatter(rw_coords[0], rw_coords[1], c=q, cmap="viridis_r")
plt.colorbar(s)
```

[33]:
```
<matplotlib.colorbar.Colorbar at 0x7fb0f9455460>
```



get_local_coords()

Method to convert real-world coordinates to local coordinates based on coordinate reference information. Input parameters include:

- `x` : float, list, or array of x coordinate values
- `y` : float, list, or array of y coordinate values

[34]:
```python
# reuse the "real world" coordinates from the previous cell
l_coords = modelgrid.get_local_coords(rw_coords[0], rw_coords[1])
```

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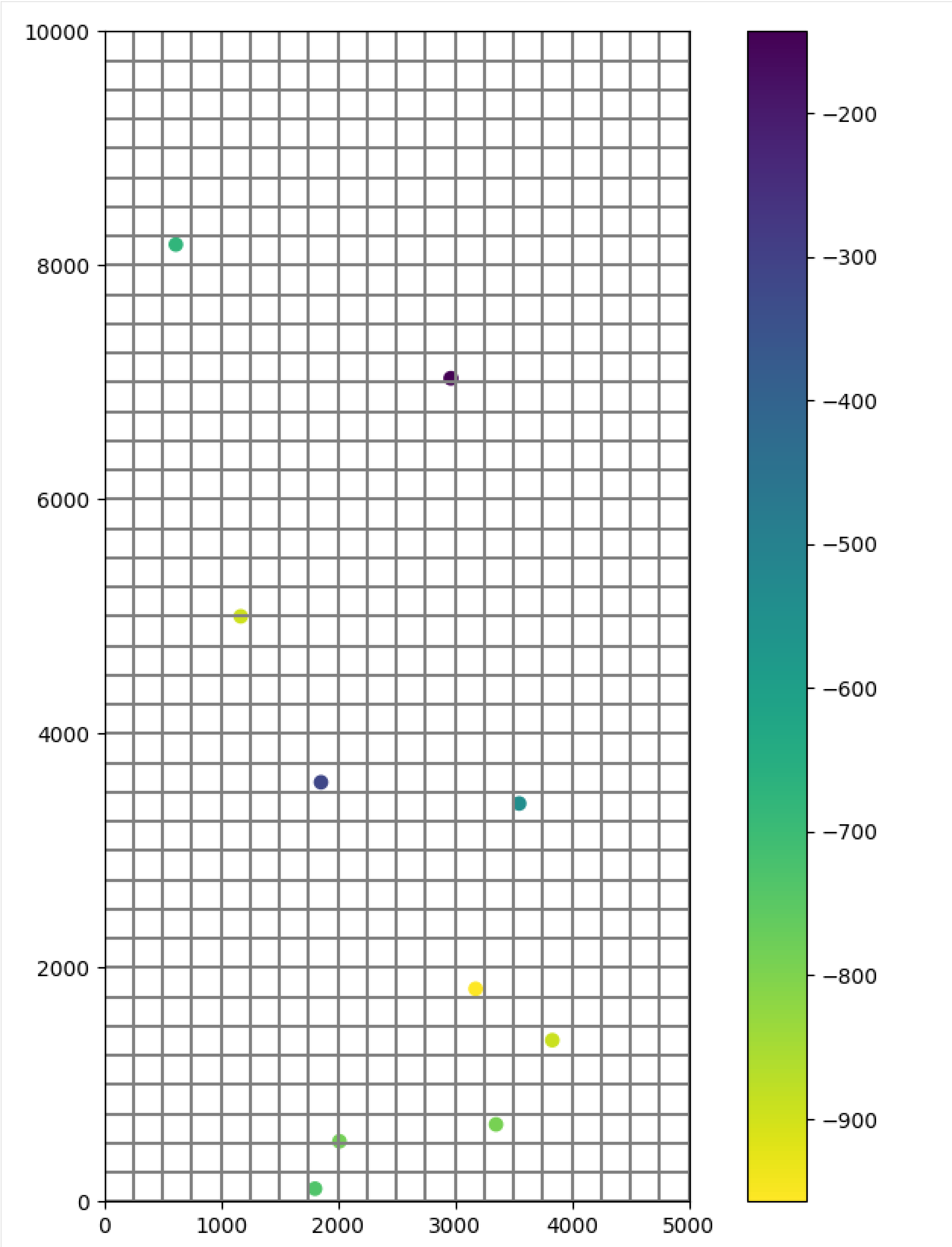
```
# show that these have been properly translated
print(np.allclose(x, l_coords[0]))
print(np.allclose(y, l_coords[1]))

# plot the local coords on a modelgrid that is in model units
modelgrid.set_coord_info(merge_coord_info=False)

fig, ax = plt.subplots(figsize=(10, 10), subplot_kw={"aspect": "equal"})

pmv = flopy.plot.PlotMapView(modelgrid=modelgrid, ax=ax)
pmv.plot_grid()

s = ax.scatter(l_coords[0], l_coords[1], c=q, cmap="viridis_r")
plt.colorbar(s)
```

```
True
True
```

[34]:
```
<matplotlib.colorbar.Colorbar at 0x7fb0f93b4340>
```


10000
8000
6000
4000
2000
0
0
1000
2000
3000
4000
5000
−200
−300
−400
−500
−600
−700
−800
−900

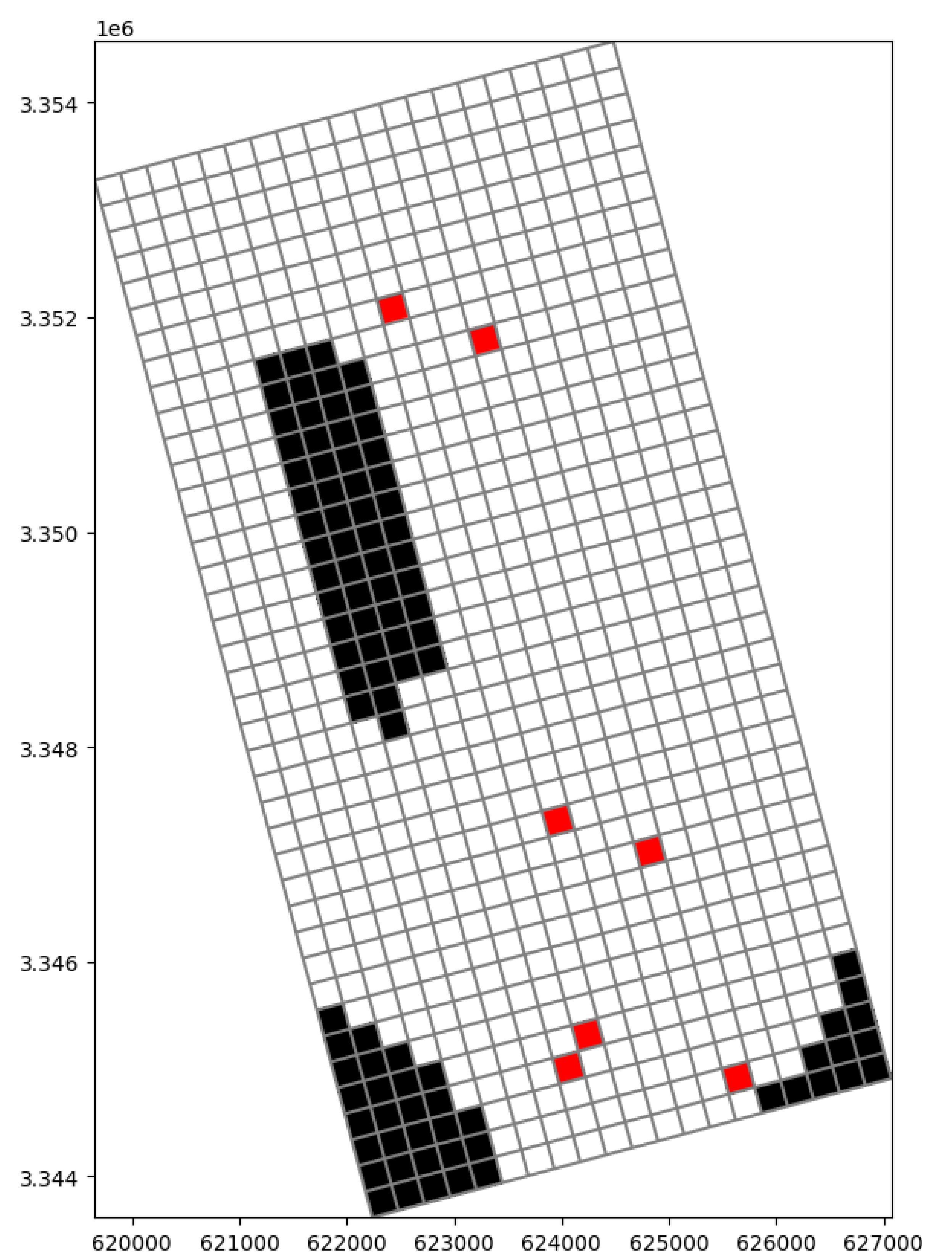
intersect()

Method to get the cellid (`StructuredGrid`=(row, column) OR `VertexGrid` & `UnstrucuturedGrid`=node number) from either model coordinates or from real-world coordinates. Parameters include:

- `x` : x coordinate value
- `y` : y coordinate value
- `local` : if True x and y are in local coordinates (default is False)
- `forgive` : forgive x, y coordinate pairs and return NaN when coordinate pairs fall outside the model domain (default is False)

[35]:
```
# apply rotation, xoffset, and yoffset to modelgrid
modelgrid.set_coord_info(
    xoff=622241.1904510253,
    yoff=3343617.741737109,
    angrot=15.0,
)

# generate some synthetic pumping data
x = modelgrid.xoffset + np.random.rand(10) * 4000
y = modelgrid.yoffset + np.random.rand(10) * 10000
q = np.random.rand(10) * -0.02

# intersect to get row and column locations and create pumping data
pdata = []
for ix, xc in enumerate(x):
    i, j = modelgrid.intersect(xc, y[ix], forgive=True)
    if not np.isnan(i) and not np.isnan(j):
        if modelgrid.idomain[0, i, j]:
            pdata.append([(0, i, j), q[ix]])

# remove existing wel package
ml.remove_package("wel_0")

# create a mf6 WEL package and add it to the existing model
stress_period_data = {0: pdata}
wel = flopy.mf6.modflow.ModflowGwfwel(
    ml, stress_period_data=stress_period_data
)

# plot the locations from the new WEL package on the modelgrid
fig, ax = plt.subplots(figsize=(10, 10), subplot_kw={"aspect": "equal"})

pmv = flopy.plot.PlotMapView(modelgrid=modelgrid, ax=ax)
pmv.plot_grid()
pmv.plot_inactive()
pmv.plot_bc(package=wel)
```

[35]:
```
<matplotlib.collections.QuadMesh at 0x7fb0f9a16f40>
```


1e6
3.354
3.352
3.350
3.348
3.346
3.344
620000
621000
622000
623000
624000
625000
626000
627000

saturated_thickness()

Method to calculate the saturated thickness of each model cell from an array of elevations. Input parameters to this method include:

- `array` : array of elevations that will be used to adjust the cell thickness
- `mask` : float, list, tuple, or array of values to replace with a NaN value (ex. hdry and hnoflo values)

[36]:
```python
# write inputs and run the mf6 simulation with the new wells we added above
sim.set_sim_path(gridgen_ws)
sim.write_simulation()
success, buff = sim.run_simulation(silent=True, report=True)
if success:
    for line in buff:
        print(line)
else:
    raise ValueError("Failed to run.")

# load the binary head file from the model
ml = sim.freyberg
hds = ml.output.head()
head = hds.get_alldata()[0]

# calculate saturated thickness
sat_thk = ml.modelgrid.saturated_thickness(head, mask=[1e30])

# get thick for comparison
thk = ml.modelgrid.cell_thickness

# plot thickness and saturated thickness for comparison
fig, ax = plt.subplots(
    nrows=1, ncols=2, figsize=(16, 7), subplot_kw={"aspect": "equal"}
)

pmv = flopy.plot.PlotMapView(modelgrid=ml.modelgrid, ax=ax[0])
pc = pmv.plot_array(thk, vmin=5, vmax=35)
pmv.plot_ibound()
pmv.plot_grid()
ax[0].set_title("Modelgrid thickness")

pmv = flopy.plot.PlotMapView(modelgrid=ml.modelgrid, ax=ax[1])
pc = pmv.plot_array(sat_thk, vmin=5, vmax=35)
pmv.plot_ibound()
pmv.plot_grid()
ax[1].set_title("Saturated thickness")

plt.tight_layout()
plt.colorbar(pc)
```

```
                                   MODFLOW 6
                U.S. GEOLOGICAL SURVEY MODULAR HYDROLOGIC MODEL
                            VERSION 6.4.2 06/28/2023

   MODFLOW 6 compiled Jul 05 2023 20:29:14 with Intel(R) Fortran Intel(R) 64
```

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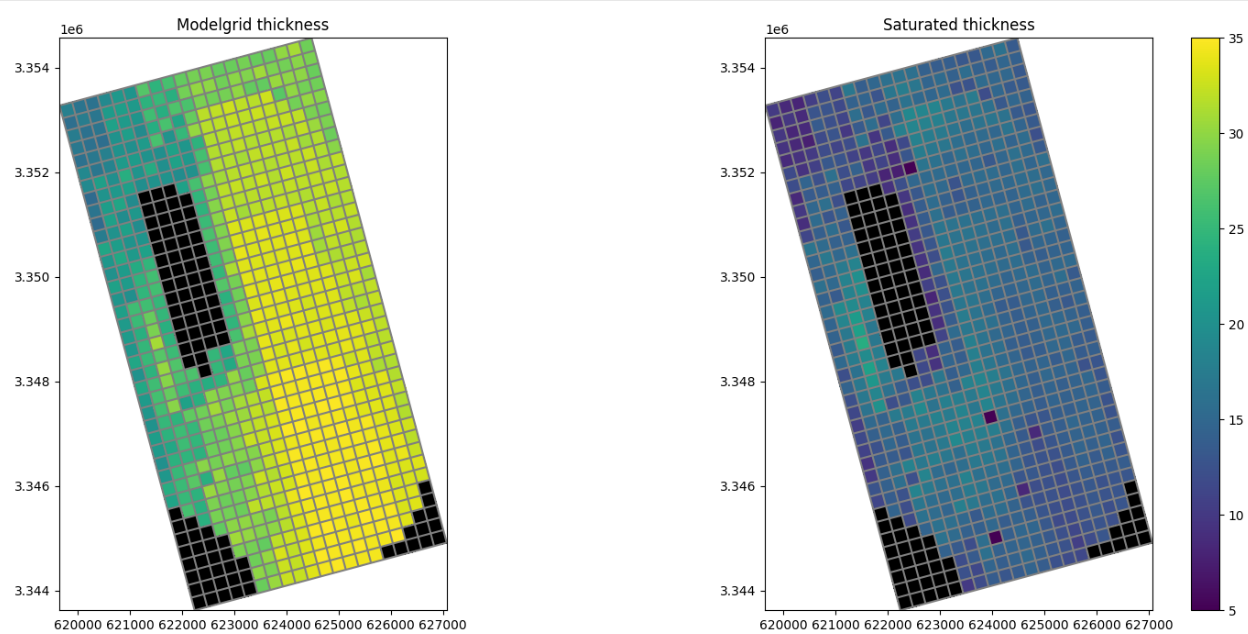
```
   Compiler Classic for applications running on Intel(R) 64, Version 2021.7.0
                             Build 20220726_000000

This software has been approved for release by the U.S. Geological
Survey (USGS). Although the software has been subjected to rigorous
review, the USGS reserves the right to update the software as needed
pursuant to further analysis and review. No warranty, expressed or
implied, is made by the USGS or the U.S. Government as to the
functionality of the software and related material nor shall the
fact of release constitute any such warranty. Furthermore, the
software is released on condition that neither the USGS nor the U.S.
Government shall be held liable for any damages resulting from its
authorized or unauthorized use. Also refer to the USGS Water
Resources Software User Rights Notice for complete use, copyright,
and distribution information.


 Run start date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:30:11

 Writing simulation list file: mfsim.lst
 Using Simulation name file: mfsim.nam

    Solving:  Stress period:     1    Time step:     1

 Run end date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:30:11
 Elapsed run time:  0.056 Seconds

 Normal termination of simulation.
```

[36]: <matplotlib.colorbar.Colorbar at 0x7fb0dde84f10>



`write_shapefile()`

Method to write a shapefile of the grid with just the cellid attributes. Input parameters include:

- `filename` : shapefile name
- `crs` : either an epsg integer code of model coordinate system, a proj4 string or pyproj CRS instance
- `prjfile` : path to ".prj" projection file that describes the model coordinate system

[37]:
```
# write a shapefile
shp_name = os.path.join(gridgen_ws, "freyberg-6_grid.shp")
epsg = 32614

ml.modelgrid.write_shapefile(shp_name, crs=epsg)
```

[38]:
```
try:
    # ignore PermissionError on Windows
    temp_dir.cleanup()
except:
    pass
```

6.1.6 Intersecting rasters with modelgrids using FloPy's Raster class

A Raster class was developed as a wrapper that leverages RasterIO, RasterStats, and SciPy built in methods for easy raster intersections and cropping.

This notebook will show some of the basic functionality of the `Raster` class with structured and unstructured model grid examples.

The `Raster` class accepts Tiff and GeoTiff, ASCII Grid (ESRI ASCII), and Erdas Imagine .img files.

Ideally this can be used to easily snap DEM rasters, PET, PPT, recharge and other rasters to a modflow grid for further processing and/or to apply as fluxes and boundary conditions to a MODFLOW model

[1]:
```
import os
import sys
import time
from tempfile import TemporaryDirectory

import matplotlib as mpl
import matplotlib.pyplot as plt
import numpy as np
import pandas as pd
import shapefile
import shapely

try:
    import flopy
    from flopy.utils import Raster
except:
    fpth = os.path.abspath(os.path.join("..", ".."))
    sys.path.append(fpth)
    import flopy
    from flopy.utils import Raster
```

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```
print(sys.version)
print(f"numpy version: {np.__version__}")
print(f"matplotlib version: {mpl.__version__}")
print(f"pandas version: {pd.__version__}")
print(f"shapely version: {shapely.__version__}")
print(f"flopy version: {flopy.__version__}")
```

```
3.8.18 (default, Aug 28 2023, 08:27:22)
[GCC 11.4.0]
numpy version: 1.24.4
matplotlib version: 3.7.4
pandas version: 2.0.3
shapely version: 2.0.2
flopy version: 3.5.0
```

[2]:
```
# temporary directory
temp_dir = TemporaryDirectory()
workspace = temp_dir.name
```

Raster files can be loaded using the `Raster.load` method

[3]:
```
raster_ws = os.path.join("..", "..", "examples", "data", "options", "dem")
raster_name = "dem.img"

rio = Raster.load(os.path.join(raster_ws, raster_name))
```

The bands within the raster can be viewed by calling the parameter `bands`; there is only one band in this raster

[4]:
```
rio.bands
```

[4]:
```
(1,)
```

[5]:
```
arr = rio.get_array(1)
idx = np.isfinite(arr)

vmin, vmax = arr[idx].min(), arr[idx].max()
vmin, vmax
```

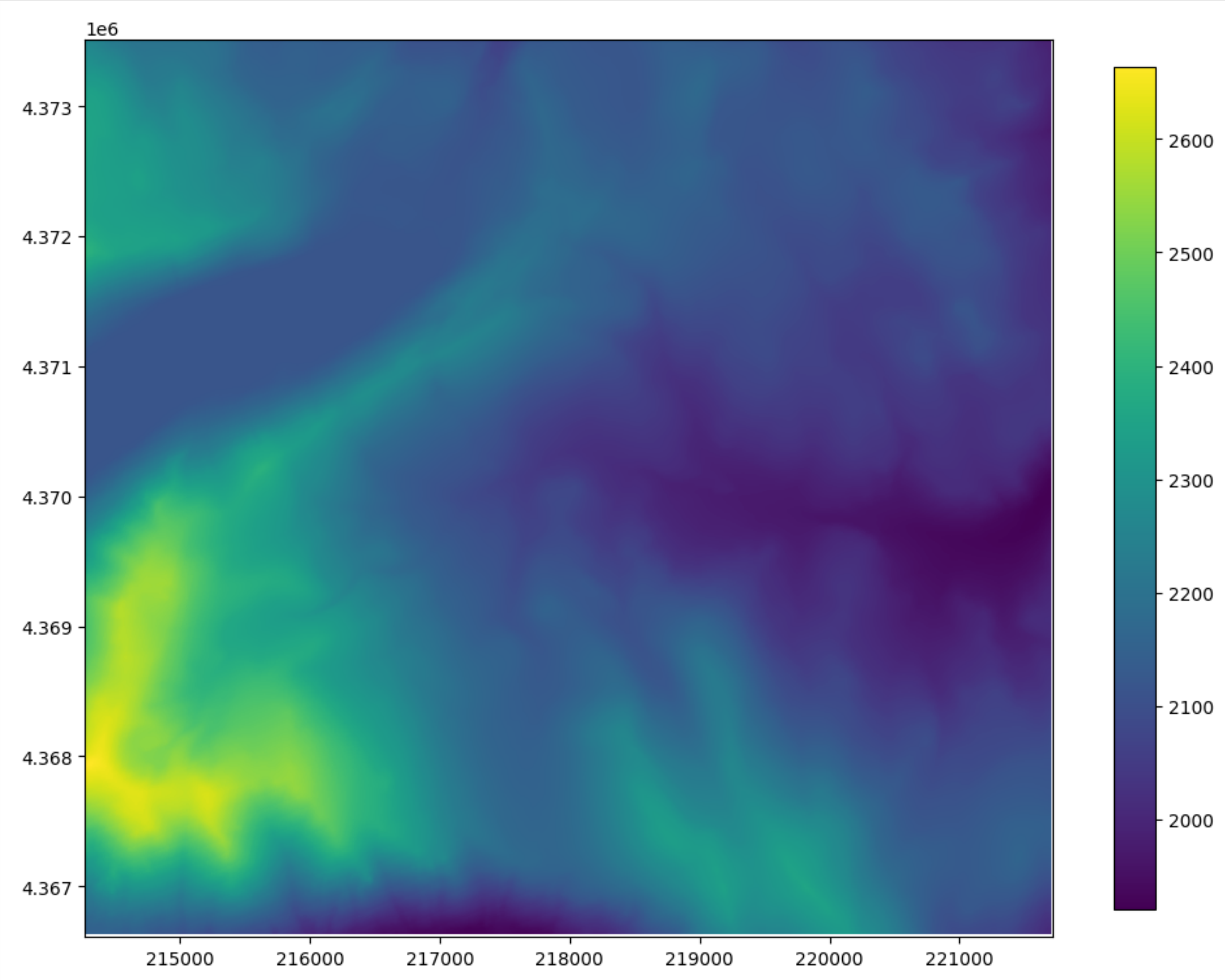
[5]:
```
(1920.5467529296875, 2663.162109375)
```

Using the built in `.plot` method, we can take a look at the DEM raster data before we start manipulating it

[6]:
```
fig = plt.figure(figsize=(12, 12))
ax = fig.add_subplot(1, 1, aspect="equal")

ax = rio.plot(ax=ax, vmin=vmin, vmax=vmax)
plt.colorbar(ax.images[0], shrink=0.7)
```

[6]:
```
<matplotlib.colorbar.Colorbar at 0x7f2981f539d0>
```



Intersecting and resampling a data using the FloPy ModelGrid

Structured Grid Example

The structured grid example uses the DIS file from the GSFLOW Sagehen example problem to create a modelgrid

[7]:
```python
model_ws = os.path.join("..", "..", "examples", "data", "options", "sagehen")
ml = flopy.modflow.Modflow.load(
    "sagehen.nam", version="mfnwt", model_ws=model_ws
)

xoff = 214110
yoff = 4366620
ml.modelgrid.set_coord_info(xoff=xoff, yoff=yoff)
```

```
   loading iuzfbnd array...
   loading vks array...
   loading eps array...
   loading thts array...
stress period 1:
```

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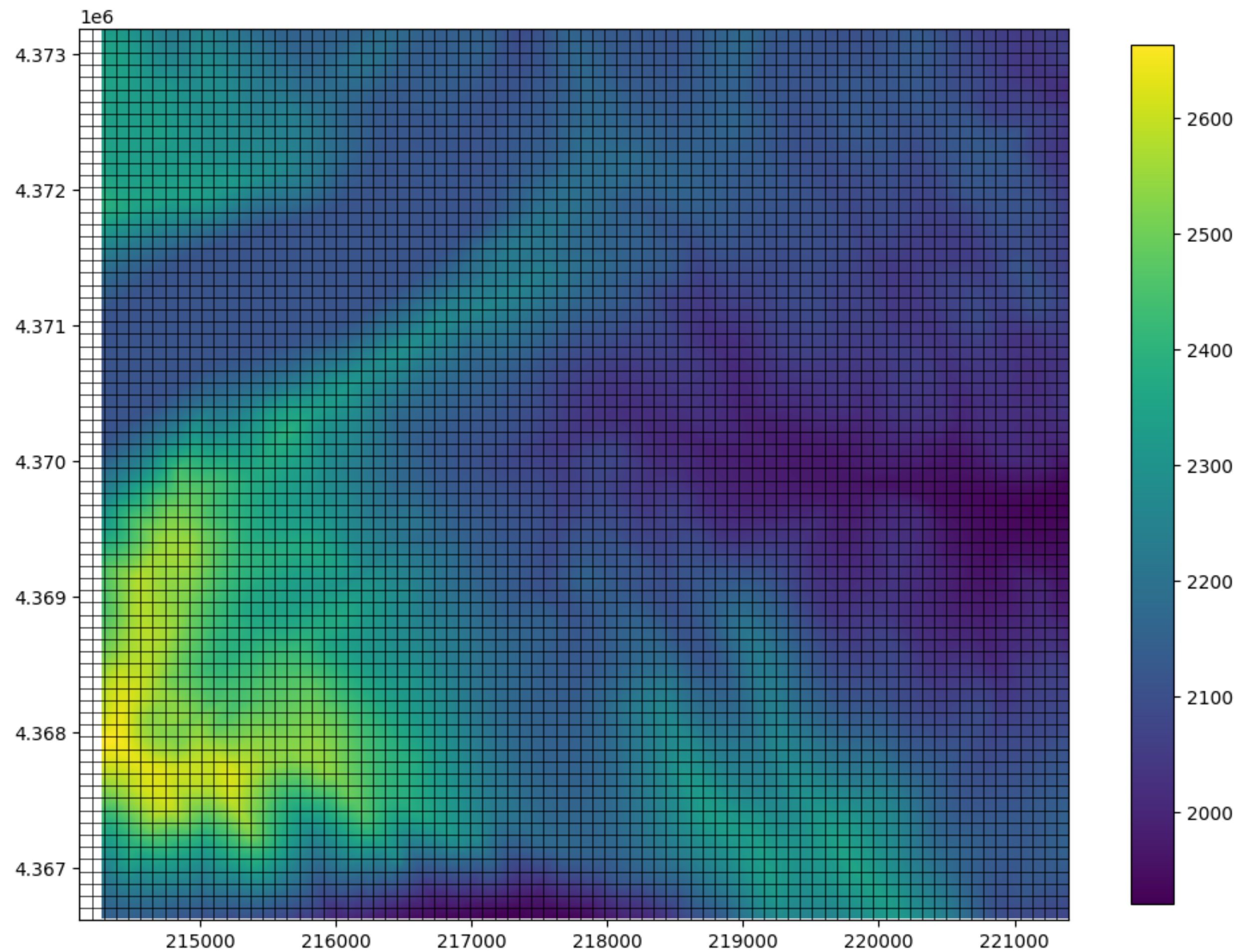
(continued from previous page)

```
   loading finf array...
stress period 2:
```

[8]:
```
fig = plt.figure(figsize=(12, 12))
ax = fig.add_subplot(1, 1, 1, aspect="equal")

ax = rio.plot(ax=ax, vmin=vmin, vmax=vmax)
plt.colorbar(ax.images[0], shrink=0.7)
pmv = flopy.plot.PlotMapView(modelgrid=ml.modelgrid)
pmv.plot_grid(ax=ax, lw=0.5, color="black")
```

[8]:
```
<matplotlib.collections.LineCollection at 0x7f2981b658e0>
```



Once a modelgrid has been loaded, the `resample_to_grid()` method can be used to re-sample the data to an array consistent with the model grid.

Inputs to `resample_to_grid()` include:

- `modelgrid` : flopy `Grid` object
- `band` : raster band to resample
- `method` : resampling method, options include:

- "nearest" for nearest neighbor
- "linear" for bilinear sampling
- "cubic" for bicubic sampling
- "mean" for mean value sampling
- "median" for median value sampling
- "min" for minimum value sampling
- "max" for maximum value sampling
- "mode" for most often (dominant) sampling

- extrapolate_edges : boolean flag to extrapolate edges using the "nearest" resampling method. For all of the sampling methods except "nearest", interpolation is only performed in areas bounded by data; nodata values are returned in areas without data. This option has no effect when the "nearest" interpolation method is used.

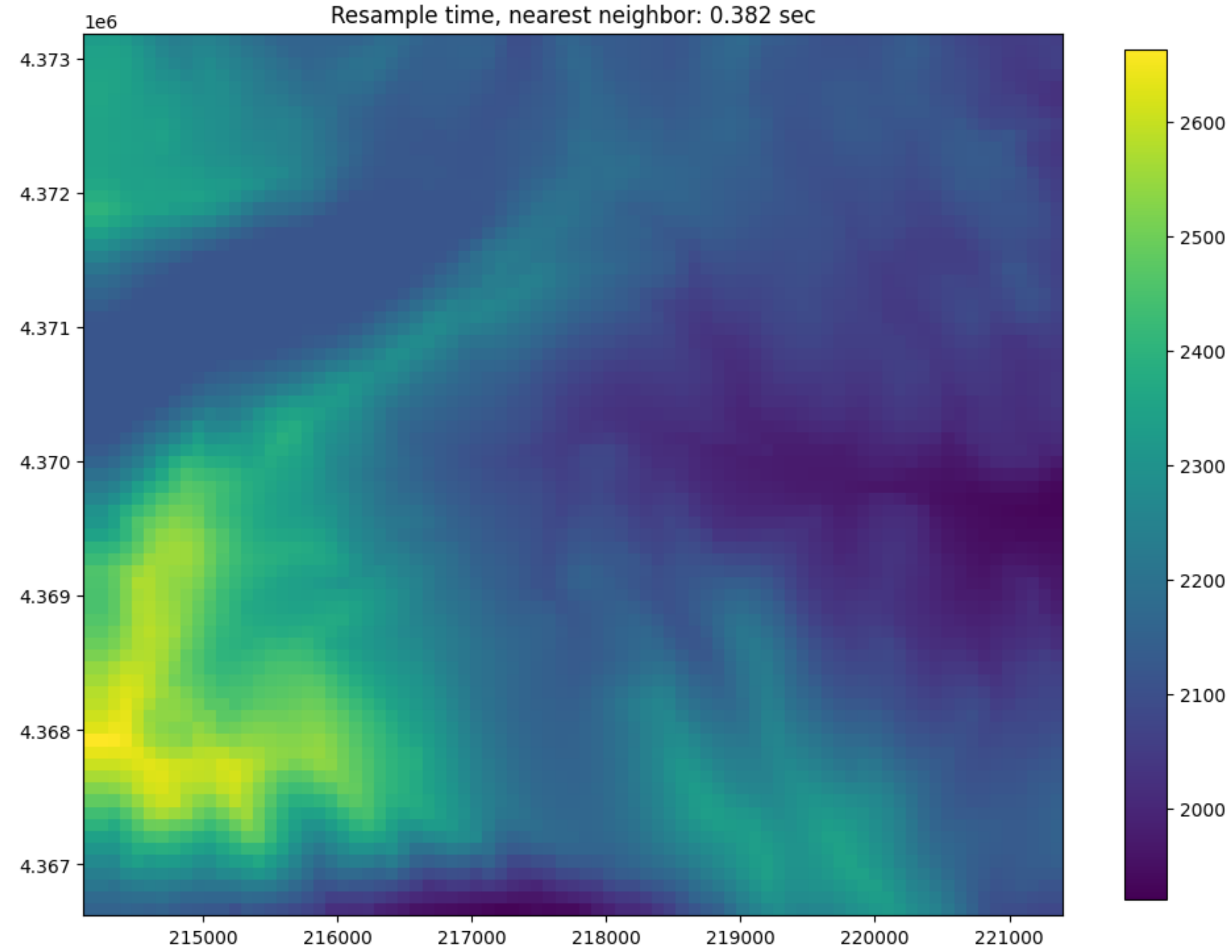
Note: Bottlenecks in sampling time depend on the resampling method used: + "nearest", "linear", and "cubic" bottlenecks are due to raster resolution. + "mean", "median", "min", "max", and "mode" are a function of the number of grid cells.

[9]:
```
t0 = time.time()
dem_data = rio.resample_to_grid(
    ml.modelgrid, band=rio.bands[0], method="nearest"
)
resample_time = time.time() - t0
```

[10]:
```
# now to visualize using flopy and matplotlib
fig = plt.figure(figsize=(12, 12))
ax = fig.add_subplot(1, 1, 1, aspect="equal")

pmv = flopy.plot.PlotMapView(modelgrid=ml.modelgrid, ax=ax)
ax = pmv.plot_array(
    dem_data, masked_values=rio.nodatavals, vmin=vmin, vmax=vmax
)
plt.title(f"Resample time, nearest neighbor: {resample_time:.3f} sec")
plt.colorbar(ax, shrink=0.7)
```

[10]:
```
<matplotlib.colorbar.Colorbar at 0x7f29691719a0>
```

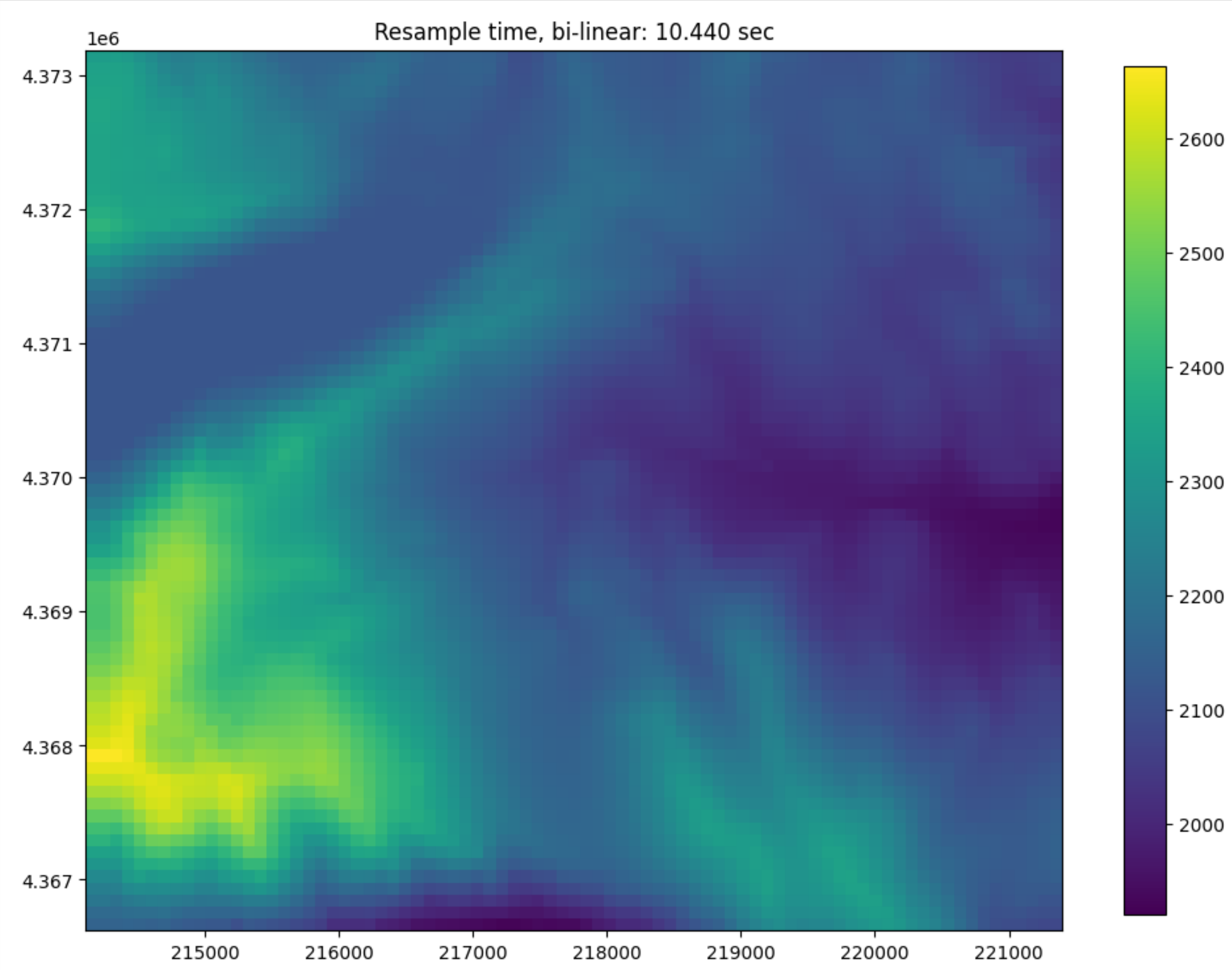


[11]:
```
t0 = time.time()
dem_data = rio.resample_to_grid(
    ml.modelgrid, band=rio.bands[0], method="linear", extrapolate_edges=True
)
resample_time = time.time() - t0
```

[12]:
```
# now to visualize using flopy and matplotlib
fig = plt.figure(figsize=(12, 12))
ax = fig.add_subplot(1, 1, 1, aspect="equal")

pmv = flopy.plot.PlotMapView(modelgrid=ml.modelgrid, ax=ax)
ax = pmv.plot_array(
    dem_data, masked_values=rio.nodatavals, vmin=vmin, vmax=vmax
)
plt.title(f"Resample time, bi-linear: {resample_time:.3f} sec")
plt.colorbar(ax, shrink=0.7)
```

[12]:
```
<matplotlib.colorbar.Colorbar at 0x7f29690dc9a0>
```

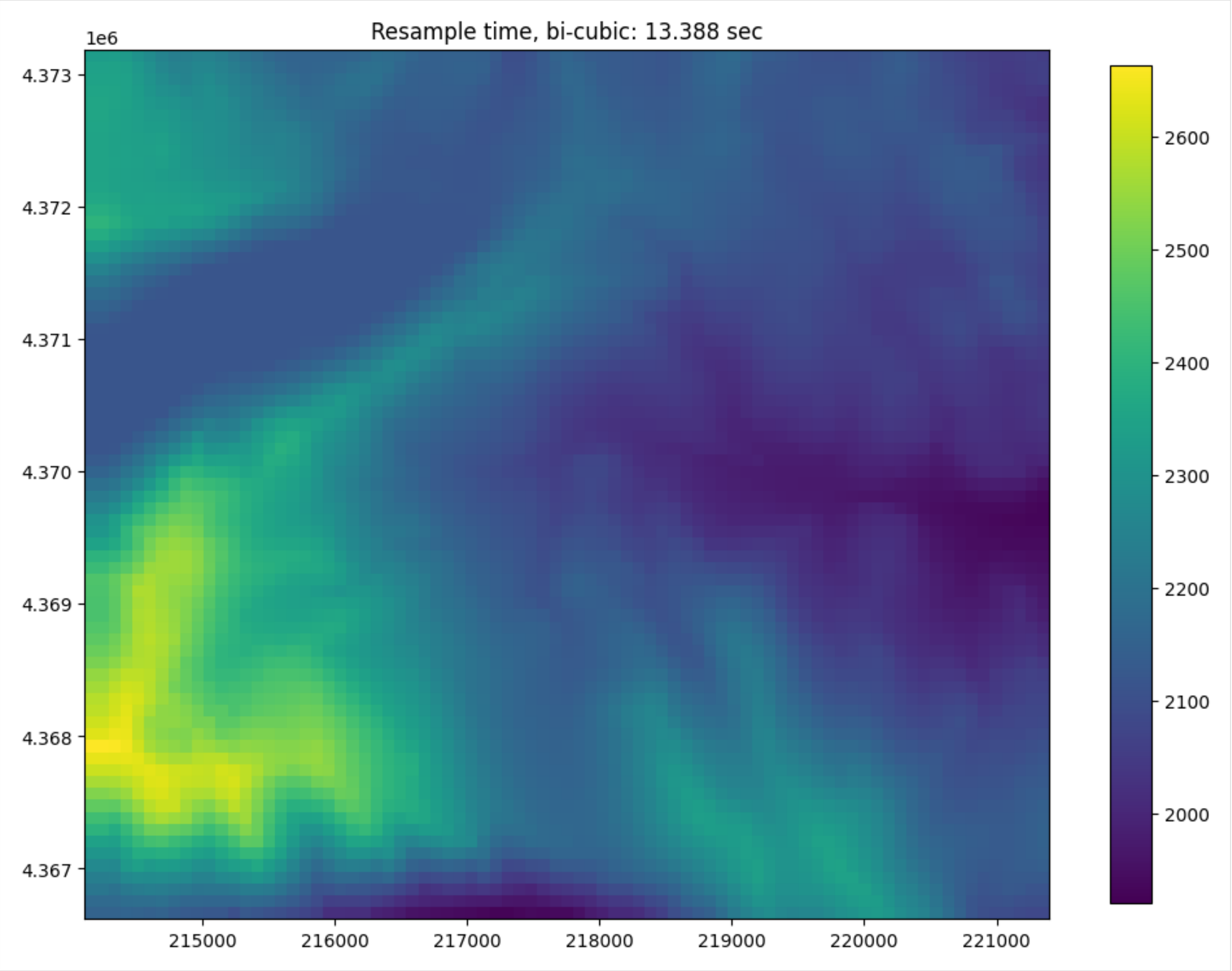


[13]:
```
t0 = time.time()
dem_data = rio.resample_to_grid(
    ml.modelgrid, band=rio.bands[0], method="cubic", extrapolate_edges=True
)
resample_time = time.time() - t0
```

[14]:
```
# now to visualize using flopy and matplotlib
fig = plt.figure(figsize=(12, 12))
ax = fig.add_subplot(1, 1, 1, aspect="equal")

pmv = flopy.plot.PlotMapView(modelgrid=ml.modelgrid, ax=ax)
ax = pmv.plot_array(
    dem_data, masked_values=rio.nodatavals, vmin=vmin, vmax=vmax
)
plt.title(f"Resample time, bi-cubic: {resample_time:.3f} sec")
plt.colorbar(ax, shrink=0.7)
```

[14]:
```
<matplotlib.colorbar.Colorbar at 0x7f2968fc9100>
```

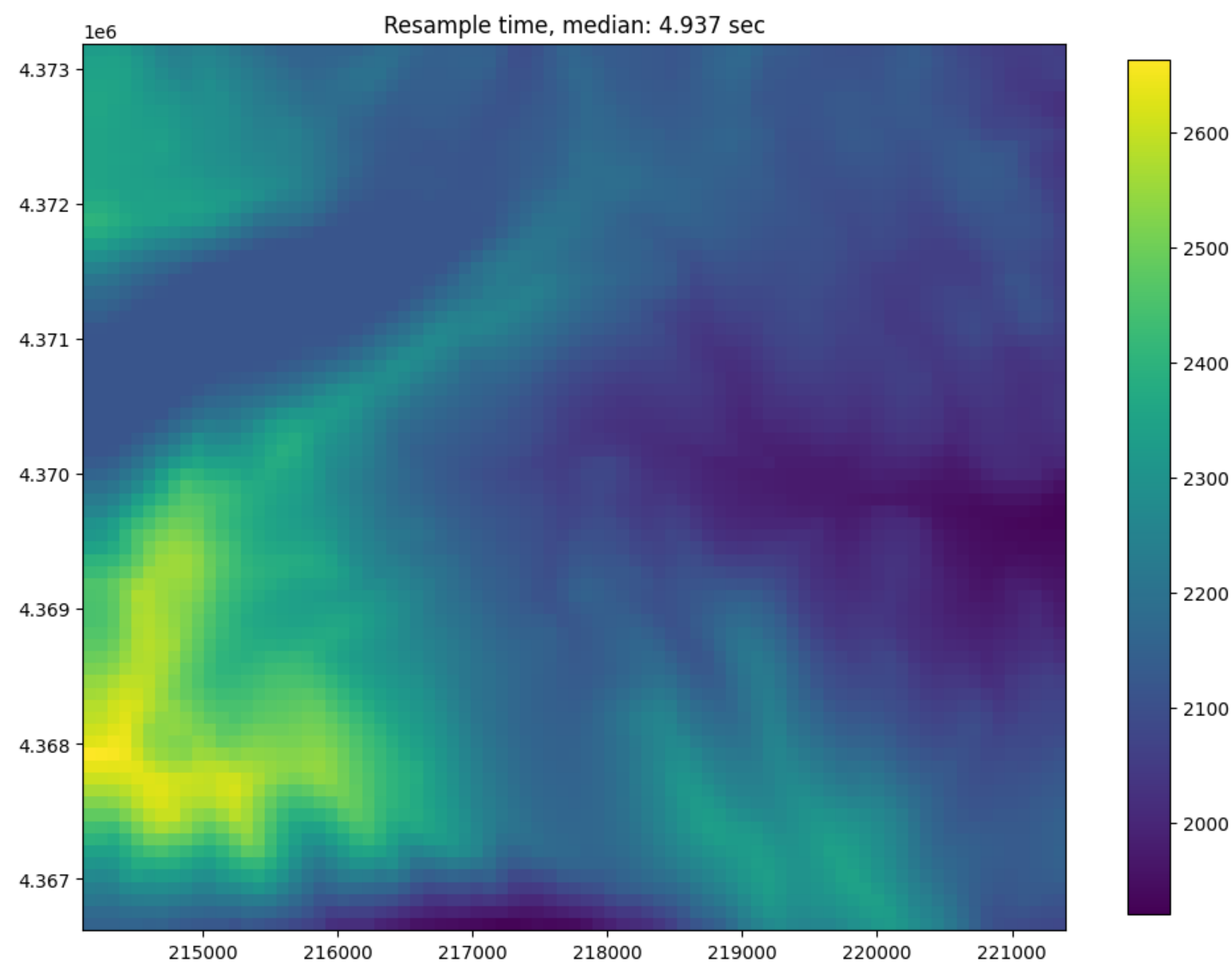


[15]:
```
t0 = time.time()
dem_data = rio.resample_to_grid(
    ml.modelgrid,
    band=rio.bands[0],
    method="median",
    extrapolate_edges=True,
)
resample_time = time.time() - t0
```

[16]:
```
# now to visualize using flopy and matplotlib
fig = plt.figure(figsize=(12, 12))
ax = fig.add_subplot(1, 1, 1, aspect="equal")

pmv = flopy.plot.PlotMapView(modelgrid=ml.modelgrid, ax=ax)
ax = pmv.plot_array(
    dem_data, masked_values=rio.nodatavals, vmin=vmin, vmax=vmax
)
plt.title(f"Resample time, median: {resample_time:.3f} sec")
plt.colorbar(ax, shrink=0.7)
```

[16]:
```
<matplotlib.colorbar.Colorbar at 0x7f2968be9970>
```



Vertex and Unstructured grid example

The user can also use either a vertex grid or an unstructured grid and resample raster data to it using the same `resample_to_grid()` method

Here is an example of building a triangular mesh and creating an unstructured grid instance to use for Raster resampling

[17]:
```python
from flopy.utils.triangle import Triangle

maximum_area = 30000.0  # 30000.

extent = rio.bounds
domainpoly = [
    (extent[0], extent[2]),
    (extent[1], extent[2]),
    (extent[1], extent[3]),
    (extent[0], extent[3]),
]
```

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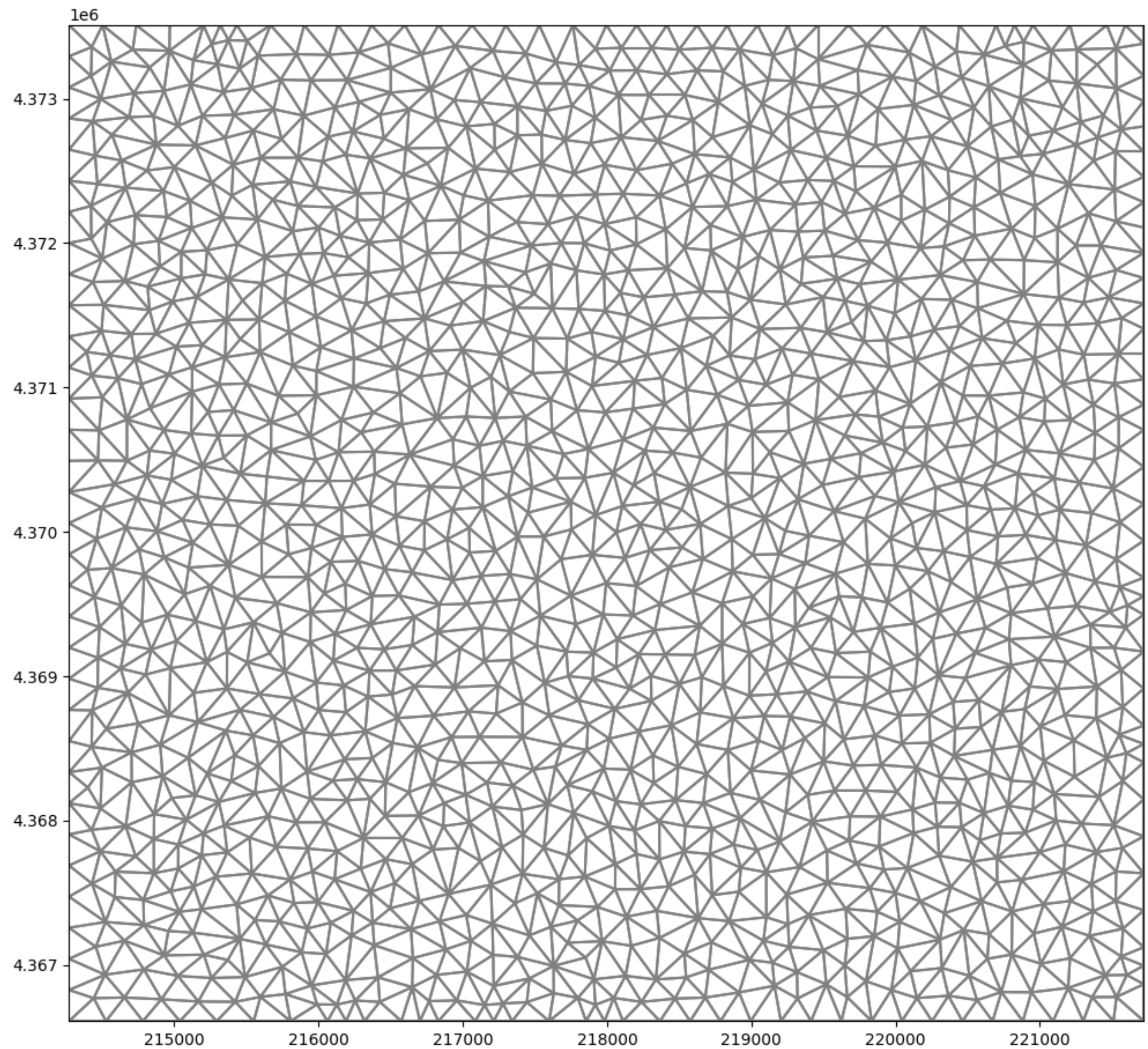
```
tri = Triangle(maximum_area=maximum_area, angle=30, model_ws=workspace)

tri.add_polygon(domainpoly)
tri.build(verbose=False)
xc, yc = tri.get_xcyc().T
verts = [[iv, x, y] for iv, (x, y) in enumerate(tri.verts)]
iverts = tri.iverts
ncpl = np.array([len(iverts)])

mg_unstruct = flopy.discretization.UnstructuredGrid(
    vertices=verts, iverts=iverts, ncpl=ncpl, xcenters=xc, ycenters=yc
)
```

[18]:
```
# now to visualize using matplotlib
fig = plt.figure(figsize=(12, 12))
ax = fig.add_subplot(1, 1, 1, aspect="equal")

pmv = flopy.plot.PlotMapView(modelgrid=mg_unstruct, ax=ax)
pmv.plot_grid()
```

[18]:
```
<matplotlib.collections.LineCollection at 0x7f2969103670>
```



Once a grid object is created, the raster can be resampled to the grid using the same `resample_to_grid()` method as the structured grid example

[19]:
```
t0 = time.time()
dem_data = rio.resample_to_grid(
    mg_unstruct, band=rio.bands[0], method="nearest"
)

resample_time = time.time() - t0
```

[20]:
```
# now to visualize using flopy and matplotlib
fig = plt.figure(figsize=(12, 12))
ax = fig.add_subplot(1, 1, 1, aspect="equal")

pmv = flopy.plot.PlotMapView(modelgrid=mg_unstruct, ax=ax)
```

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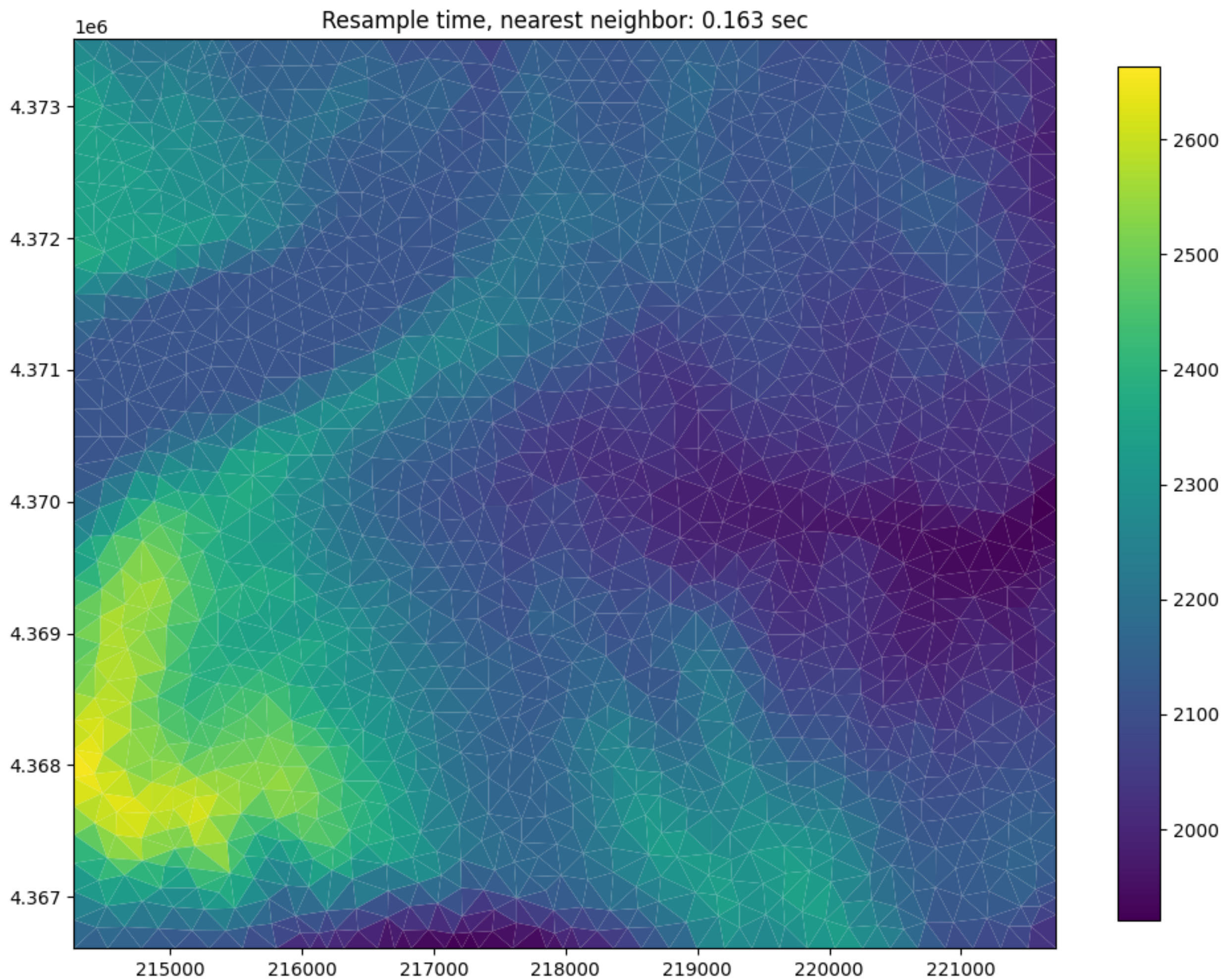
```
ax = pmv.plot_array(
    dem_data,
    masked_values=rio.nodatavals,
    cmap="viridis",
    vmin=vmin,
    vmax=vmax,
)
plt.title(f"Resample time, nearest neighbor: {resample_time:.3f} sec")
plt.colorbar(ax, shrink=0.7)
```

[20]:

```
<matplotlib.colorbar.Colorbar at 0x7f29a1acfc10>
```



[21]:

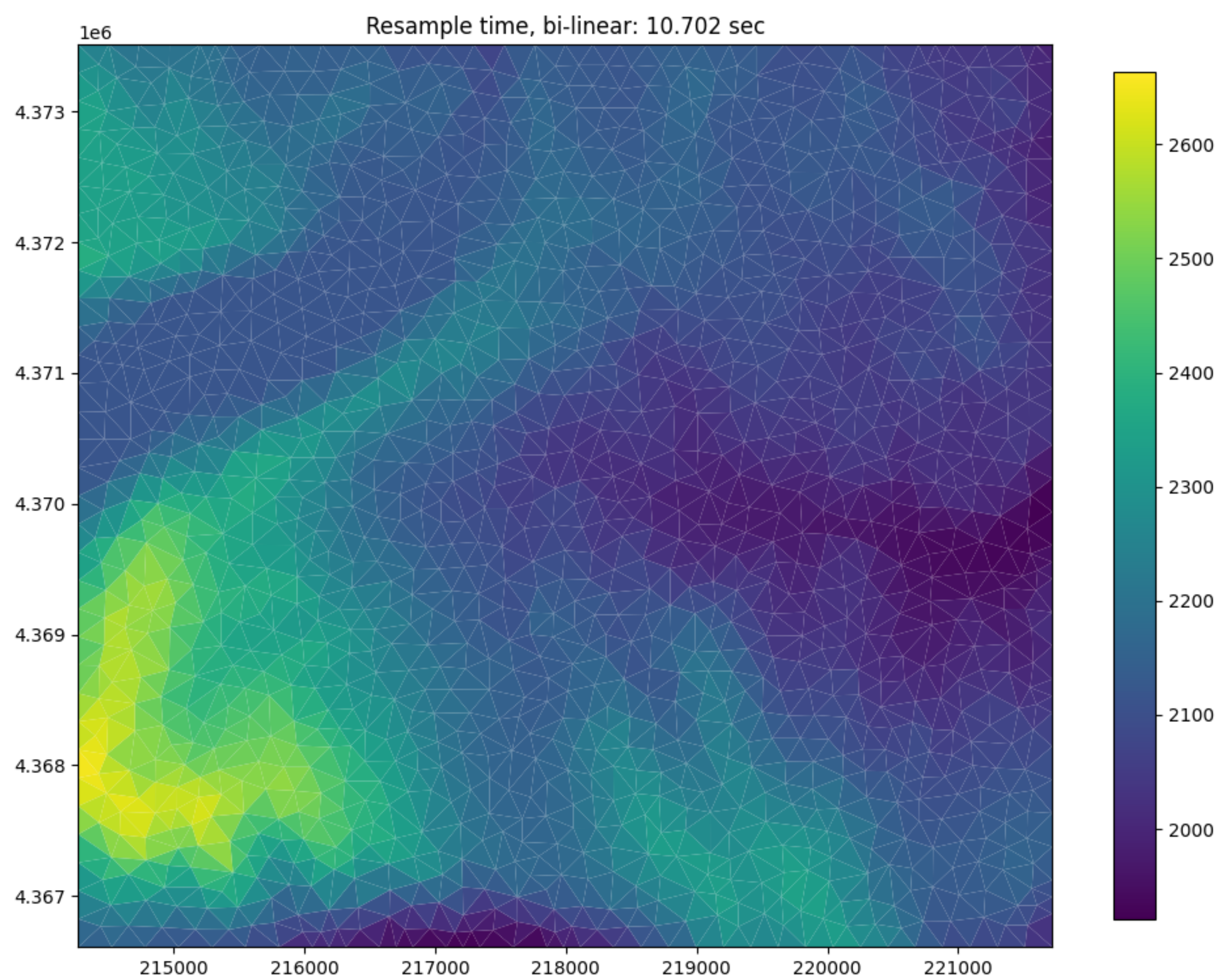
```
t0 = time.time()
dem_data = rio.resample_to_grid(
    mg_unstruct, band=rio.bands[0], method="linear"
)

resample_time = time.time() - t0
```

[22]:
```
# now to visualize using flopy and matplotlib
fig = plt.figure(figsize=(12, 12))
ax = fig.add_subplot(1, 1, 1, aspect="equal")

pmv = flopy.plot.PlotMapView(modelgrid=mg_unstruct, ax=ax)
ax = pmv.plot_array(
    dem_data,
    masked_values=rio.nodatavals,
    cmap="viridis",
    vmin=vmin,
    vmax=vmax,
)
plt.title(f"Resample time, bi-linear: {resample_time:.3f} sec")
plt.colorbar(ax, shrink=0.7)
```

[22]:
```
<matplotlib.colorbar.Colorbar at 0x7f29a1a2eaf0>
```



[23]:
```
t0 = time.time()
dem_data = rio.resample_to_grid(
    mg_unstruct,
    band=rio.bands[0],
```

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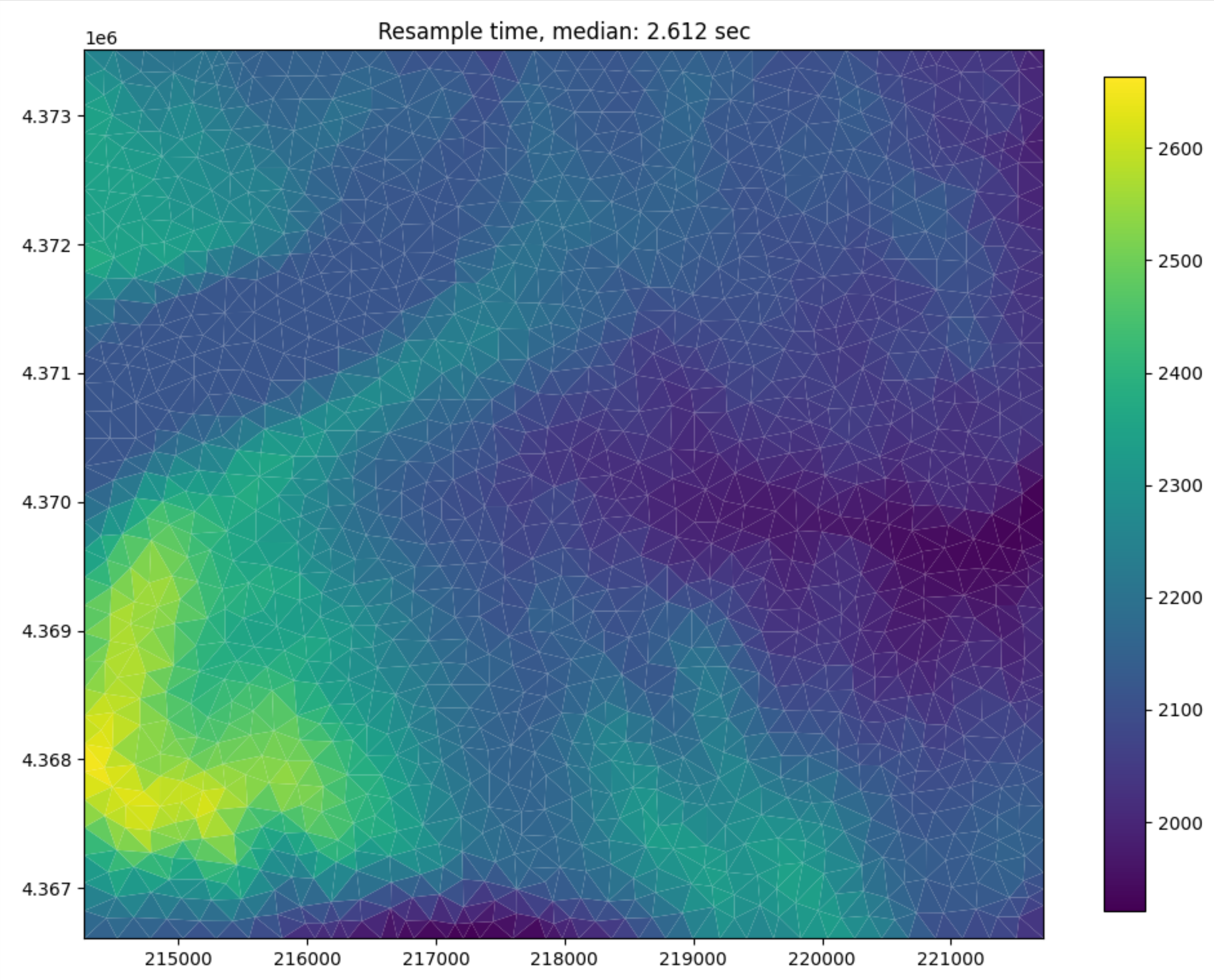
```
    method="median",
)

resample_time = time.time() - t0
```

[24]:
```
# now to visualize using flopy and matplotlib
fig = plt.figure(figsize=(12, 12))
ax = fig.add_subplot(1, 1, 1, aspect="equal")

pmv = flopy.plot.PlotMapView(modelgrid=mg_unstruct, ax=ax)
ax = pmv.plot_array(
    dem_data,
    masked_values=rio.nodatavals,
    cmap="viridis",
    vmin=vmin,
    vmax=vmax,
)
plt.title(f"Resample time, median: {resample_time:.3f} sec")
plt.colorbar(ax, shrink=0.7)
```

[24]:
```
<matplotlib.colorbar.Colorbar at 0x7f29a1a72940>
```



Note: bi-cubic sampling does not work well with triangular meshes and is not recommended for unstructured grids

Sampling points, Cropping, and performing intersections using raster data

The `Raster` class contains useful methods for sampling single points, cross sections, cropping and performing intersections.

The `sample_point()` method can be used to sample a single raster value or to sample a cross section

The `sample_polygon()` method can be used to sample all raster values within an arbitrary polygone

The `crop()` method allows the user to crop the raster in-place. This method can also be used to perform intersections.

The `crop()` and `sample_polygon()` methods apply a modified binary ray casting algorithm for extremely fast intersections. The raster data that's used for this example contains over 500,000 points. For each intersection every point must be segmented as inside or outside of an arbitratry polygon.

Sampling points or a cross section from the raster

The user can also sample from a points within the raster using the `sample_point()` method.

This can be used to create simple cross sections of data, such as an elevation profile

[25]:
```python
d = {"easting": [], "northing": [], "elevation": []}

for adj in range(1, 10000, 100):
    easting = xoff + adj
    northing = yoff + adj
    val = rio.sample_point(xoff + adj, yoff + adj, band=1)
    d["easting"].append(easting)
    d["northing"].append(northing)
    d["elevation"].append(val)

df = pd.DataFrame(d)
```

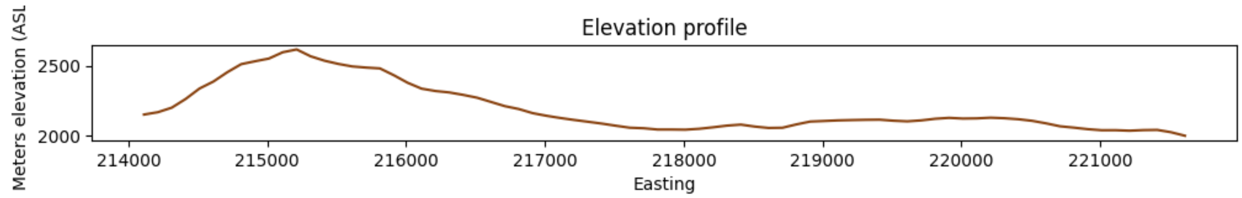
[26]:
```python
fig = plt.figure(figsize=(12, 12))
ax = fig.add_subplot(1, 1, 1, aspect="equal")

ax.plot(df.easting.values, df.elevation.values, color="saddlebrown")
ax.set_ylabel("Meters elevation (ASL)")
ax.set_xlabel("Easting")
ax.set_title("Elevation profile")

df.head()
```

[26]:

	easting	northing	elevation
0	214111	4366621	2149.143311
1	214211	4366721	2165.882812
2	214311	4366821	2198.365234
3	214411	4366921	2260.733643
4	214511	4367021	2335.735596



Sampling all points within a polygon in the raster

The user can also sample all points within an arbitrary polygon within the raster using the `sample_polygon()` method.

The `sample_polygon()` method returns an unordered array of raster values that can be used to perform statical analysis on a chunk of the raster data

[27]:
```python
x0, x1, y0, y1 = rio.bounds

# let's create an a square to use for sampling and cropping
x0 += 1000
```

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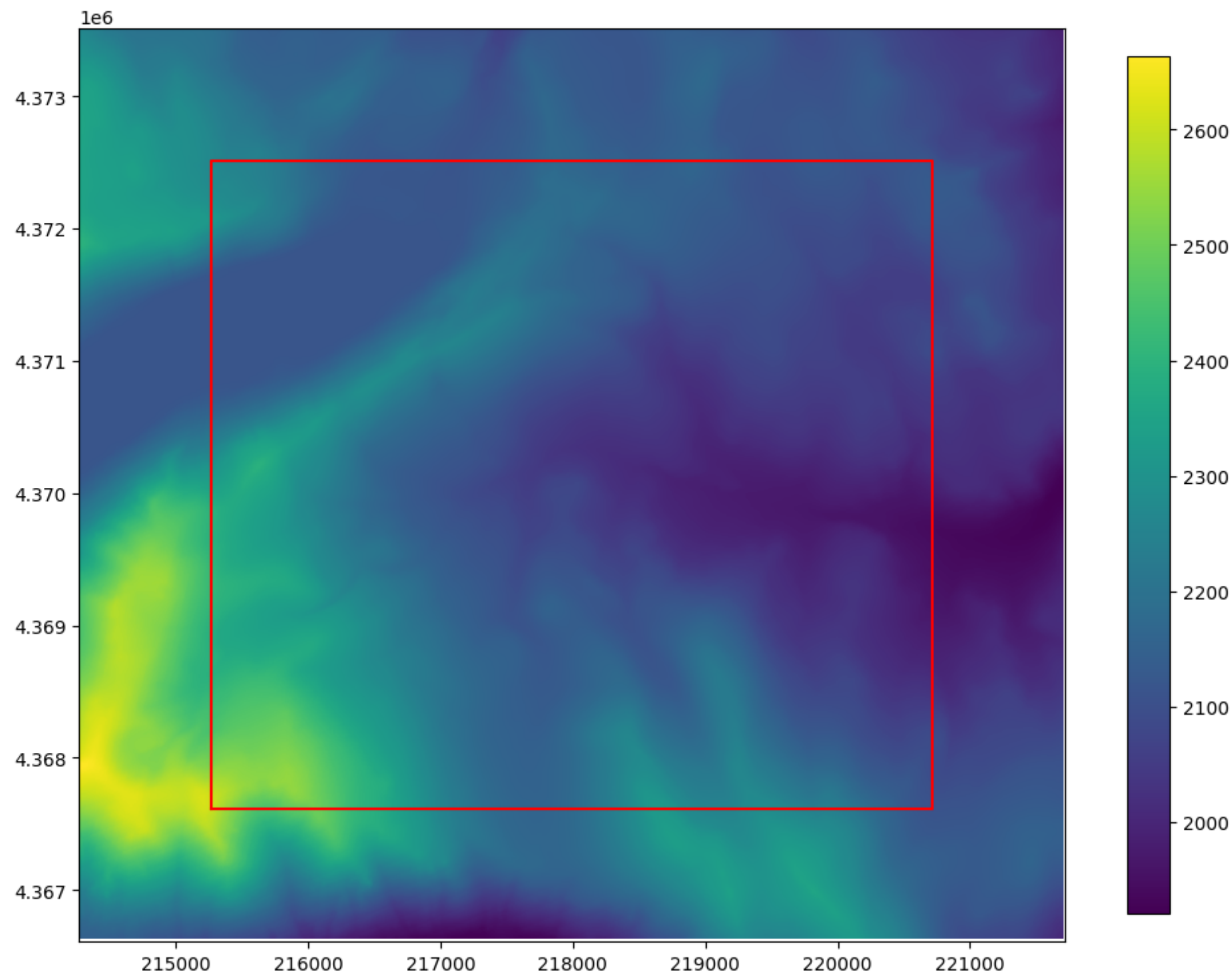
```
y0 += 1000
x1 -= 1000
y1 -= 1000

shape = np.array([(x0, y0), (x0, y1), (x1, y1), (x1, y0), (x0, y0)])
```

[28]:
```
fig = plt.figure(figsize=(12, 12))
ax = fig.add_subplot(1, 1, 1, aspect="equal")

ax = rio.plot(ax=ax, vmin=vmin, vmax=vmax)
ax.plot(shape.T[0], shape.T[1], "r-")
plt.colorbar(ax.images[0], shrink=0.7)
```

[28]: <matplotlib.colorbar.Colorbar at 0x7f29a186f4f0>



[29]:
```
data = rio.sample_polygon(shape, band=rio.bands[0])

mean = np.mean(data)
dmin = np.min(data)
dmax = np.max(data)
```

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```
stdv = np.std(data)

s = "Minimum elevation: {:.2f}\nMaximum elevation: {:.2f}\nMean elevation: {:.2f}\
↪nStandard deviation: {:.2f}"
print(s.format(dmin, dmax, mean, stdv))
```

```
Minimum elevation: 1942.17
Maximum elevation: 2608.56
Mean elevation: 2151.67
Standard deviation: 113.60
```

Cropping and resampling to a modelgrid

The `crop()` method can accept a `list` or `np.array` of vertices, a shapely `Polygon` object, or a GeoJSON dictionary

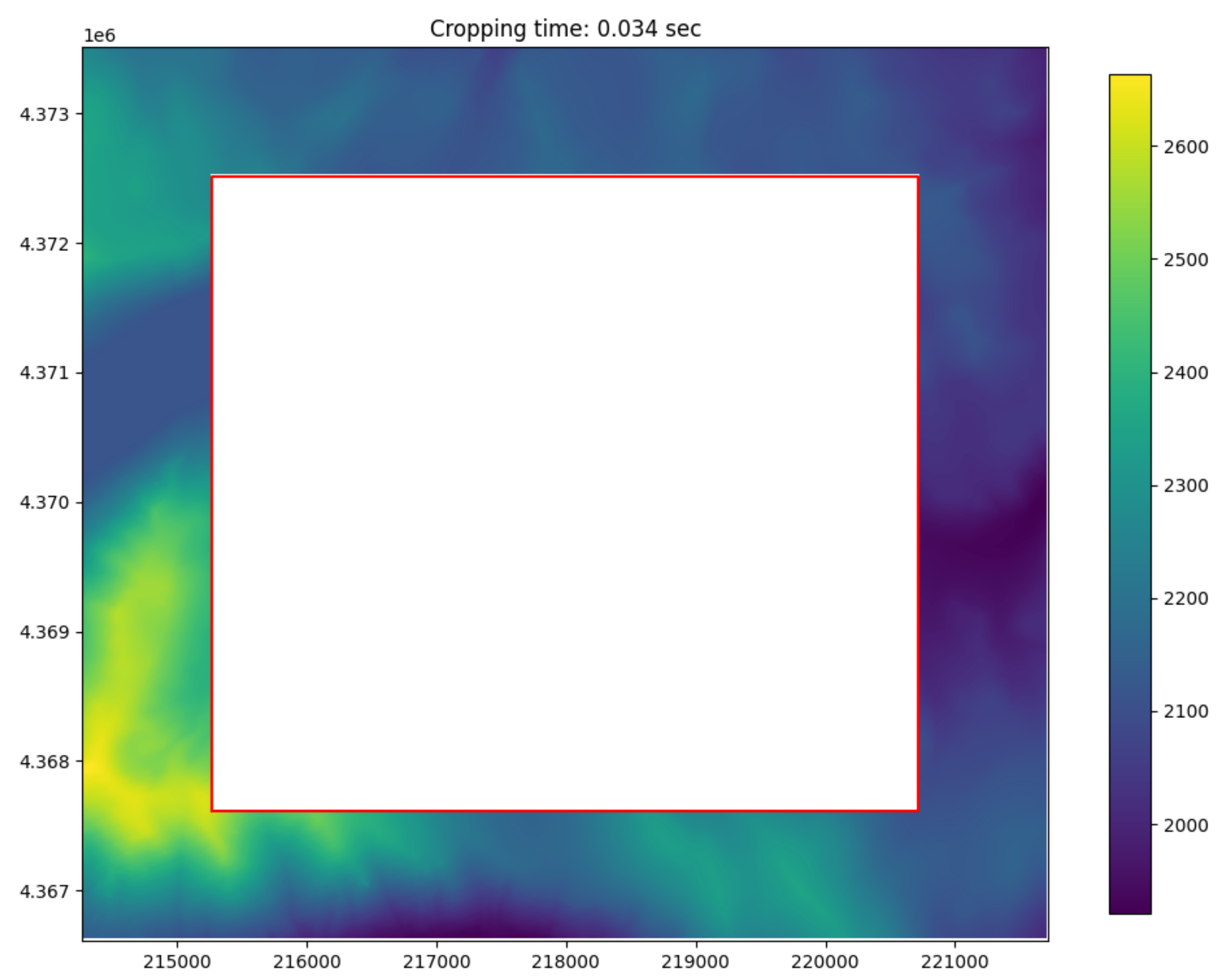
The crop can also be inverted, using `invert=True`

```
[30]: t0 = time.time()
rio.crop(shape, invert=True)
crop_time = time.time() - t0
```

```
[31]: fig = plt.figure(figsize=(12, 12))
ax = fig.add_subplot(1, 1, 1, aspect="equal")

ax = rio.plot(ax=ax, vmin=vmin, vmax=vmax)
ax.plot(shape.T[0], shape.T[1], "r-")
plt.title(f"Cropping time: {crop_time:.3f} sec")
plt.colorbar(ax.images[0], shrink=0.7)
```

```
[31]: <matplotlib.colorbar.Colorbar at 0x7f29a16a01c0>
```



And then this can be re-sampled to a ModelGrid Object

[32]:
```
t0 = time.time()
dem_data = rio.resample_to_grid(
    mg_unstruct, band=rio.bands[0], method="nearest"
)

resample_time = time.time() - t0
```

[33]:
```
# now to visualize using flopy and matplotlib
fig = plt.figure(figsize=(12, 12))
ax = fig.add_subplot(1, 1, 1, aspect="equal")

pmv = flopy.plot.PlotMapView(modelgrid=mg_unstruct, ax=ax)
ax = pmv.plot_array(
    dem_data,
    masked_values=rio.nodatavals,
    cmap="viridis",
    vmin=vmin,
    vmax=vmax,
```

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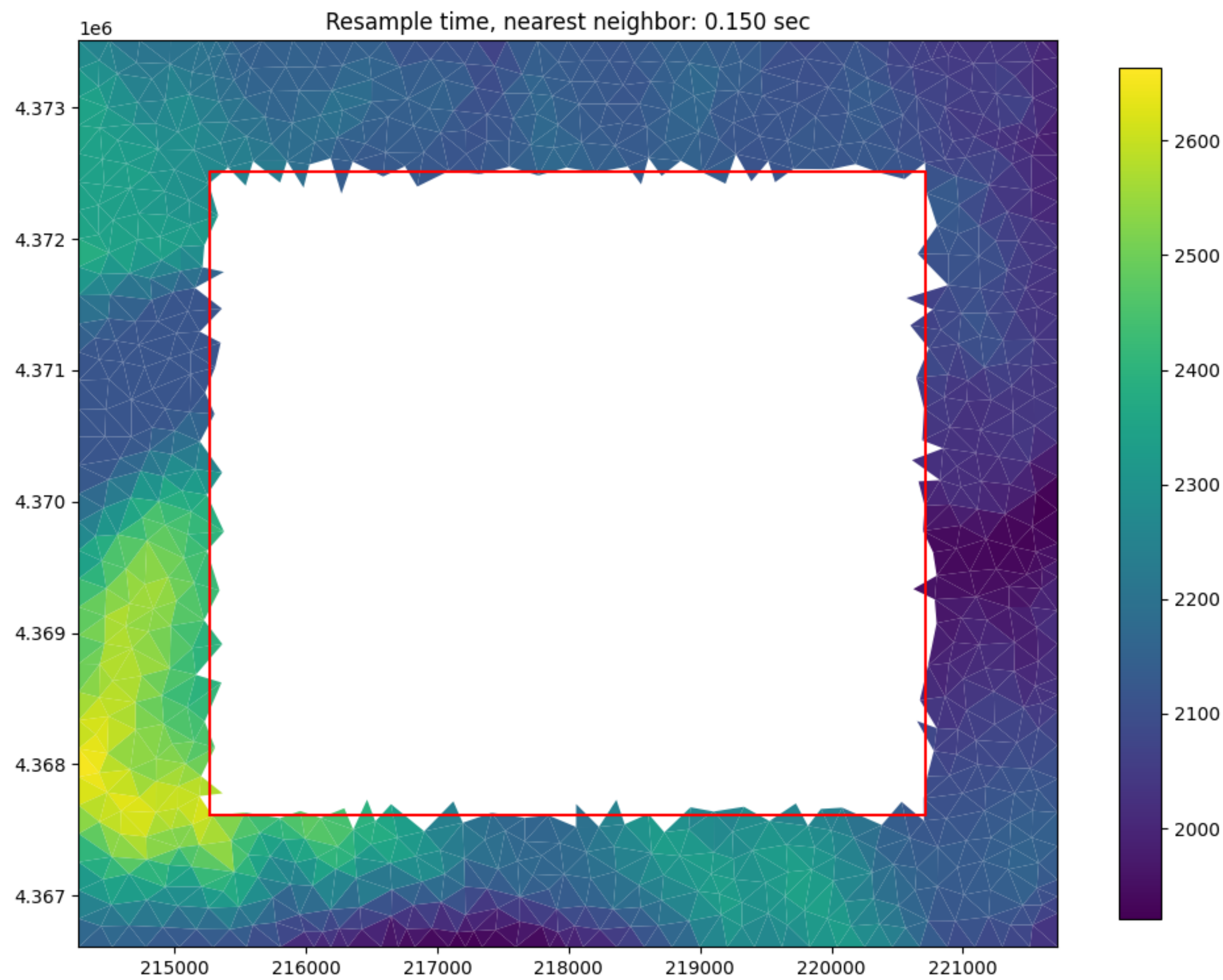
```
)
plt.plot(shape.T[0], shape.T[1], "r-")
plt.title(f"Resample time, nearest neighbor: {resample_time:.3f} sec")
plt.colorbar(ax, shrink=0.7)
```

[33]:

```
<matplotlib.colorbar.Colorbar at 0x7f29a15830d0>
```



[34]:

```
t0 = time.time()
dem_data = rio.resample_to_grid(
    mg_unstruct, band=rio.bands[0], method="linear"
)

resample_time = time.time() - t0
```

[35]:

```
# now to visualize using flopy and matplotlib
fig = plt.figure(figsize=(12, 12))
ax = fig.add_subplot(1, 1, 1, aspect="equal")

pmv = flopy.plot.PlotMapView(modelgrid=mg_unstruct, ax=ax)
ax = pmv.plot_array(
```

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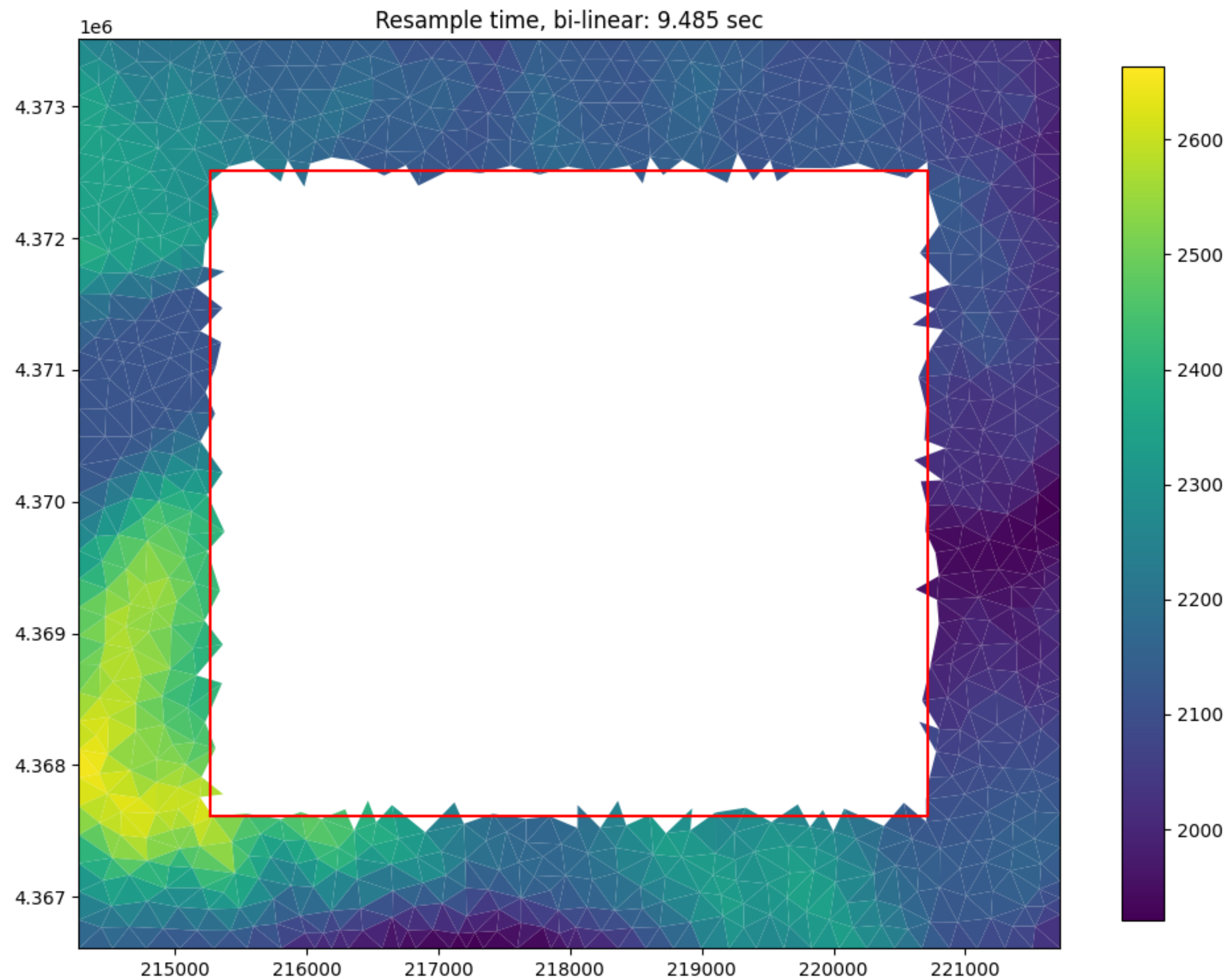
```
    dem_data,
    masked_values=rio.nodatavals,
    cmap="viridis",
    vmin=vmin,
    vmax=vmax,
)
plt.plot(shape.T[0], shape.T[1], "r-")
plt.title(f"Resample time, bi-linear: {resample_time:.3f} sec")
plt.colorbar(ax, shrink=0.7)
```

[35]: <matplotlib.colorbar.Colorbar at 0x7f29a14d9d60>



Arbitrary-shaped model boundaries

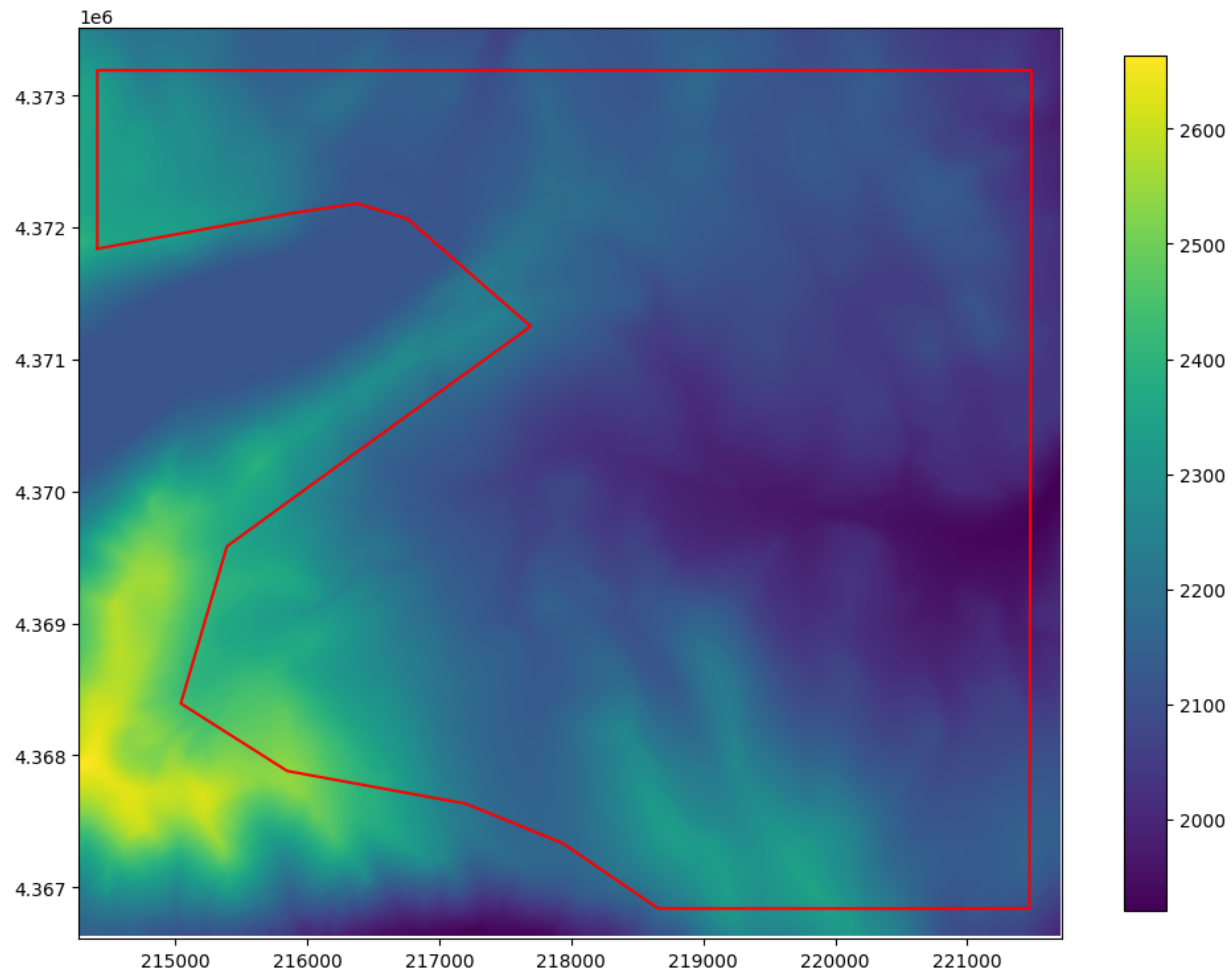
In the example pyshp and shapely are used to get geometry information and then we create a top array and an ibound array using that geometry information

First let's reload the raster (since operations are done in-place) and then load our shapefile data

[36]:
```
rio = Raster.load(os.path.join(raster_ws, raster_name))

shp_name = os.path.join(raster_ws, "model_boundary.shp")

# read in the shapefile
sf = shapefile.Reader(shp_name)
shapes = sf.shapes()
```

[37]:
```
fig = plt.figure(figsize=(12, 12))
ax = fig.add_subplot(1, 1, 1, aspect="equal")

ax = rio.plot(ax=ax, vmin=vmin, vmax=vmax)

# plot the shapes for visualization
for shp in shapes:
    shp = np.array(shp.points).T
    plt.plot(shp[0], shp[1], "r-")
plt.colorbar(ax.images[0], shrink=0.7)
```

[37]:
```
<matplotlib.colorbar.Colorbar at 0x7f29a13c5ac0>
```

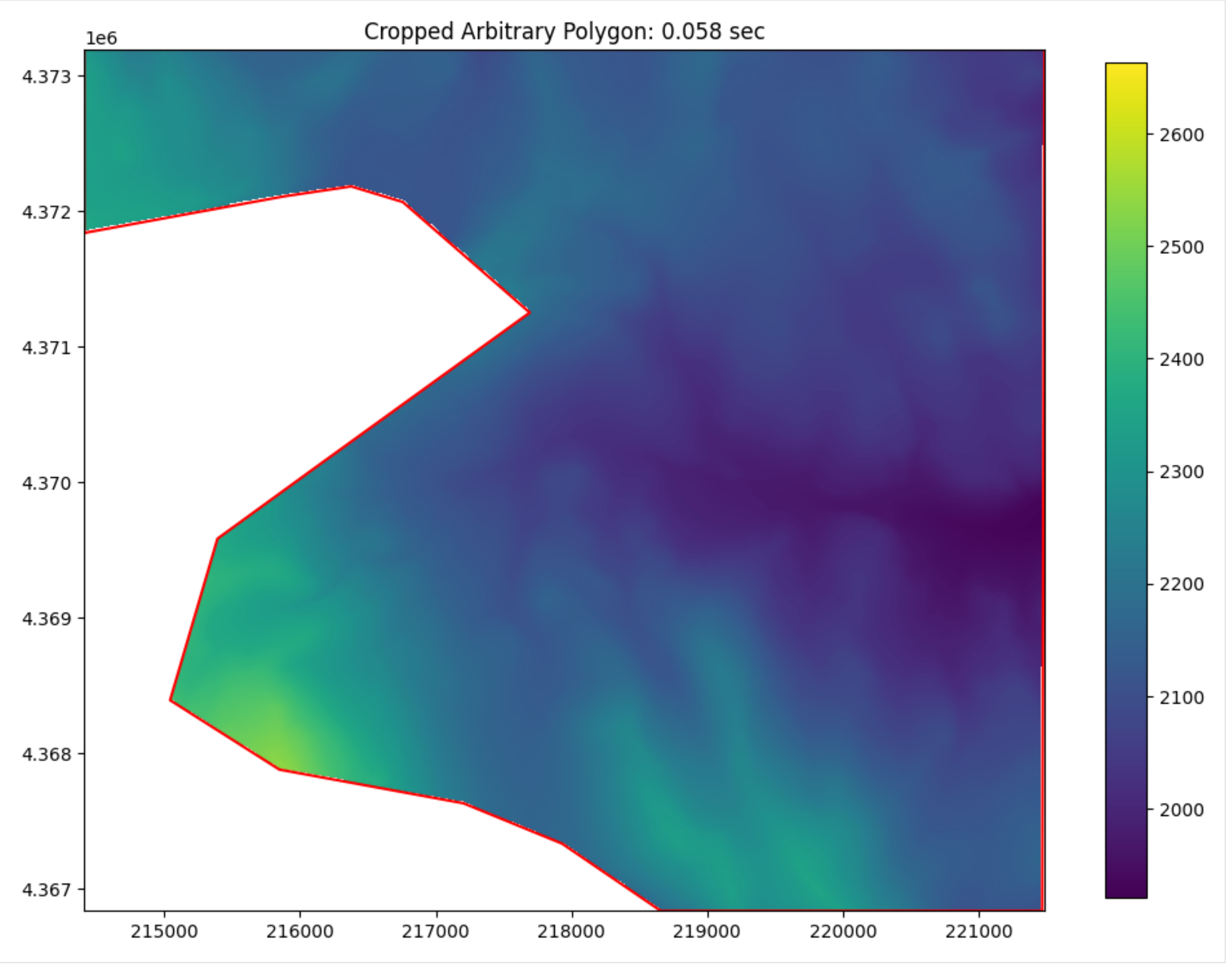


Now we can apply an intersection using the point data directly from the shapefile class

[38]:
```
polygon = shapes[0].points

t0 = time.time()
rio.crop(polygon)
crop_time = time.time() - t0
```

[39]:
```
fig = plt.figure(figsize=(12, 12))
ax = fig.add_subplot(1, 1, 1, aspect="equal")

ax = rio.plot(ax=ax, vmin=vmin, vmax=vmax)

shape = np.array(polygon).T
plt.plot(shape[0], shape[1], "r-")
plt.title(f"Cropped Arbitrary Polygon: {crop_time:.3f} sec")
plt.colorbar(ax.images[0], shrink=0.7)
```

[39]:
```
<matplotlib.colorbar.Colorbar at 0x7f29a132f610>
```



Now the data can be re-sampled to the modelgrid

[40]:
```
top = rio.resample_to_grid(mg_unstruct, band=rio.bands[0], method="linear")

# apply a "realistic" nodataval to top cells outside the model domain
for val in rio.nodatavals:
    top[top == val] = 3500

# create an ibound array
ibound = np.ones(top.shape, dtype=int)
ibound[top == 3500] = 0
```

[41]:
```
# now to visualize using flopy and matplotlib
fig = plt.figure(figsize=(12, 12))
ax = fig.add_subplot(1, 1, 1, aspect="equal")

pmv = flopy.plot.PlotMapView(modelgrid=mg_unstruct, ax=ax)
ax = pmv.plot_array(
    top,
    masked_values=[
        3500,
```

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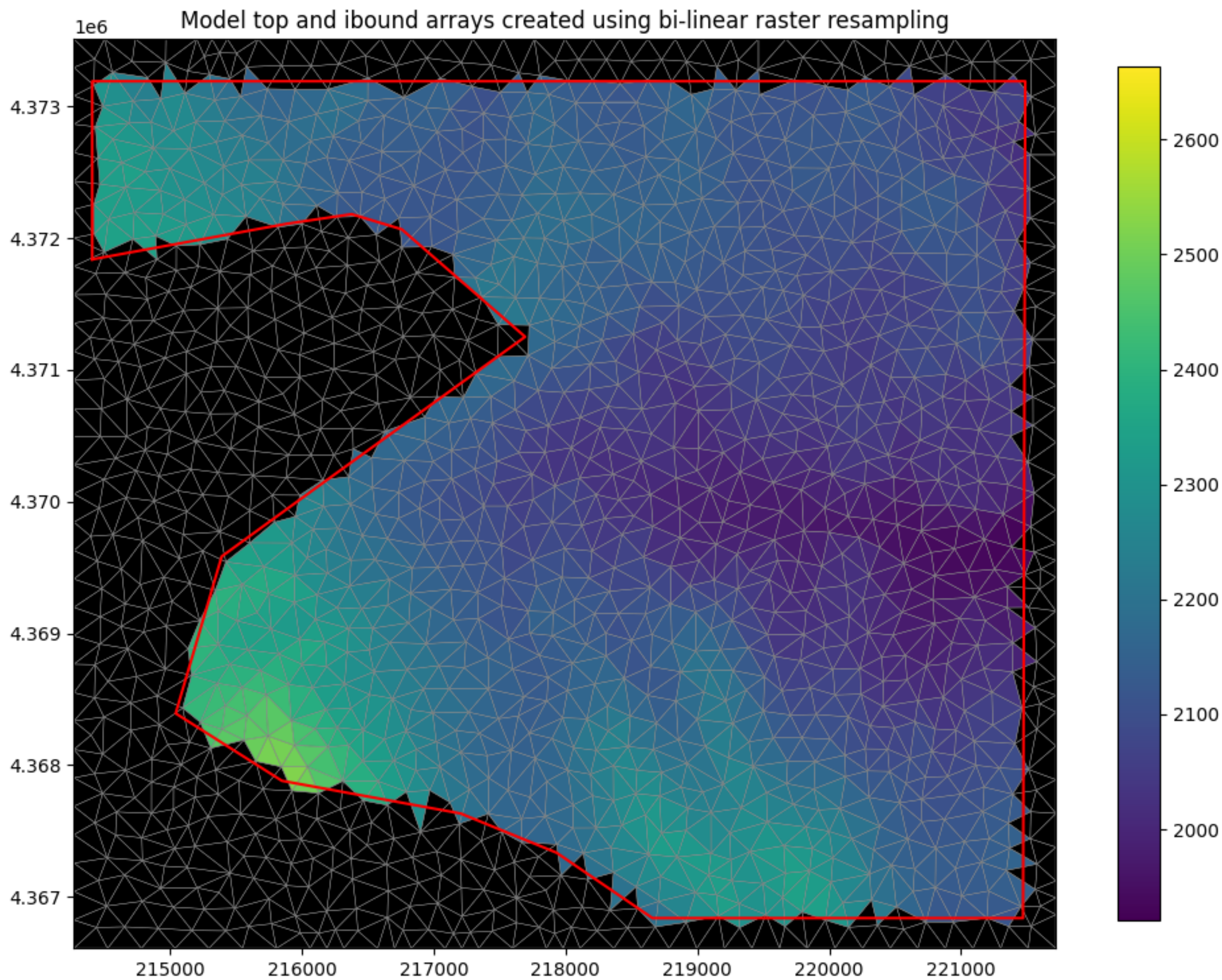
```
    ],
    cmap="viridis",
    vmin=vmin,
    vmax=vmax,
)
ib = pmv.plot_ibound(ibound)
pmv.plot_grid(linewidth=0.3)
plt.plot(shape[0], shape[1], "r-")
plt.title(
    "Model top and ibound arrays created using bi-linear raster resampling"
)
plt.colorbar(ax, shrink=0.7)
```

[41]:
```
<matplotlib.colorbar.Colorbar at 0x7f2968cb6790>
```



The `ibound` array and the `top` array can be used to build or edit the BAS and DIS file objects in FloPy

Future development

Potential features that draw on this functionality could include: + intersection with multiple polygons + flow accumulation to develop SFR networks + streambed topology from raster layers + intersection with layers of derived parameters based on multiple raster bands

[42]:
```
try:
    # ignore PermissionError on Windows
    temp_dir.cleanup()
except:
    pass
```

6.2 Postprocessing and Visualization

6.2.1 Plotting SWR Process Results

This notebook demonstrates the use of the `SwrObs` and `SwrStage`, `SwrBudget`, `SwrFlow`, and `SwrExchange`, `SwrStructure`, classes to read binary SWR Process observation, stage, budget, reach to reach flows, reach-aquifer exchange, and structure files. It demonstrates these capabilities by loading these binary file types and showing examples of plotting SWR Process data. An example showing how the simulated water surface profile at a selected time along a selection of reaches can be plotted is also presented.

[1]:
```
import os
import sys
```

[2]:
```
import matplotlib as mpl
import matplotlib.pyplot as plt
import numpy as np
```

[3]:
```
from IPython.display import Image

# run installed version of flopy or add local path
try:
    import flopy
except:
    fpth = os.path.abspath(os.path.join("..", ".."))
    sys.path.append(fpth)
    import flopy

print(sys.version)
print(f"numpy version: {np.__version__}")
print(f"matplotlib version: {mpl.__version__}")
print(f"flopy version: {flopy.__version__}")
```

```
3.8.18 (default, Aug 28 2023, 08:27:22)
[GCC 11.4.0]
numpy version: 1.24.4
matplotlib version: 3.7.4
flopy version: 3.5.0
```

```
[4]: # Set the paths
datapath = os.path.join("..", "..", "examples", "data", "swr_test")

# SWR Process binary files
files = ("SWR004.obs", "SWR004.vel", "SWR004.str", "SWR004.stg", "SWR004.flow")
```

Load SWR Process observations

Create an instance of the SwrObs class and load the observation data.

```
[5]: sobj = flopy.utils.SwrObs(os.path.join(datapath, files[0]))

ts = sobj.get_data()
```

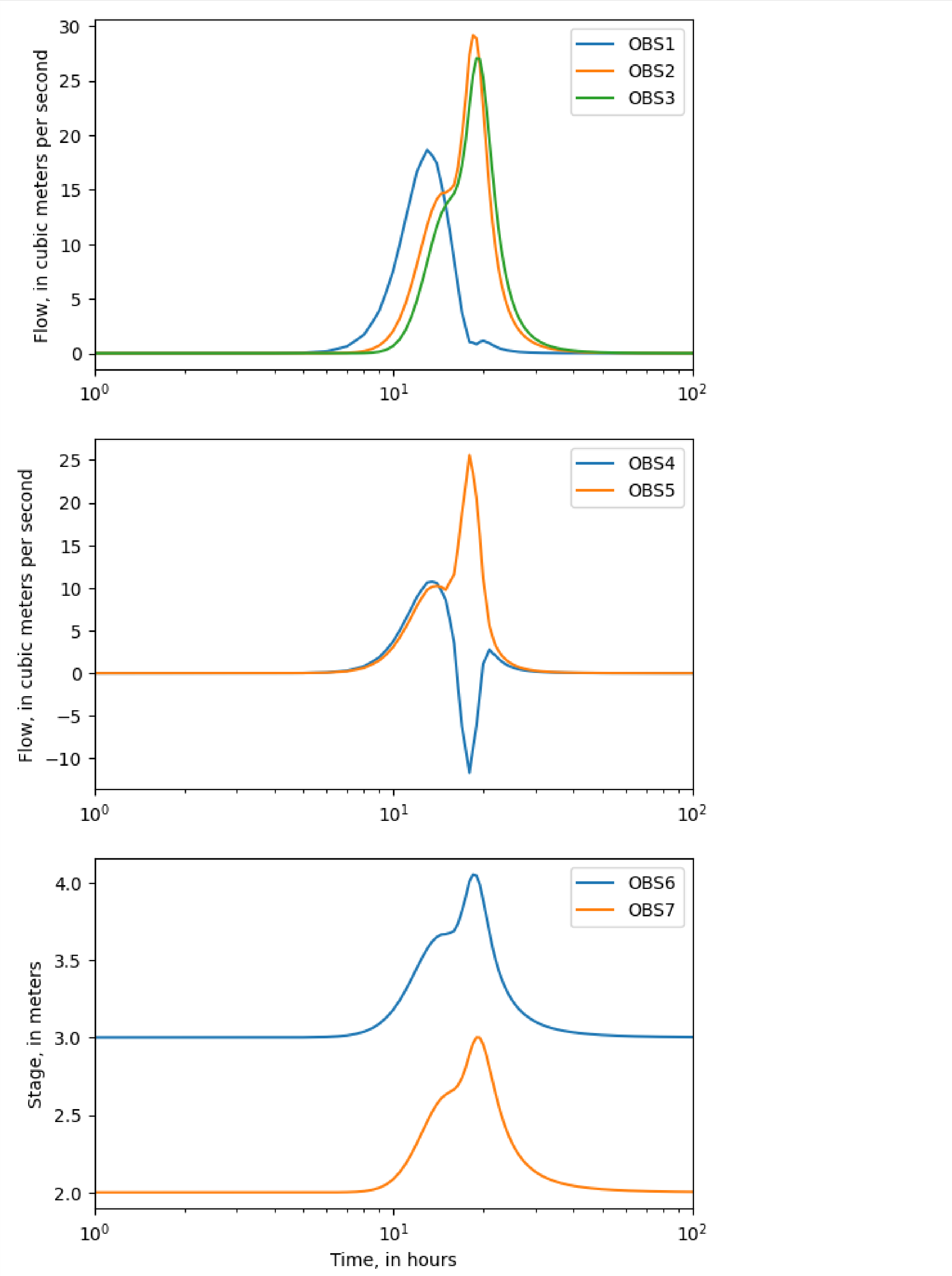
Plot the data from the binary SWR Process observation file

```
[6]: fig = plt.figure(figsize=(6, 12))
ax1 = fig.add_subplot(3, 1, 1)
ax1.semilogx(ts["totim"] / 3600.0, -ts["OBS1"], label="OBS1")
ax1.semilogx(ts["totim"] / 3600.0, -ts["OBS2"], label="OBS2")
ax1.semilogx(ts["totim"] / 3600.0, -ts["OBS9"], label="OBS3")
ax1.set_ylabel("Flow, in cubic meters per second")
ax1.legend()

ax = fig.add_subplot(3, 1, 2, sharex=ax1)
ax.semilogx(ts["totim"] / 3600.0, -ts["OBS4"], label="OBS4")
ax.semilogx(ts["totim"] / 3600.0, -ts["OBS5"], label="OBS5")
ax.set_ylabel("Flow, in cubic meters per second")
ax.legend()

ax = fig.add_subplot(3, 1, 3, sharex=ax1)
ax.semilogx(ts["totim"] / 3600.0, ts["OBS6"], label="OBS6")
ax.semilogx(ts["totim"] / 3600.0, ts["OBS7"], label="OBS7")
ax.set_xlim(1, 100)
ax.set_ylabel("Stage, in meters")
ax.set_xlabel("Time, in hours")
ax.legend()
```

```
[6]: <matplotlib.legend.Legend at 0x7f3a639b3b20>
```



OBS1
OBS2
OBS3
Flow, in cubic meters per second
OBS4
OBS5
Flow, in cubic meters per second
OBS6
OBS7
Stage, in meters
Time, in hours

Load the same data from the individual binary SWR Process files

Load discharge data from the flow file. The flow file contains the simulated flow between connected reaches for each connection in the model.

[7]:
```
sobj = flopy.utils.SwrFlow(os.path.join(datapth, files[1]))
times = np.array(sobj.get_times()) / 3600.0
obs1 = sobj.get_ts(irec=1, iconn=0)
obs2 = sobj.get_ts(irec=14, iconn=13)
obs4 = sobj.get_ts(irec=4, iconn=3)
obs5 = sobj.get_ts(irec=5, iconn=4)
```

Load discharge data from the structure file. The structure file contains the simulated structure flow for each reach with a structure.

[8]:
```
sobj = flopy.utils.SwrStructure(os.path.join(datapth, files[2]))
obs3 = sobj.get_ts(irec=17, istr=0)
```

Load stage data from the stage file. The flow file contains the simulated stage for each reach in the model.

[9]:
```
sobj = flopy.utils.SwrStage(os.path.join(datapth, files[3]))
obs6 = sobj.get_ts(irec=13)
```

Load budget data from the budget file. The budget file contains the simulated budget for each reach group in the model. The budget file also contains the stage data for each reach group. In this case the number of reach groups equals the number of reaches in the model.

[10]:
```
sobj = flopy.utils.SwrBudget(os.path.join(datapth, files[4]))
obs7 = sobj.get_ts(irec=17)
```

Plot the data loaded from the individual binary SWR Process files.

Note that the plots are identical to the plots generated from the binary SWR observation data.

[11]:
```
fig = plt.figure(figsize=(6, 12))
ax1 = fig.add_subplot(3, 1, 1)
ax1.semilogx(times, obs1["flow"], label="OBS1")
ax1.semilogx(times, obs2["flow"], label="OBS2")
ax1.semilogx(times, -obs3["strflow"], label="OBS3")
ax1.set_ylabel("Flow, in cubic meters per second")
ax1.legend()

ax = fig.add_subplot(3, 1, 2, sharex=ax1)
ax.semilogx(times, obs4["flow"], label="OBS4")
ax.semilogx(times, obs5["flow"], label="OBS5")
ax.set_ylabel("Flow, in cubic meters per second")
ax.legend()

ax = fig.add_subplot(3, 1, 3, sharex=ax1)
ax.semilogx(times, obs6["stage"], label="OBS6")
ax.semilogx(times, obs7["stage"], label="OBS7")
ax.set_xlim(1, 100)
ax.set_ylabel("Stage, in meters")
```

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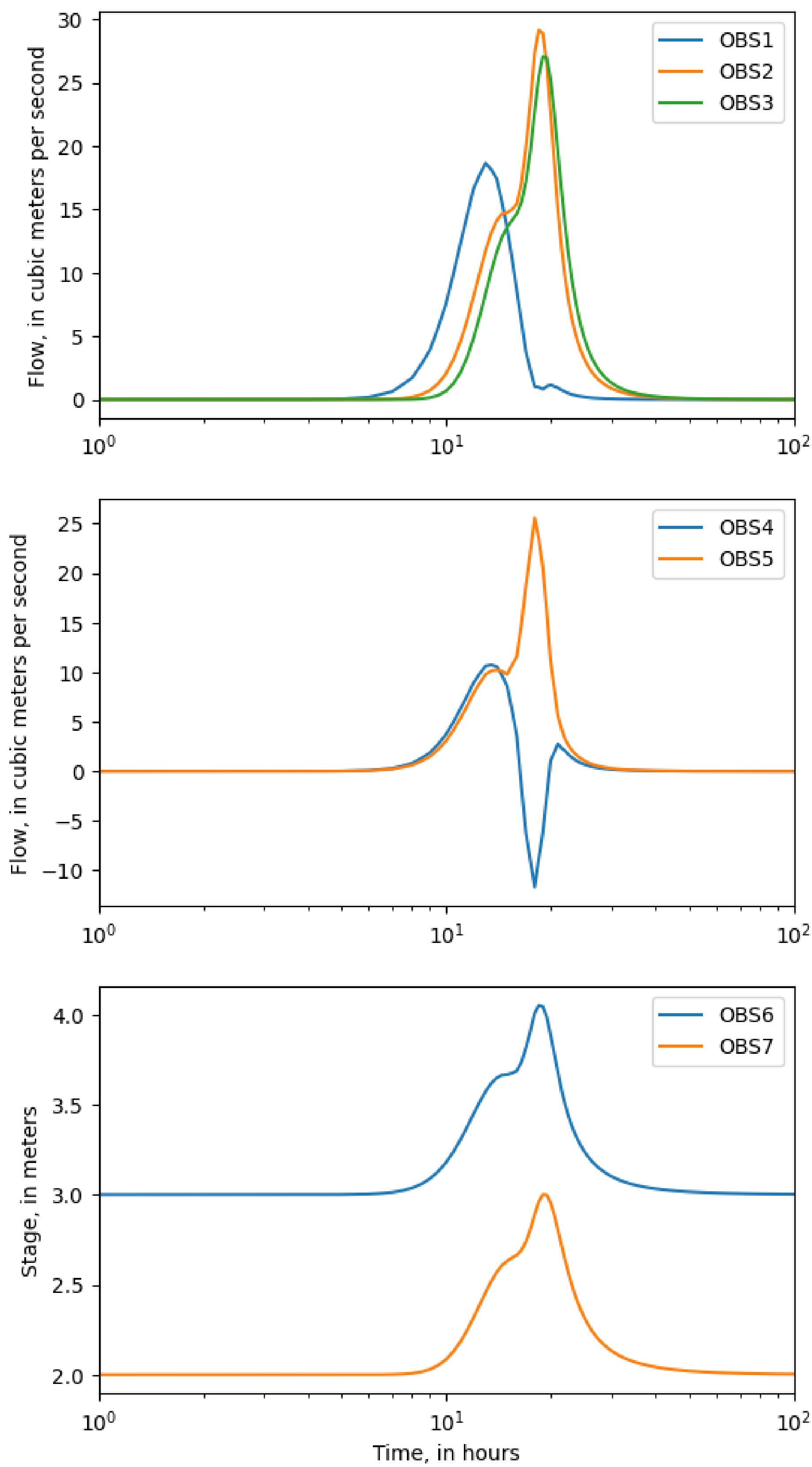
```
ax.set_xlabel("Time, in hours")
ax.legend()
```

[11]:

```
<matplotlib.legend.Legend at 0x7f3a6117f4f0>
```


Flow, in cubic meters per second
OBS1
OBS2
OBS3
Flow, in cubic meters per second
OBS4
OBS5
Stage, in meters
OBS6
OBS7
Time, in hours

Plot simulated water surface profiles

Simulated water surface profiles can be created using the `ModelCrossSection` class.

Several things that we need in addition to the stage data include reach lengths and bottom elevations. We load these data from an existing file.

[12]:
```
sd = np.genfromtxt(os.path.join(datapth, "SWR004.dis.ref"), names=True)
```

The contents of the file are shown in the cell below.

[13]:
```
fc = open(os.path.join(datapth, "SWR004.dis.ref")).readlines()
fc
```

[13]:
```
['   IRCH    RLEN      BELEV\n',
 '      1   1000.        2.0\n',
 '      2    500.       1.83\n',
 '      3    500.       1.83\n',
 '      4   1000.       1.67\n',
 '      5   1000.       1.50\n',
 '      6   1000.       1.33\n',
 '      7   1000.       1.17\n',
 '      8    500.        1.0\n',
 '      9    500.       1.83\n',
 '     10   1118.       1.65\n',
 '     11   1118.       1.41\n',
 '     12   1000.       1.17\n',
 '     13    500.        1.0\n',
 '     14    500.        1.0\n',
 '     15   1000.       0.75\n',
 '     16   1000.       0.50\n',
 '     17   1000.       0.25\n',
 '     18   1000.        0.0']
```

Create an instance of the `SwrStage` class for SWR Process stage data.

[14]:
```
sobj = flopy.utils.SwrStage(os.path.join(datapth, files[3]))
```

Create a selection condition (`iprof`) that can be used to extract data for the reaches of interest (reaches 0, 1, and 8 through 17). Use this selection condition to extract reach lengths (from `sd['RLEN']`) and the bottom elevation (from `sd['BELEV']`) for the reaches of interest. The selection condition will also be used to extract the stage data for reaches of interest.

[15]:
```
iprof = sd["IRCH"] > 0
iprof[2:8] = False
dx = np.extract(iprof, sd["RLEN"])
belev = np.extract(iprof, sd["BELEV"])
```

Create a fake model instance so that the `ModelCrossSection` class can be used.

[16]:
```
ml = flopy.modflow.Modflow()
dis = flopy.modflow.ModflowDis(
    ml,
    nrow=1,
    ncol=dx.shape[0],
```

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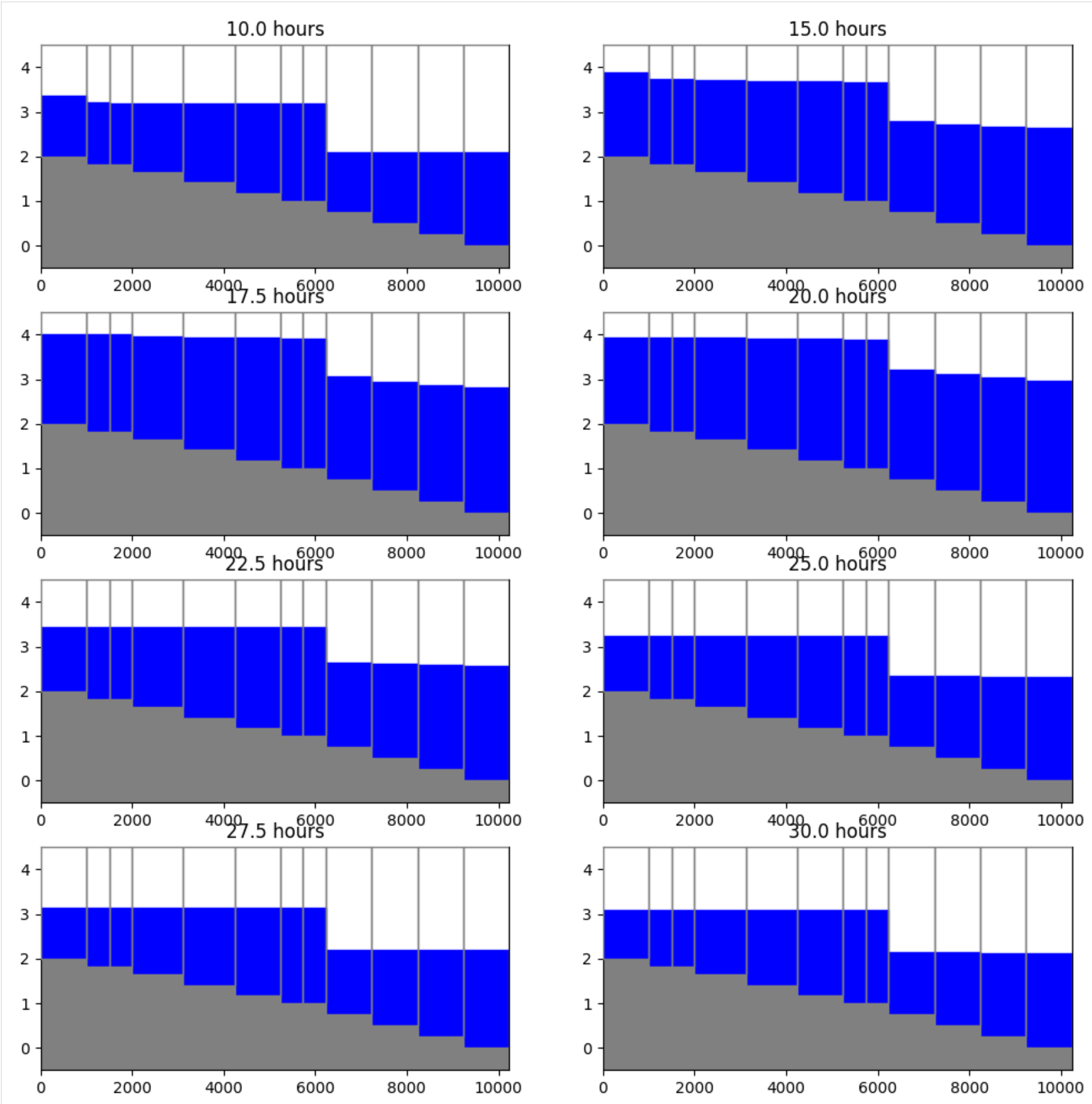
```
    delr=dx,
    top=4.5,
    botm=belev.reshape(1, 1, 12),
)
```

Create an array with the x position at the downstream end of each reach, which will be used to color the plots below each reach.

[17]:
```
x = np.cumsum(dx)
```

Plot simulated water surface profiles for 8 times.

[18]:
```
fig = plt.figure(figsize=(12, 12))
for idx, v in enumerate([19, 29, 34, 39, 44, 49, 54, 59]):
    ax = fig.add_subplot(4, 2, idx + 1)
    s = sobj.get_data(idx=v)
    stage = np.extract(iprof, s["stage"])
    xs = flopy.plot.PlotCrossSection(model=ml, line={"Row": 0})
    xs.plot_fill_between(
        stage.reshape(1, 1, 12),
        colors=["none", "blue"],
        ax=ax,
        edgecolors="none",
    )
    linecollection = xs.plot_grid(ax=ax, zorder=10)
    ax.fill_between(
        np.append(0.0, x),
        y1=np.append(belev[0], belev),
        y2=-0.5,
        facecolor="0.5",
        edgecolor="none",
        step="pre",
    )
    ax.set_title(f"{times[v]} hours")
    ax.set_ylim(-0.5, 4.5)
```



This notebook demonstrates flopy functionality for reading binary output generated by the SWR Process. Binary files that can be read include observations, stages, budgets, flow, reach-aquifer exchanges, and structure data. The binary stage data can also be used to create water-surface profiles.

Hope this gets you started!

6.2.2 Plotting Model Arrays and Results

This notebook demonstrates the simple array and results plotting capabilities of flopy. It demonstrates these capabilities by loading and running an existing model, and then showing how the `.plot()` method can be used to make simple plots of the model data and model results.

[1]:
```
import os
import sys
from tempfile import TemporaryDirectory
```

[2]:
```
import matplotlib as mpl
import matplotlib.pyplot as plt
import numpy as np
```

[3]:
```
from IPython.display import Image

# run installed version of flopy or add local path
try:
    import flopy
except:
    fpth = os.path.abspath(os.path.join("..", ".."))
    sys.path.append(fpth)
    import flopy

print(sys.version)
print(f"numpy version: {np.__version__}")
print(f"matplotlib version: {mpl.__version__}")
print(f"flopy version: {flopy.__version__}")
```

```
3.8.18 (default, Aug 28 2023, 08:27:22)
[GCC 11.4.0]
numpy version: 1.24.4
matplotlib version: 3.7.4
flopy version: 3.5.0
```

[4]:
```
# Set name of MODFLOW exe
#  assumes executable is in users path statement
version = "mf2005"
exe_name = "mf2005"

# Set the paths
loadpth = os.path.join("..", "..", "examples", "data", "secp")

# temporary directory
temp_dir = TemporaryDirectory()
modelpth = temp_dir.name

# make sure modelpth directory exists
if not os.path.isdir(modelpth):
    os.makedirs(modelpth, exist_ok=True)

files = ["secp.hds"]
```

Load and Run an Existing Model

A model called the "Southeast Coastal Plain Model" is located in the loadpth folder. In the following code block, we load that model, then change into a new workspace (modelpth) where we recreate and run the model. For this to work properly, the MODFLOW-2005 executable (mf2005) must be in the path. We verify that it worked correctly by checking for the presence of secp.hds.

[5]:
```
ml = flopy.modflow.Modflow.load(
    "secp.nam", model_ws=loadpth, exe_name=exe_name, version=version
)
ml.change_model_ws(new_pth=modelpth)
ml.write_input()

success, buff = ml.run_model(silent=True)
if not success:
    print("Something bad happened.")

# confirm that the model files have been created
for f in files:
    if os.path.isfile(os.path.join(modelpth, f)):
        msg = f"Output file located: {f}"
        print(msg)
    else:
        errmsg = f"Error. Output file cannot be found: {f}"
        print(errmsg)
```

```
Output file located: secp.hds
```

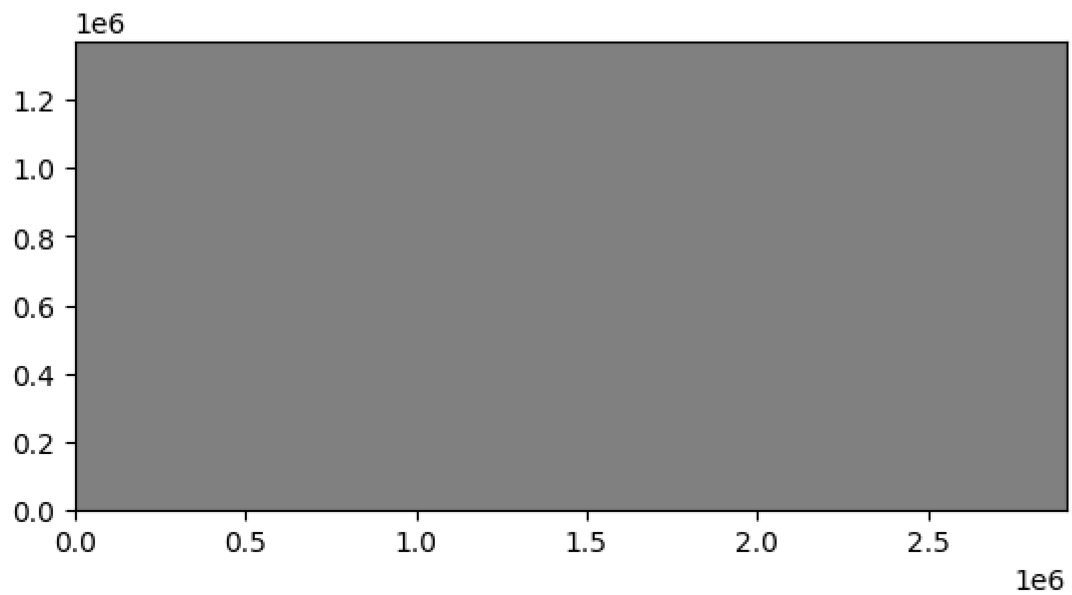
Plotting Model Data

Once a model object is created MODFLOW package data can be plotted using the `.plot()` method.

Two-dimensional data (for example the model top) can be plotted by calling the `.plot()` method for each data array.

[6]:
```
ml.modelgrid.plot()
```

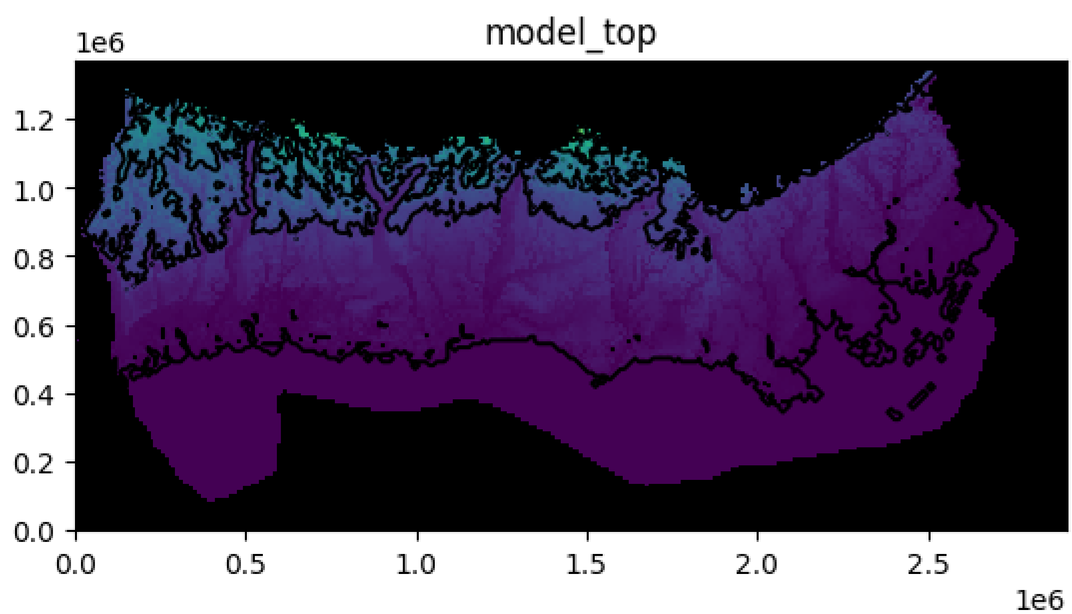
[6]:
```
<matplotlib.collections.LineCollection at 0x7f47922102b0>
```



As you can see, the `.plot()` methods returns a `matplotlib.pyplot` axis object, which can be used to add additional data to the figure. Below we will add black contours to the axis returned in the first line.

[7]:
```
ax = ml.dis.top.plot()
ml.dis.top.plot(axes=ax, contour=True, pcolor=False)
```

[7]:
```
<Axes: title={'center': 'model_top'}>
```




```
<Figure size 640x480 with 0 Axes>
```

You will notice that we passed several keywords in the second line. There are a number of keywords that can be passed to the `.plot()` method to control plotting. Available keywords are:

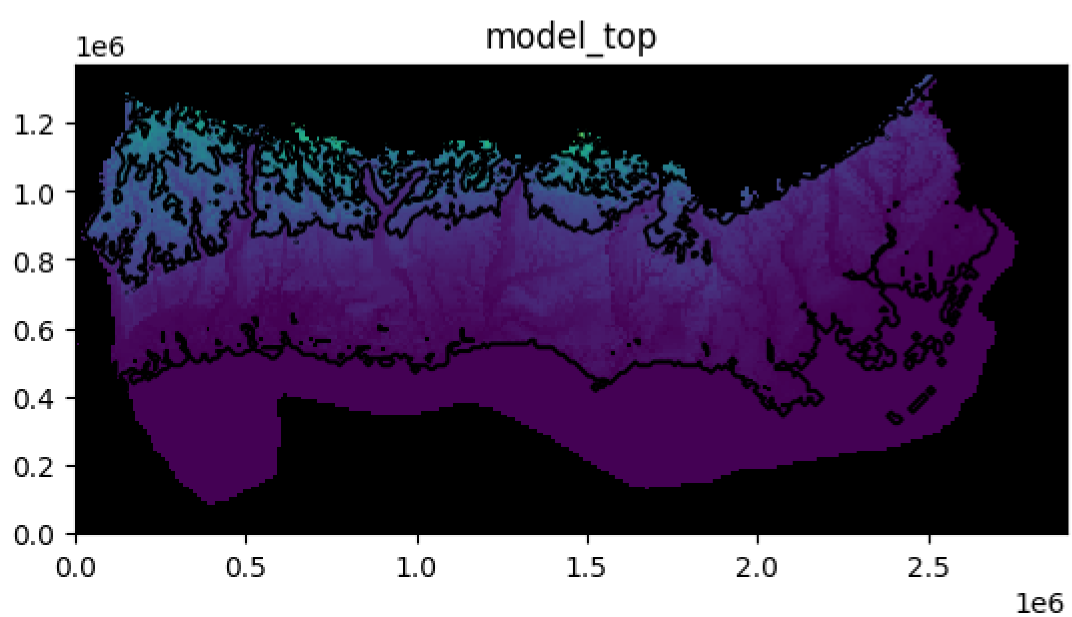
1. `axes` - if you already have plot axes you can pass them to the method

2. `pcolor` - turns pcolor on if `pcolor=True` or off if `pcolor=False`, default is `pcolor=True`
3. `colorbar` - turns on colorbar if `colorbar=True` or off if `colorbar=False`, default is `colorbar=False` and is only used if `pcolor=True`
4. `inactive` - turns on a black inactive cell overlay if `inactive=True` or turns off the inactive cell overlay if `inactive=False`, default is `inactive=True`
5. `contour` - turns on contours if `contour=True` or off if `contour=False`, default is `contour=False`
6. `clabel` - turns on contour labels if `clabel=True` or off if `clabel=False`, default is `clabel=False` and is only used if `contour=True`
7. `grid` - turns on model grid if `grid=True` or off if `grid=False`, default is `grid=False`
8. `masked_values` - list with unique values to be excluded from the plot (for example, HNOFLO)
9. `mflay` - for three-dimensional data (for example layer bottoms or simulated heads) `mflay` can be used to plot data for a single layer - note `mflay` is zero-based
10. `kper` - for transient two-dimensional data (for example recharge package data) `kper` can be used to plot data for a single stress period - note `kper` is zero-based
11. `filename_base` - a base file name that will be used to automatically generate file names for two-dimensional, three-dimensional, and transient two-dimensional data, default is `filename_base=None`
12. `file_extension` - valid `matplotlib` file extension, default is `png` and is only used if `filename_base` is specified
13. `matplotlib.pyplot` keywords are also accepted

The previous code block is recreated in a single line using keywords in the code block below.

[8]:
```
ml.dis.top.plot(contour=True)
```

[8]:
```
<Axes: title={'center': 'model_top'}>
```



We can save the same image to a file.

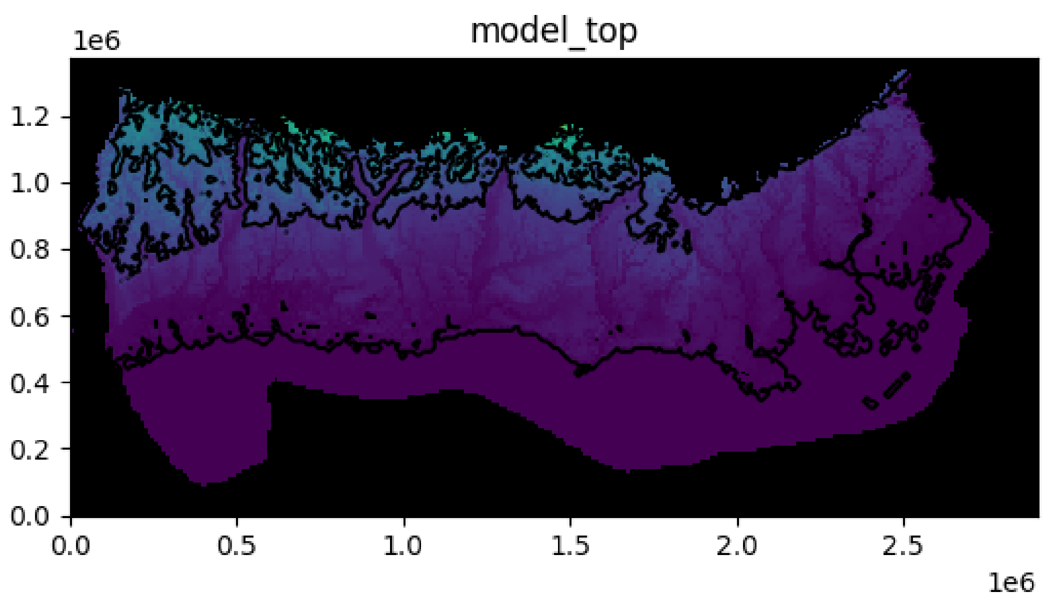
[9]:
```
fname = os.path.join(modelpth, "secp")
ml.dis.top.plot(contour=True, filename_base=fname)
```

```
created...secp_model_top.png
```

The image file that was just created is shown below

[10]:
```
fname = os.path.join(modelpth, "secp_model_top.png")
Image(filename=fname)
```

[10]:



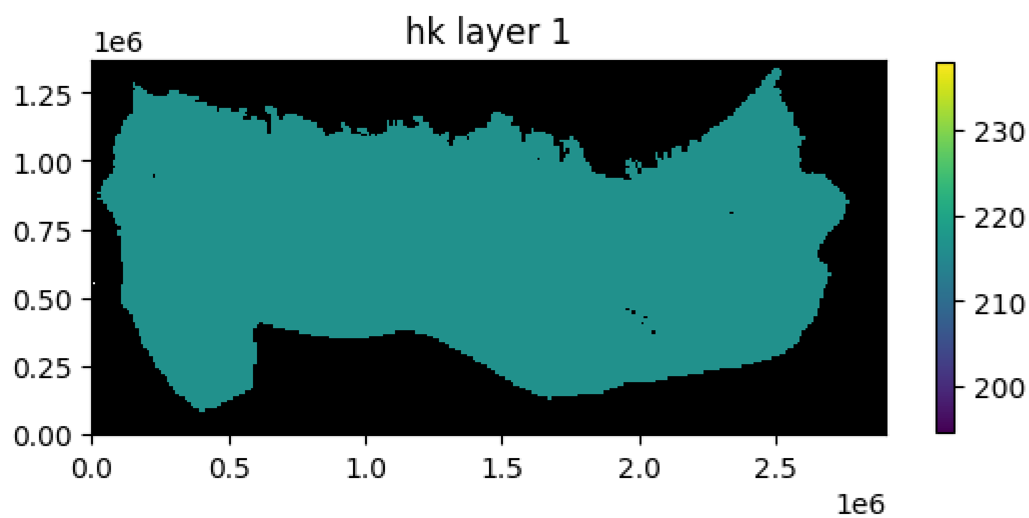
Plotting three-dimensional data

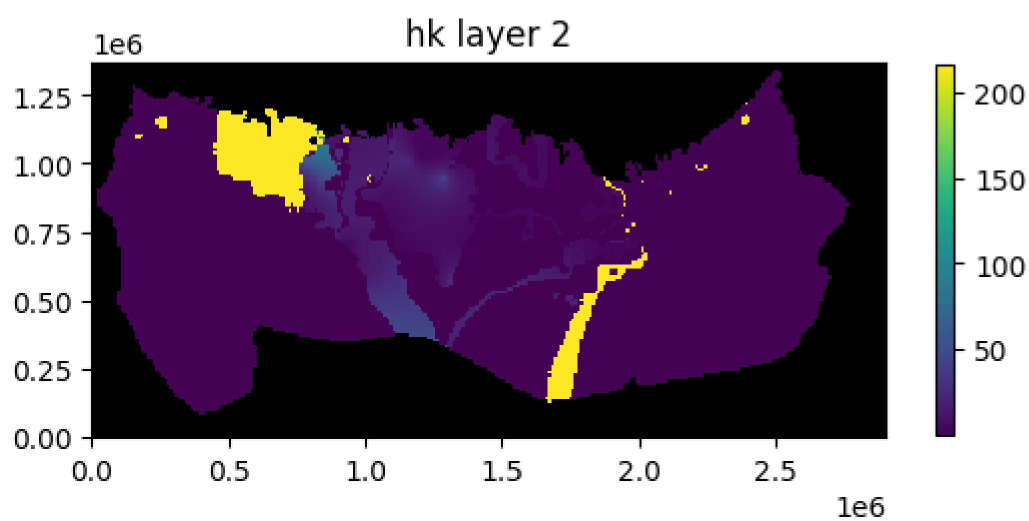
Three-dimensional data can be plotted using the `.plot()` method. User's do not actually need to know that the data are two- or three-dimensional. The `.plot()` method is attached to the two- and three-dimensional data objects so it knows how to process the model data. Examples of three-dimensional data are horizontal hydraulic conductivity (`hk`), layer bottoms (`botm`), specific yield (`sy`), *etc.*

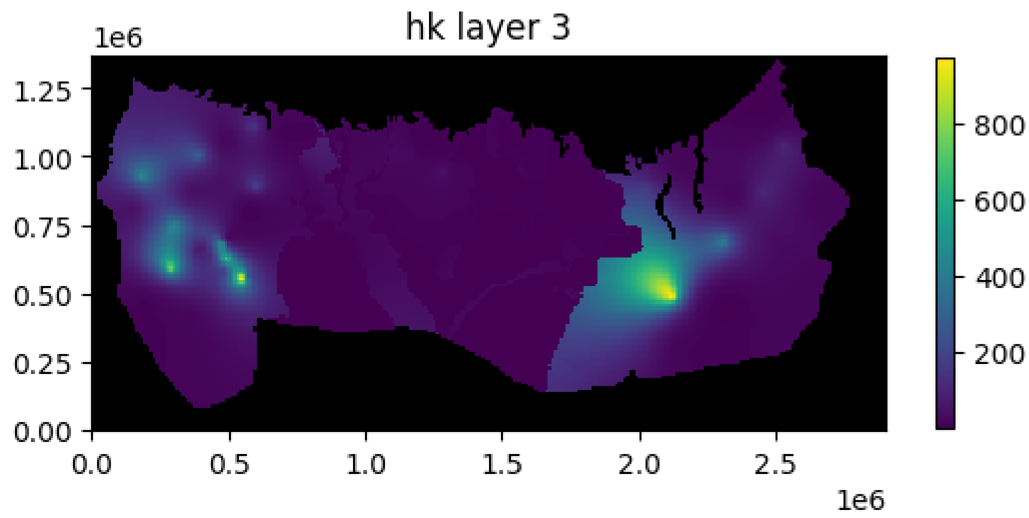
Here we plot the horizontal hydraulic conductivity for each layer. We are also masking areas where the horizontal hydraulic conductivity is zero and adding a color bar.

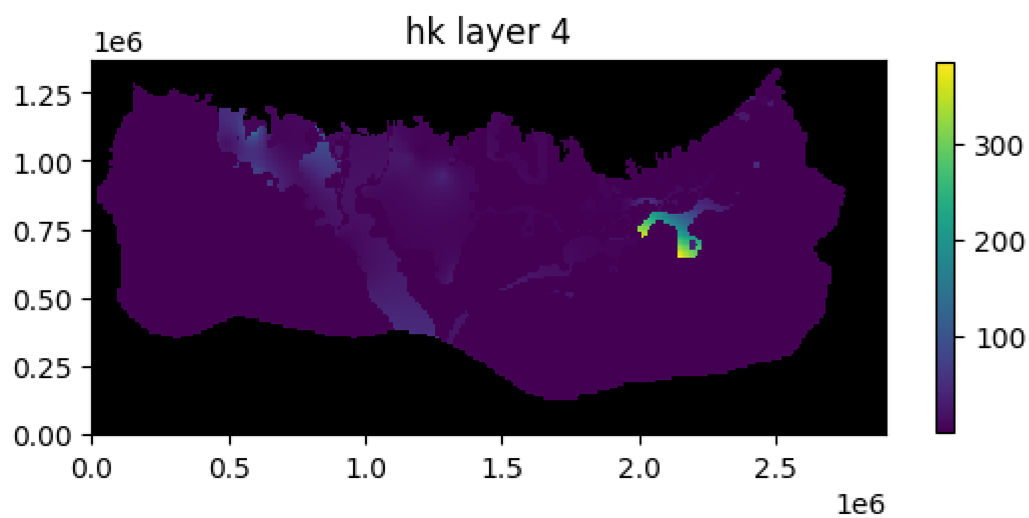
[11]:
```
ml.lpf.hk.plot(masked_values=[0.0], colorbar=True)
```

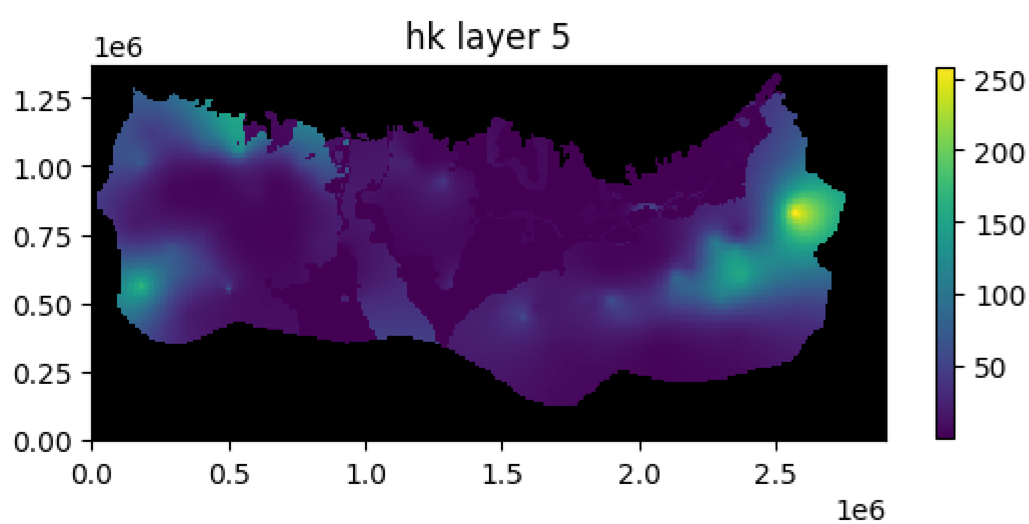
[11]:
```
[<Axes: title={'center': 'hk layer 1'}>,
 <Axes: title={'center': 'hk layer 2'}>,
 <Axes: title={'center': 'hk layer 3'}>,
 <Axes: title={'center': 'hk layer 4'}>,
 <Axes: title={'center': 'hk layer 5'}>,
 <Axes: title={'center': 'hk layer 6'}>,
 <Axes: title={'center': 'hk layer 7'}>,
 <Axes: title={'center': 'hk layer 8'}>,
 <Axes: title={'center': 'hk layer 9'}>,
 <Axes: title={'center': 'hk layer 10'}>,
 <Axes: title={'center': 'hk layer 11'}>,
 <Axes: title={'center': 'hk layer 12'}>,
 <Axes: title={'center': 'hk layer 13'}>,
 <Axes: title={'center': 'hk layer 14'}>,
 <Axes: title={'center': 'hk layer 15'}>,
 <Axes: title={'center': 'hk layer 16'}>]
```

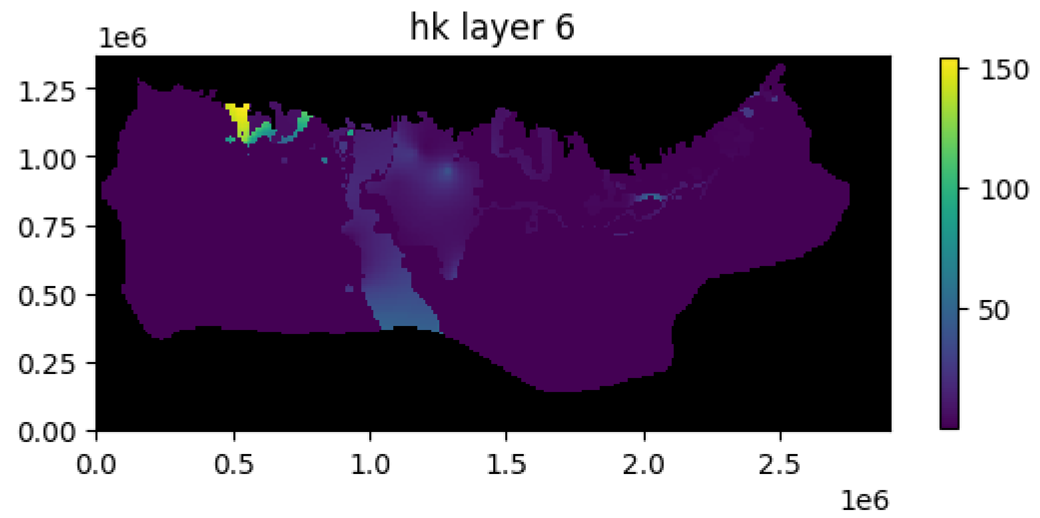


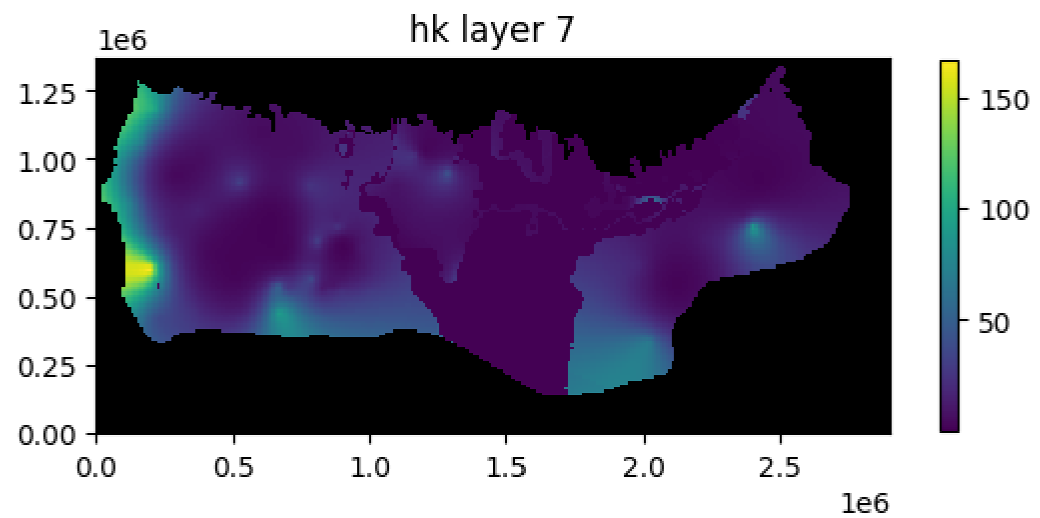


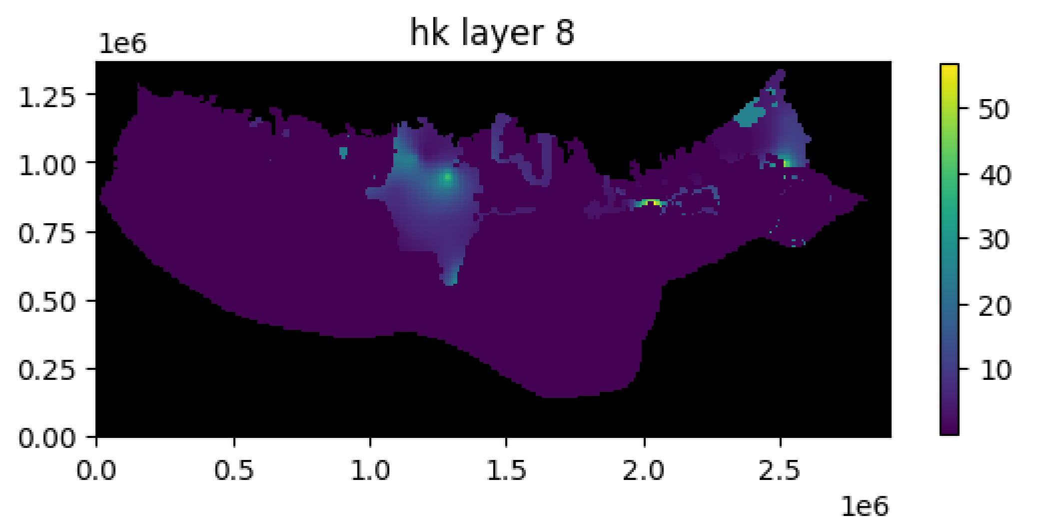

hk layer 3
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
800
600
400
200

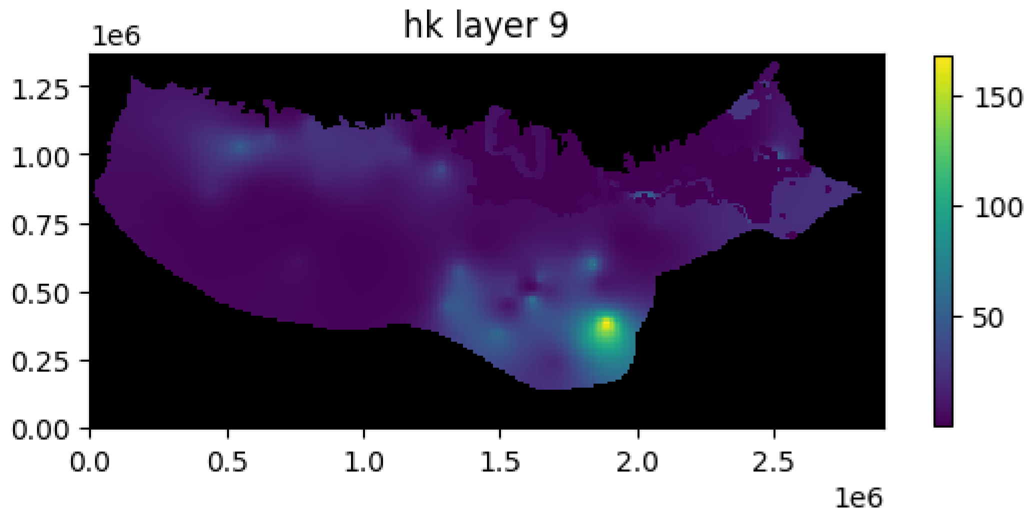

hk layer 4
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
300
200
100

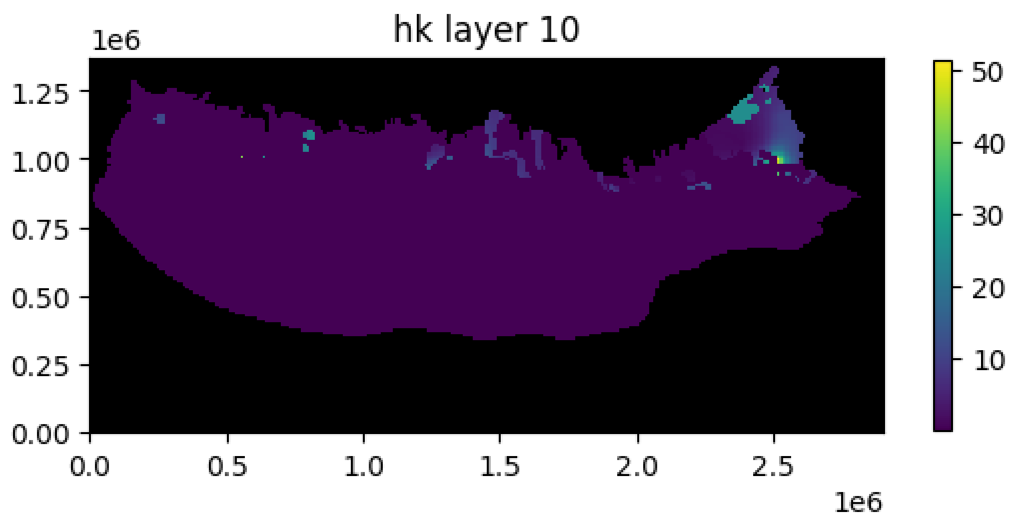

hk layer 5
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
250
200
150
100
50

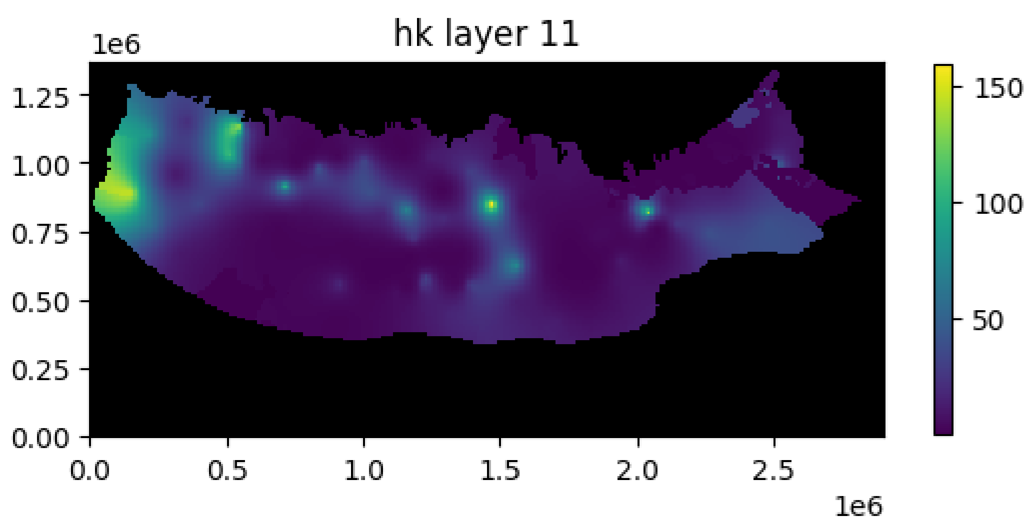

hk layer 6
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
150
100
50

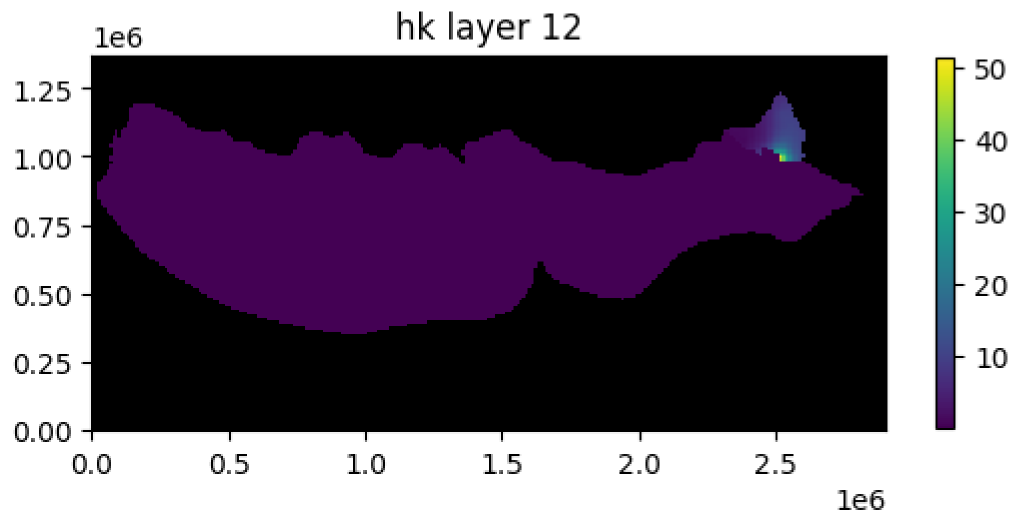

hk layer 7
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
150
100
50

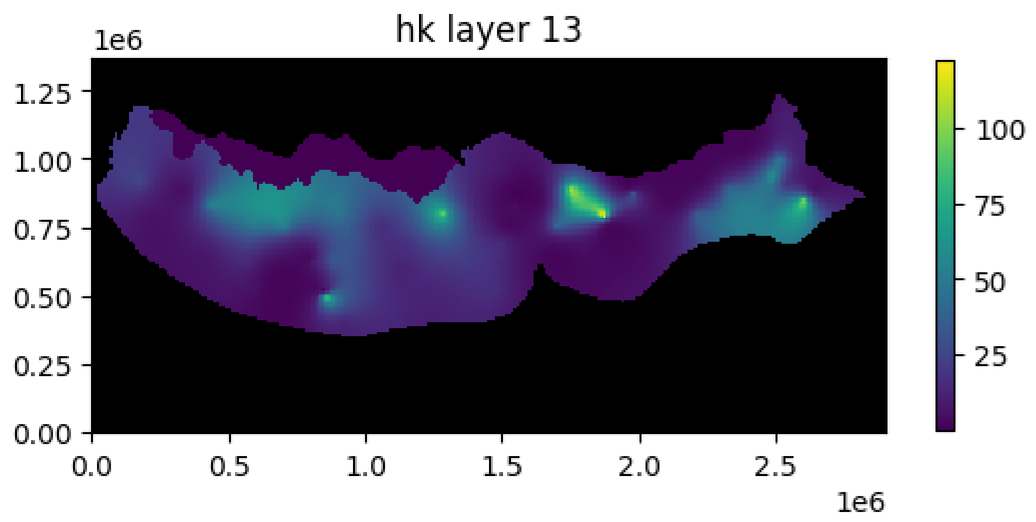

hk layer 8
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
50
40
30
20
10

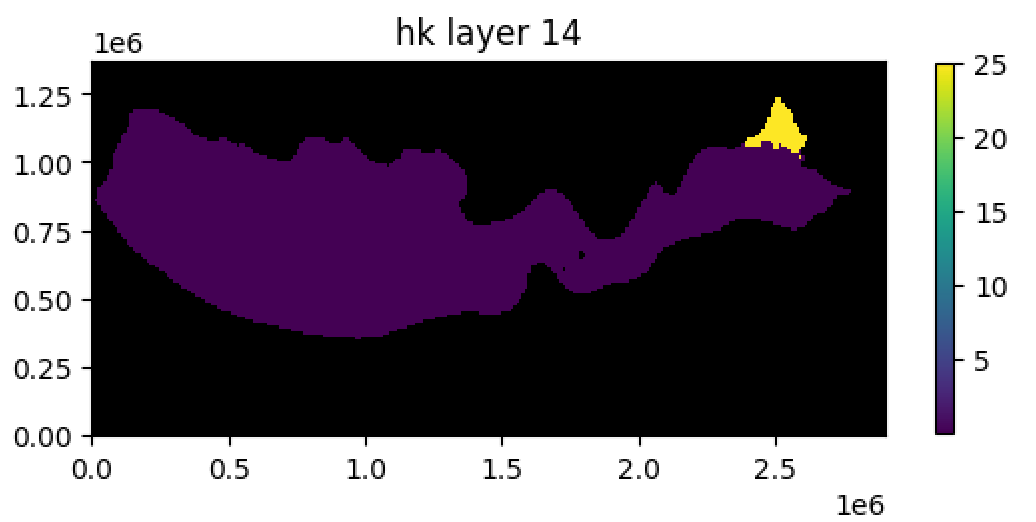

hk layer 9
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
150
100
50

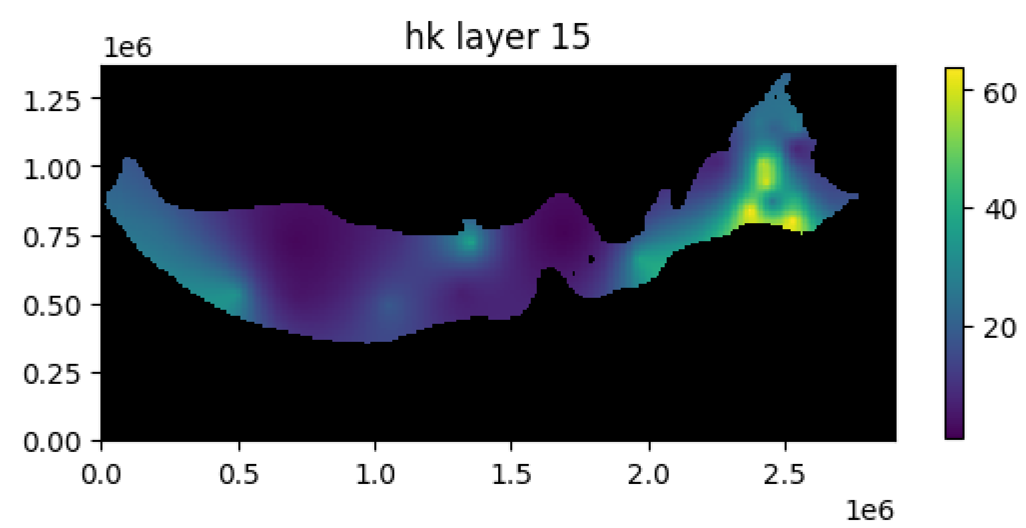

hk layer 10
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
50
40
30
20
10

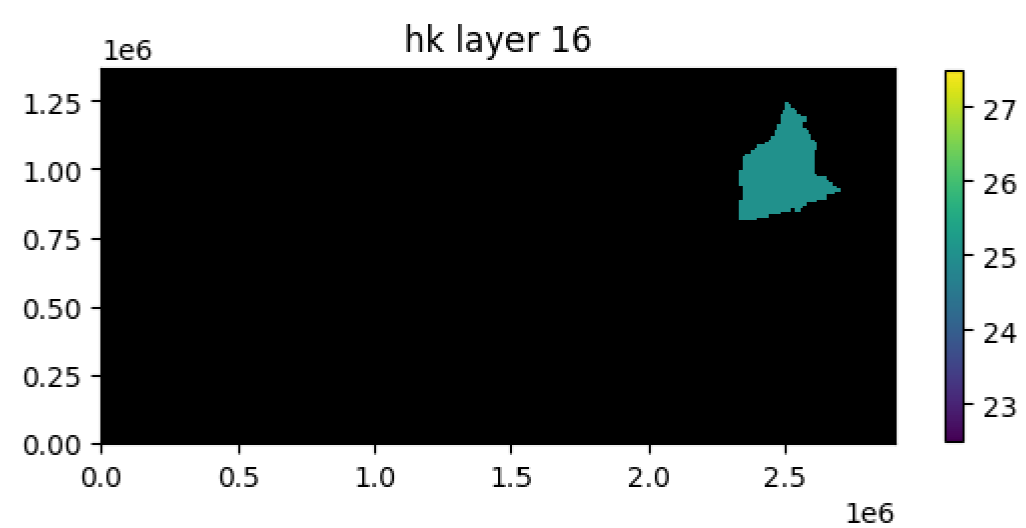

hk layer 11
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
150
100
50


hk layer 12
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
50
40
30
20
10


hk layer 13
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
100
75
50
25


hk layer 14
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
25
20
15
10
5





In addition to the plots of horizontal hydraulic conductivity you can see that the `.plot()` method returned a list containing 16 axis objects (one for each layer).

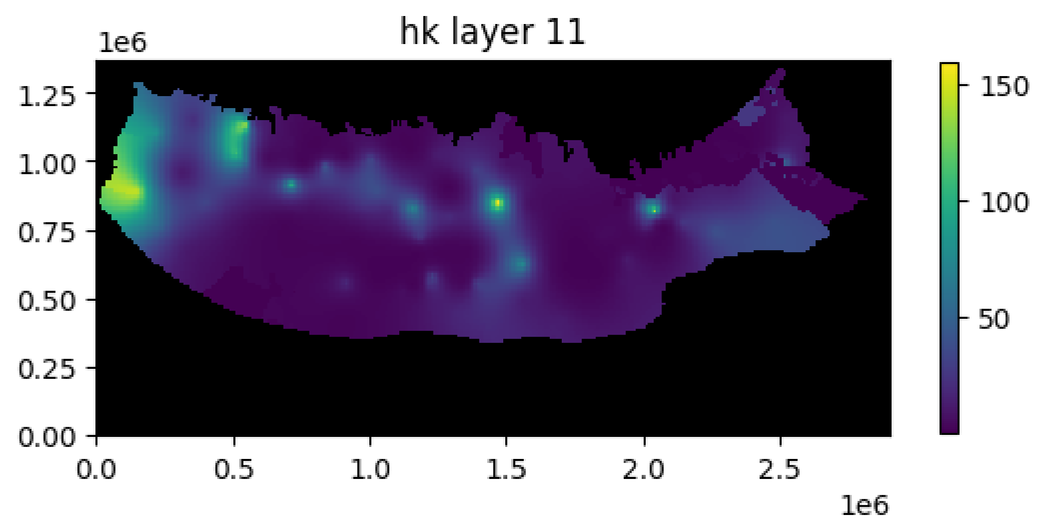
Plotting data for a single layer

If the `mflay=` keyword is provided to the `plot.()` method then data for an individual layer is plotted. Remember `mflay` is zero-based.

Here we plot the horizontal hydraulic conductivity for layer 11 (`mflay=10`).

[12]:
```
ml.lpf.hk.plot(mflay=10, masked_values=[0.0], colorbar=True)
```

[12]:
```
<Axes: title={'center': 'hk layer 11'}>
```



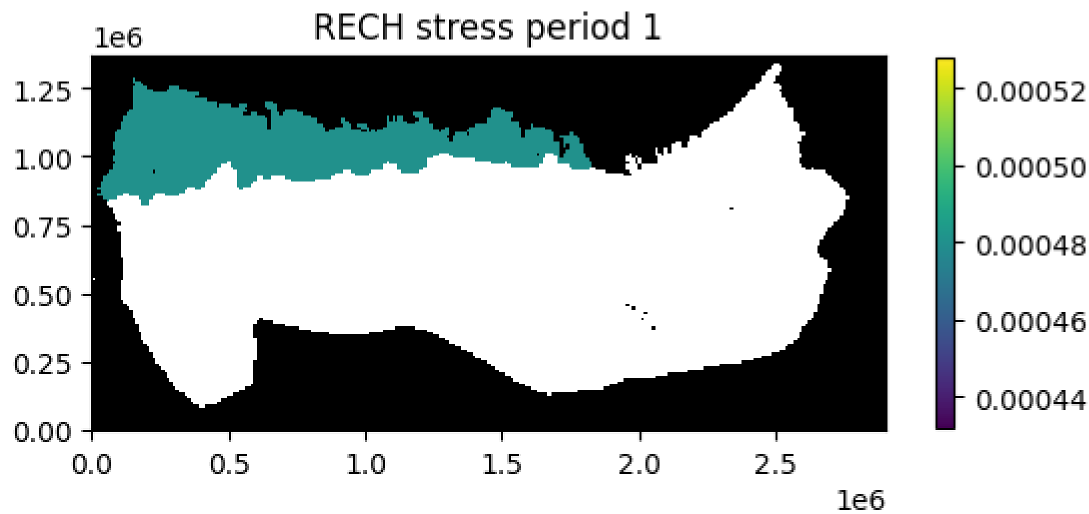
Plotting transient two-dimensional data

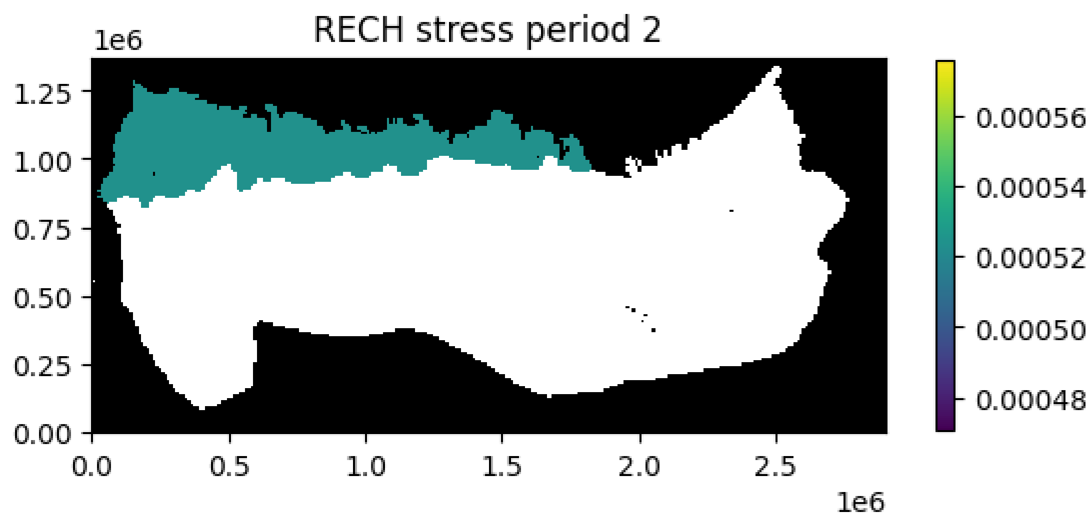
Transient two-dimensional data can be plotted using the `.plot()` method. User's do not actually need to know that the data are two- or three-dimensional. The `.plot()` method is attached to the two- and three-dimensional, and transient two-dimensional data objects so it knows how to process the model data. Examples of transient two-dimensional data are recharge rates (`rch.rech`) and evapotranspiration rates (`evt.evtr`).

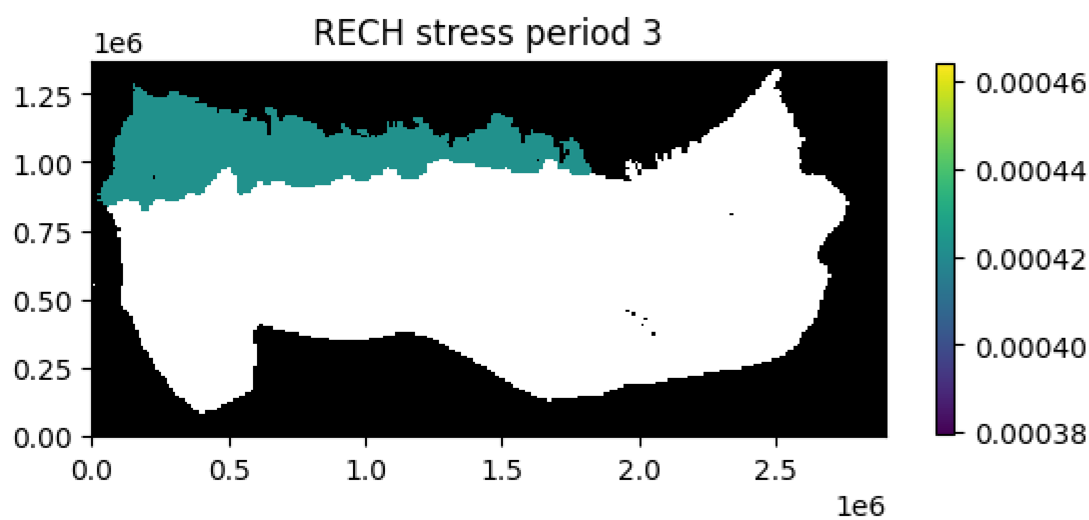
Here we plot recharge rates for all six stress periods in the model. We are also masking areas where the recharge rate is zero and adding a color bar.

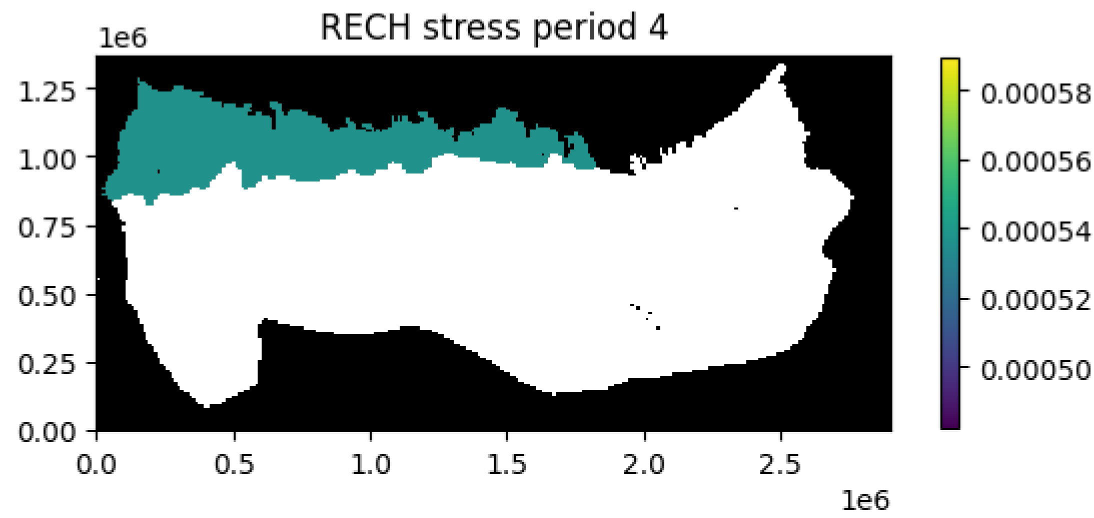
[13]:
```
ml.rch.rech.plot(kper="all", masked_values=[0.0], colorbar=True)
```

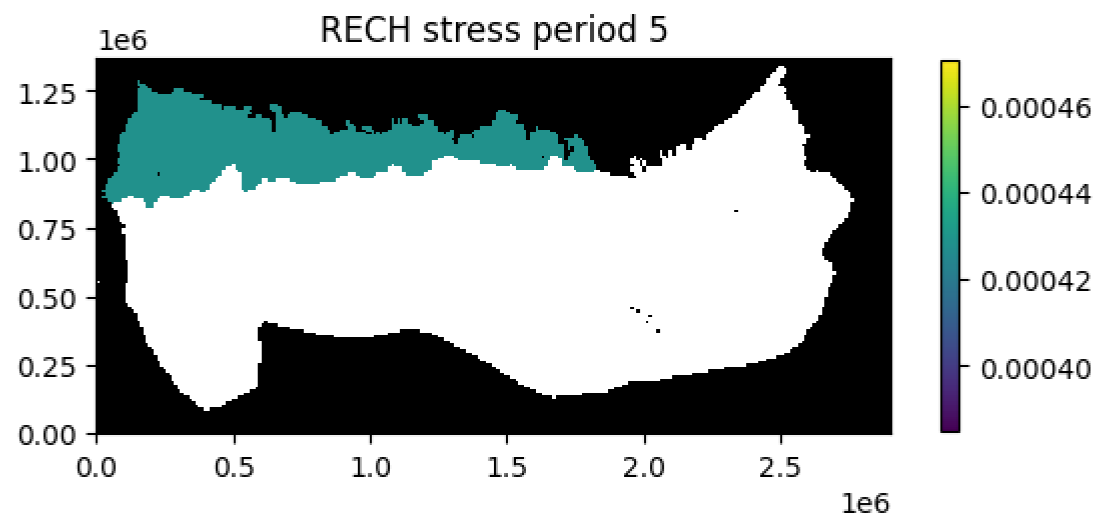
[13]:
```
[<Axes: title={'center': 'RECH stress period 1'}>,
 <Axes: title={'center': 'RECH stress period 2'}>,
 <Axes: title={'center': 'RECH stress period 3'}>,
 <Axes: title={'center': 'RECH stress period 4'}>,
 <Axes: title={'center': 'RECH stress period 5'}>,
 <Axes: title={'center': 'RECH stress period 6'}>]
```

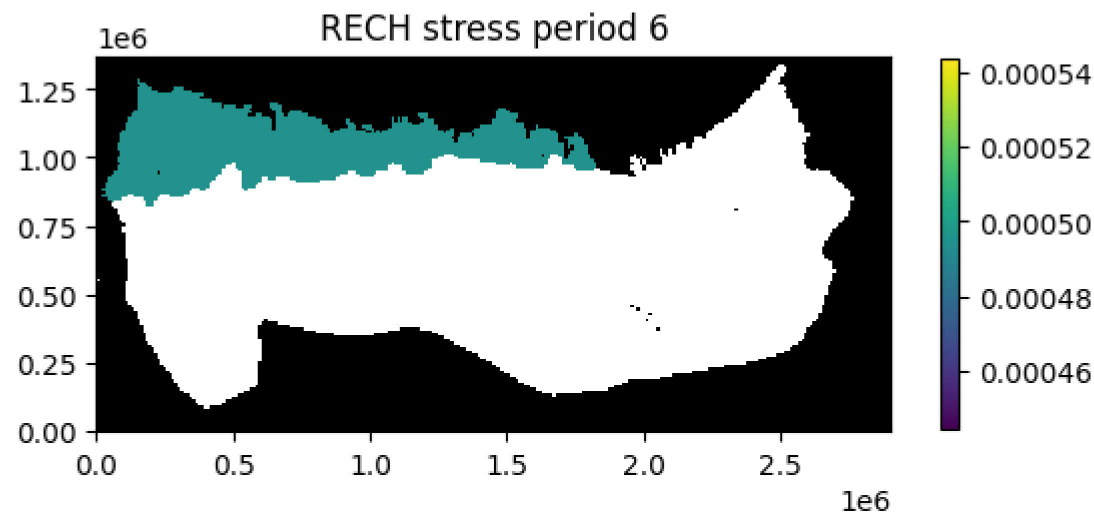

RECH stress period 1
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
0.00052
0.00050
0.00048
0.00046
0.00044


RECH stress period 2
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
0.00056
0.00054
0.00052
0.00050
0.00048


RECH stress period 3
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
0.00046
0.00044
0.00042
0.00040
0.00038


RECH stress period 4
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
0.00058
0.00056
0.00054
0.00052
0.00050


RECH stress period 5
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
0.00046
0.00044
0.00042
0.00040


RECH stress period 6
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
0.00054
0.00052
0.00050
0.00048
0.00046

In addition to the plots of recharge rates you can see that the `.plot()` method returned a list containing 6 axis objects (one for each stress period).

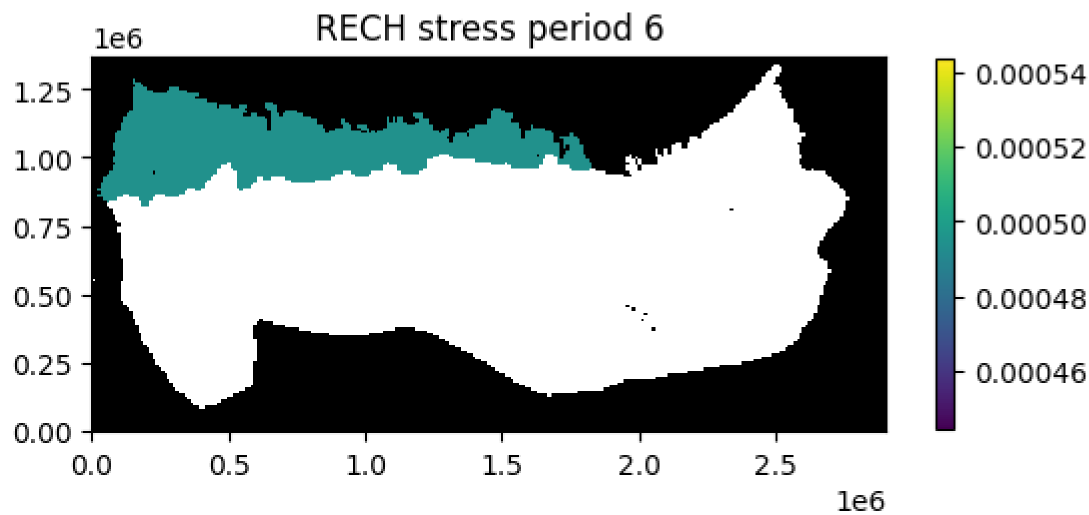
Plotting data for a single stress period

If the `kper=` keyword is provided to the `plot.()` method then data for an individual stress period is plotted. Remember `kper` is zero-based.

Here we plot the recharge rate for stress period 6 (`kper=5`).

[14]:
```
ml.rch.rech.plot(kper=5, masked_values=[0.0], colorbar=True)
```

[14]:
```
[<Axes: title={'center': 'RECH stress period 6'}>]
```



We can also save the image to a file by provided the `filename_base` keyword with an appropriate base file name.

[15]:
```
fr = os.path.join(modelpth, "secp")
ml.rch.rech.plot(kper=5, masked_values=[0.0], colorbar=True, filename_base=fr)
```

```
    created...secp_RECH_00006.png
```

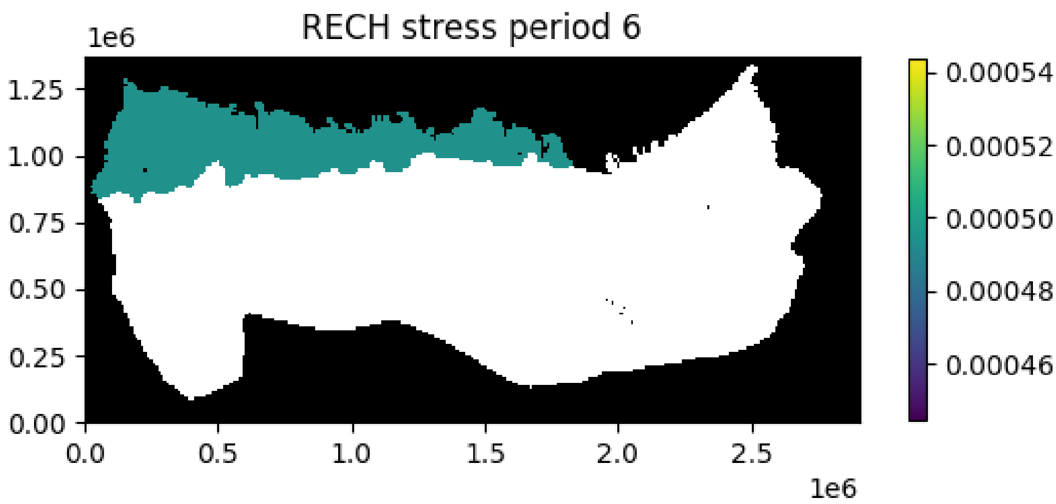
[15]:
```
[None]
```

If the `kper` keyword is not provided images are saved for each stress period in the model.

The image file that was just created of recharge rates for stress period 6 is is shown below.

[16]:
```
fname = os.path.join(modelpth, "secp_RECH_00006.png")
Image(filename=fname)
```

[16]:



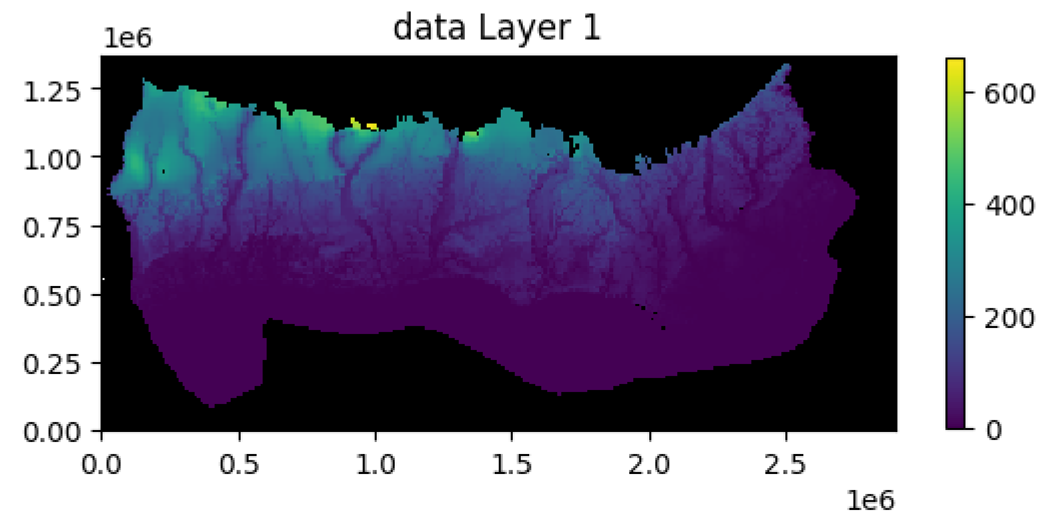
Plotting simulated model results

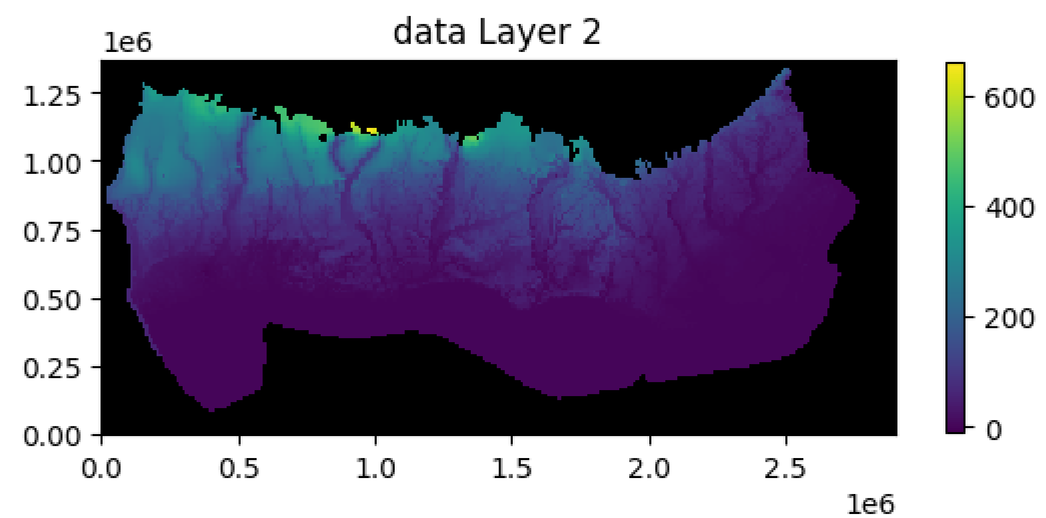
Simulated model results can be plotted using the `.plot()` method.

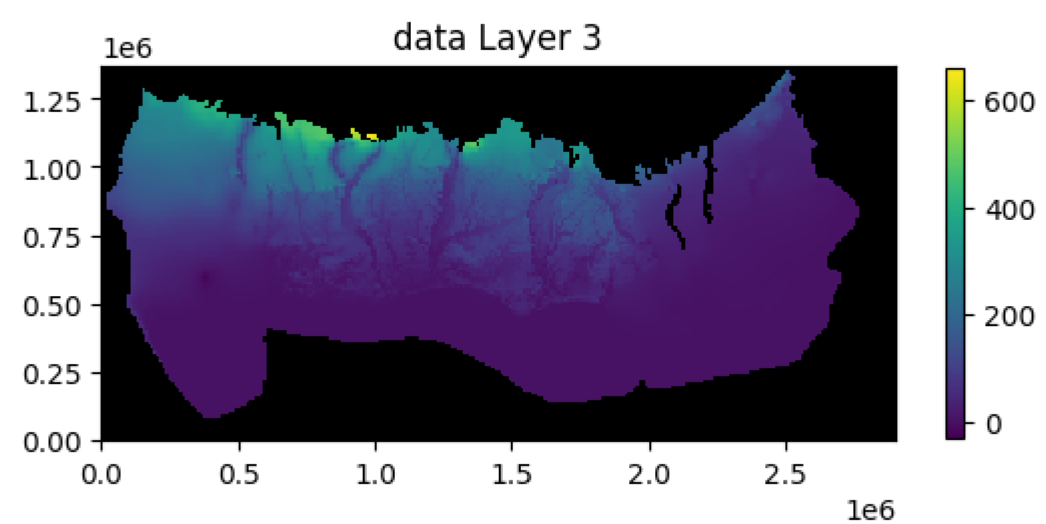
First we create an instance of the `HeadFile` class with the simulated head file (secp.hds) and extract the simulation times available in the binary head file using the `.get_times()` method. Here we plot last simulated heads in the binary heads file (`totim=times[-1]`). We are also masking cells having the `HDRY` (-9999.0) value and adding a color bar.

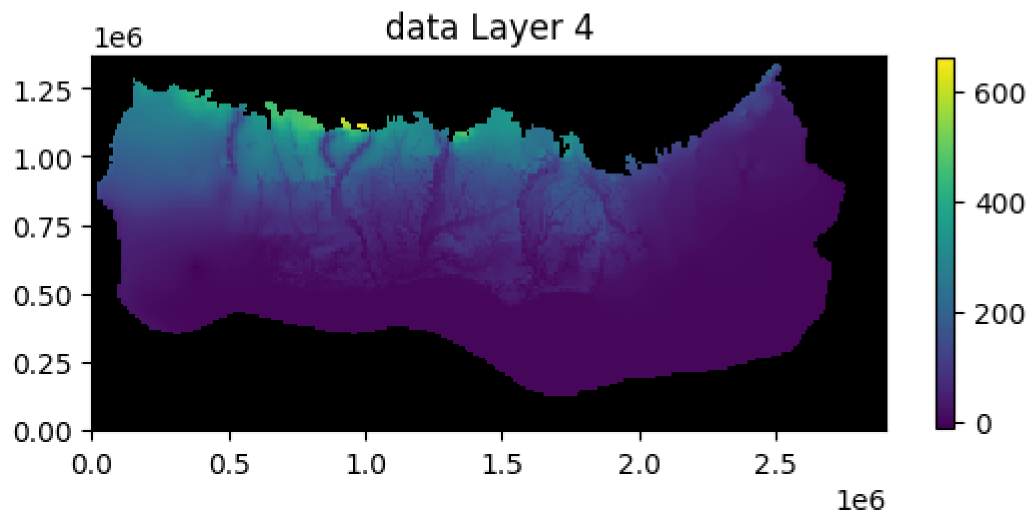
[17]:
```
print(files)
fname = os.path.join(modelpth, files[0])
hdobj = flopy.utils.HeadFile(fname, model=ml)
times = hdobj.get_times()
head = hdobj.plot(totim=times[-1], masked_values=[-9999.0], colorbar=True)
```

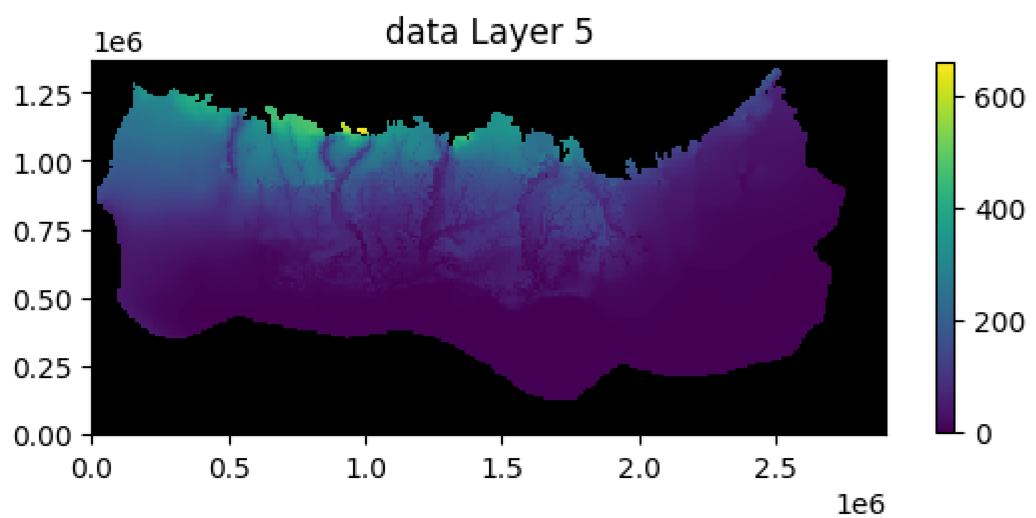
```
['secp.hds']
```

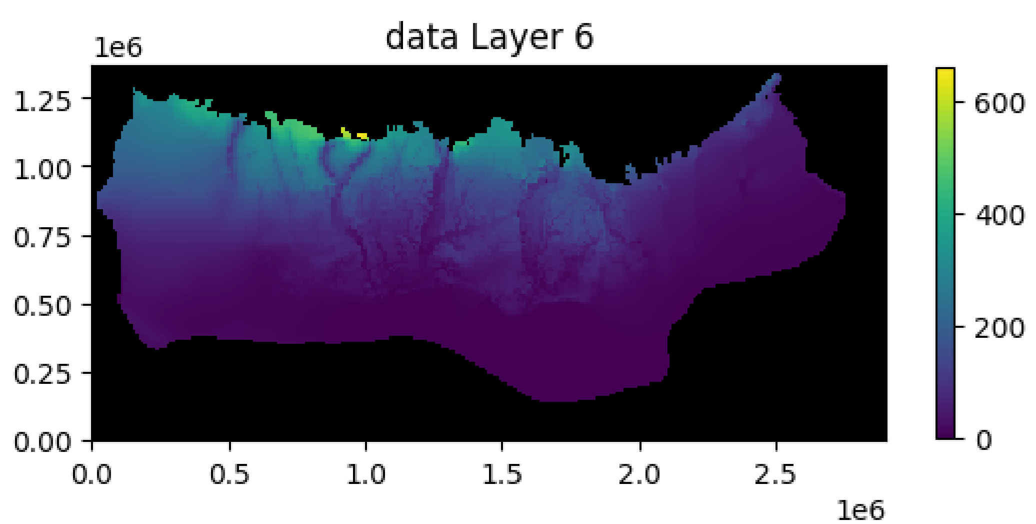

data Layer 1
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
600
400
200
0

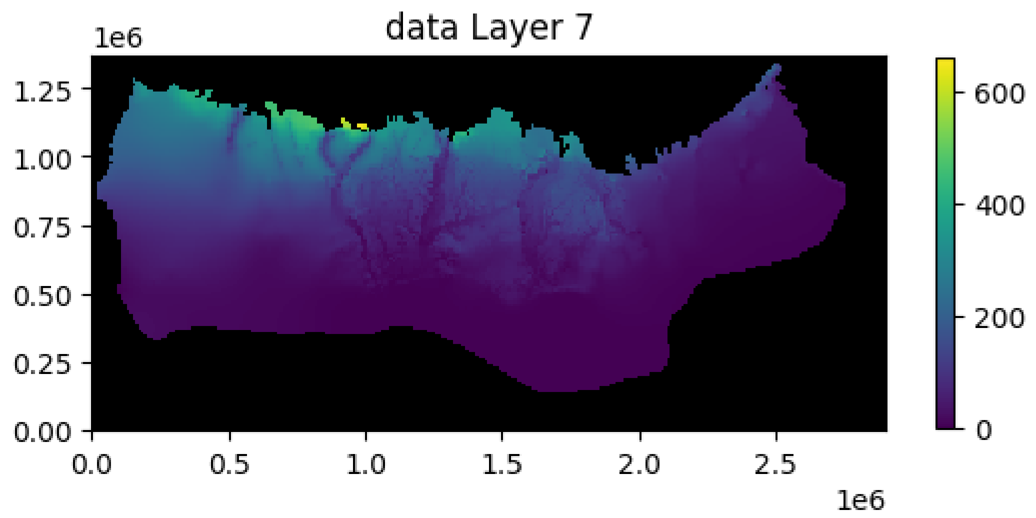

data Layer 2
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
600
400
200
0

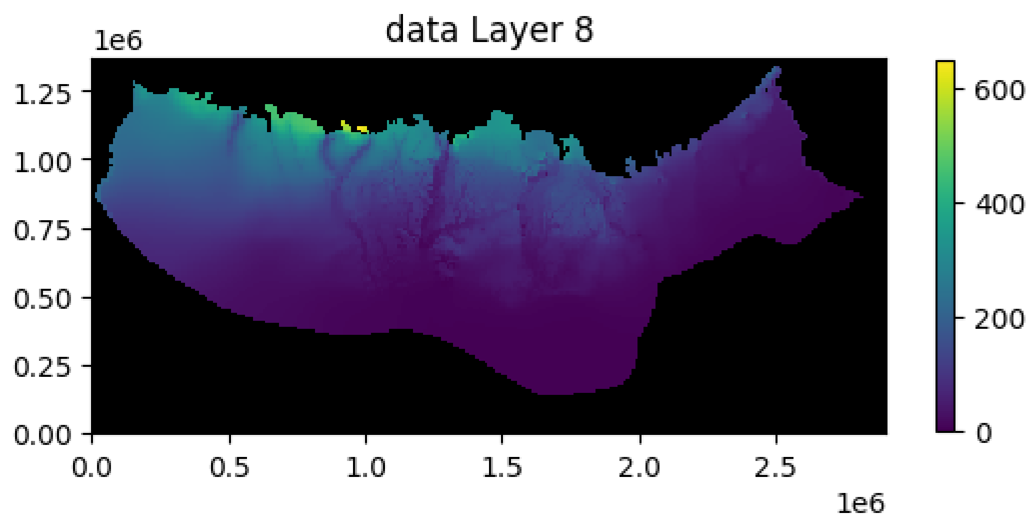

data Layer 3
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
600
400
200
0

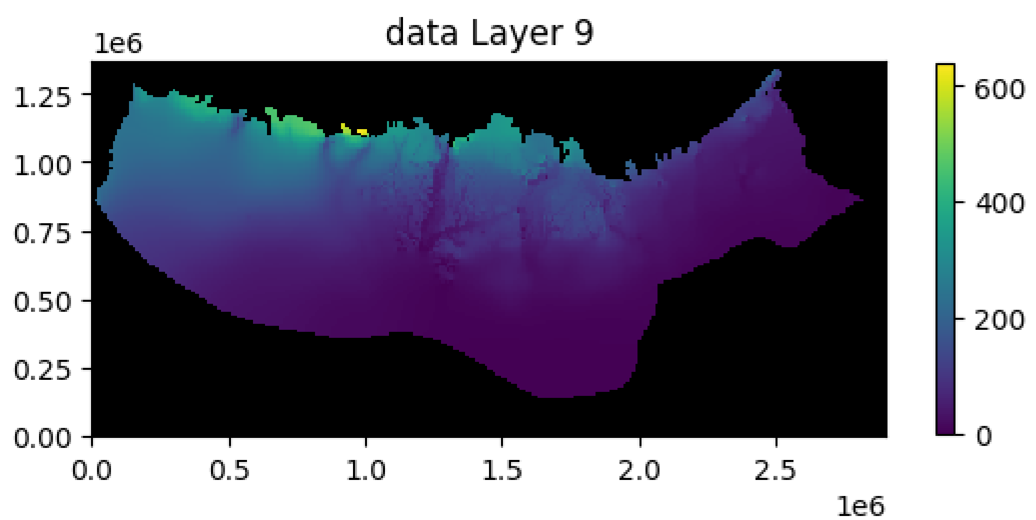

data Layer 4
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
600
400
200
0

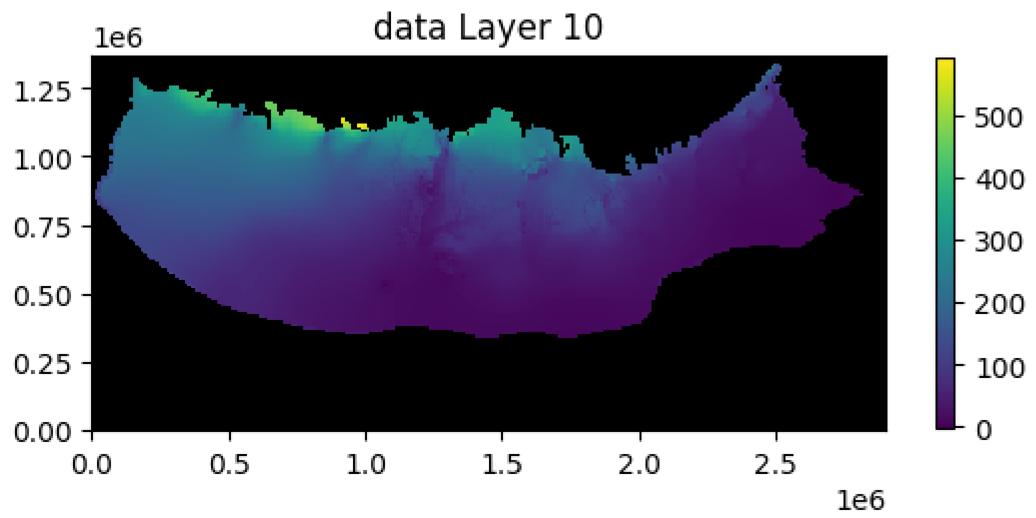

data Layer 5
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
600
400
200
0

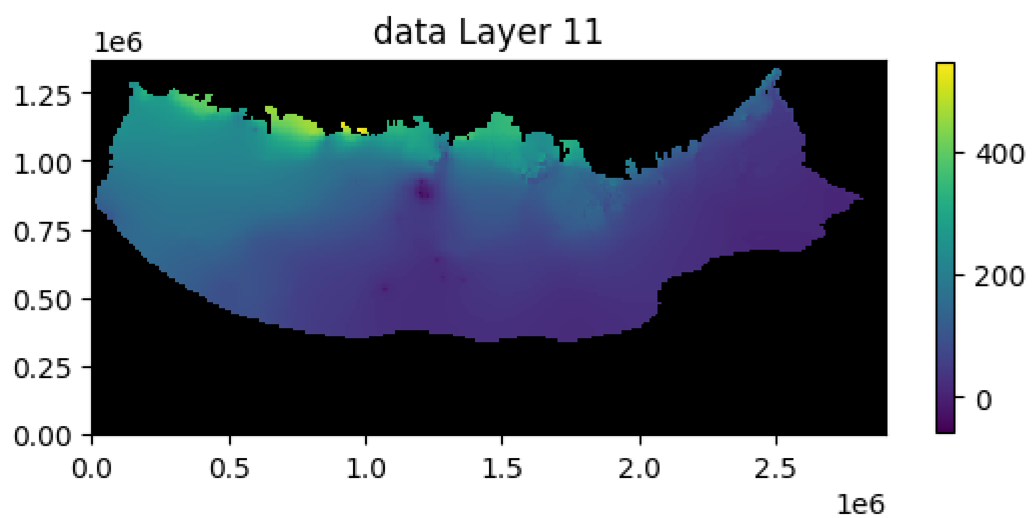

data Layer 6
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
600
400
200
0

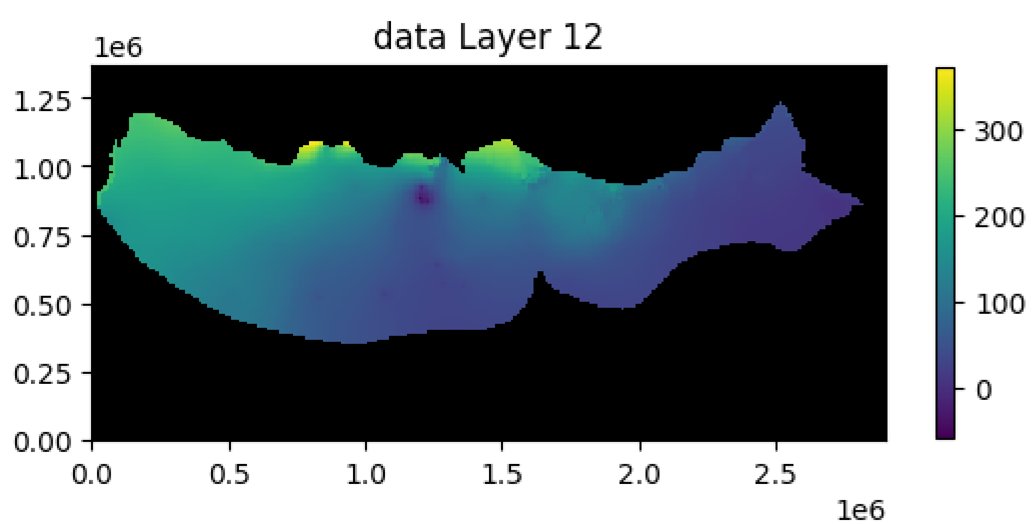

data Layer 7
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
600
400
200
0

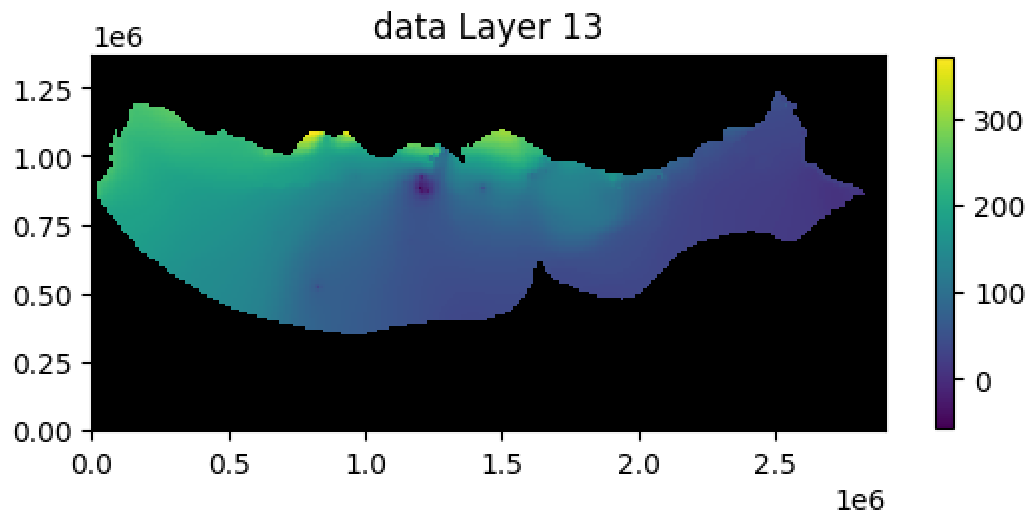

data Layer 8
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
600
400
200
0

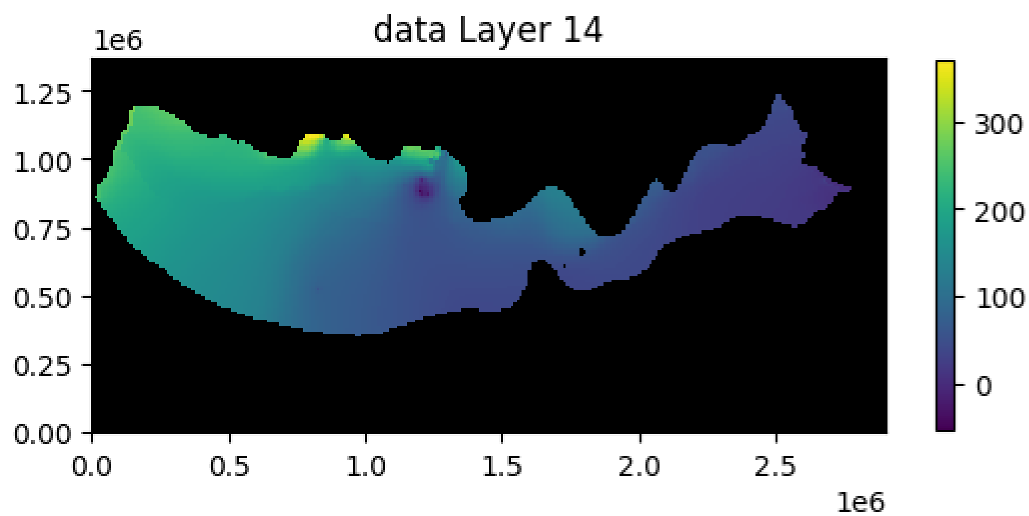

data Layer 9
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
600
400
200
0

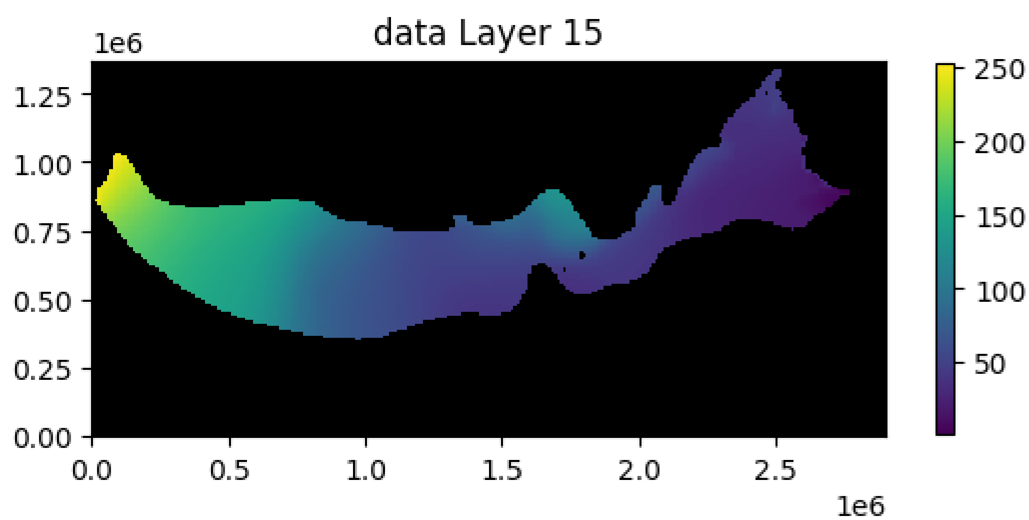

data Layer 10
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
500
400
300
200
100
0

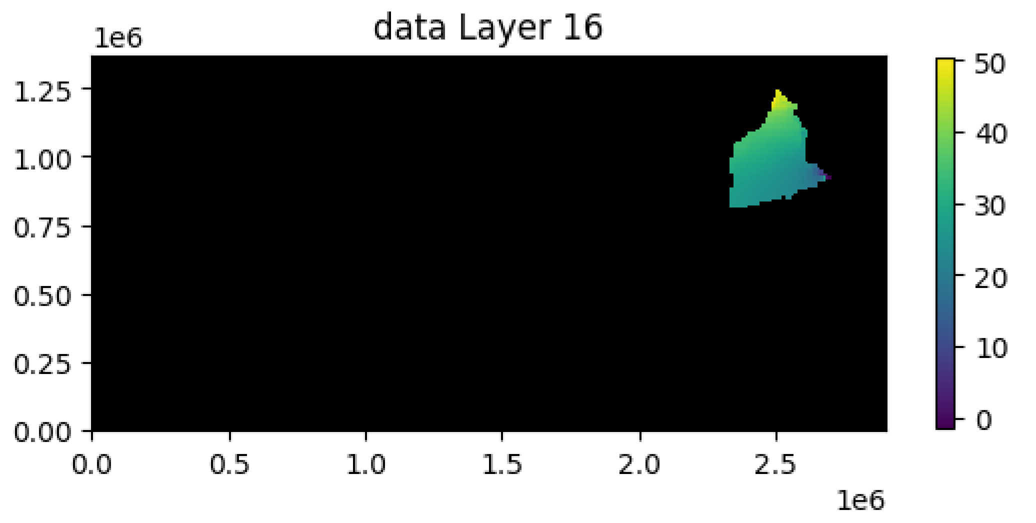

data Layer 11
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
400
200
0


data Layer 12
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
300
200
100
0


data Layer 13
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
300
200
100
0


data Layer 14
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
300
200
100
0


data Layer 15
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
250
200
150
100
50

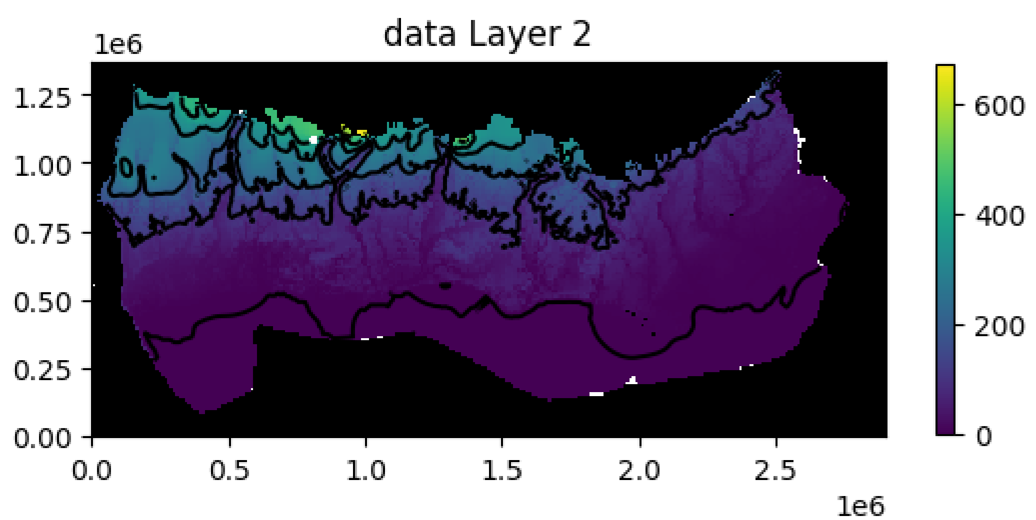


Plotting results for a single layer

If the `mflay=` keyword is provided to the `plot.()` method then results for an individual layer can be plotted. Remember `mflay` is zero-based.

Here we plot the results for layer 2 (`mflay=1`) for stress period 2 (`totim=times[1]`). We also add black contour lines.

[18]:
```
head = hdobj.plot(
    totim=times[1],
    mflay=1,
    masked_values=[-9999.0],
    colorbar=True,
    contour=True,
    colors="black",
)
```



We can also save the plots of the head results for every layer (or a single layer) to a file by provided the `filename_base` keyword with an appropriate base file name.

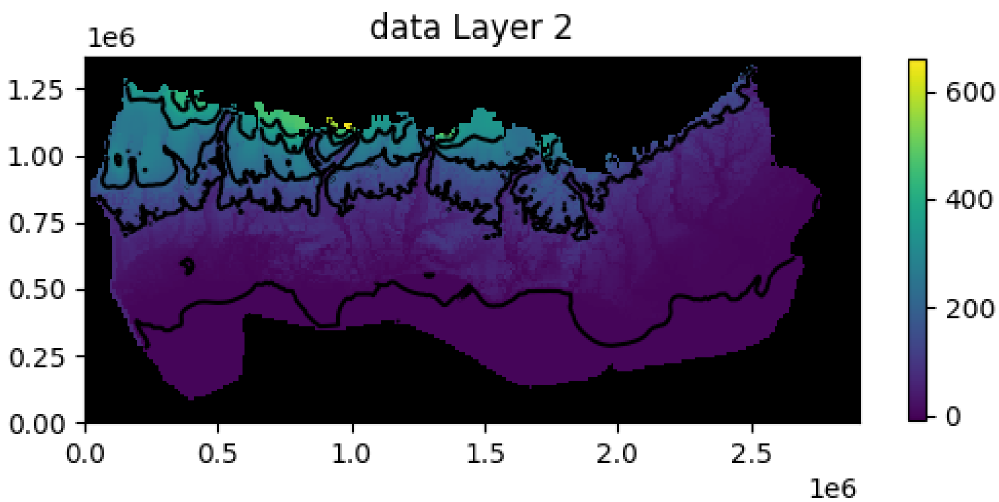
[19]:
```
fh = os.path.join(modelpth, "secp_head")
head = hdobj.plot(
    totim=times[-1],
    masked_values=[-9999.0],
    colorbar=True,
    contour=True,
    colors="black",
    filename_base=fh,
)
```

```
    created...secp_head_Layer1.png
    created...secp_head_Layer2.png
    created...secp_head_Layer3.png
    created...secp_head_Layer4.png
    created...secp_head_Layer5.png
    created...secp_head_Layer6.png
    created...secp_head_Layer7.png
    created...secp_head_Layer8.png
    created...secp_head_Layer9.png
    created...secp_head_Layer10.png
    created...secp_head_Layer11.png
    created...secp_head_Layer12.png
    created...secp_head_Layer13.png
    created...secp_head_Layer14.png
    created...secp_head_Layer15.png
    created...secp_head_Layer16.png
```

The image file that was just created of the simulated head for layer 2 for stress period 6 is is shown below.

[20]:
```
fname = os.path.join(modelpth, "secp_head_Layer2.png")
Image(filename=fname)
```

[20]:



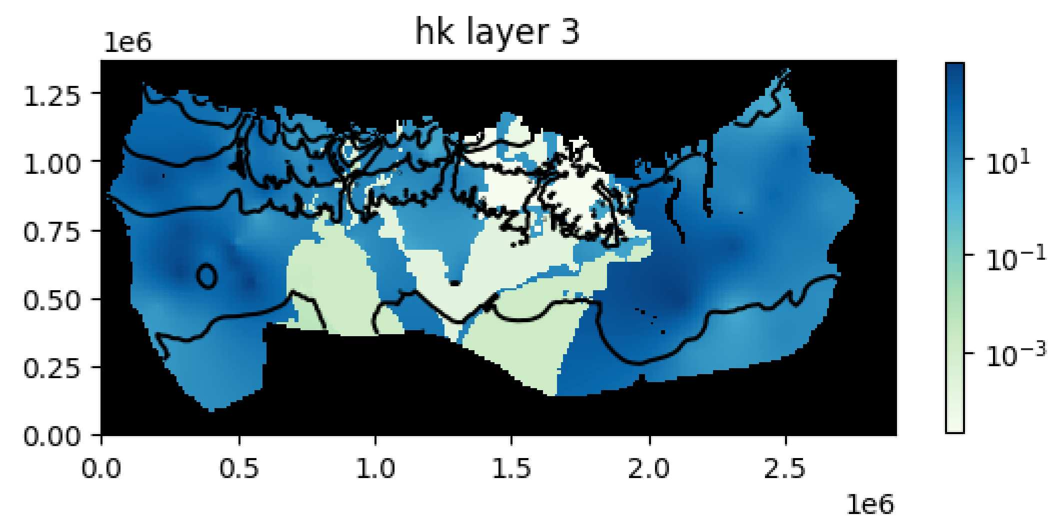
Passing other `matplotlib.pyplot` keywords to `.plot()` methods

We can also pass `matplotlib.pyplot` keywords to `.plot()` methods attached to the model input data arrays. For example you can pass a `matplotlib` colormap (`cmap=`) keyword to the `.plot()` method to plot contours of simulated heads over a color flood of hk. We can also use the `norm=LogNorm()` keyword to use a log color scale when plotting hydraulic conductivity.

Available `matplotlib` colormaps can be found at https://matplotlib.org/stable/tutorials/colors/colormaps.html

[21]:
```
from matplotlib.colors import LogNorm

ax = ml.lpf.hk.plot(mflay=2, cmap="GnBu", norm=LogNorm(), colorbar=True)
t = hdobj.plot(
    axes=ax,
    mflay=2,
    masked_values=[-9999.0],
    pcolor=False,
    contour=True,
    colors="black",
)
```




```
<Figure size 640x480 with 0 Axes>
```

Plotting data for a package or a model

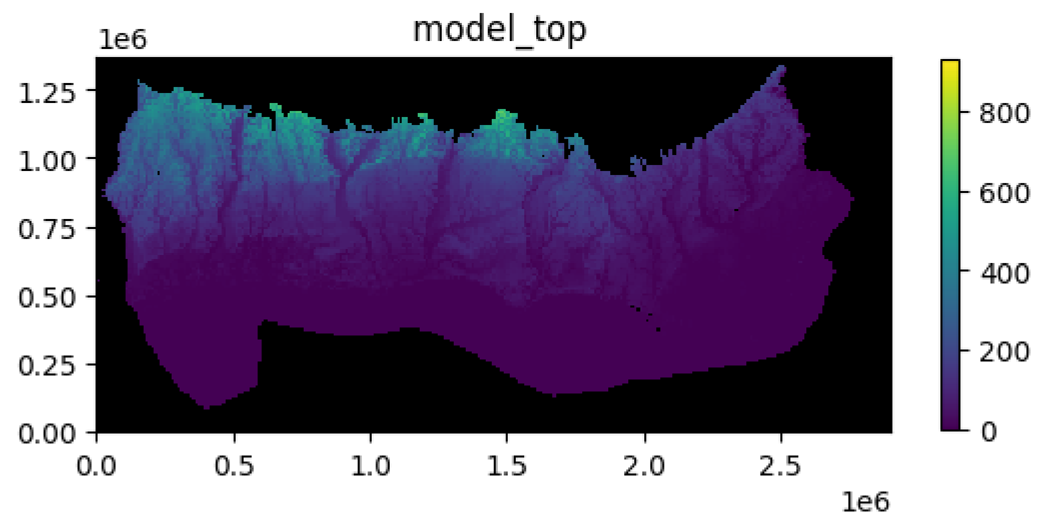
The input data for a model or an individual package can also be plotted using the `.plot()` method. The `.plot()` methods attached to a model or an individual package are meant to provide a method to quickly evaluate model or package input. As a result, there is limited ability to customize the plots. Example of using the `.plot()` method with a model or and individual packages is demonstrated below.

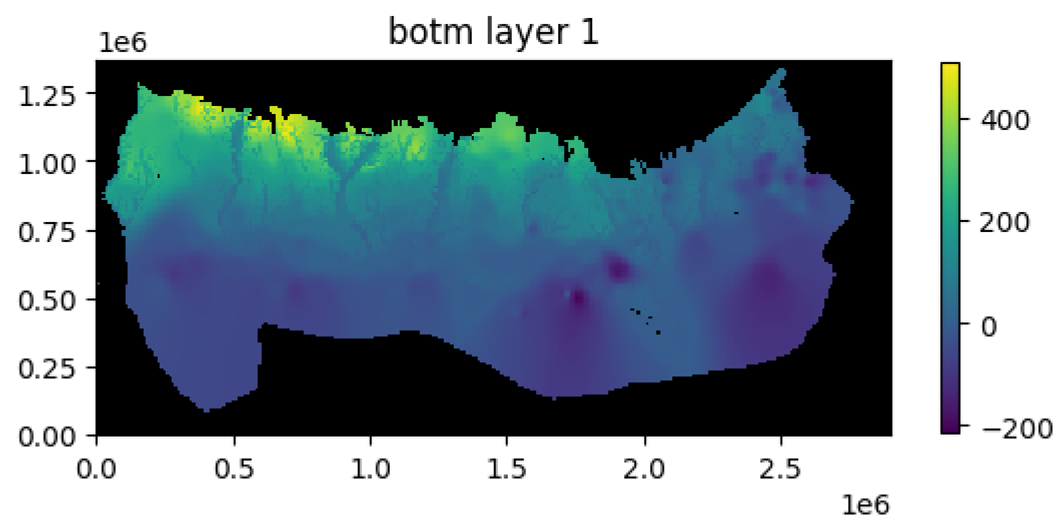
Plot all data for a package

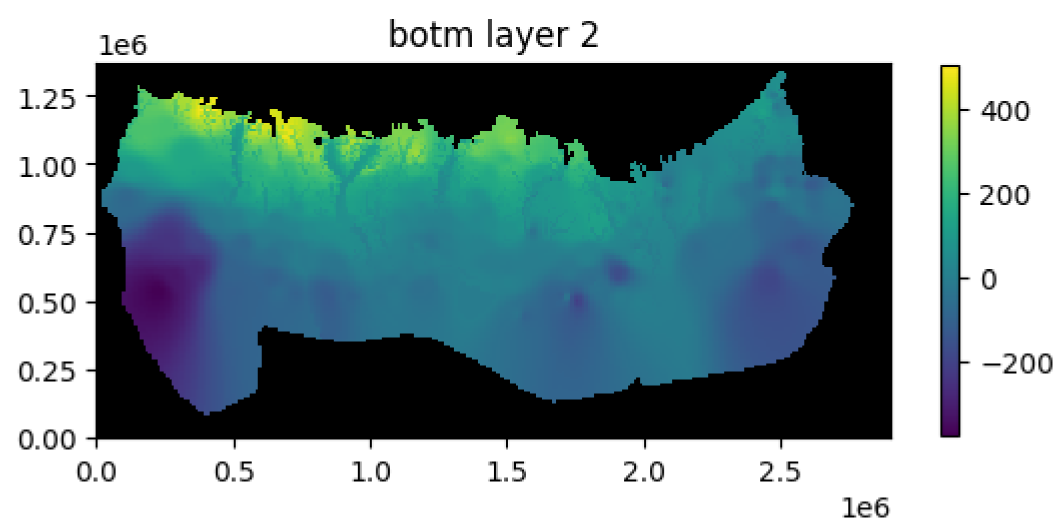
All input data for a package can be plotted using the `.plot()` method. Below all of the data for the lpf package is plotted.

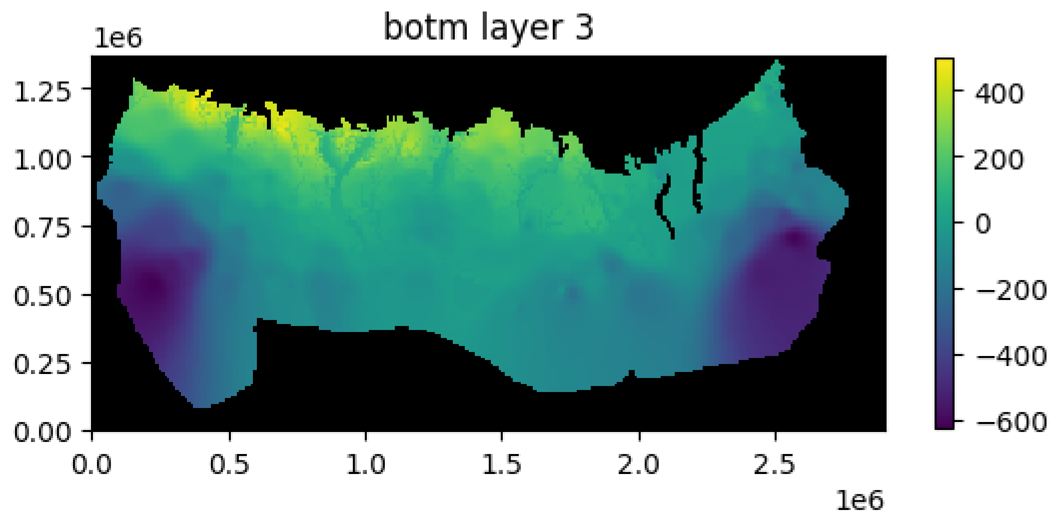
[22]:
```
ml.dis.plot()
```

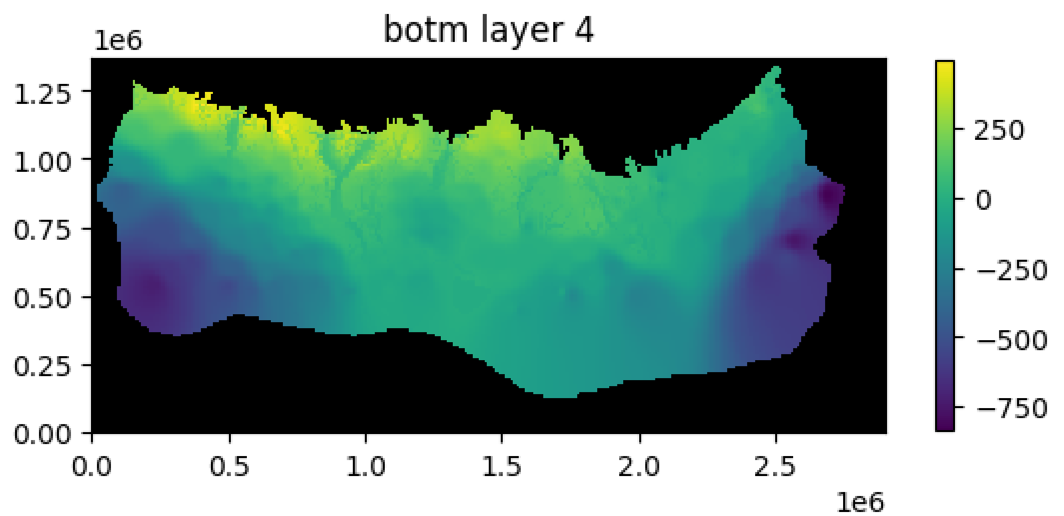
[22]:
```
[<Axes: title={'center': ' model_top'}>,
 <Axes: title={'center': 'botm layer 1'}>,
 <Axes: title={'center': 'botm layer 2'}>,
 <Axes: title={'center': 'botm layer 3'}>,
 <Axes: title={'center': 'botm layer 4'}>,
 <Axes: title={'center': 'botm layer 5'}>,
 <Axes: title={'center': 'botm layer 6'}>,
 <Axes: title={'center': 'botm layer 7'}>,
 <Axes: title={'center': 'botm layer 8'}>,
 <Axes: title={'center': 'botm layer 9'}>,
 <Axes: title={'center': 'botm layer 10'}>,
 <Axes: title={'center': 'botm layer 11'}>,
 <Axes: title={'center': 'botm layer 12'}>,
 <Axes: title={'center': 'botm layer 13'}>,
 <Axes: title={'center': 'botm layer 14'}>,
 <Axes: title={'center': 'botm layer 15'}>,
 <Axes: title={'center': 'botm layer 16'}>]
```

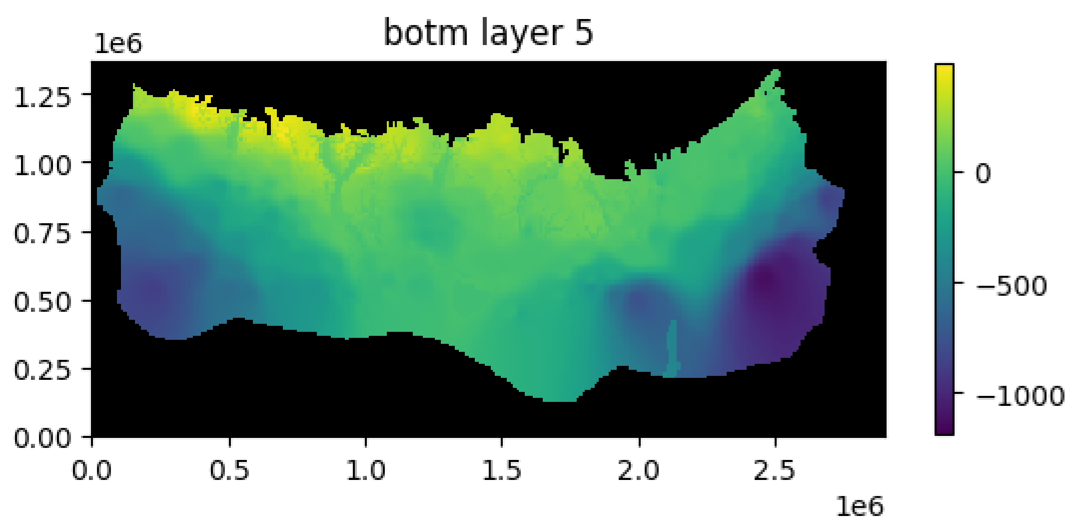

model_top
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
800
600
400
200
0

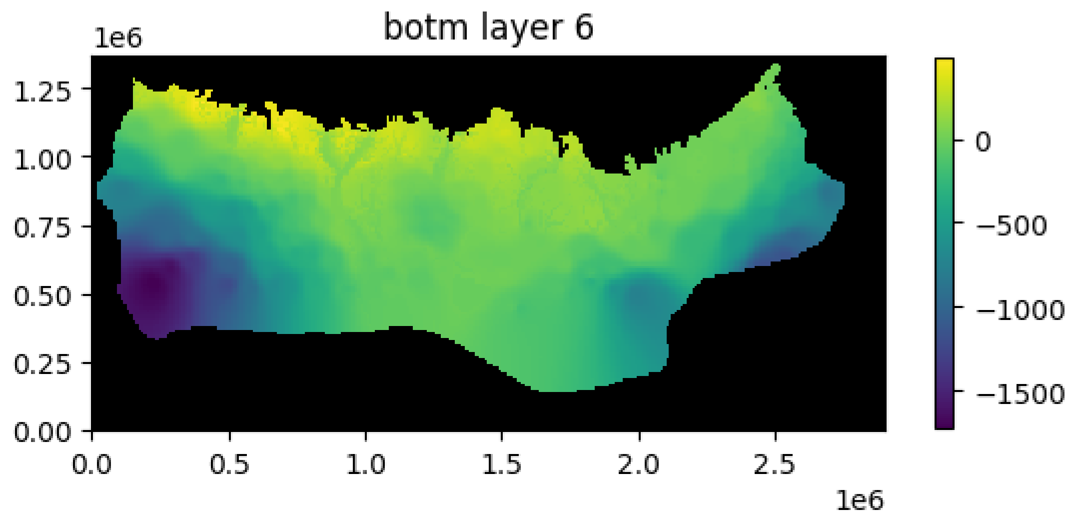

botm layer 1
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
400
200
0
−200

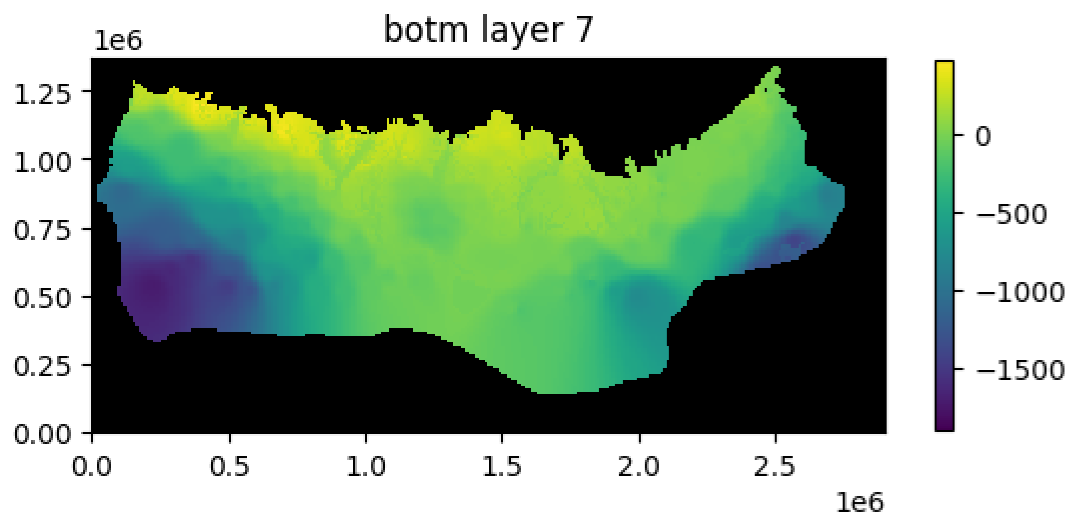

botm layer 2
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
400
200
0
−200

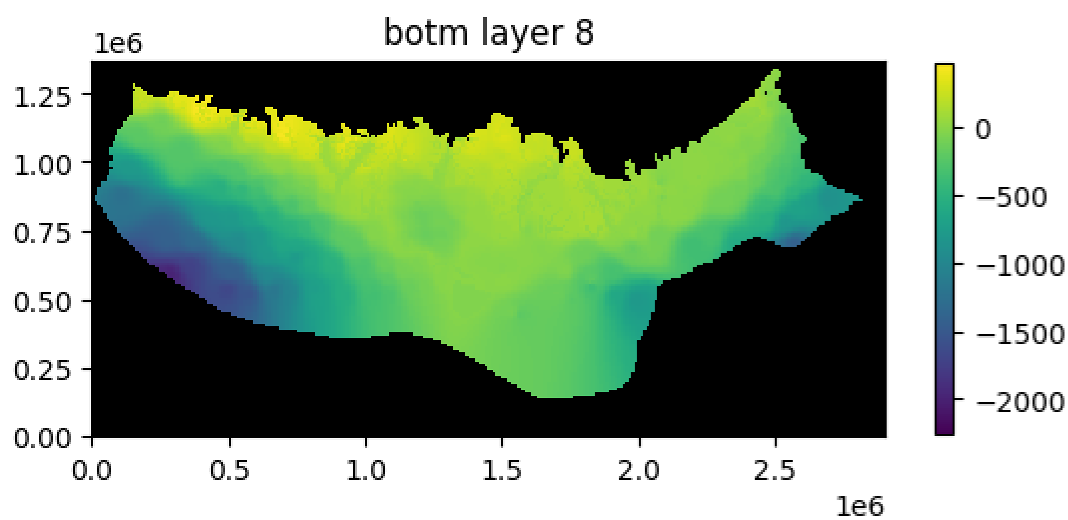

botm layer 3
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
400
200
0
−200
−400
−600

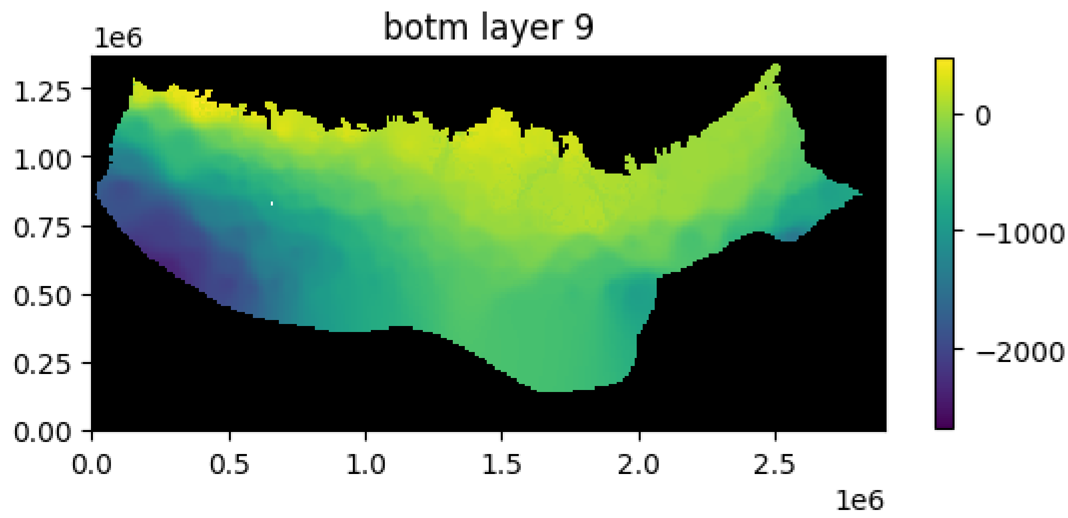

botm layer 4
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
250
0
−250
−500
−750

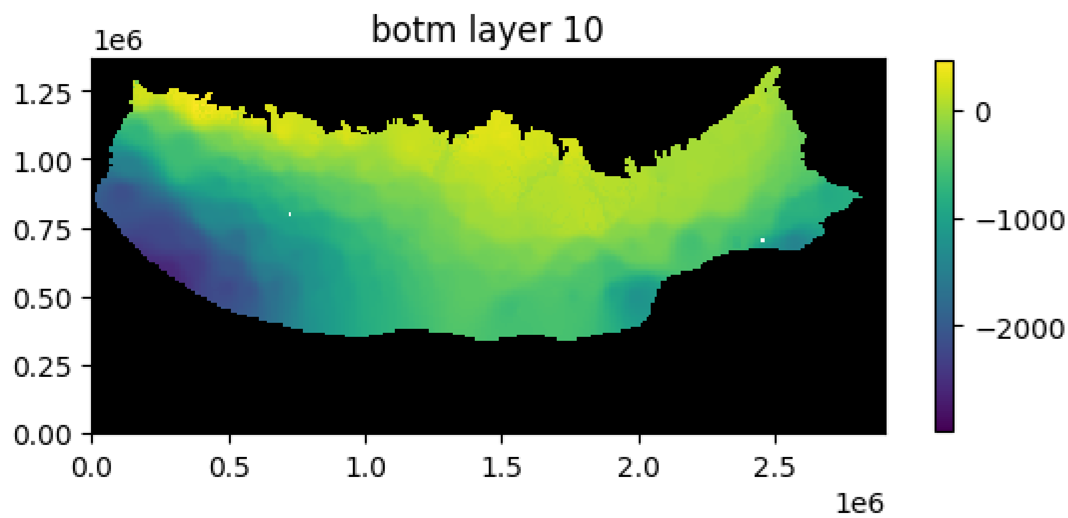

botm layer 5
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
0
−500
−1000

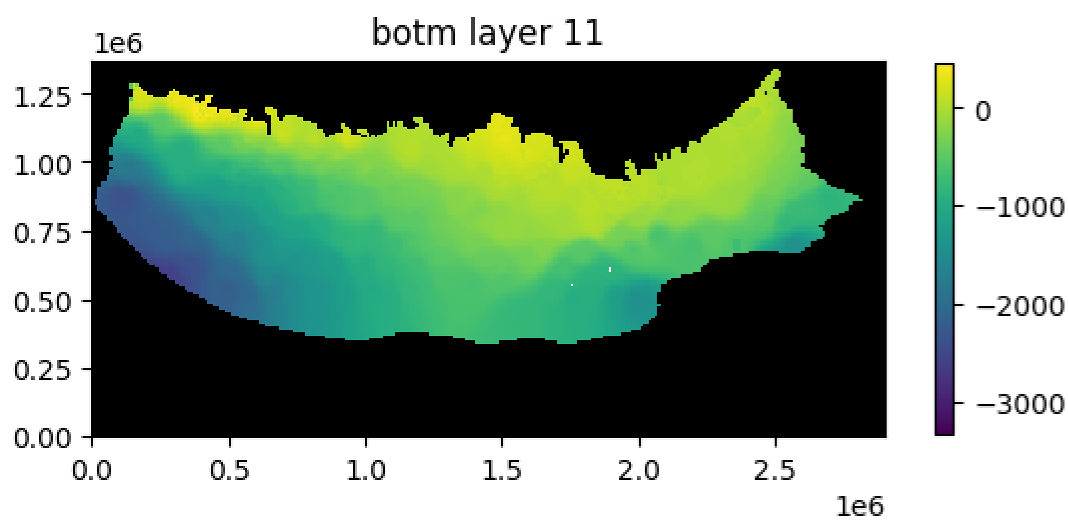

botm layer 6
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
0
−500
−1000
−1500

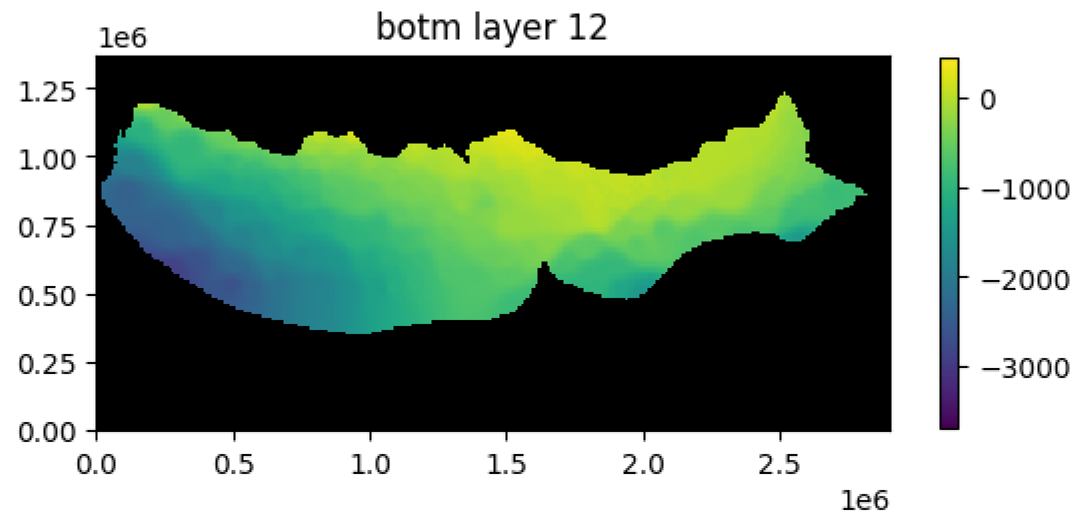

botm layer 7
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
0
−500
−1000
−1500

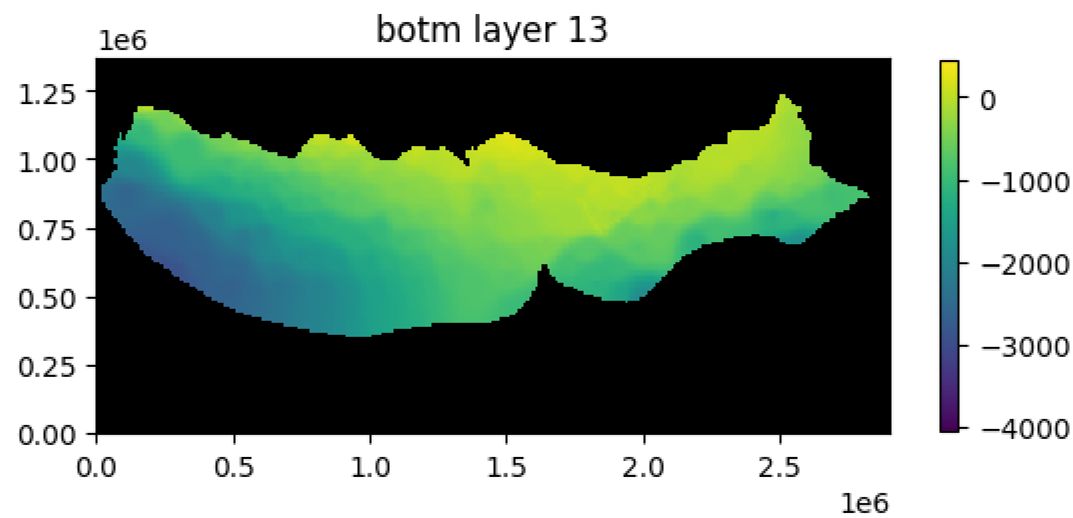

botm layer 8
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
0
−500
−1000
−1500
−2000

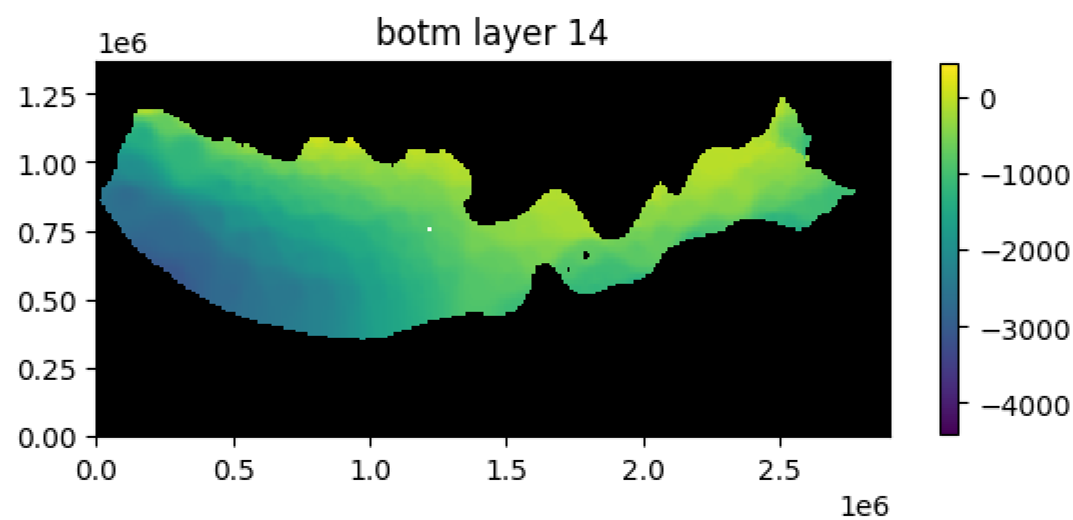

botm layer 9
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
0
−1000
−2000

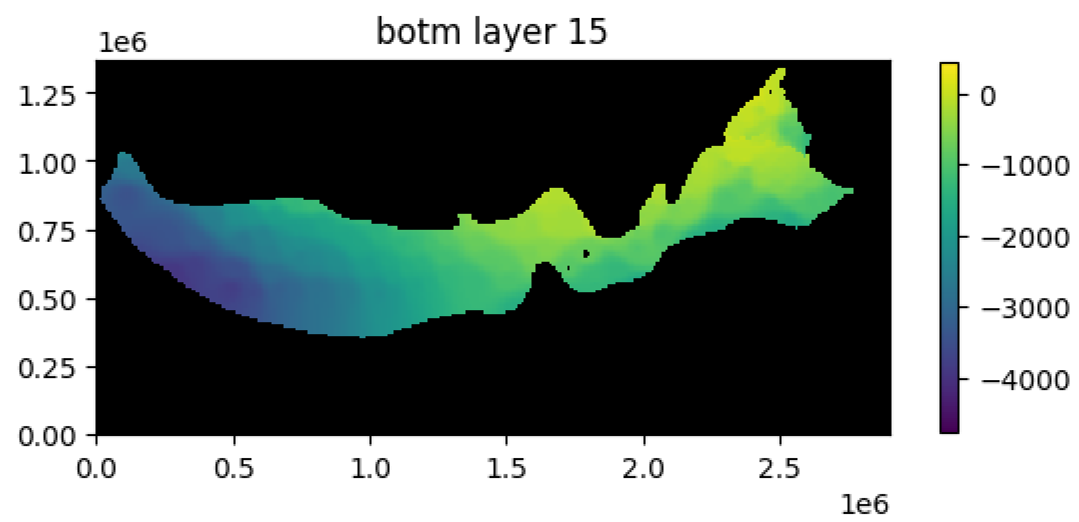

botm layer 10
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
0
−1000
−2000

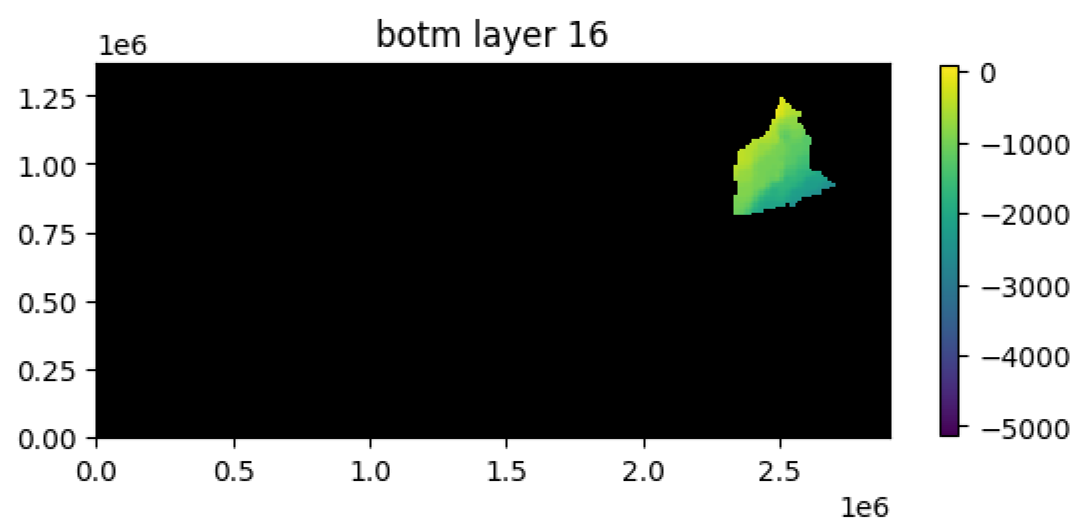

botm layer 11
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
0
−1000
−2000
−3000


botm layer 12
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
0
−1000
−2000
−3000


botm layer 13
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
0
−1000
−2000
−3000
−4000


botm layer 14
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
0
−1000
−2000
−3000
−4000



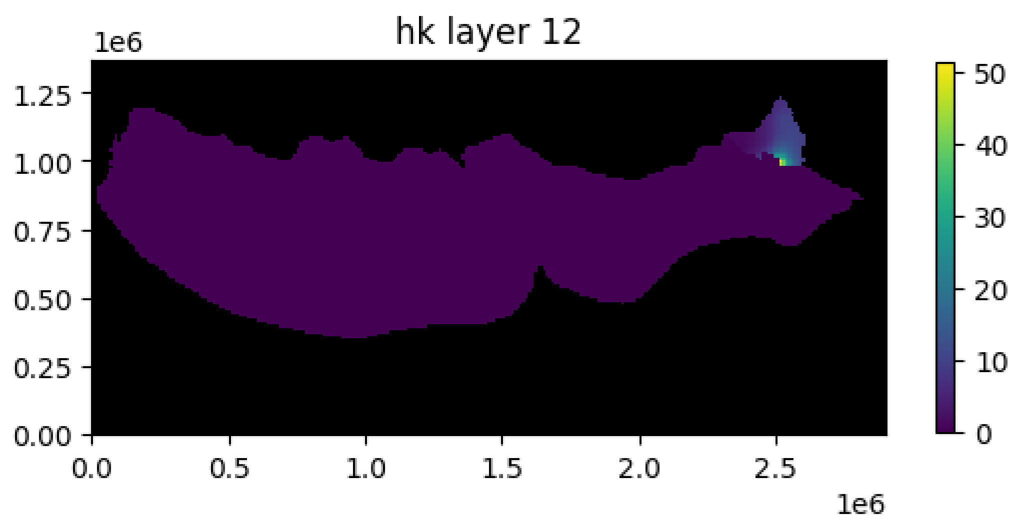


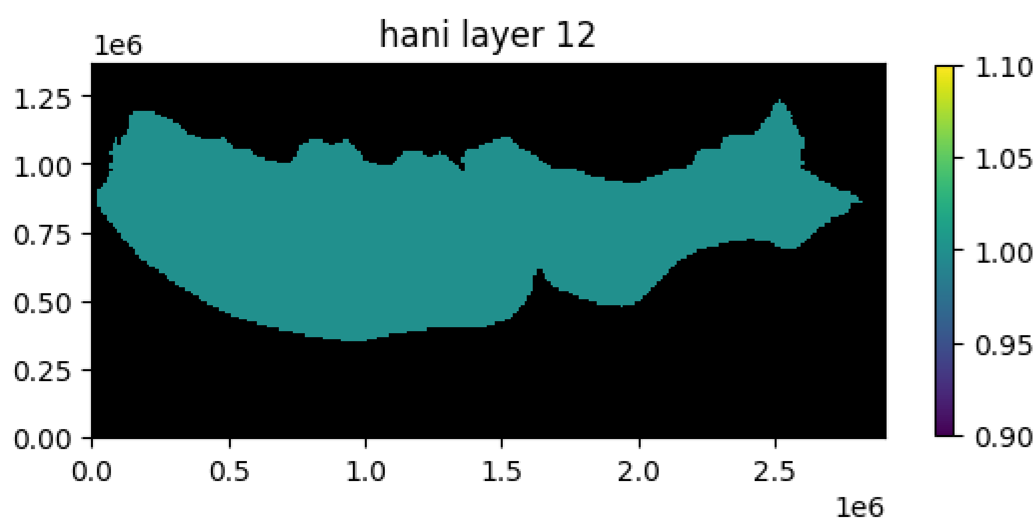
Plot package input data for a specified layer

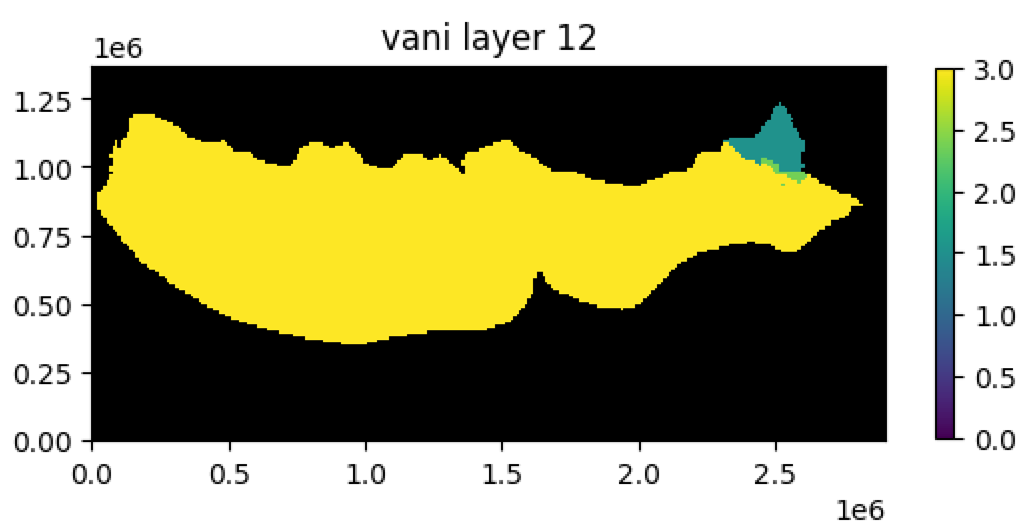
Package input data for a specified layer can be plotted by passing the `mflay` keyword to the package `.plot()` method. Below lpf package input data for layer 12 (`mflay=11`) is plotted.

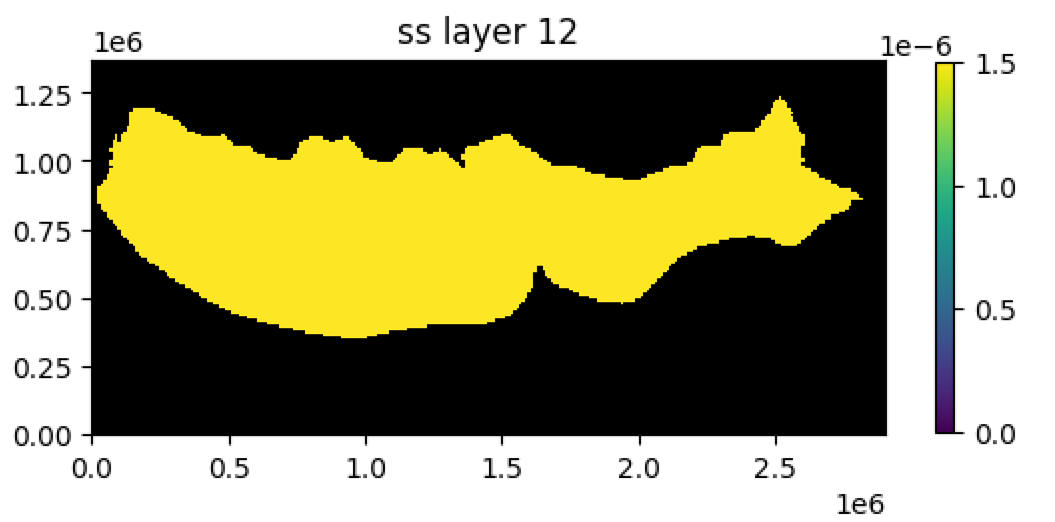
[23]:
```
ml.lpf.plot(mflay=11)
```

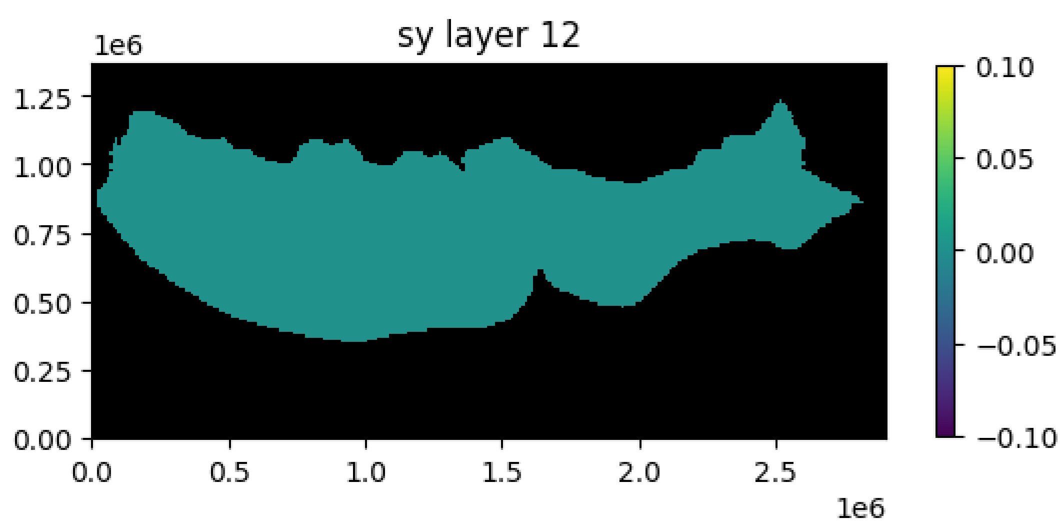
[23]:
```
[<Axes: title={'center': 'hk layer 12'}>,
 <Axes: title={'center': 'hani layer 12'}>,
 <Axes: title={'center': 'vani layer 12'}>,
 <Axes: title={'center': 'ss layer 12'}>,
 <Axes: title={'center': 'sy layer 12'}>,
 <Axes: title={'center': 'vkcb layer 12'}>,
 <Axes: title={'center': 'wetdry layer 12'}>]
```

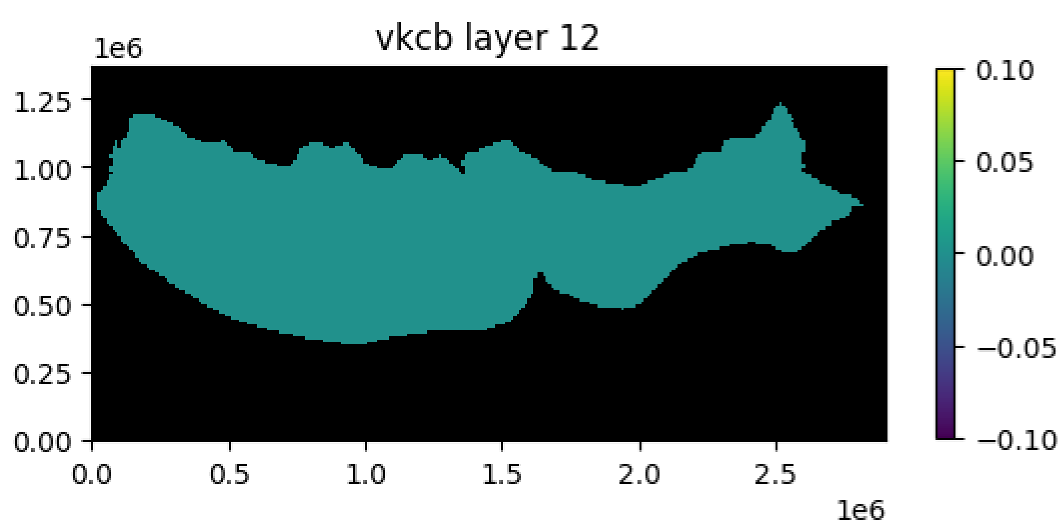

hk layer 12
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
50
40
30
20
10
0

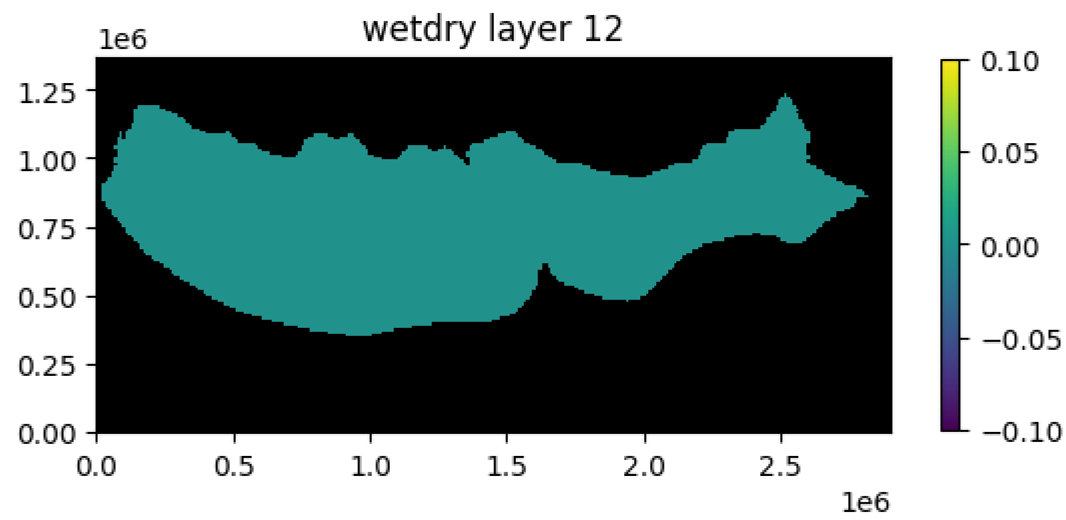

hani layer 12
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
1.10
1.05
1.00
0.95
0.90


vani layer 12
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
3.0
2.5
2.0
1.5
1.0
0.5
0.0


ss layer 12
1e6
1e−6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
1.5
1.0
0.5
0.0


sy layer 12
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
0.10
0.05
0.00
−0.05
−0.10

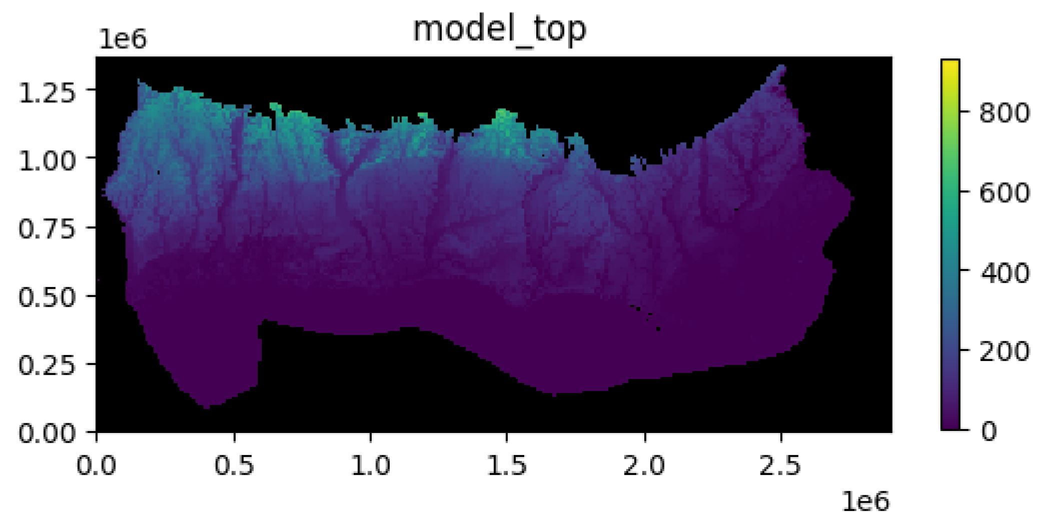

vkcb layer 12
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
0.10
0.05
0.00
−0.05
−0.10

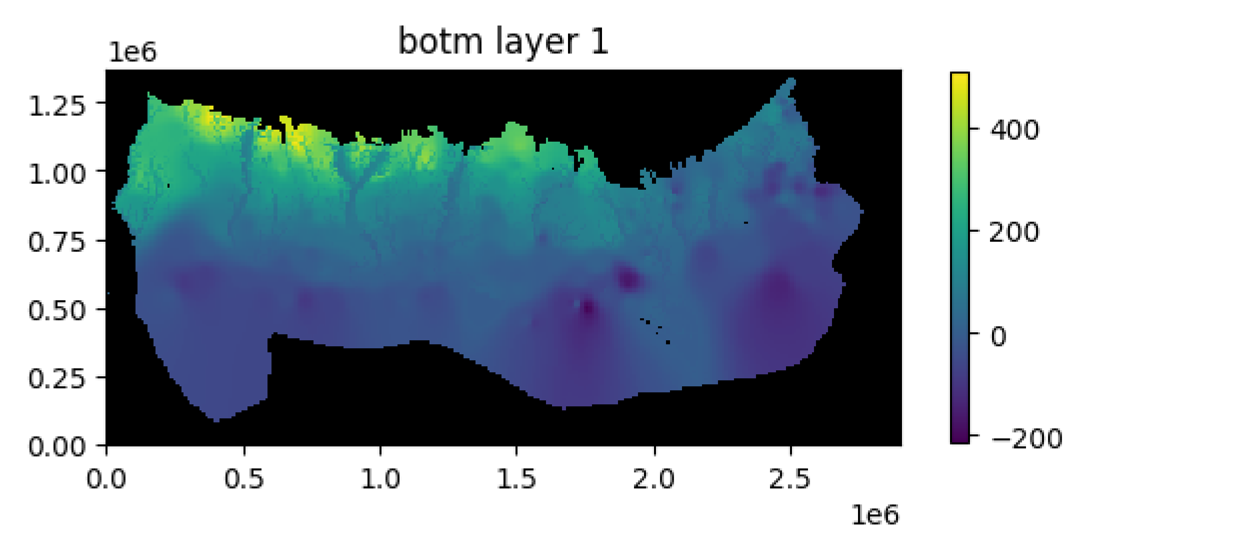


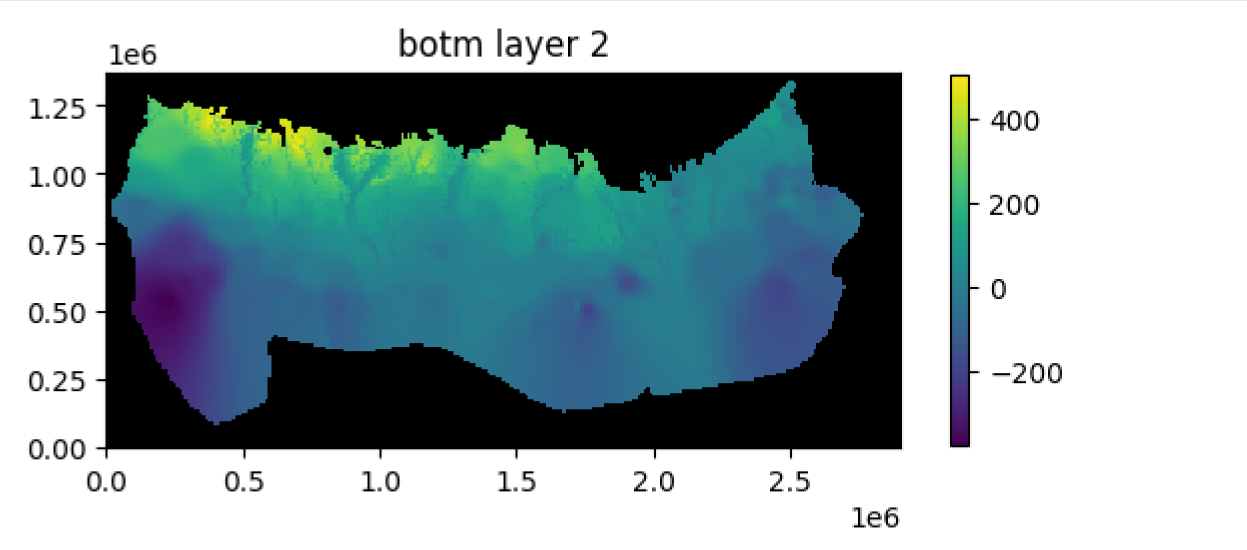
Plot all input data for a model

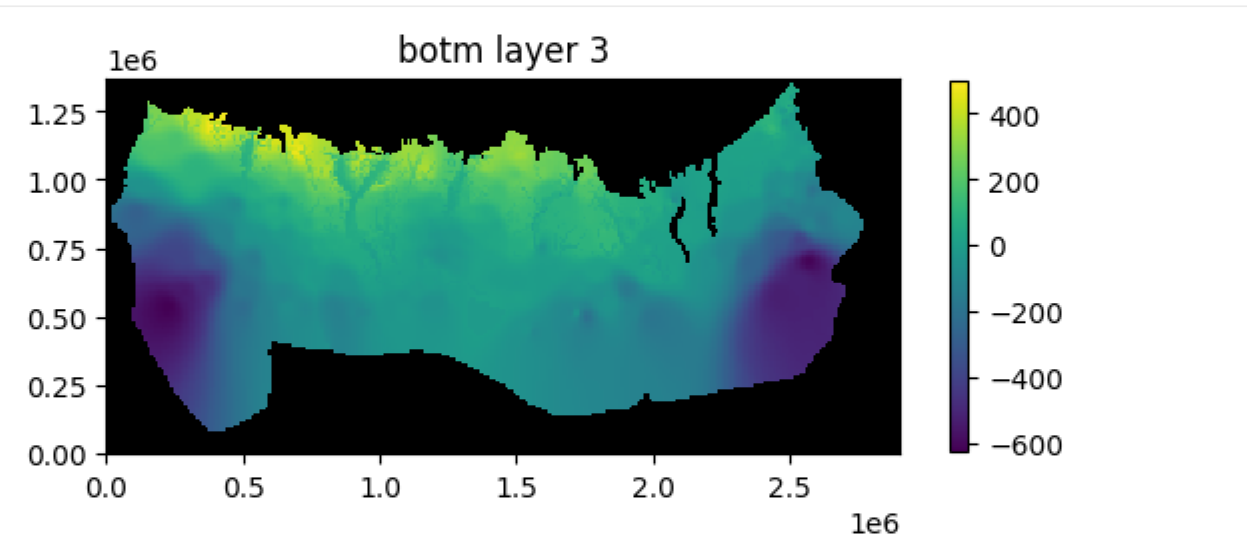
All of the input data for a model can be plotted using the `.plot()` method.

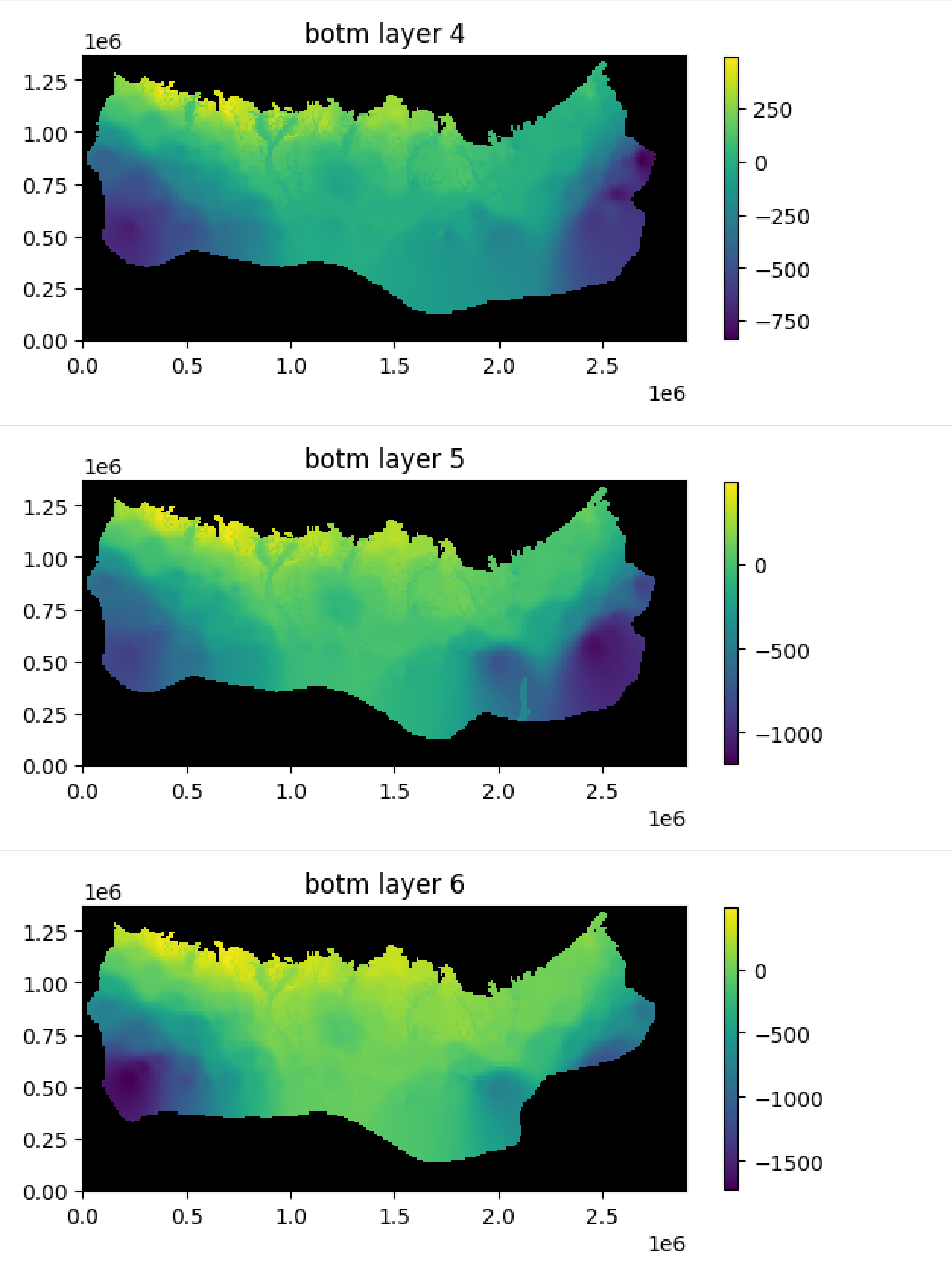
[24]:
```
ap = ml.plot()
```

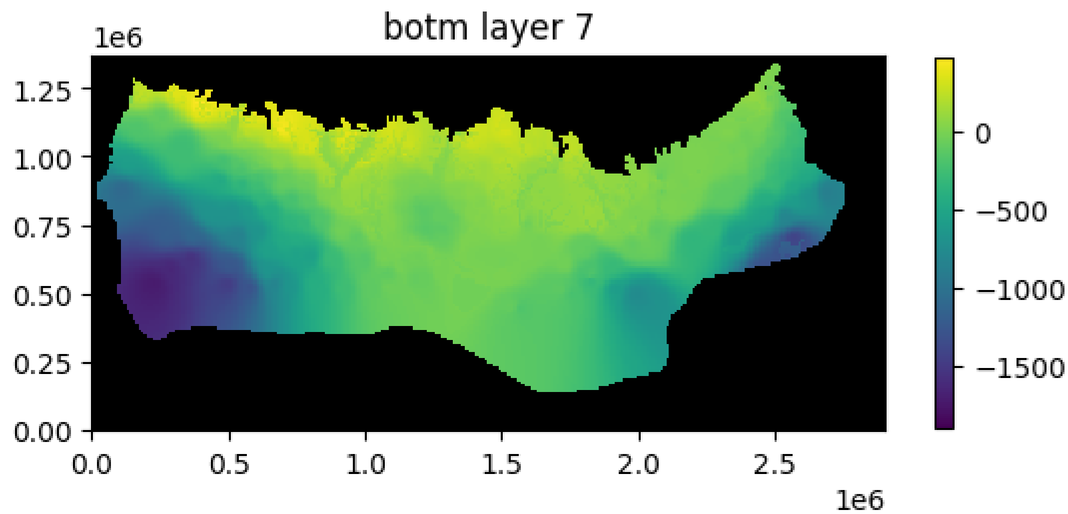


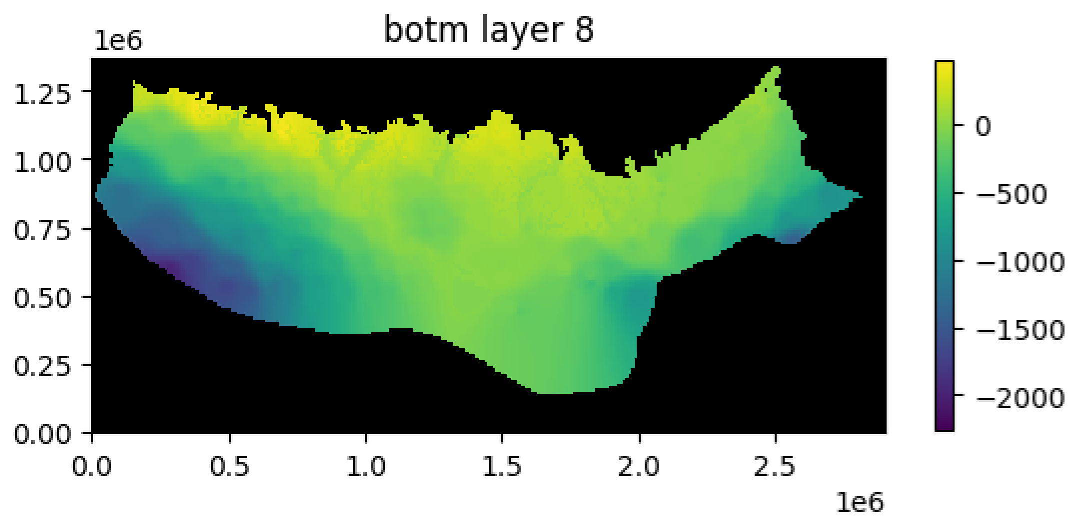

botm layer 1
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
400
200
0
−200

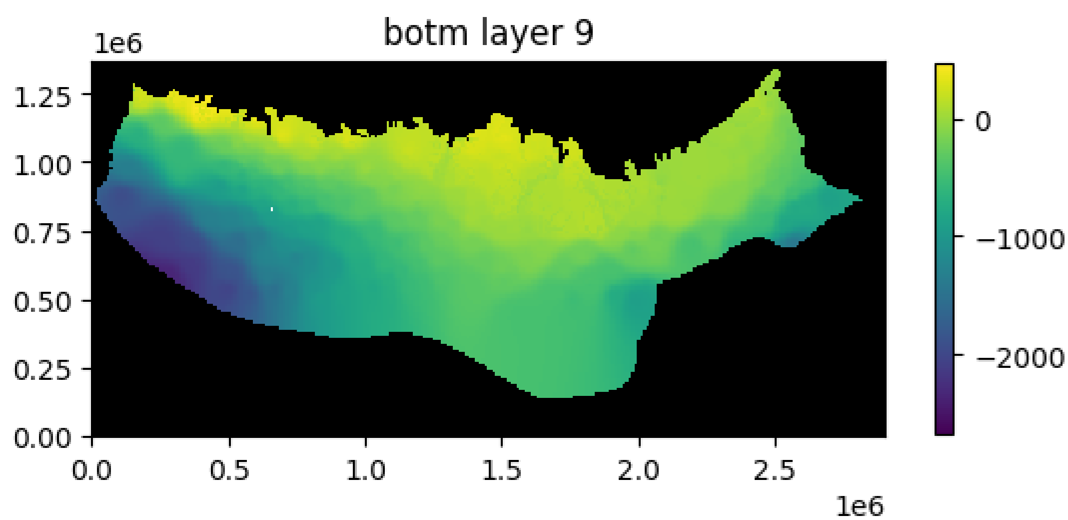

botm layer 2
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
400
200
0
−200

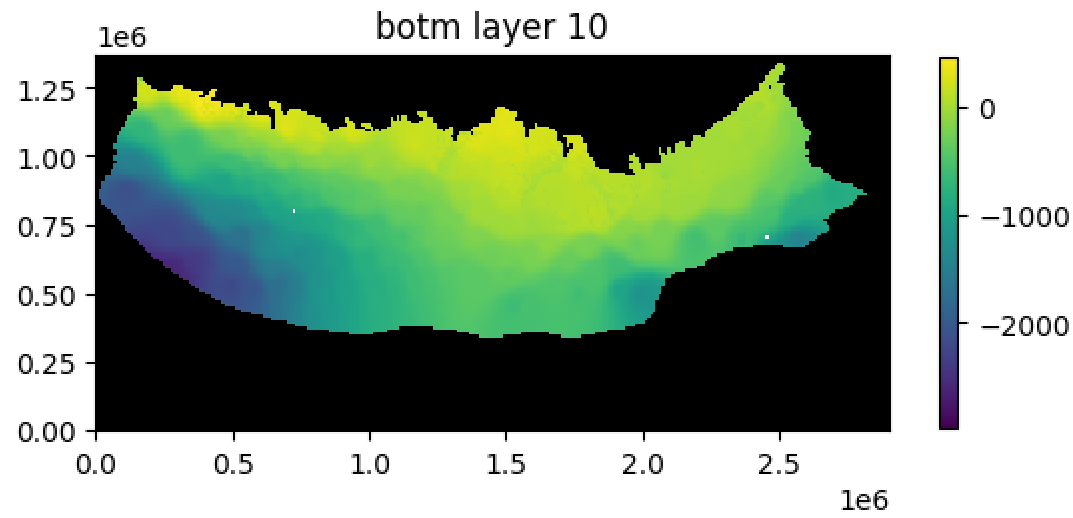

botm layer 3
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
400
200
0
−200
−400
−600

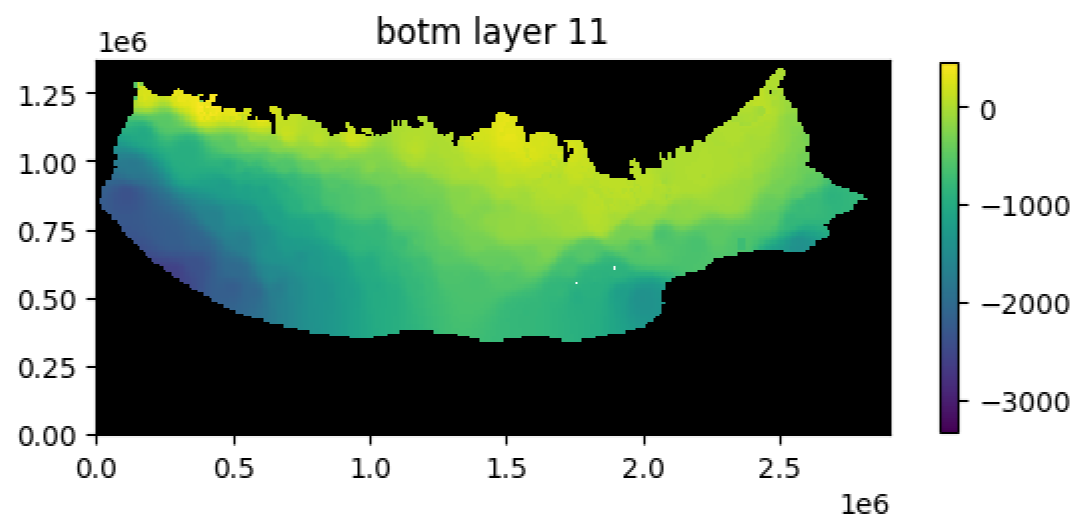

botm layer 4
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
250
0
−250
−500
−750
botm layer 5
1e6
0
−500
−1000
botm layer 6
1e6
0
−500
−1000
−1500

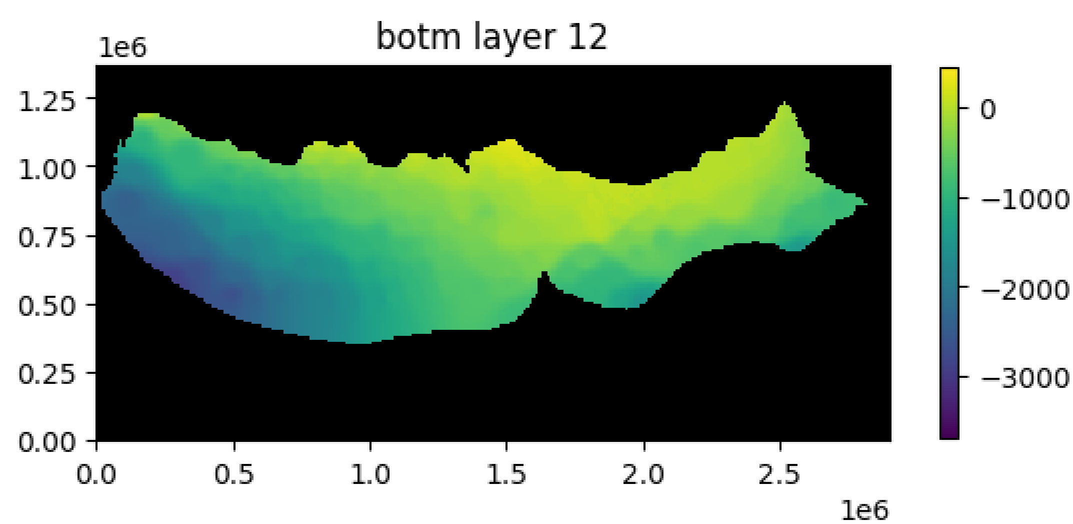

botm layer 7
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
0
−500
−1000
−1500

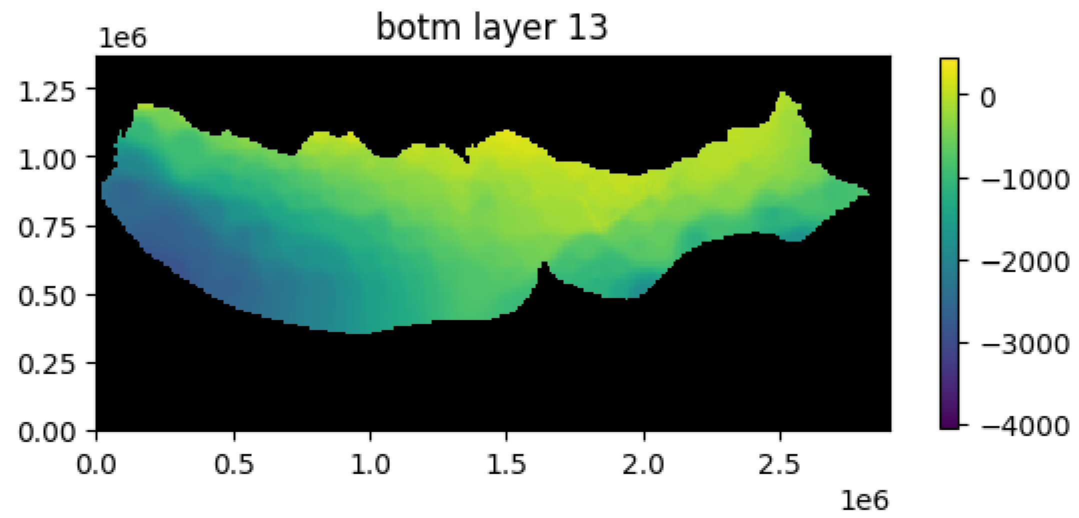

botm layer 8
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
0
−500
−1000
−1500
−2000

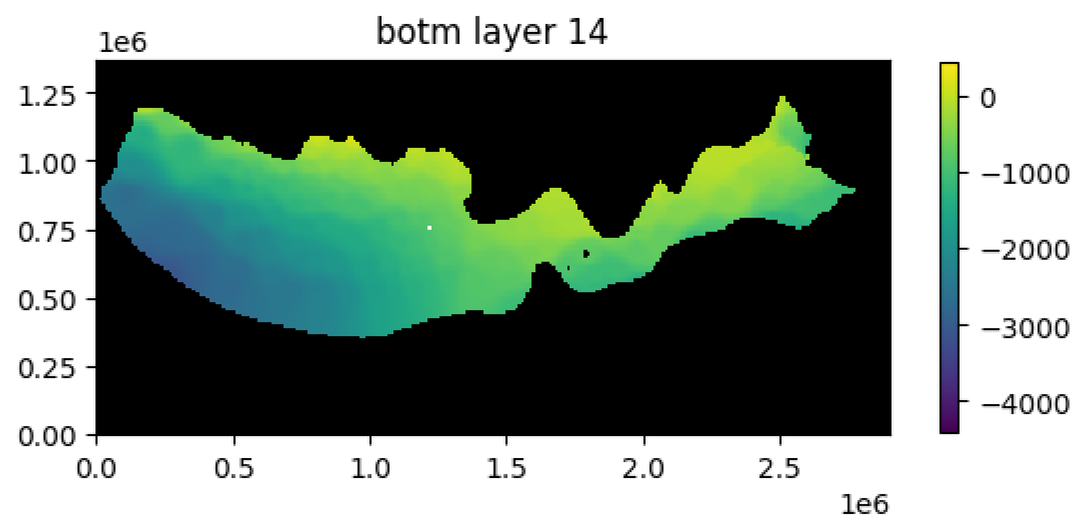

botm layer 9
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
0
−1000
−2000

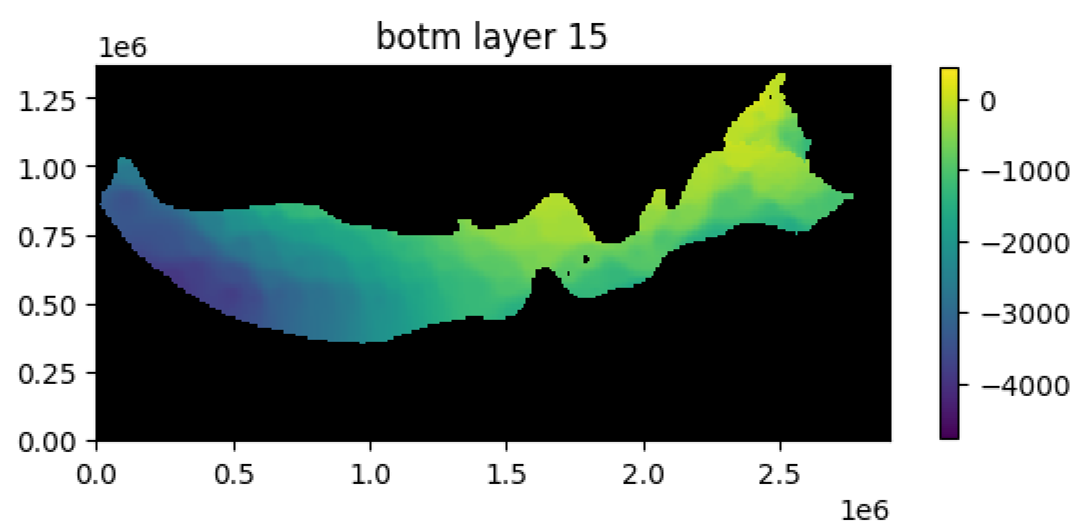

botm layer 10
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
0
−1000
−2000

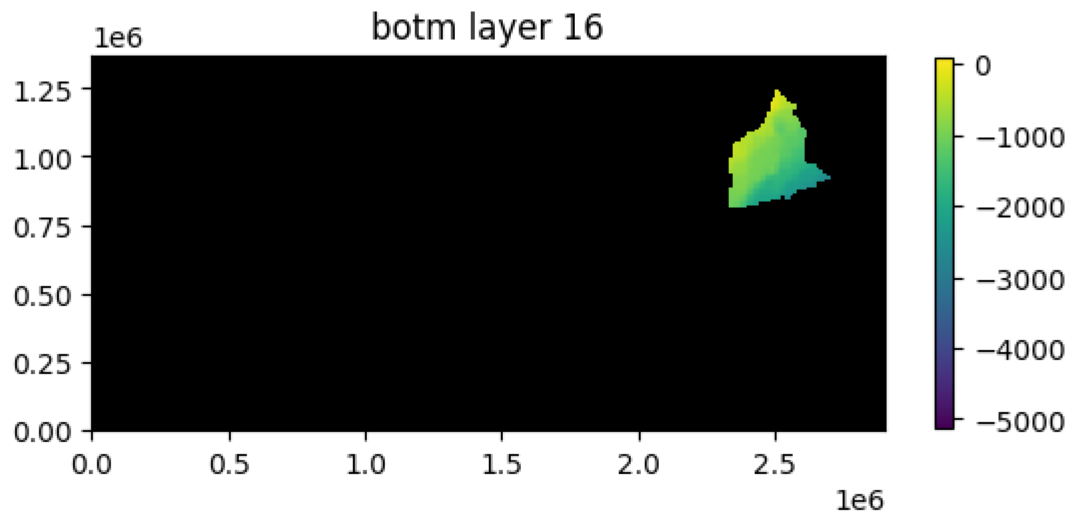

botm layer 11
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
0
−1000
−2000
−3000

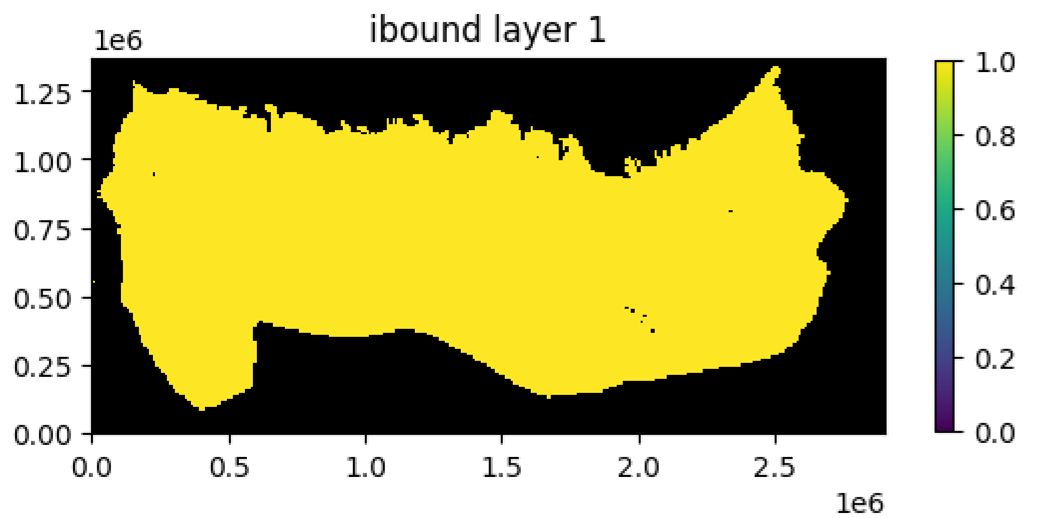

botm layer 12
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
0
−1000
−2000
−3000

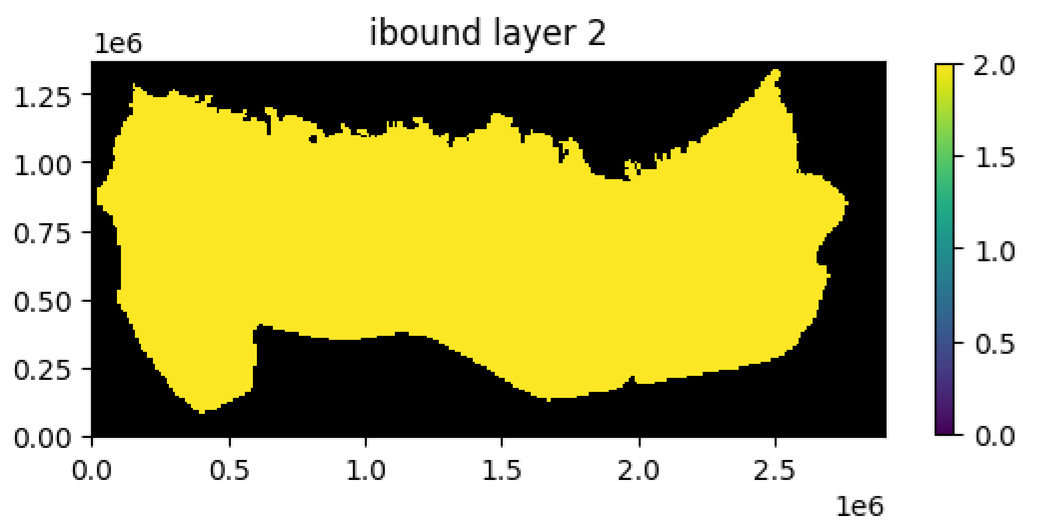

botm layer 13
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
0
−1000
−2000
−3000
−4000


botm layer 14
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
0
−1000
−2000
−3000
−4000


botm layer 15
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
0
−1000
−2000
−3000
−4000


botm layer 16
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
0
−1000
−2000
−3000
−4000
−5000


ibound layer 1
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
1.0
0.8
0.6
0.4
0.2
0.0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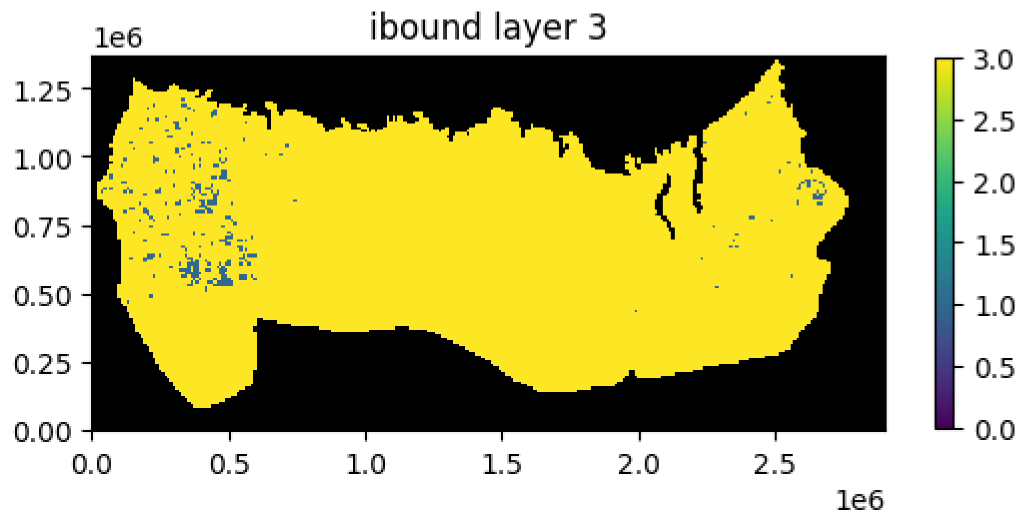
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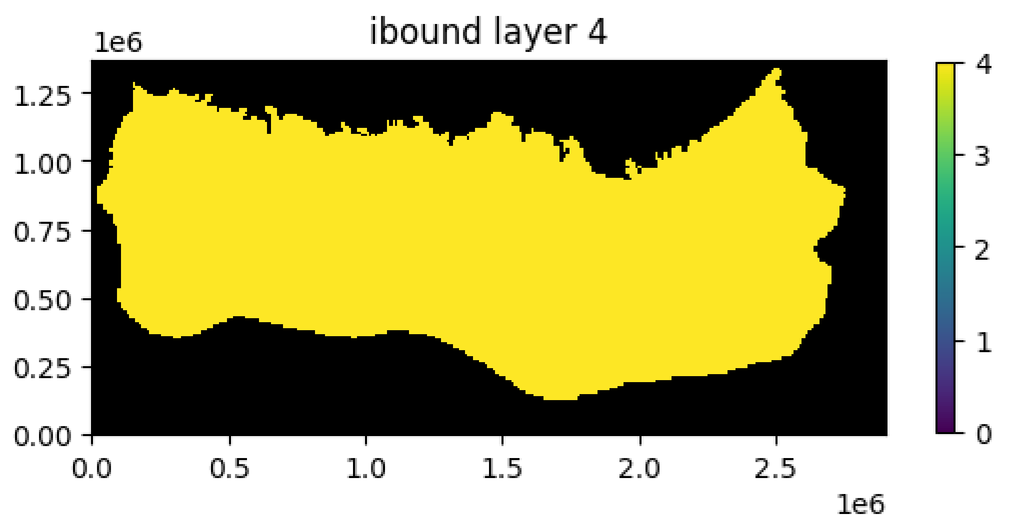
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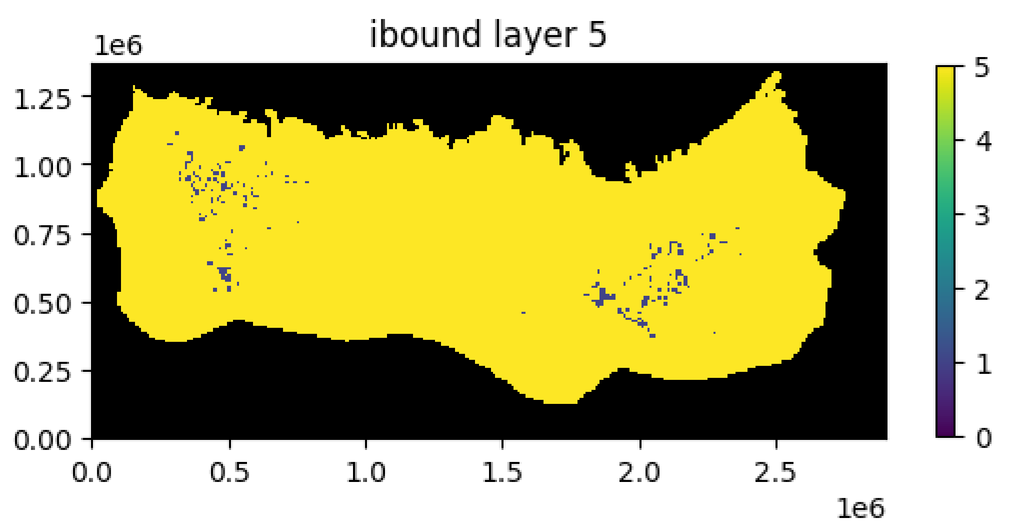
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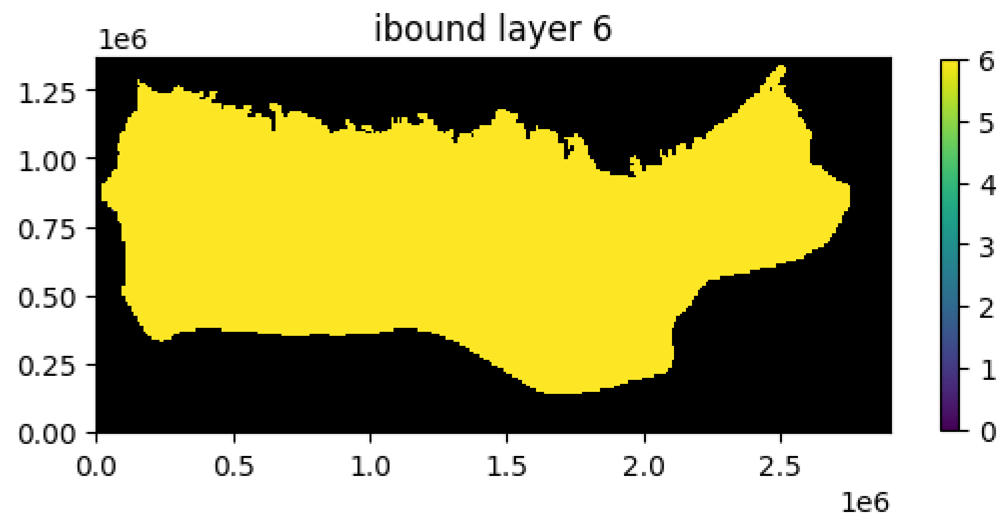
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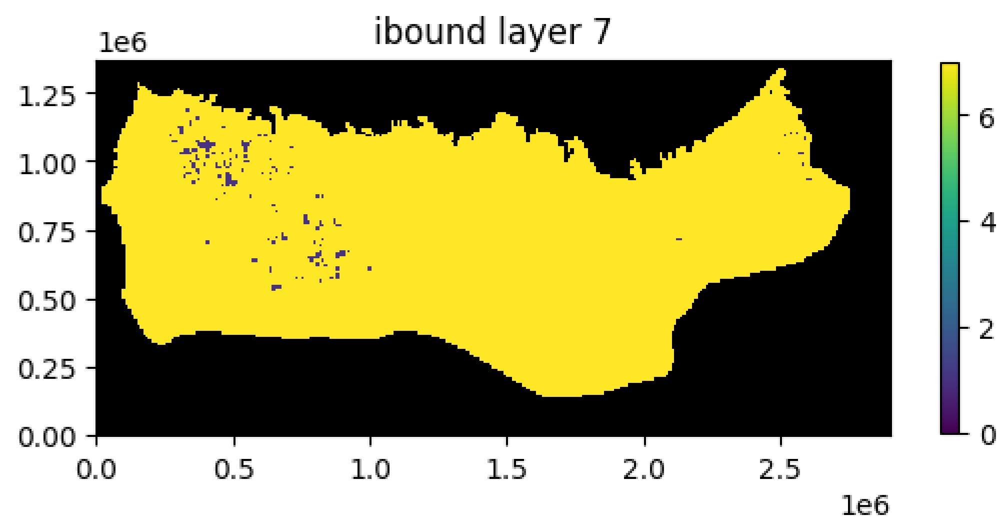
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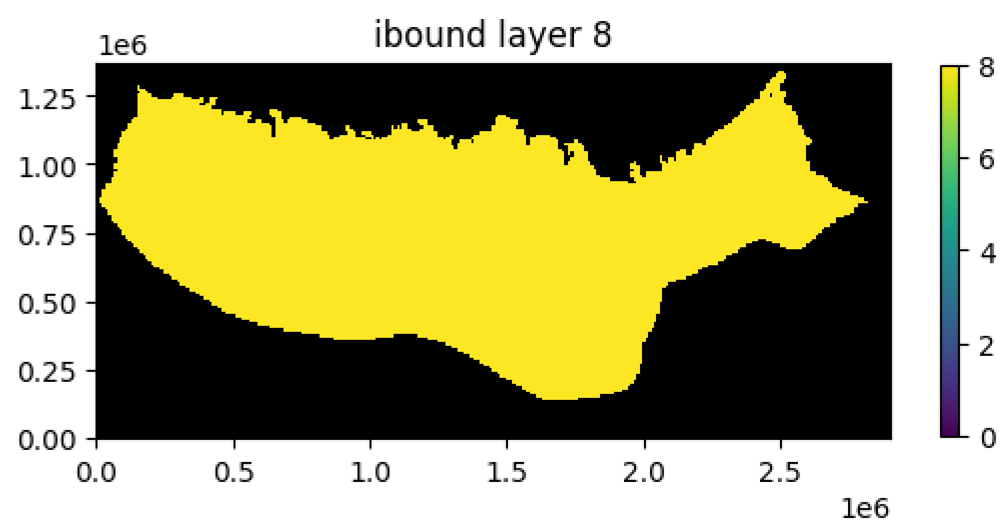
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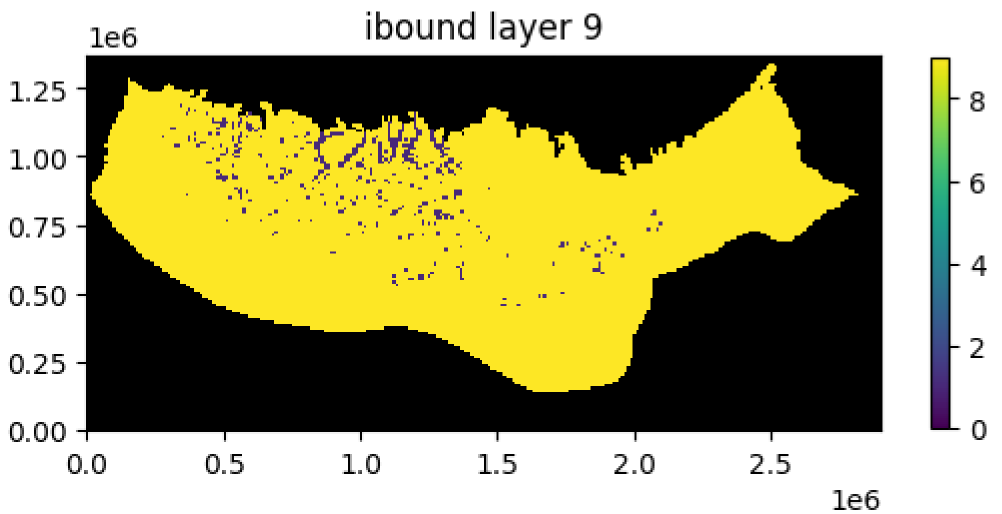
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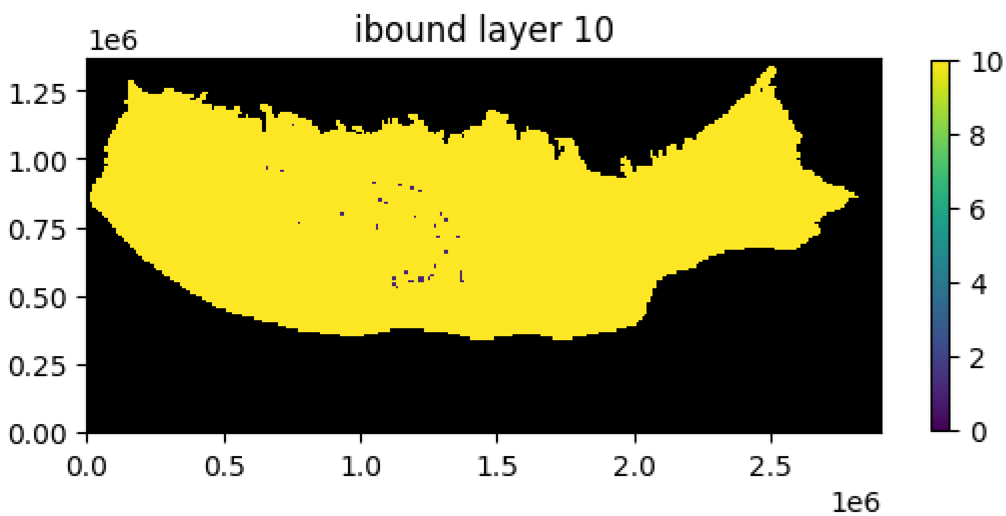
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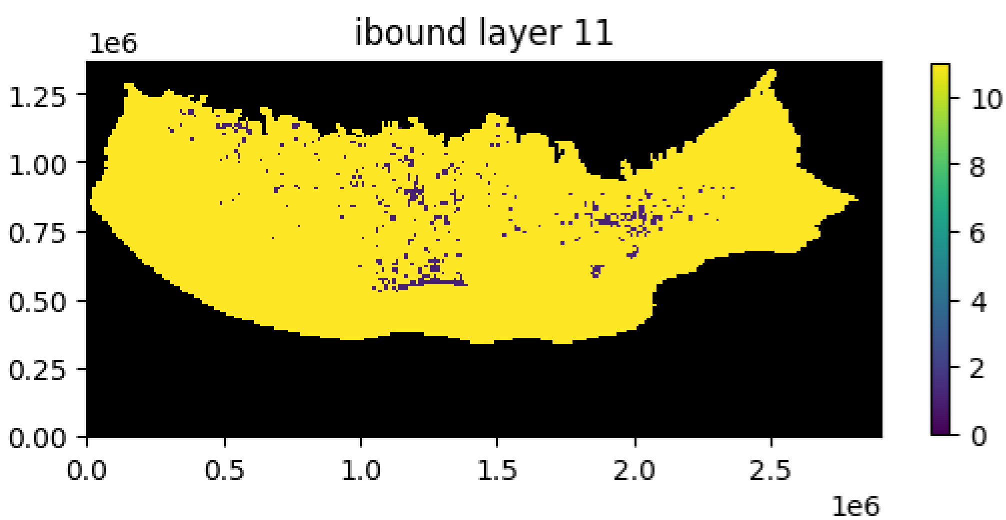
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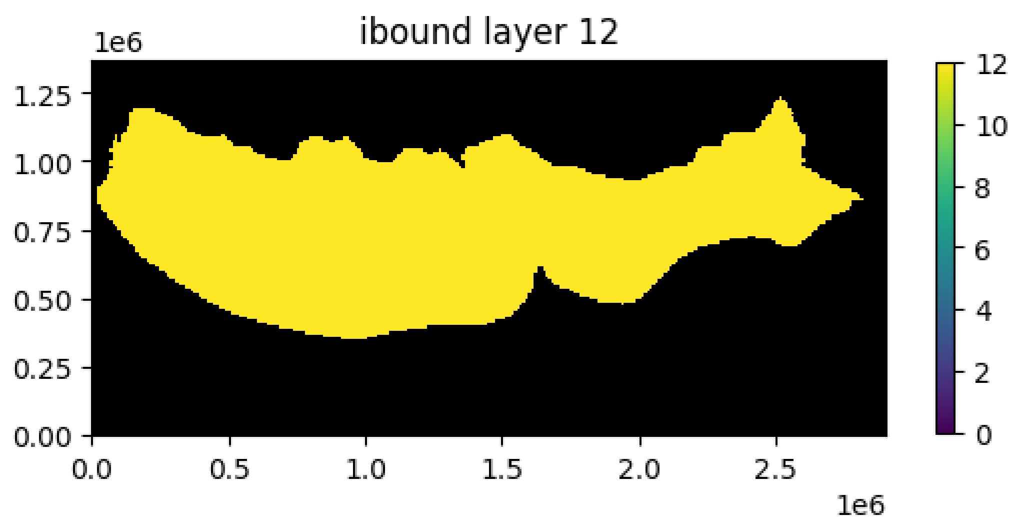
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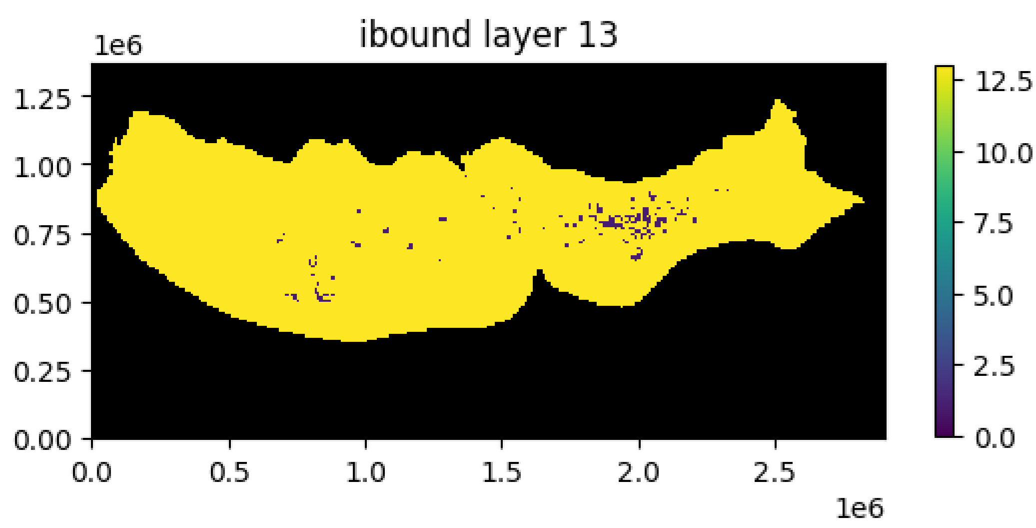
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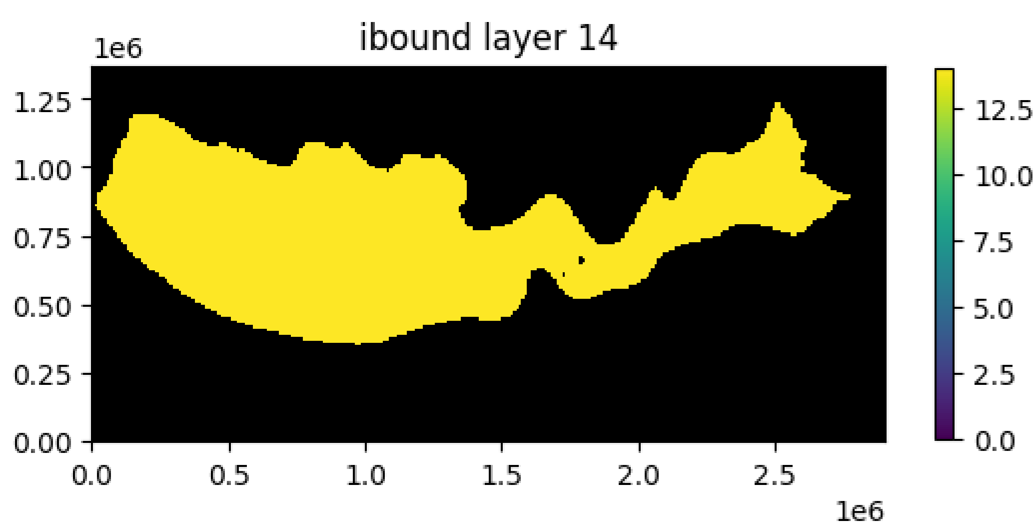
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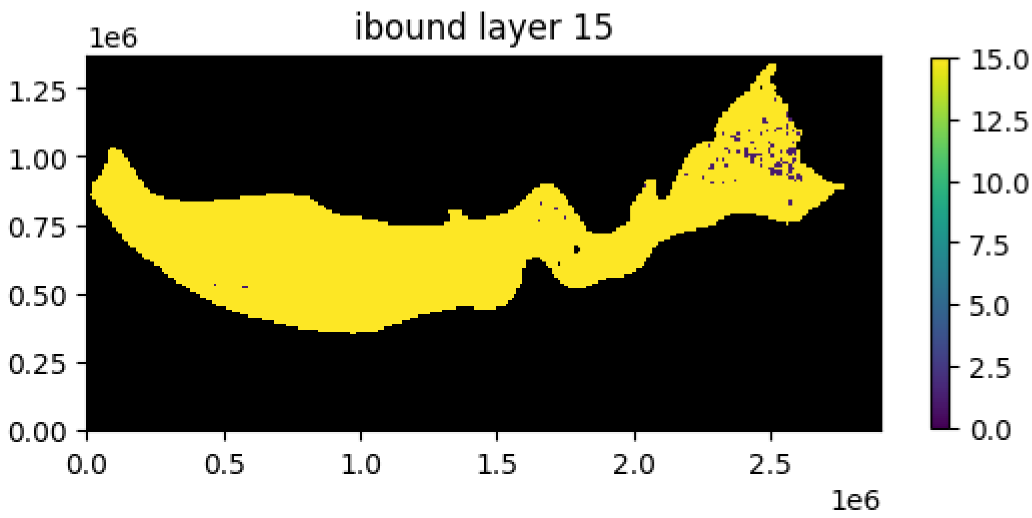
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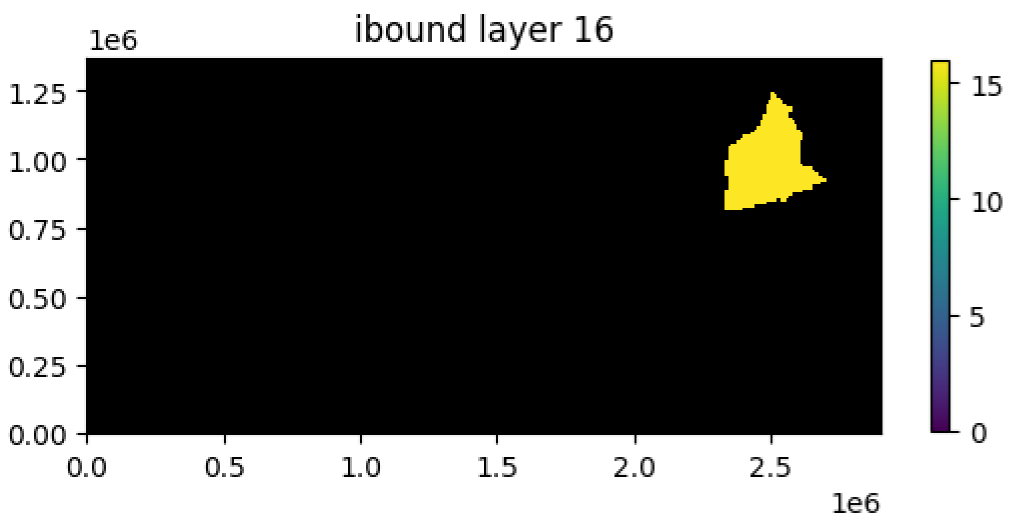
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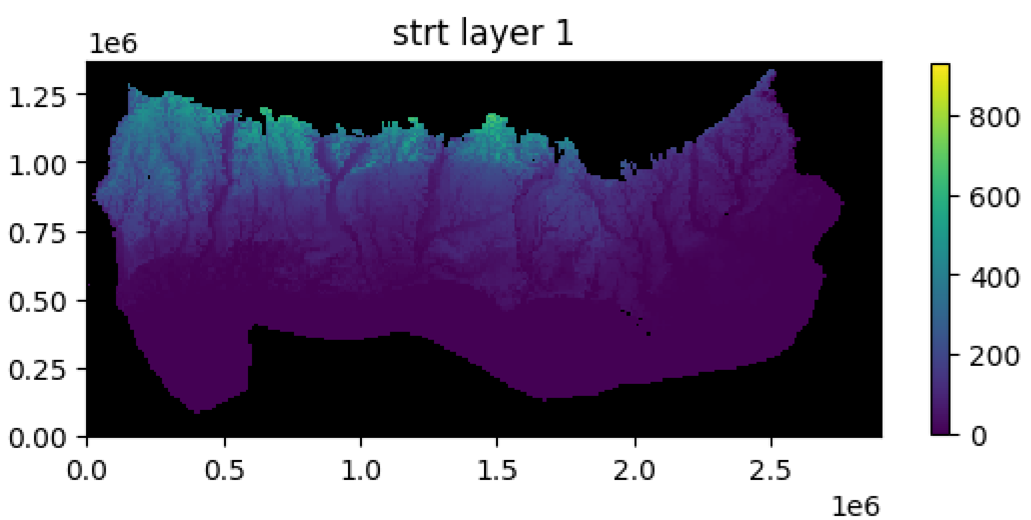
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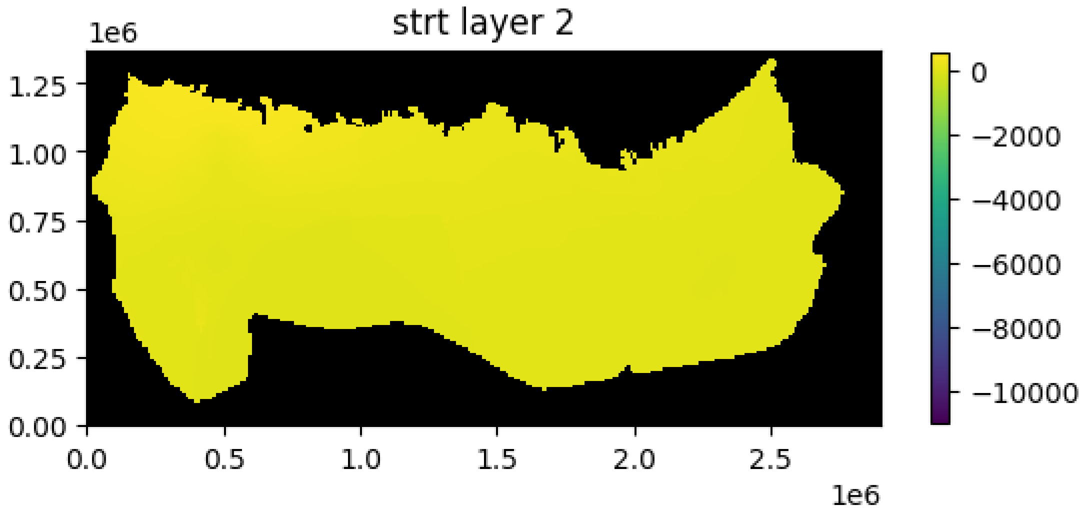
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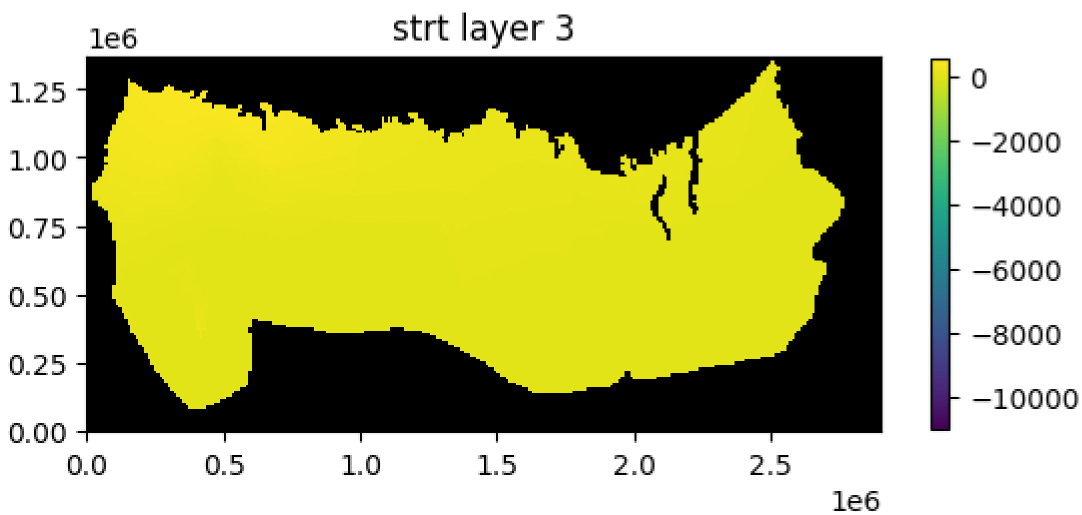
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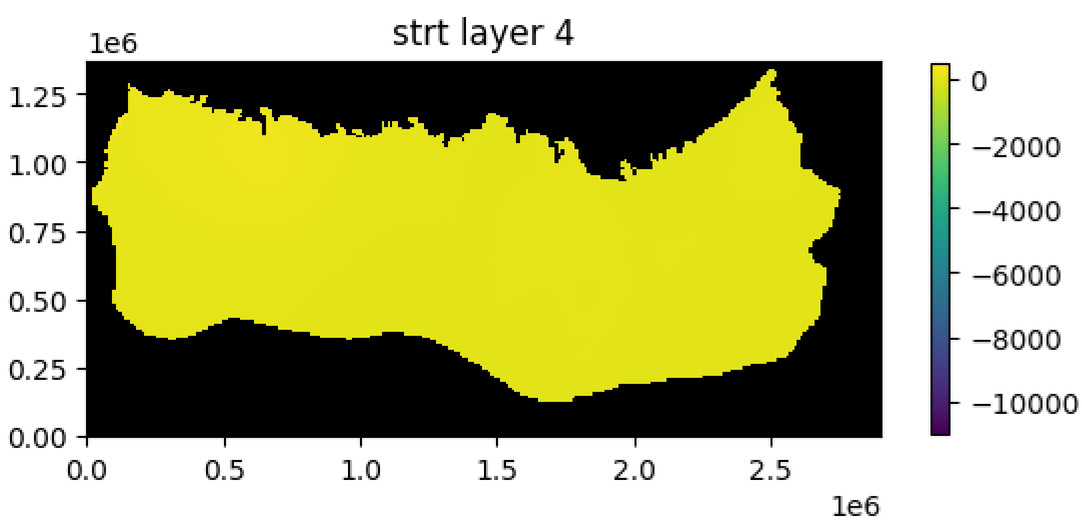
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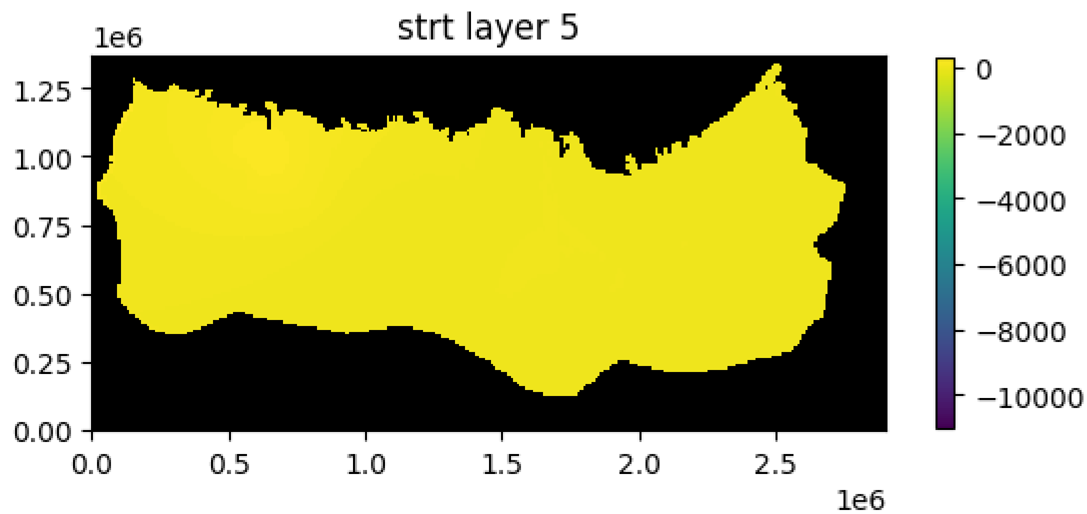
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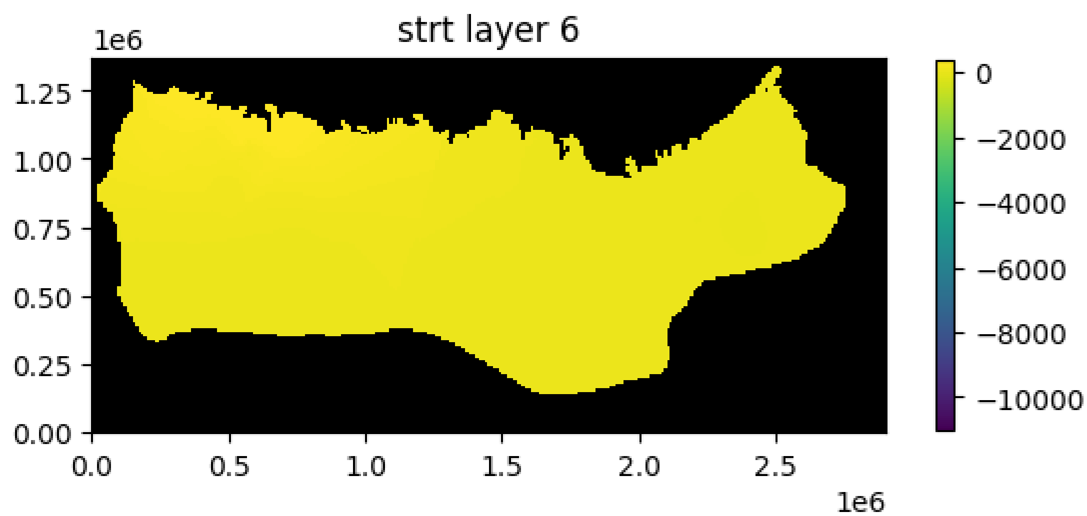
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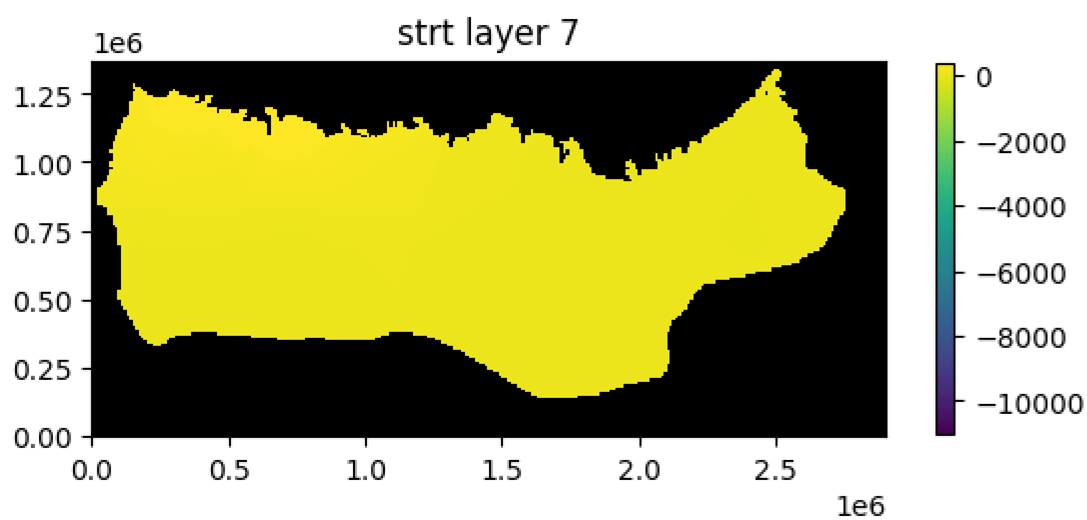
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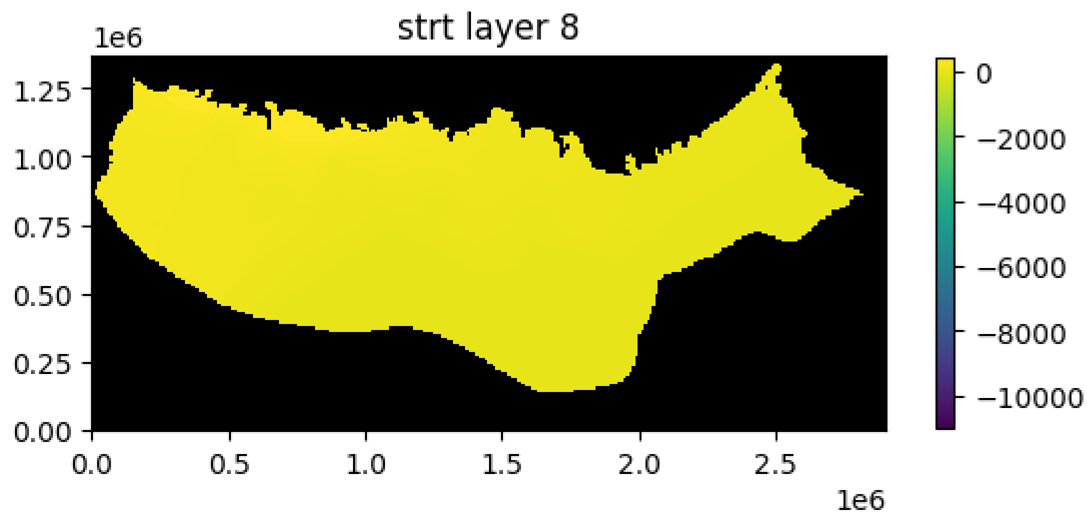
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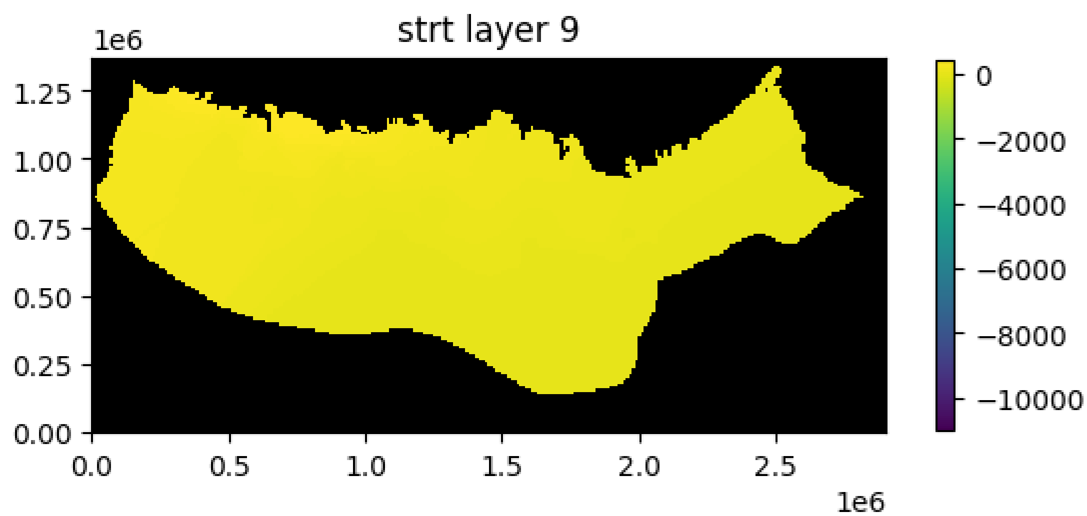
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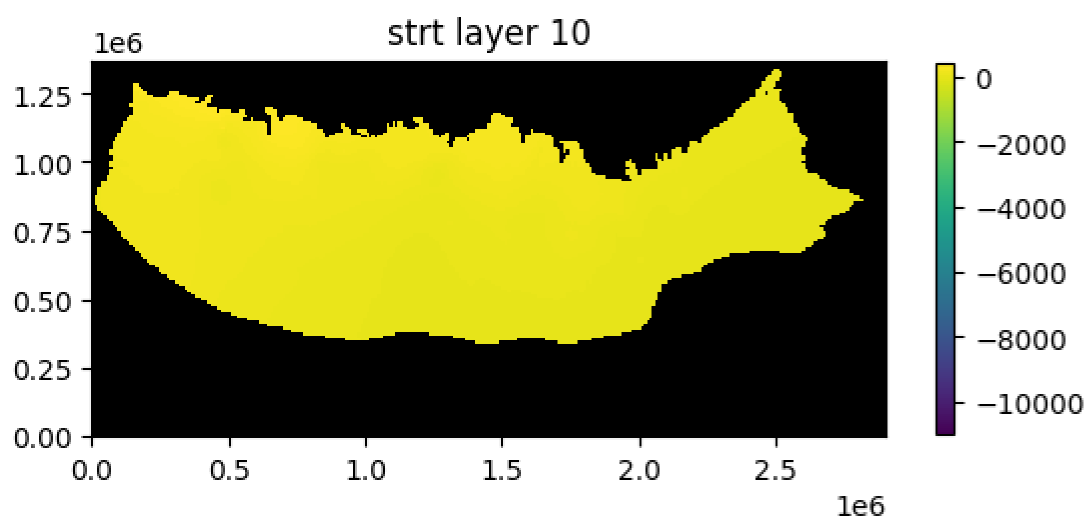
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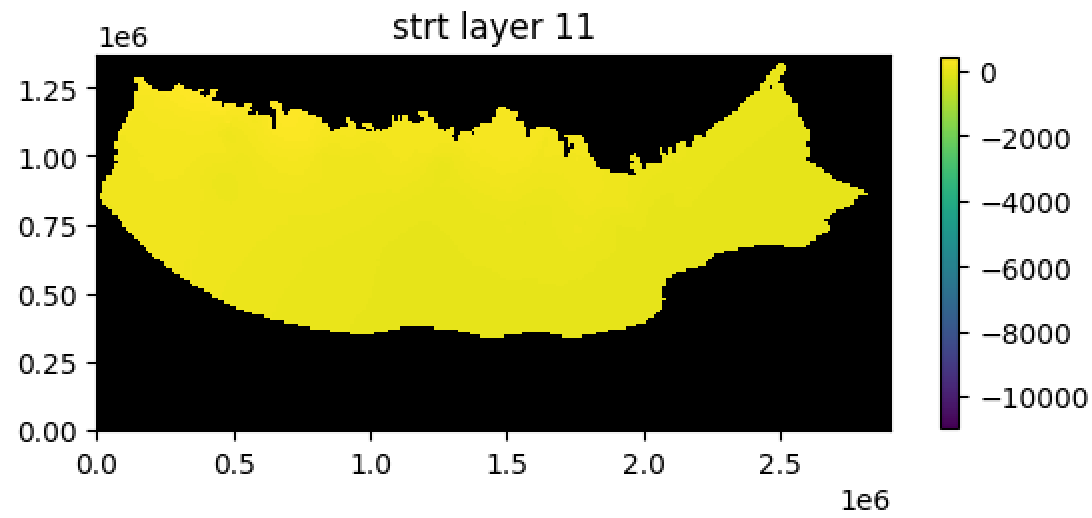
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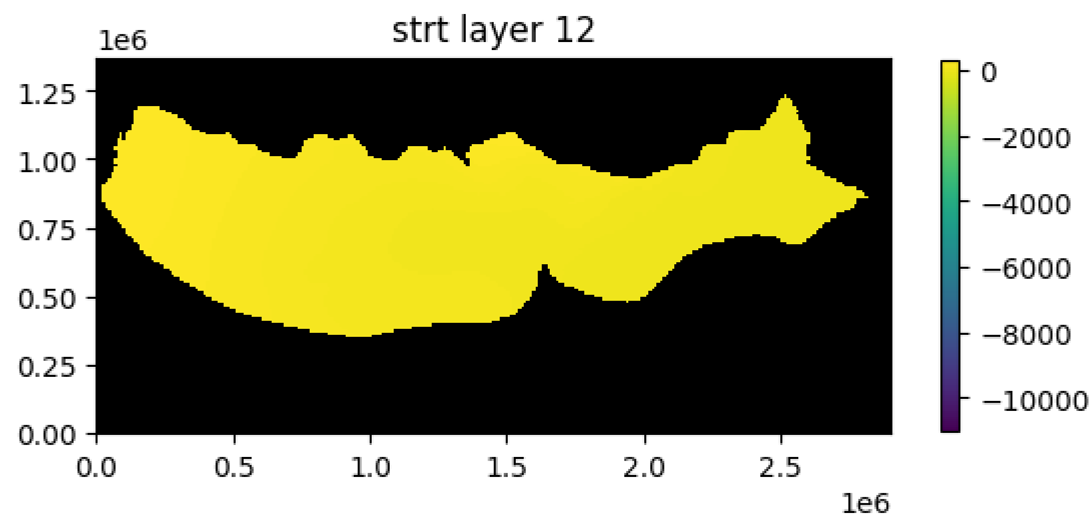
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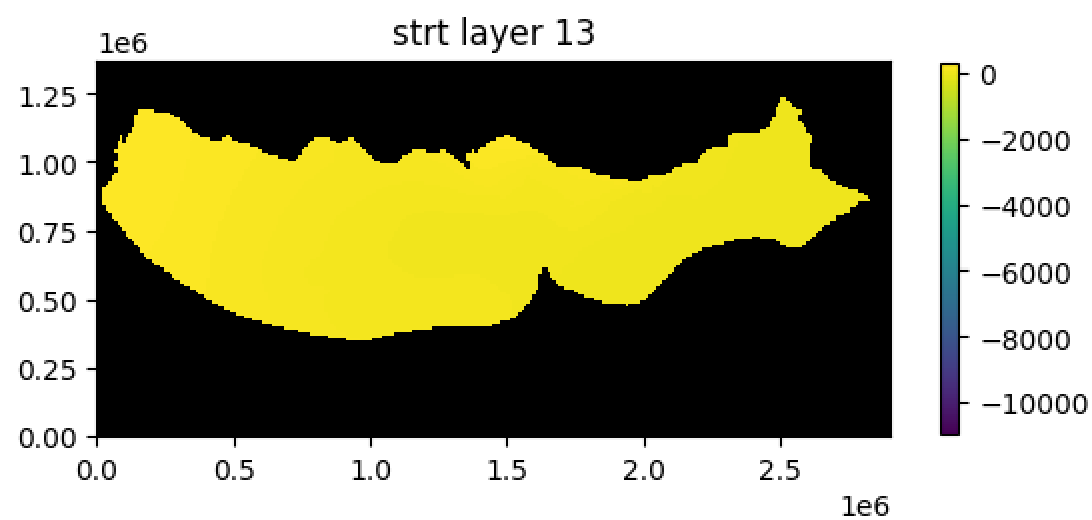
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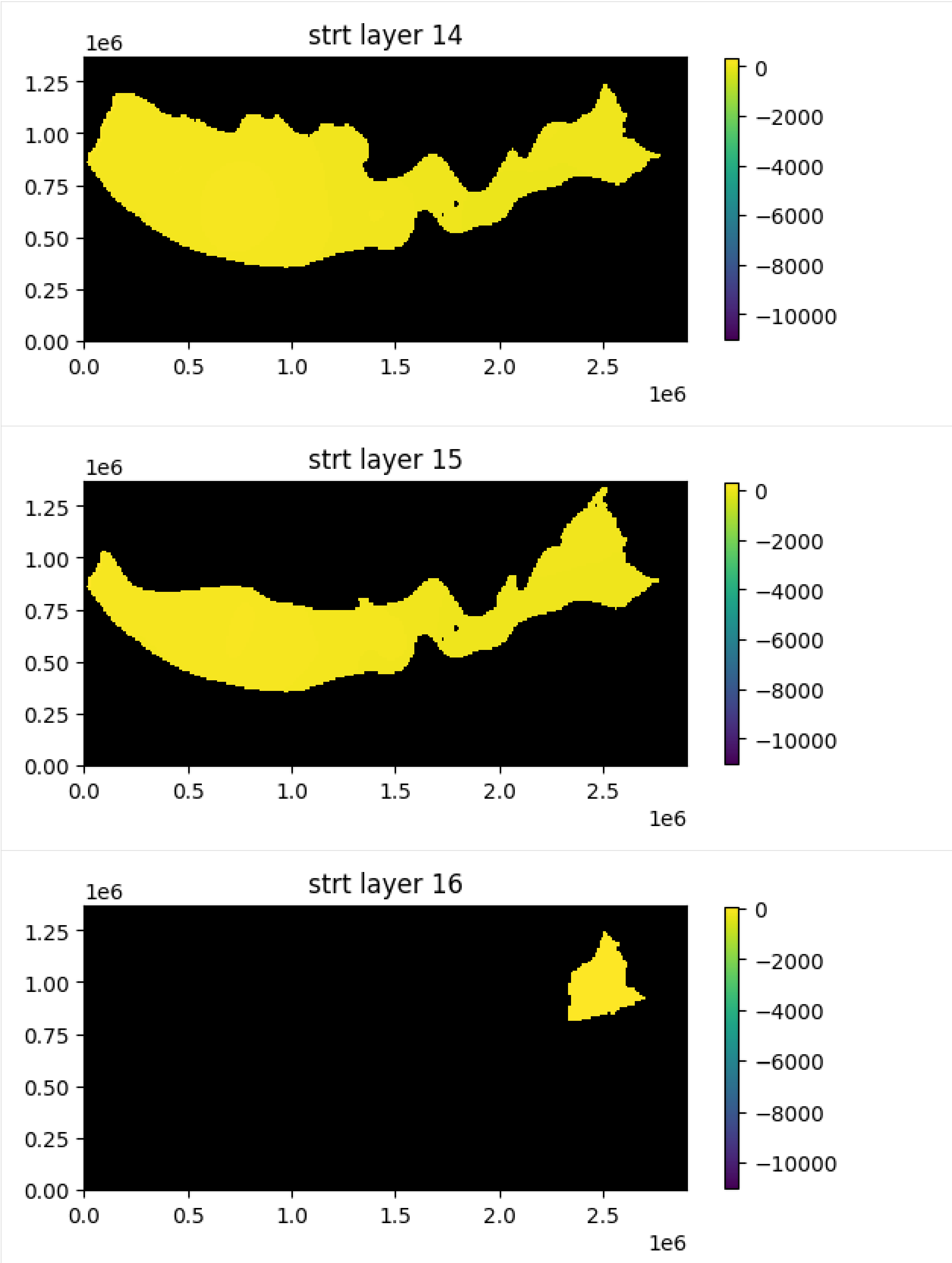
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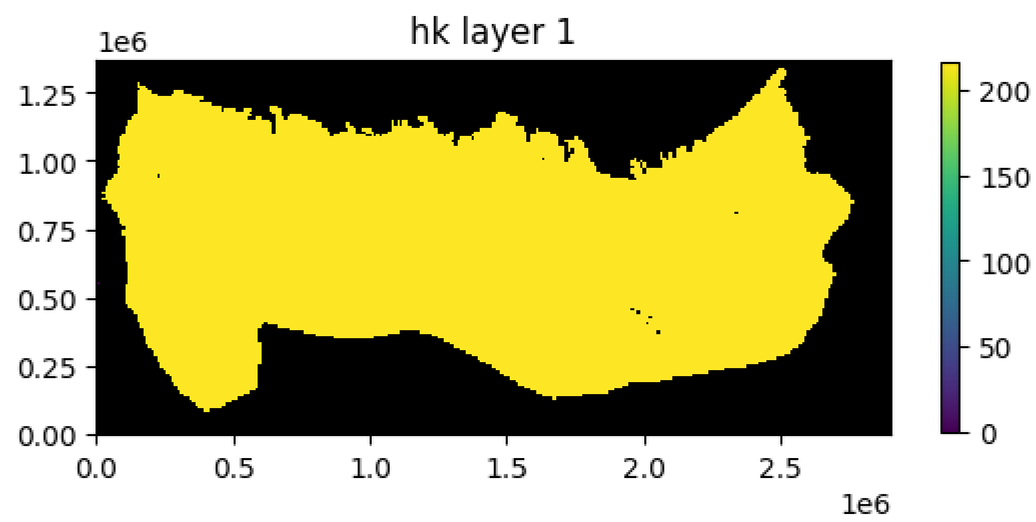
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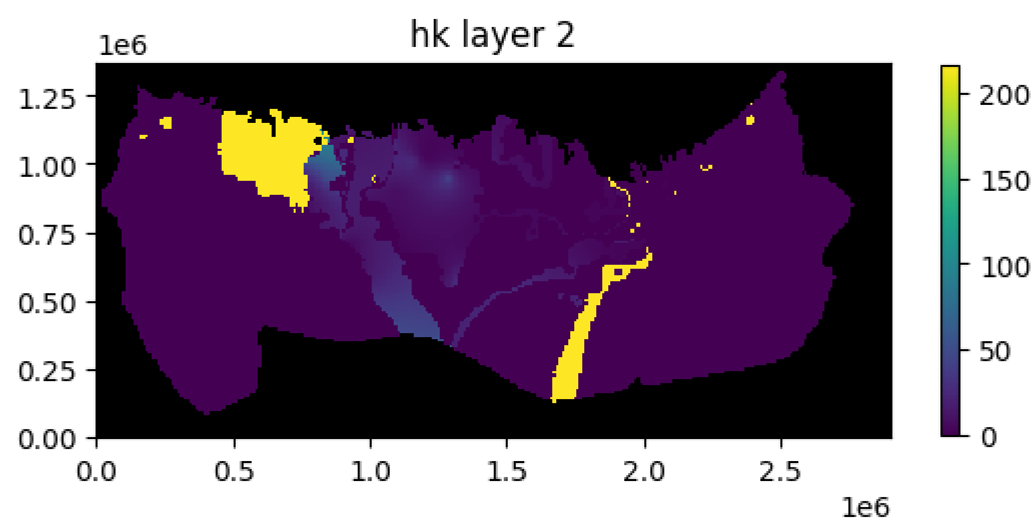
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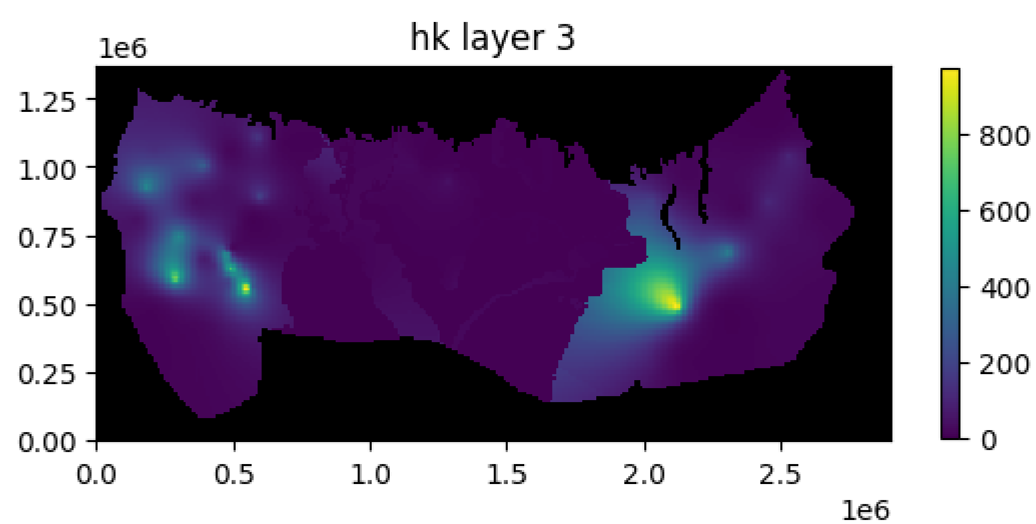
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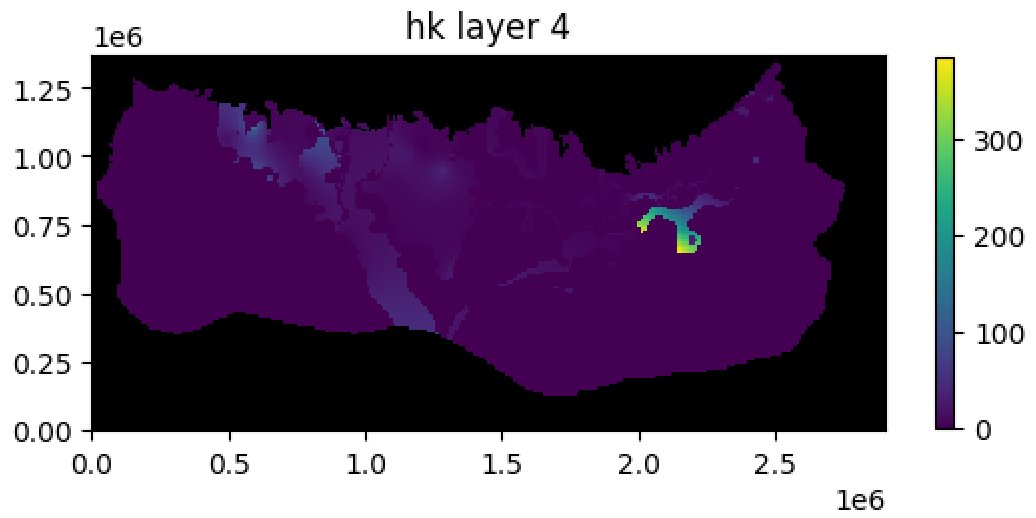
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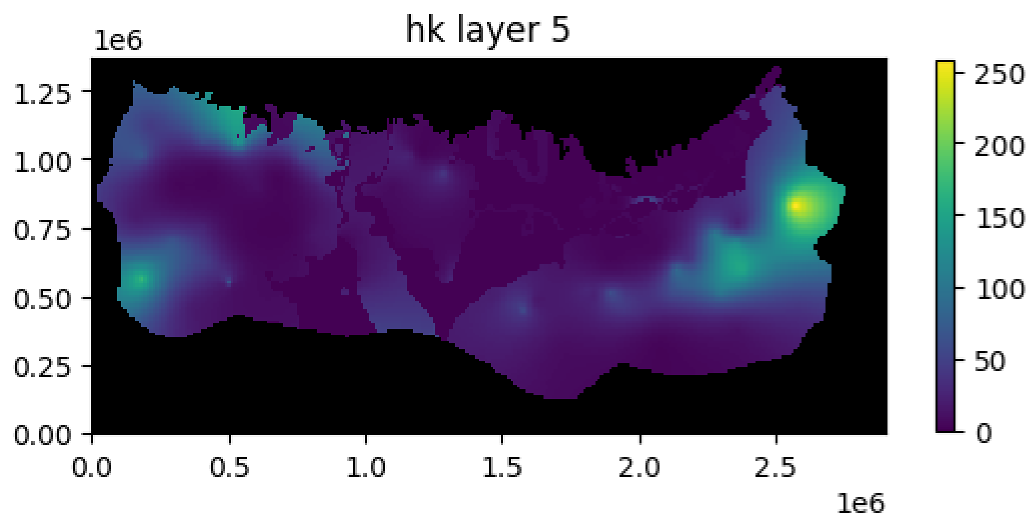
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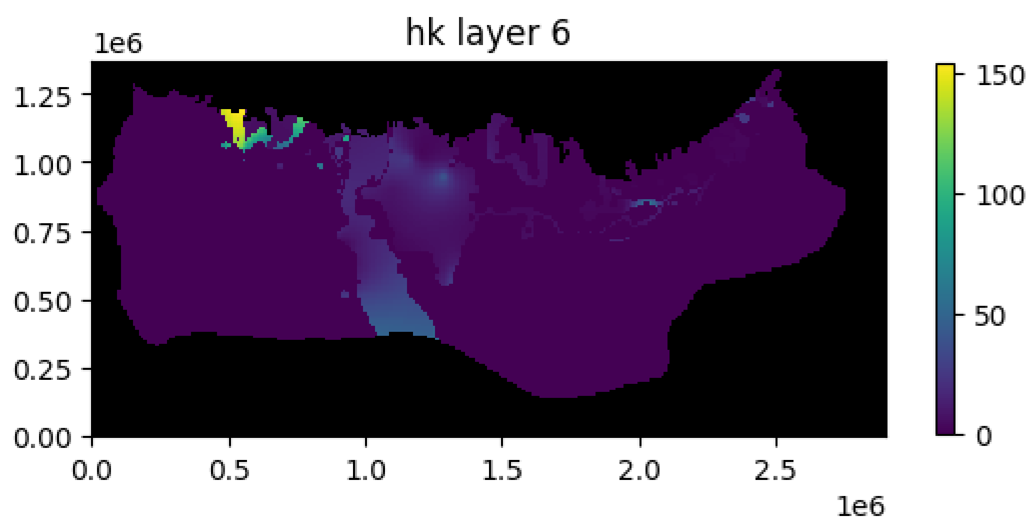
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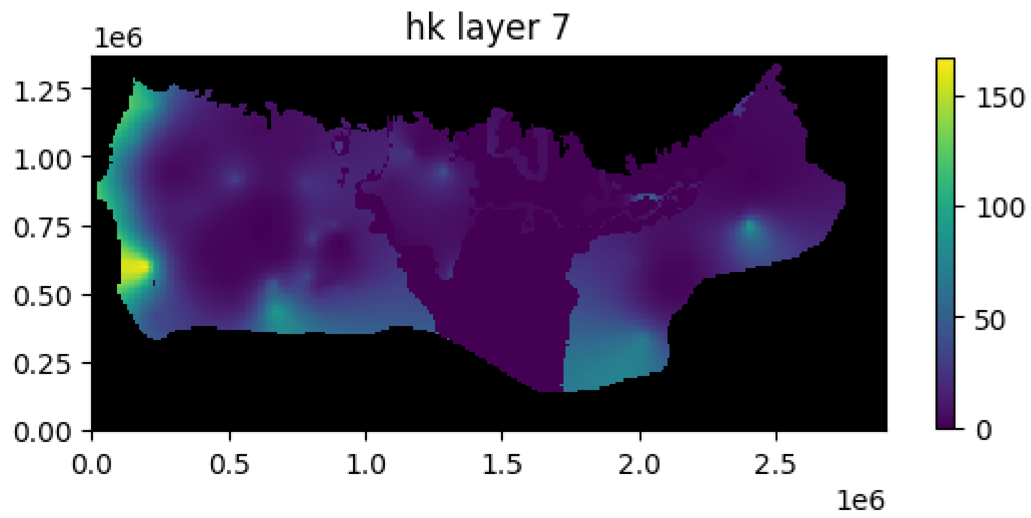
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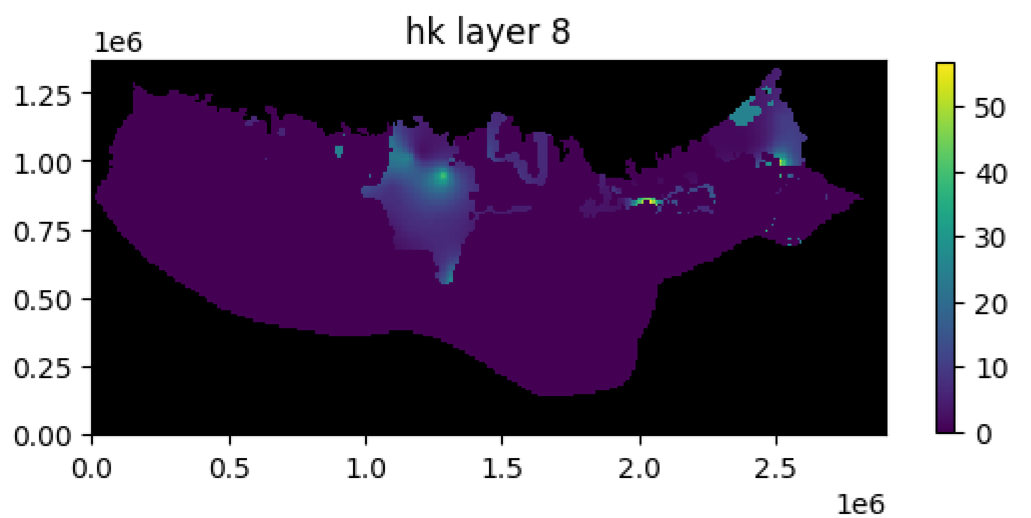
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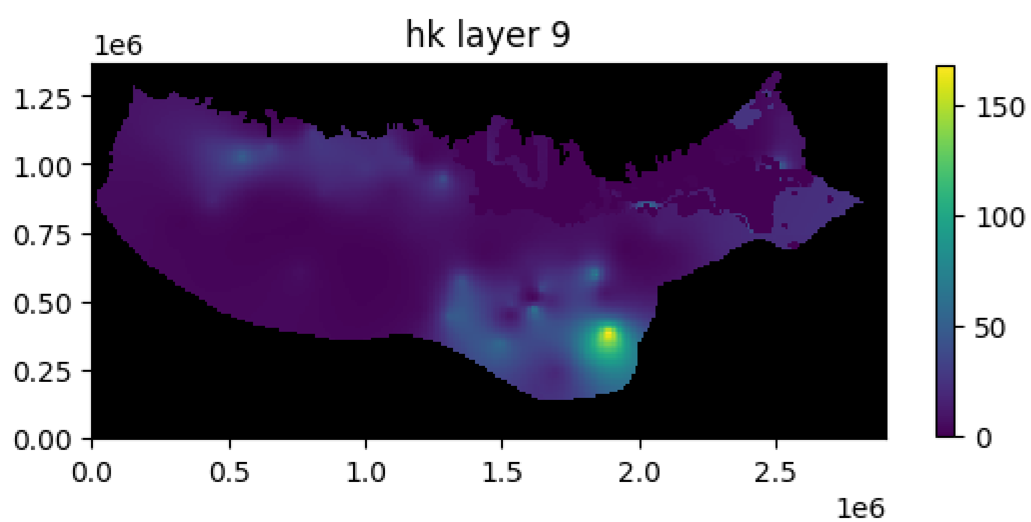
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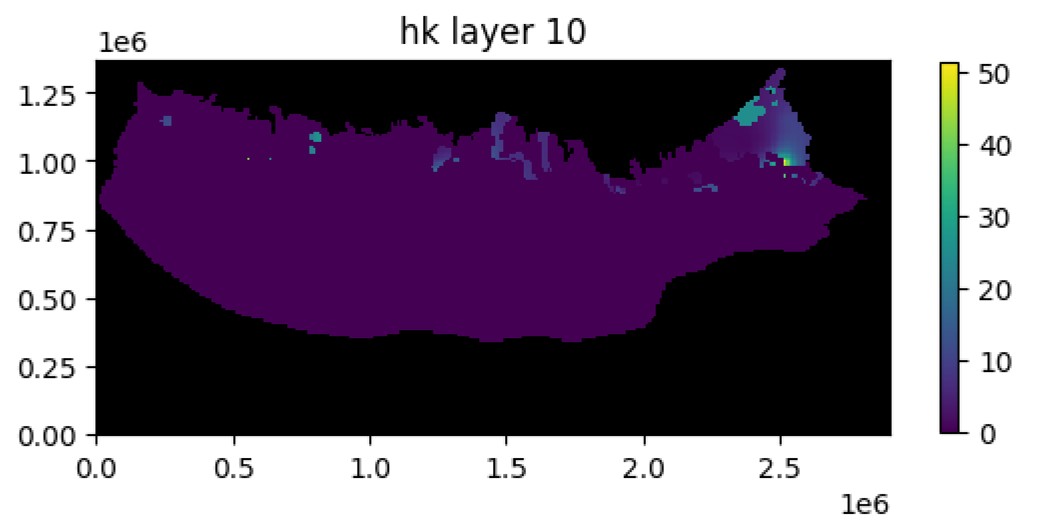
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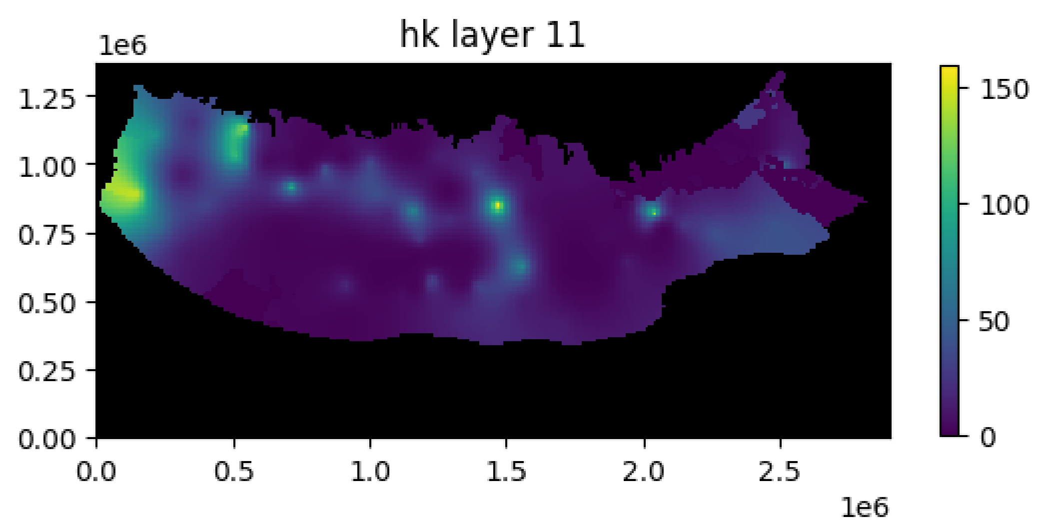
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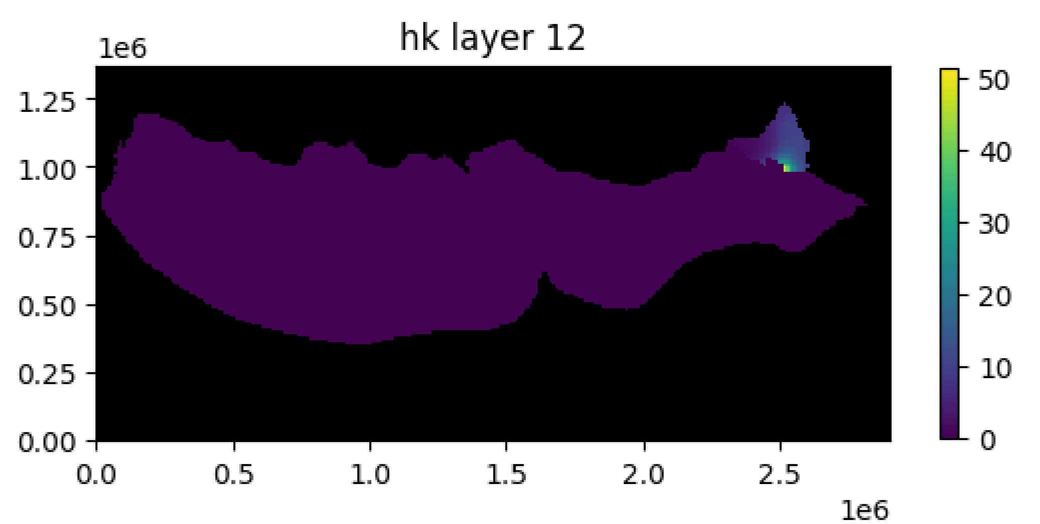
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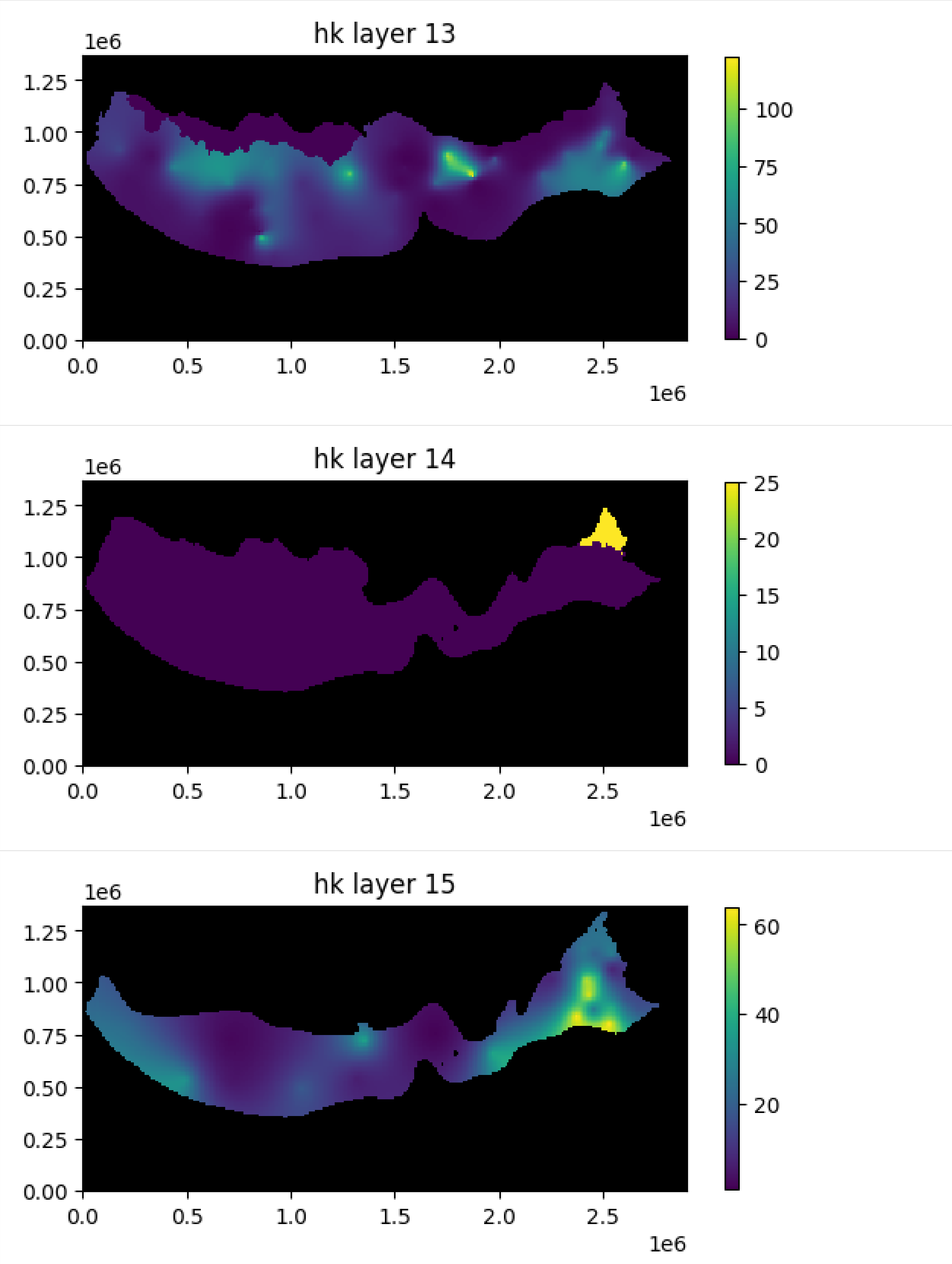
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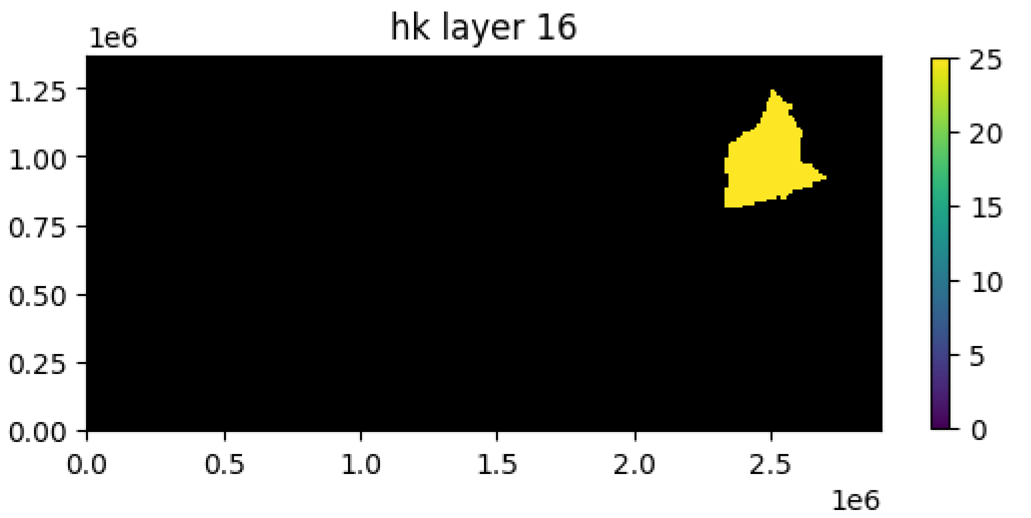
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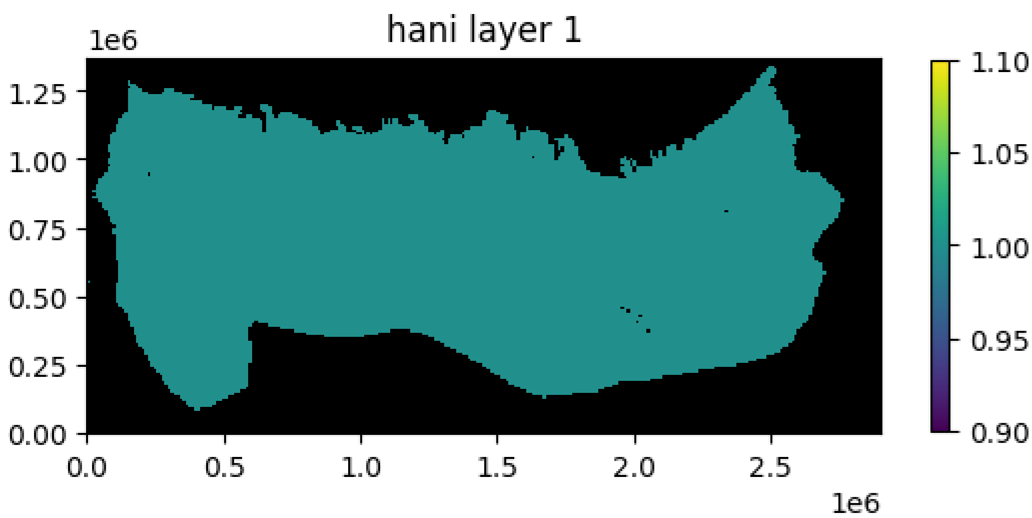
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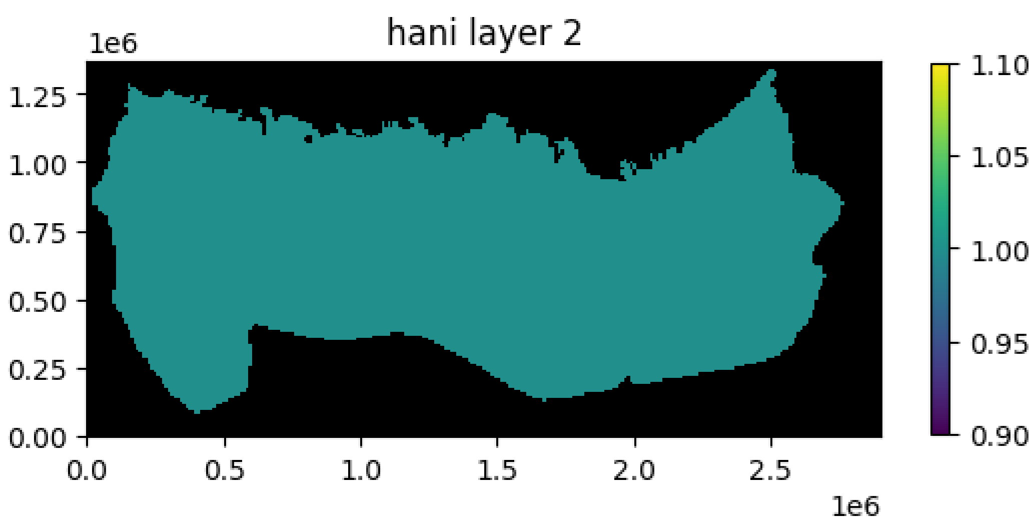
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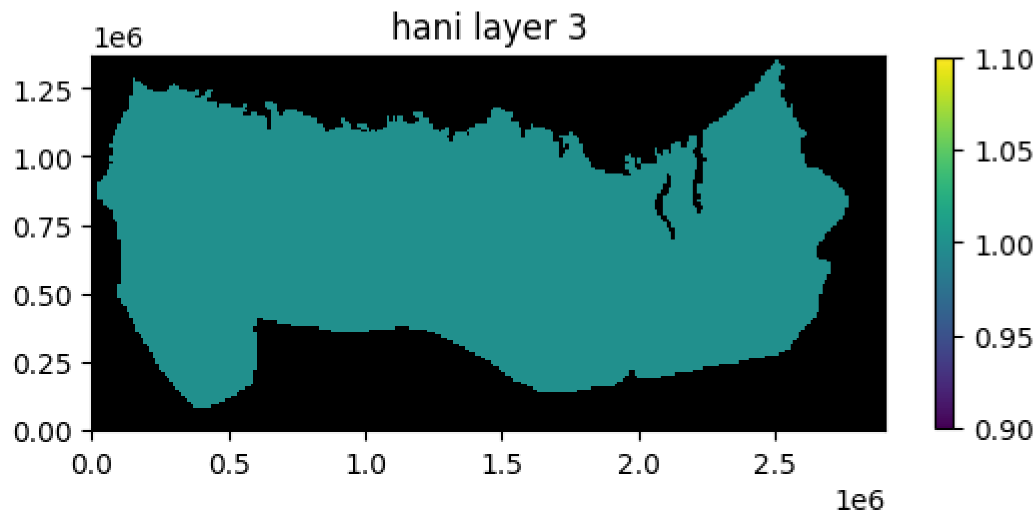
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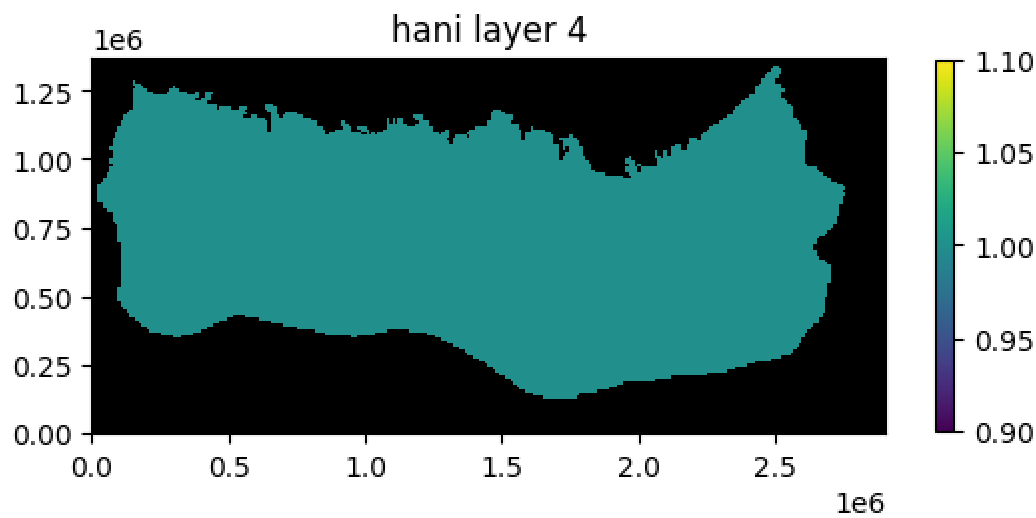
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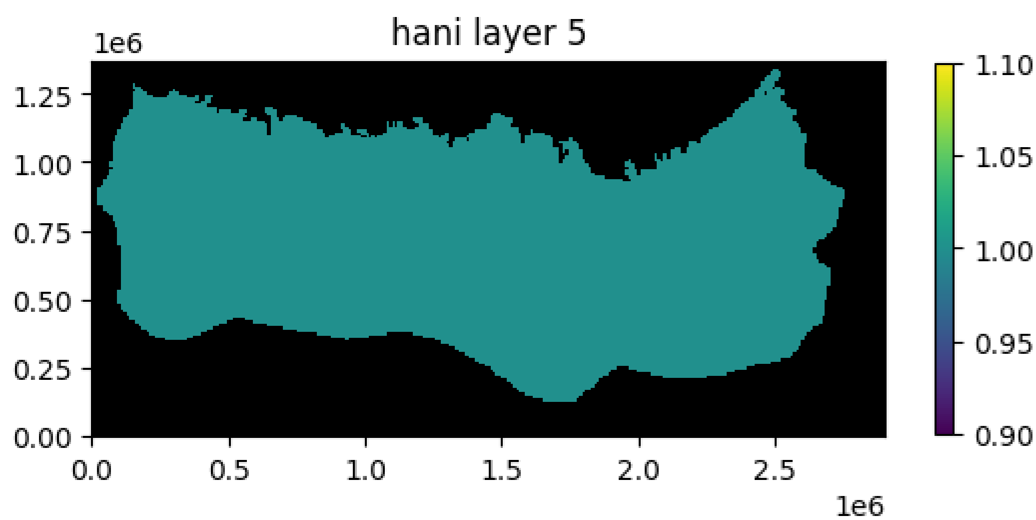
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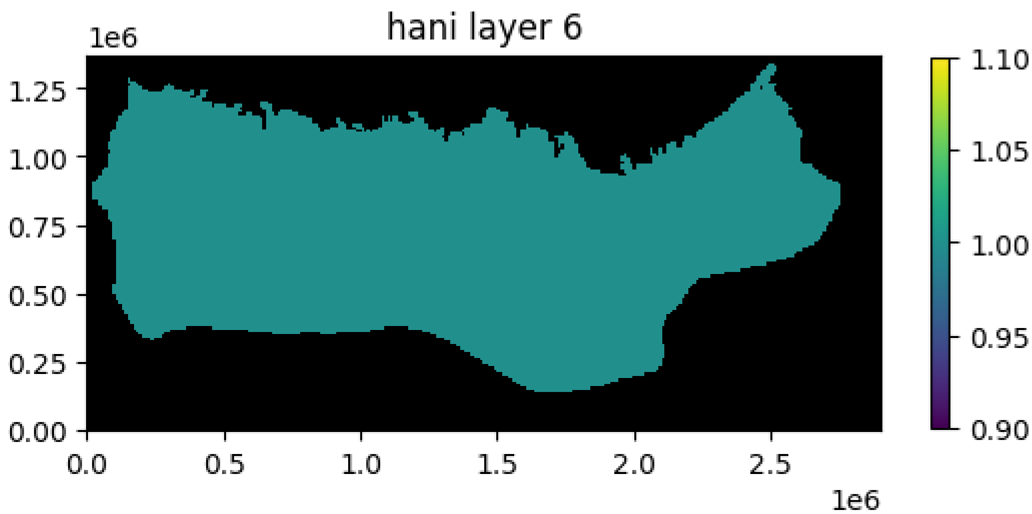
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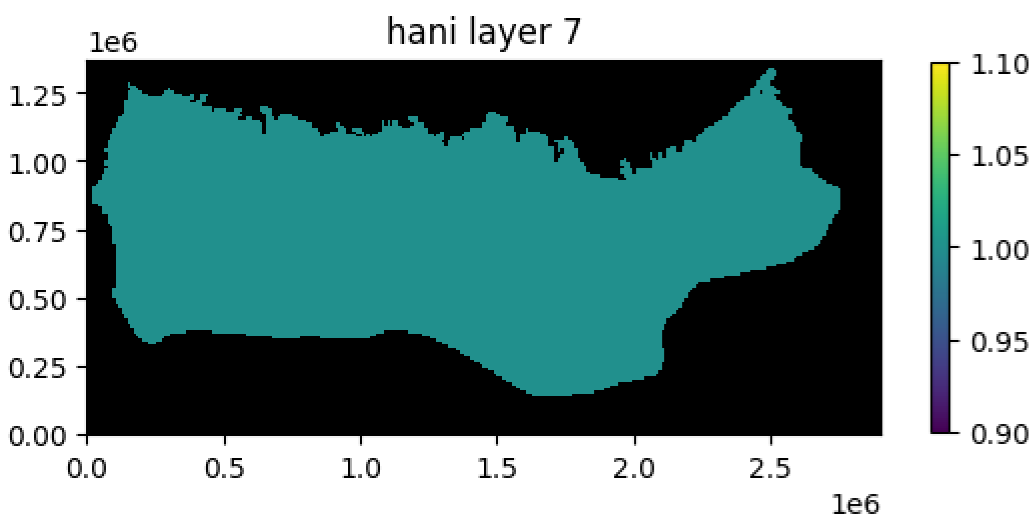
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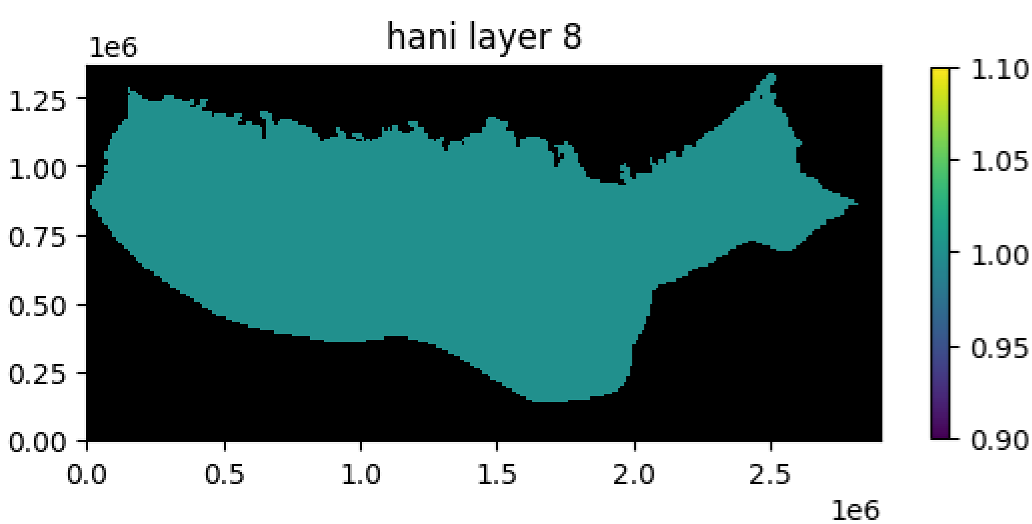
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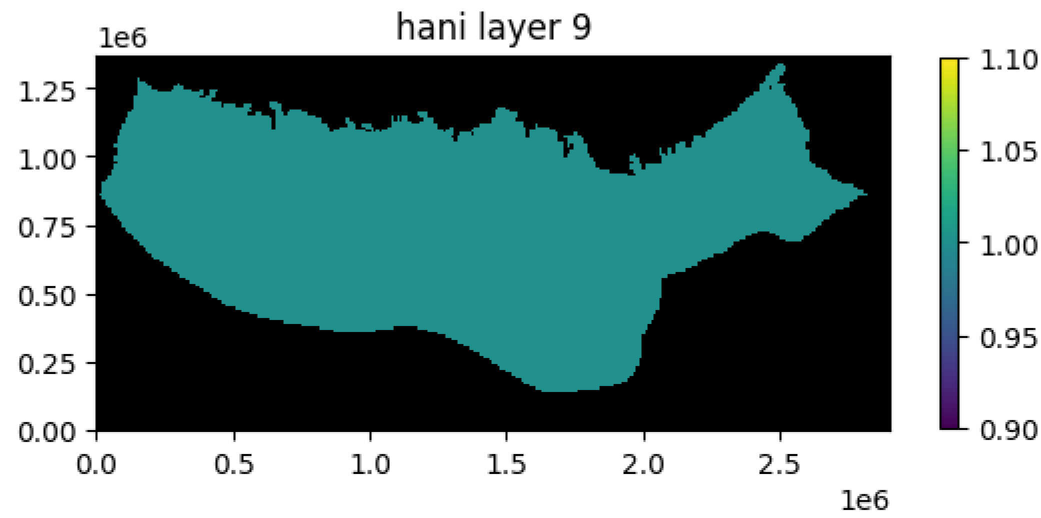
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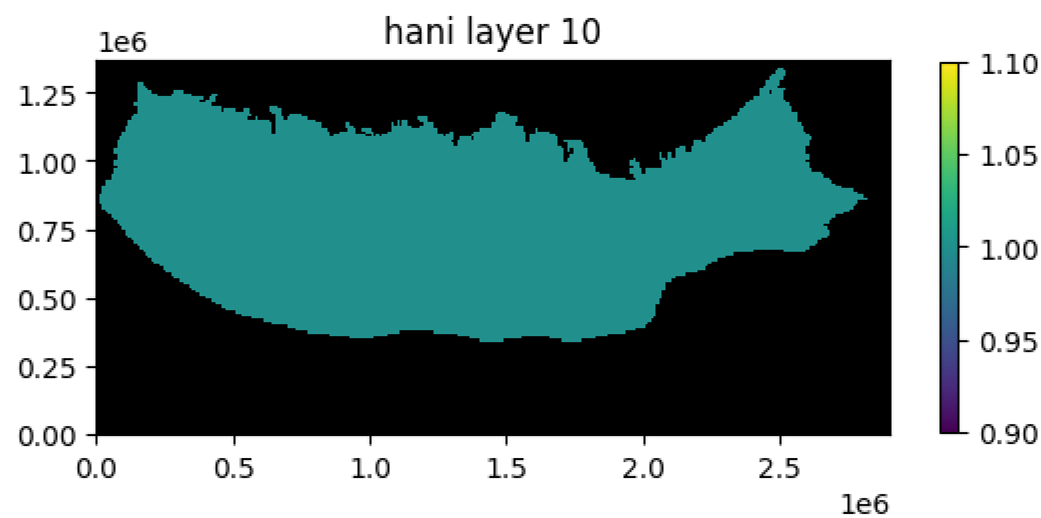
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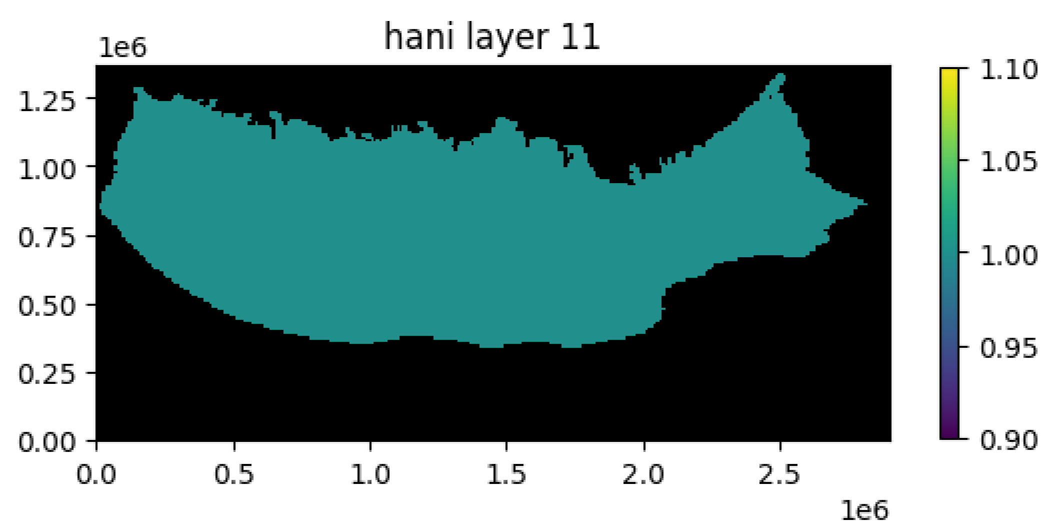
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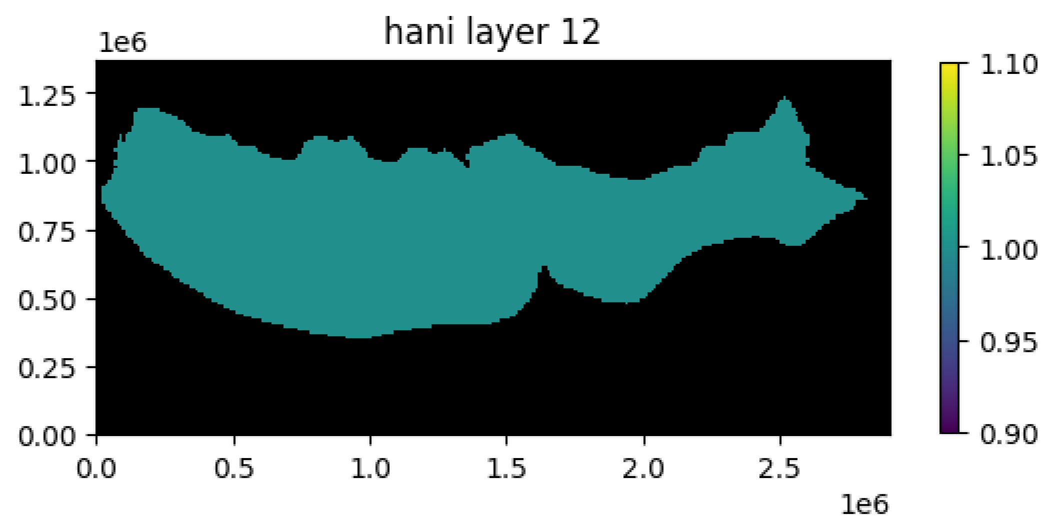
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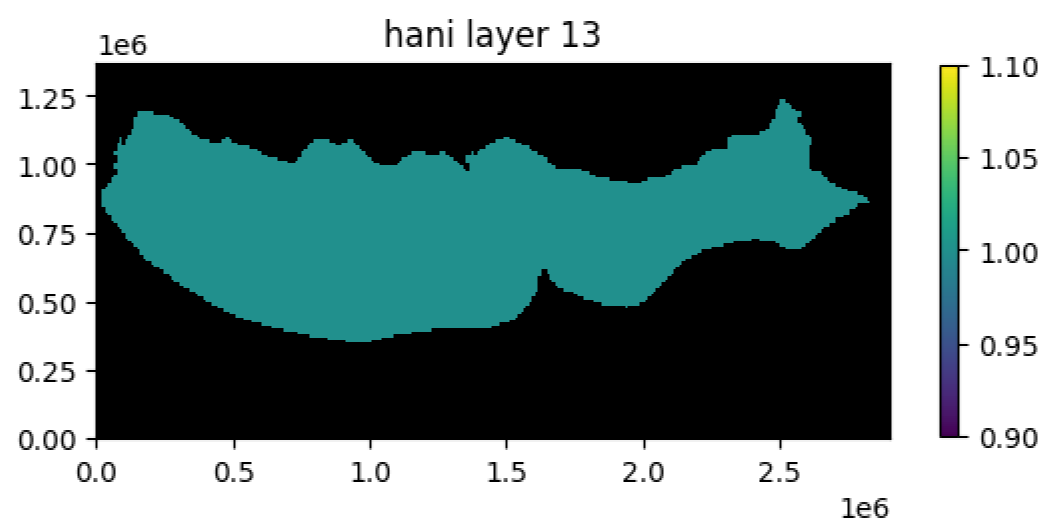
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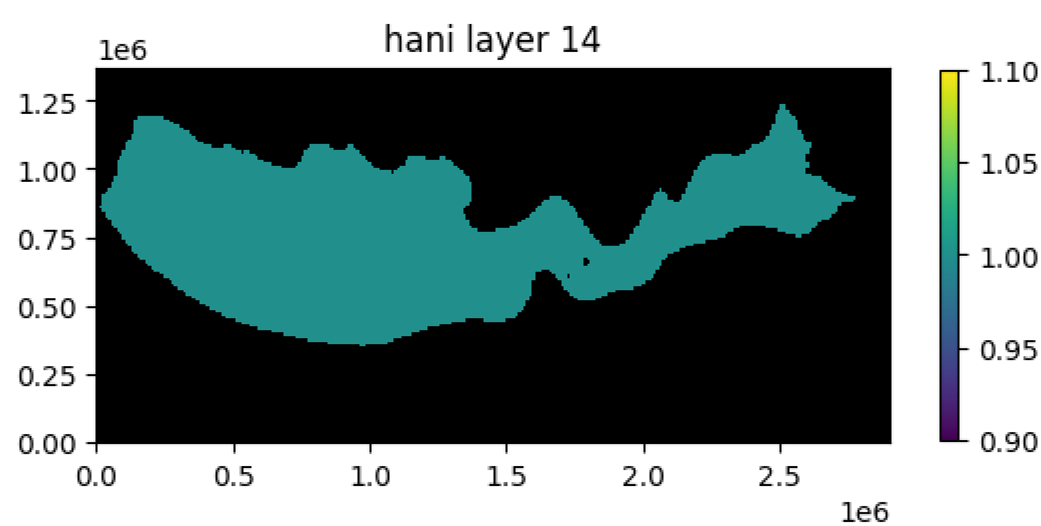
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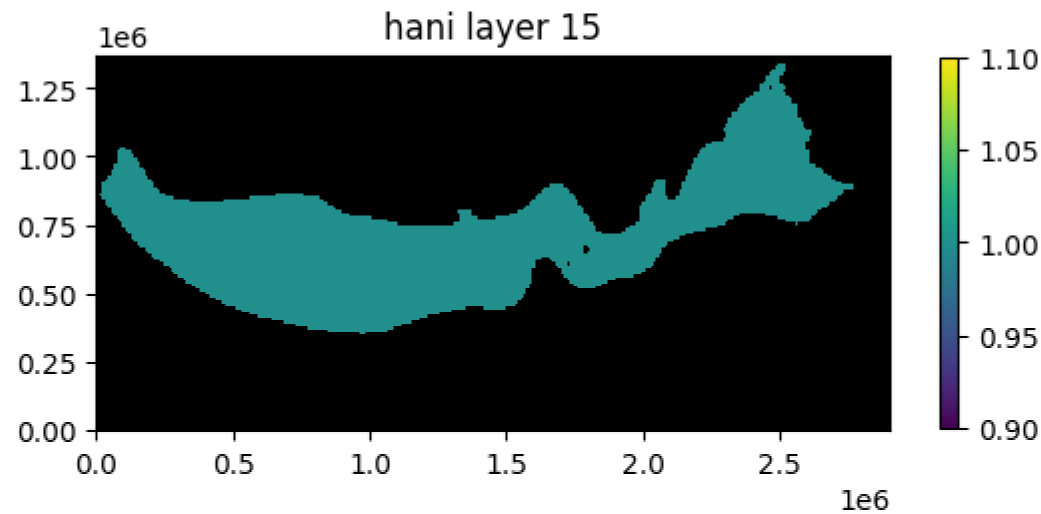
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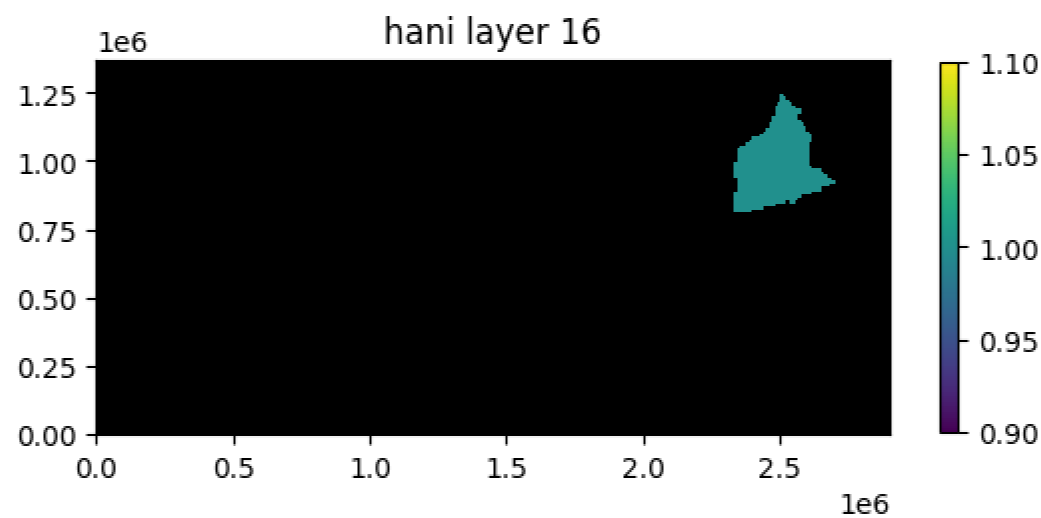
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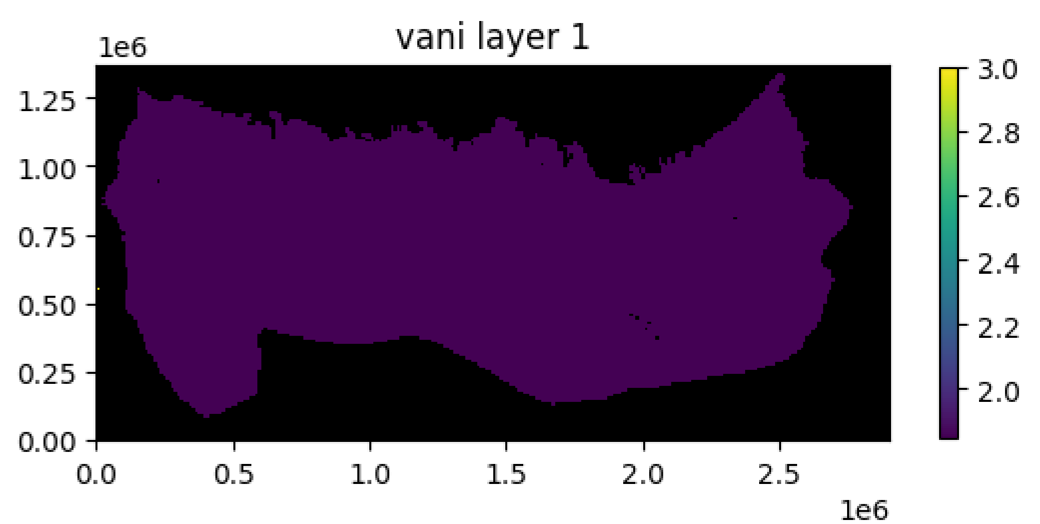
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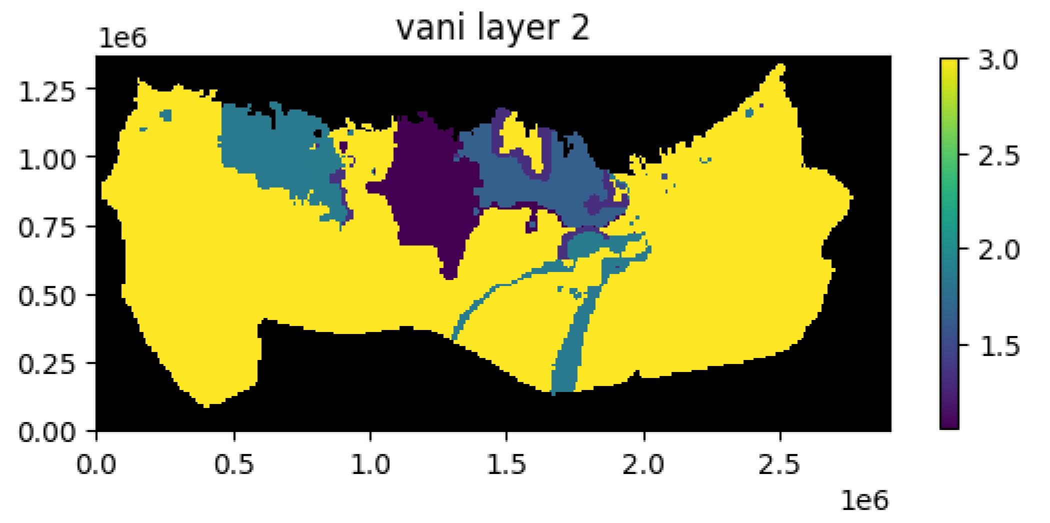
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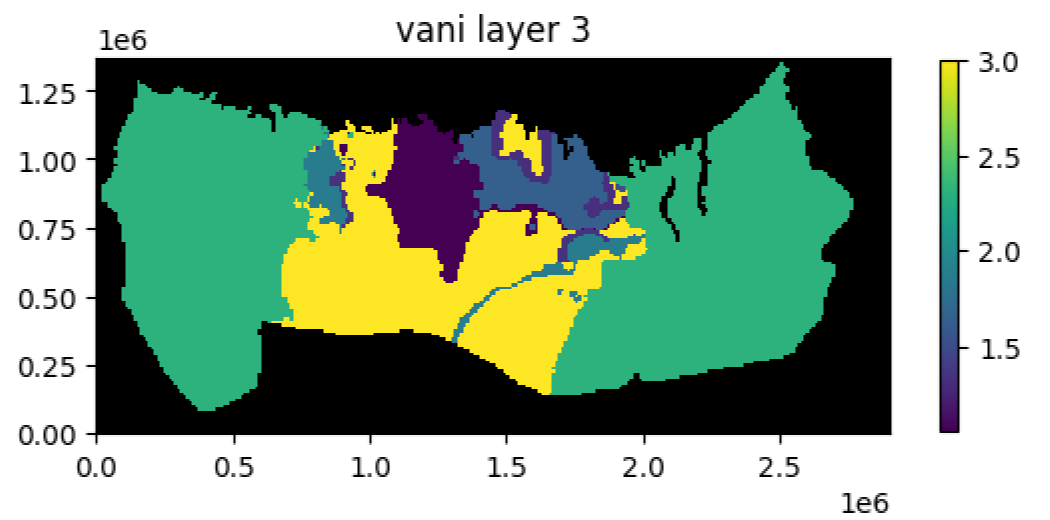
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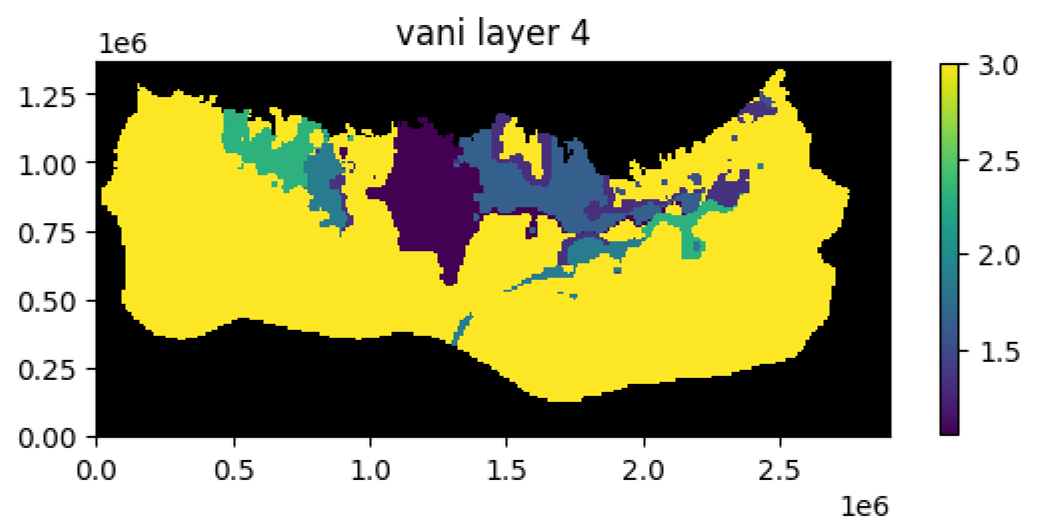
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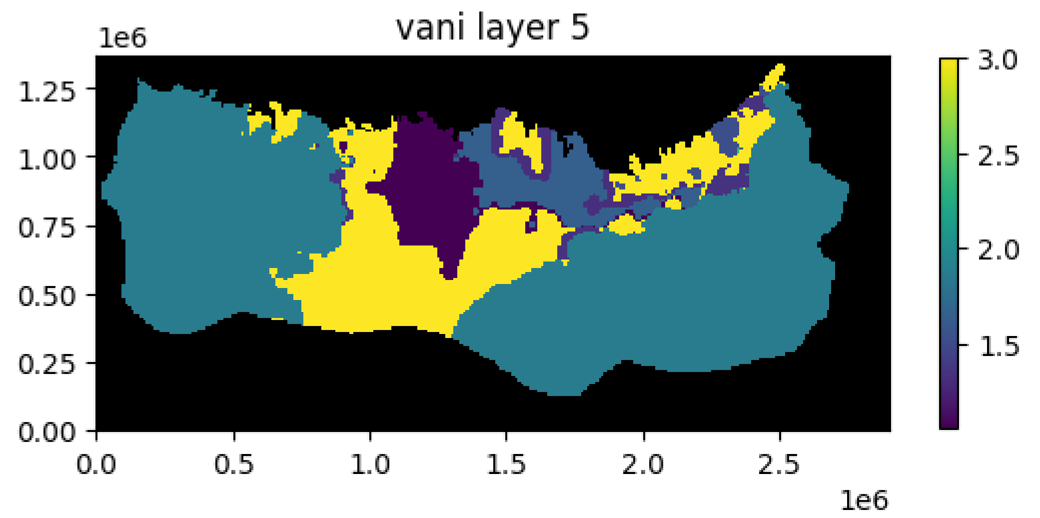
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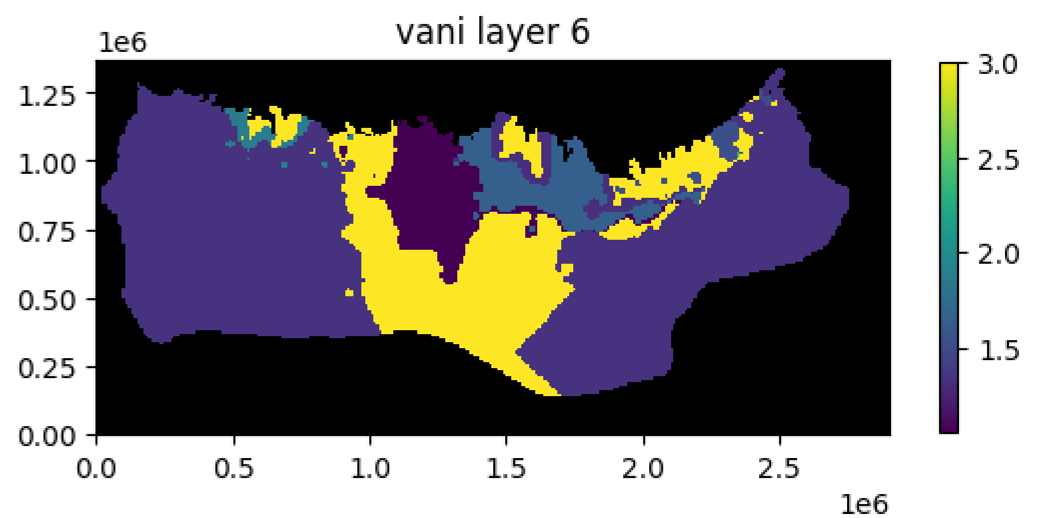
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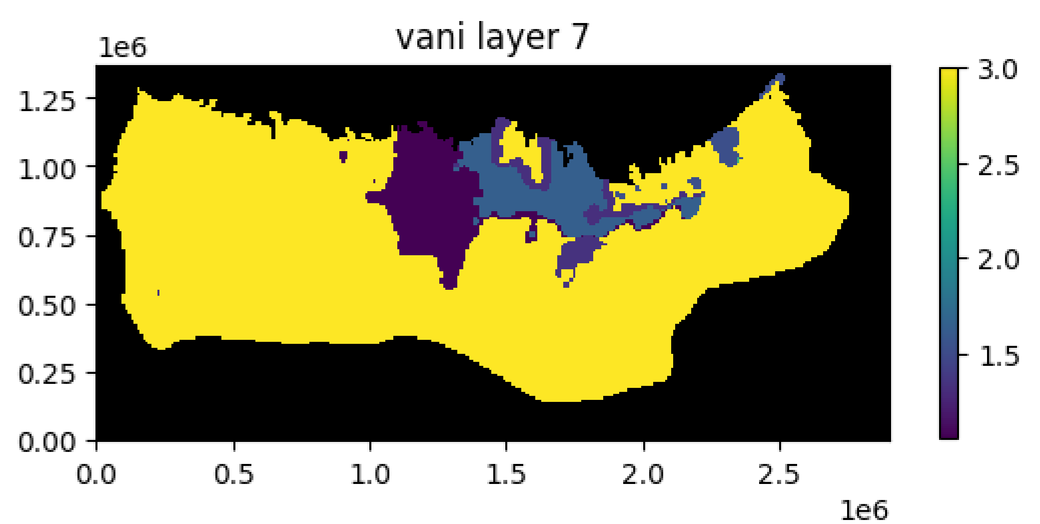
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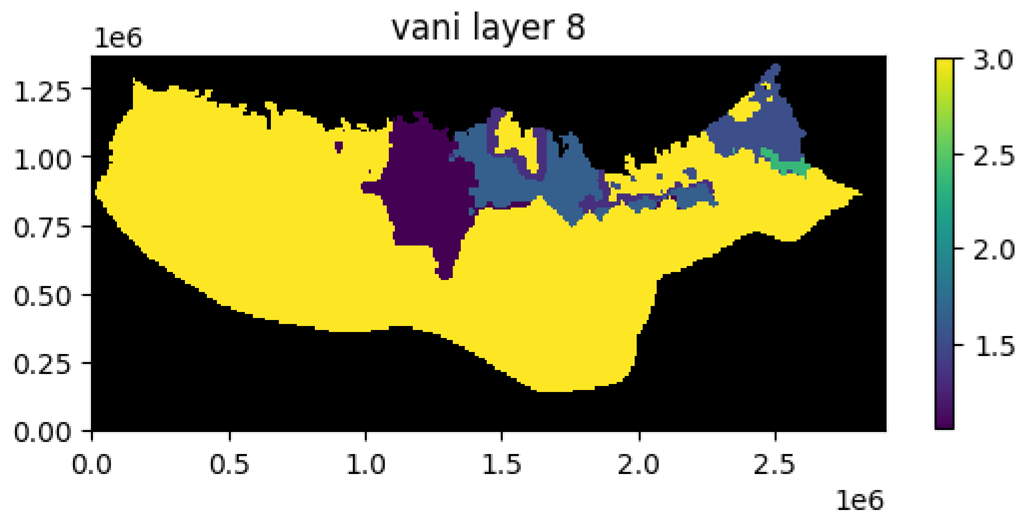
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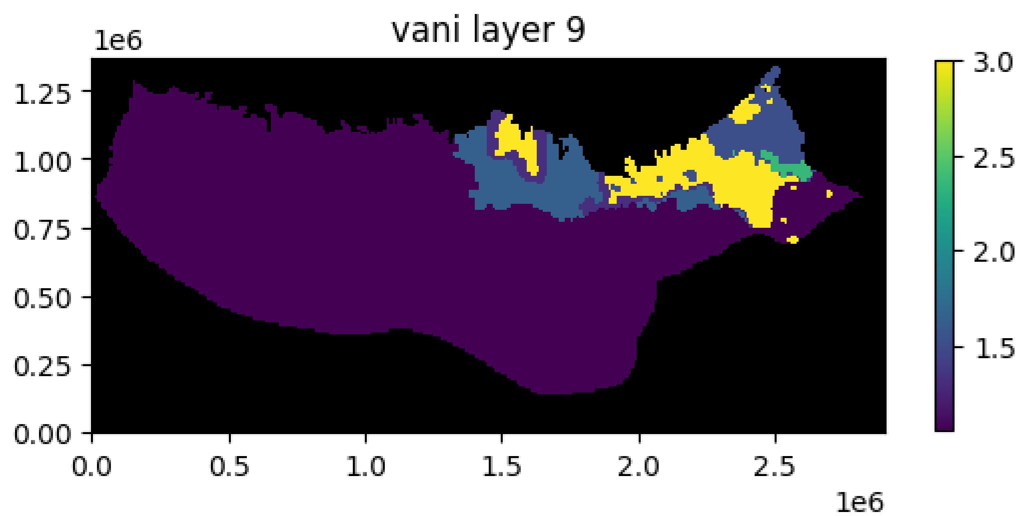
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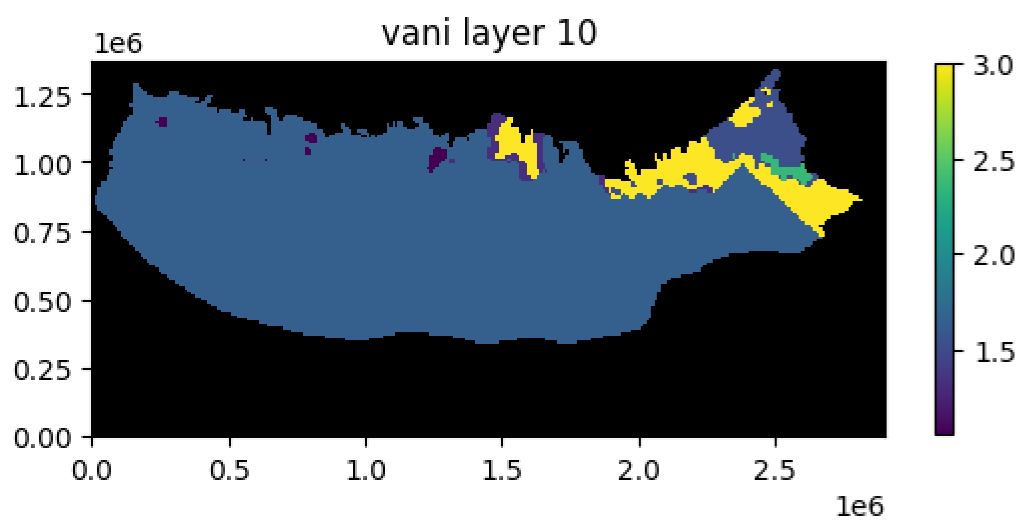
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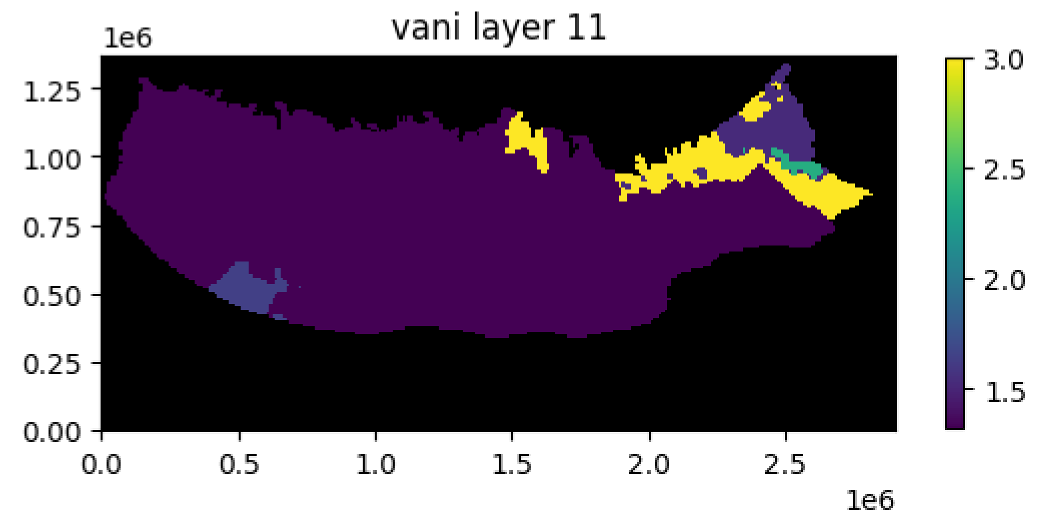
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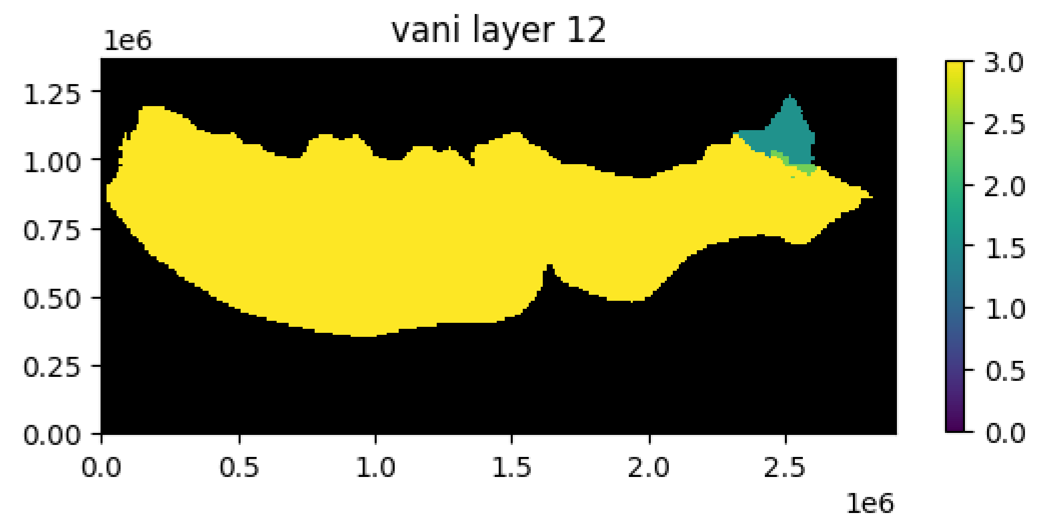
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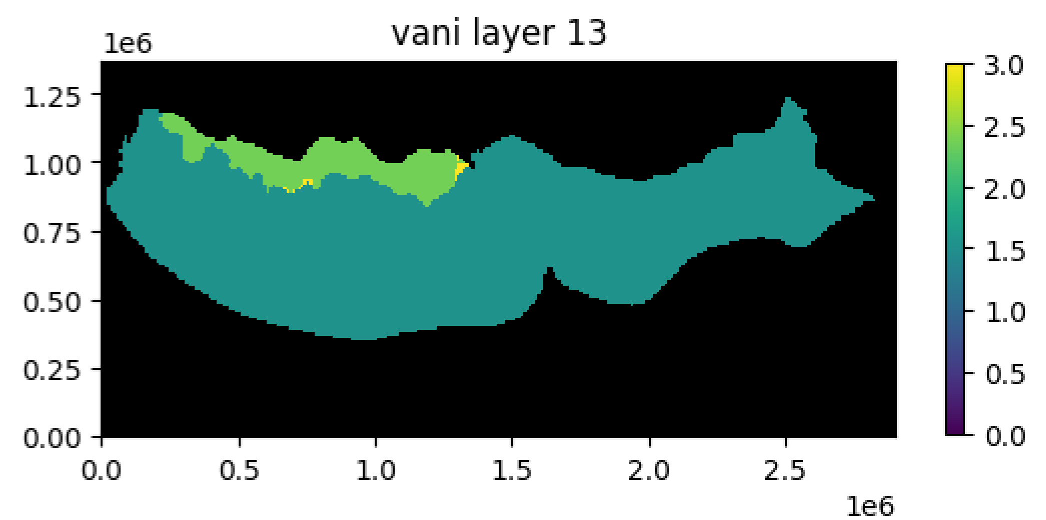
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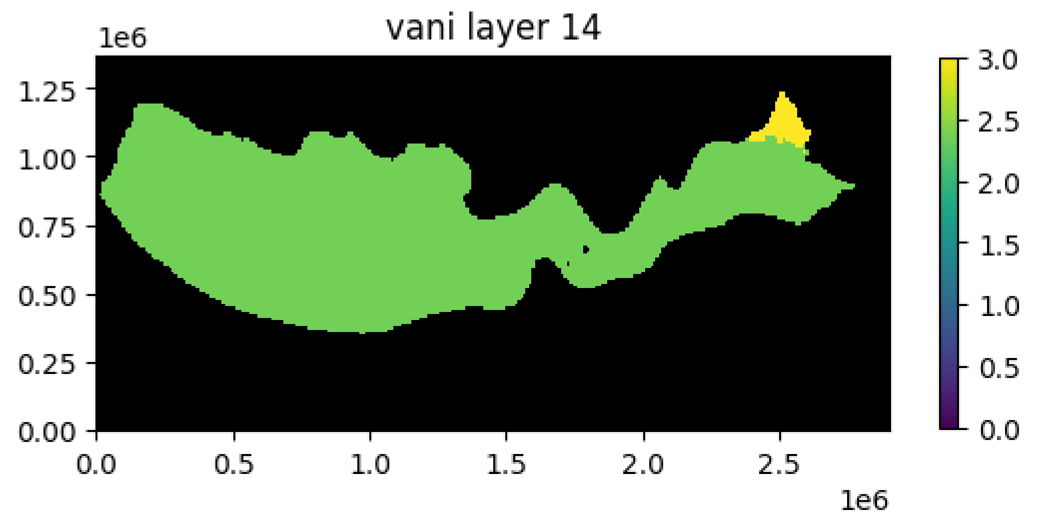
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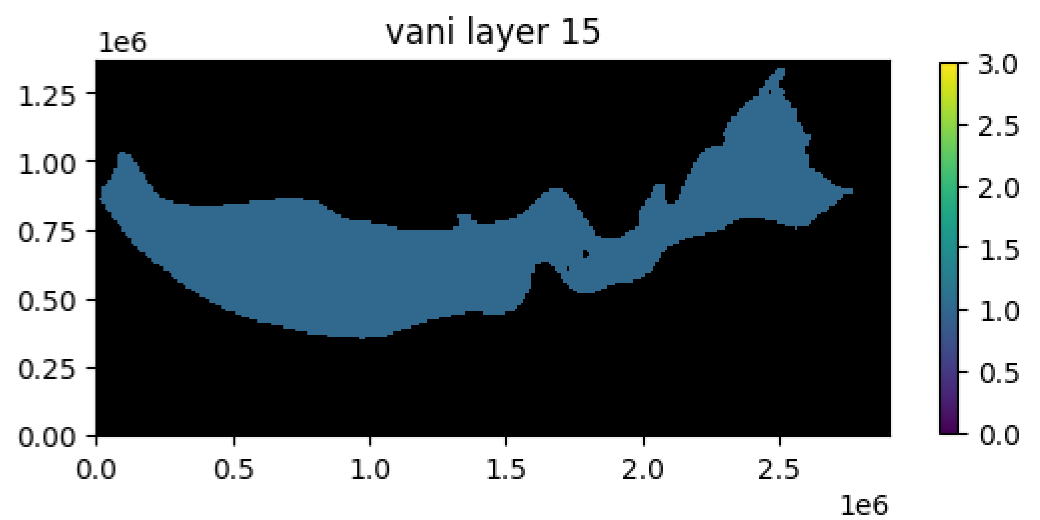
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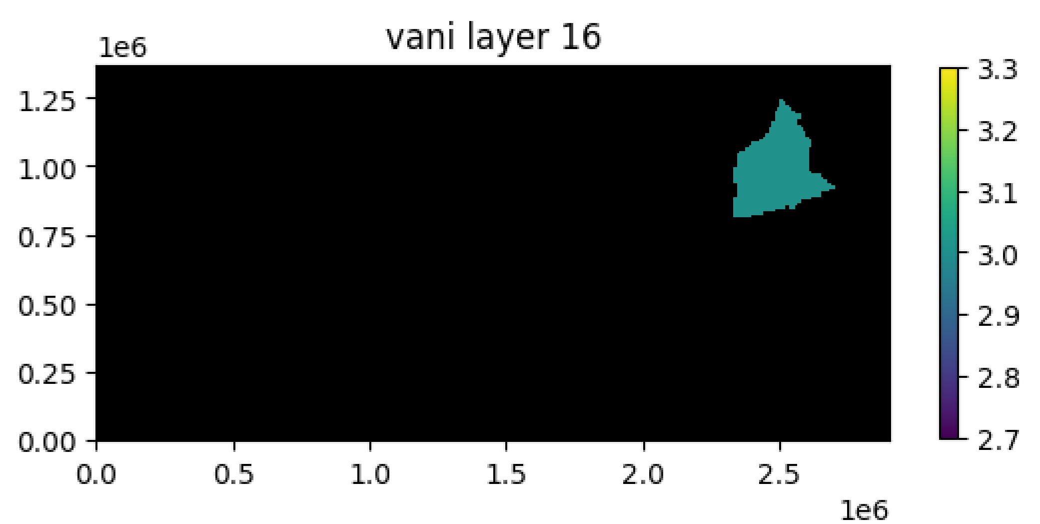
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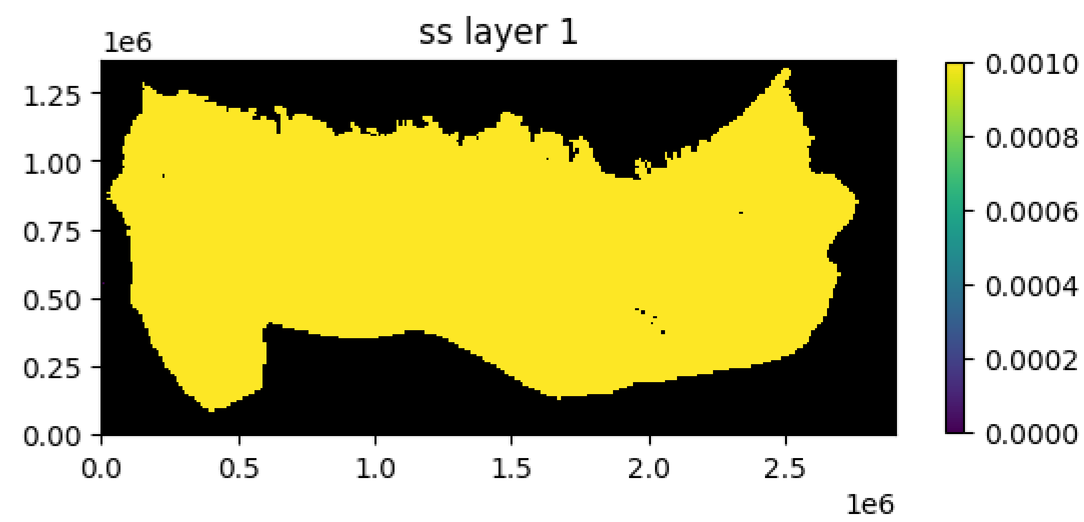
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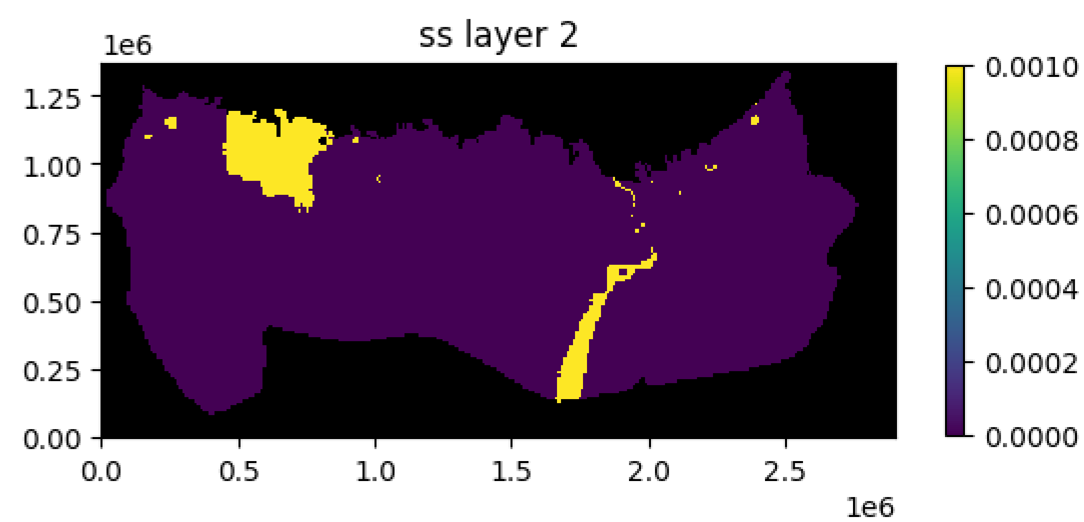
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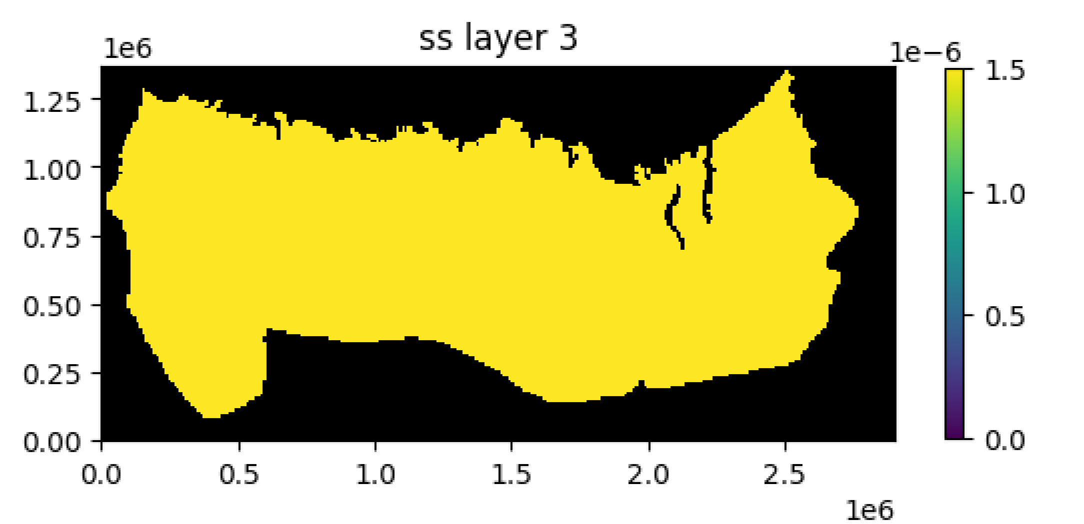
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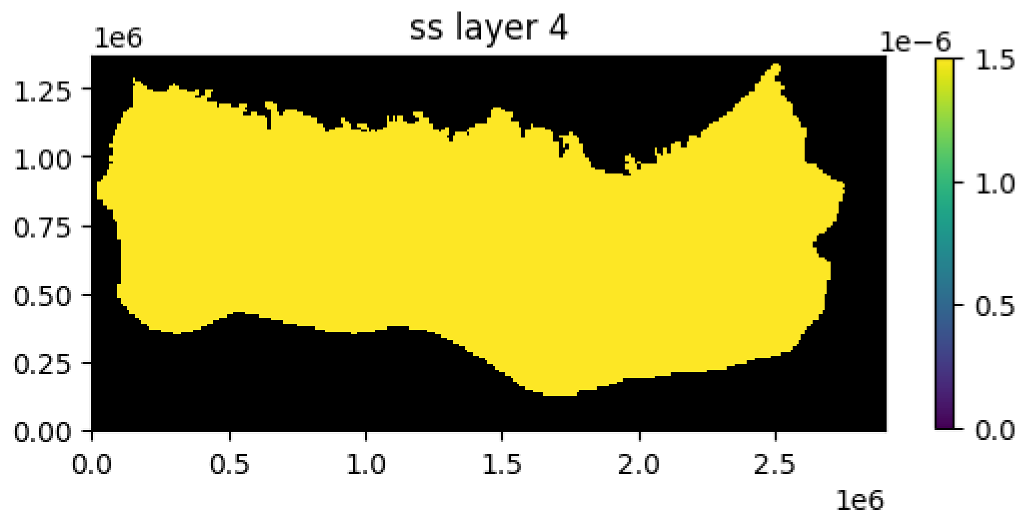
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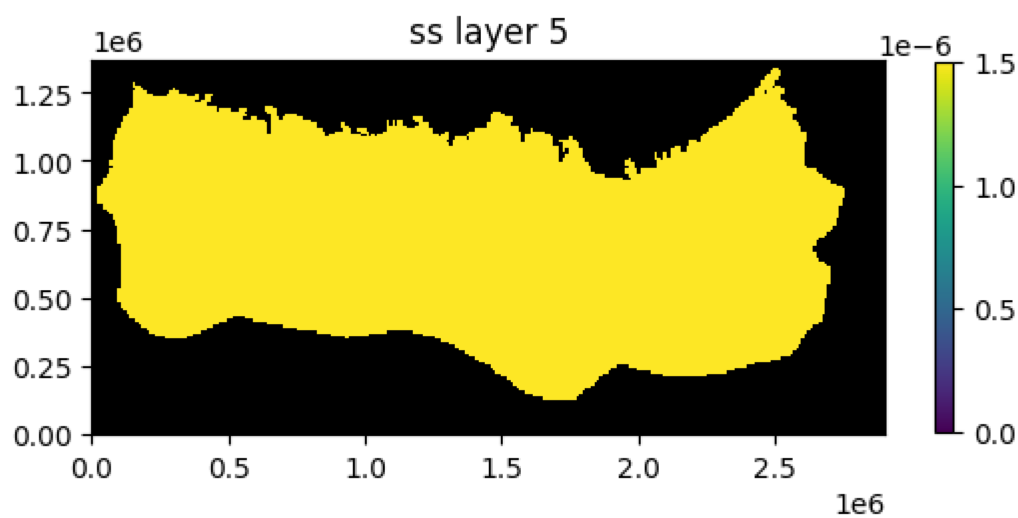
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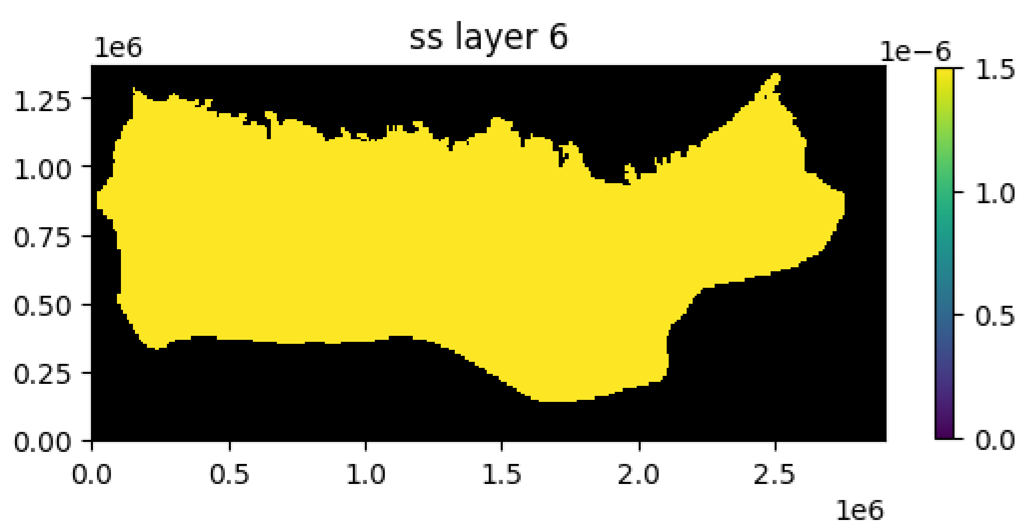
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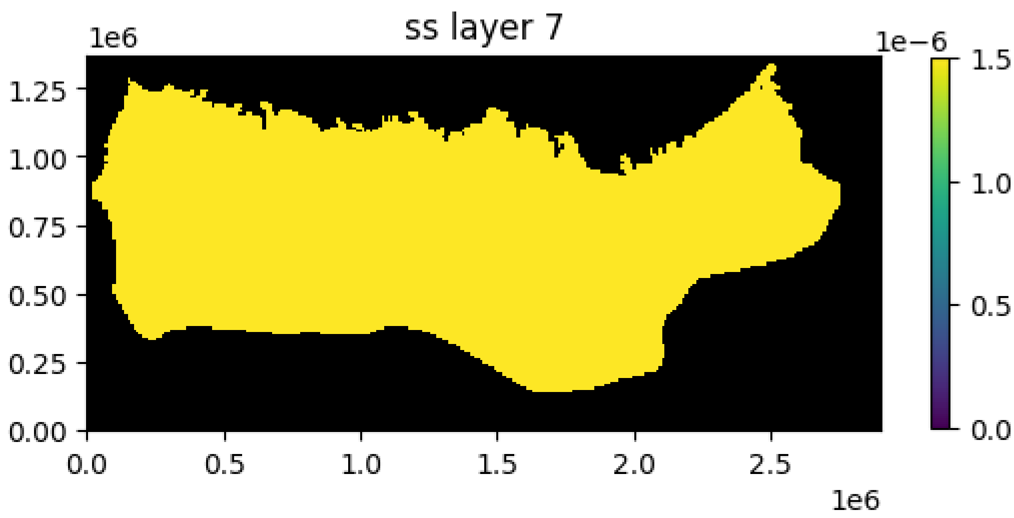
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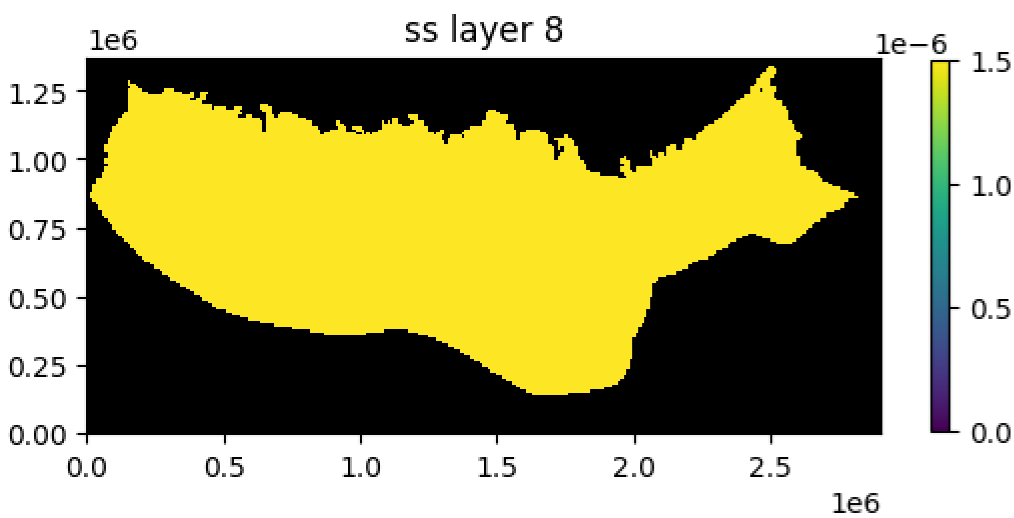
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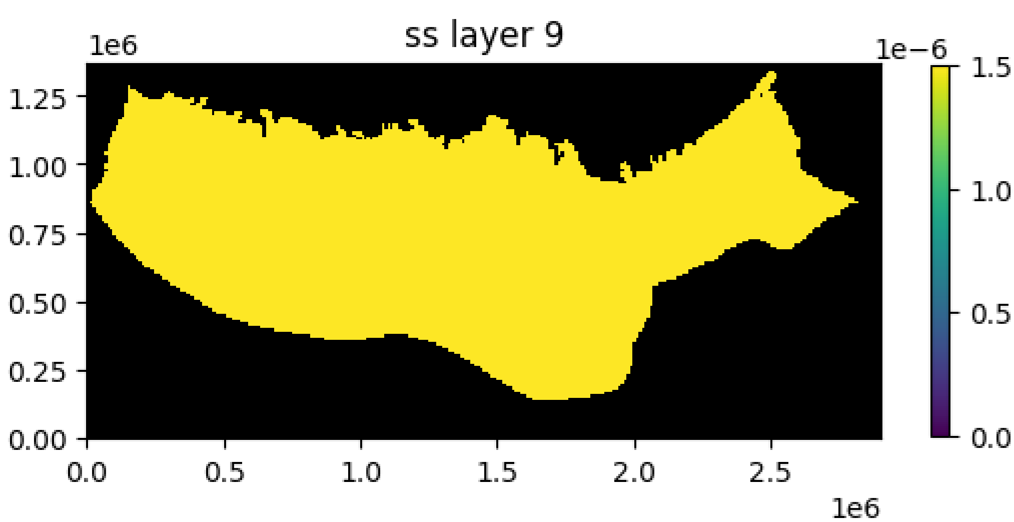
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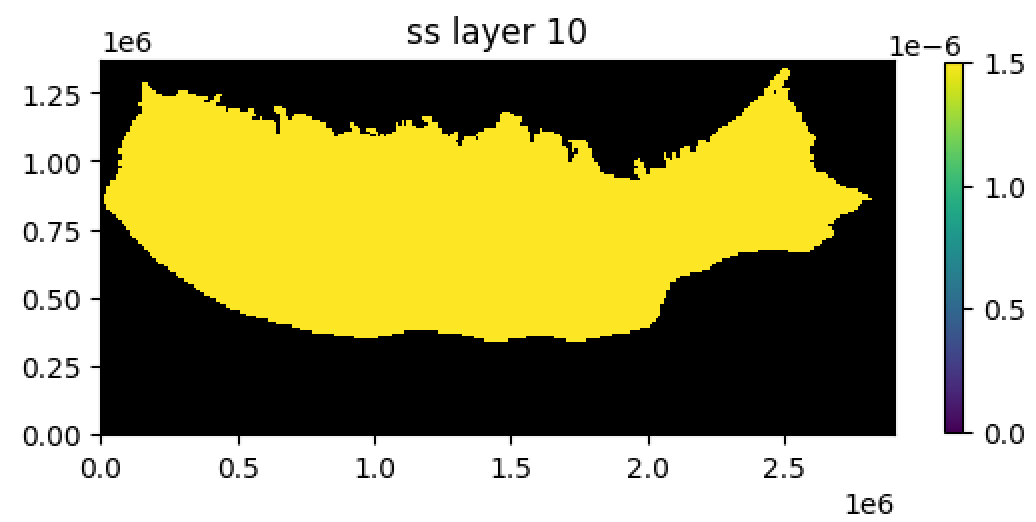
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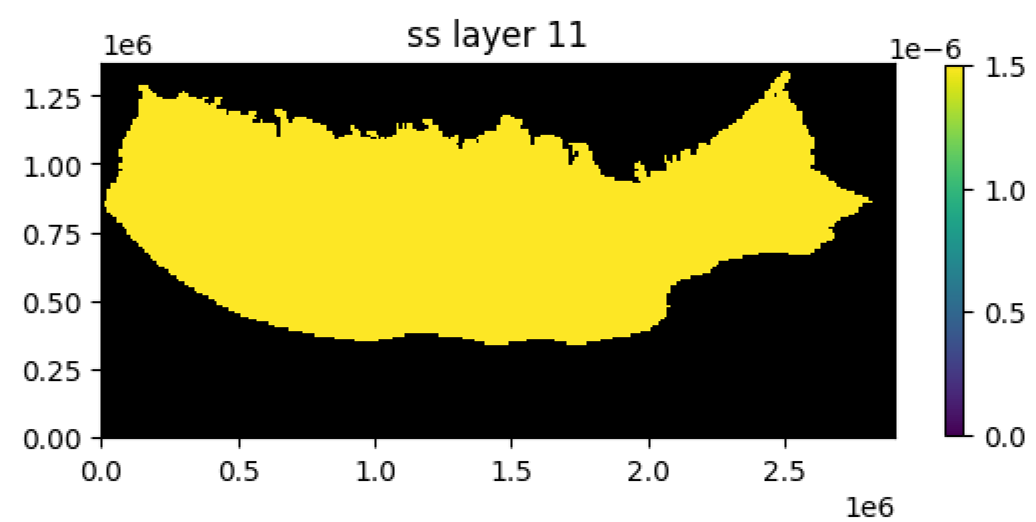
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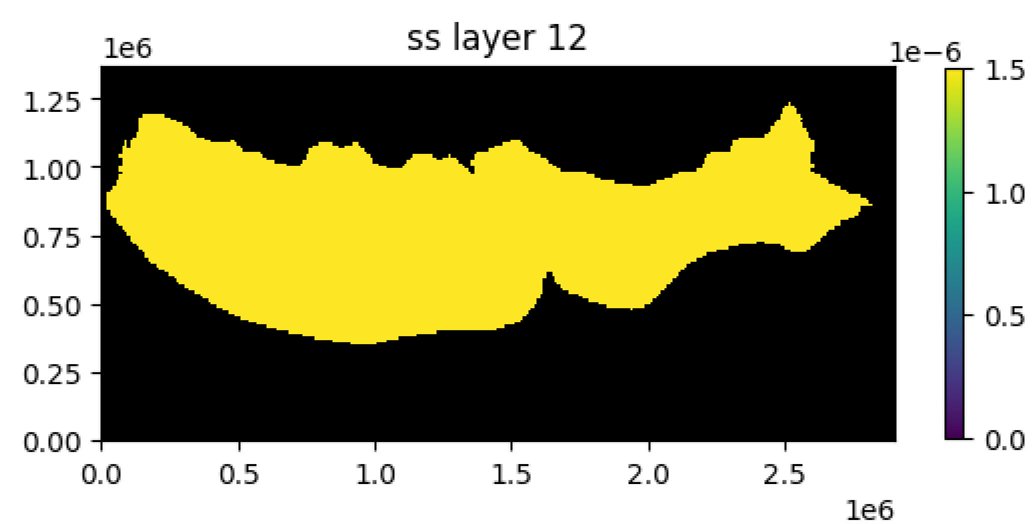
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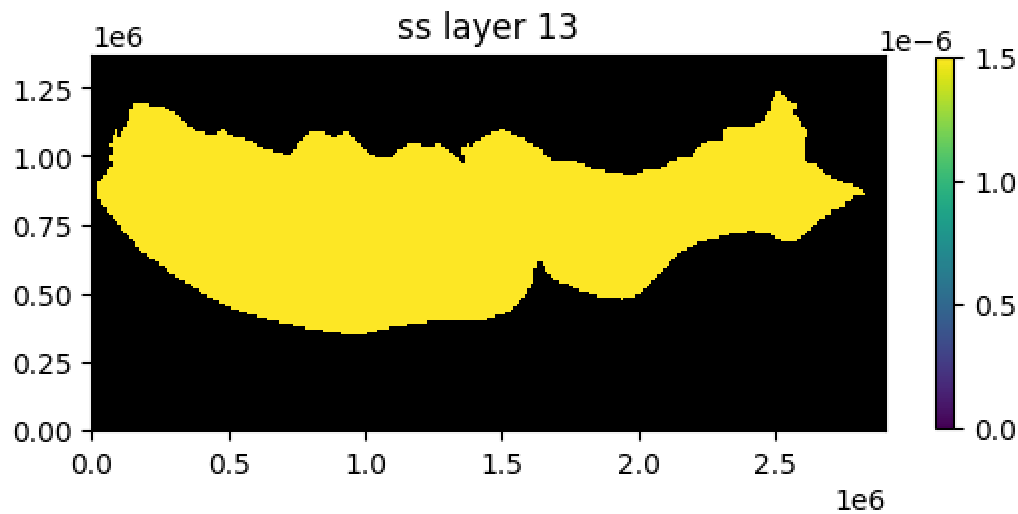
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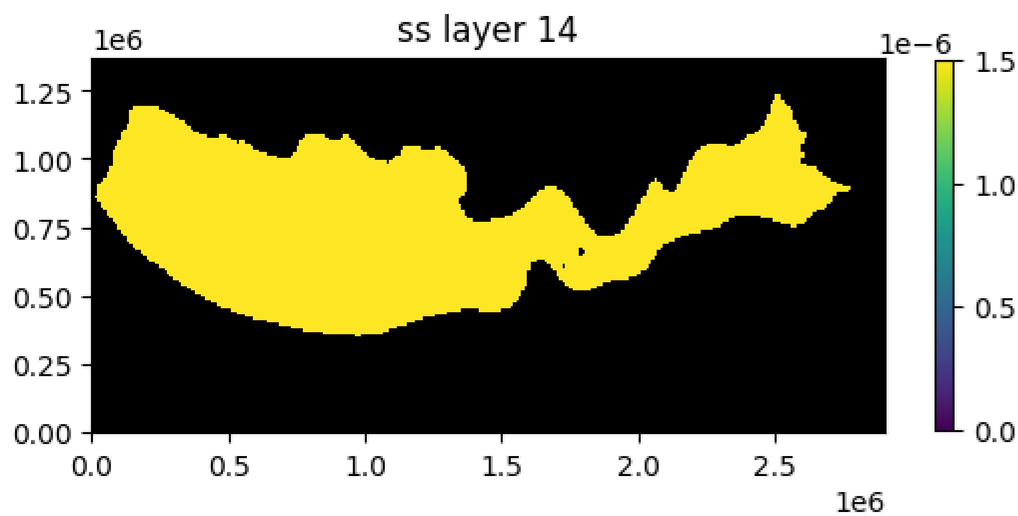
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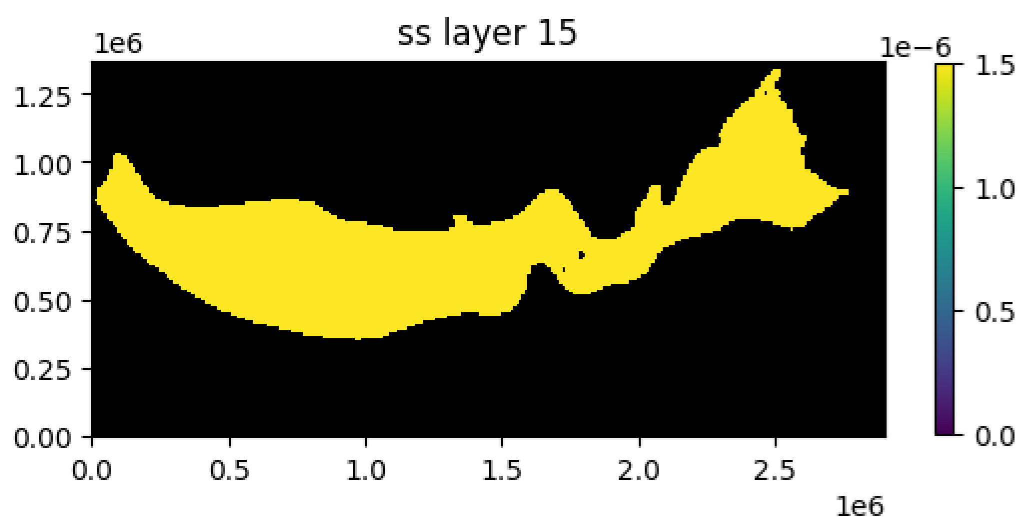
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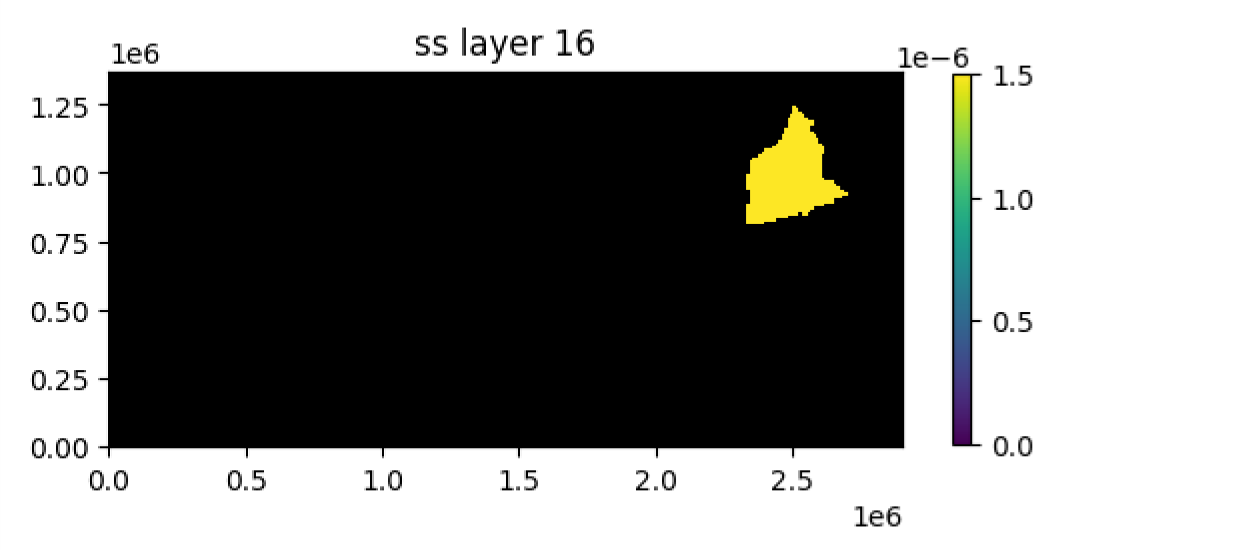
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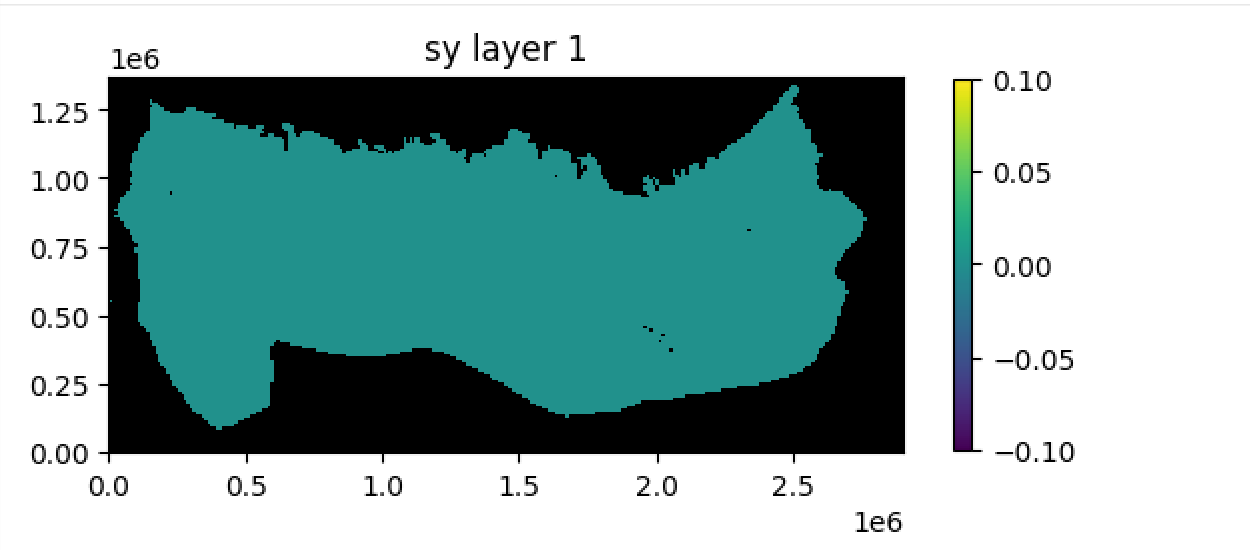
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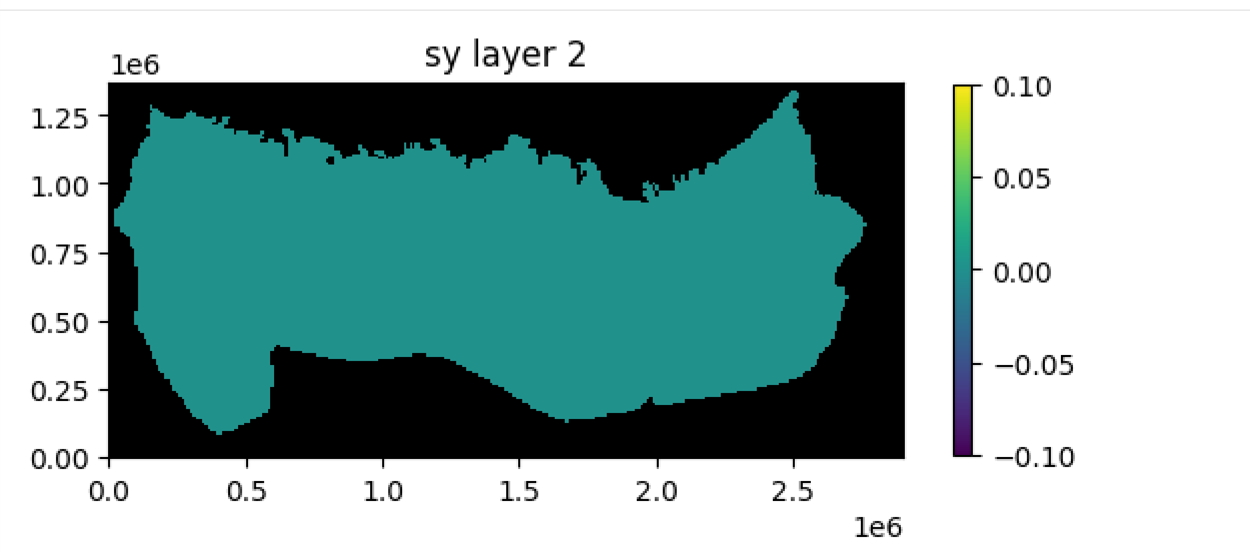
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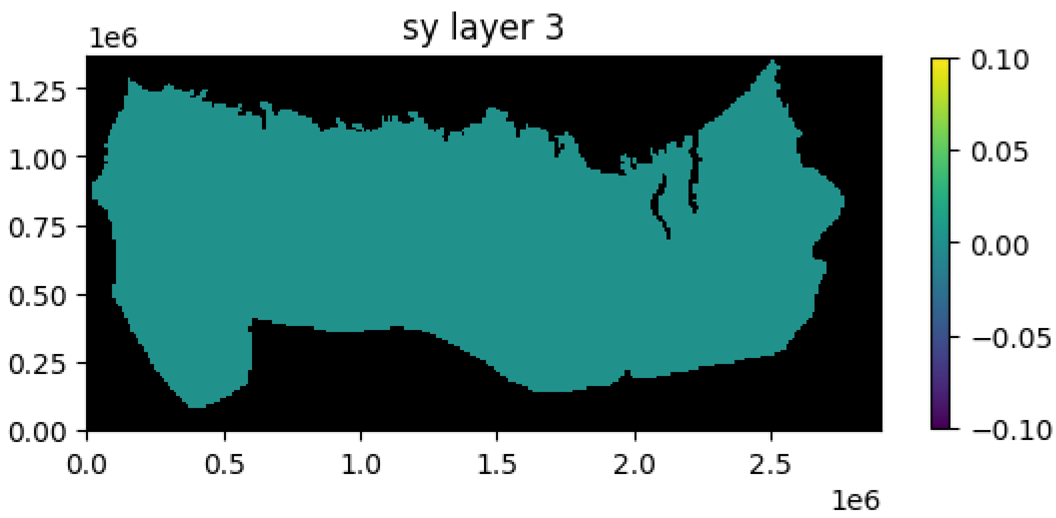
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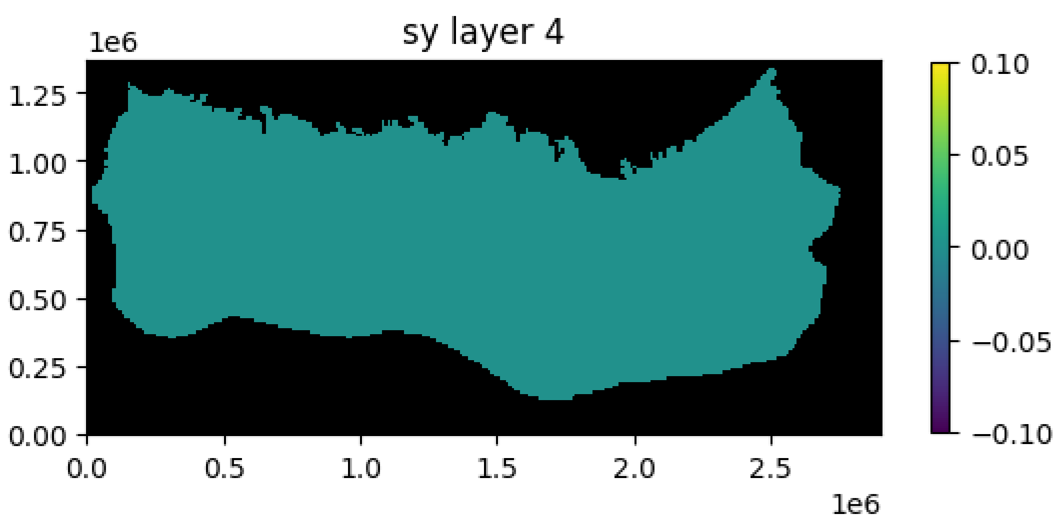
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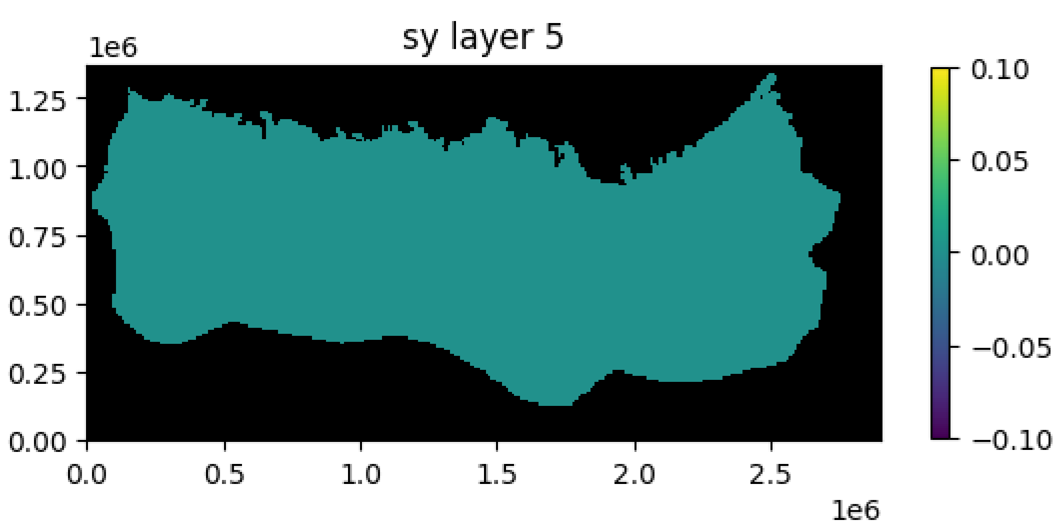
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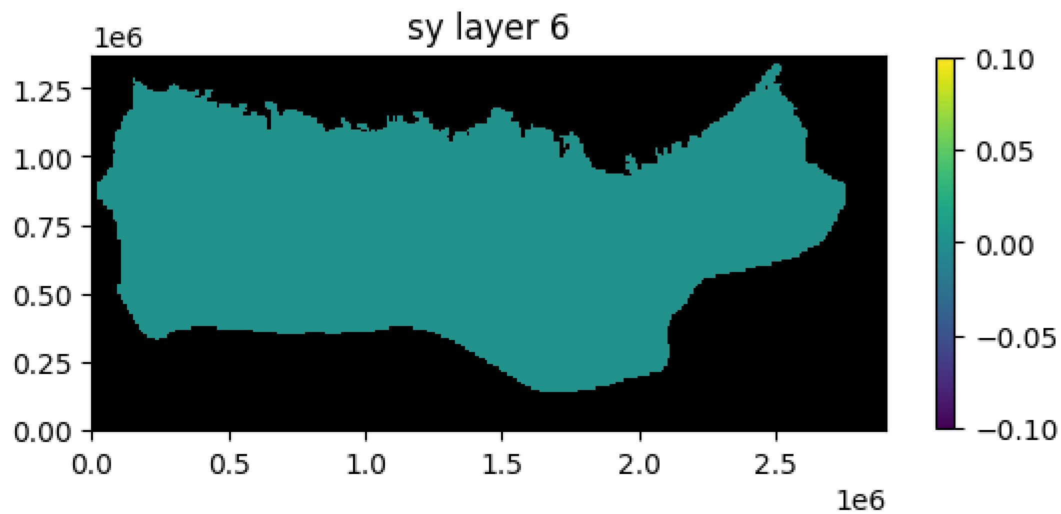
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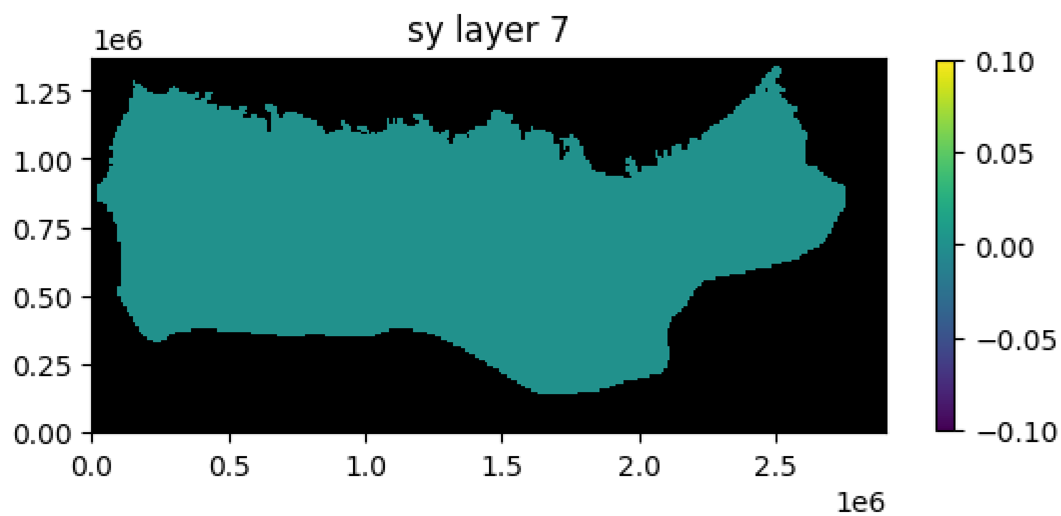
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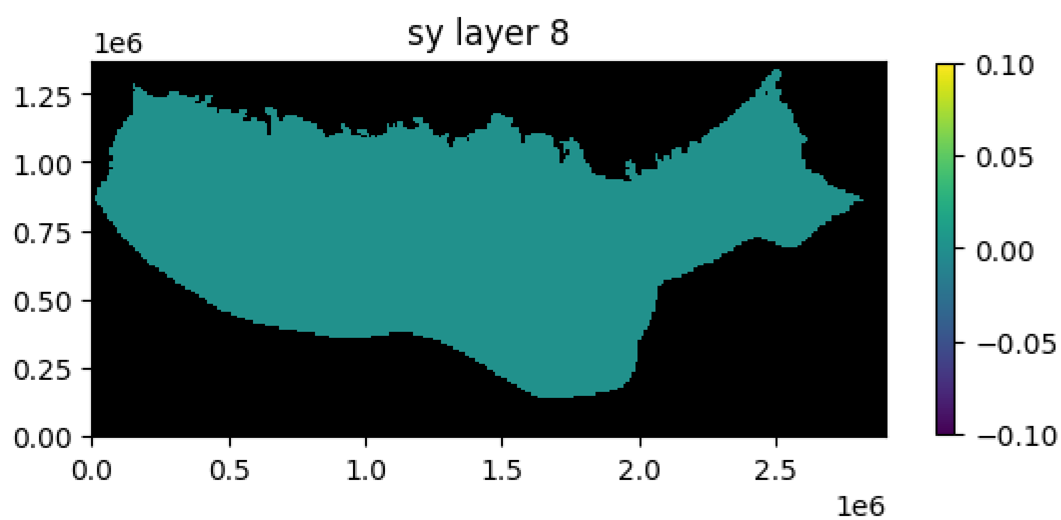
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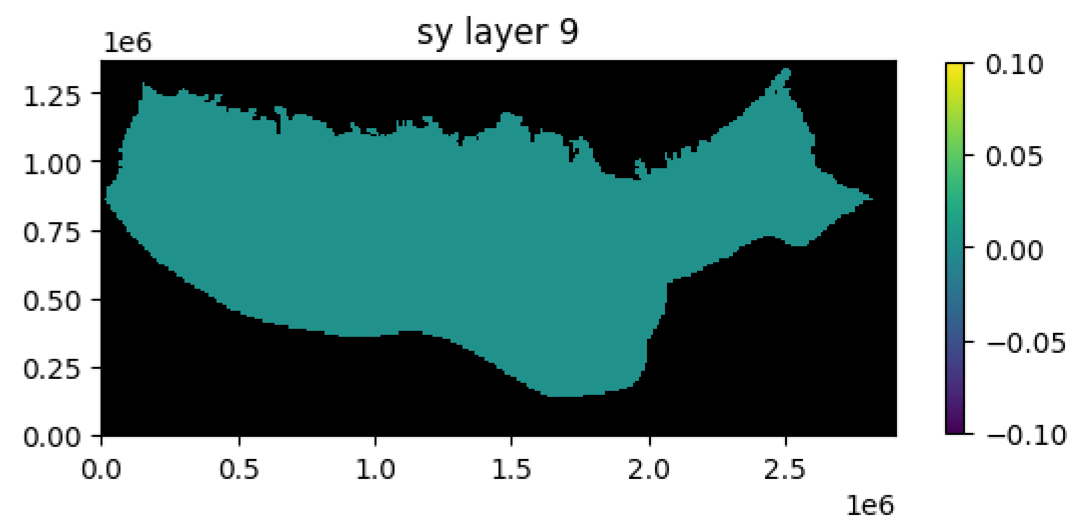

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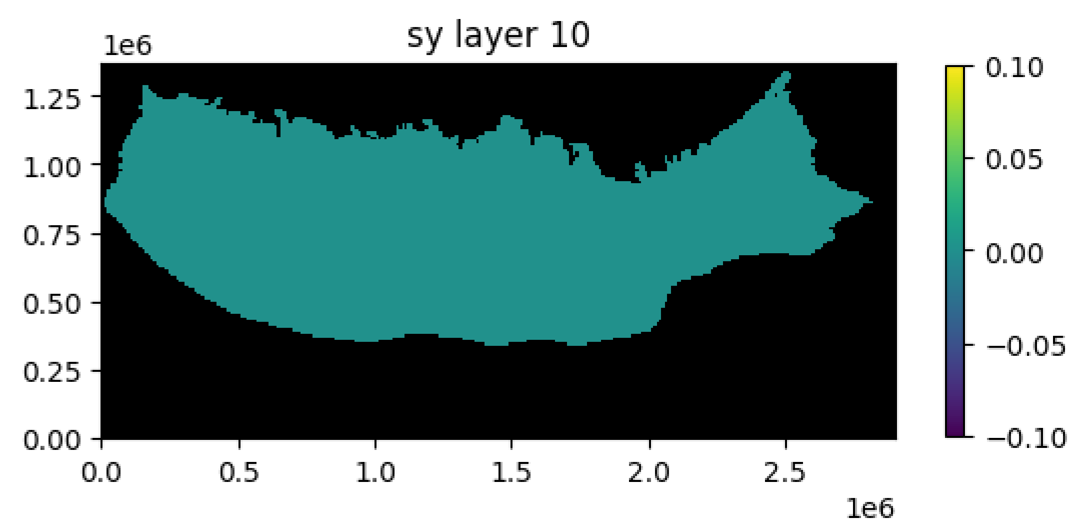

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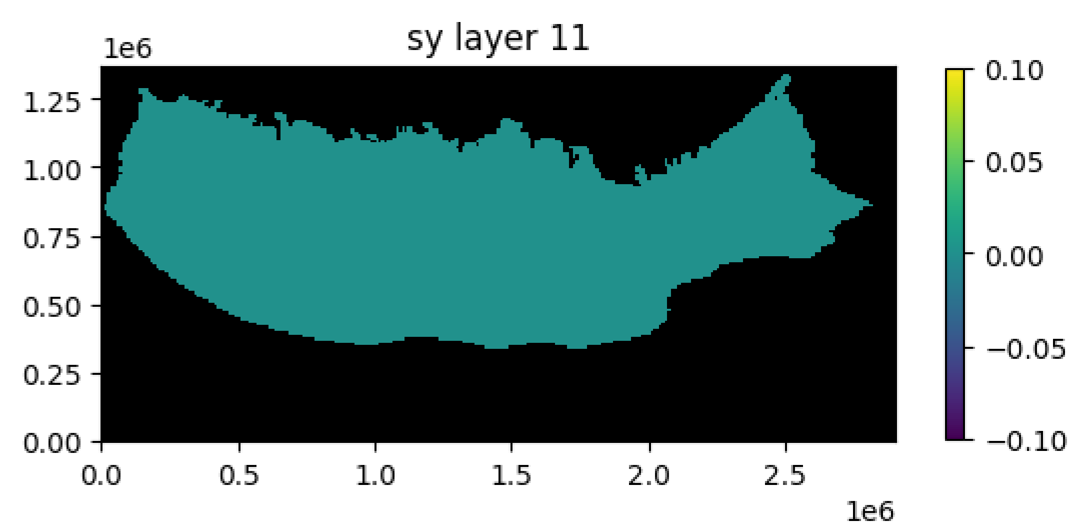

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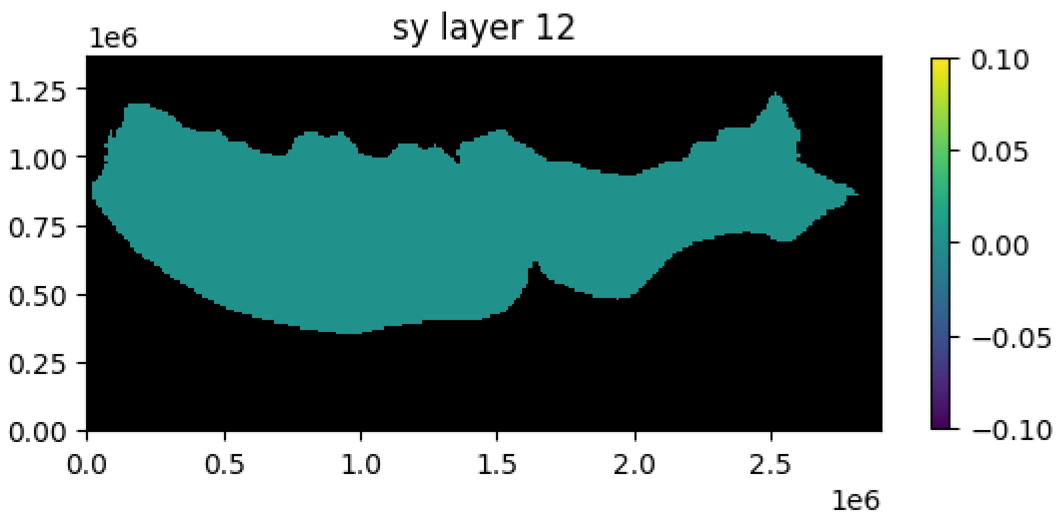
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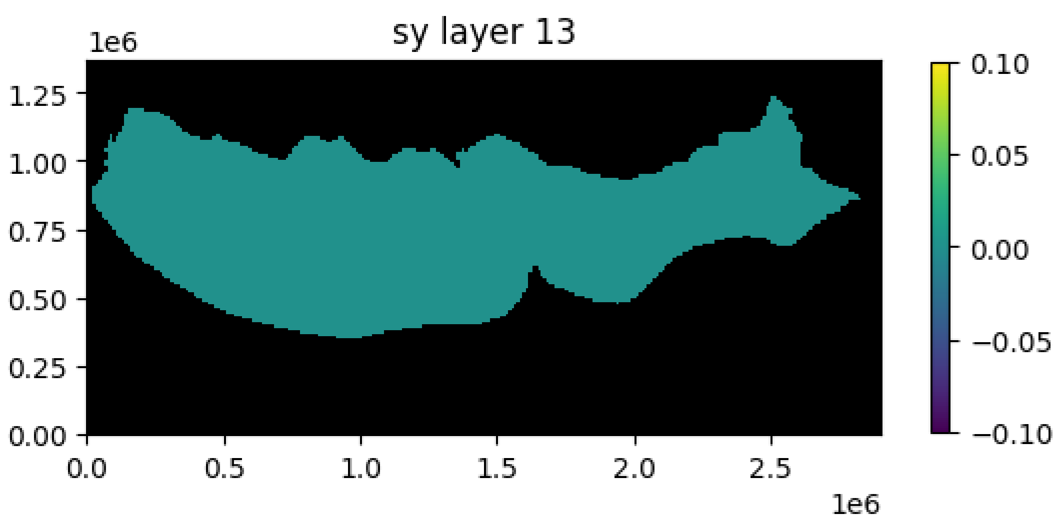
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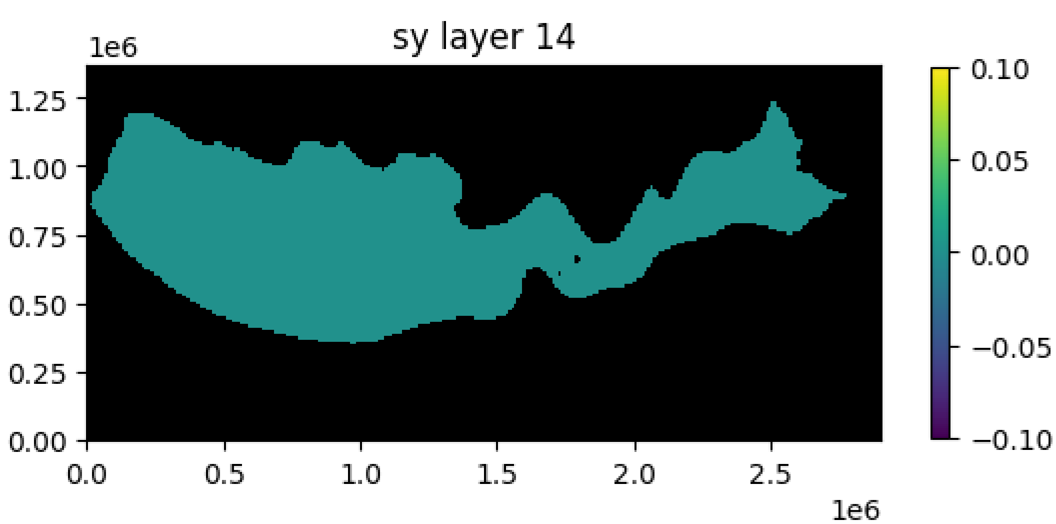
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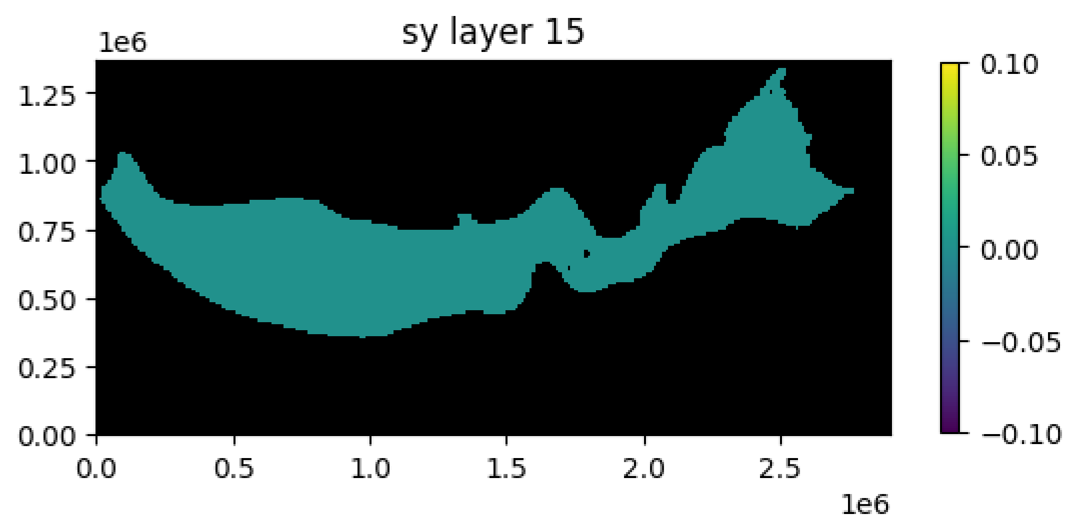
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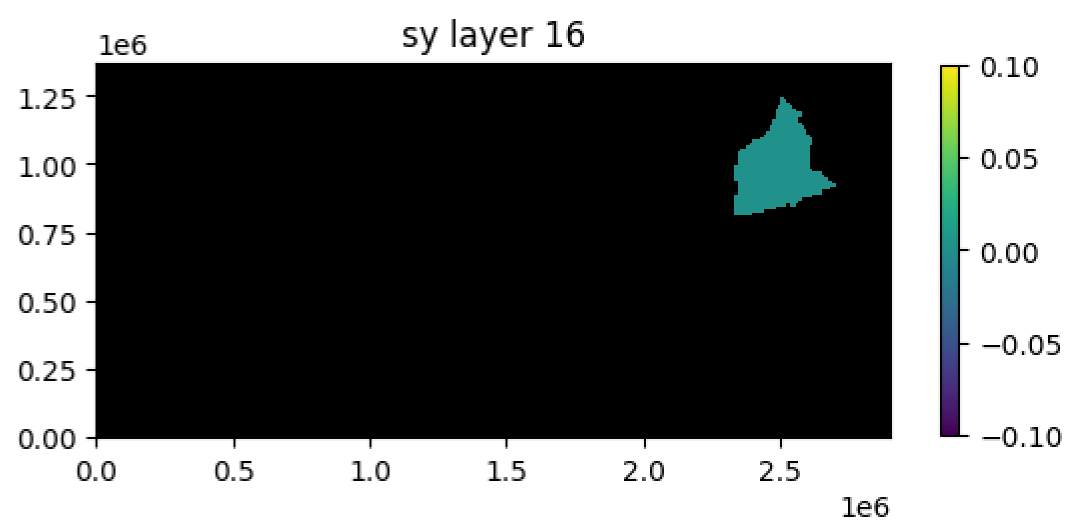
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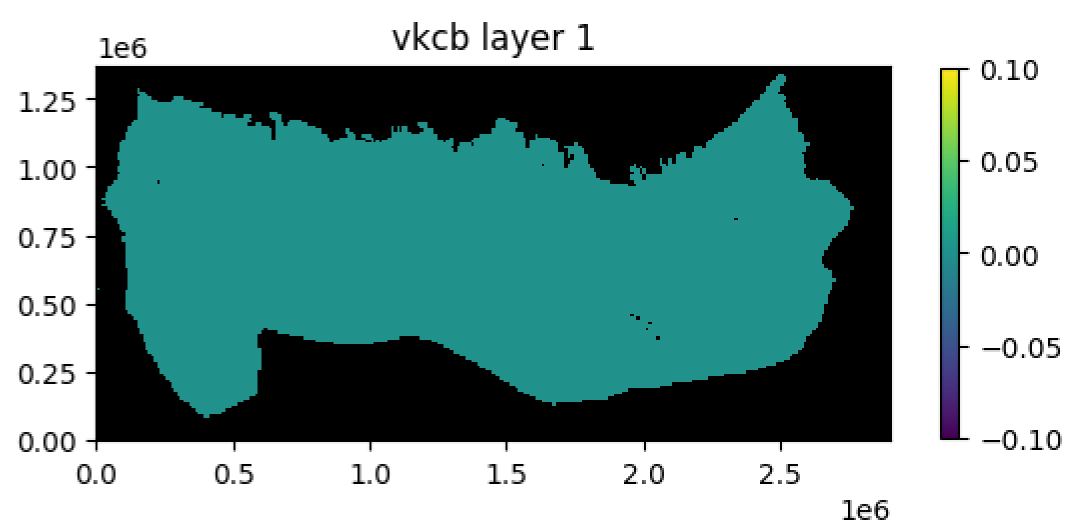
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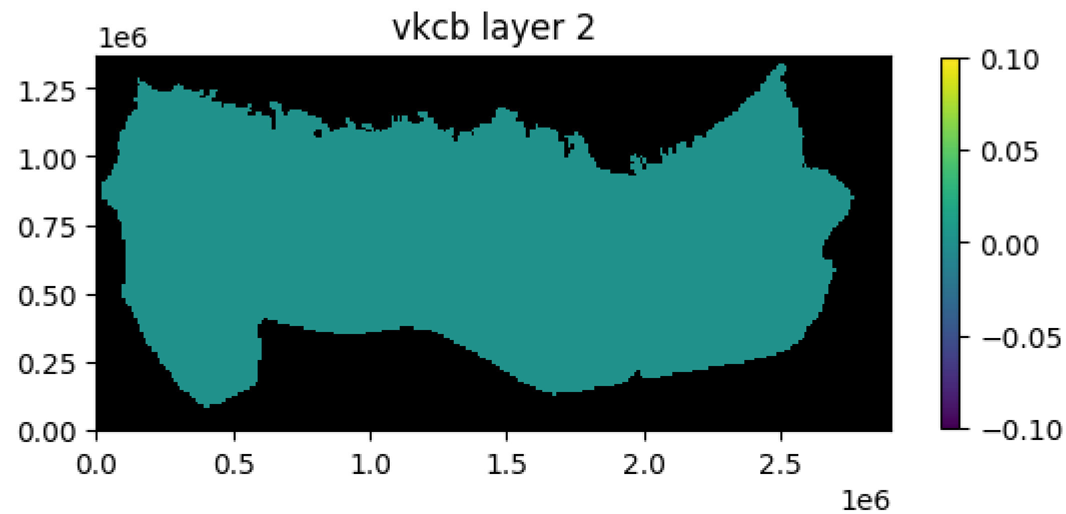
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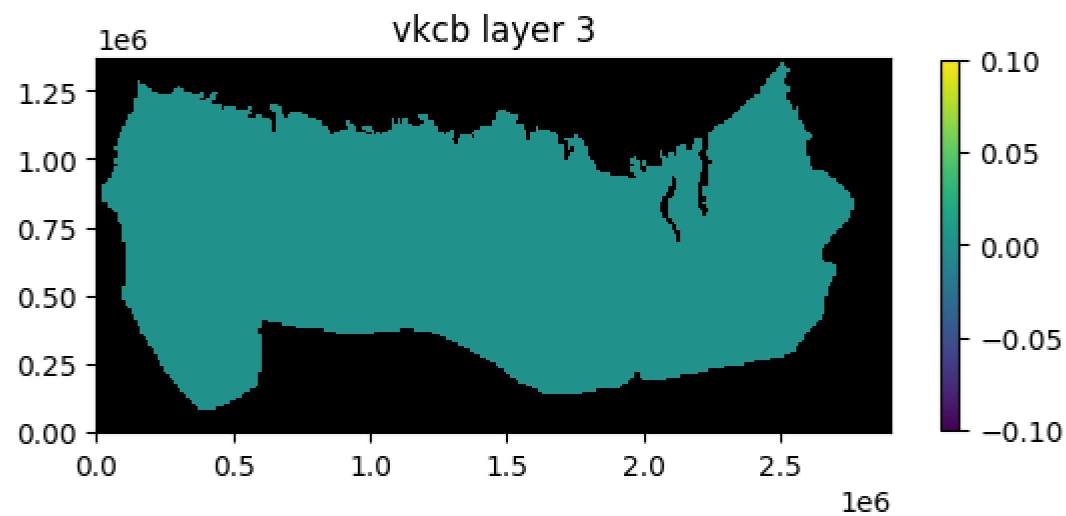
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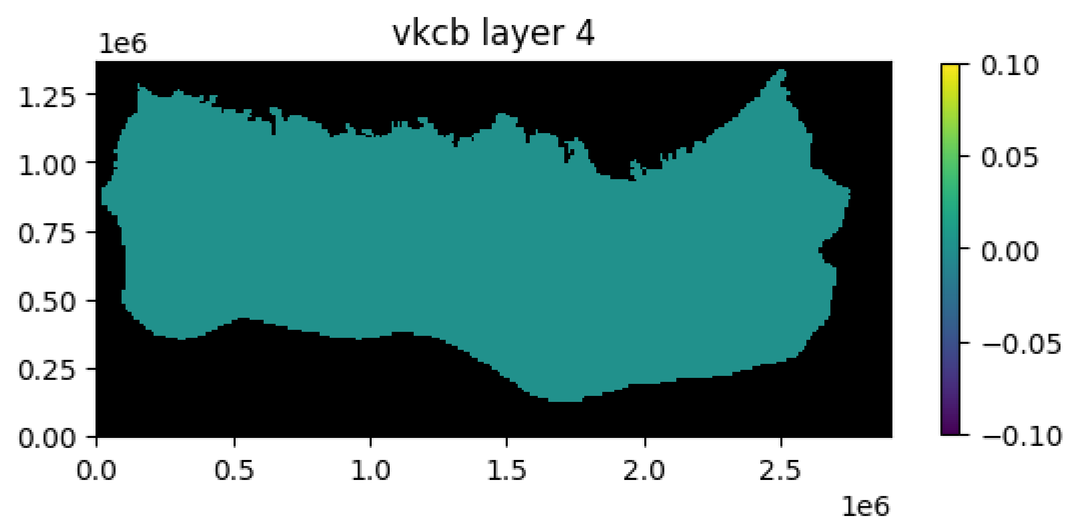
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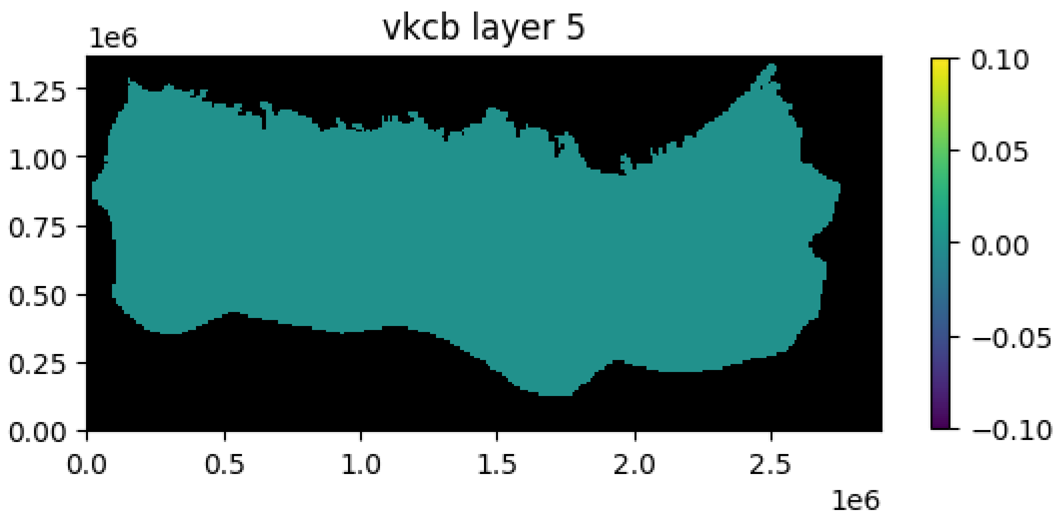
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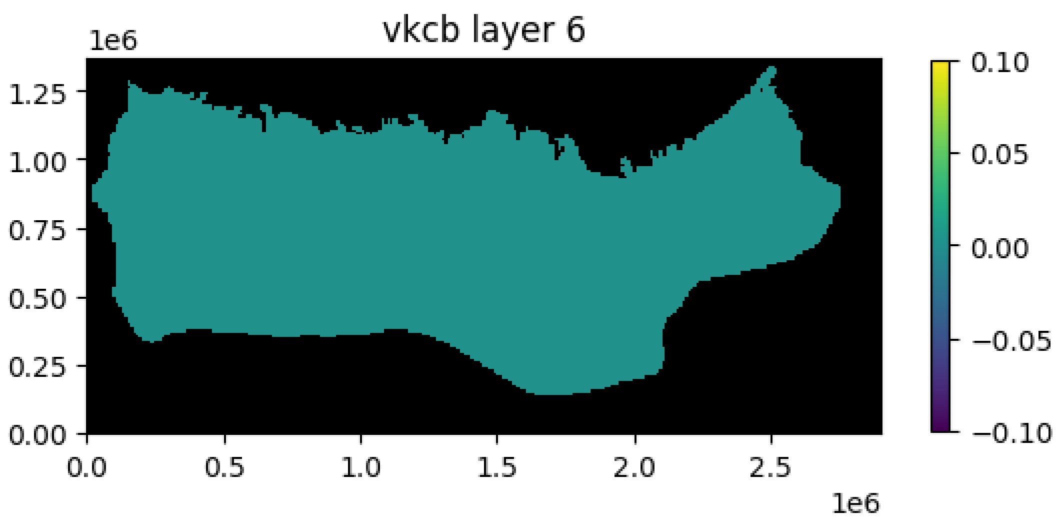
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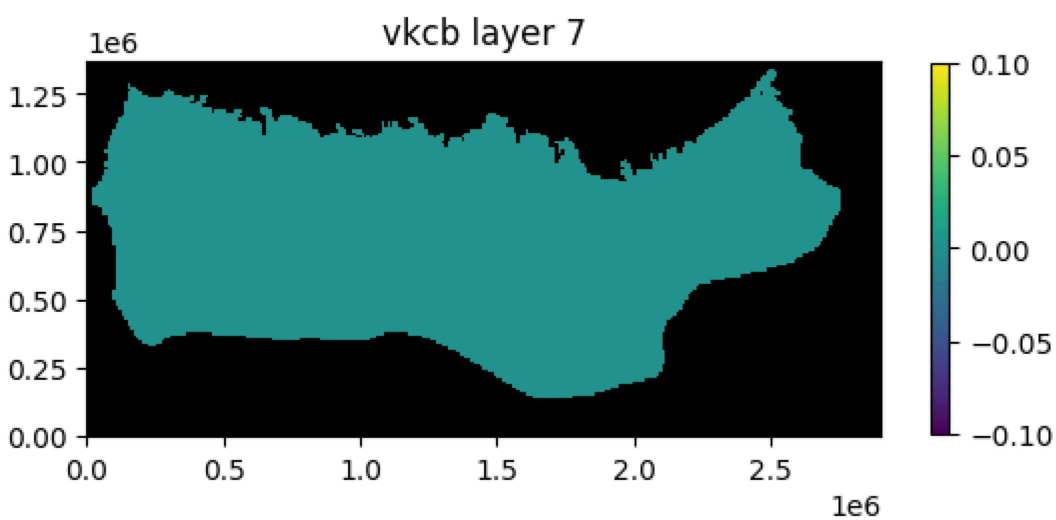
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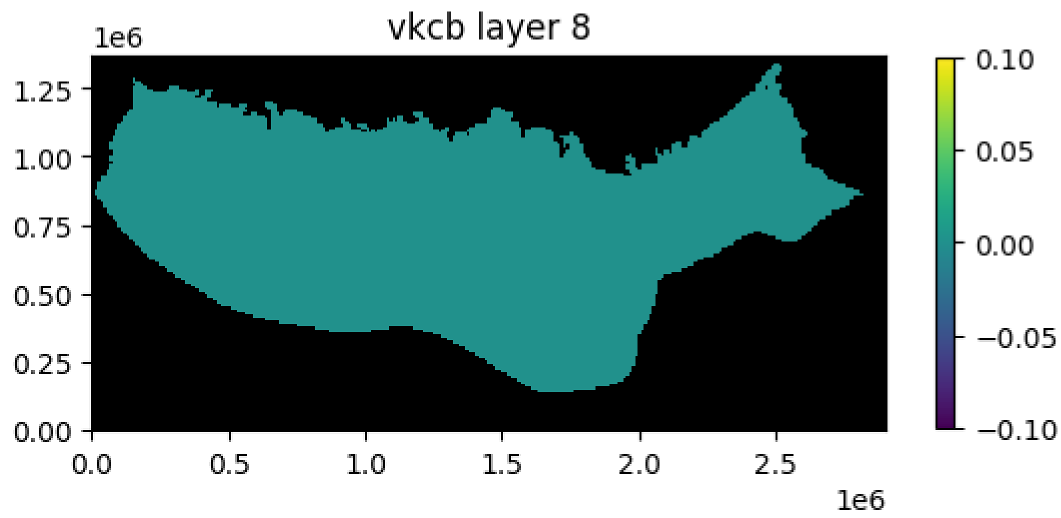
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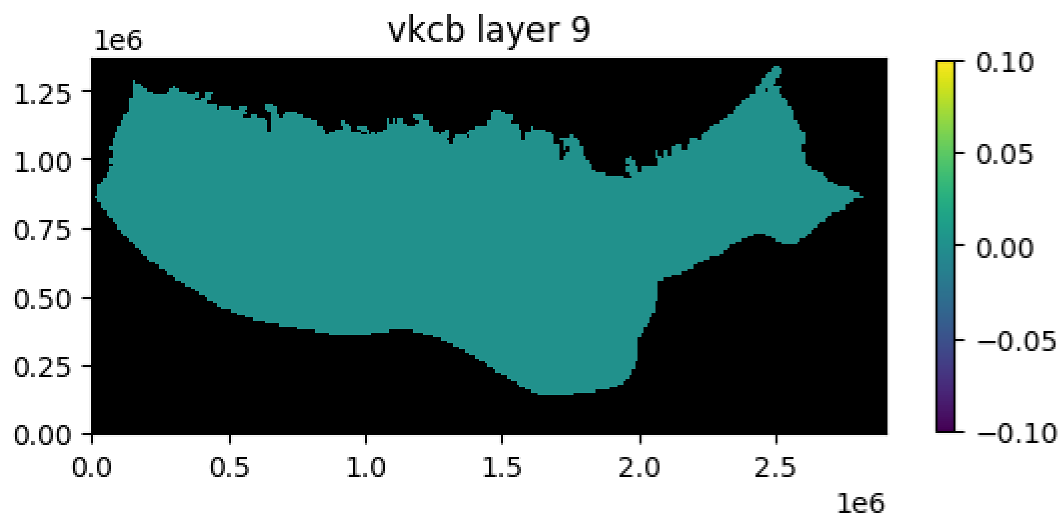
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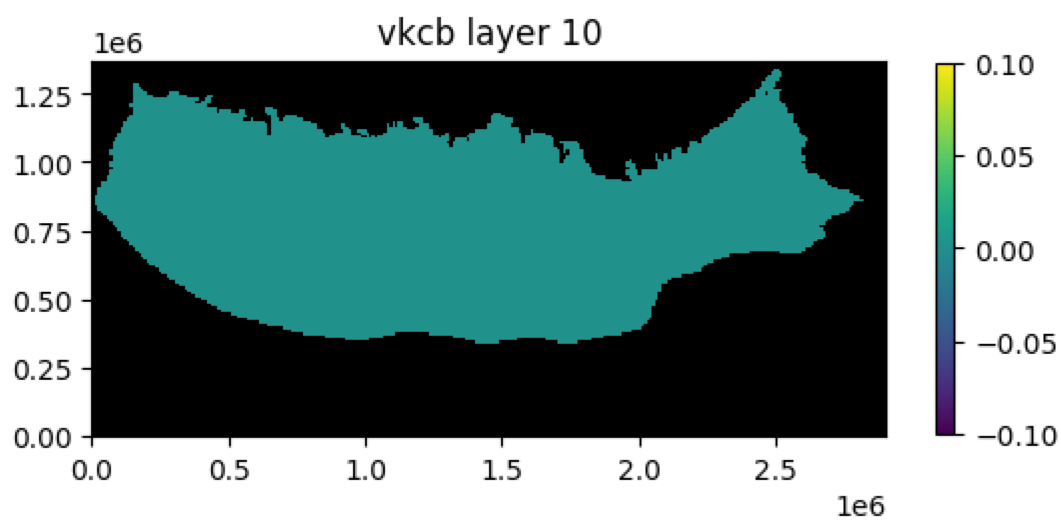
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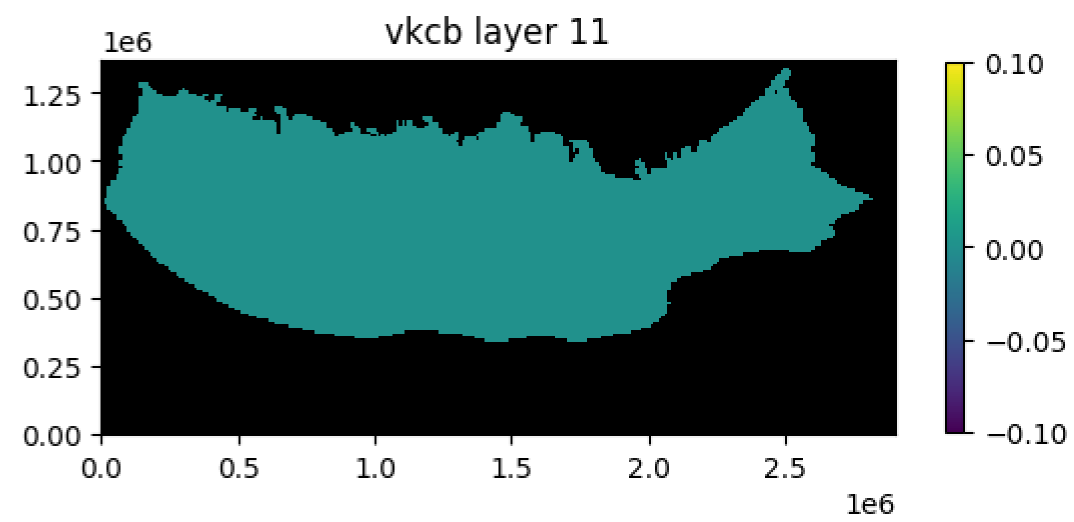
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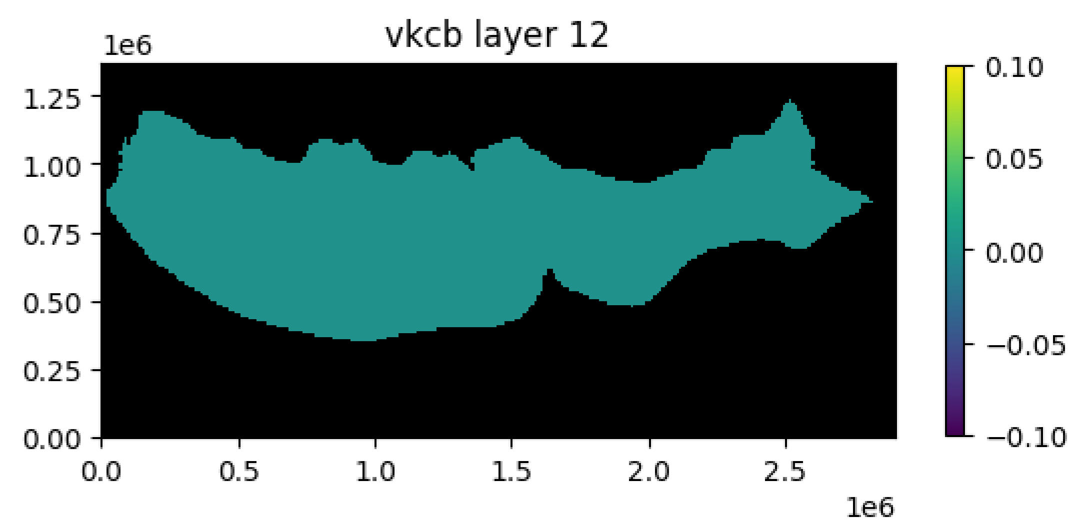
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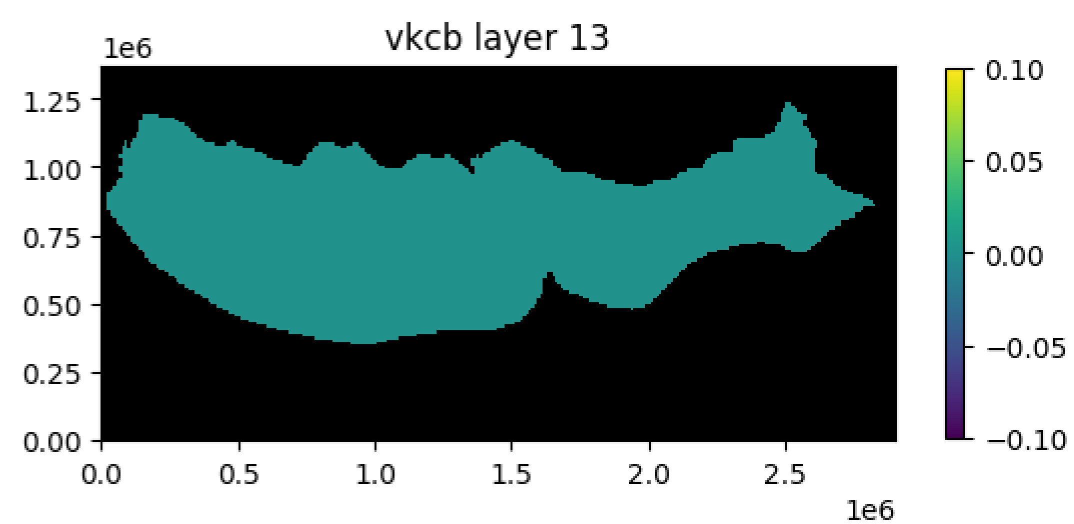
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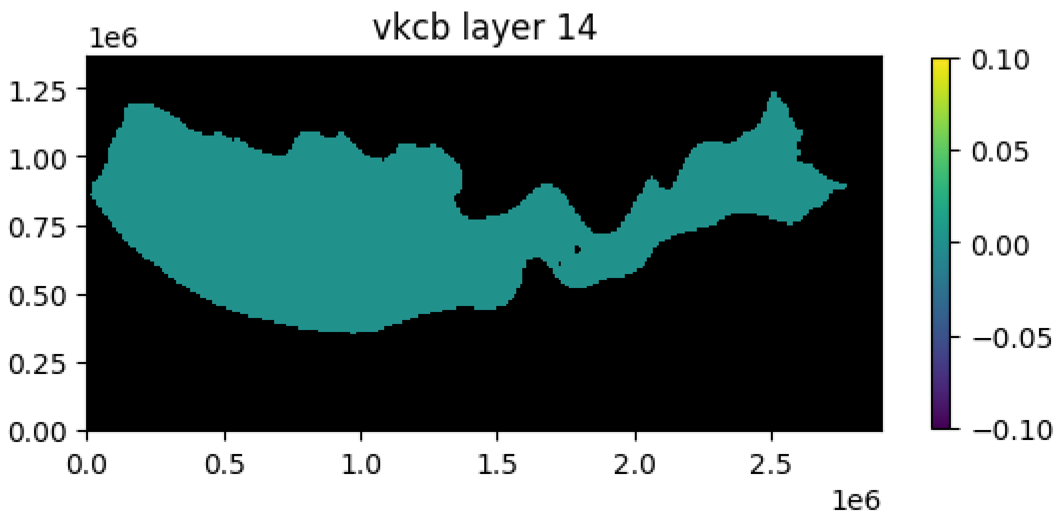
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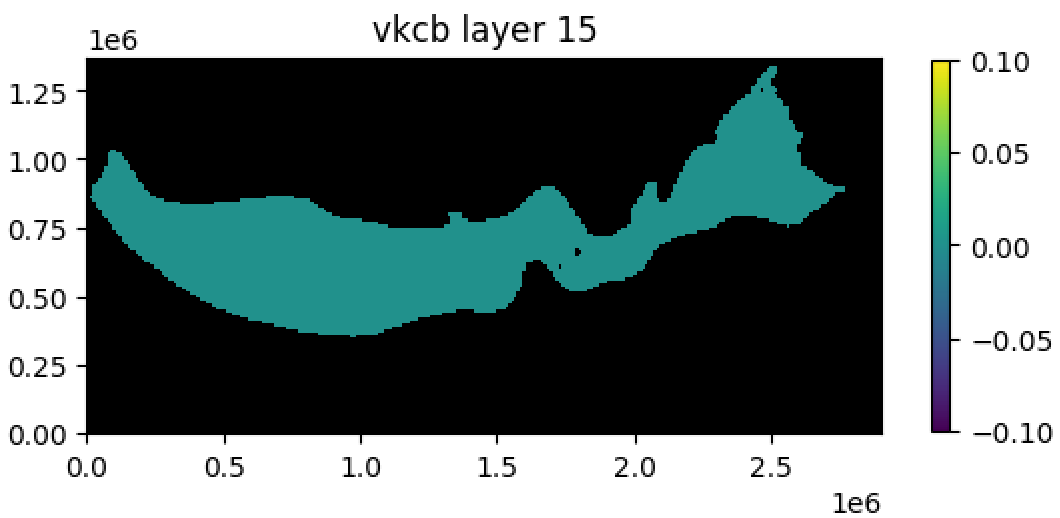
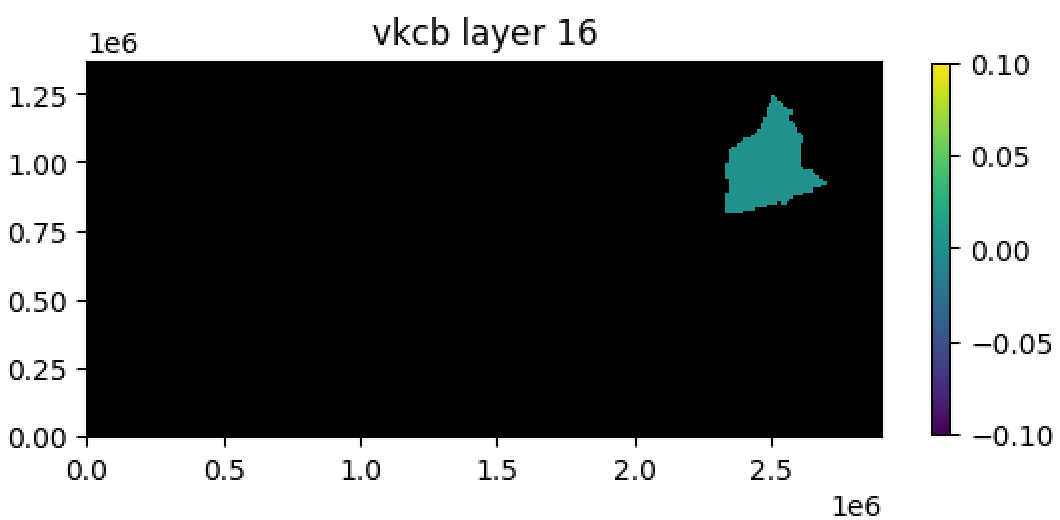
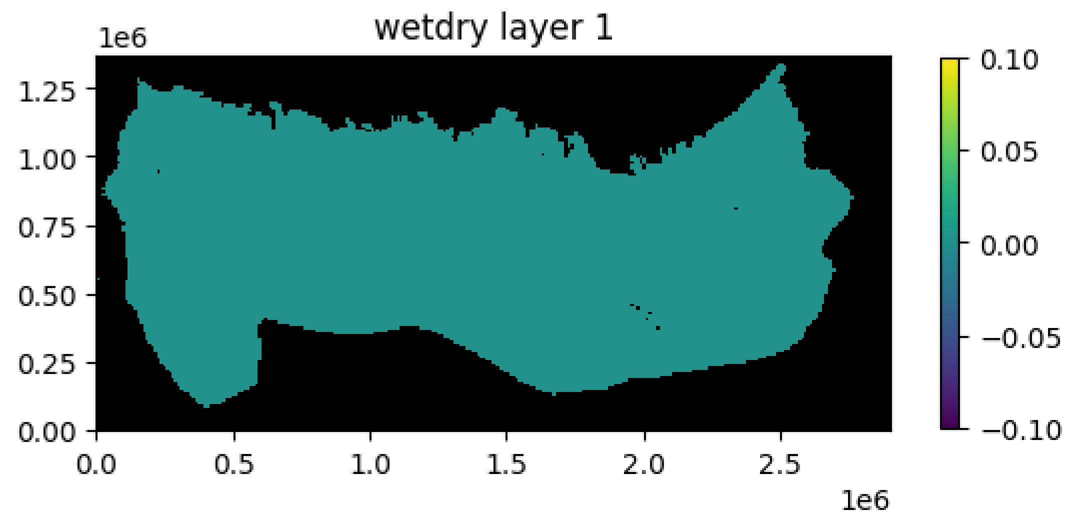
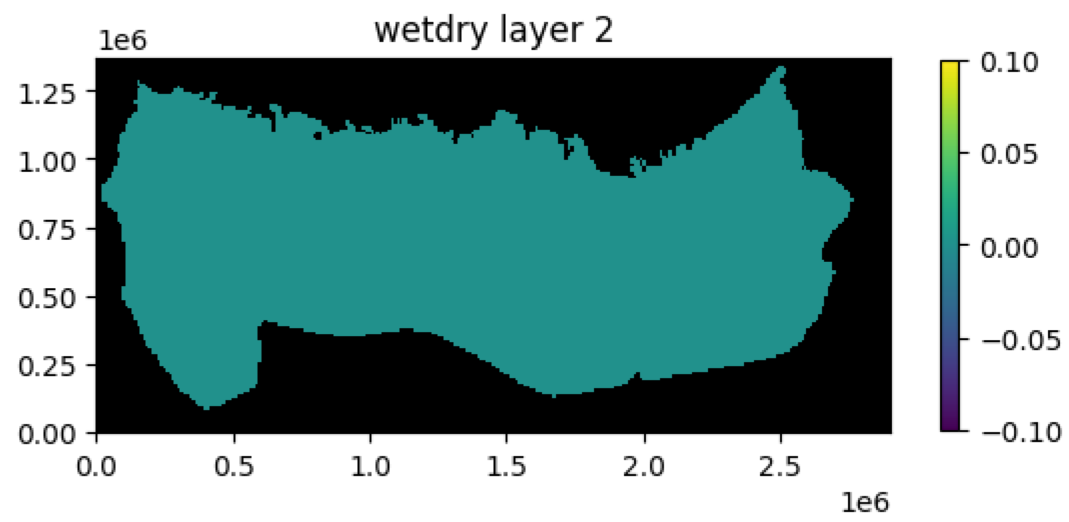
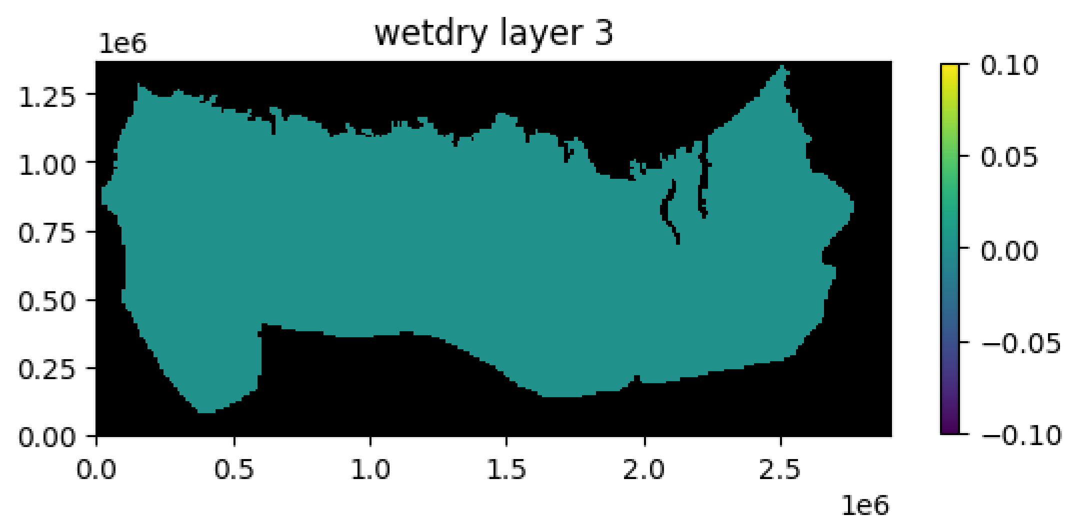
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
0.10
0.05
0.00
−0.05
−0.10

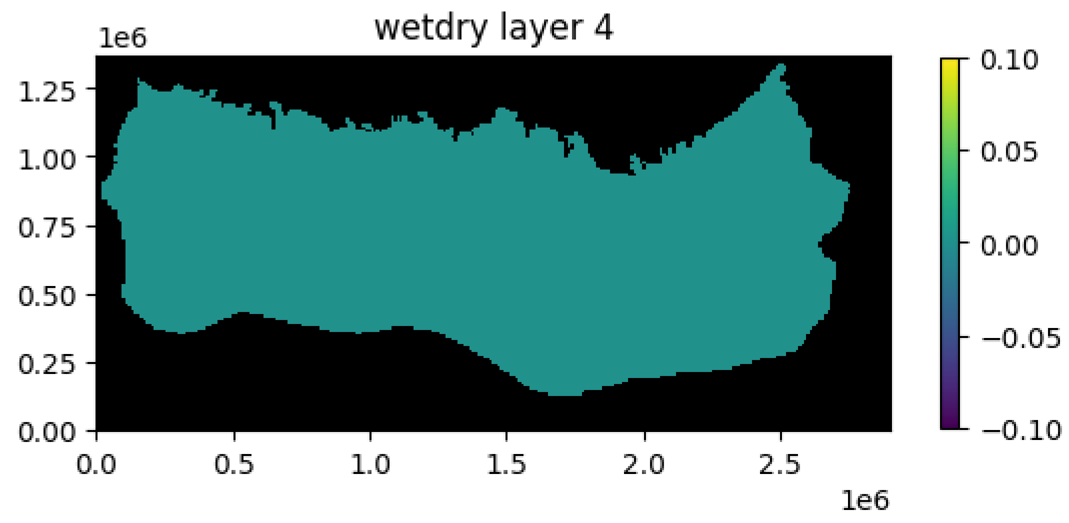

vkcb layer 15
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
0.10
0.05
0.00
−0.05
−0.10

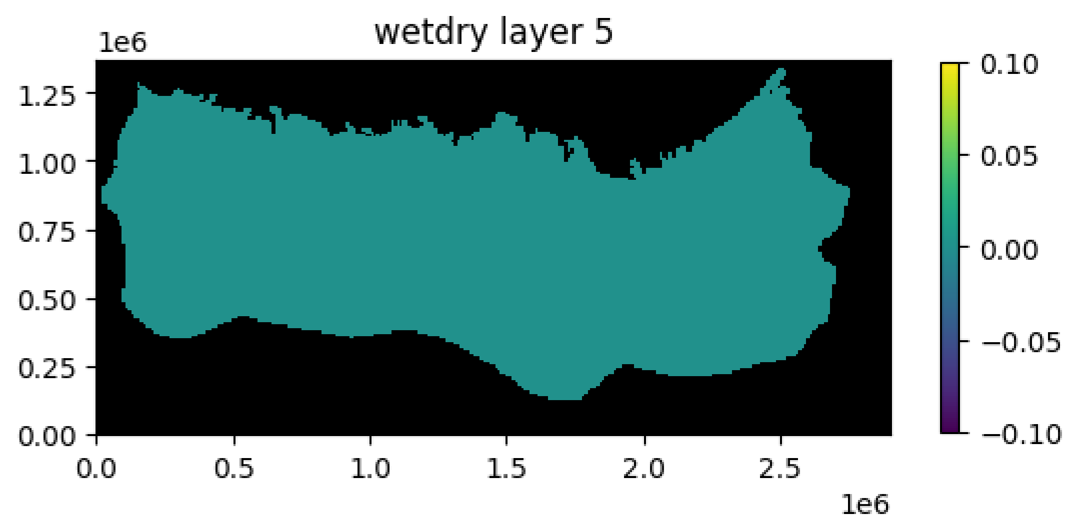

vkcb layer 16
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
0.10
0.05
0.00
−0.05
−0.10

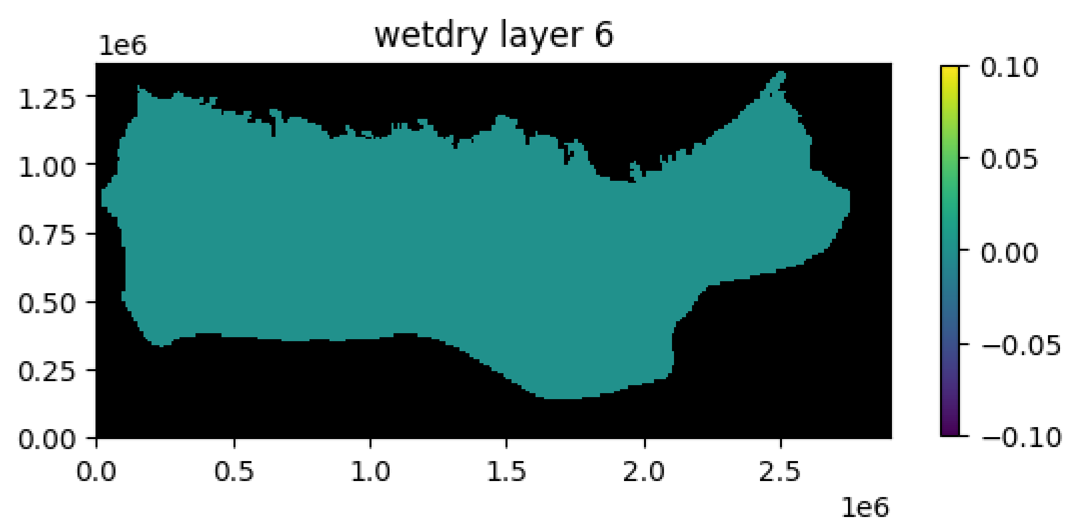

wetdry layer 1
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
0.10
0.05
0.00
−0.05
−0.10

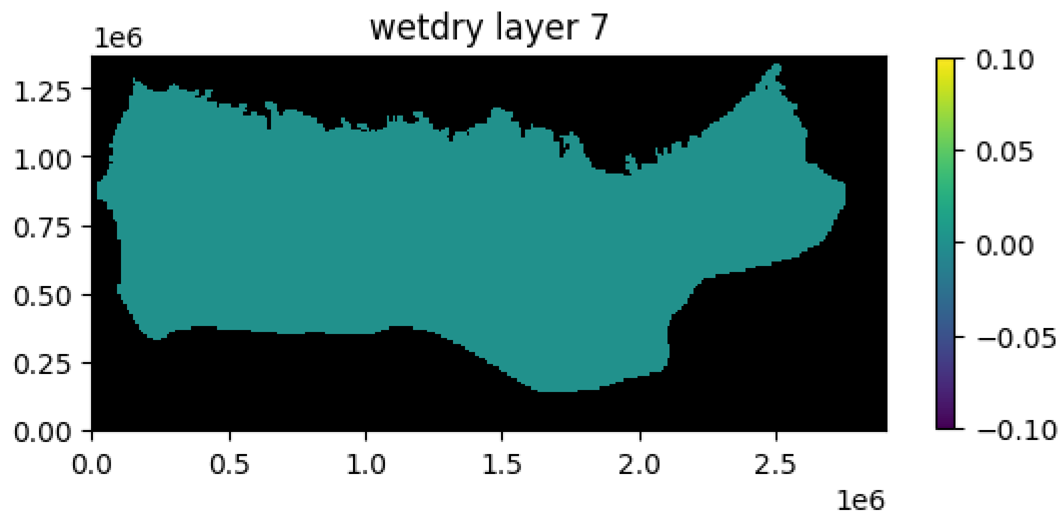

wetdry layer 2
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
0.10
0.05
0.00
−0.05
−0.10

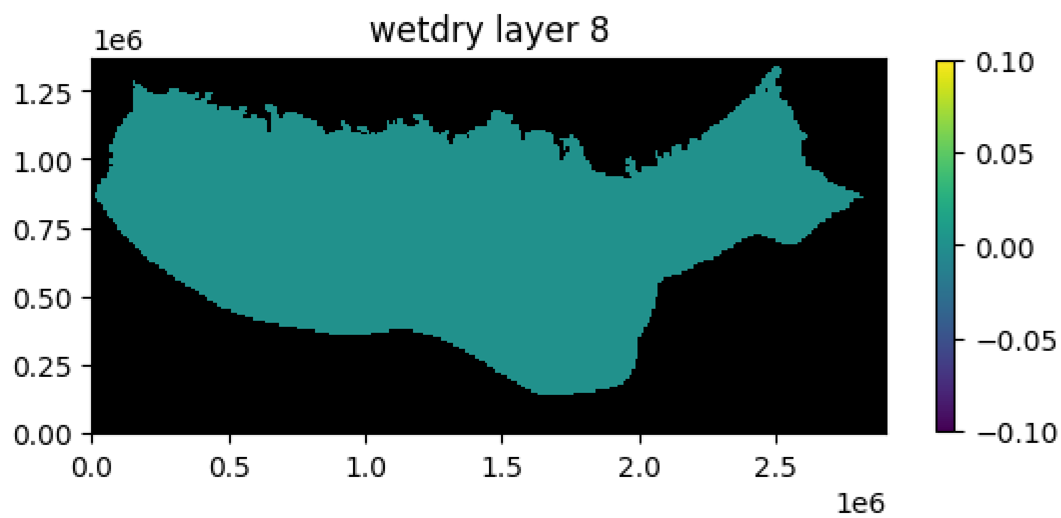

wetdry layer 3
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
0.10
0.05
0.00
−0.05
−0.10

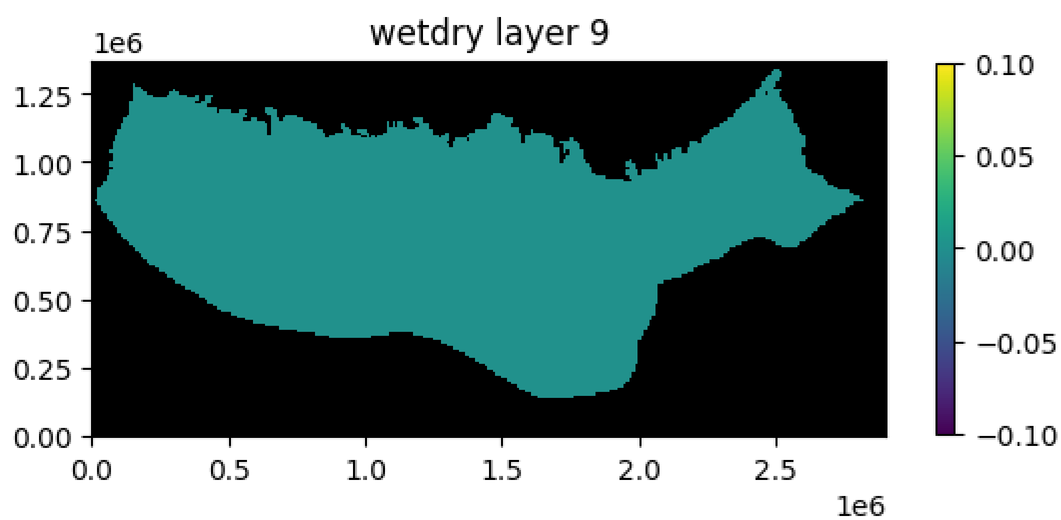

wetdry layer 4
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
0.10
0.05
0.00
−0.05
−0.10

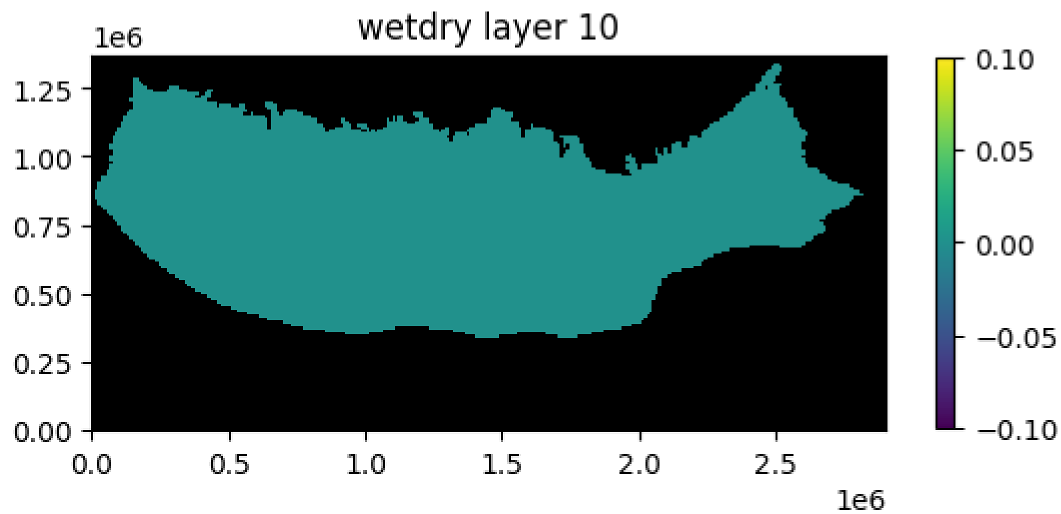

wetdry layer 5
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
0.10
0.05
0.00
−0.05
−0.10

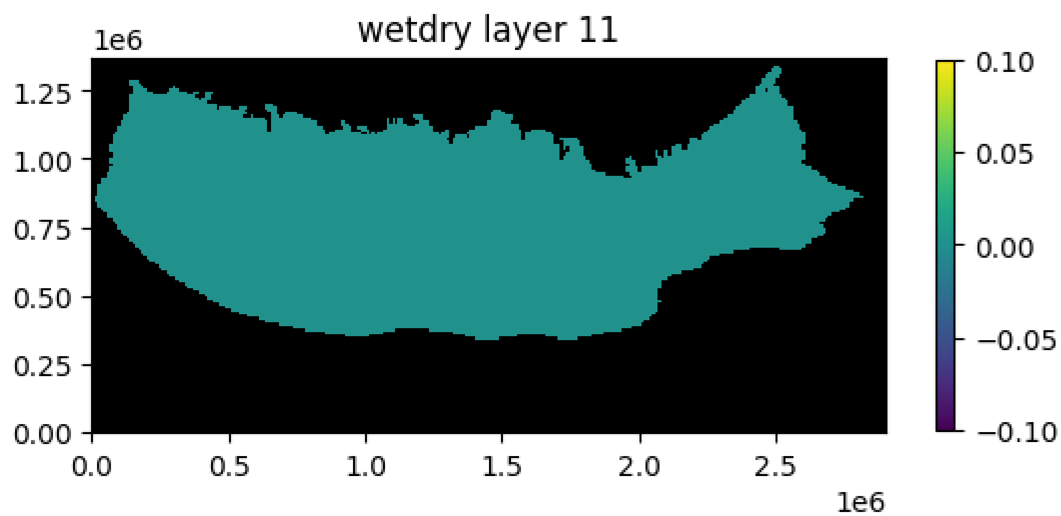

wetdry layer 6
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
0.10
0.05
0.00
−0.05
−0.10

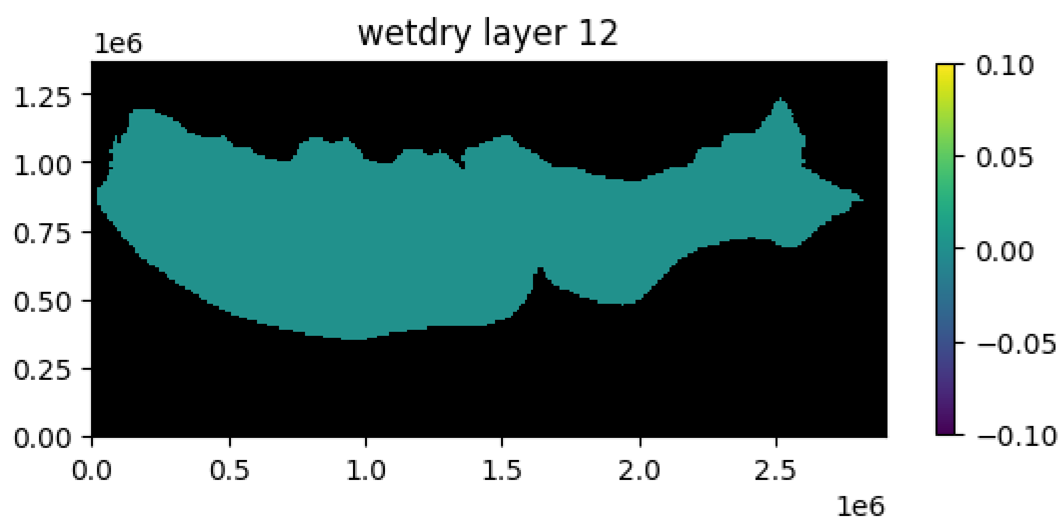

wetdry layer 7
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
0.10
0.05
0.00
−0.05
−0.10

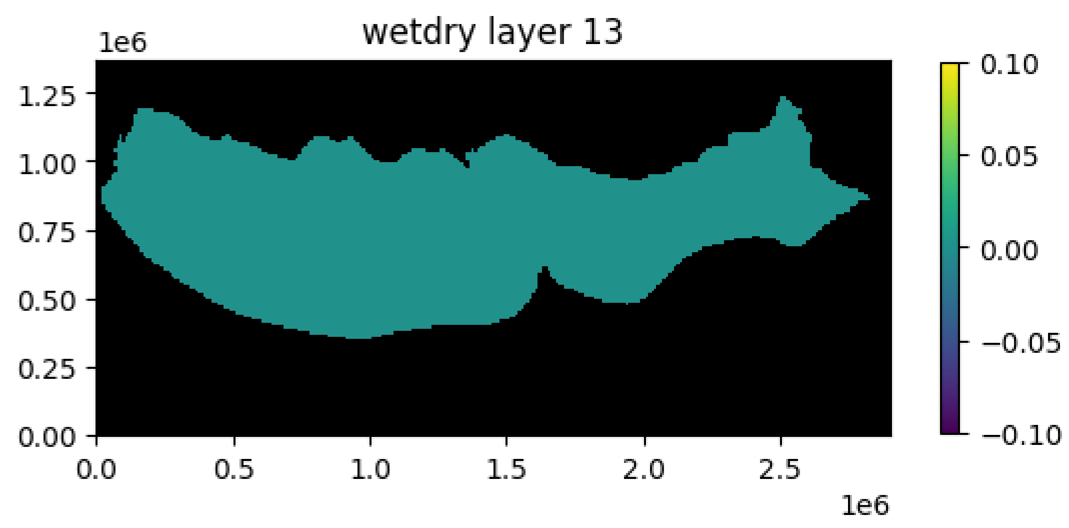

wetdry layer 8
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
0.10
0.05
0.00
−0.05
−0.10

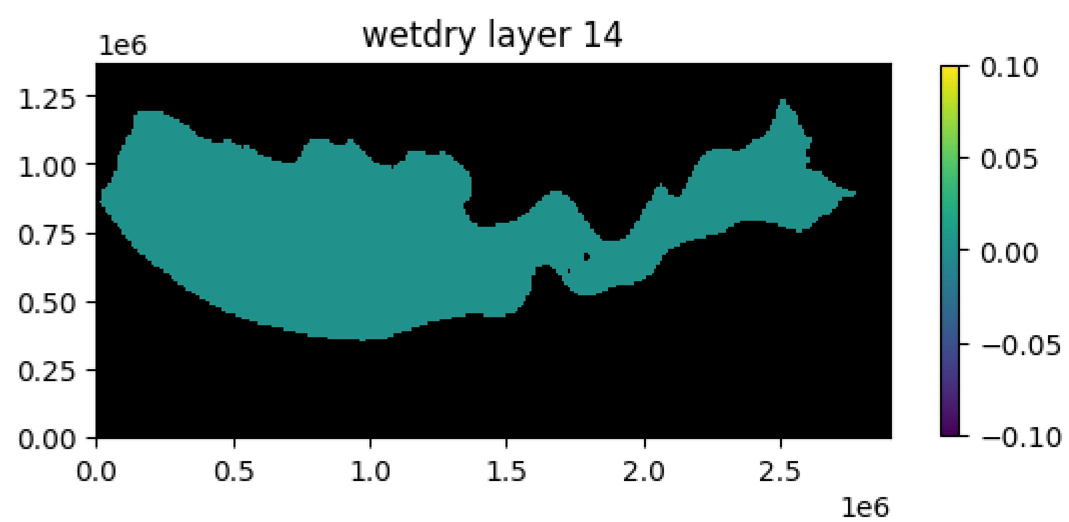

wetdry layer 9
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
0.10
0.05
0.00
−0.05
−0.10

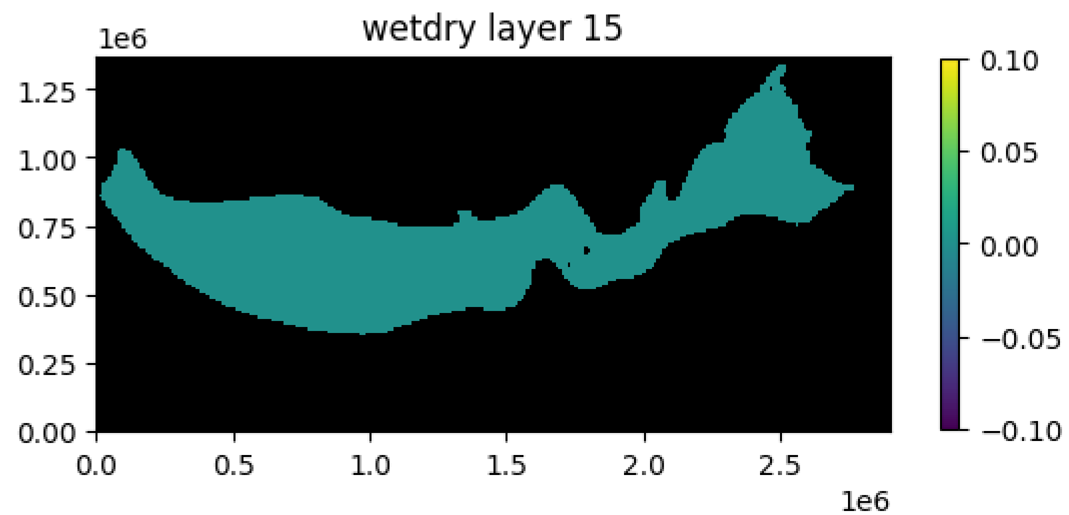

wetdry layer 10
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
0.10
0.05
0.00
−0.05
−0.10

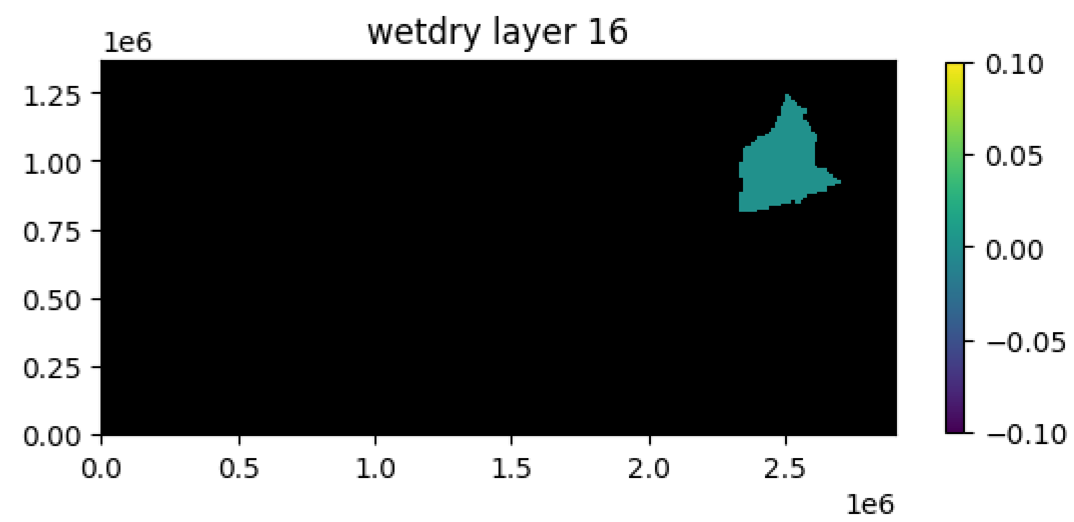

wetdry layer 11
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
0.10
0.05
0.00
−0.05
−0.10

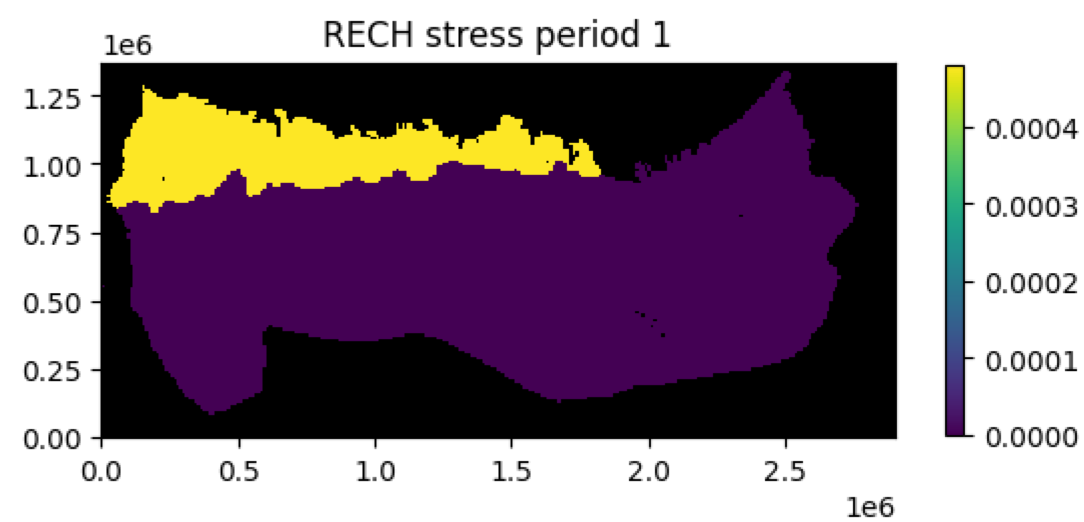

wetdry layer 12
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
0.10
0.05
0.00
−0.05
−0.10

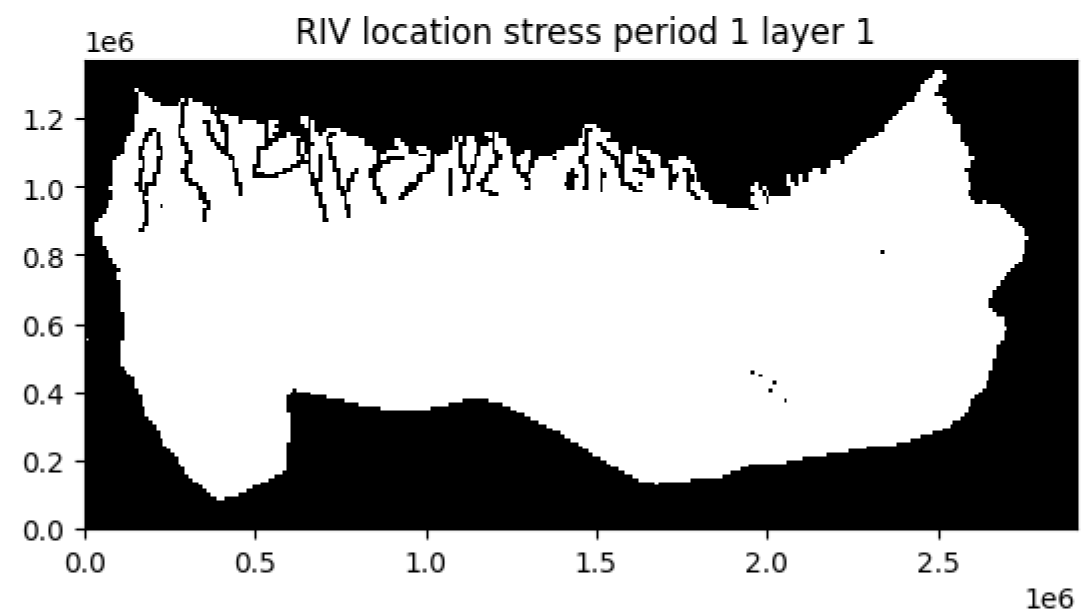

wetdry layer 13
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
0.10
0.05
0.00
−0.05
−0.10

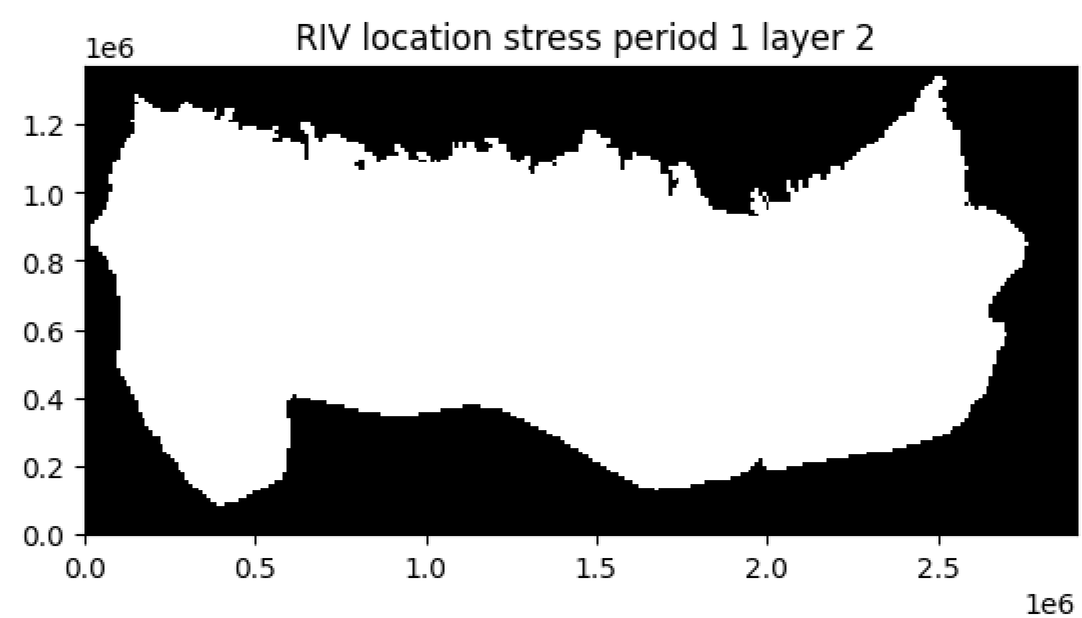

wetdry layer 14
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
0.10
0.05
0.00
−0.05
−0.10

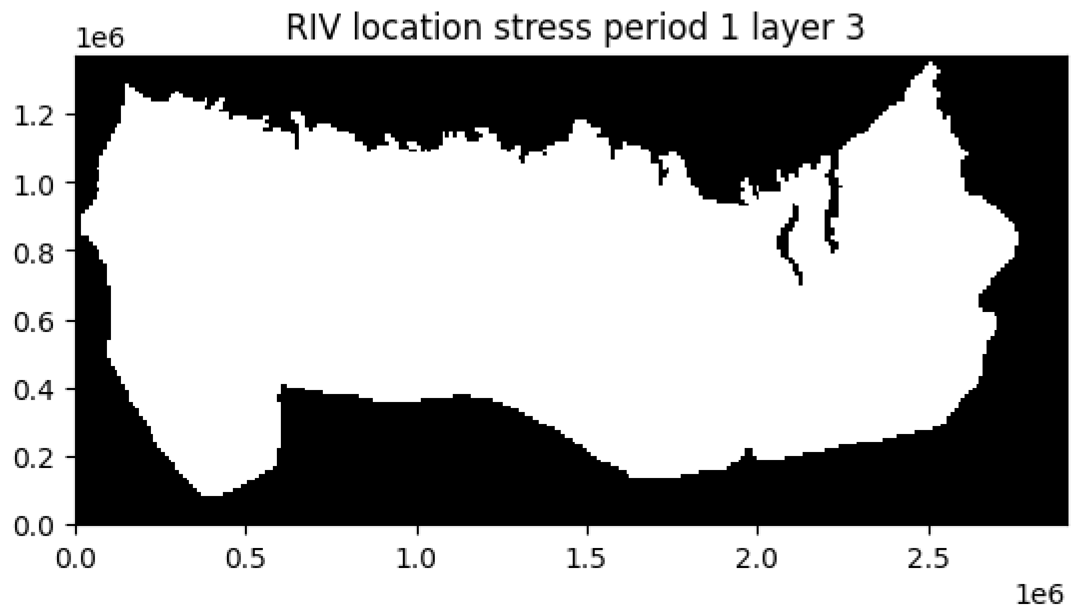

wetdry layer 15
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
0.10
0.05
0.00
−0.05
−0.10

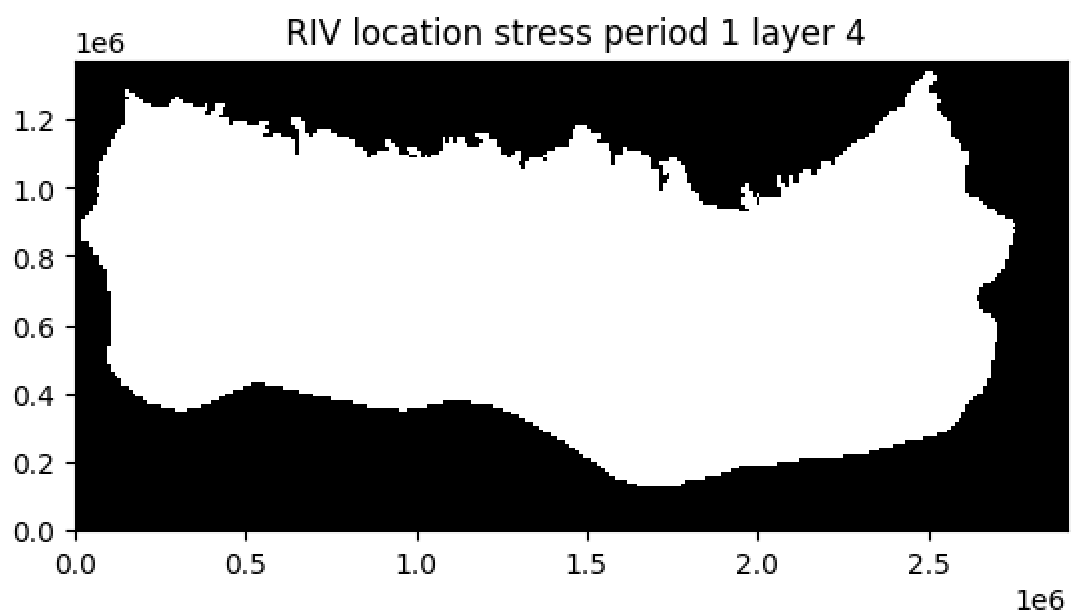

wetdry layer 16
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
0.10
0.05
0.00
−0.05
−0.10

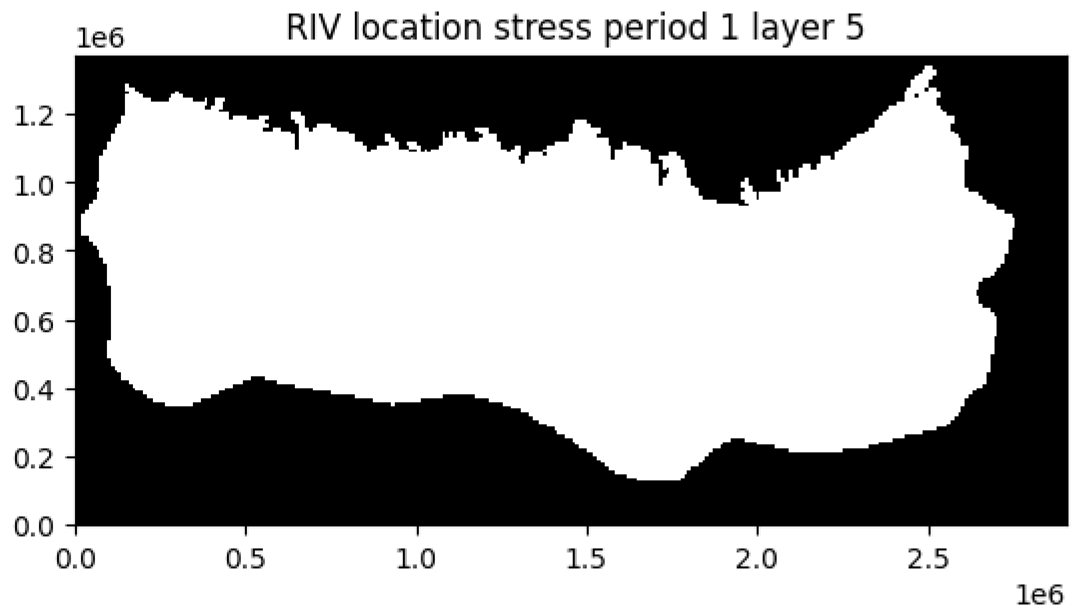

RECH stress period 1
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
0.0004
0.0003
0.0002
0.0001
0.0000

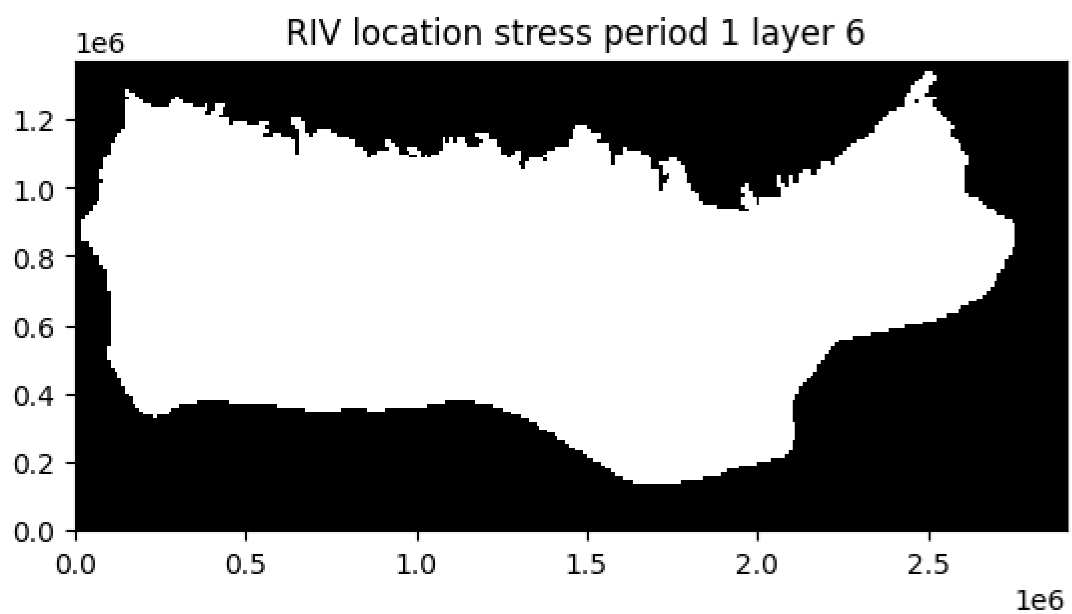

RIV location stress period 1 layer 1
1e6
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.5
1.0
1.5
2.0
2.5
1e6

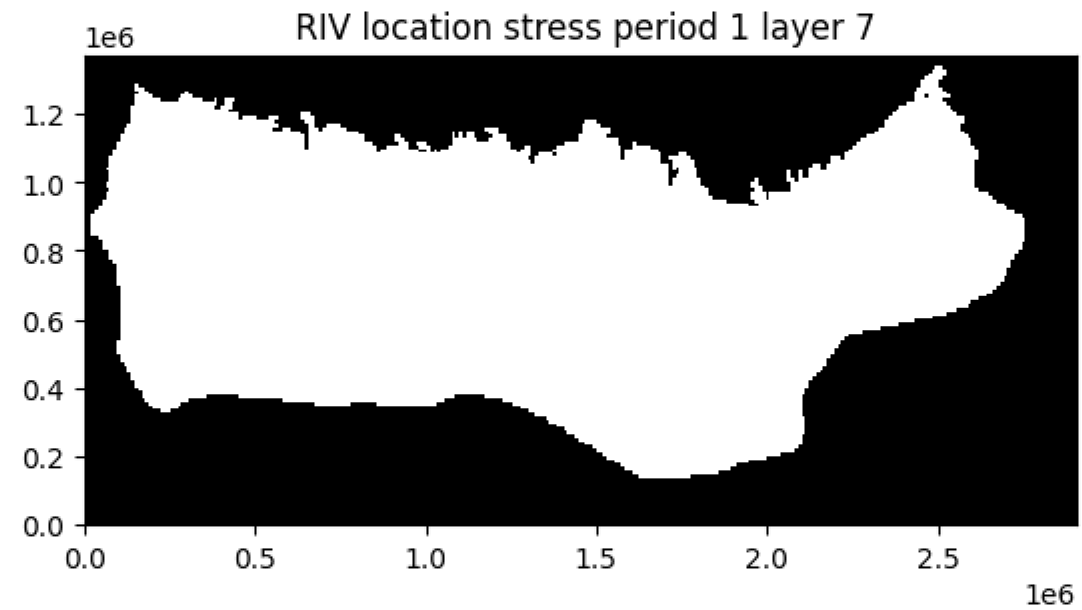

RIV location stress period 1 layer 2
1e6
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.5
1.0
1.5
2.0
2.5
1e6


RIV location stress period 1 layer 3
1e6
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.5
1.0
1.5
2.0
2.5
1e6


RIV location stress period 1 layer 4
1e6
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.5
1.0
1.5
2.0
2.5
1e6


RIV location stress period 1 layer 5
1e6
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.5
1.0
1.5
2.0
2.5
1e6


RIV location stress period 1 layer 6
1e6
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.5
1.0
1.5
2.0
2.5
1e6


RIV location stress period 1 layer 7
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1.2
1.0
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0.6
0.4
0.2
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0.0
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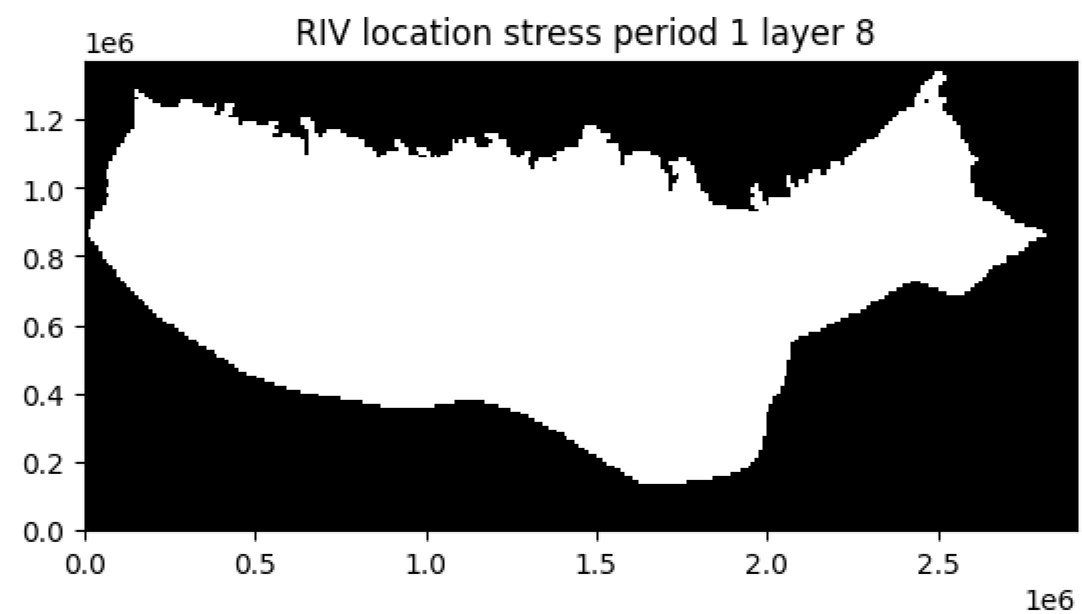
1.0
1.5
2.0
2.5
1e6


RIV location stress period 1 layer 8
1e6
1.2
1.0
0.8
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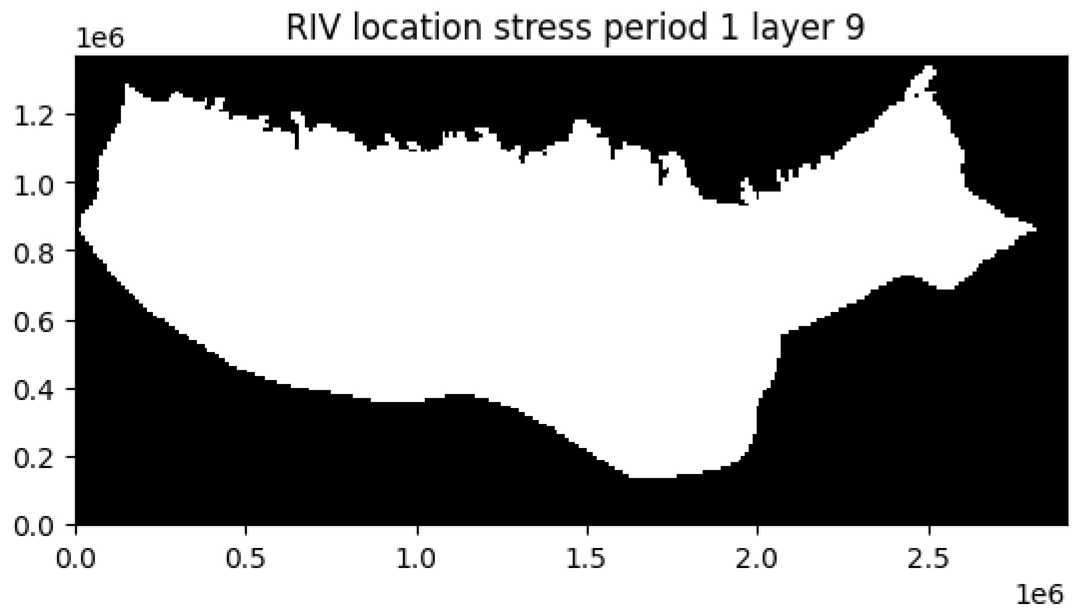
0.4
0.2
0.0
0.0
0.5
1.0
1.5
2.0
2.5
1e6


RIV location stress period 1 layer 9
1e6
1.2
1.0
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0.4
0.2
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0.0
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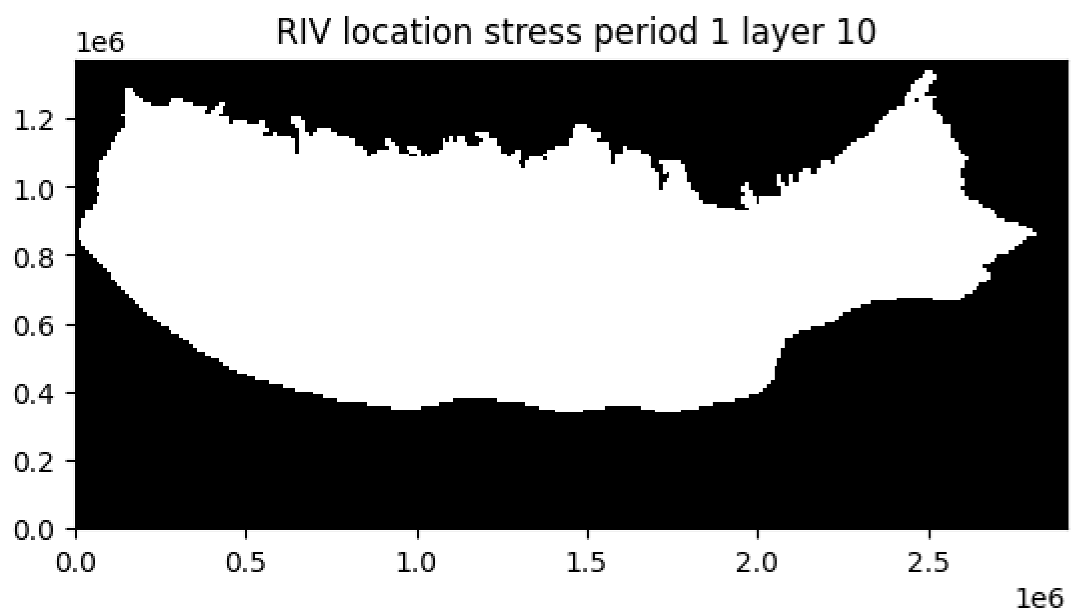
1.0
1.5
2.0
2.5
1e6


RIV location stress period 1 layer 10
1e6
1.2
1.0
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0.4
0.2
0.0
0.0
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1.0
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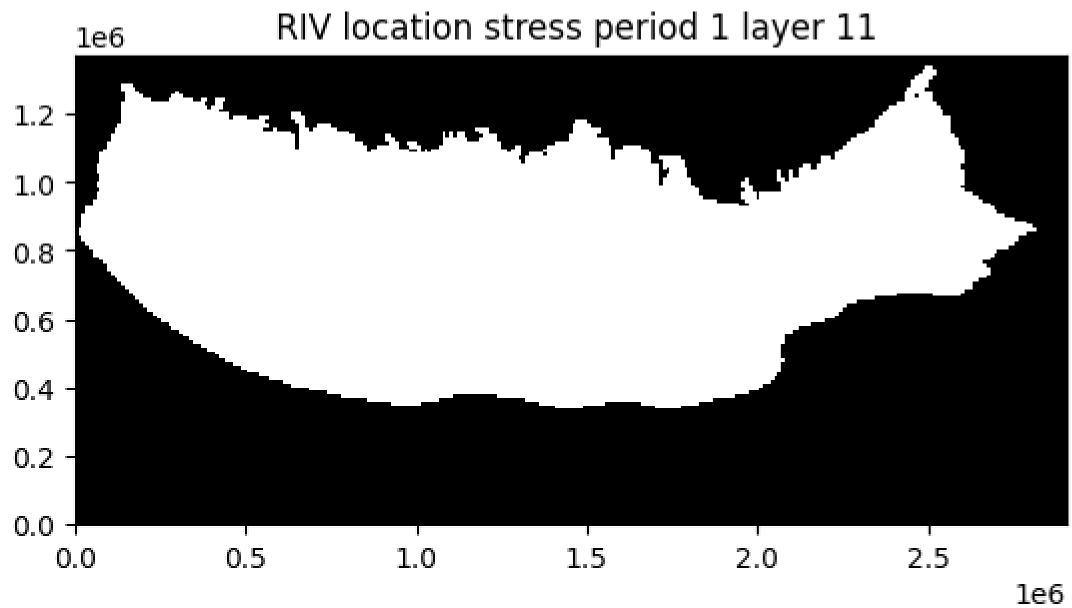
2.0
2.5
1e6


RIV location stress period 1 layer 11
1e6
1.2
1.0
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0.6
0.4
0.2
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0.0
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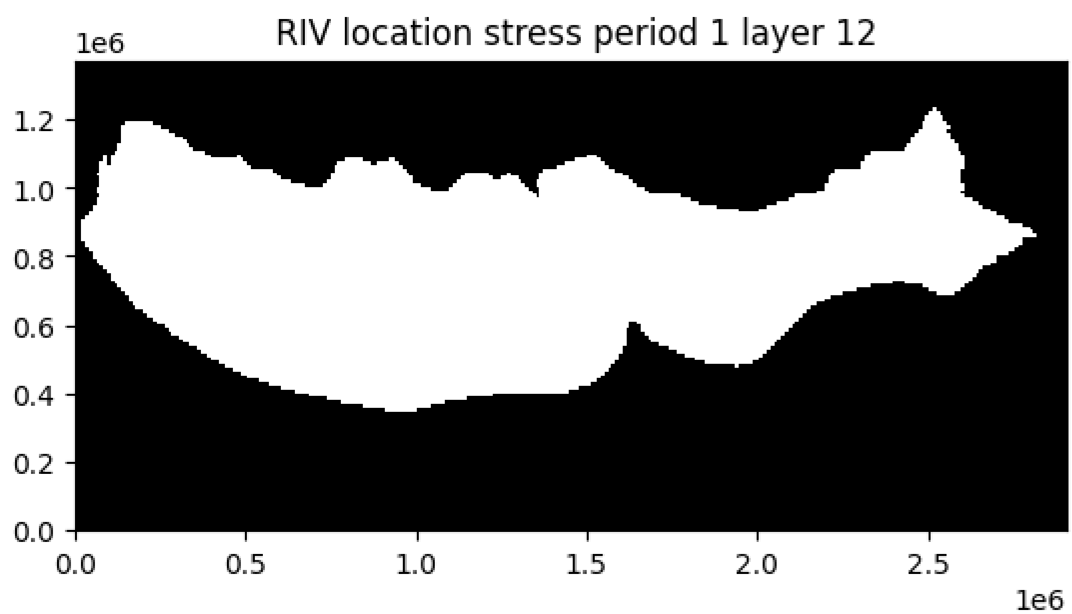
1.0
1.5
2.0
2.5
1e6


RIV location stress period 1 layer 12
1e6
1.2
1.0
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0.2
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1.0
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2.0
2.5
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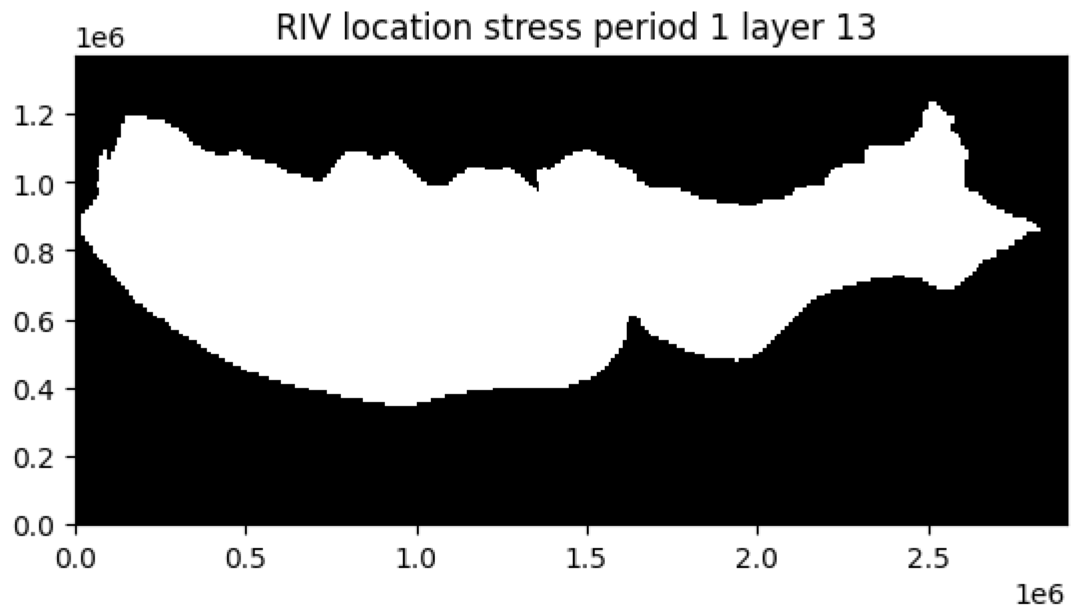
RIV location stress period 1 layer 13
1e6
1.2
1.0
0.8
0.6
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0.2
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0.0
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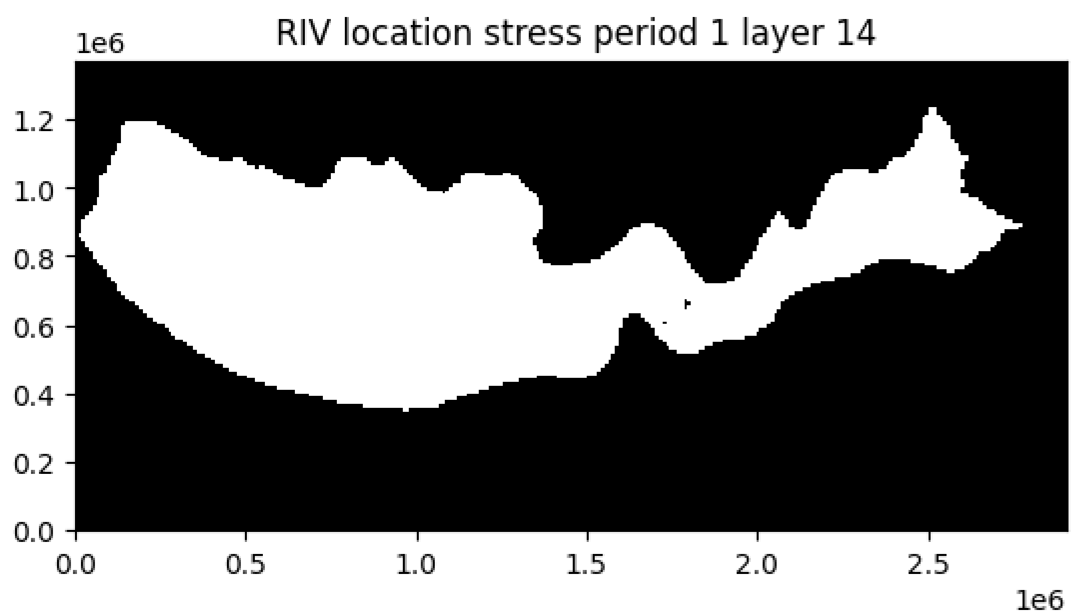
1.0
1.5
2.0
2.5
1e6


RIV location stress period 1 layer 14
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1.2
1.0
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0.4
0.2
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0.0
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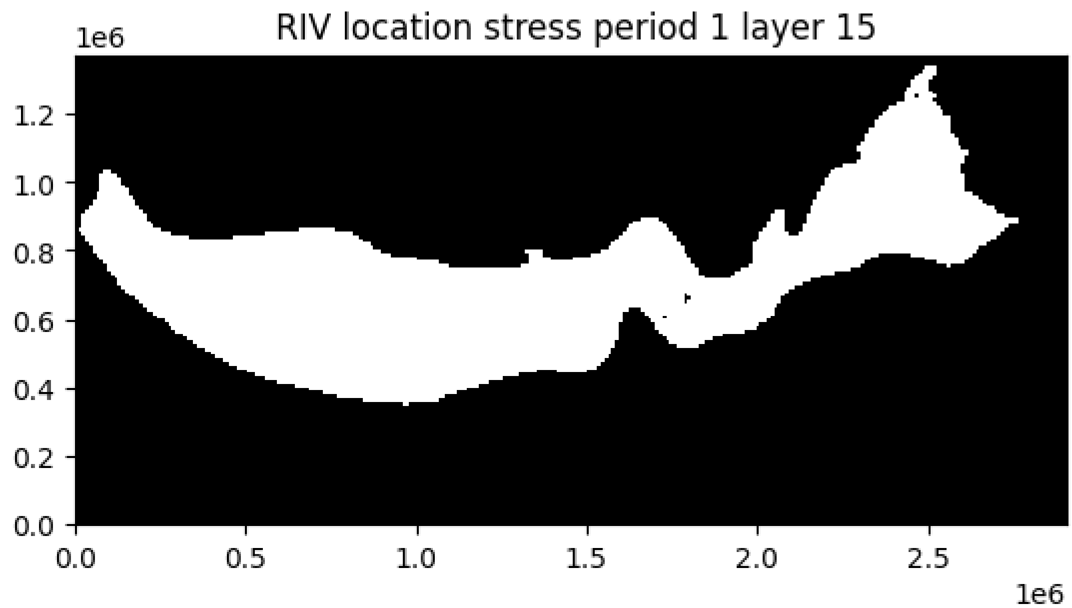
1.0
1.5
2.0
2.5
1e6


RIV location stress period 1 layer 15
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1.0
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0.2
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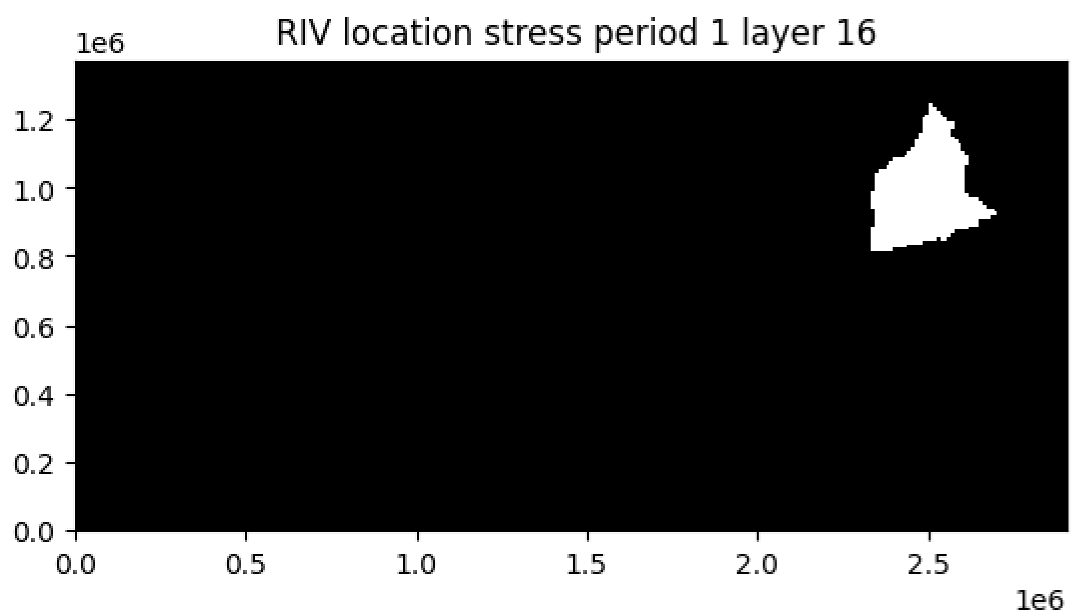
1.0
1.5
2.0
2.5
1e6


RIV location stress period 1 layer 16
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0.4
0.2
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0.0
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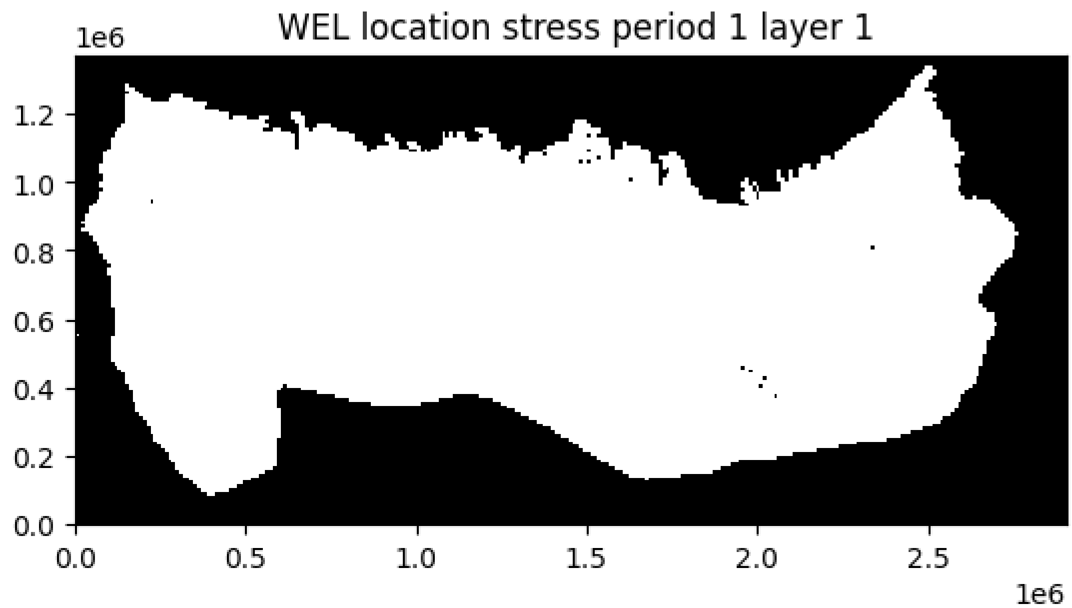
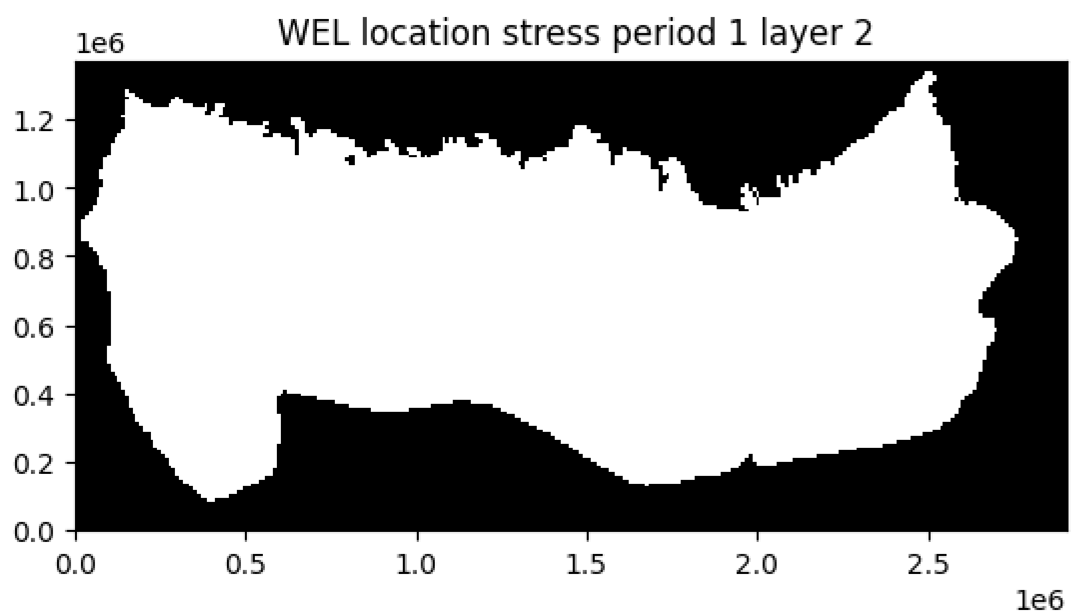
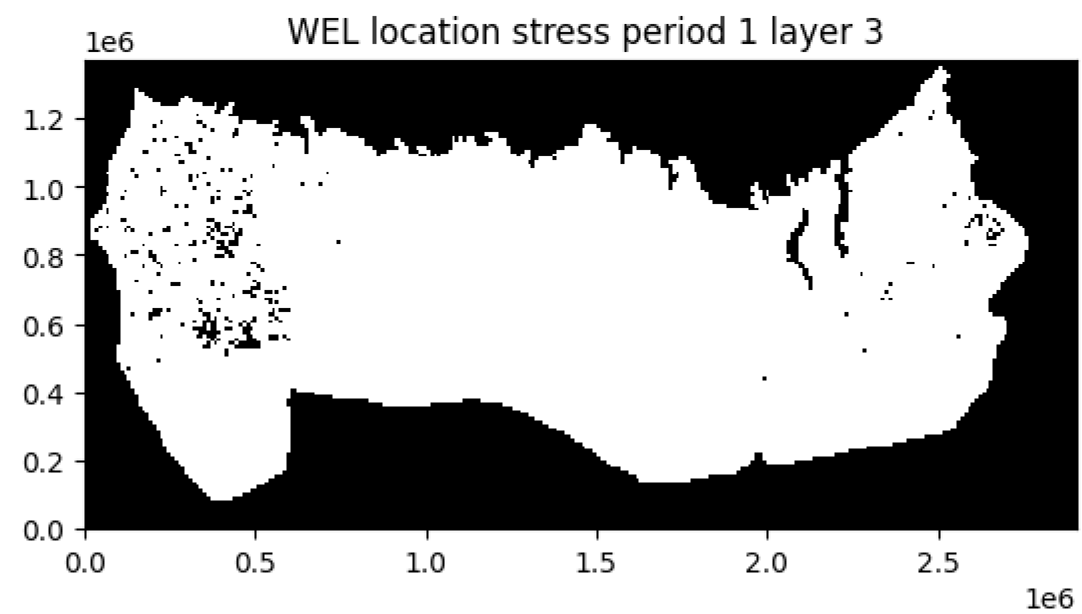
1.0
1.5
2.0
2.5
1e6


WEL location stress period 1 layer 1
1e6
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.5
1.0
1.5
2.0
2.5
1e6


WEL location stress period 1 layer 2
1e6
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.5
1.0
1.5
2.0
2.5
1e6


WEL location stress period 1 layer 3
1e6
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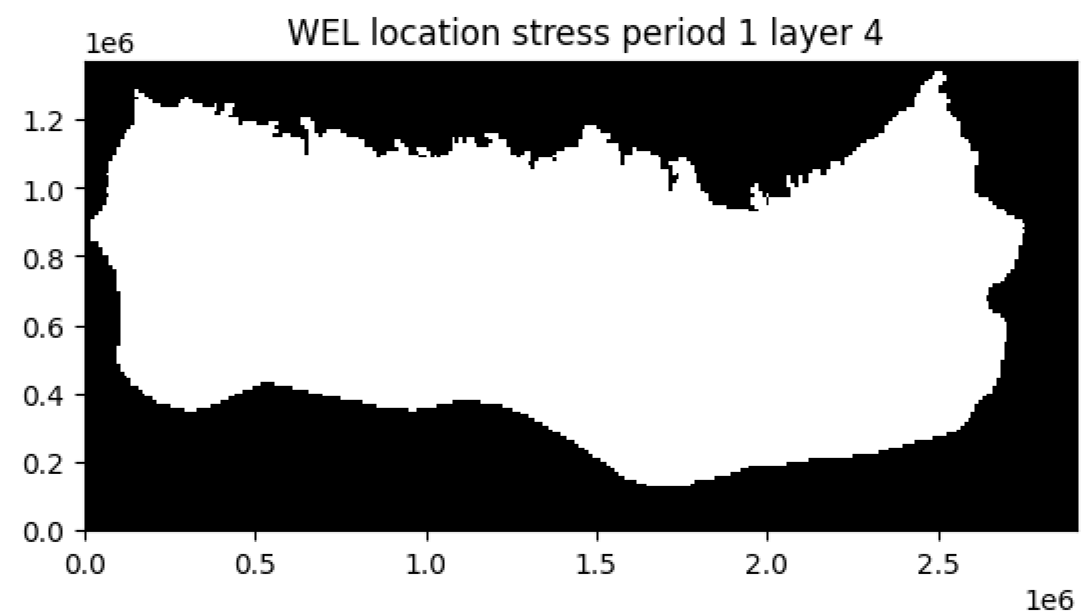
1.0
1.5
2.0
2.5
1e6


WEL location stress period 1 layer 4
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0.0
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1.0
1.5
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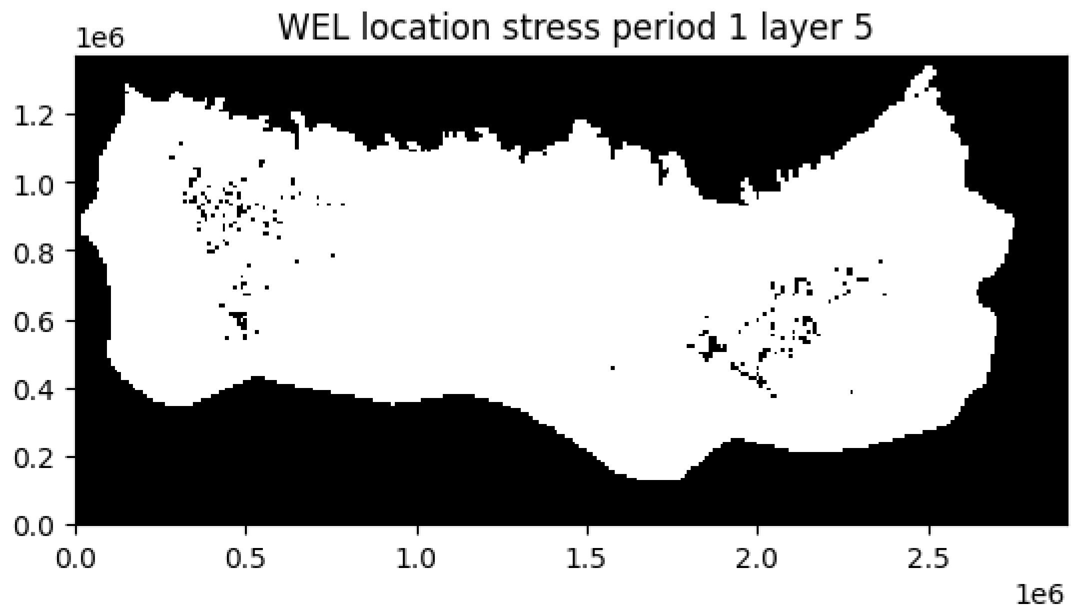
2.5
1e6


WEL location stress period 1 layer 5
1e6
1.2
1.0
0.8
0.6
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0.0
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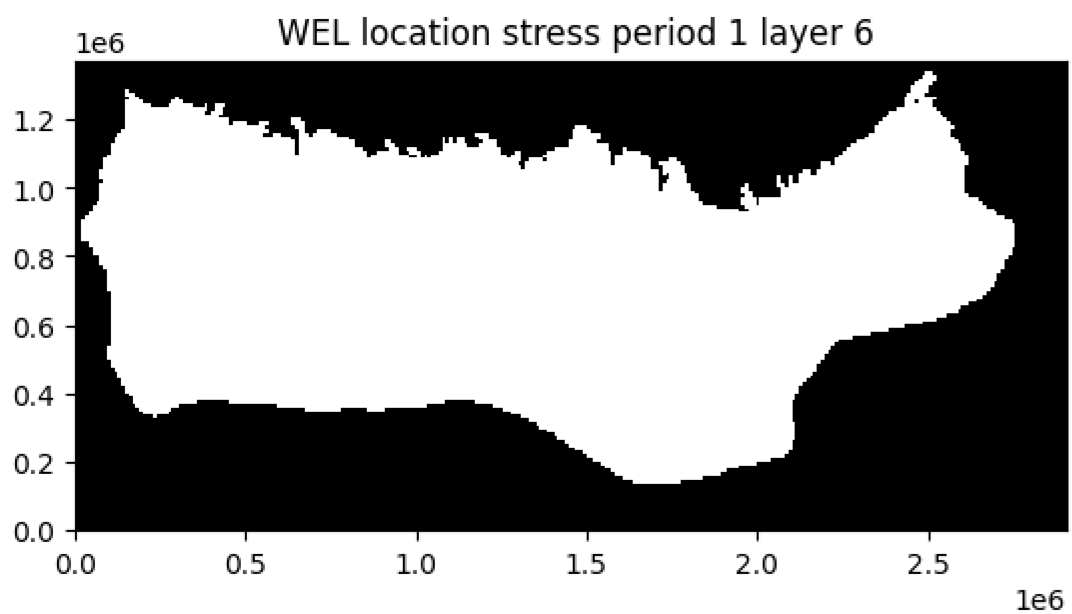
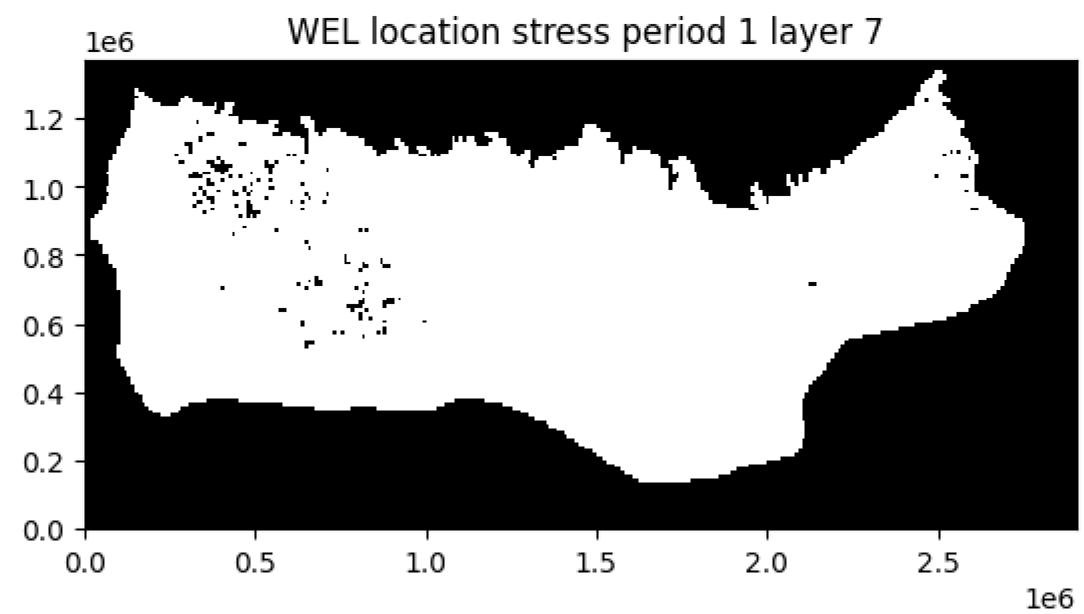
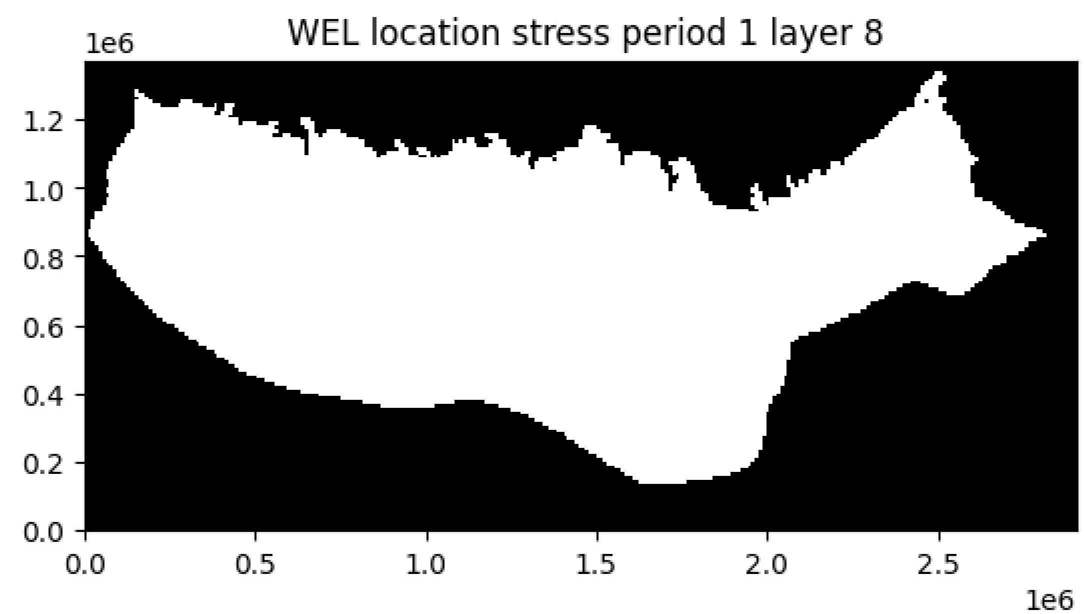
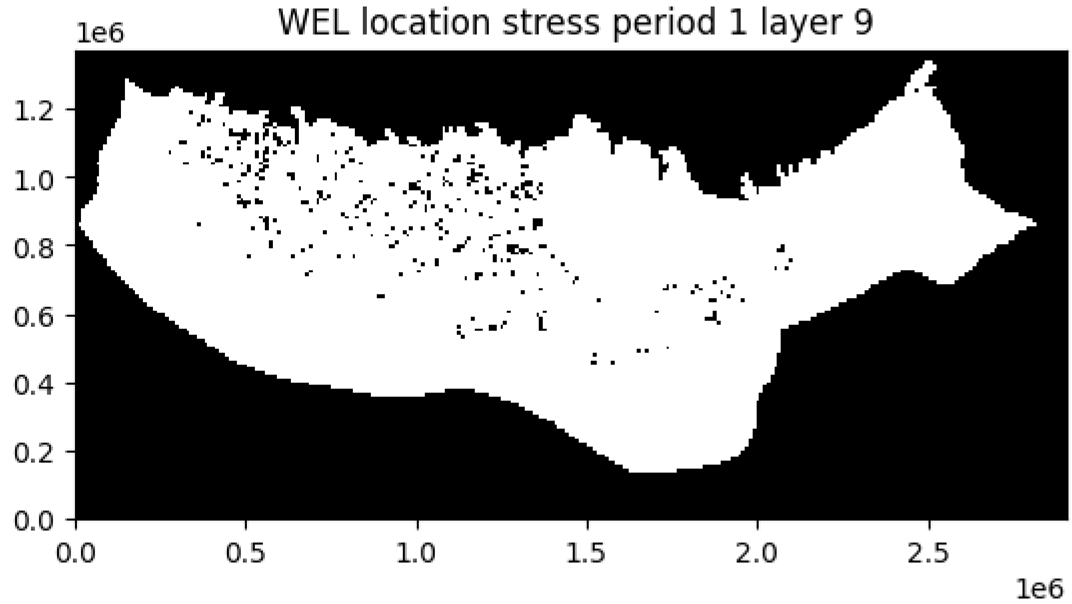
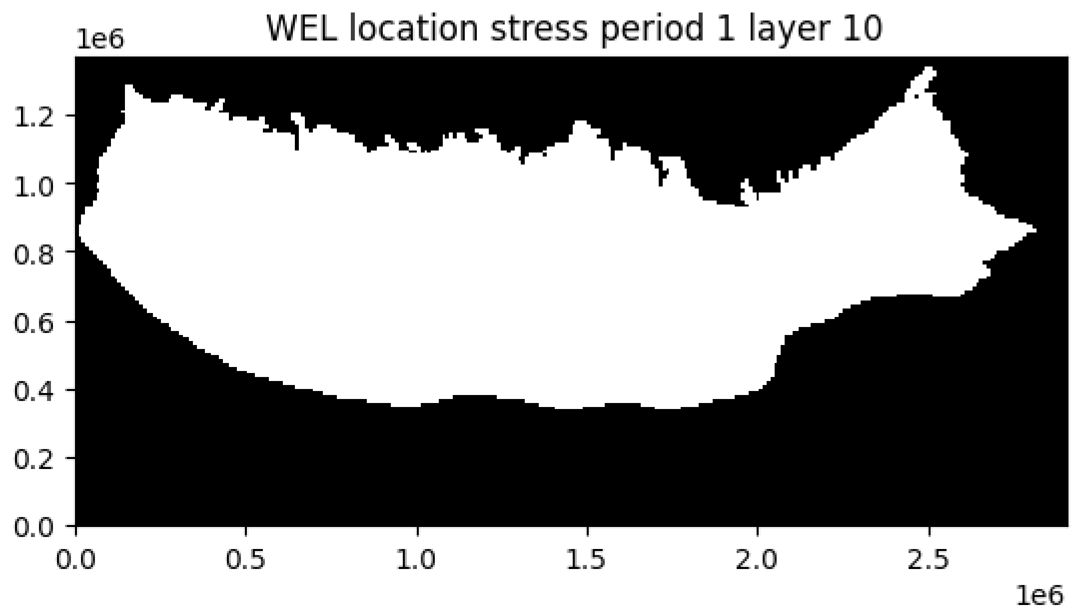
0.5
1.0
1.5
2.0
2.5
1e6

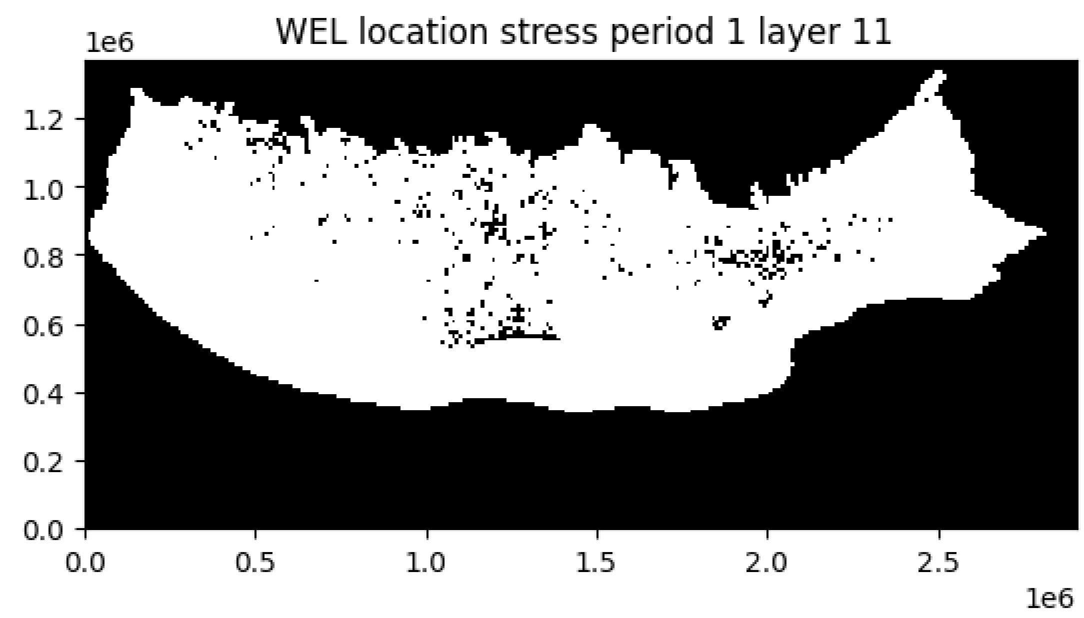

WEL location stress period 1 layer 6
1e6
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.5
1.0
1.5
2.0
2.5
1e6

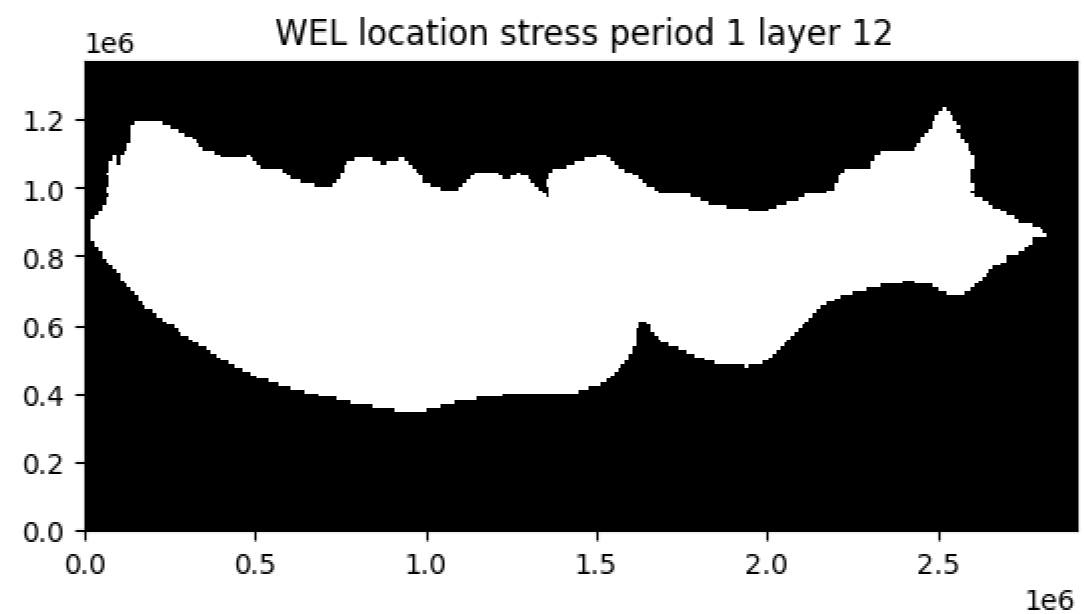

WEL location stress period 1 layer 7
1e6
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.5
1.0
1.5
2.0
2.5
1e6

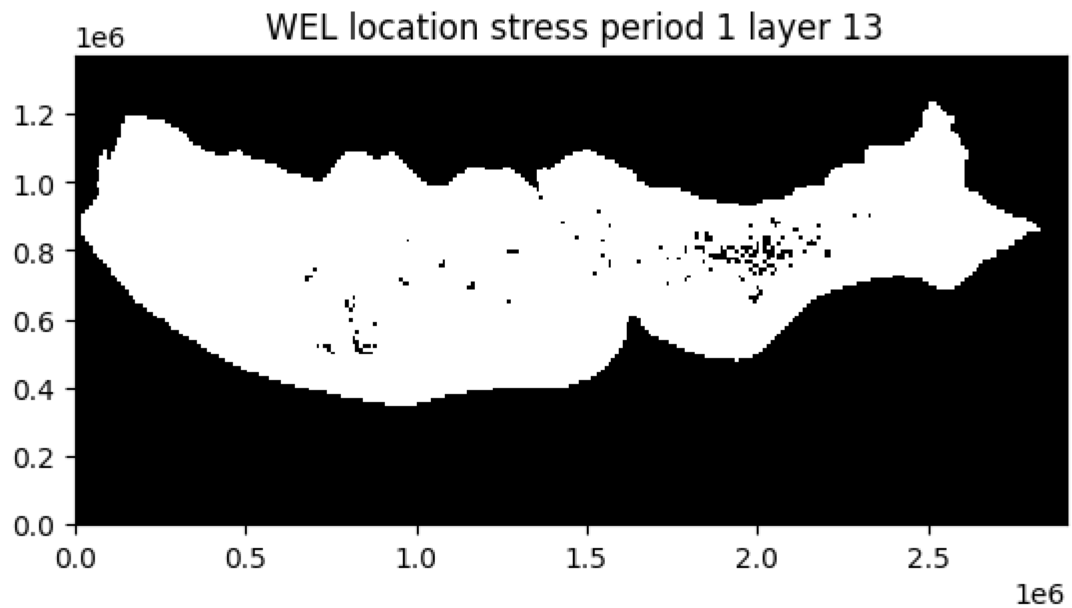

WEL location stress period 1 layer 8
1e6
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.5
1.0
1.5
2.0
2.5
1e6

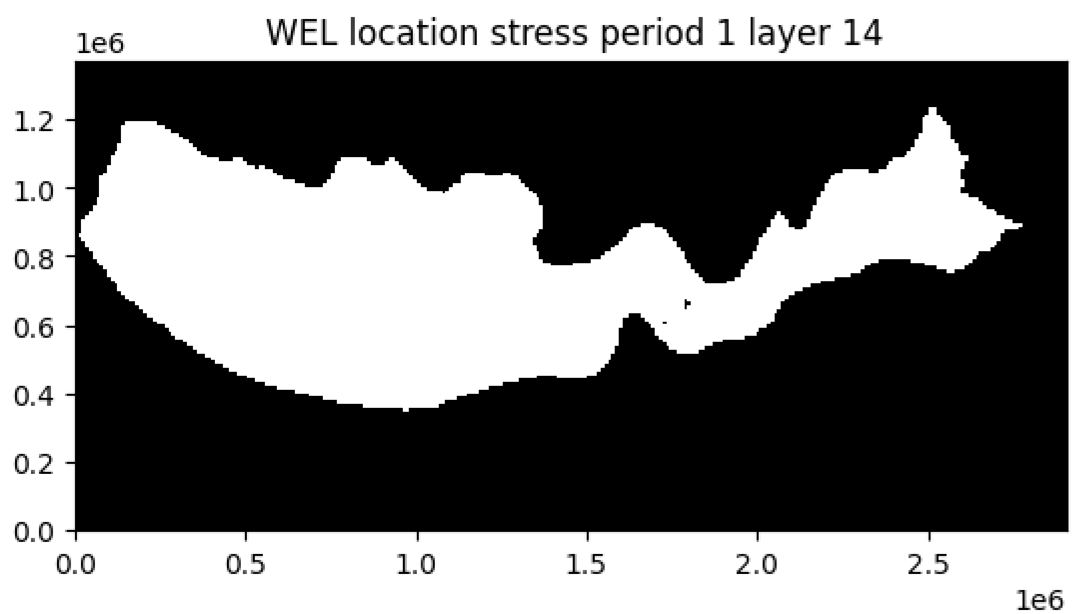

WEL location stress period 1 layer 9
1e6
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.5
1.0
1.5
2.0
2.5
1e6

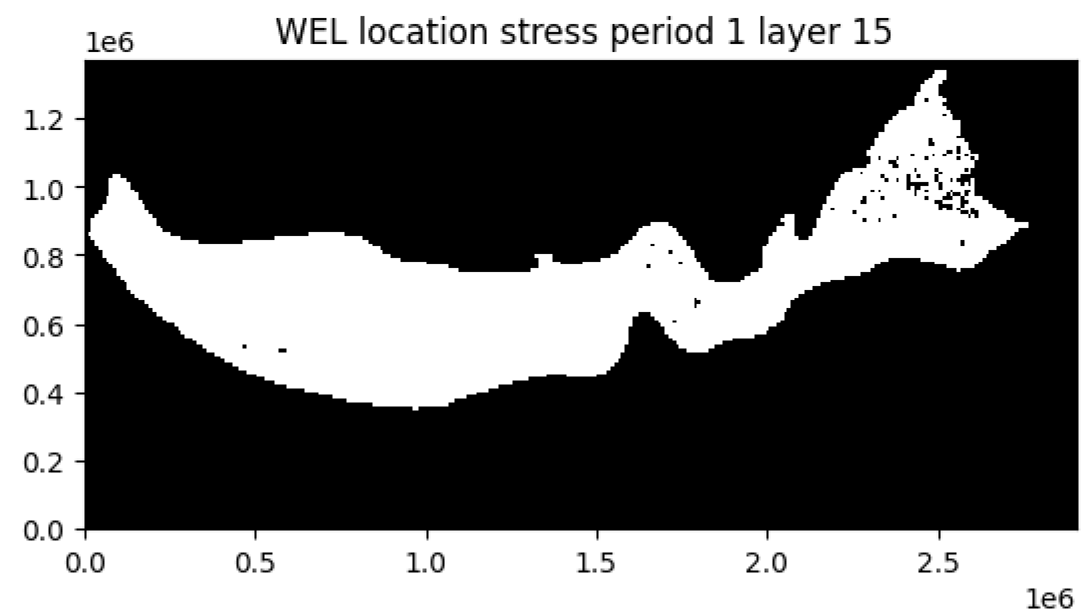

WEL location stress period 1 layer 10
1e6
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.5
1.0
1.5
2.0
2.5
1e6

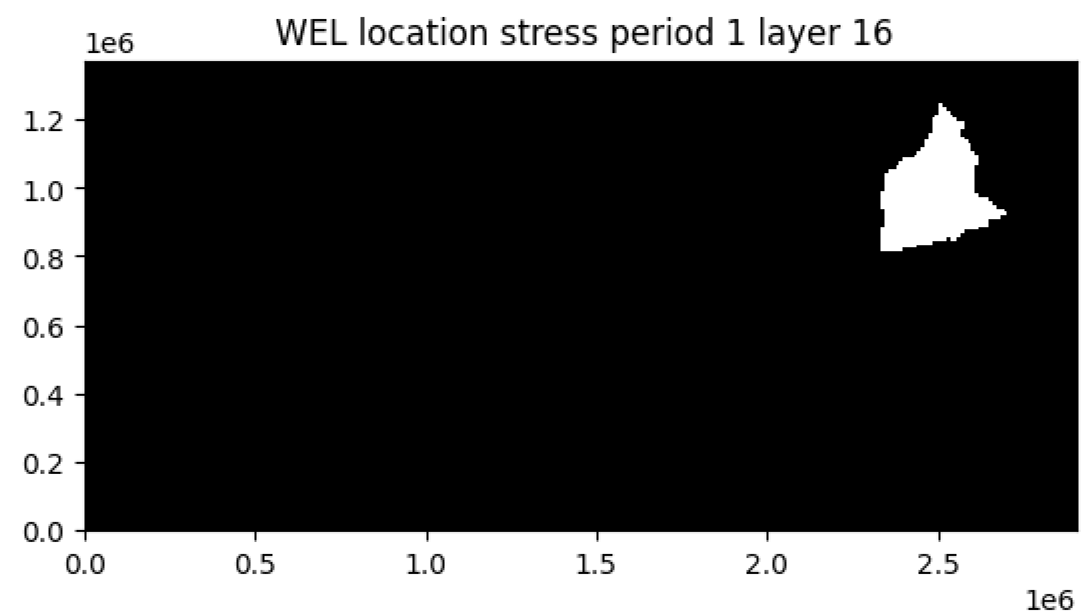

WEL location stress period 1 layer 11
1e6
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.5
1.0
1.5
2.0
2.5
1e6

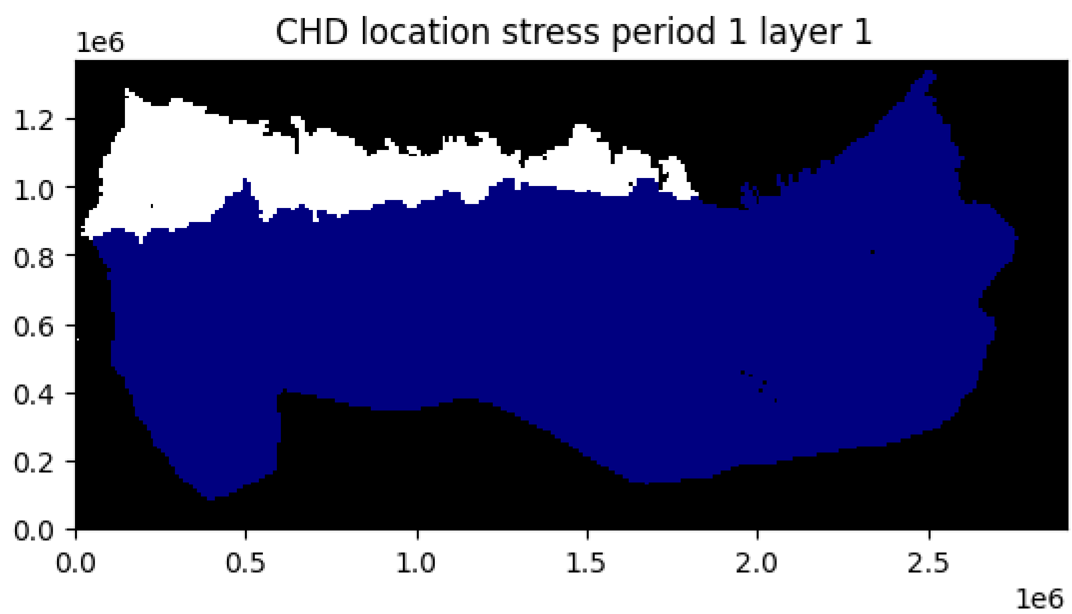

WEL location stress period 1 layer 12
1e6
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.5
1.0
1.5
2.0
2.5
1e6


WEL location stress period 1 layer 13
1e6
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.5
1.0
1.5
2.0
2.5
1e6

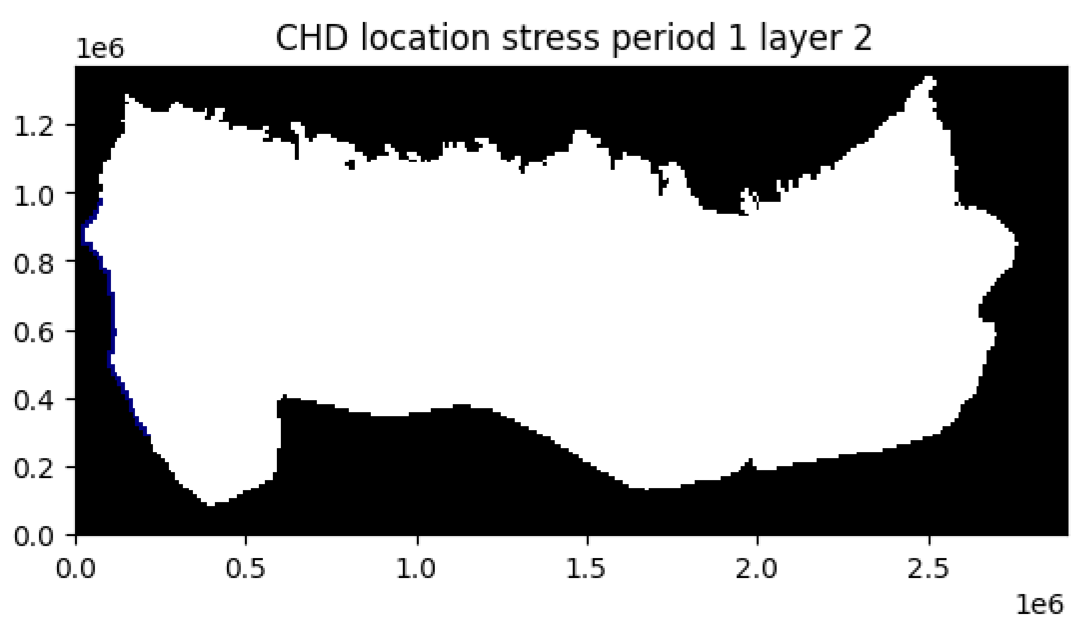

WEL location stress period 1 layer 14
1e6
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.5
1.0
1.5
2.0
2.5
1e6


WEL location stress period 1 layer 15
1e6
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.5
1.0
1.5
2.0
2.5
1e6

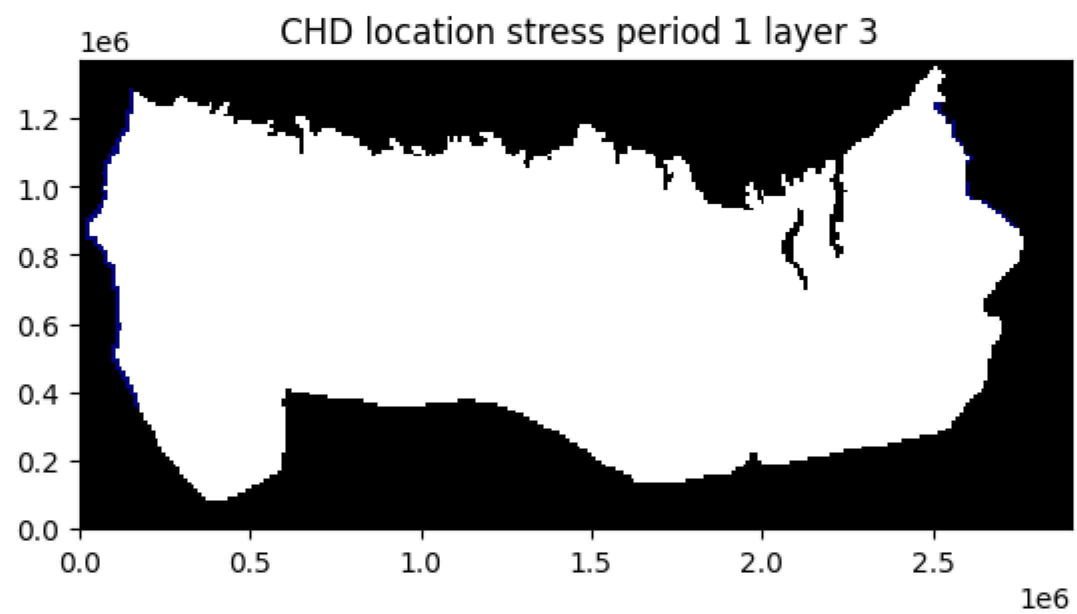

WEL location stress period 1 layer 16
1e6
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.5
1.0
1.5
2.0
2.5
1e6

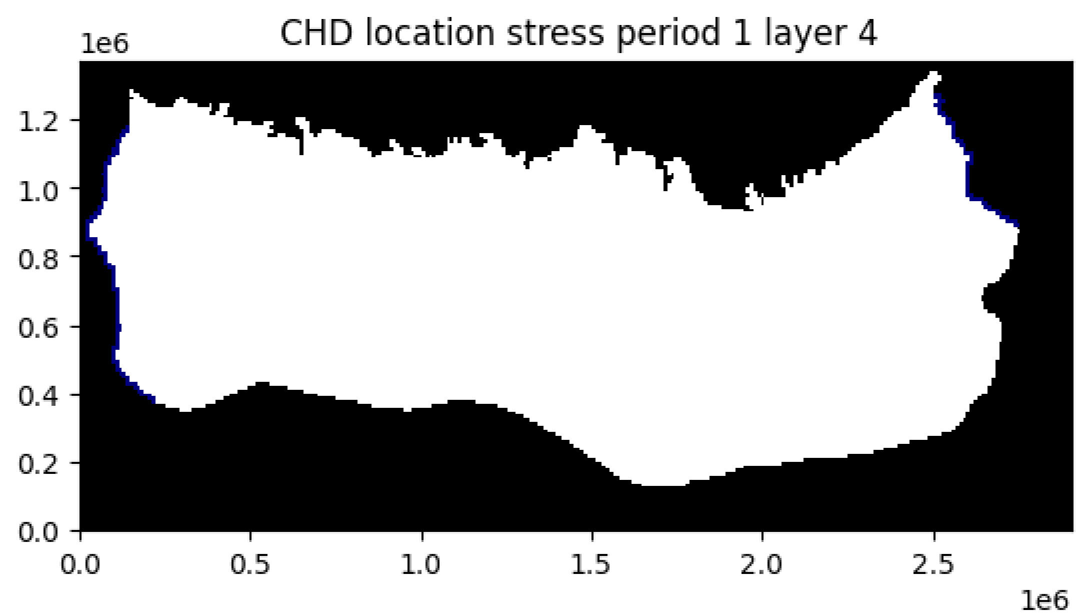


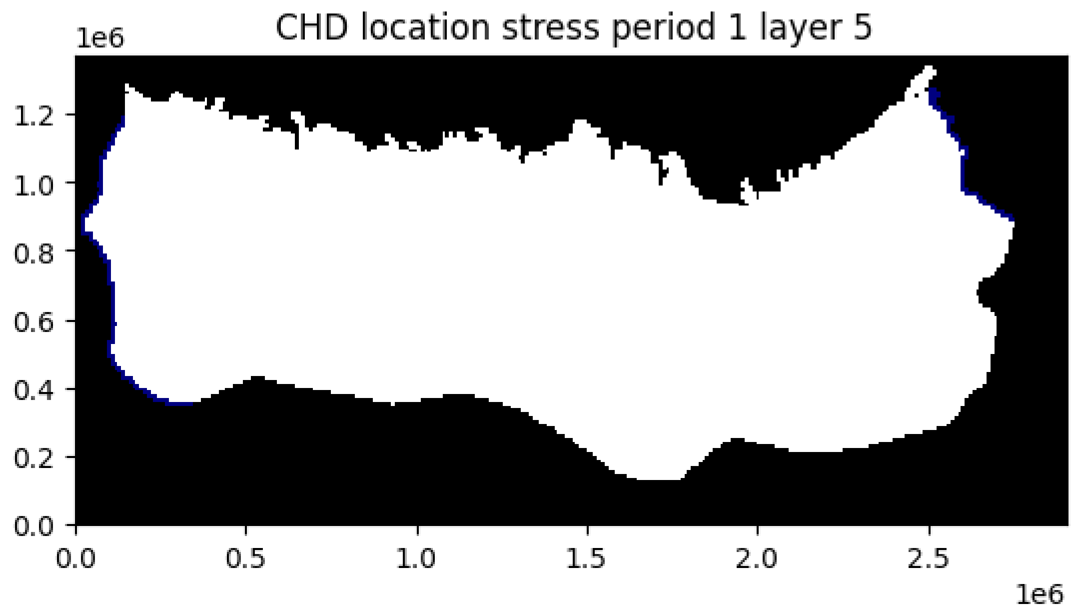
CHD location stress period 1 layer 1
1e6
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.5
1.0
1.5
2.0
2.5
1e6

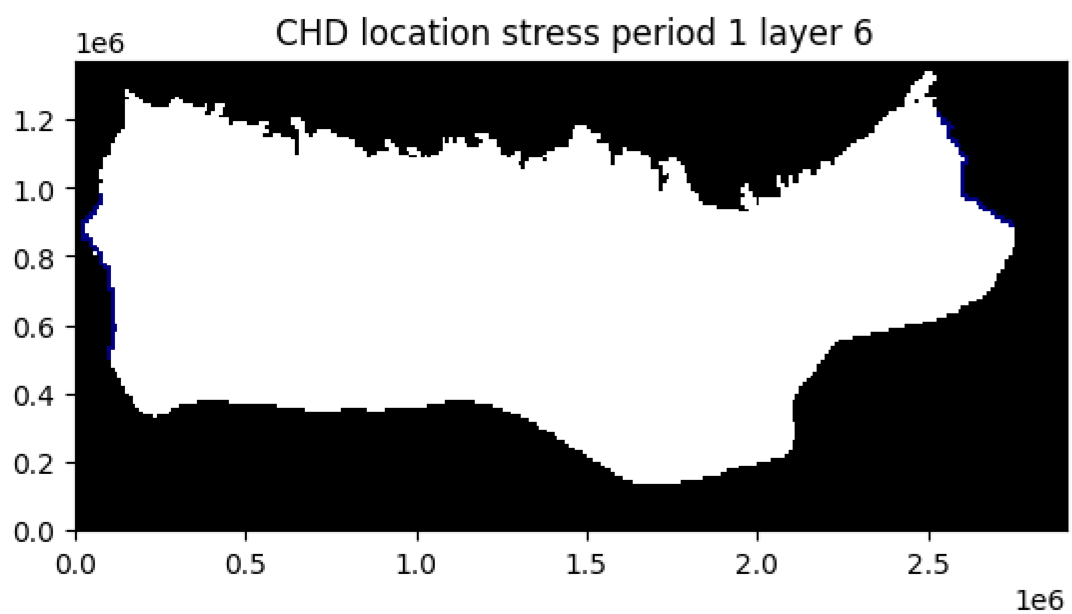


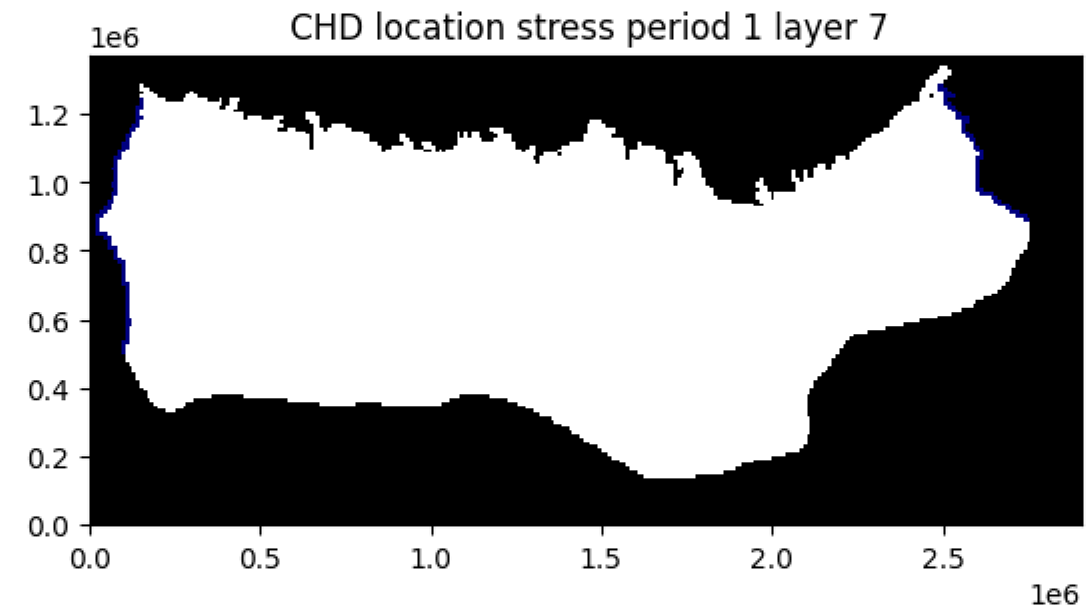
CHD location stress period 1 layer 2
1e6
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.5
1.0
1.5
2.0
2.5
1e6

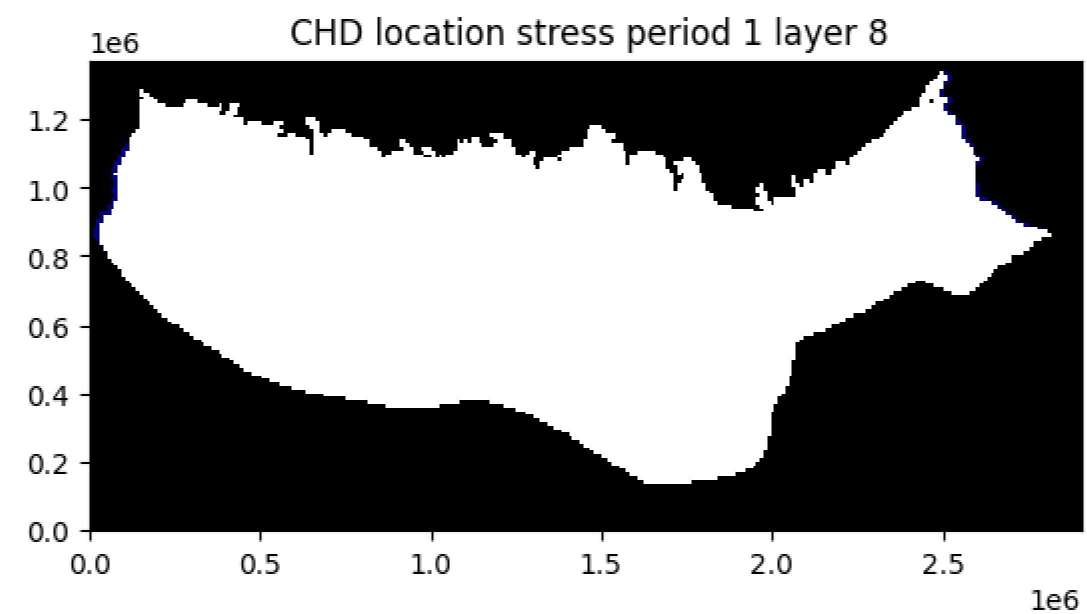

CHD location stress period 1 layer 3
1e6
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.5
1.0
1.5
2.0
2.5
1e6

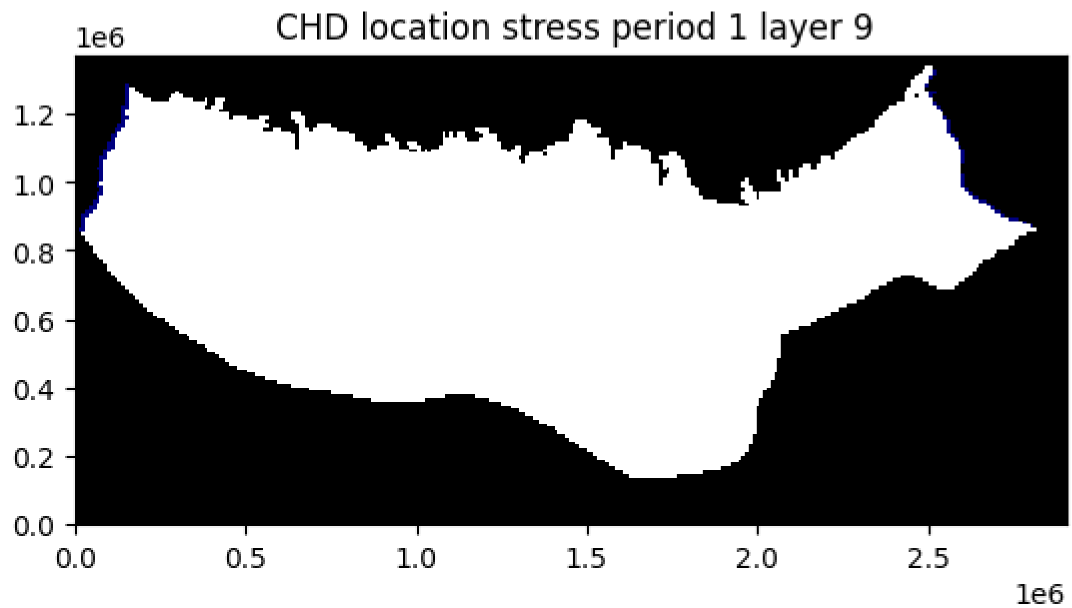

CHD location stress period 1 layer 4
1e6
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.5
1.0
1.5
2.0
2.5
1e6

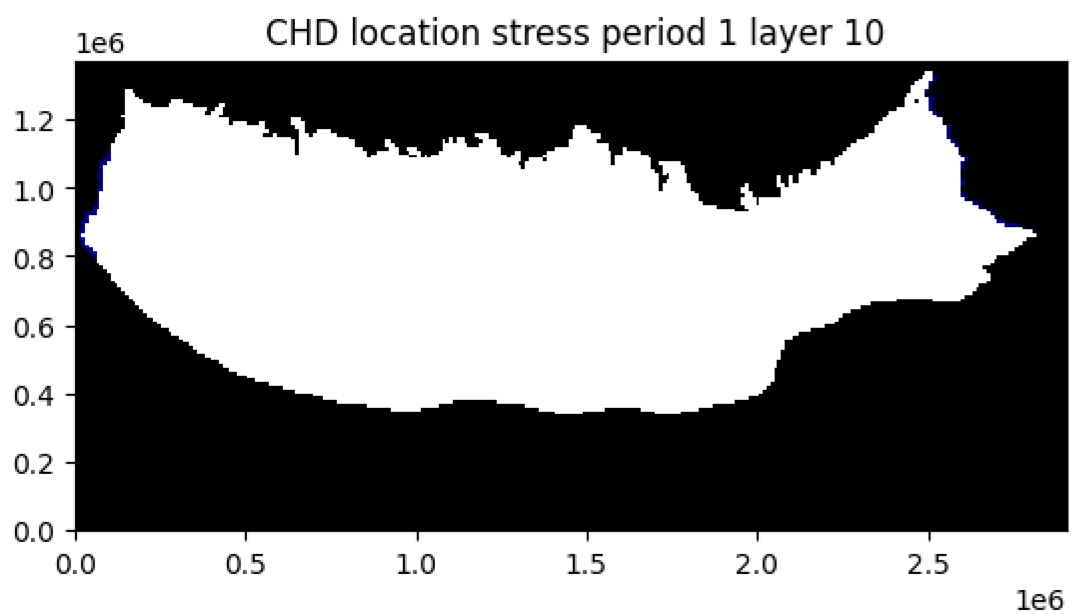

CHD location stress period 1 layer 5
1e6
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.5
1.0
1.5
2.0
2.5
1e6

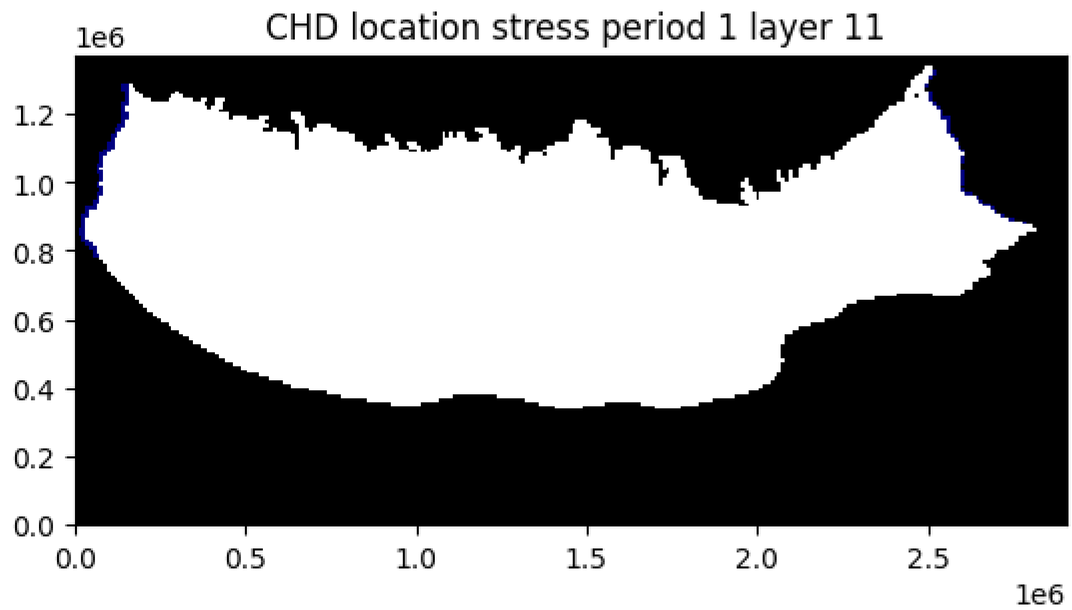

CHD location stress period 1 layer 6
1e6
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.5
1.0
1.5
2.0
2.5
1e6

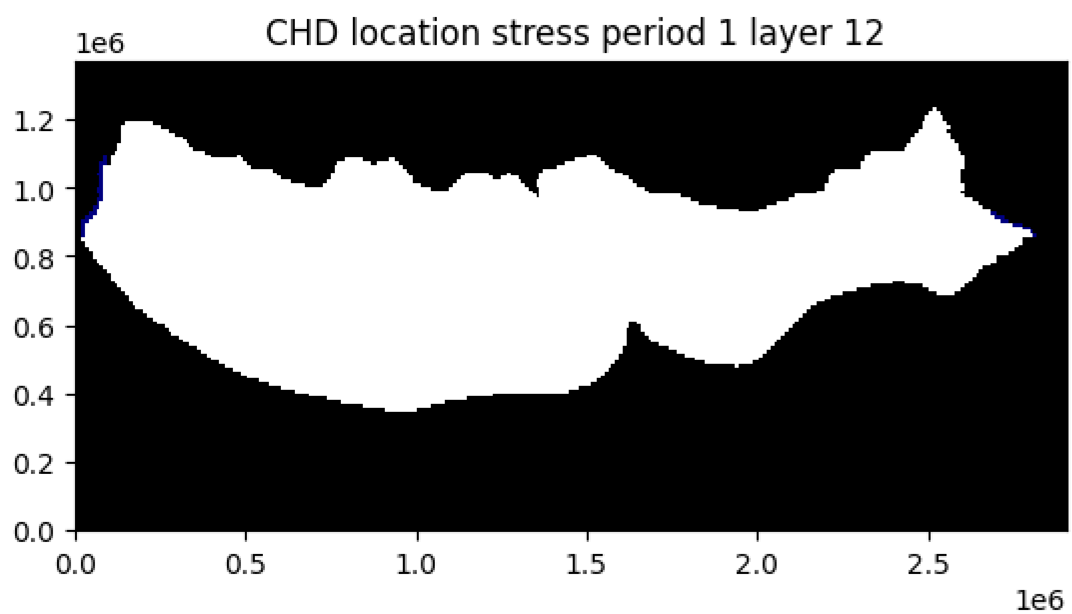

CHD location stress period 1 layer 7
1e6
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.5
1.0
1.5
2.0
2.5
1e6

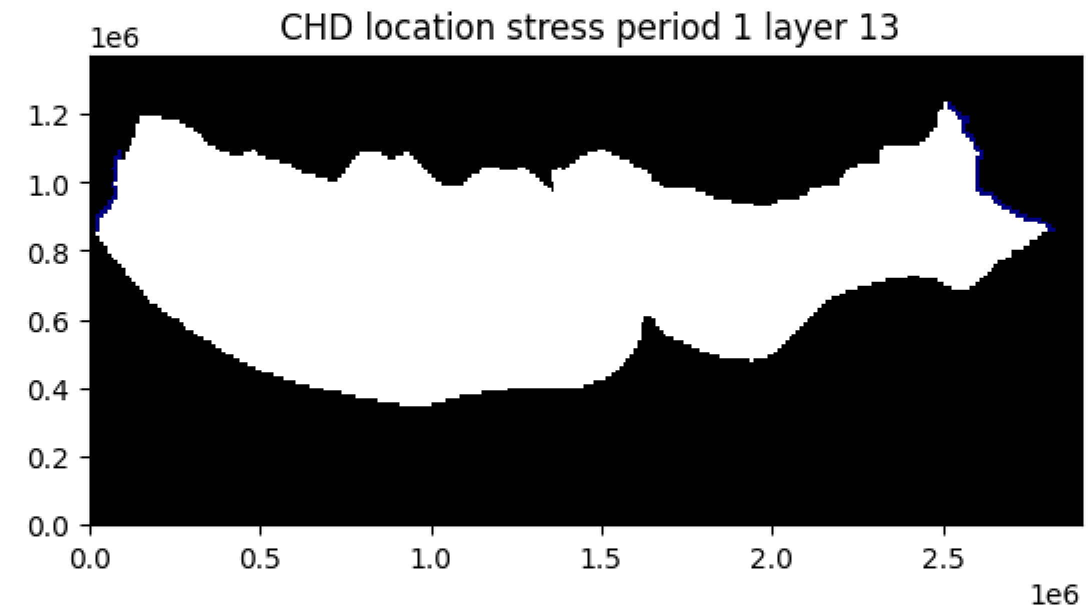

CHD location stress period 1 layer 8
1e6
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.5
1.0
1.5
2.0
2.5
1e6

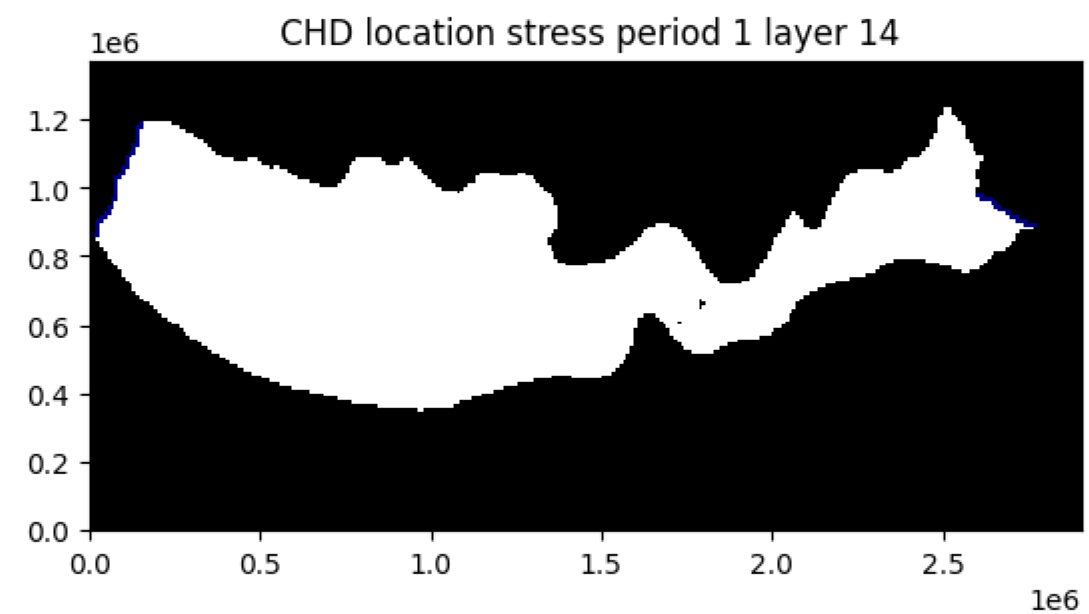

CHD location stress period 1 layer 9
1e6
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.5
1.0
1.5
2.0
2.5
1e6

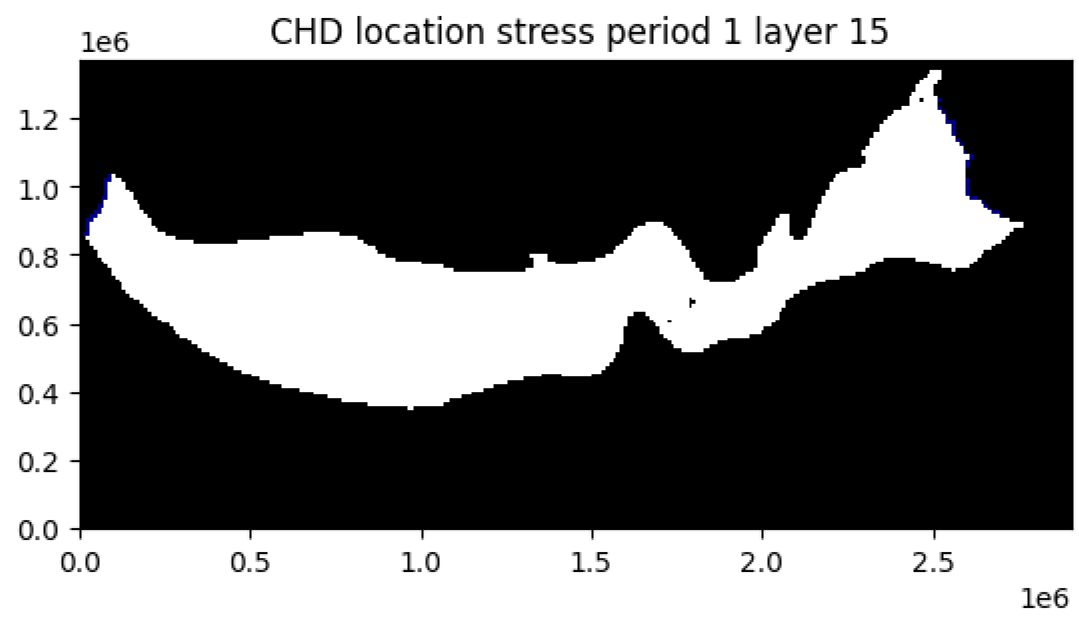

CHD location stress period 1 layer 10
1e6
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.5
1.0
1.5
2.0
2.5
1e6

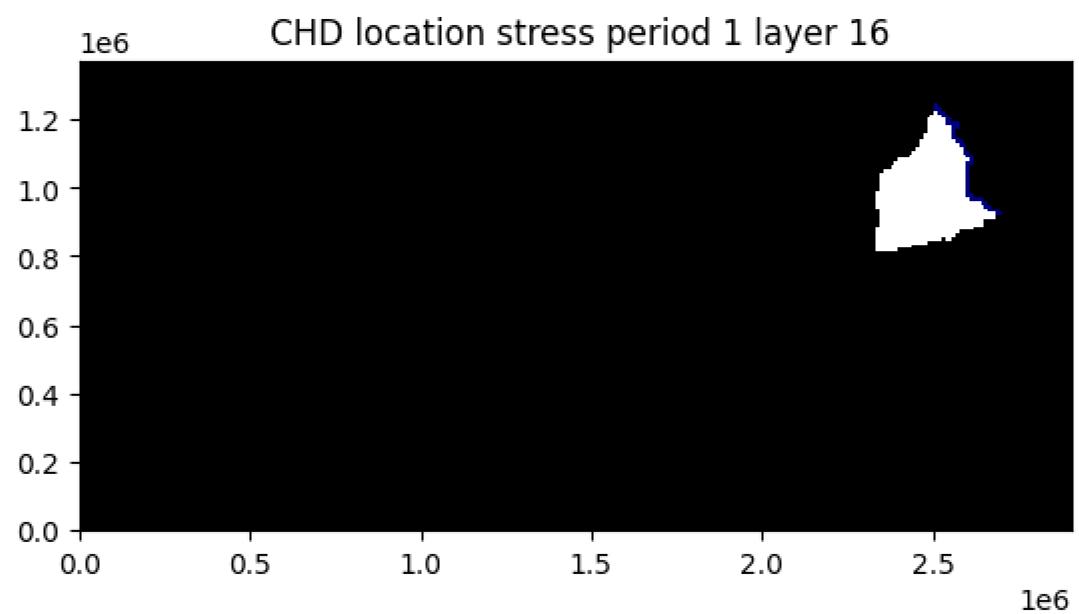

CHD location stress period 1 layer 11
1e6
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.5
1.0
1.5
2.0
2.5
1e6


CHD location stress period 1 layer 12
1e6
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.5
1.0
1.5
2.0
2.5
1e6


CHD location stress period 1 layer 13
1e6
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.5
1.0
1.5
2.0
2.5
1e6


CHD location stress period 1 layer 14
1e6
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.5
1.0
1.5
2.0
2.5
1e6

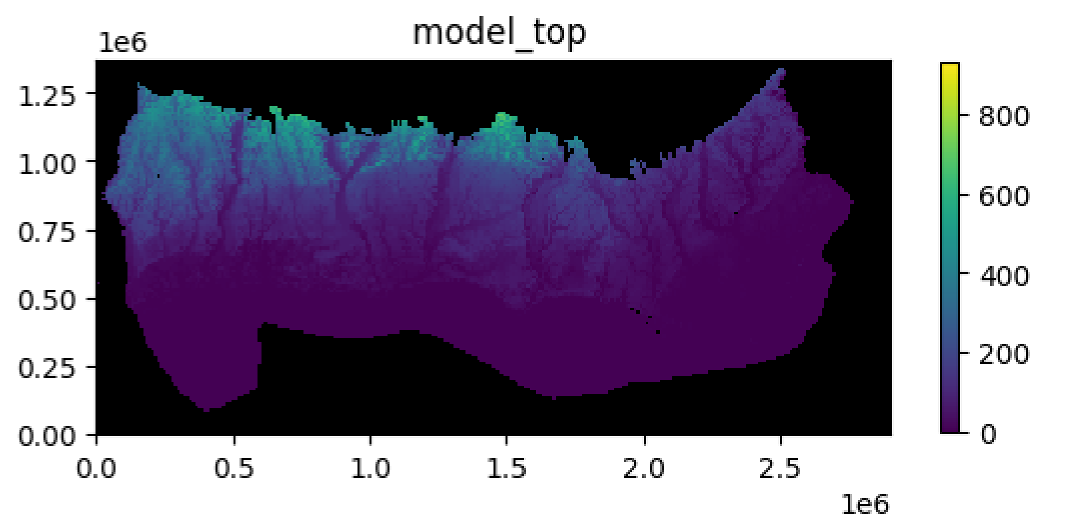


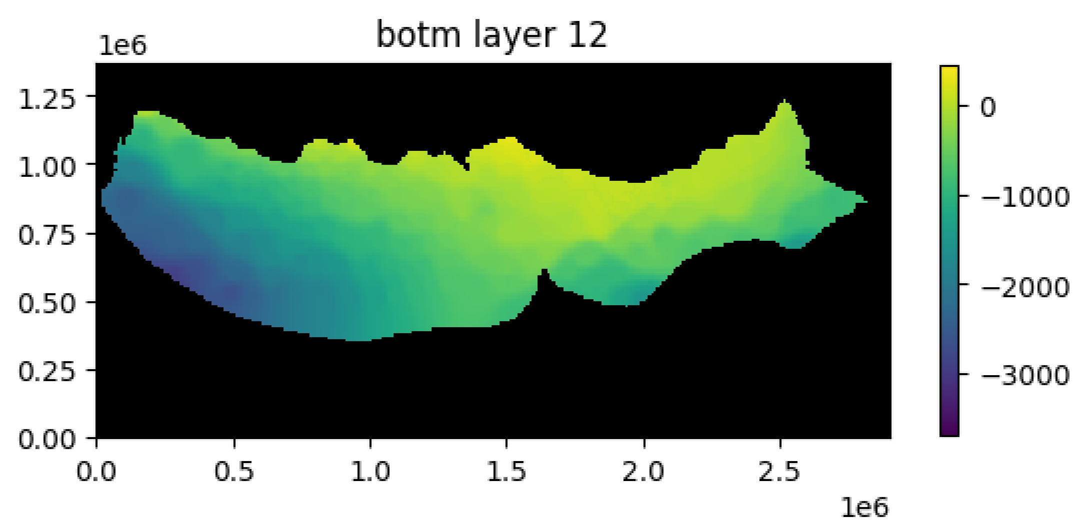


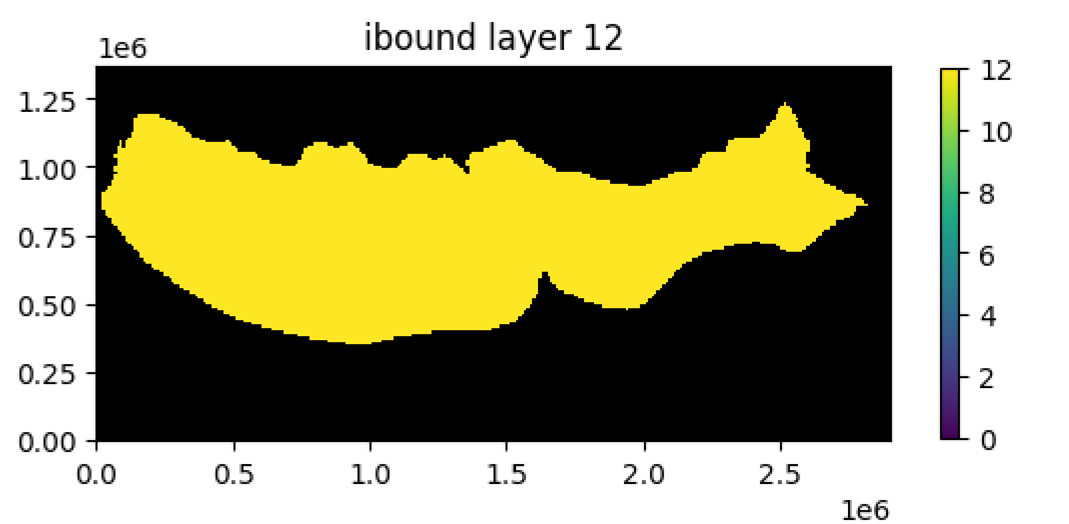
Plot model input data for a specified layer

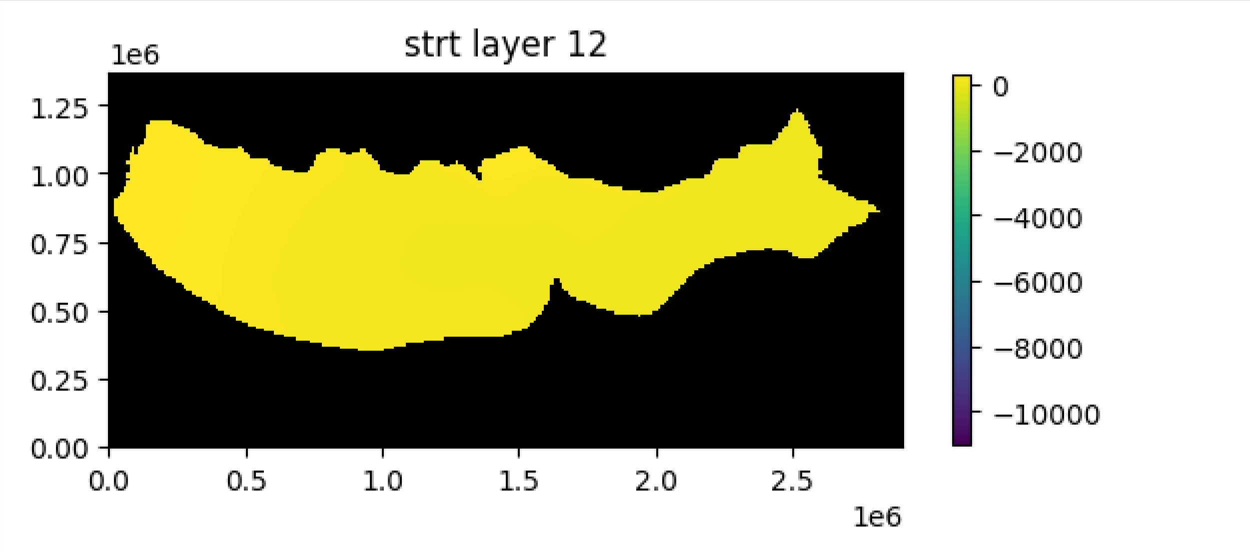
Model input data for a specified layer can be plotted by passing the `mflay` keyword to the package `.plot()` method. Below model input data for layer 12 (`mflay=11`) is plotted.

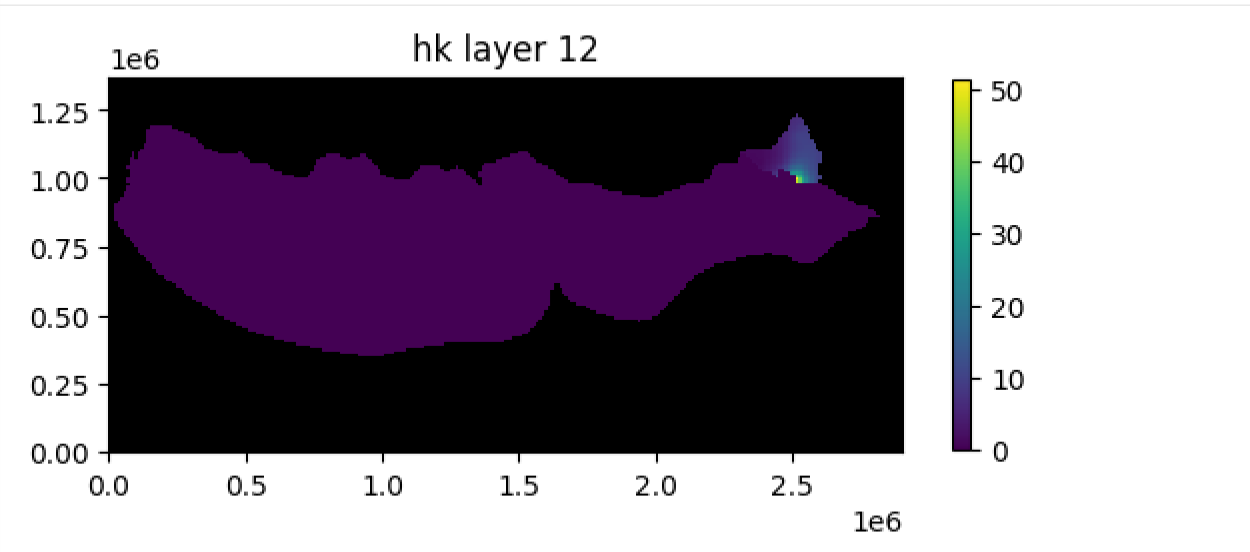
[25]:
```
ap = ml.plot(mflay=11)
```

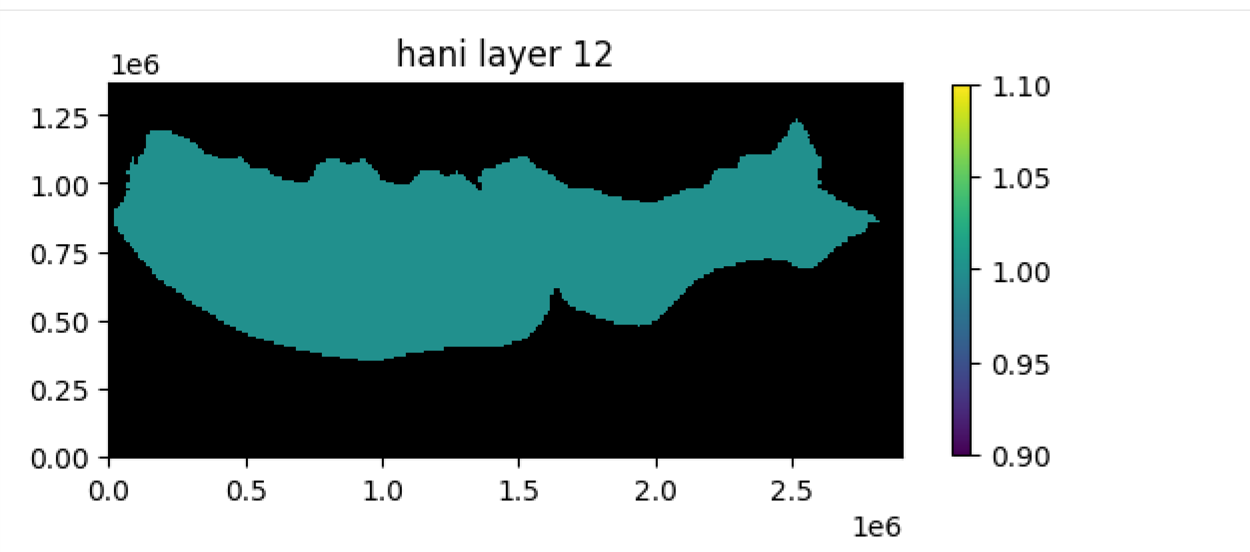

model_top
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
800
600
400
200
0

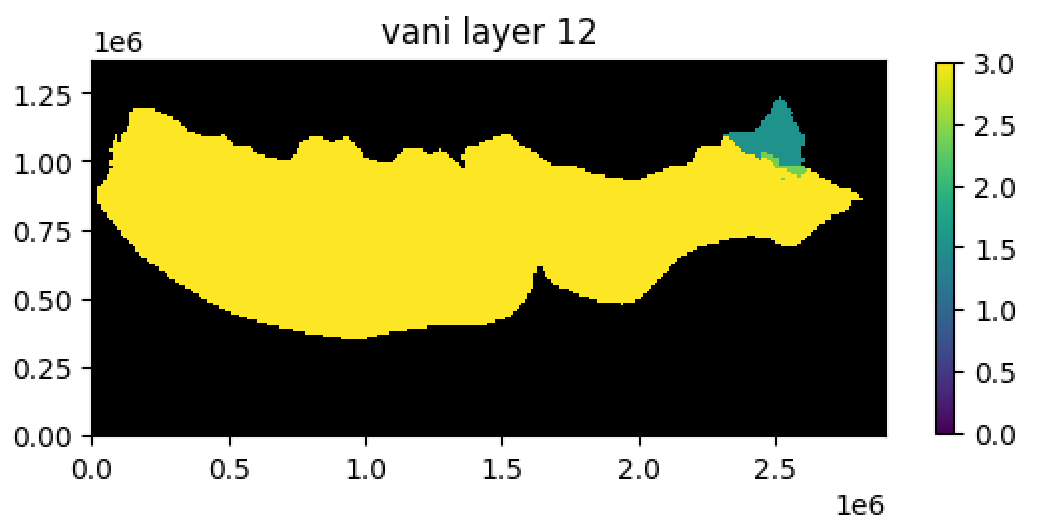

botm layer 12
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
0
−1000
−2000
−3000

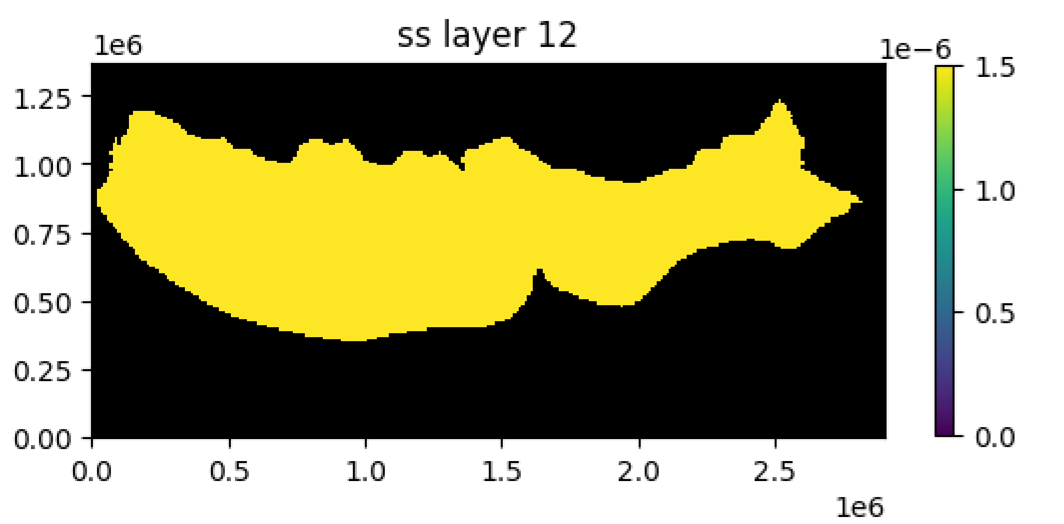

ibound layer 12
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
12
10
8
6
4
2
0

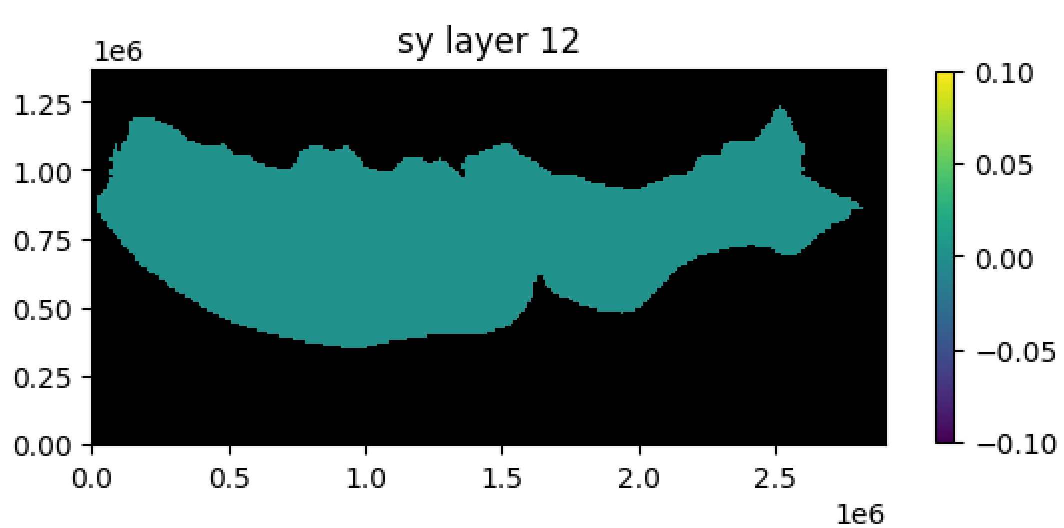

strt layer 12
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
0
−2000
−4000
−6000
−8000
−10000

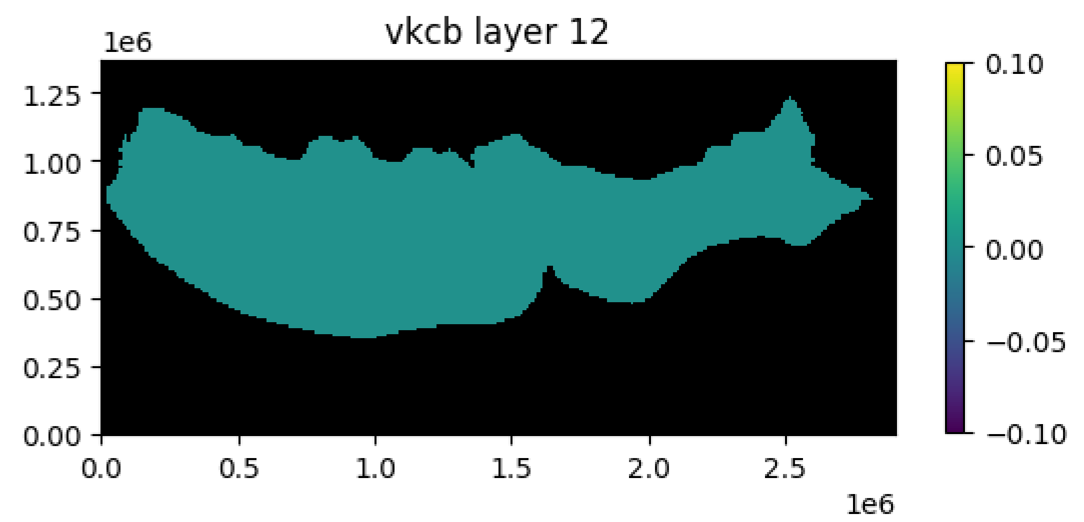

hk layer 12
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
50
40
30
20
10
0

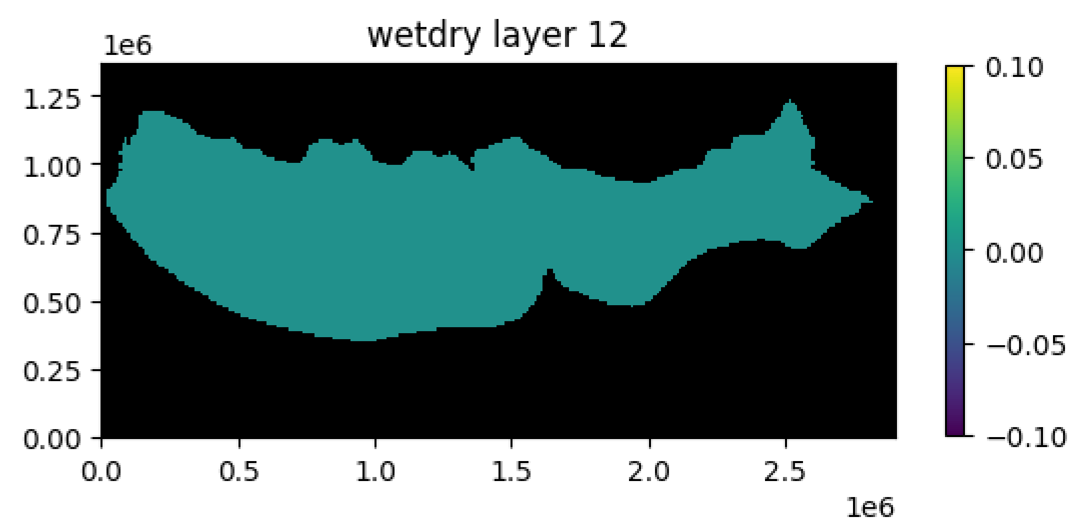

hani layer 12
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
1.10
1.05
1.00
0.95
0.90

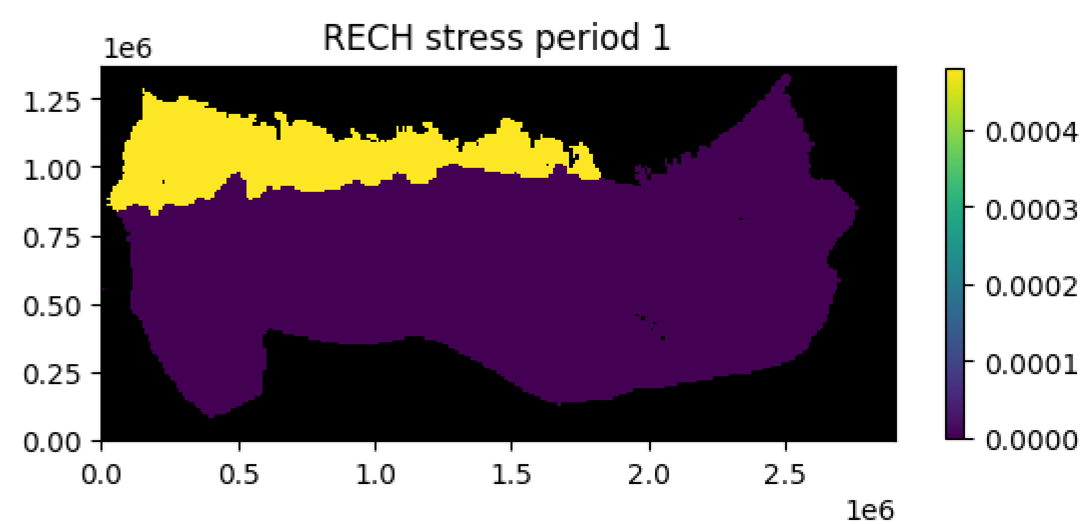

vani layer 12
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
3.0
2.5
2.0
1.5
1.0
0.5
0.0

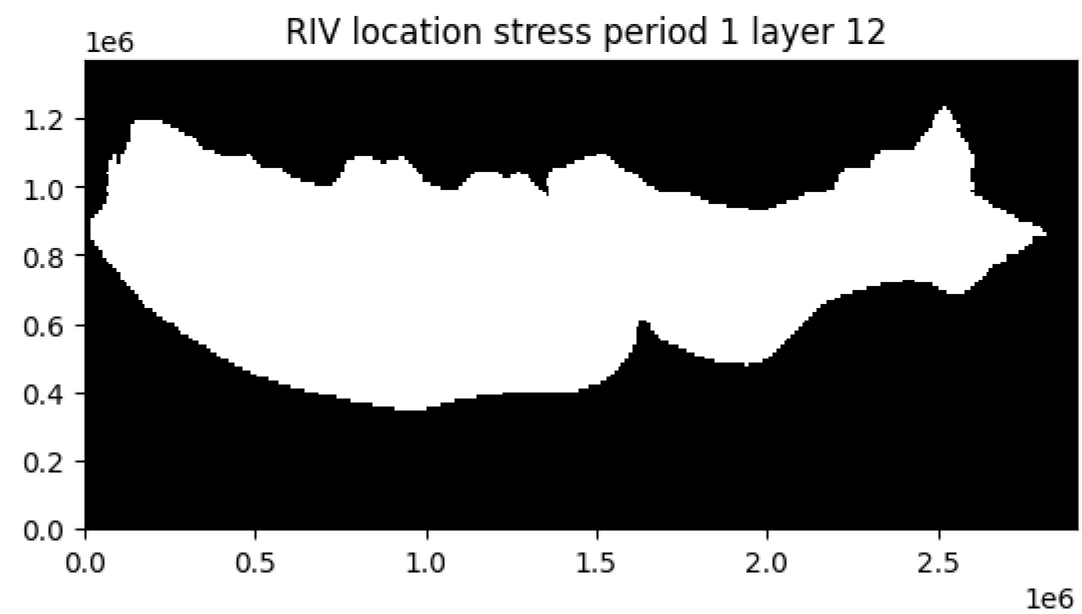

ss layer 12
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
1e−6
1.5
1.0
0.5
0.0

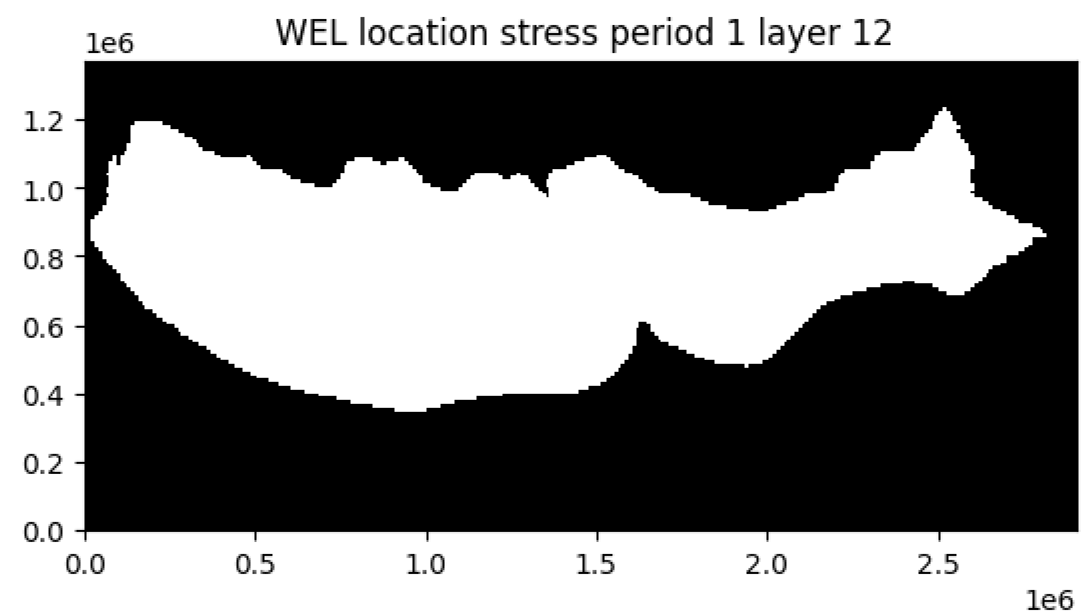

sy layer 12
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
0.10
0.05
0.00
−0.05
−0.10

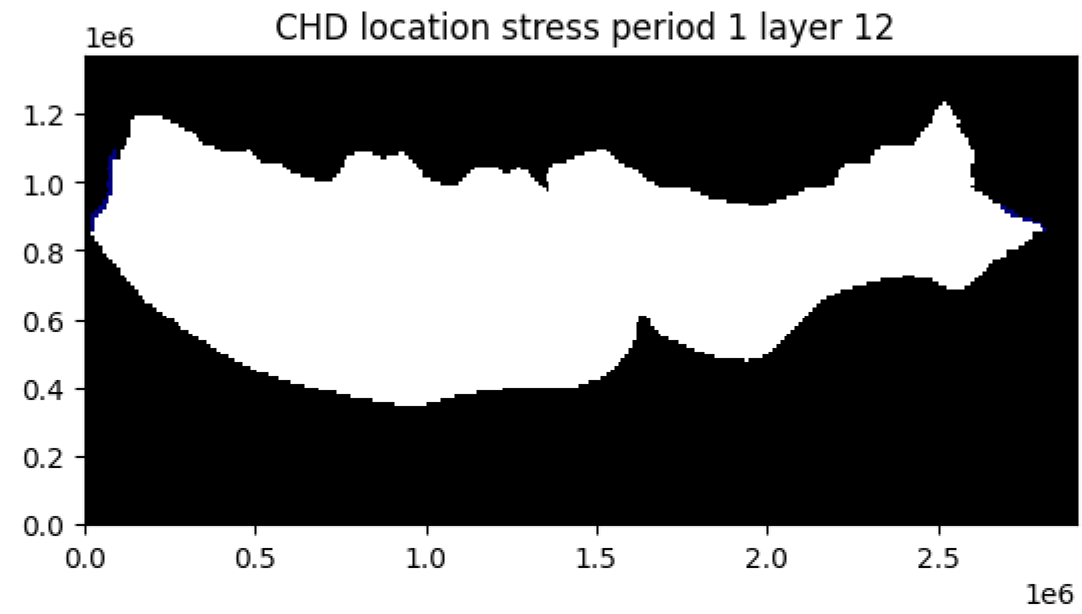

vkcb layer 12
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
0.10
0.05
0.00
−0.05
−0.10


wetdry layer 12
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
0.10
0.05
0.00
−0.05
−0.10


RECH stress period 1
1e6
1.25
1.00
0.75
0.50
0.25
0.00
0.0
0.5
1.0
1.5
2.0
2.5
1e6
0.0004
0.0003
0.0002
0.0001
0.0000


RIV location stress period 1 layer 12
1e6
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.5
1.0
1.5
2.0
2.5
1e6


WEL location stress period 1 layer 12
1e6
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.5
1.0
1.5
2.0
2.5
1e6



This notebook demonstrates some of the simple plotting functionality available with flopy. Although not described here, the plotting functionality tries to be general by passing keyword arguments passed to the `plot()` and `plot_data()` methods down into the `matplotlib.pyplot` routines that do the actual plotting. For those looking to customize these plots, it may be necessary to search for the available keywords. The `plot()` method return the `matplotlib.pyplot` axis objects that are created (or passed). These axes objects can be used to plot additional data (except when plots are saved as image files).

Hope this gets you started!

[26]:
```python
try:
    # ignore PermissionError on Windows
    temp_dir.cleanup()
except:
    pass
```

6.2.3 Making Cross Sections of Your Model

This notebook demonstrates the cross sectional mapping capabilities of FloPy. It demonstrates these capabilities by loading and running existing models and then showing how the `PlotCrossSection` object and its methods can be used to make nice plots of the model grid, boundary conditions, model results, shape files, etc.

Mapping is demonstrated for MODFLOW-2005 and MODFLOW-6 models in this notebook

[1]:
```python
import os
import sys
from tempfile import TemporaryDirectory

import matplotlib as mpl
import matplotlib.pyplot as plt
import numpy as np
```

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```
sys.path.append(os.path.join("..", "common"))
import notebook_utils

# run installed version of flopy or add local path
try:
    import flopy
except:
    fpth = os.path.abspath(os.path.join("..", ".."))
    sys.path.append(fpth)
    import flopy

print(sys.version)
print(f"numpy version: {np.__version__}")
print(f"matplotlib version: {mpl.__version__}")
print(f"flopy version: {flopy.__version__}")
```

```
3.8.18 (default, Aug 28 2023, 08:27:22)
[GCC 11.4.0]
numpy version: 1.24.4
matplotlib version: 3.7.4
flopy version: 3.5.0
```

[2]:
```
# Set names of the MODFLOW exes
# assumes that the executable is in users path statement
v2005 = "mf2005"
exe_name_2005 = "mf2005"
vmf6 = "mf6"
exe_name_mf6 = "mf6"

# Set the paths
prj_root = notebook_utils.get_project_root_path()
loadpth = str(prj_root / "examples" / "data" / "freyberg")
tempdir = TemporaryDirectory()
modelpth = tempdir.name
```

Load and Run an Existing MODFLOW-2005 Model

A model called the "Freyberg Model" is located in the loadpth folder. In the following code block, we load that model, then change into a new workspace (modelpth) where we recreate and run the model. For this to work properly, the MODFLOW-2005 executable (mf2005) must be in the path. We verify that it worked correctly by checking for the presence of freyberg.hds and freyberg.cbc.

[3]:
```
ml = flopy.modflow.Modflow.load(
    "freyberg.nam", model_ws=loadpth, exe_name=exe_name_2005, version=v2005
)
ml.change_model_ws(new_pth=str(modelpth))
ml.write_input()
success, buff = ml.run_model(silent=True, report=True)
if success:
    for line in buff:
```

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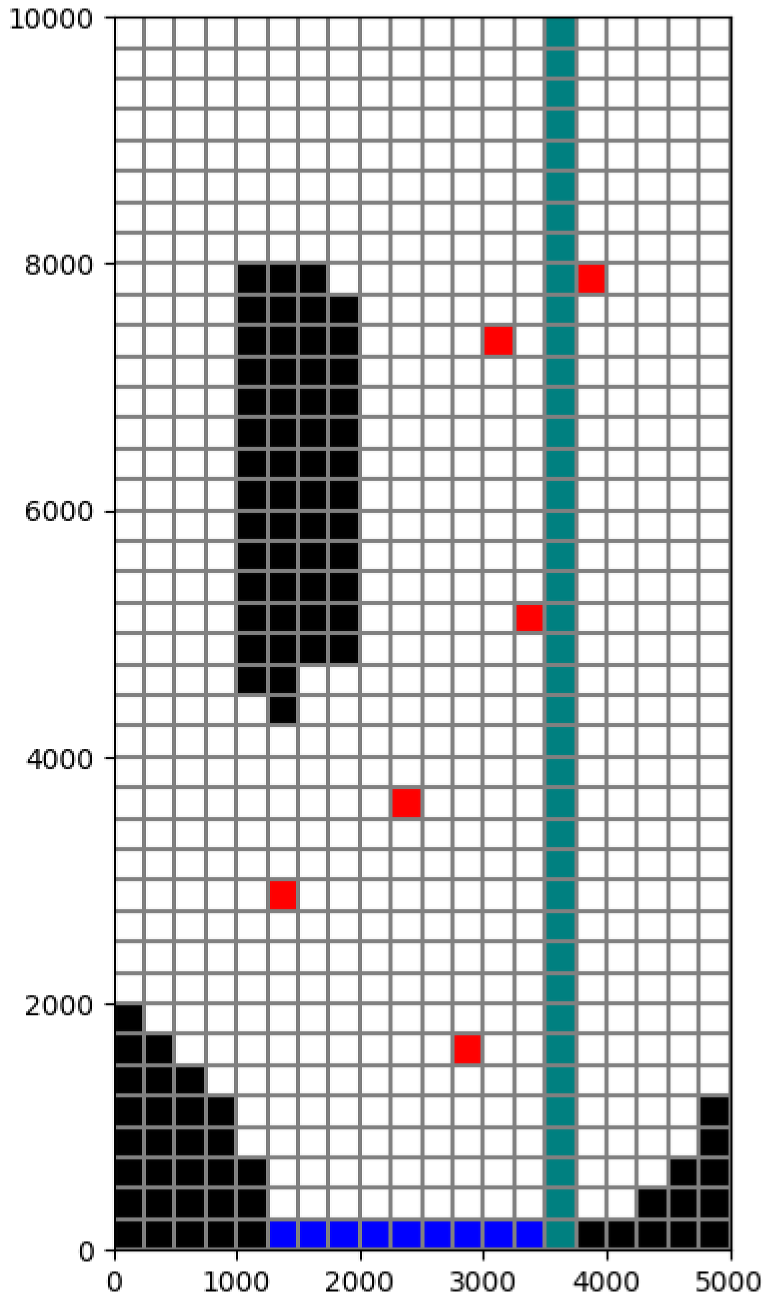
```
        print(line)
else:
    raise ValueError("Something bad happened.")

files = ["freyberg.hds", "freyberg.cbc"]
for f in files:
    if os.path.isfile(os.path.join(str(modelpth), f)):
        msg = f"Output file located: {f}"
        print(msg)
    else:
        errmsg = f"Error. Output file cannot be found: {f}"
        print(errmsg)
```

```
                                  MODFLOW-2005
    U.S. GEOLOGICAL SURVEY MODULAR FINITE-DIFFERENCE GROUND-WATER FLOW MODEL
                             Version 1.12.00 2/3/2017

 Using NAME file: freyberg.nam
 Run start date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:34:12

 Solving:  Stress period:     1    Time step:     1    Ground-Water Flow Eqn.
 Run end date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:34:12
 Elapsed run time:  0.006 Seconds

  Normal termination of simulation
Output file located: freyberg.hds
Output file located: freyberg.cbc
```

Creating a Cross-Section of the Model Grid

Now that we have a model, we can use the FloPy plotting utilities to make cross-sections. We'll start by making a Map to show the model grid and basic boundary conditions. Then we'll begin making a cross section using the `PlotCrossSection` class and the `plot_grid()` method of that class.

[4]:
```
# let's take a look at our grid before making a cross section
fig = plt.figure(figsize=(8, 8))
ax = fig.add_subplot(1, 1, 1, aspect="equal")
mapview = flopy.plot.PlotMapView(model=ml)
ibound = mapview.plot_ibound()
wel = mapview.plot_bc("WEL")
riv = mapview.plot_bc("RIV")
linecollection = mapview.plot_grid()
```



Next we will make a cross-section of the model grid at column 6.

[5]:
```
# First step is to set up the plot
fig = plt.figure(figsize=(15, 5))
ax = fig.add_subplot(1, 1, 1)

# Next we create an instance of the PlotCrossSection class
xsect = flopy.plot.PlotCrossSection(model=ml, line={"Column": 5})

# Then we can use the plot_grid() method to draw the grid
```

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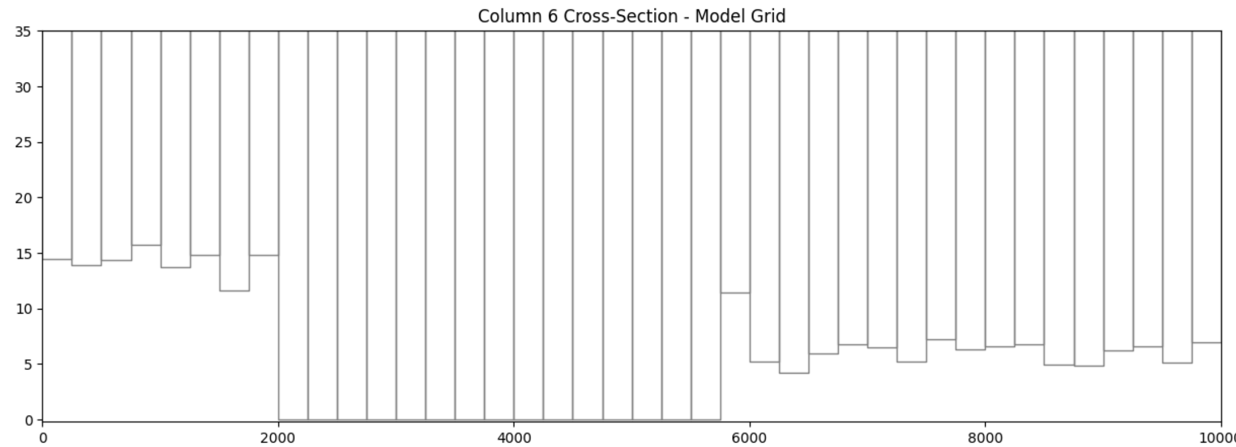
```
# The return value for this function is a matplotlib LineCollection object,
# which could be manipulated (or used) later if necessary.
linecollection = xsect.plot_grid()
t = ax.set_title("Column 6 Cross-Section - Model Grid")
```

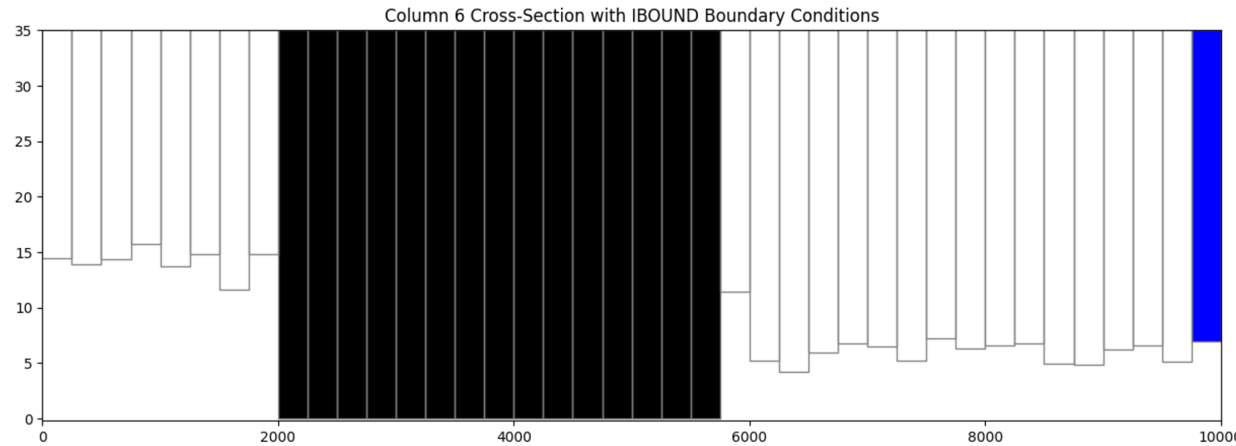


Ploting Ibound

The `plot_ibound()` method can be used to plot the boundary conditions contained in the ibound arrray, which is part of the MODFLOW Basic Package. The `plot_ibound()` method returns a matplotlib PatchCollection object (matplotlib.collections.PatchCollection). If you are familiar with the matplotlib collections, then this may be important to you, but if not, then don't worry about the return objects of these plotting function.

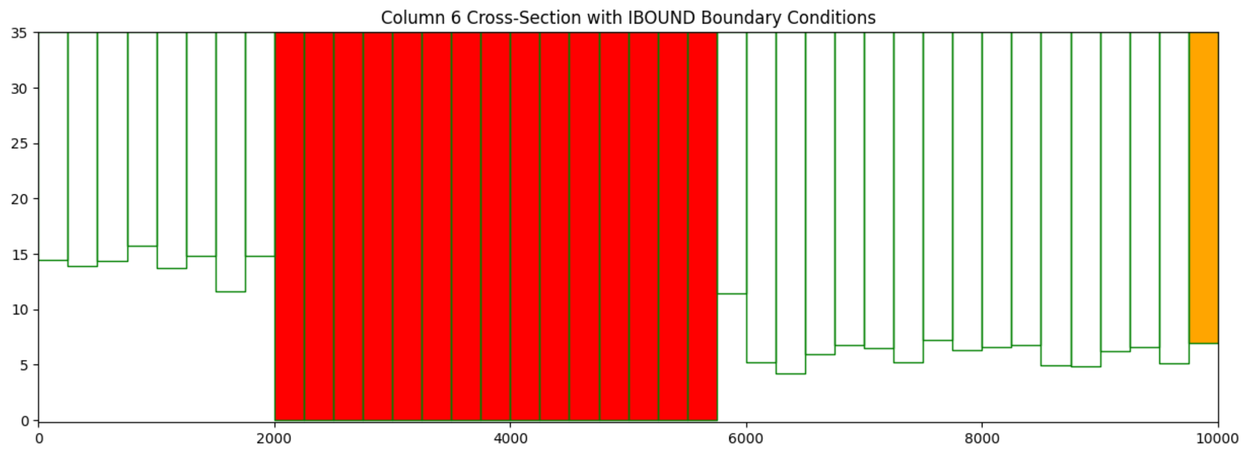
[6]:
```
fig = plt.figure(figsize=(15, 5))
ax = fig.add_subplot(1, 1, 1)

xsect = flopy.plot.PlotCrossSection(model=ml, line={"Column": 5})
patches = xsect.plot_ibound()
linecollection = xsect.plot_grid()
t = ax.set_title("Column 6 Cross-Section with IBOUND Boundary Conditions")
```



[7]:
```
# Or we could change the colors!
fig = plt.figure(figsize=(15, 5))
ax = fig.add_subplot(1, 1, 1)

xsect = flopy.plot.PlotCrossSection(model=ml, line={"Column": 5})
patches = xsect.plot_ibound(color_noflow="red", color_ch="orange")
linecollection = xsect.plot_grid(color="green")
t = ax.set_title("Column 6 Cross-Section with IBOUND Boundary Conditions")
```



Plotting Boundary Conditions

The `plot_bc()` method can be used to plot boundary conditions on a cross section. It is setup to use the following dictionary to assign colors, however, these colors can be changed in the method call.

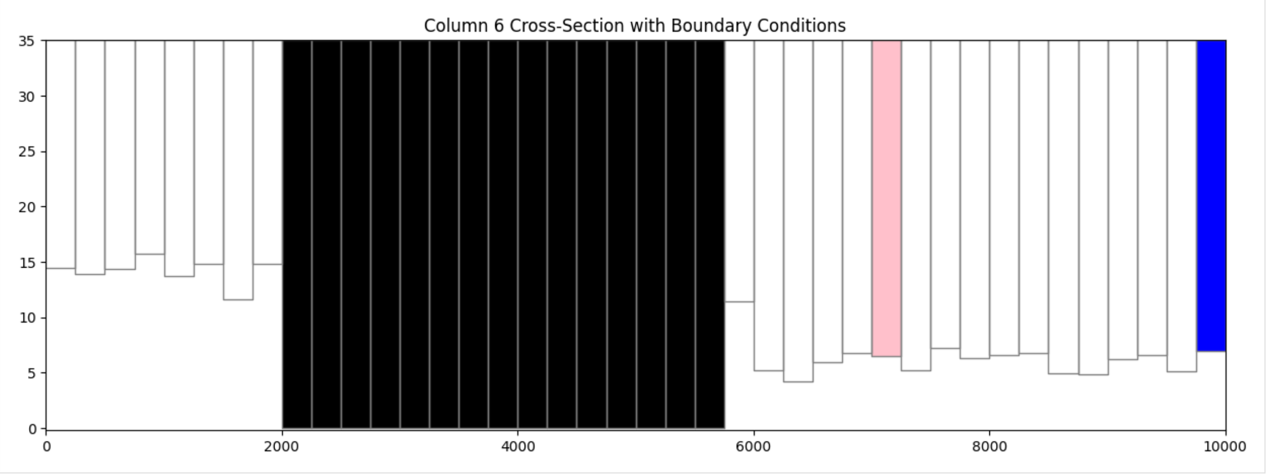
```
bc_color_dict = {'default': 'black', 'WEL': 'red', 'DRN': 'yellow',
             'RIV': 'green', 'GHB': 'cyan', 'CHD': 'navy'}
```

Just like the `plot_bc()` method for `PlotMapView`, the default boundary condition colors can be changed in the method call.

Here, we plot the location of well cells in column 6.

[8]:
```
fig = plt.figure(figsize=(15, 5))
ax = fig.add_subplot(1, 1, 1)

xsect = flopy.plot.PlotCrossSection(model=ml, line={"Column": 5})
patches = xsect.plot_bc("WEL", color="pink")
patches = xsect.plot_ibound()
linecollection = xsect.plot_grid()
t = ax.set_title("Column 6 Cross-Section with Boundary Conditions")
```

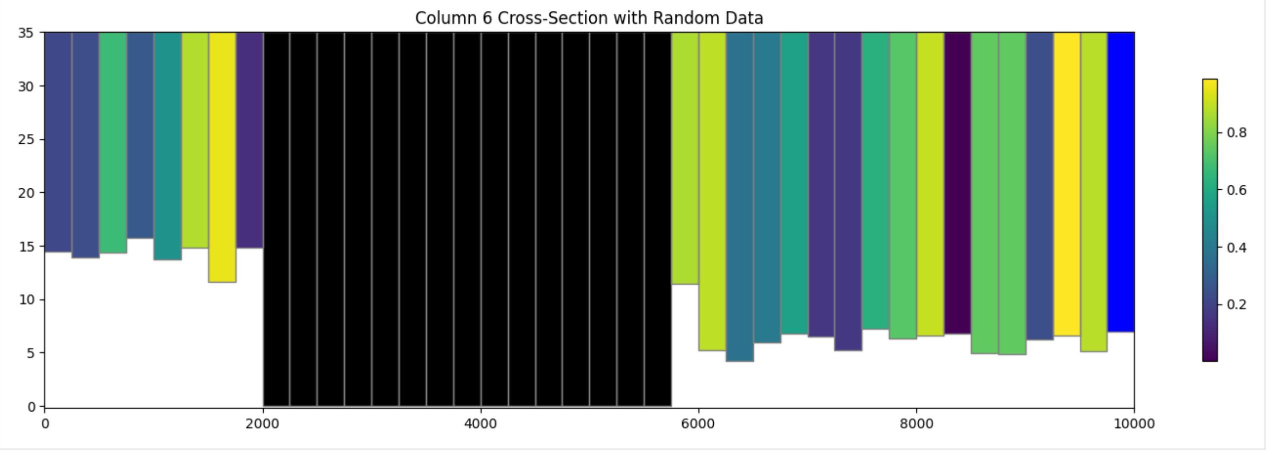


Plotting an Array

`PlotCrossSection` has a `plot_array()` method. The `plot_array()` method will only accept 3D arrays for structured grids.

[9]:
```python
# Create a random array and plot it
a = np.random.random((ml.dis.nlay, ml.dis.nrow, ml.dis.ncol))

fig = plt.figure(figsize=(18, 5))
ax = fig.add_subplot(1, 1, 1)
xsect = flopy.plot.PlotCrossSection(model=ml, line={"Column": 5})
csa = xsect.plot_array(a)
patches = xsect.plot_ibound()
linecollection = xsect.plot_grid()
t = ax.set_title("Column 6 Cross-Section with Random Data")
cb = plt.colorbar(csa, shrink=0.75)
```



[10]:
```python
# plot the horizontal hydraulic conductivities
a = ml.lpf.hk.array

fig = plt.figure(figsize=(18, 5))
ax = fig.add_subplot(1, 1, 1)
```

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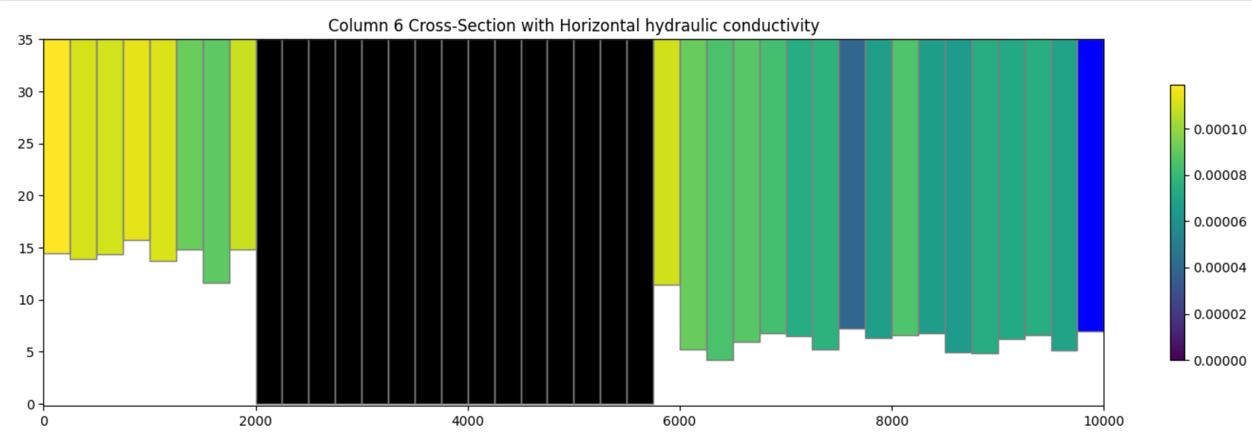
```
xsect = flopy.plot.PlotCrossSection(model=ml, line={"Column": 5})
csa = xsect.plot_array(a)
patches = xsect.plot_ibound()
linecollection = xsect.plot_grid()
t = ax.set_title(
    "Column 6 Cross-Section with Horizontal hydraulic conductivity"
)
cb = plt.colorbar(csa, shrink=0.75)
```

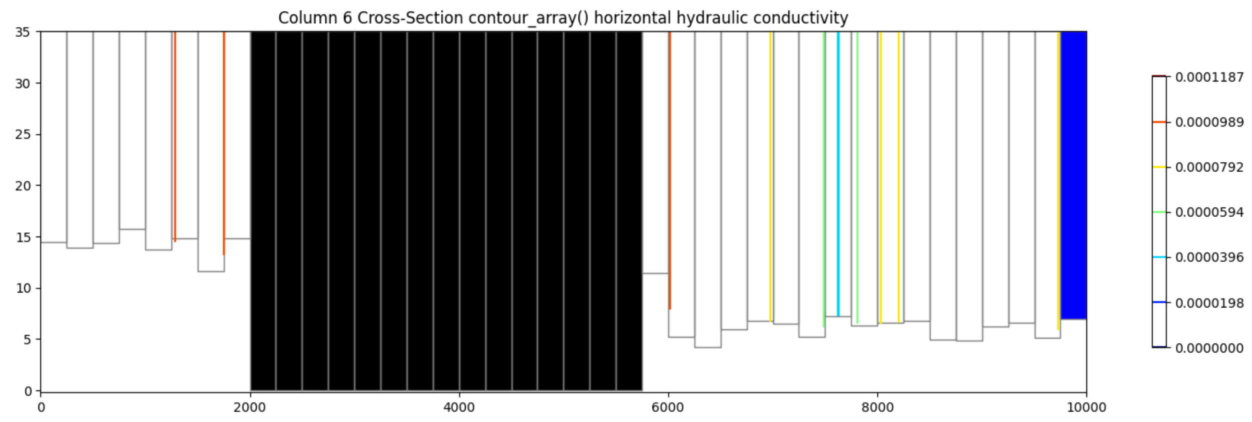


Contouring an Array

`PlotCrossSection` also has a `contour_array()` method. It also accepts a 3D array for structured grids.

[11]:
```
# plot the horizontal hydraulic conductivities
a = ml.lpf.hk.array

fig = plt.figure(figsize=(18, 5))
ax = fig.add_subplot(1, 1, 1)
xsect = flopy.plot.PlotCrossSection(model=ml, line={"Column": 5})
contour_set = xsect.contour_array(a, masked_values=[0], cmap="jet")
patches = xsect.plot_ibound()
linecollection = xsect.plot_grid(color="grey")
t = ax.set_title(
    "Column 6 Cross-Section contour_array() horizontal hydraulic conductivity"
)
cb = plt.colorbar(contour_set, shrink=0.75)
```



Plotting Heads

We can easily plot results from the simulation by extracting heads using `flopy.utils.HeadFile`.

The head can be passed into the `plot_array()` and `contour_array()` using the `head=` keyword argument to fix the top of the colored patch and contour lines at the top of the water table in each cell, respectively.

[12]:
```
fname = os.path.join(str(modelpth), "freyberg.hds")
hdobj = flopy.utils.HeadFile(fname)
head = hdobj.get_data()

fig = plt.figure(figsize=(18, 5))

ax = fig.add_subplot(1, 1, 1)
ax.set_title("plot_array() used to plotting Heads")
xsect = flopy.plot.PlotCrossSection(model=ml, line={"Column": 5})
pc = xsect.plot_array(head, head=head, alpha=0.5)
patches = xsect.plot_ibound(head=head)
linecollection = xsect.plot_grid()
cb = plt.colorbar(pc, shrink=0.75)
```

[13]:
```
# contour array on top of heads
levels = np.arange(17, 26, 1)
```

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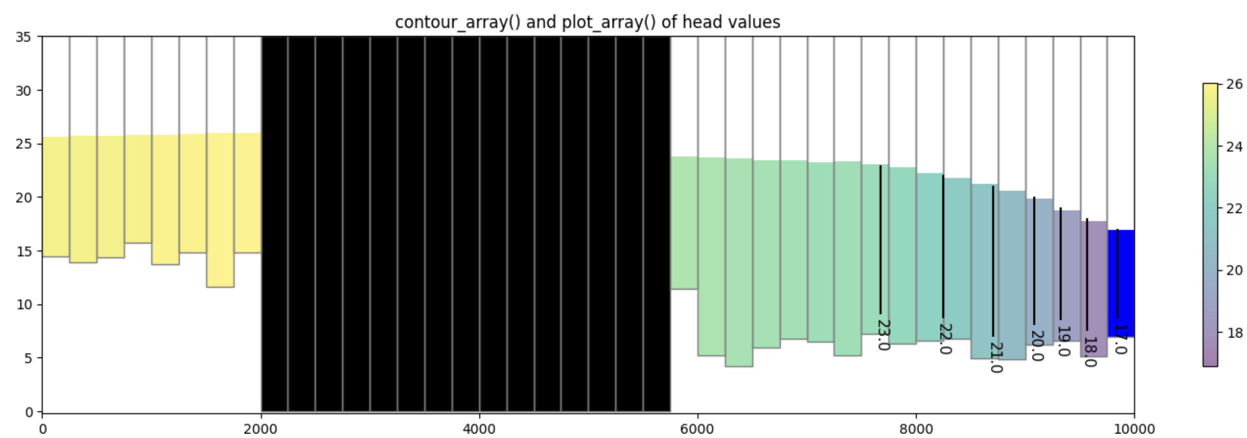
```
fig = plt.figure(figsize=(18, 5))
ax = fig.add_subplot(1, 1, 1)
ax.set_title("contour_array() and plot_array() of head values")

# instantiate the PlotCrossSection object
xsect = flopy.plot.PlotCrossSection(model=ml, line={"Column": 5})

# plot the head array and model grid
pc = xsect.plot_array(head, masked_values=[999.0], head=head, alpha=0.5)
patches = xsect.plot_ibound(head=head)
linecollection = xsect.plot_grid()

# do black contour lines of the head array
contour_set = xsect.contour_array(head, head=head, levels=levels, colors="k")
plt.clabel(contour_set, fmt="%.1f", colors="k", fontsize=11)

cb = plt.colorbar(pc, shrink=0.75)
```



Plotting a surface on the cross section

The plot_surface() method allows the user to plot a surface along the cross section. Here is a short example using head data.

[14]:
```
levels = np.arange(10, 30, 0.5)

fig = plt.figure(figsize=(18, 5))
xsect = flopy.plot.PlotCrossSection(model=ml, line={"Column": 5})

# contour array and plot ibound
ct = xsect.contour_array(
    head, masked_values=[999.0], head=head, levels=levels, linewidths=2.5
)
pc = xsect.plot_ibound(head=head)

# plot the surface and model grid
wt = xsect.plot_surface(head, color="blue", lw=2.5)
```

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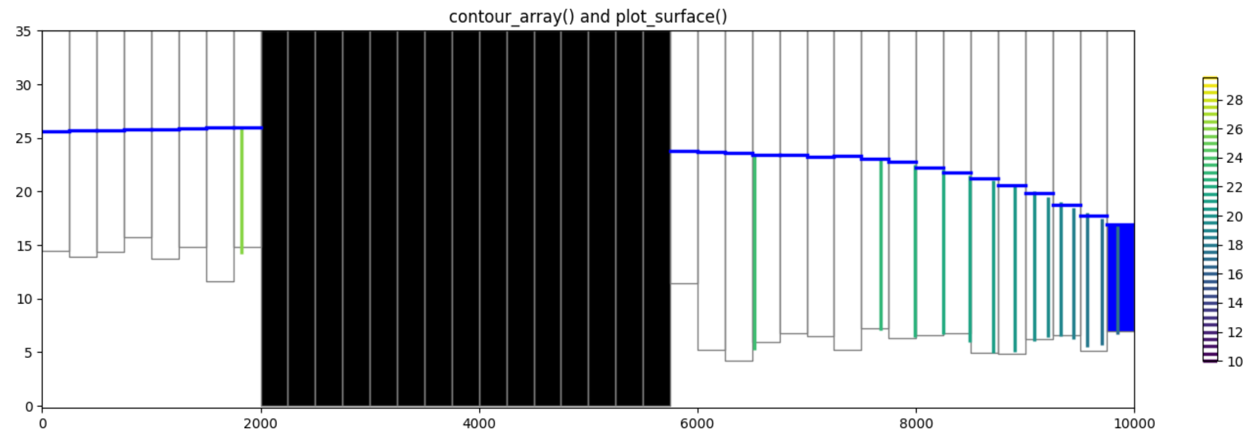
```
linecollection = xsect.plot_grid()

plt.title("contour_array() and plot_surface()")
cb = plt.colorbar(ct, shrink=0.75)
```



Plotting discharge vectors

PlotCrossSection has a plot_vector() method, which takes qx, qy, and qz vector arrays (ex. specific discharge or flow across a cell faces). The flow array values can be extracted from the cell by cell flow file using the flopy.utils.CellBudgetFile object as shown below. Once they are extracted, they either be can be passed to the plot_vector() method or they can be post processed into specific discharge using postprocessing.get_specific_discharge. Note that get_specific_discharge() also takes the head array as an argument. The head array is used by get_specific_discharge() to convert the volumetric flow in dimensions of L^3/T to specific discharge in dimensions of L/T and to plot the specific discharge in the center of each saturated cell. For this problem, there is no 'FLOW LOWER FACE' array since the Freyberg Model is a one layer model.

[15]:
```
fname = os.path.join(str(modelpth), "freyberg.cbc")
cbb = flopy.utils.CellBudgetFile(fname)
frf = cbb.get_data(text="FLOW RIGHT FACE")[0]
fff = cbb.get_data(text="FLOW FRONT FACE")[0]
qx, qy, qz = flopy.utils.postprocessing.get_specific_discharge(
    (frf, fff, None), ml, head=head
)
```

[16]:
```
fig = plt.figure(figsize=(18, 5))
ax = fig.add_subplot(1, 1, 1)

ax.set_title("plot_array() and plot_vector()")
xsect = flopy.plot.PlotCrossSection(model=ml, ax=ax, line={"Column": 5})
csa = xsect.plot_array(head, head=head, alpha=0.5)
patches = xsect.plot_ibound(head=head)
linecollection = xsect.plot_grid()
quiver = xsect.plot_vector(
    qx,
    qy,
    qz,
```

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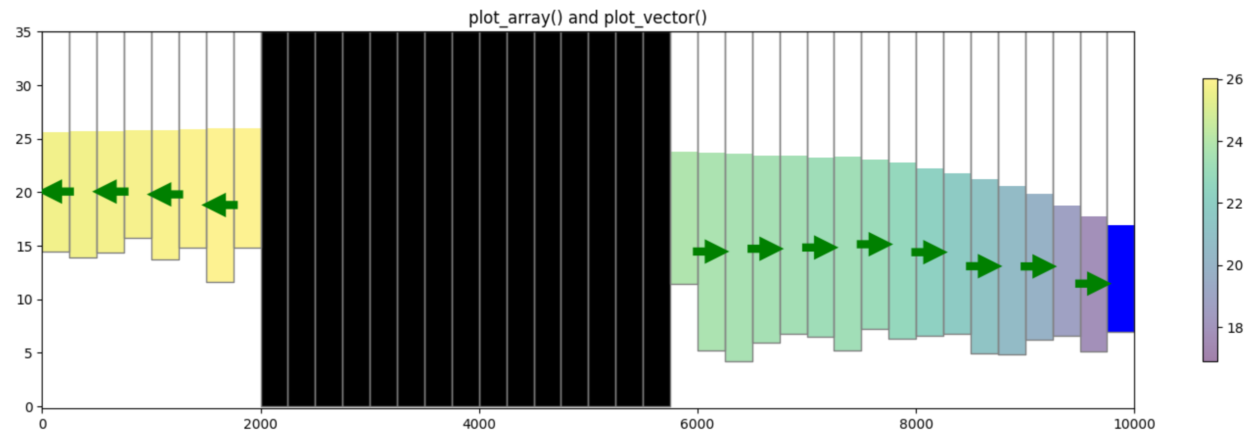
```
    head=head,
    hstep=2,
    normalize=True,
    color="green",
    scale=30,
    headwidth=3,
    headlength=3,
    headaxislength=3,
    zorder=10,
)

cb = plt.colorbar(csa, shrink=0.75)
```



Plotting a cross section from Shapefile data

A shapefile can be used to define the vertices for a instance of the `PlotCrossSection` class. The function `flopy.plot.plotutil.shapefile_get_vertices()` will return a list of vertices for each polyline in a shapefile.

Let's plot the shapefiles and the Freyberg model using `PlotMapView` for visualization purposes and then plot the cross-section.

[17]:
```
# Setup the figure and PlotMapView. Show a very faint map of ibound and
# model grid by specifying a transparency alpha value.

# set the modelgrid rotation and offset
ml.modelgrid.set_coord_info(
    xoff=-2419.2189559966773, yoff=297.0427372400354, angrot=-14
)

fig = plt.figure(figsize=(12, 12))
ax = fig.add_subplot(1, 1, 1, aspect="equal")
mapview = flopy.plot.PlotMapView(model=ml)

# Plot a shapefile of
shp = os.path.join(loadpth, "gis", "bedrock_outcrop_hole_rotate14")
patch_collection = mapview.plot_shapefile(
    shp, edgecolor="green", linewidths=2, alpha=0.5  # facecolor='none',
```

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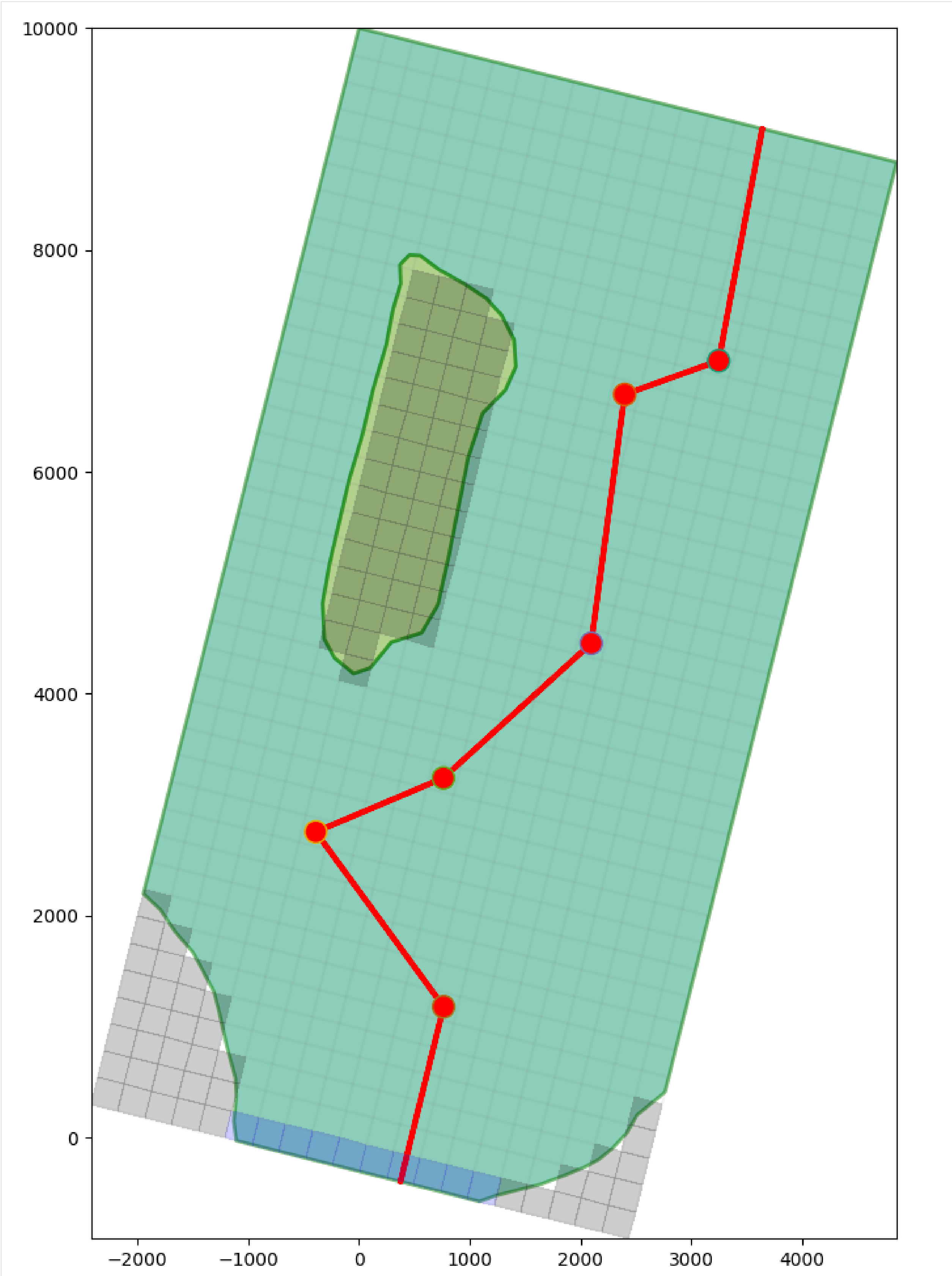
```
)
# Plot a shapefile of a cross-section line
shp = os.path.join(loadpth, "gis", "cross_section_rotate14")
patch_collection = mapview.plot_shapefile(
    shp, radius=0, lw=3, edgecolor="red", facecolor="None"
)

# Plot a shapefile of well locations
shp = os.path.join(loadpth, "gis", "wells_locations_rotate14")
patch_collection = mapview.plot_shapefile(shp, radius=100, facecolor="red")

# Plot the grid and boundary conditions over the top
quadmesh = mapview.plot_ibound(alpha=0.1)
linecollection = mapview.plot_grid(alpha=0.1)
```


10000
8000
6000
4000
2000
0
−2000
−1000
0
1000
2000
3000
4000

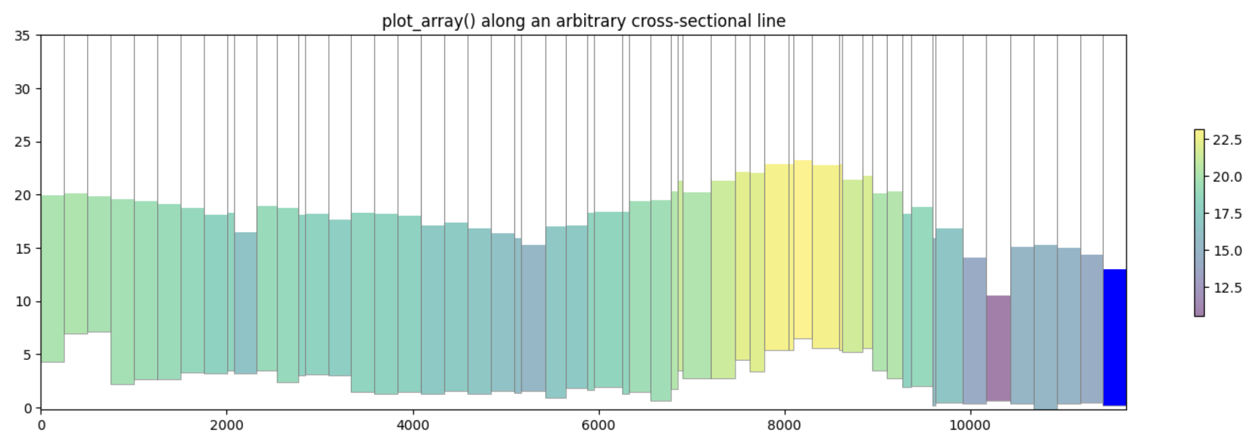
Now let's make a cross section based on this arbitrary cross-sectional line. We can load the cross sectional line vertices using `flopy.plot.plotutil.shapefile_get_vertices()`

Note: in previous examples we passed `line={'column', 5}` to plot a cross section along a column. In this example we pass vertex information into `PlotCrossSection` using `line={'line', line[0]}` where `line[0]` is a list of vertices.

[18]:
```
# get the vertices for cross-section lines in a shapefile
fpth = os.path.join(loadpth, "gis", "cross_section_rotate14")
line = flopy.plot.plotutil.shapefile_get_vertices(fpth)

# Set up the figure
fig = plt.figure(figsize=(18, 5))
ax = fig.add_subplot(1, 1, 1)
ax.set_title("plot_array() along an arbitrary cross-sectional line")

# plot head values along the cross sectional line
xsect = flopy.plot.PlotCrossSection(model=ml, line={"line": line[0]})
csa = xsect.plot_array(head, head=head, alpha=0.5)
patches = xsect.plot_ibound(head=head)
linecollection = xsect.plot_grid(lw=0.5)
cb = fig.colorbar(csa, ax=ax, shrink=0.5)
```



Plotting geographic coordinates on the x-axis using the `PlotCrossSection` class

The default cross section plotting method plots cells with regard to their intersection distance along the cross sectional line defined by the user. While this method is perfectly acceptable and in many cases may be preferred for plotting arbitrary cross sections, a flag has been added to plot based on geographic coordinates.

The flag `geographic_coords` defaults to `False` which maintains FloPy's previous method of plotting cross sections.

[19]:
```
# get the vertices for cross-section lines in a shapefile
fpth = os.path.join(loadpth, "gis", "cross_section_rotate14")
line = flopy.plot.plotutil.shapefile_get_vertices(fpth)

# Set up the figure
fig = plt.figure(figsize=(18, 5))
ax = fig.add_subplot(1, 1, 1)
ax.set_title("plot_array() along an arbitrary cross-sectional line")
```

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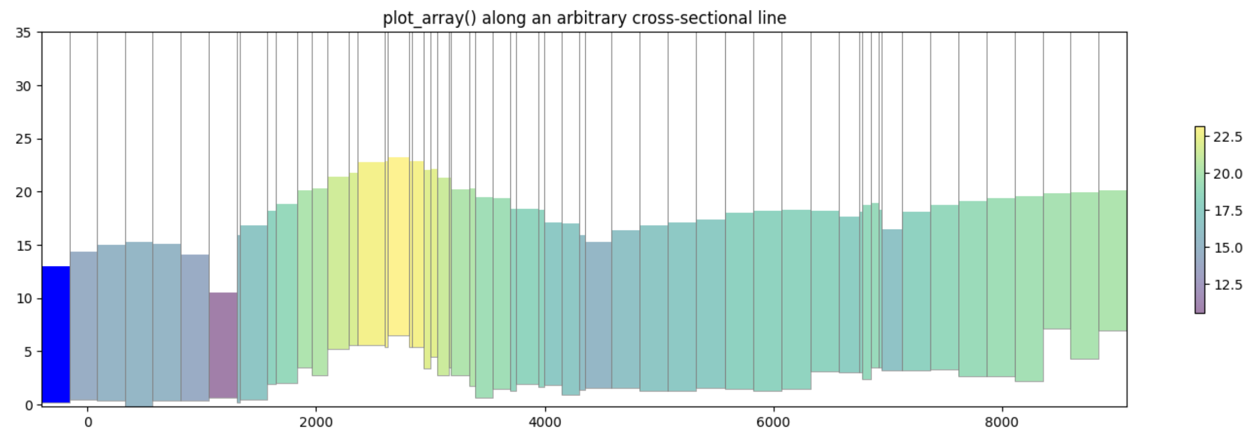
```
# plot head values along the cross sectional line
xsect = flopy.plot.PlotCrossSection(
    model=ml, line={"line": line[0]}, geographic_coords=True
)
csa = xsect.plot_array(head, head=head, alpha=0.5)
patches = xsect.plot_ibound(head=head)
linecollection = xsect.plot_grid(lw=0.5)
cb = fig.colorbar(csa, ax=ax, shrink=0.5)
```



Plotting Cross Sections with MODFLOW-6 models

`PlotCrossSection` has support for MODFLOW-6 models and operates in the same fashion for Structured Grids, Vertex Grids, and Unstructured Grids. Here is a short example on how to plot with MODFLOW-6 structured grids using a version of the Freyberg model created for MODFLOW-6|

[20]:
```
# load the Freyberg model into mf6-flopy and run the simulation
sim_name = "mfsim.nam"
sim_path = str(prj_root / "examples" / "data" / "mf6-freyberg")
sim = flopy.mf6.MFSimulation.load(
    sim_name=sim_name, version=vmf6, exe_name=exe_name_mf6, sim_ws=sim_path
)

sim.set_sim_path(modelpth)
sim.write_simulation()
success, buff = sim.run_simulation(silent=True, report=True)
if success:
    for line in buff:
        print(line)
else:
    raise ValueError("Something bad happened.")
files = ["freyberg.hds", "freyberg.cbc"]
for f in files:
    if os.path.isfile(os.path.join(str(modelpth), f)):
        msg = f"Output file located: {f}"
        print(msg)
```

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```
    else:
        errmsg = f"Error. Output file cannot be found: {f}"
        print(errmsg)
```

```
loading simulation...
  loading simulation name file...
  loading tdis package...
  loading model gwf6...
    loading package dis...
    loading package ic...
WARNING: Block "options" is not a valid block name for file type ic.
    loading package oc...
    loading package npf...
    loading package sto...
    loading package chd...
    loading package riv...
    loading package wel...
    loading package rch...
  loading solution package freyberg...
writing simulation...
  writing simulation name file...
  writing simulation tdis package...
  writing solution package freyberg...
  writing model freyberg...
    writing model name file...
    writing package dis...
    writing package ic...
    writing package oc...
    writing package npf...
    writing package sto...
    writing package chd-1...
    writing package riv-1...
    writing package wel-1...
    writing package rch-1...
                                   MODFLOW 6
                U.S. GEOLOGICAL SURVEY MODULAR HYDROLOGIC MODEL
                            VERSION 6.4.2 06/28/2023

   MODFLOW 6 compiled Jul 05 2023 20:29:14 with Intel(R) Fortran Intel(R) 64
   Compiler Classic for applications running on Intel(R) 64, Version 2021.7.0
                             Build 20220726_000000

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Government shall be held liable for any damages resulting from its
authorized or unauthorized use. Also refer to the USGS Water
```

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```
Resources Software User Rights Notice for complete use, copyright,
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 Run start date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:34:17

 Writing simulation list file: mfsim.lst
 Using Simulation name file: mfsim.nam

    Solving:  Stress period:     1    Time step:     1

 Run end date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:34:17
 Elapsed run time:  0.047 Seconds

 Normal termination of simulation.
Output file located: freyberg.hds
Output file located: freyberg.cbc
```

Plotting boundary conditions and arrays

This works the same as modflow-2005, however the simulation object can host a number of modflow-6 models so we need to grab a model before attempting to plot with `PlotCrossSection`

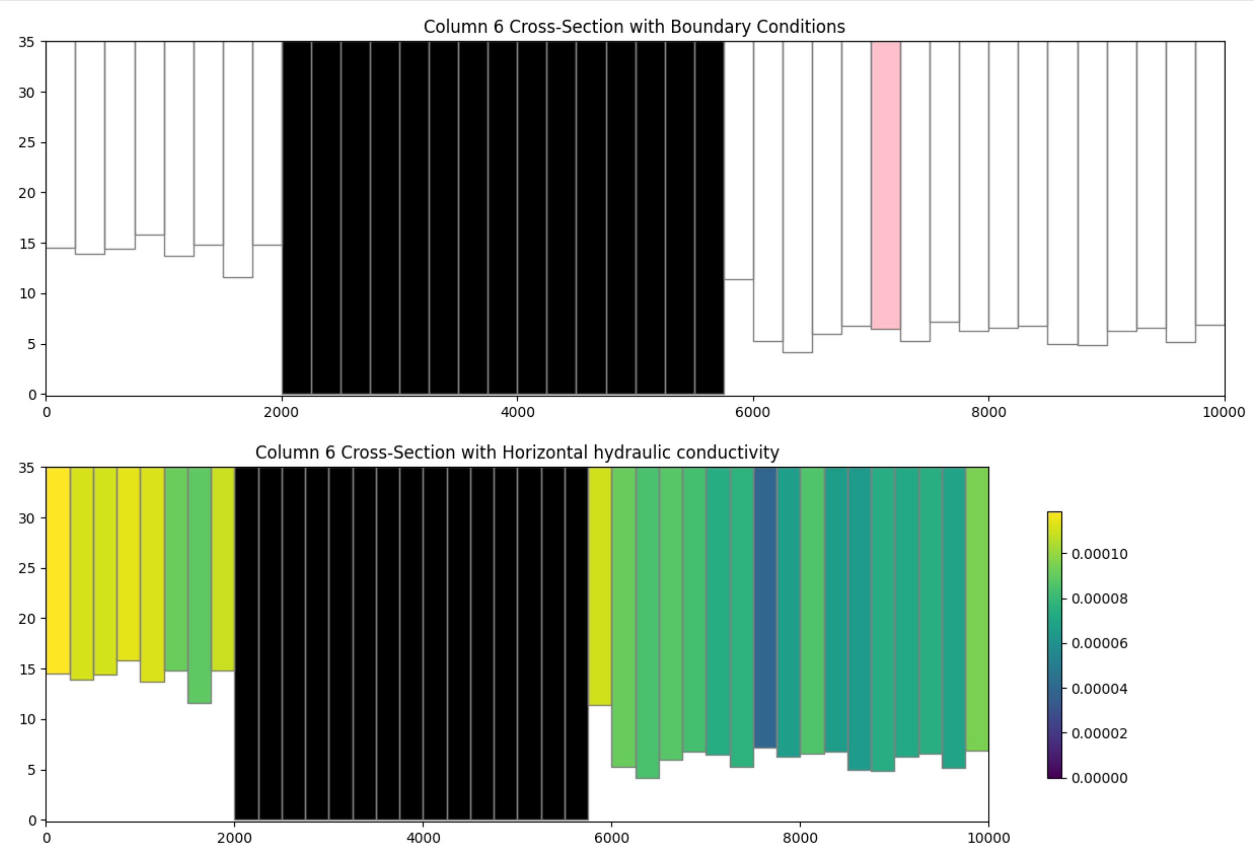
[21]:
```python
# get the modflow-6 model we want to plot
ml6 = sim.get_model("freyberg")

fig = plt.figure(figsize=(15, 10))
ax = fig.add_subplot(2, 1, 1)

# plot boundary conditions
xsect = flopy.plot.PlotCrossSection(model=ml6, line={"Column": 5})
patches = xsect.plot_bc("WEL", color="pink")
patches = xsect.plot_ibound()
linecollection = xsect.plot_grid()
t = ax.set_title("Column 6 Cross-Section with Boundary Conditions")

# plot xxxx
ax = fig.add_subplot(2, 1, 2)
# plot the horizontal hydraulic conductivities
a = ml6.npf.k.array

xsect = flopy.plot.PlotCrossSection(model=ml6, line={"Column": 5})
csa = xsect.plot_array(a)
patches = xsect.plot_ibound()
linecollection = xsect.plot_grid()
t = ax.set_title(
    "Column 6 Cross-Section with Horizontal hydraulic conductivity"
)
cb = plt.colorbar(csa, shrink=0.75)
```



Plotting specific discharge with a MODFLOW-6 model

MODFLOW-6 includes a the PLOT_SPECIFIC_DISCHARGE flag in the NPF package to calculate and store discharge vectors for easy plotting. The `postprocessing.get_specific_discharge()` method will preprocess the data into vectors and `PlotCrossSection` has the `plot_vector()` method to use this data. The specific discharge array is stored in the cell budget file.

[22]:
```
# get the head from the head file
head_file = os.path.join(modelpth, "freyberg.hds")
hds = flopy.utils.HeadFile(head_file)
head = hds.get_alldata()[0]

# get the specific discharge from the cell budget file
cbc_file = os.path.join(modelpth, "freyberg.cbc")
cbc = flopy.utils.CellBudgetFile(cbc_file, precision="double")
spdis = cbc.get_data(text="SPDIS")[-1]
qx, qy, qz = flopy.utils.postprocessing.get_specific_discharge(
    spdis, ml6, head=head
)

fig = plt.figure(figsize=(18, 5))
ax = fig.add_subplot(1, 1, 1)

ax.set_title("plot_array() and plot_vector()")
```

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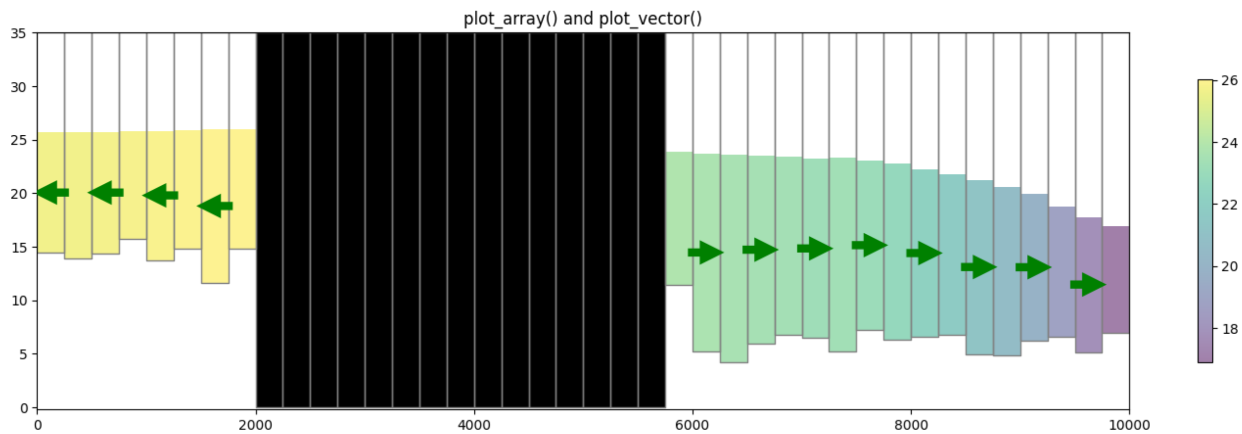
```
xsect = flopy.plot.PlotCrossSection(model=ml6, ax=ax, line={"Column": 5})
csa = xsect.plot_array(head, head=head, alpha=0.5)
patches = xsect.plot_ibound(head=head)
linecollection = xsect.plot_grid()
quiver = xsect.plot_vector(
    qx,
    qy,
    qz,
    head=head,
    hstep=2,
    normalize=True,
    color="green",
    scale=30,
    headwidth=3,
    headlength=3,
    headaxislength=3,
    zorder=10,
)

cb = plt.colorbar(csa, shrink=0.75)
```



Vertex cross section plotting with MODFLOW-6 (DISV)

FloPy fully supports vertex discretization (DISV) plotting through the `PlotCrossSection` class. The method calls are identical to the ones presented previously for Structured discretization (DIS) and the same matplotlib keyword arguments are supported. Let's run through an example using a vertex model grid.

[23]:
```
# build and run vertex model grid demo problem
notebook_utils.run(modelpth)

# check if model ran properly
modelpth = os.path.join(modelpth, "mp7_ex2", "mf6")
# from pprint import pprint
# pprint([str(p) for p in (Path(tempdir.name) / "mp7_ex2").glob('*')])
files = ["mp7p2.hds", "mp7p2.cbb"]
for f in files:
```

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```
    if os.path.isfile(os.path.join(modelpth, f)):
        msg = f"Output file located: {f}"
        print(msg)
    else:
        errmsg = f"Error. Output file cannot be found: {f}"
        print(errmsg)
```

```
WARNING: Unable to resolve dimension of ('gwf6', 'disv', 'cell2d', 'cell2d', 'icvert')␣
↪based on shape "ncvert".
writing simulation...
  writing simulation name file...
  writing simulation tdis package...
  writing solution package ims...
  writing model mp7p2...
    writing model name file...
    writing package disv...
    writing package ic...
    writing package npf...
    writing package wel_0...
INFORMATION: maxbound in ('gwf6', 'wel', 'dimensions') changed to 1 based on size of␣
↪stress_period_data
    writing package rcha_0...
    writing package riv_0...
INFORMATION: maxbound in ('gwf6', 'riv', 'dimensions') changed to 21 based on size of␣
↪stress_period_data
    writing package oc...
                                   MODFLOW 6
                U.S. GEOLOGICAL SURVEY MODULAR HYDROLOGIC MODEL
                            VERSION 6.4.2 06/28/2023

   MODFLOW 6 compiled Jul 05 2023 20:29:14 with Intel(R) Fortran Intel(R) 64
   Compiler Classic for applications running on Intel(R) 64, Version 2021.7.0
                             Build 20220726_000000

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 Run start date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:34:18

 Writing simulation list file: mfsim.lst
 Using Simulation name file: mfsim.nam
```

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```
    Solving:  Stress period:     1    Time step:     1

 Run end date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:34:18
 Elapsed run time:  0.096 Seconds


WARNING REPORT:

  1. NONLINEAR BLOCK VARIABLE 'OUTER_HCLOSE' IN FILE 'mp7p2.ims' WAS
     DEPRECATED IN VERSION 6.1.1. SETTING OUTER_DVCLOSE TO OUTER_HCLOSE VALUE.
  2. LINEAR BLOCK VARIABLE 'INNER_HCLOSE' IN FILE 'mp7p2.ims' WAS DEPRECATED
     IN VERSION 6.1.1. SETTING INNER_DVCLOSE TO INNER_HCLOSE VALUE.
 Normal termination of simulation.

MODPATH Version 7.2.001
Program compiled Jul 05 2023 20:31:49 with IFORT compiler (ver. 20.21.7)


Run particle tracking simulation ...
Processing Time Step     1 Period     1.  Time =  1.00000E+03  Steady-state flow

Particle Summary:
         0 particles are pending release.
         0 particles remain active.
        16 particles terminated at boundary faces.
         0 particles terminated at weak sink cells.
         0 particles terminated at weak source cells.
         0 particles terminated at strong source/sink cells.
         0 particles terminated in cells with a specified zone number.
         0 particles were stranded in inactive or dry cells.
         0 particles were unreleased.
         0 particles have an unknown status.

Normal termination.

MODPATH Version 7.2.001
Program compiled Jul 05 2023 20:31:49 with IFORT compiler (ver. 20.21.7)


Run particle tracking simulation ...
Processing Time Step     1 Period     1.  Time =  1.00000E+03  Steady-state flow

Particle Summary:
         0 particles are pending release.
         0 particles remain active.
       416 particles terminated at boundary faces.
         0 particles terminated at weak sink cells.
         0 particles terminated at weak source cells.
         0 particles terminated at strong source/sink cells.
         0 particles terminated in cells with a specified zone number.
         0 particles were stranded in inactive or dry cells.
```

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```
        0 particles were unreleased.
        0 particles have an unknown status.

Normal termination.
Output file located: mp7p2.hds
Output file located: mp7p2.cbb
```

[24]:
```
# load the simulation and get the model
vertex_sim_name = "mfsim.nam"
vertex_sim = flopy.mf6.MFSimulation.load(
    sim_name=vertex_sim_name,
    version=vmf6,
    exe_name=exe_name_mf6,
    sim_ws=modelpth,
)
vertex_ml6 = vertex_sim.get_model("mp7p2")
```

```
loading simulation...
  loading simulation name file...
  loading tdis package...
  loading model gwf6...
    loading package disv...
WARNING: Unable to resolve dimension of ('gwf6', 'disv', 'cell2d', 'cell2d', 'icvert')␣
↪based on shape "ncvert".
    loading package ic...
    loading package npf...
    loading package wel...
    loading package rch...
    loading package riv...
    loading package oc...
  loading solution package mp7p2...
```

Plotting a line based cross section through the model grid

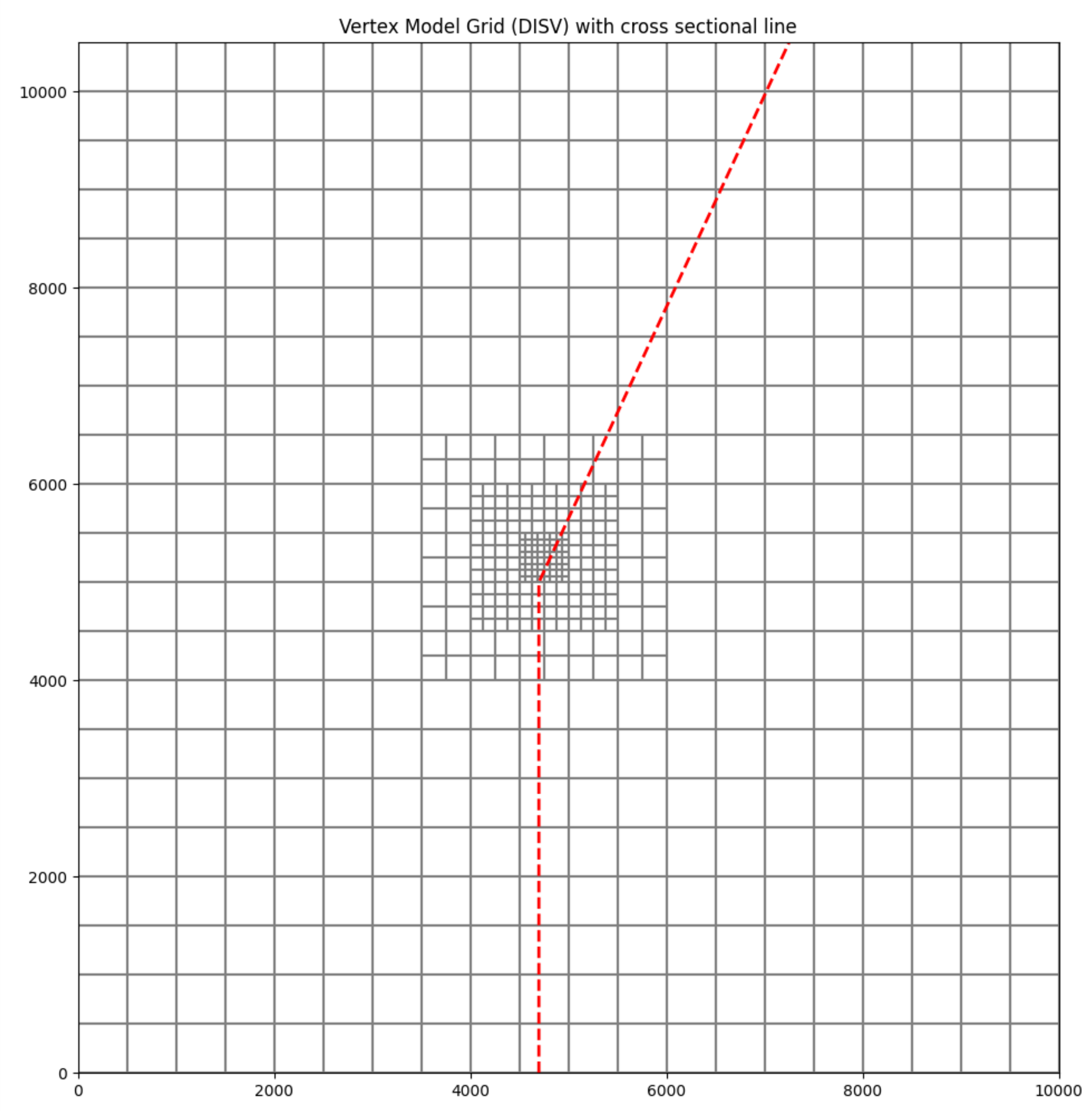
Because a `VertexGrid` has no row or column number, the cross-section line must be defined explicitly. This is done by passing a dictionary to the `line` parameter with key `line` — the value may be an array-like of 2 or more points, e.g. `{"line": [(x0, y0), (x1, y1), ...]}`, or a `flopy.utils.geometry.LineString` or `shapely.geometry.LineString`. Below we show an example of setting up a cross-section line with a MODFLOW-6 DISV model.

[25]:
```
line = np.array([(4700, 0), (4700, 5000), (7250, 10500)])

# Let's plot the model grid in map view to look at it
fig = plt.figure(figsize=(12, 12))
ax = fig.add_subplot(1, 1, 1, aspect="equal")
ax.set_title("Vertex Model Grid (DISV) with cross sectional line")

# use PlotMapView to plot a DISV (vertex) model
mapview = flopy.plot.PlotMapView(vertex_ml6, layer=0)
linecollection = mapview.plot_grid()

# plot the line over the model grid
lc = plt.plot(line.T[0], line.T[1], "r--", lw=2)
```



Now we can plot a cross section of the model grid defined by this line

[26]:
```
fig = plt.figure(figsize=(15, 5))
ax = fig.add_subplot(1, 1, 1)

# Next we create an instance of the PlotCrossSection class
xsect = flopy.plot.PlotCrossSection(model=vertex_ml6, line={"line": line})

# Then we can use the plot_grid() method to draw the grid
# The return value for this function is a matplotlib LineCollection object,
# which could be manipulated (or used) later if necessary.
linecollection = xsect.plot_grid()
```

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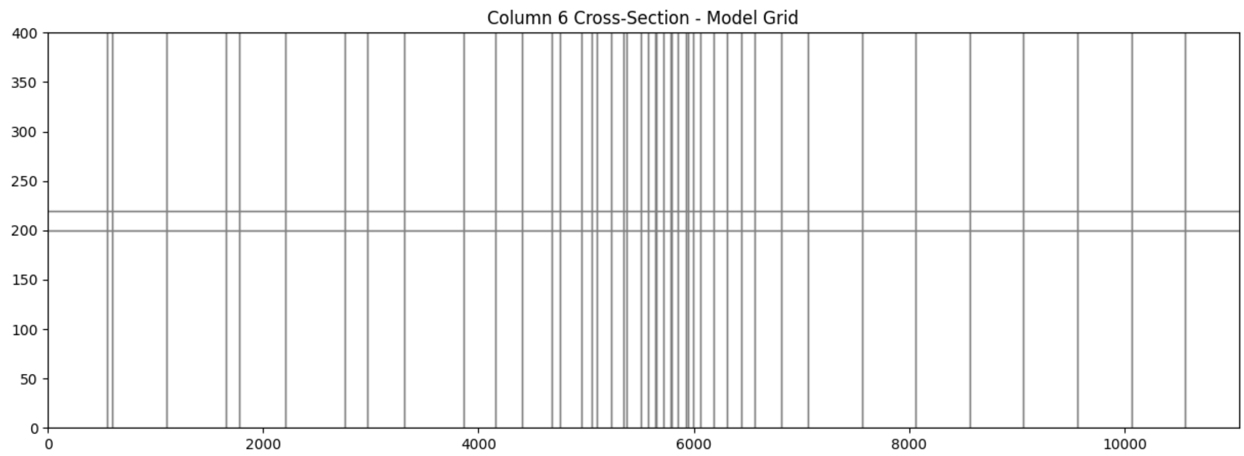
```
t = ax.set_title("Column 6 Cross-Section - Model Grid")
```



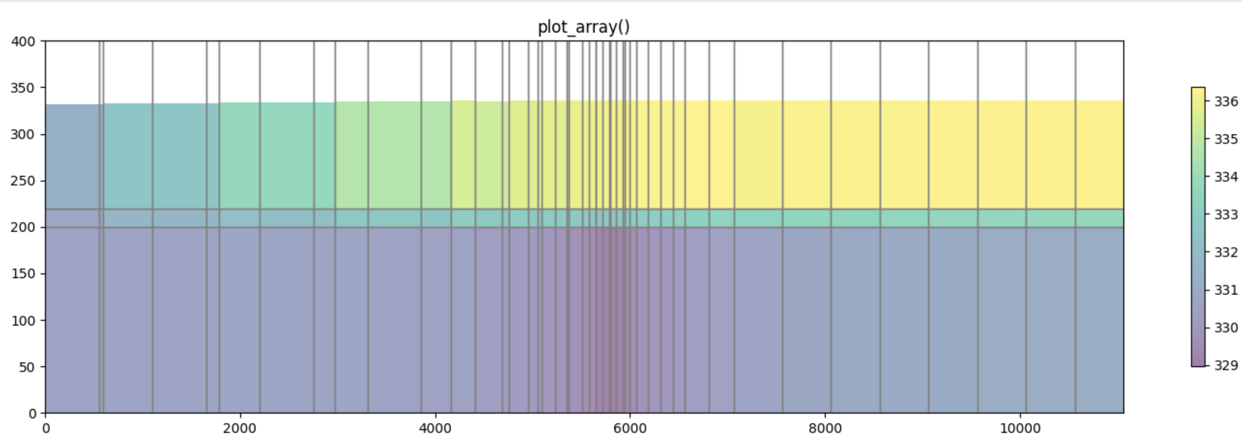
Plotting Arrays and Contouring with Vertex Model grids

`PlotCrossSection` allows the user to plot arrays and contour with DISV based discretization. The `plot_array()` method is called in the same way as using a structured grid. The only difference is that `PlotCrossSection` builds a matplotlib patch collection for Vertex based grids.

[27]:
```
# get the head output for stress period 1 from the modflow6 head file
head = flopy.utils.HeadFile(os.path.join(modelpth, "mp7p2.hds"))
hdata = head.get_alldata()[0, :, :, :]

fig = plt.figure(figsize=(18, 5))
ax = fig.add_subplot(1, 1, 1)
ax.set_title("plot_array()")

xsect = flopy.plot.PlotCrossSection(model=vertex_ml6, line={"line": line})
patch_collection = xsect.plot_array(hdata, head=hdata, alpha=0.5)
line_collection = xsect.plot_grid()
cb = plt.colorbar(patch_collection, shrink=0.75)
```



The `contour_array()` method operates in the same way as the sturctured example.

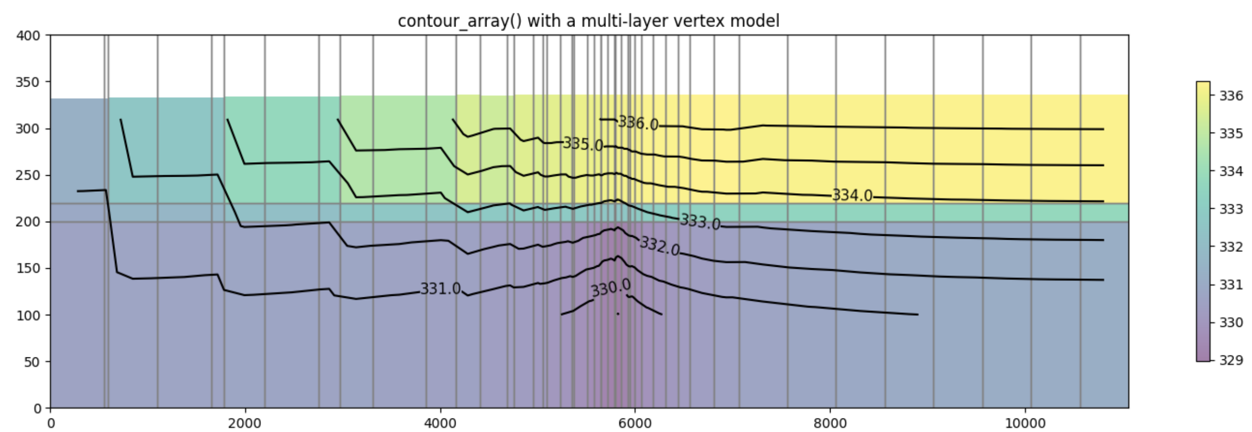
[28]:
```
levels = np.arange(329, 337, 1)

fig = plt.figure(figsize=(18, 5))
ax = fig.add_subplot(1, 1, 1)
ax.set_title("contour_array() with a multi-layer vertex model")

xsect = flopy.plot.PlotCrossSection(model=vertex_ml6, line={"line": line})
patch_collection = xsect.plot_array(hdata, head=hdata, alpha=0.5)
line_collection = xsect.plot_grid()

contour_set = xsect.contour_array(hdata, levels=levels, colors="k")
plt.clabel(contour_set, fmt="%.1f", colors="k", fontsize=11)

cb = plt.colorbar(patch_collection, shrink=0.75)
```



Plotting specific discharge vectors for DISV

MODFLOW-6 includes a the PLOT_SPECIFIC_DISCHARGE flag in the NPF package to calculate and store discharge vectors for easy plotting.The `postprocessing.get_specific_discharge()` method will preprocess the data into vectors and `PlotCrossSection` has the `plot_vector()` method to use this data. The specific discharge array is stored in the cell budget file.

Note: When plotting specific discharge, an arbitrary cross section cannot be used. The cross sectional line must be orthogonal to the model grid

[29]:
```
# define and plot our orthogonal line
line = np.array([(0, 4700), (10000, 4700)])

# Let's plot the model grid in map view to look at it
fig = plt.figure(figsize=(12, 12))
ax = fig.add_subplot(1, 1, 1, aspect="equal")
ax.set_title("Vertex Model Grid (DISV) with cross sectional line")

# use PlotMapView to plot a DISV (vertex) model
mapview = flopy.plot.PlotMapView(vertex_ml6, layer=0)
linecollection = mapview.plot_grid()

# plot the line over the model grid
```

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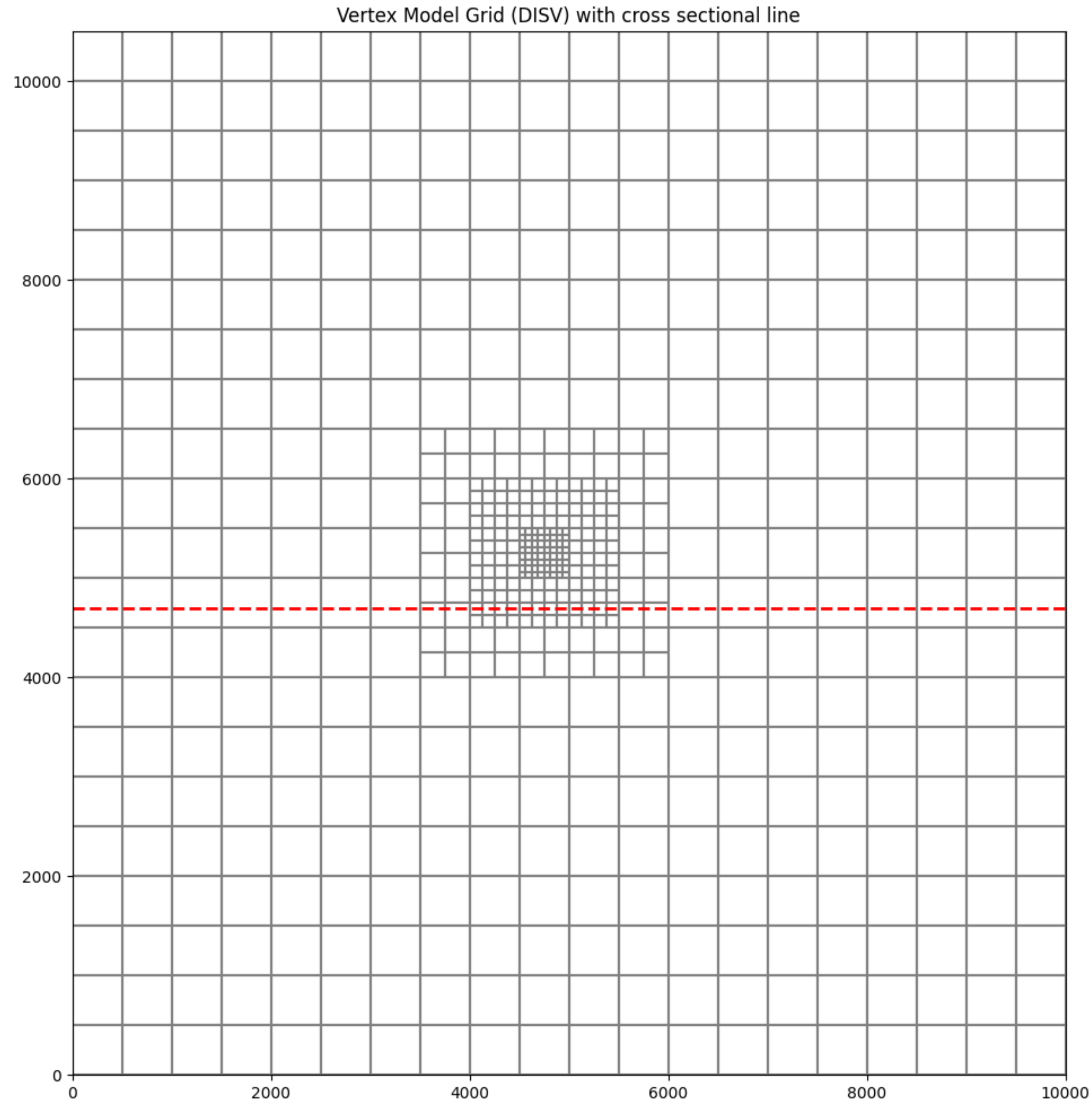
```
lc = plt.plot(line.T[0], line.T[1], "r--", lw=2)
```



[30]:
```
# plot specific discharge on cross section
cbb = flopy.utils.CellBudgetFile(os.path.join(modelpth, "mp7p2.cbb"))
spdis = cbb.get_data(text="SPDIS")[-1]
qx, qy, qz = flopy.utils.postprocessing.get_specific_discharge(
    spdis, vertex_ml6, head=hdata
)

fig = plt.figure(figsize=(18, 5))
ax = fig.add_subplot(1, 1, 1)
```

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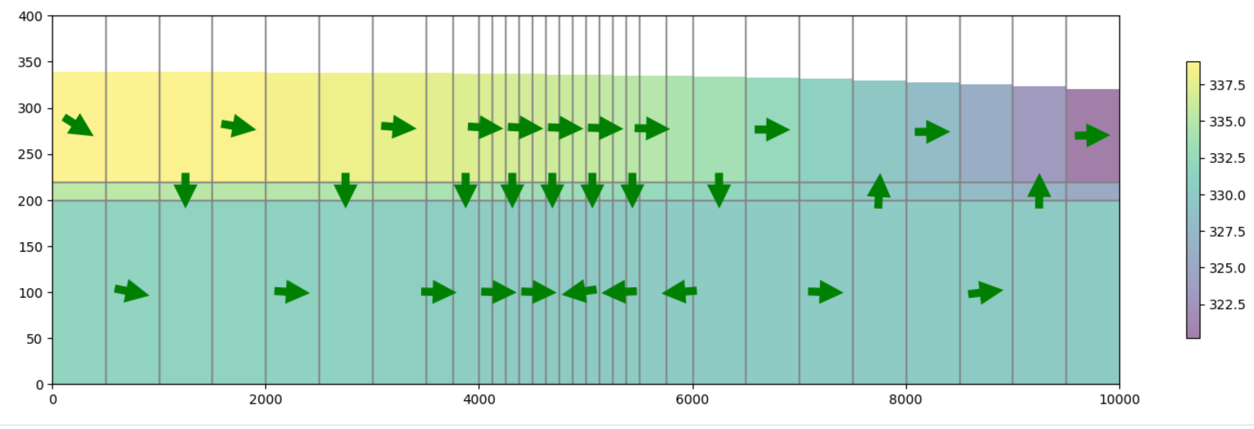
```
xsect = flopy.plot.PlotCrossSection(model=vertex_ml6, line={"line": line})
patch_collection = xsect.plot_array(hdata, head=hdata, alpha=0.5)
line_collection = xsect.plot_grid()
quiver = xsect.plot_vector(
    qx,
    qy,
    qz,
    head=hdata,
    hstep=3,
    normalize=True,
    color="green",
    scale=30,
    headwidth=3,
    headlength=3,
    headaxislength=3,
    zorder=10,
)

cb = plt.colorbar(patch_collection, shrink=0.75)
```



Plotting using built in styles

FloPy's plotting routines can be used with built in styles from the `styles` module. The `styles` module takes advantage of matplotlib's temporary styling routines by reading in pre-built style sheets. Two different types of styles have been built for flopy: `USGSMap()` and `USGSPlot()` styles which can be used to create report quality figures. The styles module also contains a number of methods that can be used for adding axis labels, text, annotations, headings, removing tick lines, and updating the current font.

This example will load the Keating groundwater transport model and plot results using `styles`

[31]:
```
notebook_utils.run_keating_model(modelpth)
```

```
Running mf6gwf model...
Running mf6gwt model...
```

[31]:
```
True
```

Load the flow and transport models

[32]:
```
sim_path = os.path.join(modelpth, "mf6-gwt-keating", "mf6gwf")
tr_path = os.path.join(modelpth, "mf6-gwt-keating", "mf6gwt")
sim_name = "mfsim.nam"
sim = flopy.mf6.MFSimulation.load(
    sim_name=sim_name, version=vmf6, exe_name=exe_name_mf6, sim_ws=sim_path
)
gwf6 = sim.get_model("flow")

sim = flopy.mf6.MFSimulation.load(
    sim_name=sim_name, version=vmf6, exe_name=exe_name_mf6, sim_ws=tr_path
)
gwt6 = sim.get_model("trans")
```

```
loading simulation...
  loading simulation name file...
  loading tdis package...
  loading model gwf6...
    loading package dis...
    loading package npf...
    loading package ic...
    loading package chd...
    loading package rch...
    loading package oc...
  loading solution package flow...
loading simulation...
  loading simulation name file...
  loading tdis package...
  loading model gwt6...
    loading package dis...
    loading package ic...
    loading package mst...
    loading package adv...
    loading package dsp...
    loading package fmi...
    loading package ssm...
    loading package oc...
    loading package obs...
  loading solution package trans...
```

[33]:
```
# import styles
from flopy.plot import styles

# load head file and plot
head = gwf6.output.head().get_data()

with styles.USGSMap():
    fig, ax = plt.subplots(1, 1, figsize=(12, 8), dpi=300, tight_layout=True)

    xsect = flopy.plot.PlotCrossSection(model=gwf6, ax=ax, line={"row": 0})
    pc = xsect.plot_array(head, head=head, cmap="jet")
    xsect.plot_bc(ftype="RCH", color="red")
    xsect.plot_bc(ftype="CHD")
    plt.colorbar(pc, shrink=0.25)
```

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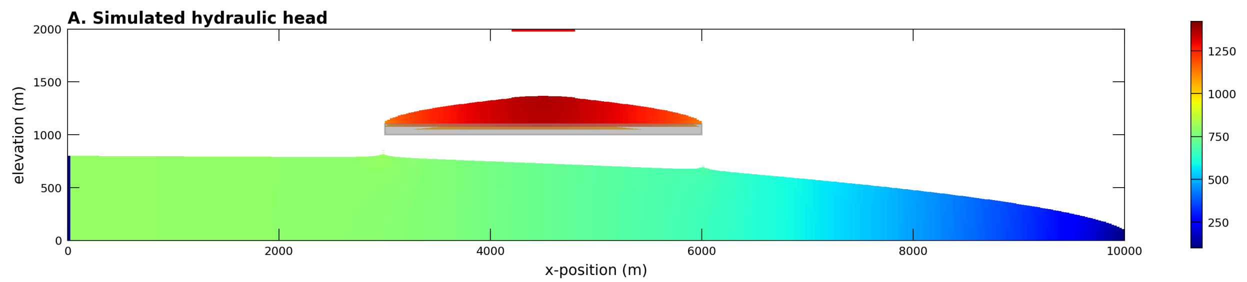
```
    # add a rectangle to show the confining layer
    confining_rect = mpl.patches.Rectangle(
        (3000, 1000), 3000, 100, color="gray", alpha=0.5
    )
    ax.add_patch(confining_rect)

    # set labels using styles
    styles.xlabel(label="x-position (m)")
    styles.ylabel(label="elevation (m)")
    styles.heading(
        letter="A.", heading="Simulated hydraulic head", fontsize=10
    )
    ax.set_aspect(1.0)
```



Plotting concentration model results using the USGSMap() style

[34]:
```
# load the transport output file
cobj = gwt6.output.concentration()
plot_times = [100, 1000, 3000]
obs1 = (48, 0, 118)  # Layer, row, and column for observation 1
obs2 = (76, 0, 358)  # Layer, row, and column for observation 2
xgrid, _, zgrid = gwf6.modelgrid.xyzcellcenters


with styles.USGSPlot():
    fig, axes = plt.subplots(3, 1, figsize=(15, 9), tight_layout=True)
    for ix, totim in enumerate(plot_times):
        heading = f"Time = {totim}"
        conc = cobj.get_data(totim=totim)
        ax = axes[ix]
        xsect = flopy.plot.PlotCrossSection(model=gwf6, ax=ax, line={"row": 0})
        pc = xsect.plot_array(conc, head=head, cmap="jet", vmin=0, vmax=1)
        xsect.plot_bc(ftype="RCH", color="red")
        xsect.plot_bc(ftype="CHD")

        # plot confining layer
        confining_rect = mpl.patches.Rectangle(
            (3000, 1000), 3000, 100, color="gray", alpha=0.5
        )
        ax.add_patch(confining_rect)
```

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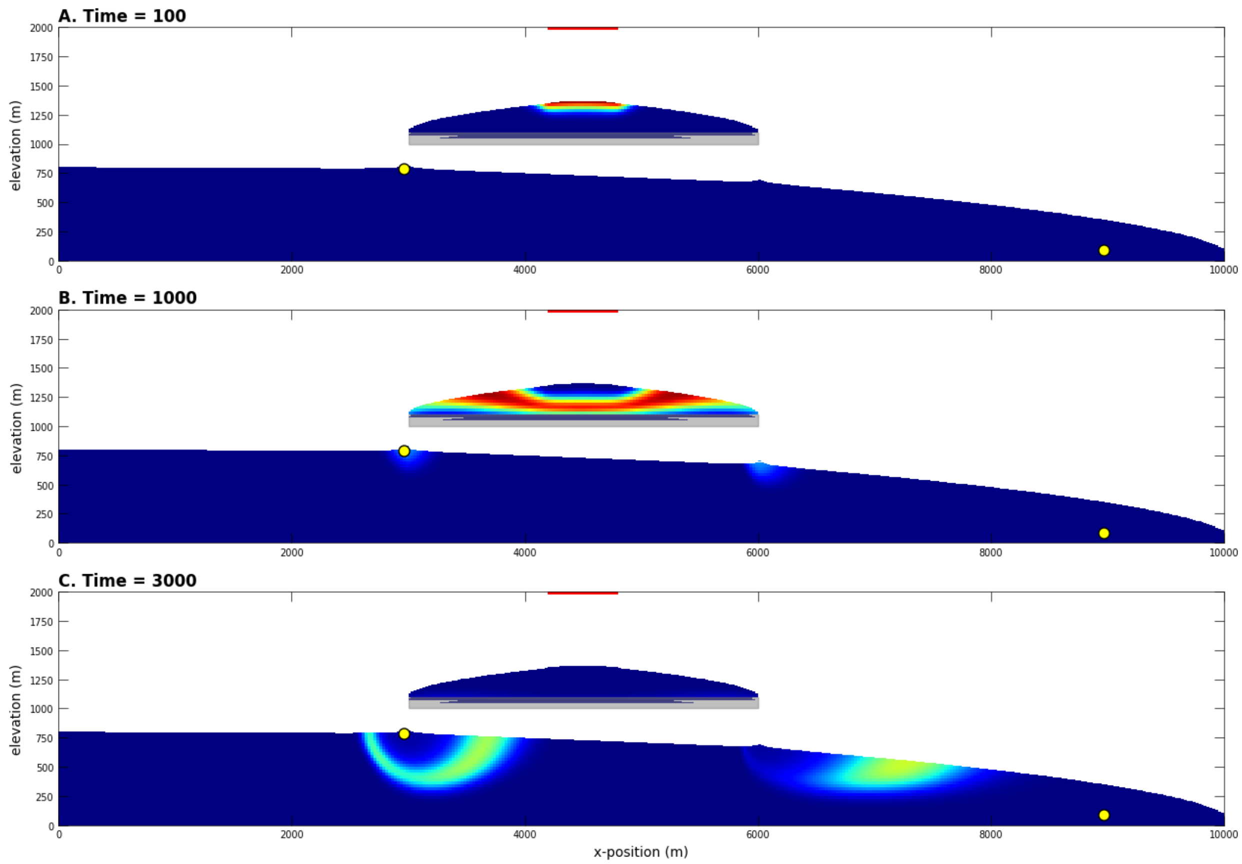
```
        # set axis labels and title using styles
        styles.ylabel(ax=ax, label="elevation (m)", fontsize=10)
        if ix == 2:
            styles.xlabel(ax=ax, label="x-position (m)", fontsize=10)
        styles.heading(ax=ax, heading=heading, idx=ix, fontsize=12)

        ax.set_aspect(1.0)

        # add observation locations based on grid cell centers
        for k, i, j in [obs1, obs2]:
            x = xgrid[i, j]
            z = zgrid[k, i, j]
            ax.plot(x, z, mfc="yellow", mec="black", marker="o", ms="8")
```



Summary

This notebook demonstrates some of the plotting functionality available with flopy. Although not described here, the plotting functionality tries to be general by passing keyword arguments passed to the `PlotCrossSection` methods down into the `matplotlib.pyplot` routines that do the actual plotting. For those looking to customize these plots, it may be necessary to search for the available keywords by understanding the types of objects that are created by the `PlotCrossSection` methods. The `PlotCrossSection` methods return these matplotlib.collections objects so that they could be fine-tuned later in the script before plotting.

Hope this gets you started!

[35]:
```
try:
    # ignore PermissionError on Windows
    tempdir.cleanup()
except:
    pass
```

6.2.4 Making Maps of Your Model

This notebook demonstrates the mapping capabilities of FloPy. It demonstrates these capabilities by loading and running existing models and then showing how the PlotMapView object and its methods can be used to make nice plots of the model grid, boundary conditions, model results, shape files, etc.

Mapping is demonstrated for MODFLOW-2005, MODFLOW-USG, and MODFLOW-6 models in this notebook

[1]:
```
import os
import sys
from tempfile import TemporaryDirectory

import matplotlib as mpl
import matplotlib.pyplot as plt
import numpy as np
import shapefile

sys.path.append(os.path.join("..", "common"))
import notebook_utils

# run installed version of flopy or add local path
try:
    import flopy
except:
    fpth = os.path.abspath(os.path.join("..", ".."))
    sys.path.append(fpth)
    import flopy

print(sys.version)
print(f"numpy version: {np.__version__}")
print(f"matplotlib version: {mpl.__version__}")
print(f"flopy version: {flopy.__version__}")
```

```
3.8.18 (default, Aug 28 2023, 08:27:22)
[GCC 11.4.0]
numpy version: 1.24.4
matplotlib version: 3.7.4
flopy version: 3.5.0
```

[2]:
```
# Set name of MODFLOW exe
# assumes executable is in users path statement
v2005 = "mf2005"
exe_name_2005 = "mf2005"
vmf6 = "mf6"
exe_name_mf6 = "mf6"
exe_mp = "mp6"

# Set the paths
prj_root = notebook_utils.get_project_root_path()
loadpth = str(prj_root / "examples" / "data" / "freyberg")
tempdir = TemporaryDirectory()
modelpth = tempdir.name
```

Load and Run an Existing MODFLOW-2005 Model

A model called the "Freyberg Model" is located in the loadpth folder. In the following code block, we load that model, then change into a new workspace (modelpth) where we recreate and run the model. For this to work properly, the MODFLOW-2005 executable (mf2005) must be in the path. We verify that it worked correctly by checking for the presence of freyberg.hds and freyberg.cbc.

[3]:
```
ml = flopy.modflow.Modflow.load(
    "freyberg.nam", model_ws=loadpth, exe_name=exe_name_2005, version=v2005
)
ml.change_model_ws(new_pth=modelpth)
ml.write_input()
success, buff = ml.run_model(silent=True, report=True)
if success:
    for line in buff:
        print(line)
else:
    raise ValueError("Failed to run.")

files = ["freyberg.hds", "freyberg.cbc"]
for f in files:
    if os.path.isfile(os.path.join(modelpth, f)):
        msg = f"Output file located: {f}"
        print(msg)
    else:
        errmsg = f"Error. Output file cannot be found: {f}"
        print(errmsg)
```

```
                                  MODFLOW-2005
    U.S. GEOLOGICAL SURVEY MODULAR FINITE-DIFFERENCE GROUND-WATER FLOW MODEL
                             Version 1.12.00 2/3/2017
```

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```
 Using NAME file: freyberg.nam
 Run start date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:31:39

 Solving:  Stress period:     1    Time step:     1    Ground-Water Flow Eqn.
 Run end date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:31:39
 Elapsed run time:  0.006 Seconds

  Normal termination of simulation
Output file located: freyberg.hds
Output file located: freyberg.cbc
```

Create and Run MODPATH 6 model

The MODFLOW-2005 model created in the previous code block will be used to create a endpoint capture zone and pathline analysis for the pumping wells in the model.

[4]:
```
mp = flopy.modpath.Modpath6(
    "freybergmp", exe_name=exe_mp, modflowmodel=ml, model_ws=modelpth
)
mpbas = flopy.modpath.Modpath6Bas(
    mp,
    hnoflo=ml.bas6.hnoflo,
    hdry=ml.lpf.hdry,
    ibound=ml.bas6.ibound.array,
    prsity=0.2,
    prsityCB=0.2,
)
sim = mp.create_mpsim(trackdir="forward", simtype="endpoint", packages="RCH")
mp.write_input()
success, buff = mp.run_model(silent=True, report=True)
if success:
    for line in buff:
        print(line)
else:
    raise ValueError("Failed to run.")

mpp = flopy.modpath.Modpath6(
    "freybergmpp", exe_name=exe_mp, modflowmodel=ml, model_ws=modelpth
)
mpbas = flopy.modpath.Modpath6Bas(
    mpp,
    hnoflo=ml.bas6.hnoflo,
    hdry=ml.lpf.hdry,
    ibound=ml.bas6.ibound.array,
    prsity=0.2,
    prsityCB=0.2,
)
sim = mpp.create_mpsim(trackdir="backward", simtype="pathline", packages="WEL")
mpp.write_input()
mpp.run_model()
```

```
Processing basic data ...
Checking head file ...
Checking budget file and building index ...

Run particle tracking simulation ...
Processing Time Step     1 Period     1.  Time =  1.00000E+01
Particle tracking complete. Writing endpoint file ...
End of MODPATH simulation. Normal termination.
FloPy is using the following executable to run the model: ../../home/runner/.local/bin/
↪modflow/mp6
Processing basic data ...
Checking head file ...
Checking budget file and building index ...

Run particle tracking simulation ...
Processing Time Step     1 Period     1.  Time =  1.00000E+01
Particle tracking complete. Writing endpoint file ...
End of MODPATH simulation. Normal termination.
```

[4]:

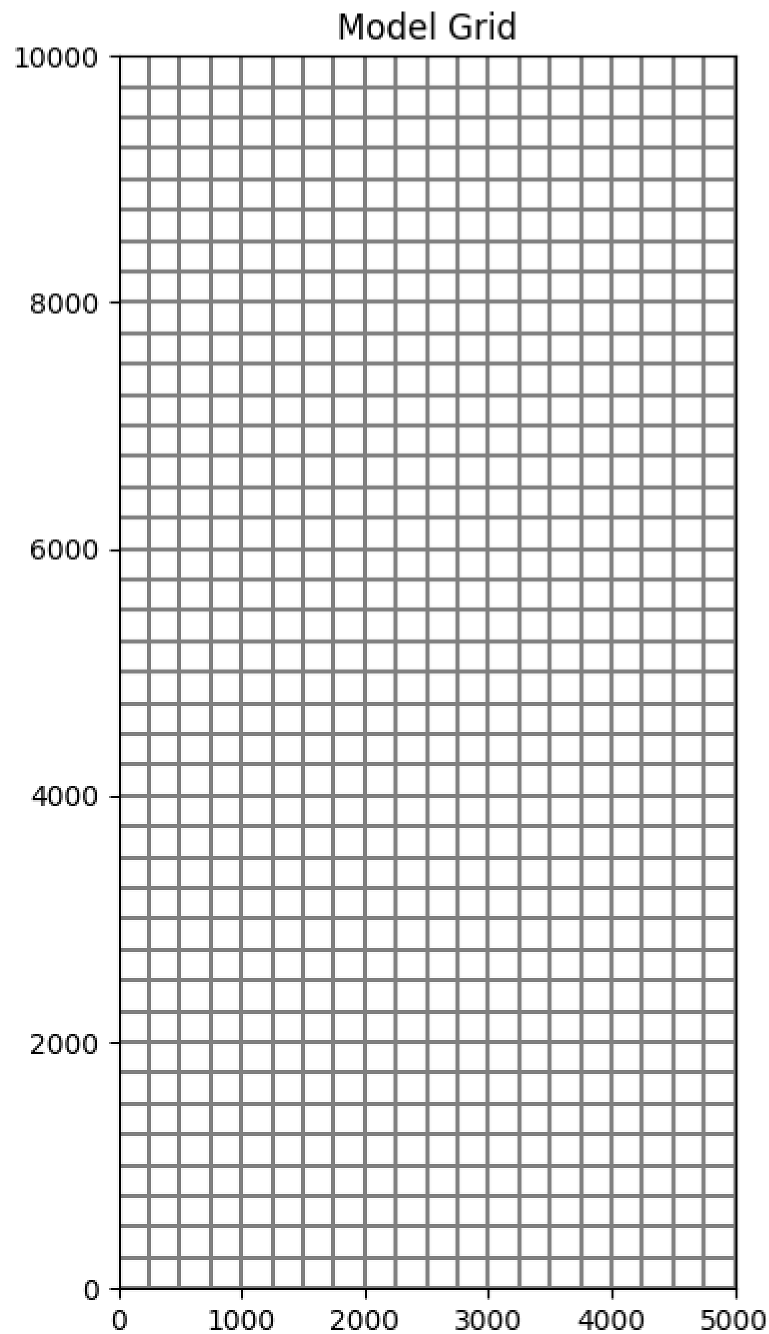
```
(True, [])
```

Creating a Map of the Model Grid

Now that we have a model, we can use the flopy plotting utilities to make maps. We will start by making a map of the model grid using the `PlotMapView` class and the `plot_grid()` method of that class.

[5]:

```
# First step is to set up the plot
fig = plt.figure(figsize=(8, 8))
ax = fig.add_subplot(1, 1, 1, aspect="equal")

# Next we create an instance of the PlotMapView class
mapview = flopy.plot.PlotMapView(model=ml)

# Then we can use the plot_grid() method to draw the grid
# The return value for this function is a matplotlib LineCollection object,
# which could be manipulated (or used) later if necessary.
linecollection = mapview.plot_grid()

t = ax.set_title("Model Grid")
```

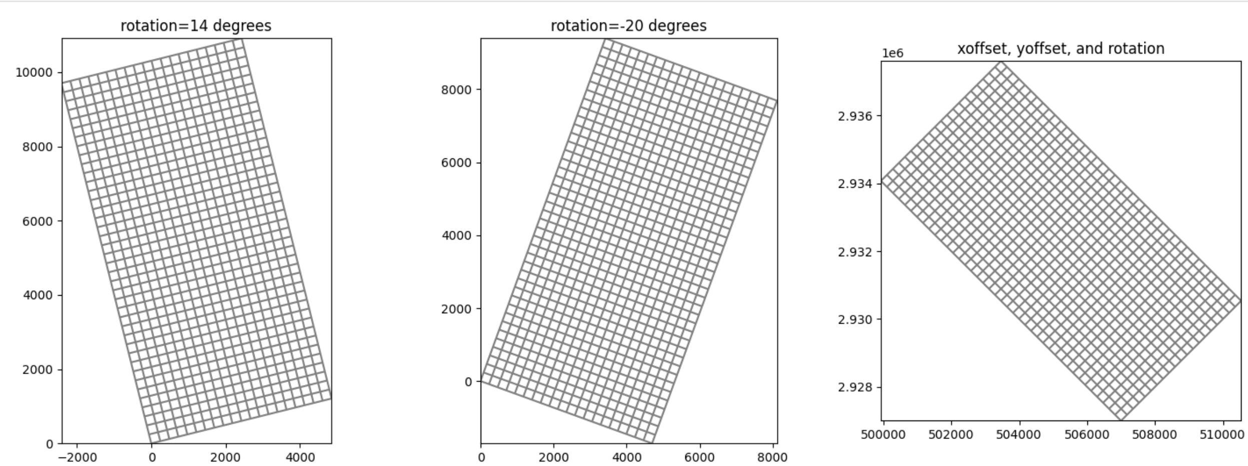

Model Grid
10000
8000
6000
4000
2000
0
0
1000
2000
3000
4000
5000

Grid transformations and setting coordinate information

The `PlotMapView` class can plot the position of the model grid in space. However, transformations must be done on the modelgrid using `set_coord_info()`. This allows the user to set the coordinate information once, and then they are able to generate as many instanstances of `PlotMapView` as they wish, without providing the coordinate info again.

Here we demonstrate the effects of these values. In the first two plots, the grid origin (lower left corner) remains fixed at (0, 0). These first two plots demostrate how work with coordinate info in the `PlotMapView` class. The third example shows the grid origin set at (507000 E, 2927000 N)

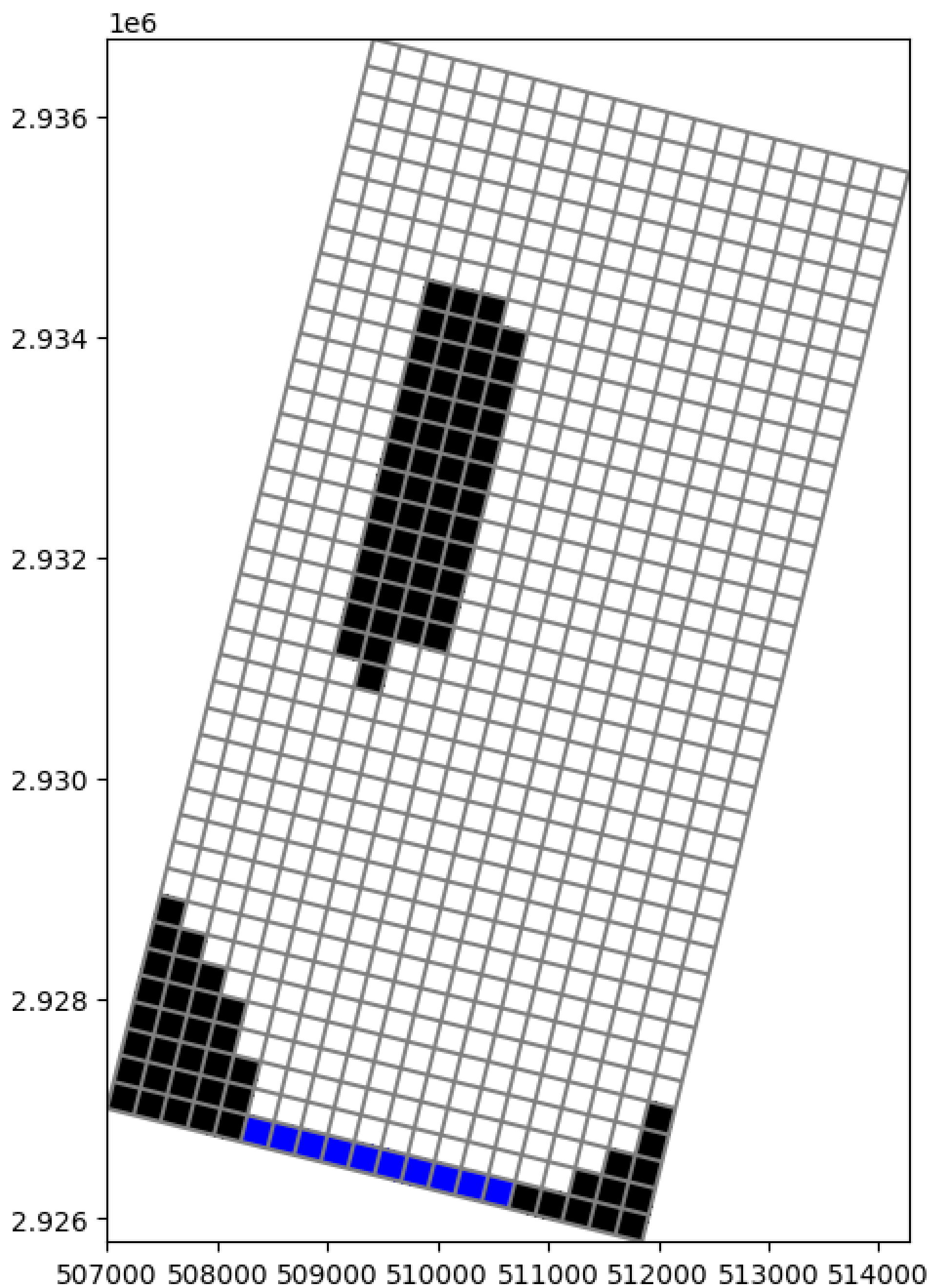
[6]:
```
fig = plt.figure(figsize=(18, 6))

ax = fig.add_subplot(1, 3, 1, aspect="equal")

# set modelgrid rotation
ml.modelgrid.set_coord_info(angrot=14)

# generate a plot
mapview = flopy.plot.PlotMapView(model=ml)
linecollection = mapview.plot_grid()
t = ax.set_title("rotation=14 degrees")

# re-set the modelgrid rotation
ml.modelgrid.set_coord_info(angrot=-20)

ax = fig.add_subplot(1, 3, 2, aspect="equal")
mapview = flopy.plot.PlotMapView(model=ml)
linecollection = mapview.plot_grid()
t = ax.set_title("rotation=-20 degrees")

# re-set the modelgrid origin and rotation
ml.modelgrid.set_coord_info(xoff=507000, yoff=2927000, angrot=45)

ax = fig.add_subplot(1, 3, 3, aspect="equal")
mapview = flopy.plot.PlotMapView(model=ml)
linecollection = mapview.plot_grid()
t = ax.set_title("xoffset, yoffset, and rotation")
```



Ploting Ibound

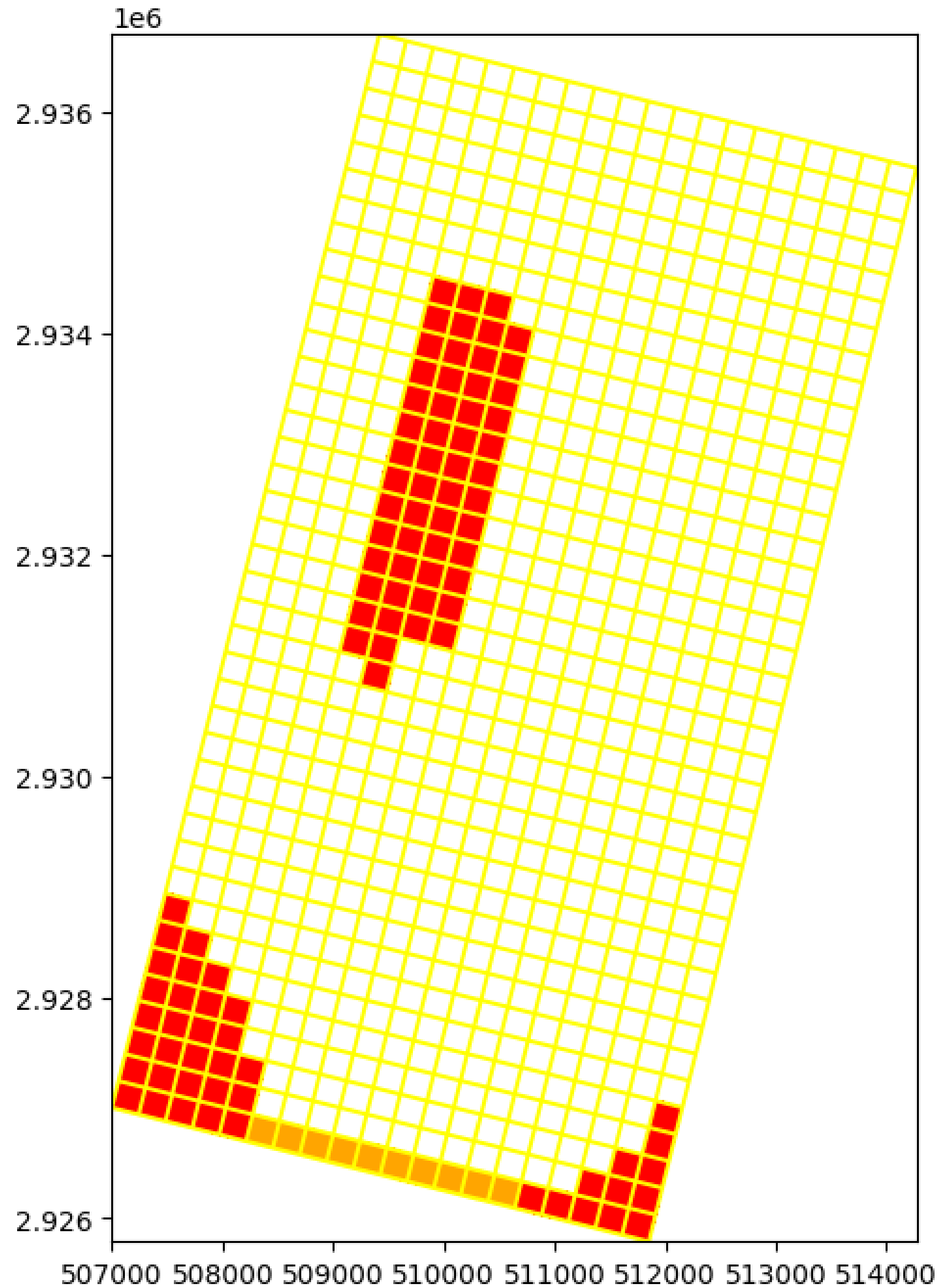
The `plot_ibound()` method can be used to plot the boundary conditions contained in the ibound arrray, which is part of the MODFLOW Basic Package. The `plot_ibound()` method returns a matplotlib QuadMesh object (matplotlib.collections.QuadMesh). If you are familiar with the matplotlib collections, then this may be important to you, but if not, then don't worry about the return objects of these plotting function.

[7]:
```python
fig = plt.figure(figsize=(8, 8))
ax = fig.add_subplot(1, 1, 1, aspect="equal")

# set the grid rotation and then plot
ml.modelgrid.set_coord_info(angrot=-14)
mapview = flopy.plot.PlotMapView(model=ml)
quadmesh = mapview.plot_ibound()
linecollection = mapview.plot_grid()
```



We can also change the colors by calling the `color_noflow` and `color_ch` parameters in `plot_ibound()` and the `colors` parameter in `plot_grid()`

[8]:
```
fig = plt.figure(figsize=(8, 8))
ax = fig.add_subplot(1, 1, 1, aspect="equal")
mapview = flopy.plot.PlotMapView(model=ml)
quadmesh = mapview.plot_ibound(color_noflow="red", color_ch="orange")
linecollection = mapview.plot_grid(colors="yellow")
```


1e6
2.936
2.934
2.932
2.930
2.928
2.926
507000
508000
509000
510000
511000
512000
513000
514000

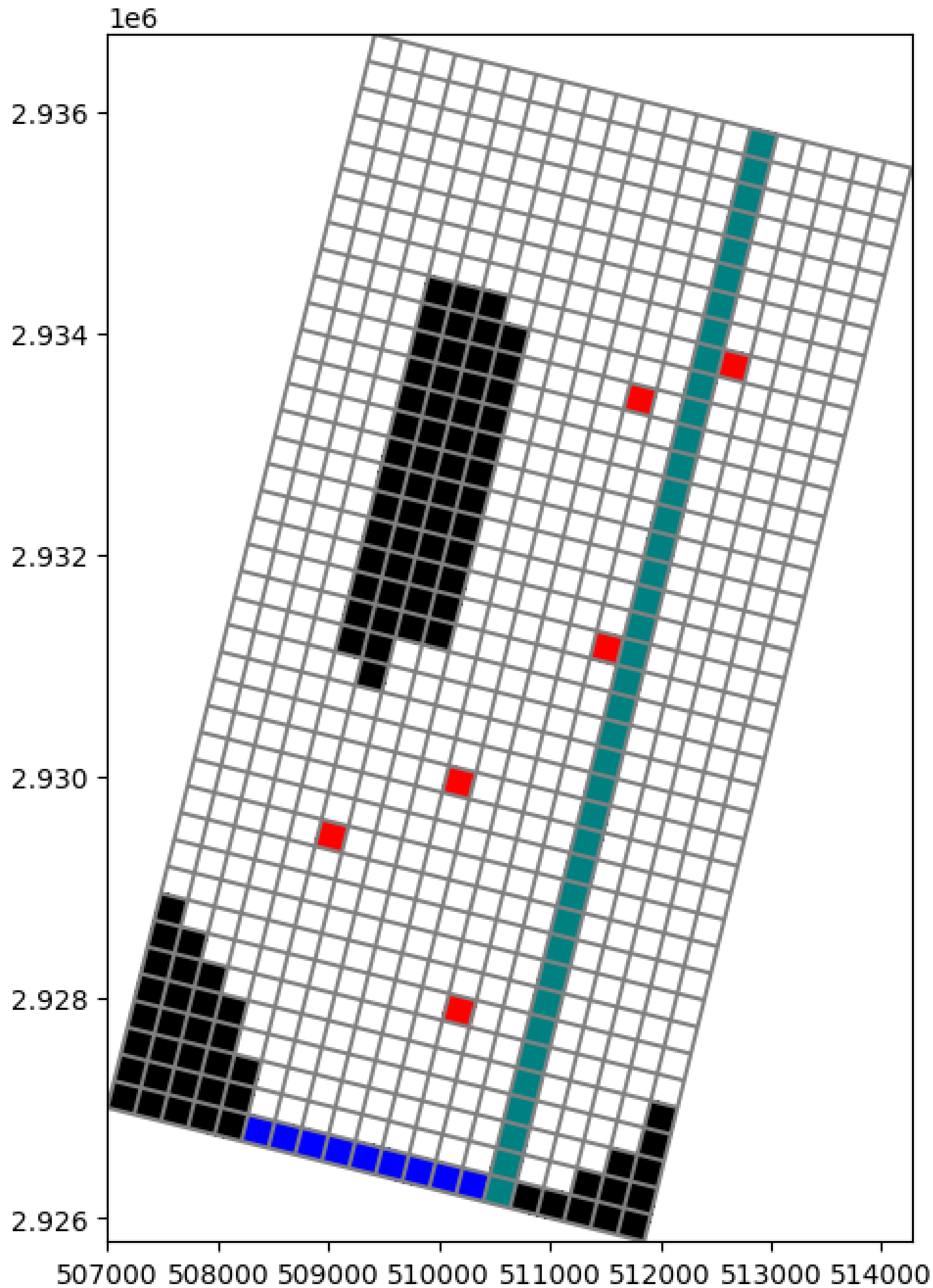
Plotting Boundary Conditions

The plot_bc() method can be used to plot boundary conditions. It is setup to use the following dictionary to assign colors, however, these colors can be changed in the method call.

```
bc_color_dict = {'default': 'black', 'WEL': 'red', 'DRN': 'yellow',
                 'RIV': 'green', 'GHB': 'cyan', 'CHD': 'navy'}
```

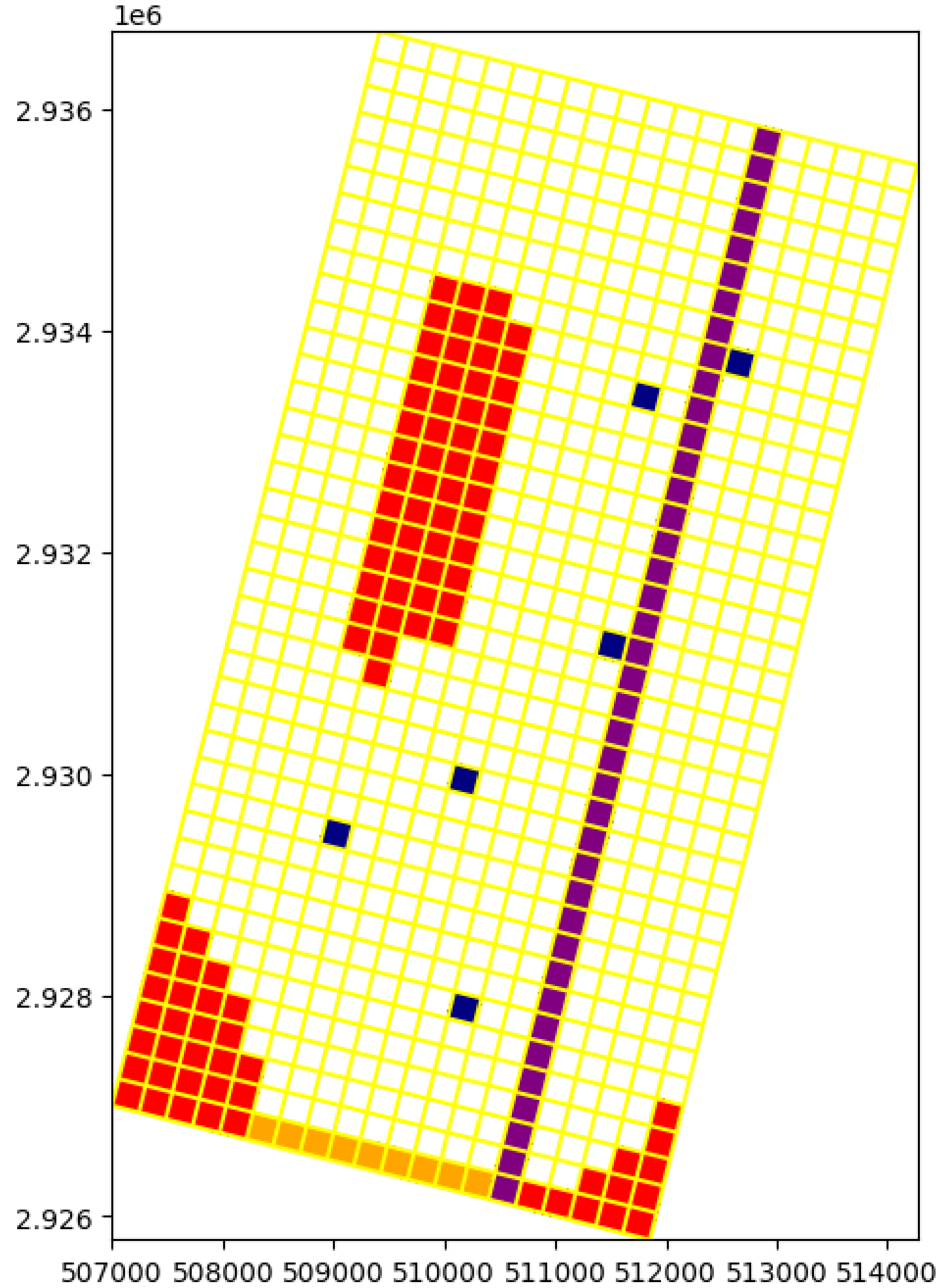
Here, we plot the location of river cells and the location of well cells.

[9]:
```
fig = plt.figure(figsize=(8, 8))
ax = fig.add_subplot(1, 1, 1, aspect="equal")
mapview = flopy.plot.PlotMapView(model=ml)
quadmesh = mapview.plot_ibound()
quadmesh = mapview.plot_bc("RIV")
quadmesh = mapview.plot_bc("WEL")
linecollection = mapview.plot_grid()
```



The colors can be changed by using the `color_noflow` and `color_ch` parameters in `plot_ibound()`, the `color` parameter in `plot_bc()`, and the `colors` parameter in `plot_grid()`

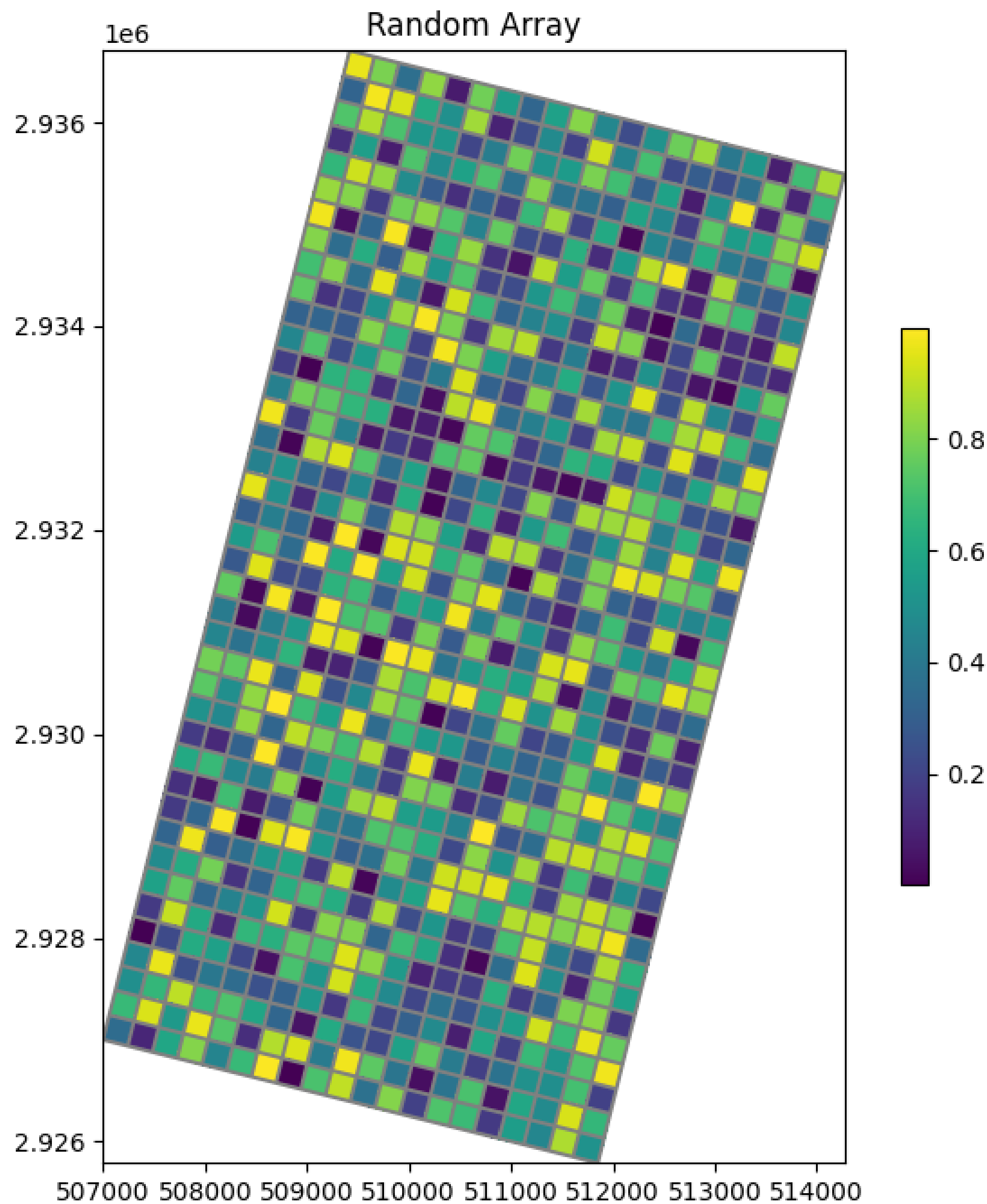
[10]:
```python
fig = plt.figure(figsize=(8, 8))
ax = fig.add_subplot(1, 1, 1, aspect="equal")
mapview = flopy.plot.PlotMapView(model=ml)
quadmesh = mapview.plot_ibound(color_noflow="red", color_ch="orange")
quadmesh = mapview.plot_bc("RIV", color="purple")
quadmesh = mapview.plot_bc("WEL", color="navy")
linecollection = mapview.plot_grid(colors="yellow")
```


1e6
2.936
2.934
2.932
2.930
2.928
2.926
507000 508000 509000 510000 511000 512000 513000 514000

Plotting an Array

PlotMapView has a plot_array() method. The plot_array() method will accept either a 2D or 3D array. If a 3D array is passed, then the layer parameter for the PlotMapView object will be used (note that the PlotMapView object can be created with a layer= argument).

[11]:
```
# Create a random array and plot it
a = np.random.random((ml.dis.nrow, ml.dis.ncol))

fig = plt.figure(figsize=(8, 8))
ax = fig.add_subplot(1, 1, 1, aspect="equal")
ax.set_title("Random Array")
mapview = flopy.plot.PlotMapView(model=ml, layer=0)
quadmesh = mapview.plot_array(a)
linecollection = mapview.plot_grid()
cb = plt.colorbar(quadmesh, shrink=0.5)
```



[12]:
```
# Plot the model bottom array
a = ml.dis.botm.array

fig = plt.figure(figsize=(8, 8))
ax = fig.add_subplot(1, 1, 1, aspect="equal")
ax.set_title("Model Bottom Elevations")
mapview = flopy.plot.PlotMapView(model=ml, layer=0)
quadmesh = mapview.plot_array(a)
```

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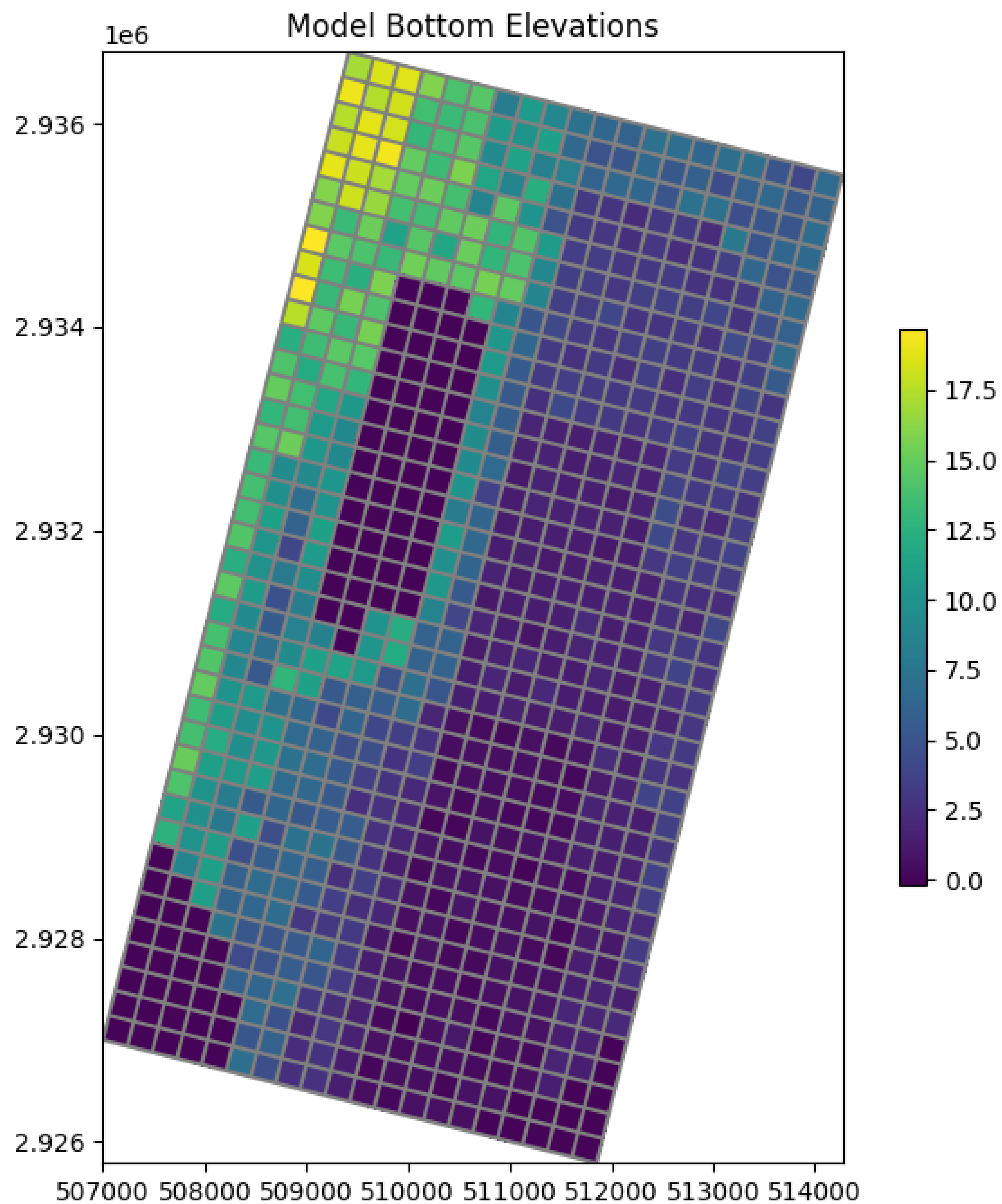
```
linecollection = mapview.plot_grid()
cb = plt.colorbar(quadmesh, shrink=0.5)
```



Contouring an Array

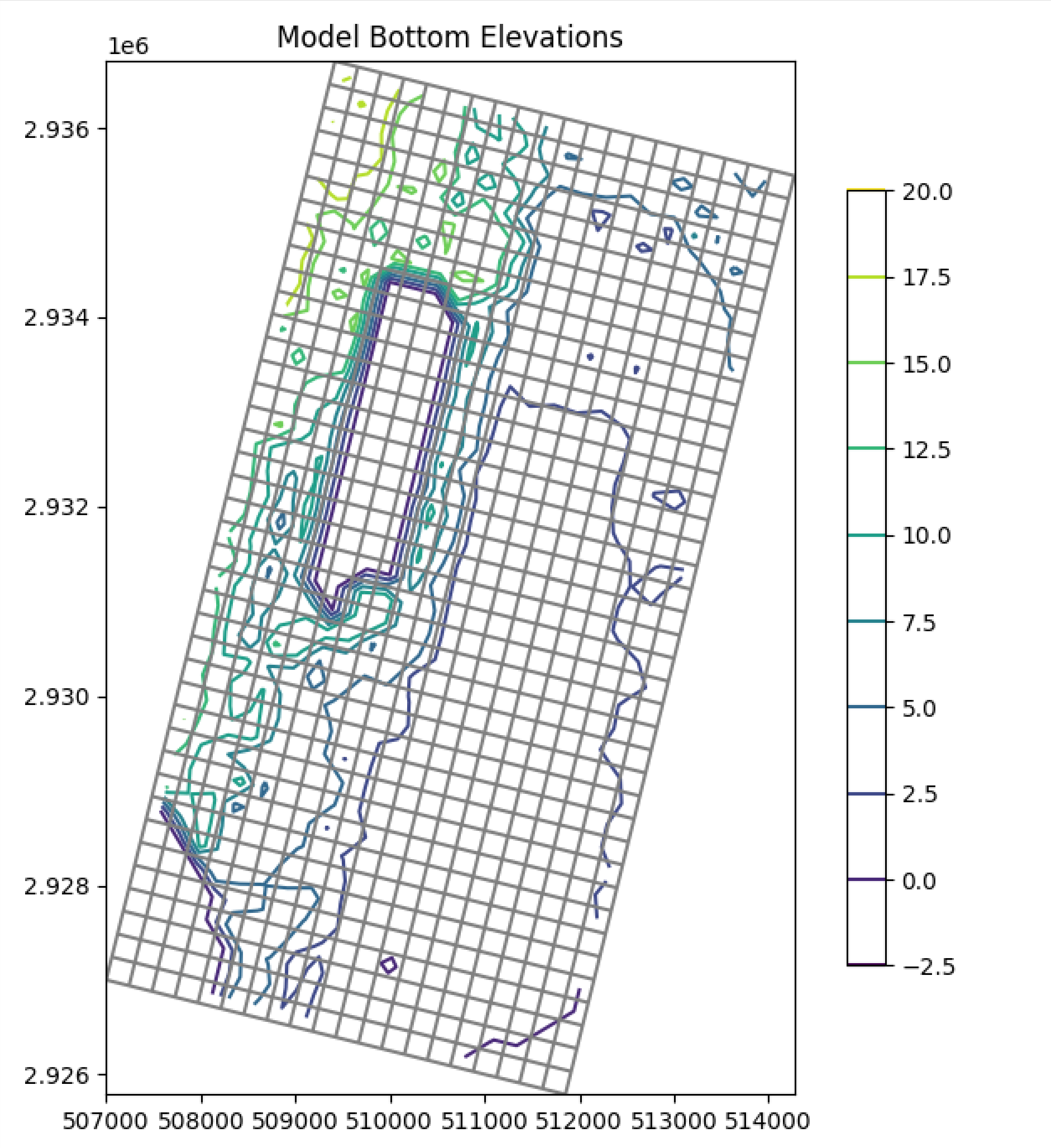
`PlotMapView` also has a `contour_array()` method. It also takes a 2D or 3D array and will contour the layer slice if 3D.

[13]:
```
# Contour the model bottom array
a = ml.dis.botm.array

fig = plt.figure(figsize=(8, 8))
ax = fig.add_subplot(1, 1, 1, aspect="equal")
ax.set_title("Model Bottom Elevations")
mapview = flopy.plot.PlotMapView(model=ml, layer=0)
contour_set = mapview.contour_array(a)
linecollection = mapview.plot_grid()

plt.colorbar(contour_set, shrink=0.75)
```

[13]:
```
<matplotlib.colorbar.Colorbar at 0x7fbc454ac130>
```



[14]:
```python
# The contour_array() method will take any keywords
# that can be used by the matplotlib.pyplot.contour
# function. So we can pass in levels, for example.
a = ml.dis.botm.array
levels = np.arange(0, 20, 0.5)

fig = plt.figure(figsize=(8, 8))
ax = fig.add_subplot(1, 1, 1, aspect="equal")
```

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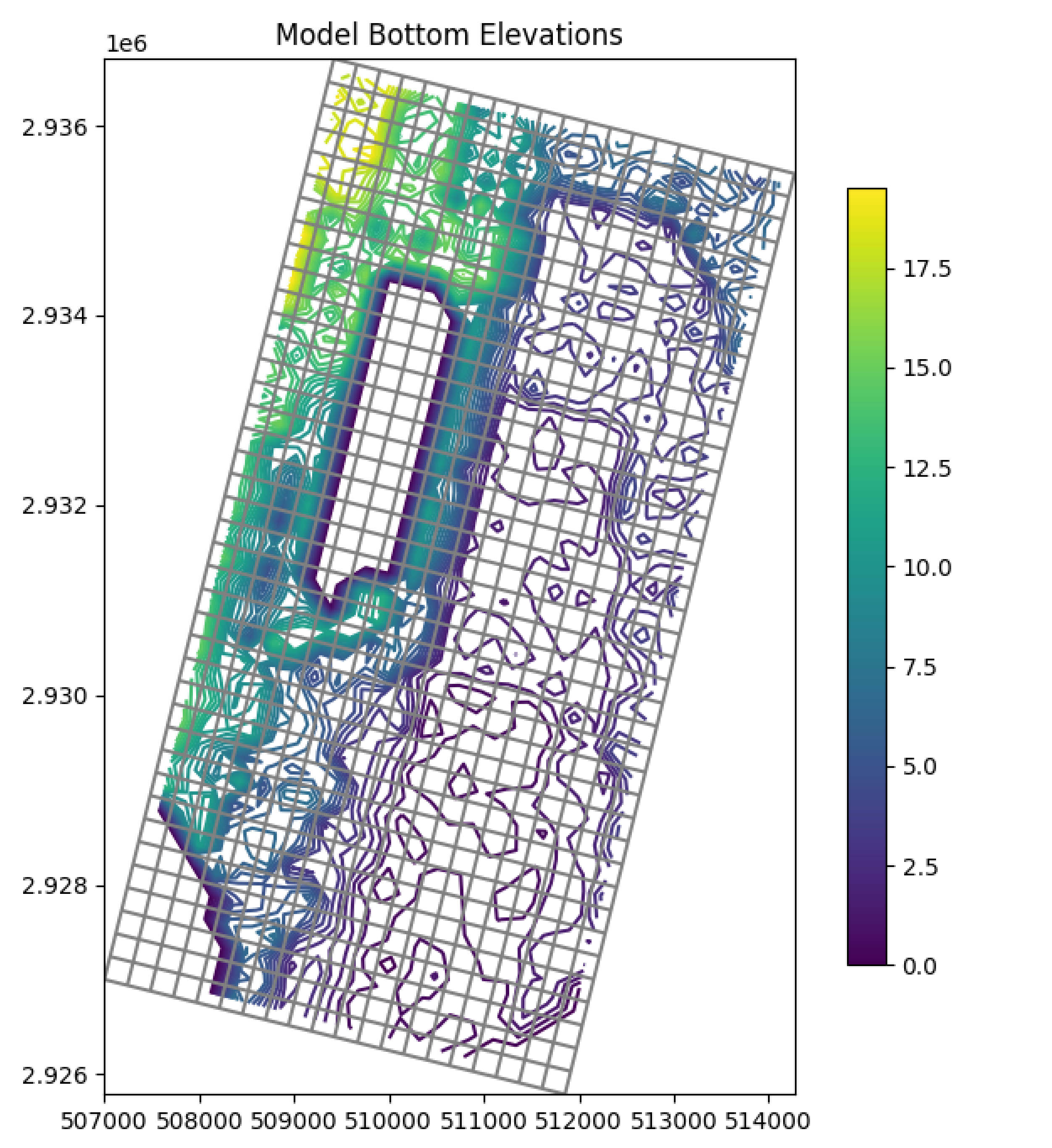
```
ax.set_title("Model Bottom Elevations")
mapview = flopy.plot.PlotMapView(model=ml, layer=0)
contour_set = mapview.contour_array(a, levels=levels)
linecollection = mapview.plot_grid()

# set up and plot a continuous colorbar in matplotlib for a contour plot
norm = mpl.colors.Normalize(
    vmin=contour_set.cvalues.min(), vmax=contour_set.cvalues.max()
)
sm = plt.cm.ScalarMappable(norm=norm, cmap=contour_set.cmap)
sm.set_array([])
fig.colorbar(sm, shrink=0.75, ax=ax)
```

[14]:
```
<matplotlib.colorbar.Colorbar at 0x7fbc45b64d90>
```



Array contours can be exported directly to a shapefile.

[15]:
```
from flopy.export.utils import (  # use export_contourf for filled contours
    export_contours,
)

shp_path = os.path.join(modelpth, "contours.shp")
export_contours(shp_path, contour_set)
```

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```
from shapefile import Reader

with Reader(shp_path) as r:
    nshapes = len(r.shapes())
    print("Contours:", nshapes)
```

```
No CRS information for writing a .prj file.
Supply an valid coordinate system reference to the attached modelgrid object or .
↪export() method.
Contours: 360
```

Plotting Heads

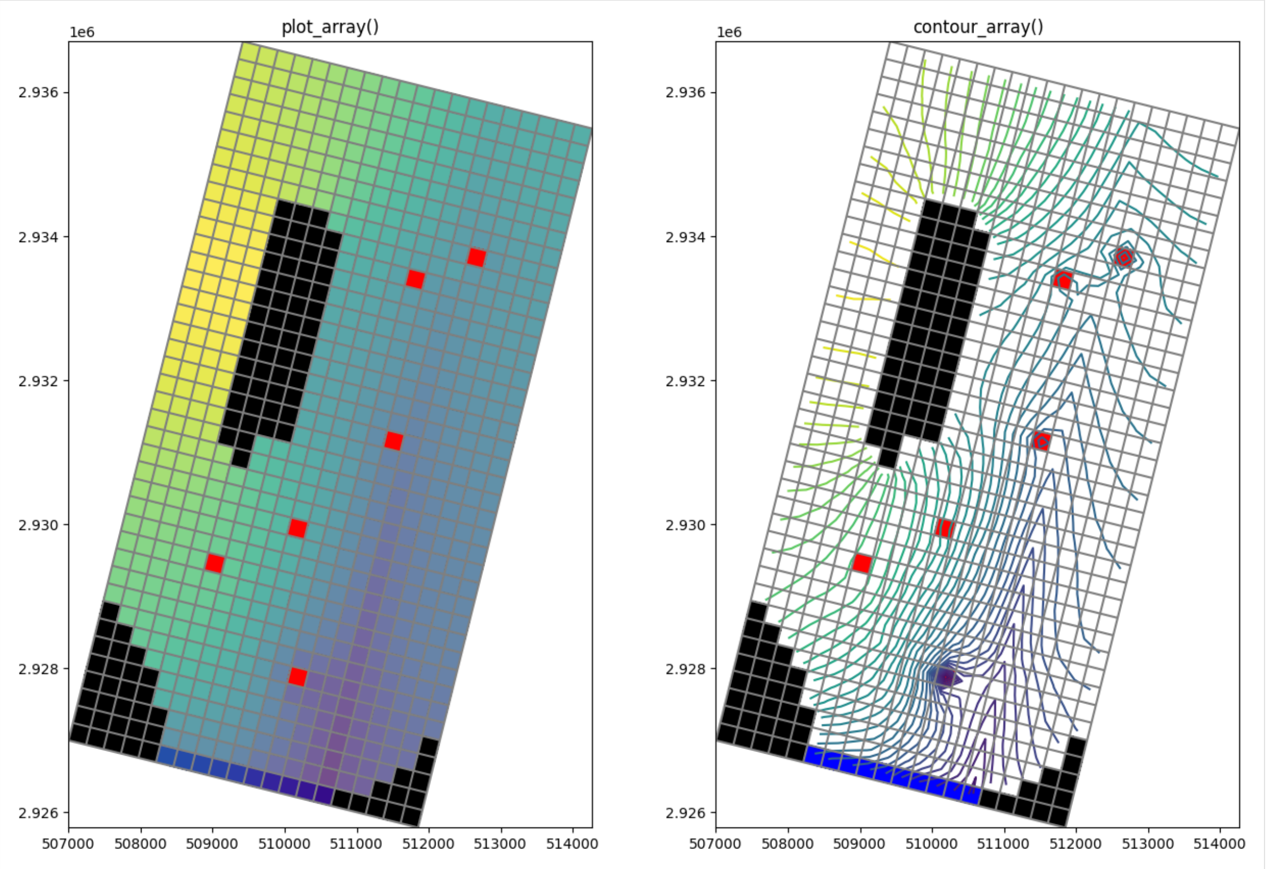
So this means that we can easily plot results from the simulation by extracting heads using `flopy.utils.HeadFile`. Here we plot the simulated heads.

[16]:
```
fname = os.path.join(modelpth, "freyberg.hds")
hdobj = flopy.utils.HeadFile(fname)
head = hdobj.get_data()
levels = np.arange(10, 30, 0.5)

fig = plt.figure(figsize=(15, 10))

ax = fig.add_subplot(1, 2, 1, aspect="equal")
ax.set_title("plot_array()")
mapview = flopy.plot.PlotMapView(model=ml)
quadmesh = mapview.plot_ibound()
quadmesh = mapview.plot_array(head, alpha=0.5)
mapview.plot_bc("WEL")
linecollection = mapview.plot_grid()

ax = fig.add_subplot(1, 2, 2, aspect="equal")
ax.set_title("contour_array()")
mapview = flopy.plot.PlotMapView(model=ml)
quadmesh = mapview.plot_ibound()
mapview.plot_bc("WEL")
contour_set = mapview.contour_array(head, levels=levels)
linecollection = mapview.plot_grid()
```



Plotting Discharge Vectors

`PlotMapView` has a `plot_vector()` method, which takes vector components in the x- and y-directions at the cell centers. The x- and y-vector components are calculated from the `'FLOW RIGHT FACE'` and `'FLOW FRONT FACE'` arrays, which can be written by MODFLOW to the cell by cell budget file. These array can be extracted from the cell by cell flow file using the `flopy.utils.CellBudgetFile` object as shown below. Once they are extracted, they can be passed to the `postprocessing.get_specific_discharge()` method to get the discharge vectors and plotted using the `plot_vector()` method.

Note: `postprocessing.get_specific_discharge()` also takes the head array as an optional argument. The head array is used to convert the volumetric discharge in dimensions of L^3/T to specific discharge in dimensions of L/T.

[17]:
```
fname = os.path.join(modelpth, "freyberg.cbc")
cbb = flopy.utils.CellBudgetFile(fname)
head = hdobj.get_data()
frf = cbb.get_data(text="FLOW RIGHT FACE")[0]
fff = cbb.get_data(text="FLOW FRONT FACE")[0]
flf = None

qx, qy, qz = flopy.utils.postprocessing.get_specific_discharge(
    (frf, fff, None), ml
)  # no head array for volumetric discharge
sqx, sqy, sqz = flopy.utils.postprocessing.get_specific_discharge(
    (frf, fff, None), ml, head
```

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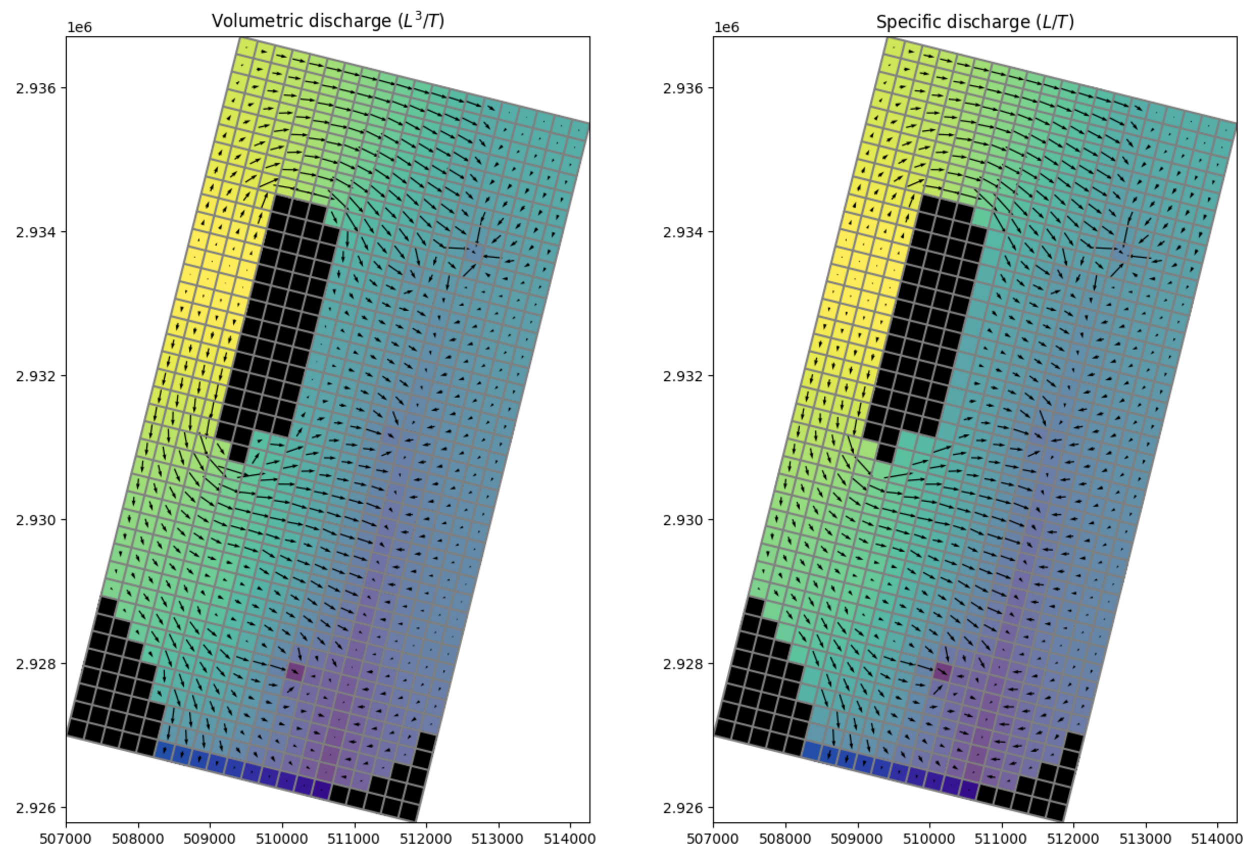
```
)

fig = plt.figure(figsize=(15, 10))

ax = fig.add_subplot(1, 2, 1, aspect="equal")
ax.set_title("Volumetric discharge (" + r"$L^3/T$" + ")")
mapview = flopy.plot.PlotMapView(model=ml)
quadmesh = mapview.plot_ibound()
quadmesh = mapview.plot_array(head, alpha=0.5)
quiver = mapview.plot_vector(qx, qy)
linecollection = mapview.plot_grid()

ax = fig.add_subplot(1, 2, 2, aspect="equal")
ax.set_title("Specific discharge (" + r"$L/T$" + ")")
mapview = flopy.plot.PlotMapView(model=ml)
quadmesh = mapview.plot_ibound()
quadmesh = mapview.plot_array(head, alpha=0.5)
quiver = mapview.plot_vector(
    sqx, sqy
)  # include the head array for specific discharge
linecollection = mapview.plot_grid()
```

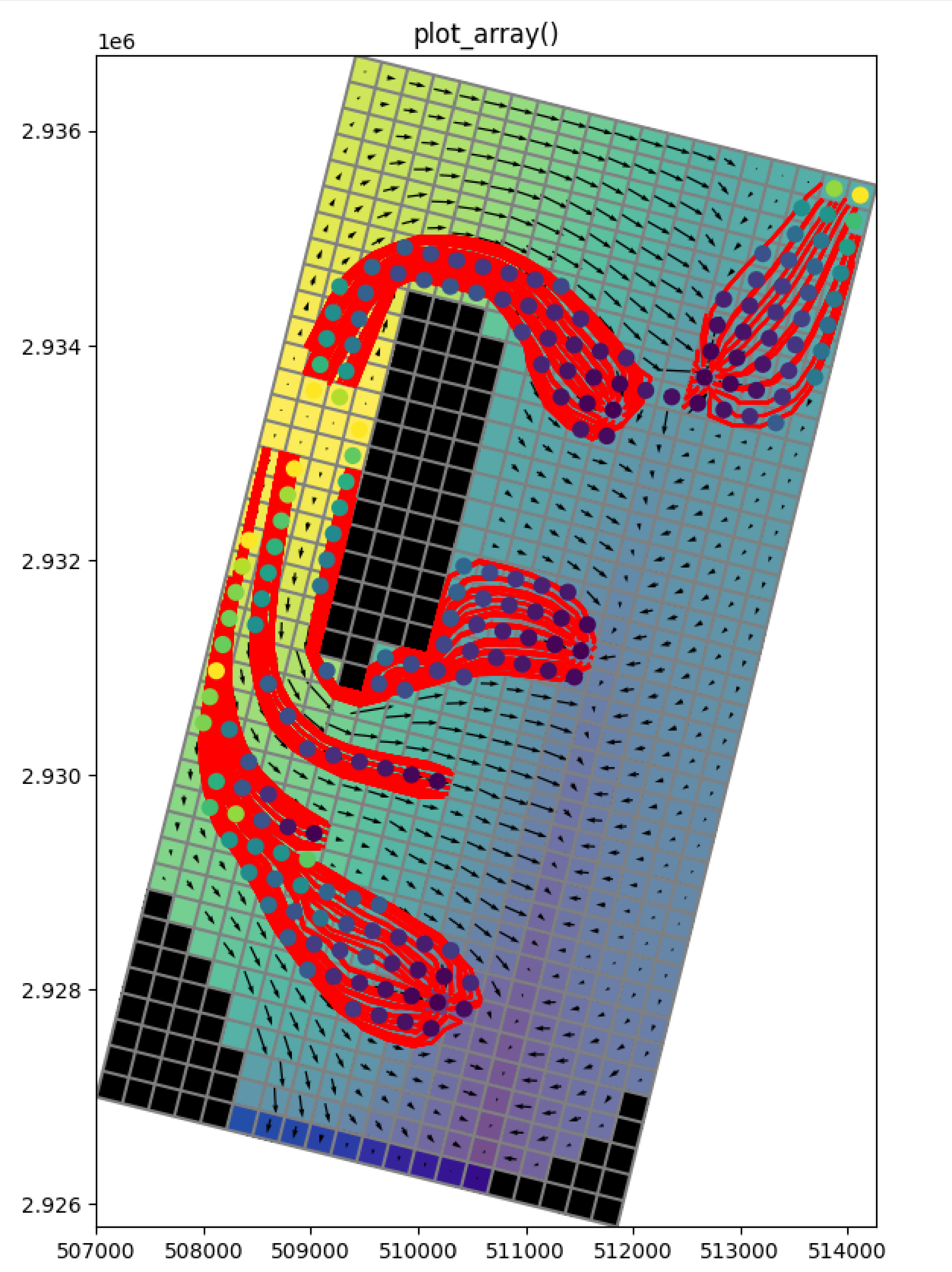


Plotting MODPATH endpoints and pathlines

PlotMapView has a plot_endpoint() and plot_pathline() method, which takes MODPATH endpoint and pathline data and plots them on the map object. Here we load the endpoint and pathline data and plot them on the head and discharge data previously plotted. Pathlines are shown for all times less than or equal to 200 years. Recharge capture zone data for all of the pumping wells are plotted as circle markers colored by travel time.

[18]:
```python
# load the endpoint data
endfile = os.path.join(modelpth, mp.sim.endpoint_file)
endobj = flopy.utils.EndpointFile(endfile)
ept = endobj.get_alldata()

# load the pathline data
pthfile = os.path.join(modelpth, mpp.sim.pathline_file)
pthobj = flopy.utils.PathlineFile(pthfile)
plines = pthobj.get_alldata()

# plot the data
fig = plt.figure(figsize=(10, 10))

ax = fig.add_subplot(1, 1, 1, aspect="equal")
ax.set_title("plot_array()")
mapview = flopy.plot.PlotMapView(model=ml)
quadmesh = mapview.plot_ibound()
quadmesh = mapview.plot_array(head, alpha=0.5)
quiver = mapview.plot_vector(sqx, sqy)
linecollection = mapview.plot_grid()
for d in ml.wel.stress_period_data[0]:
    mapview.plot_endpoint(
        ept,
        direction="starting",
        selection_direction="ending",
        selection=(d[0], d[1], d[2]),
        zorder=100,
    )

# construct maximum travel time to plot (200 years - MODFLOW time unit is seconds)
travel_time_max = 200.0 * 365.25 * 24.0 * 60.0 * 60.0
ctt = f"<={travel_time_max}"

# plot the pathlines
mapview.plot_pathline(plines, layer="all", colors="red", travel_time=ctt)
```

[18]:
```
<matplotlib.collections.LineCollection at 0x7fbc3190feb0>
```


plot_array()
1e6
2.936
2.934
2.932
2.930
2.928
2.926
507000
508000
509000
510000
511000
512000
513000
514000

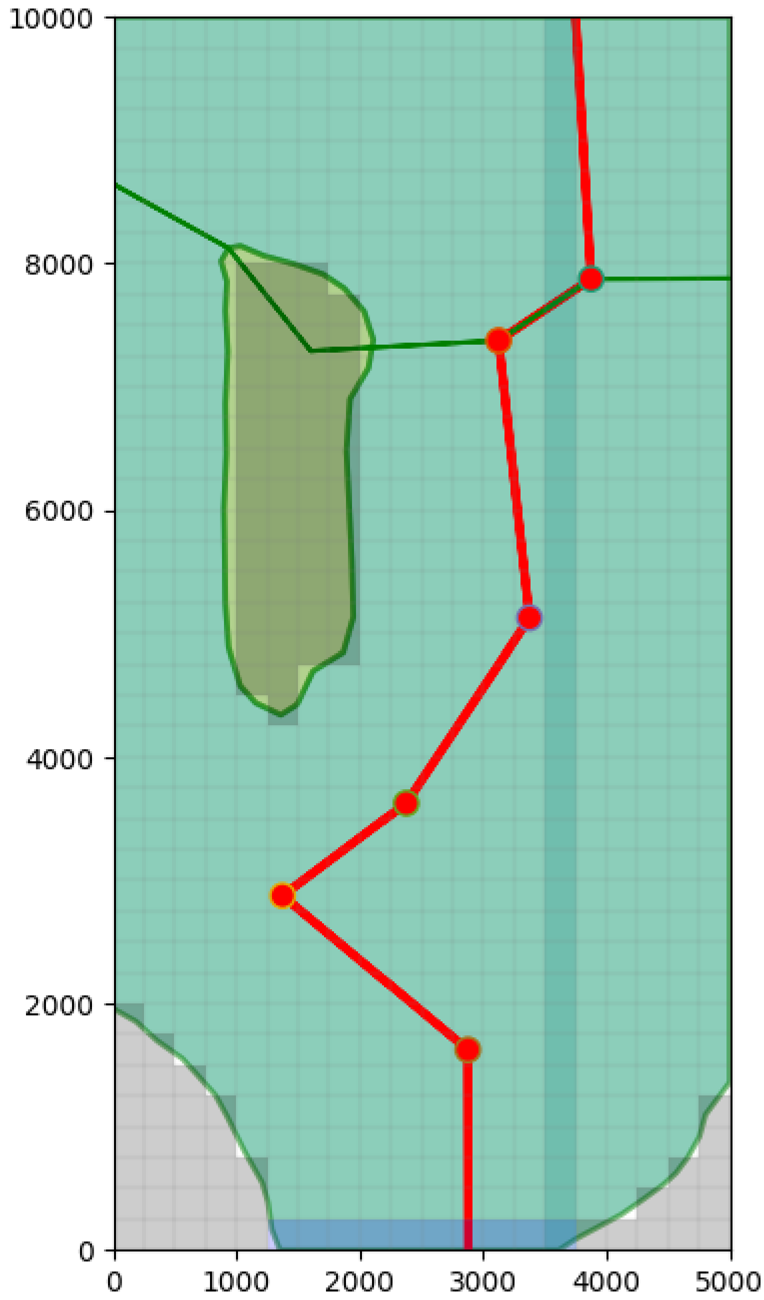
Plotting a Shapefile

PlotMapView has a plot_shapefile() method that can be used to quickly plot a shapefile on your map. In order to use the plot_shapefile() method, you must be able to "import shapefile". The command import shapefile is part of the pyshp package.

The plot_shapefile() function can plot points, lines, and polygons and will return a patch_collection of objects from the shapefile. For a shapefile of polygons, the plot_shapefile() function will try to plot and fill them all using a different color. For a shapefile of points, you may need to specify a radius, in model units, in order for the circles to show up properly.

The shapefile must have intersecting geographic coordinates as the PlotMapView object in order for it to overlay correctly on the plot. The plot_shapefile() method and function do not use any of the projection information that may be stored with the shapefile. If you reset xoff, yoff, and angrot in the ml.modelgrid.set_coord_info() call below, you will see that the grid will no longer overlay correctly with the shapefile.

[19]:
```
# Setup the figure and PlotMapView. Show a very faint map of ibound and
# model grid by specifying a transparency alpha value.
fig = plt.figure(figsize=(8, 8))
ax = fig.add_subplot(1, 1, 1, aspect="equal")

# reset the grid rotation and offsets to 0
ml.modelgrid.set_coord_info(xoff=0, yoff=0, angrot=0)

mapview = flopy.plot.PlotMapView(model=ml, ax=ax)

# Plot a shapefile of
shp = os.path.join(loadpth, "gis", "bedrock_outcrop_hole")
patch_collection = mapview.plot_shapefile(
    shp, edgecolor="green", linewidths=2, alpha=0.5  # facecolor='none',
)
# Plot a shapefile of a cross-section line
shp = os.path.join(loadpth, "gis", "cross_section")
patch_collection = mapview.plot_shapefile(
    shp, radius=0, lw=[3, 1.5], edgecolor=["red", "green"], facecolor="None"
)

# Plot a shapefile of well locations
shp = os.path.join(loadpth, "gis", "wells_locations")
patch_collection = mapview.plot_shapefile(shp, radius=100, facecolor="red")

# Plot the grid and boundary conditions over the top
quadmesh = mapview.plot_ibound(alpha=0.1)
quadmesh = mapview.plot_bc("RIV", alpha=0.1)
linecollection = mapview.plot_grid(alpha=0.1)
```



Although the PlotMapView's plot_shapefile() method does not consider projection information when plotting maps, it can be used to plot shapefiles when a PlotMapView instance is rotated and offset into geographic coordinates. The same shapefiles plotted above (but in geographic coordinates rather than model coordinates) are plotted on the rotated model grid. The offset from model coordinates to geographic coordinates relative to the lower left corner are xoff=-2419.22, yoff=297.04 and the rotation angle is 14°.

[20]:
```
# Setup the figure and PlotMapView. Show a very faint map of ibound and
# model grid by specifying a transparency alpha value.

# set the modelgrid rotation and offset
```

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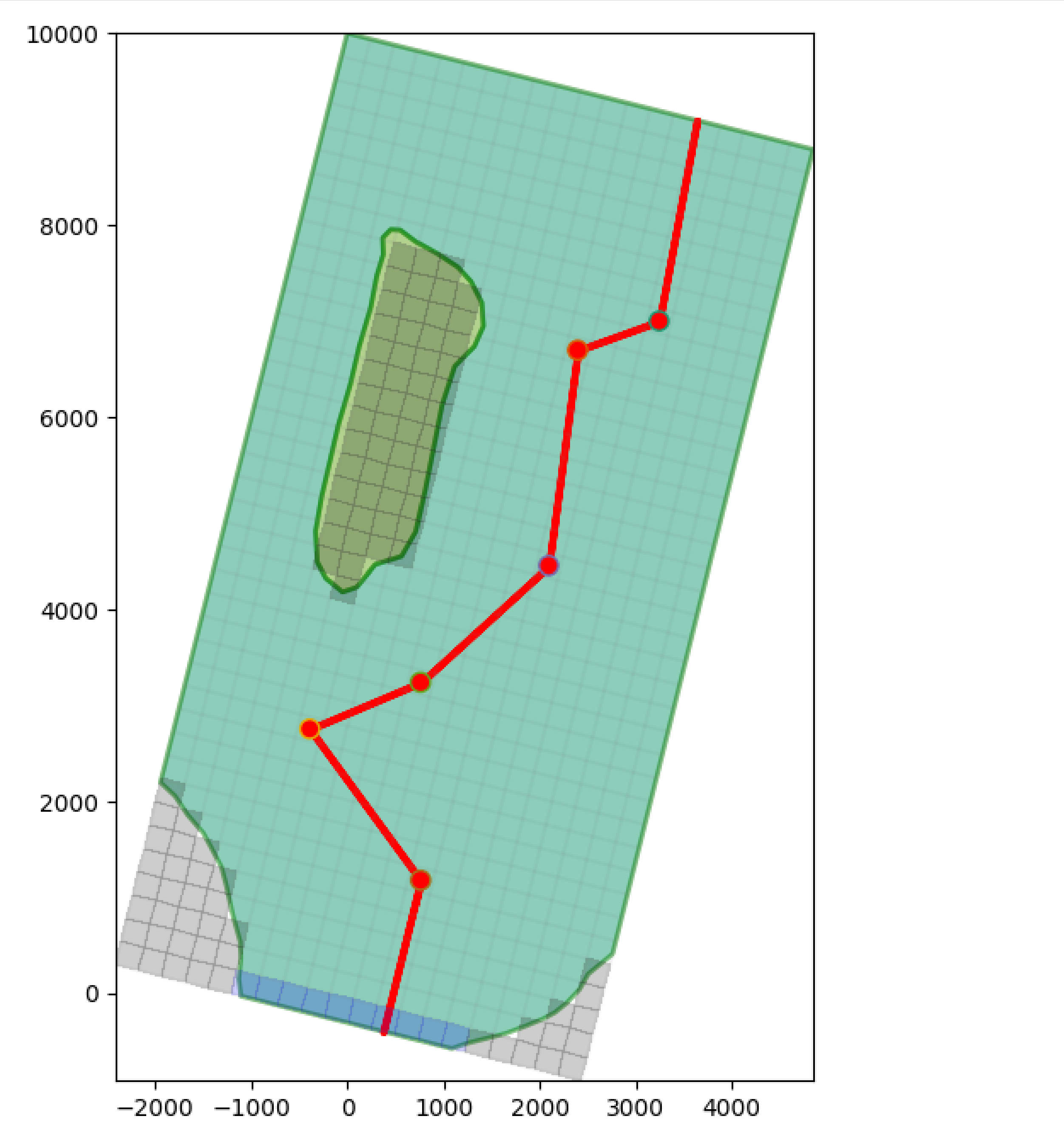
```
ml.modelgrid.set_coord_info(
    xoff=-2419.2189559966773, yoff=297.0427372400354, angrot=-14
)

fig = plt.figure(figsize=(8, 8))
ax = fig.add_subplot(1, 1, 1, aspect="equal")
mapview = flopy.plot.PlotMapView(model=ml)

# Plot a shapefile of
shp = os.path.join(loadpth, "gis", "bedrock_outcrop_hole_rotate14")
patch_collection = mapview.plot_shapefile(
    shp, edgecolor="green", linewidths=2, alpha=0.5  # facecolor='none',
)
# Plot a shapefile of a cross-section line
shp = os.path.join(loadpth, "gis", "cross_section_rotate14")
patch_collection = mapview.plot_shapefile(shp, lw=3, edgecolor="red")

# Plot a shapefile of well locations
shp = os.path.join(loadpth, "gis", "wells_locations_rotate14")
patch_collection = mapview.plot_shapefile(shp, radius=100, facecolor="red")

# Plot the grid and boundary conditions over the top
quadmesh = mapview.plot_ibound(alpha=0.1)
linecollection = mapview.plot_grid(alpha=0.1)
```



10000
8000
6000
4000
2000
0
−2000
−1000
0
1000
2000
3000
4000

Plotting GIS Shapes

PlotMapView has a plot_shapes() method that can be used to quickly plot GIS based shapes on your map. In order to use the plot_shapes() method, you must be able to "import shapefile". The command import shapefile is part of the pyshp package.

The plot_shapes() function can plot points, lines, polygons, and multipolygons and will return a patch_collection. For a list or collection of polygons, the plot_shapes() function will try to plot and fill them all using a different color. For a list or collection of points, you may need to specify a radius, in model units, in order for the circles to show up properly.

Note: The supplied shapes must have intersecting geographic coordinates as the PlotMapView object in order for it to overlay correctly on the plot.

plot_shapes() supports many GIS based input types and they are listed below:

[ ]:

[ ]:

[ ]:

[ ]:

[ ]:

[ ]:

[ ]:

[ ]:

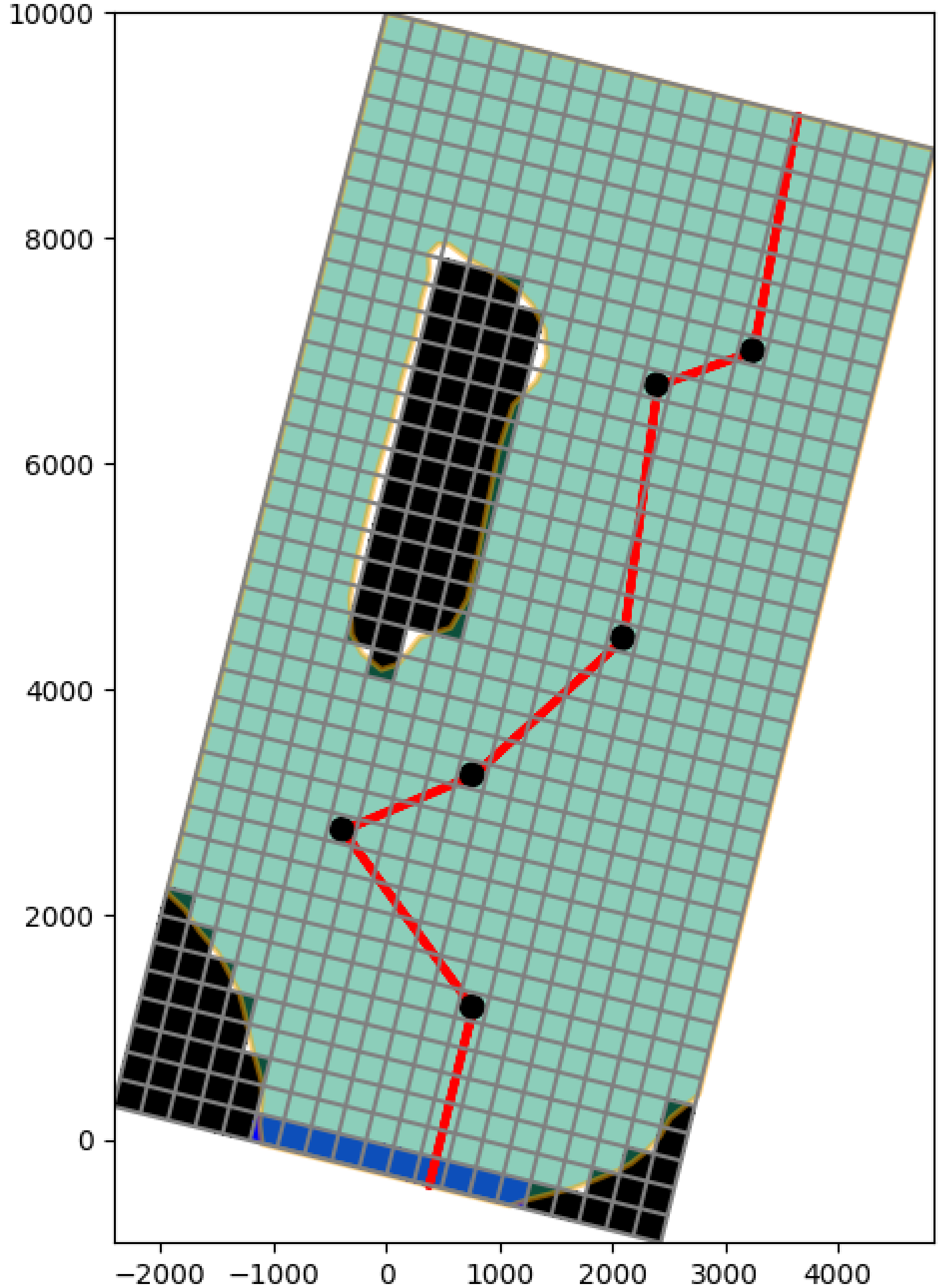
[ ]:

[21]:
```
#
# Here is a basic example of how to use the method:
```

[22]:
```
# lets extract some shapes from our shapefiles
shp = os.path.join(loadpth, "gis", "bedrock_outcrop_hole_rotate14")
with shapefile.Reader(shp) as r:
    polygon_w_hole = [
        r.shape(0),
    ]

shp = os.path.join(loadpth, "gis", "cross_section_rotate14")
with shapefile.Reader(shp) as r:
    cross_section = r.shapes()

# Plot a shapefile of well locations
shp = os.path.join(loadpth, "gis", "wells_locations_rotate14")
with shapefile.Reader(shp) as r:
    wells = r.shapes()
```

Now that the shapes are extracted from the shapefiles, they can be plotted using `plot_shapes()`

[23]:
```
# set the modelgrid rotation and offset
ml.modelgrid.set_coord_info(
    xoff=-2419.2189559966773, yoff=297.0427372400354, angrot=-14
)

fig = plt.figure(figsize=(8, 8))
ax = fig.add_subplot(1, 1, 1, aspect="equal")
mapview = flopy.plot.PlotMapView(model=ml)

# Plot the grid and boundary conditions
quadmesh = mapview.plot_ibound()
linecollection = mapview.plot_grid()

# plot polygon(s)
patch_collection0 = mapview.plot_shapes(
    polygon_w_hole, edgecolor="orange", linewidths=2, alpha=0.5
)

# plot_line(s)
patch_collection1 = mapview.plot_shapes(cross_section, lw=3, edgecolor="red")

# plot_point(s)
patch_collection3 = mapview.plot_shapes(
    wells, radius=100, facecolor="k", edgecolor="k"
)
```


10000
8000
6000
4000
2000
0
−2000
−1000
0
1000
2000
3000
4000

Working with MODFLOW-6 models

`PlotMapView` has support for MODFLOW-6 models and operates in the same fashion for Structured Grids, Vertex Grids, and Unstructured Grids. Here is a short example on how to plot with MODFLOW-6 structured grids using a version of the Freyberg model created for MODFLOW-6

[24]:
```python
# load the Freyberg model into mf6-flopy and run the simulation
sim_name = "mfsim.nam"
sim_path = str(prj_root / "examples" / "data" / "mf6-freyberg")
sim = flopy.mf6.MFSimulation.load(
    sim_name=sim_name, version=vmf6, exe_name=exe_name_mf6, sim_ws=sim_path
)

newpth = os.path.join(modelpth)
sim.set_sim_path(newpth)
sim.write_simulation()
success, buff = sim.run_simulation()
if not success:
    print("Something bad happened.")
files = ["freyberg.hds", "freyberg.cbc"]
for f in files:
    if os.path.isfile(os.path.join(modelpth, f)):
        msg = f"Output file located: {f}"
        print(msg)
    else:
        errmsg = f"Error. Output file cannot be found: {f}"
        print(errmsg)
```

```
loading simulation...
  loading simulation name file...
  loading tdis package...
  loading model gwf6...
    loading package dis...
    loading package ic...
WARNING: Block "options" is not a valid block name for file type ic.
    loading package oc...
    loading package npf...
    loading package sto...
    loading package chd...
    loading package riv...
    loading package wel...
    loading package rch...
  loading solution package freyberg...
writing simulation...
  writing simulation name file...
  writing simulation tdis package...
  writing solution package freyberg...
  writing model freyberg...
    writing model name file...
    writing package dis...
    writing package ic...
    writing package oc...
    writing package npf...
    writing package sto...
```

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```
    writing package chd-1...
    writing package riv-1...
    writing package wel-1...
    writing package rch-1...
FloPy is using the following executable to run the model: ../../home/runner/.local/bin/
→modflow/mf6
                                   MODFLOW 6
                U.S. GEOLOGICAL SURVEY MODULAR HYDROLOGIC MODEL
                            VERSION 6.4.2 06/28/2023

   MODFLOW 6 compiled Jul 05 2023 20:29:14 with Intel(R) Fortran Intel(R) 64
   Compiler Classic for applications running on Intel(R) 64, Version 2021.7.0
                             Build 20220726_000000

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Survey (USGS). Although the software has been subjected to rigorous
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and distribution information.


 Run start date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:31:44

 Writing simulation list file: mfsim.lst
 Using Simulation name file: mfsim.nam

    Solving:  Stress period:     1    Time step:     1

 Run end date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:31:44
 Elapsed run time:  0.048 Seconds

 Normal termination of simulation.
Output file located: freyberg.hds
Output file located: freyberg.cbc
```

Plotting boundary conditions and arrays

This works the same as modflow-2005, however the simulation object can host a number of modflow-6 models so we need to grab a model before attempting to plot with `PlotMapView`

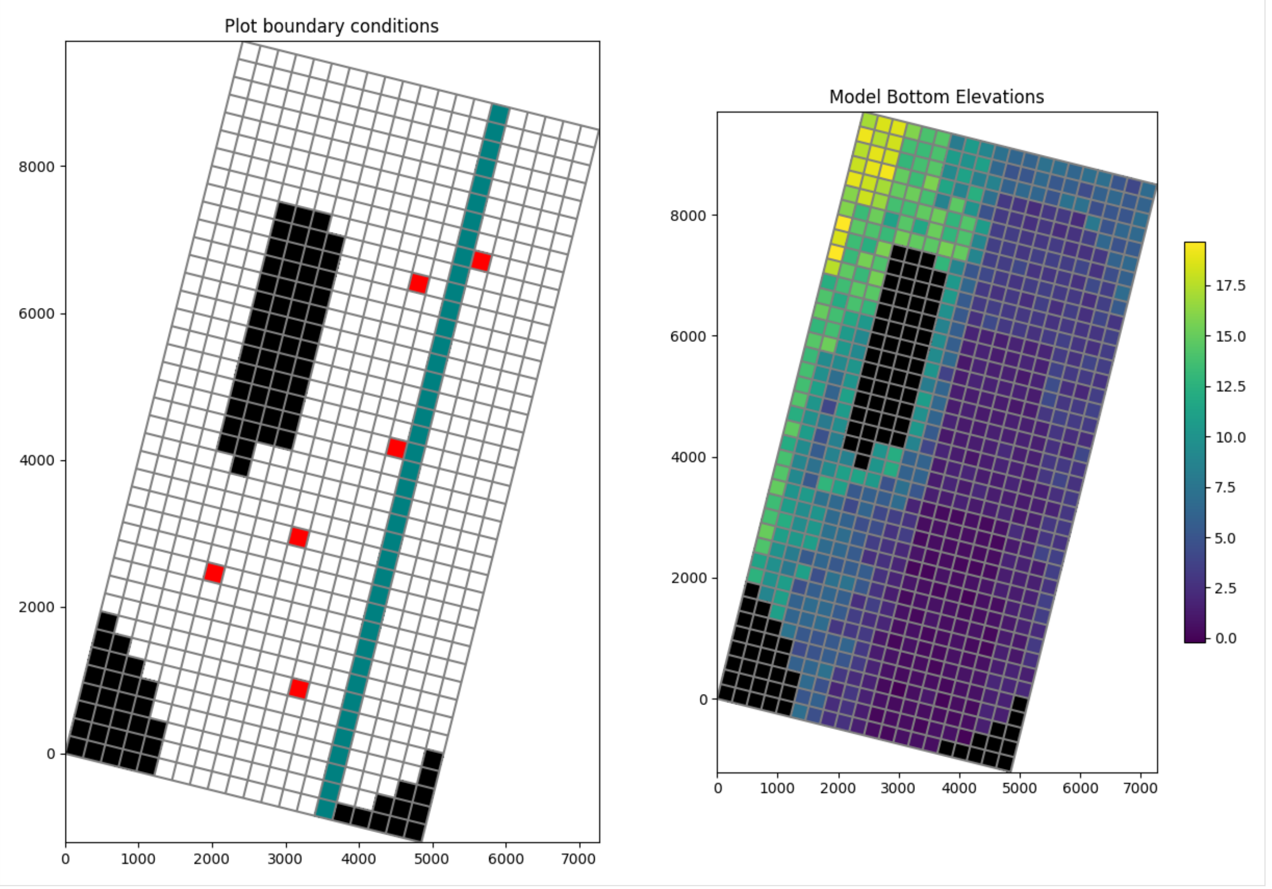
[25]:
```
# get the modflow-6 model we want to plot
ml6 = sim.get_model("freyberg")
ml6.modelgrid.set_coord_info(angrot=-14)

fig = plt.figure(figsize=(15, 10))

# plot boundary conditions
ax = fig.add_subplot(1, 2, 1, aspect="equal")
mapview = flopy.plot.PlotMapView(model=ml6)
quadmesh = mapview.plot_ibound()
quadmesh = mapview.plot_bc("RIV")
quadmesh = mapview.plot_bc("WEL")
linecollection = mapview.plot_grid()
ax.set_title("Plot boundary conditions")

# plot model bottom elevations
a = ml6.dis.botm.array

ax = fig.add_subplot(1, 2, 2, aspect="equal")
ax.set_title("Model Bottom Elevations")
mapview = flopy.plot.PlotMapView(model=ml6, layer=0)
quadmesh = mapview.plot_array(a)
inactive = mapview.plot_inactive()
linecollection = mapview.plot_grid()
cb = plt.colorbar(quadmesh, shrink=0.5, ax=ax)
```



Contouring Arrays

Contouring arrays follows the same code signature for MODFLOW-6 as the MODFLOW-2005 example. Just use the `contour_array()` method

[26]:
```
# The contour_array() method will take any keywords
# that can be used by the matplotlib.pyplot.contour
# function. So we can pass in levels, for example.
a = ml6.dis.botm.array
levels = np.arange(0, 20, 0.5)

fig = plt.figure(figsize=(8, 8))
ax = fig.add_subplot(1, 1, 1, aspect="equal")
ax.set_title("Model Bottom Elevations")
mapview = flopy.plot.PlotMapView(model=ml6, layer=0)
contour_set = mapview.contour_array(a, levels=levels)
linecollection = mapview.plot_grid()

# set up and plot a continuous colorbar in matplotlib for a contour plot
norm = mpl.colors.Normalize(
    vmin=contour_set.cvalues.min(), vmax=contour_set.cvalues.max()
)
sm = plt.cm.ScalarMappable(norm=norm, cmap=contour_set.cmap)
```

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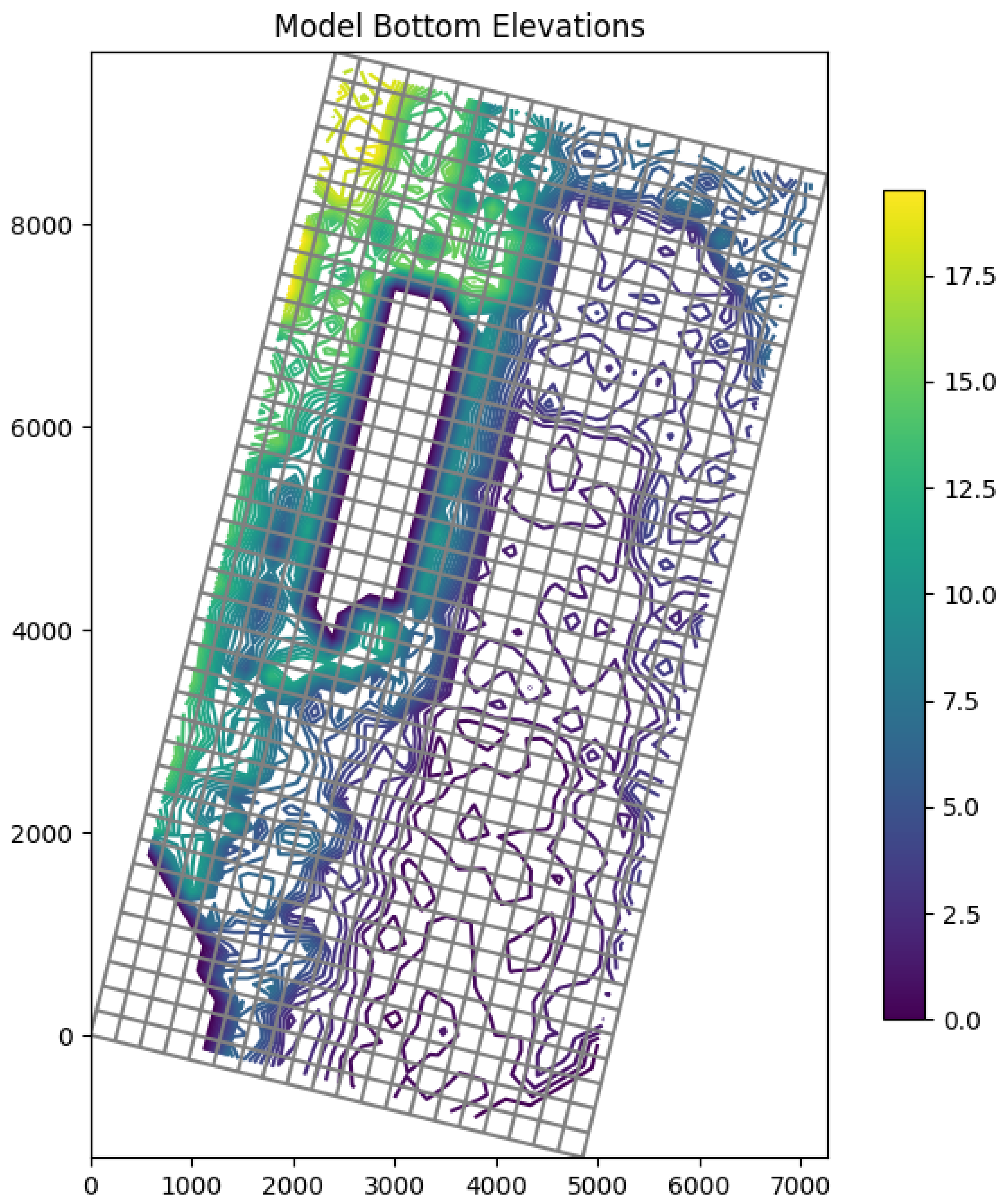
```
sm.set_array([])
fig.colorbar(sm, shrink=0.75, ax=ax)
```

[26]: <matplotlib.colorbar.Colorbar at 0x7fbc419aed00>

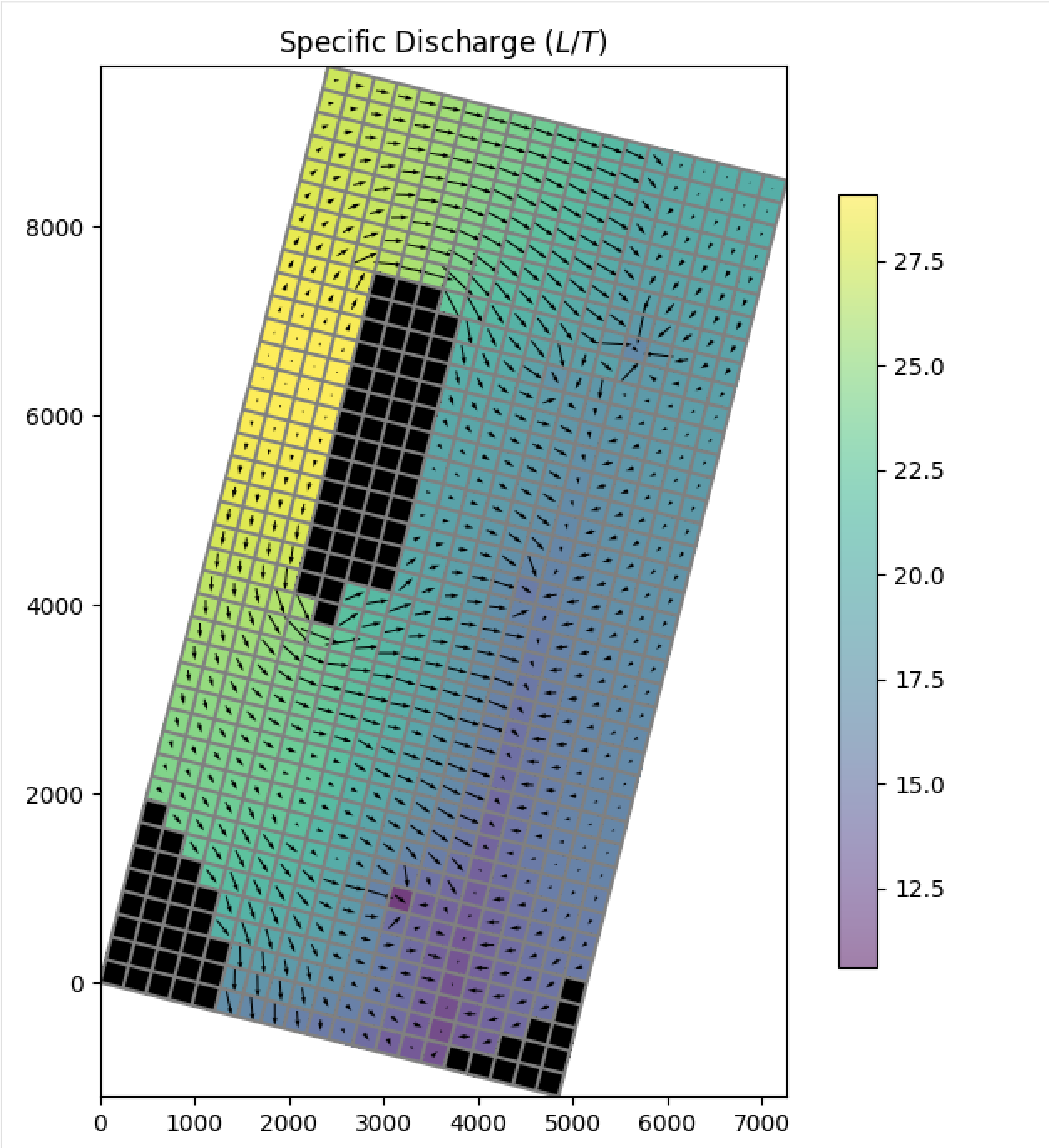


Plotting specific discharge with a MODFLOW-6 model

MODFLOW-6 includes a the PLOT_SPECIFIC_DISCHARGE flag in the NPF package to calculate and store discharge vectors for easy plotting. The postprocessing module will translate the specific dischage into vector array and `PlotMapView` has the `plot_vector()` method to use this data. The specific discharge array is stored in the cell budget file.

[27]:
```
# get the specific discharge from the cell budget file
cbc_file = os.path.join(newpth, "freyberg.cbc")
cbc = flopy.utils.CellBudgetFile(cbc_file)
spdis = cbc.get_data(text="SPDIS")[0]

qx, qy, qz = flopy.utils.postprocessing.get_specific_discharge(spdis, ml6)

# get the head from the head file
head_file = os.path.join(newpth, "freyberg.hds")
head = flopy.utils.HeadFile(head_file)
hdata = head.get_alldata()[0]

# plot specific discharge using PlotMapView
fig = plt.figure(figsize=(8, 8))

mapview = flopy.plot.PlotMapView(model=ml6, layer=0)
linecollection = mapview.plot_grid()
quadmesh = mapview.plot_array(a=hdata, alpha=0.5)
quiver = mapview.plot_vector(qx, qy)
inactive = mapview.plot_inactive()

plt.title("Specific Discharge (" + r"$L/T$" + ")")
plt.colorbar(quadmesh, shrink=0.75)
```

[27]:
```
<matplotlib.colorbar.Colorbar at 0x7fbc418b1f10>
```



Specific Discharge (L/T)
8000
6000
4000
2000
0
0
1000
2000
3000
4000
5000
6000
7000
27.5
25.0
22.5
20.0
17.5
15.0
12.5

Vertex model plotting with MODFLOW-6

FloPy fully supports vertex discretization (DISV) plotting through the `PlotMapView` class. The method calls are identical to the ones presented previously for Structured discretization (DIS) and the same matplotlib keyword arguments are supported. Let's run through an example using a vertex model grid.

[28]:
```python
# build and run vertex model grid demo problem
notebook_utils.run(modelpth)

# check if model ran properly
modelpth = os.path.join(modelpth, "mp7_ex2", "mf6")
files = ["mp7p2.hds", "mp7p2.cbb"]
for f in files:
    if os.path.isfile(os.path.join(modelpth, f)):
        msg = f"Output file located: {f}"
        print(msg)
    else:
        errmsg = f"Error. Output file cannot be found: {f}"
        print(errmsg)
```

```
WARNING: Unable to resolve dimension of ('gwf6', 'disv', 'cell2d', 'cell2d', 'icvert')␣
↪based on shape "ncvert".
writing simulation...
  writing simulation name file...
  writing simulation tdis package...
  writing solution package ims...
  writing model mp7p2...
    writing model name file...
    writing package disv...
    writing package ic...
    writing package npf...
    writing package wel_0...
INFORMATION: maxbound in ('gwf6', 'wel', 'dimensions') changed to 1 based on size of␣
↪stress_period_data
    writing package rcha_0...
    writing package riv_0...
INFORMATION: maxbound in ('gwf6', 'riv', 'dimensions') changed to 21 based on size of␣
↪stress_period_data
    writing package oc...
                                   MODFLOW 6
                U.S. GEOLOGICAL SURVEY MODULAR HYDROLOGIC MODEL
                            VERSION 6.4.2 06/28/2023

   MODFLOW 6 compiled Jul 05 2023 20:29:14 with Intel(R) Fortran Intel(R) 64
   Compiler Classic for applications running on Intel(R) 64, Version 2021.7.0
                             Build 20220726_000000

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```

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```
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and distribution information.


 Run start date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:31:46

 Writing simulation list file: mfsim.lst
 Using Simulation name file: mfsim.nam

    Solving:  Stress period:     1    Time step:     1

 Run end date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:31:46
 Elapsed run time:  0.097 Seconds


WARNING REPORT:

  1. NONLINEAR BLOCK VARIABLE 'OUTER_HCLOSE' IN FILE 'mp7p2.ims' WAS
     DEPRECATED IN VERSION 6.1.1. SETTING OUTER_DVCLOSE TO OUTER_HCLOSE VALUE.
  2. LINEAR BLOCK VARIABLE 'INNER_HCLOSE' IN FILE 'mp7p2.ims' WAS DEPRECATED
     IN VERSION 6.1.1. SETTING INNER_DVCLOSE TO INNER_HCLOSE VALUE.
 Normal termination of simulation.

MODPATH Version 7.2.001
Program compiled Jul 05 2023 20:31:49 with IFORT compiler (ver. 20.21.7)


Run particle tracking simulation ...
Processing Time Step     1 Period     1.  Time =  1.00000E+03  Steady-state flow

Particle Summary:
         0 particles are pending release.
         0 particles remain active.
        16 particles terminated at boundary faces.
         0 particles terminated at weak sink cells.
         0 particles terminated at weak source cells.
         0 particles terminated at strong source/sink cells.
         0 particles terminated in cells with a specified zone number.
         0 particles were stranded in inactive or dry cells.
         0 particles were unreleased.
         0 particles have an unknown status.

Normal termination.

MODPATH Version 7.2.001
Program compiled Jul 05 2023 20:31:49 with IFORT compiler (ver. 20.21.7)


Run particle tracking simulation ...
```

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```
Processing Time Step     1 Period     1.  Time =  1.00000E+03  Steady-state flow

Particle Summary:
         0 particles are pending release.
         0 particles remain active.
       416 particles terminated at boundary faces.
         0 particles terminated at weak sink cells.
         0 particles terminated at weak source cells.
         0 particles terminated at strong source/sink cells.
         0 particles terminated in cells with a specified zone number.
         0 particles were stranded in inactive or dry cells.
         0 particles were unreleased.
         0 particles have an unknown status.

Normal termination.
Output file located: mp7p2.hds
Output file located: mp7p2.cbb
```

[29]:
```
# load the simulation and get the model
vertex_sim_name = "mfsim.nam"
vertex_sim = flopy.mf6.MFSimulation.load(
    sim_name=vertex_sim_name,
    version=vmf6,
    exe_name=exe_name_mf6,
    sim_ws=modelpth,
)
vertex_ml6 = vertex_sim.get_model("mp7p2")
```

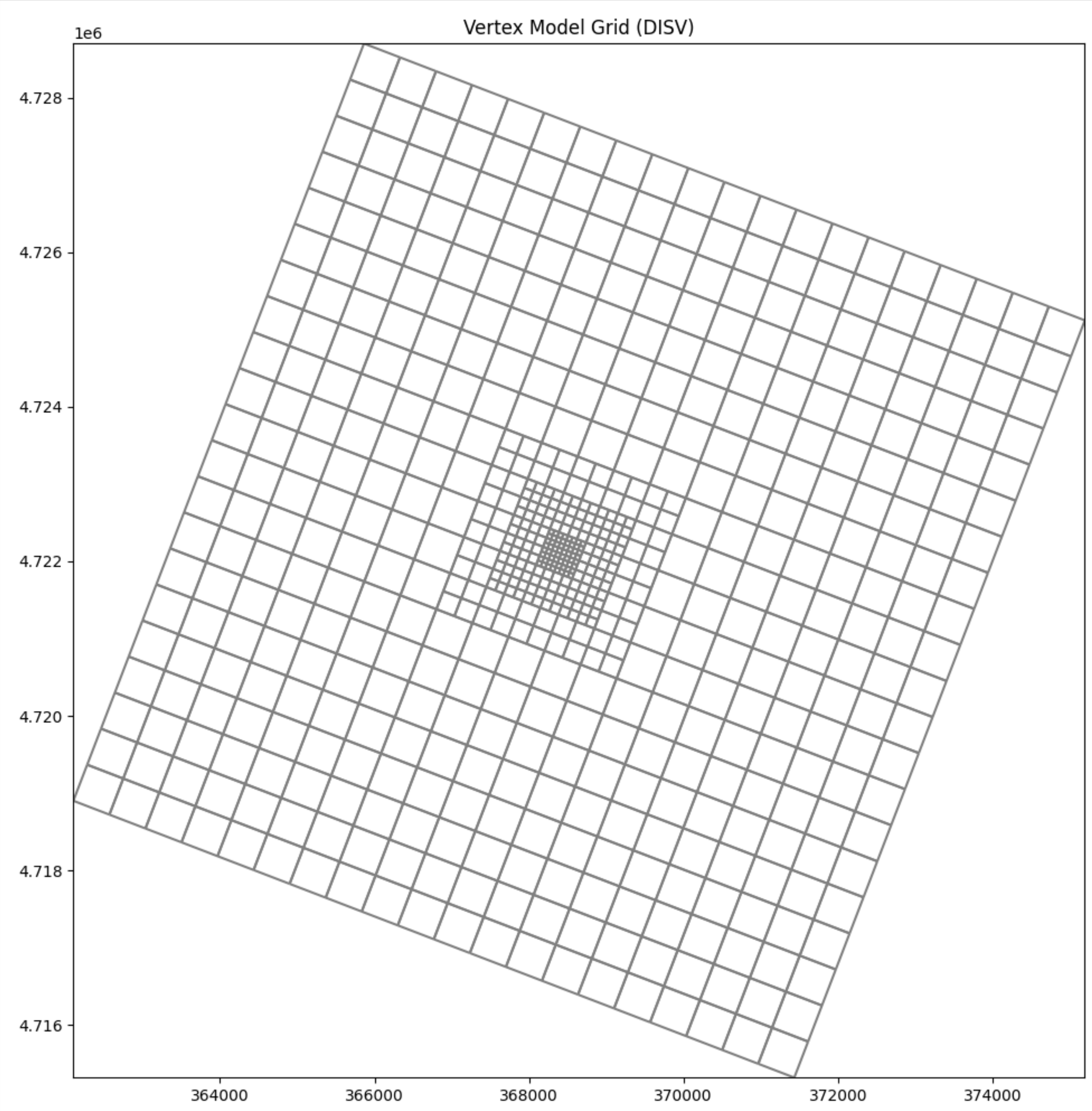
```
loading simulation...
  loading simulation name file...
  loading tdis package...
  loading model gwf6...
    loading package disv...
WARNING: Unable to resolve dimension of ('gwf6', 'disv', 'cell2d', 'cell2d', 'icvert')␣
↪based on shape "ncvert".
    loading package ic...
    loading package npf...
    loading package wel...
    loading package rch...
    loading package riv...
    loading package oc...
  loading solution package mp7p2...
```

Setting MODFLOW-6 Vertex Model Grid offsets, rotation and plotting

Setting the `Grid` offsets and rotation is consistent in FloPy, no matter which type of discretization the user is using. The `set_coord_info()` method on the `modelgrid` is used.

Plotting works consistently too, the user just calls the `PlotMapView` class and it accounts for the discretization type

[30]:
```python
# set coordinate information on the modelgrid
vertex_ml6.modelgrid.set_coord_info(xoff=362100, yoff=4718900, angrot=-21)

fig = plt.figure(figsize=(12, 12))
ax = fig.add_subplot(1, 1, 1, aspect="equal")
ax.set_title("Vertex Model Grid (DISV)")

# use PlotMapView to plot a DISV (vertex) model
mapview = flopy.plot.PlotMapView(vertex_ml6, layer=0)
linecollection = mapview.plot_grid()
```



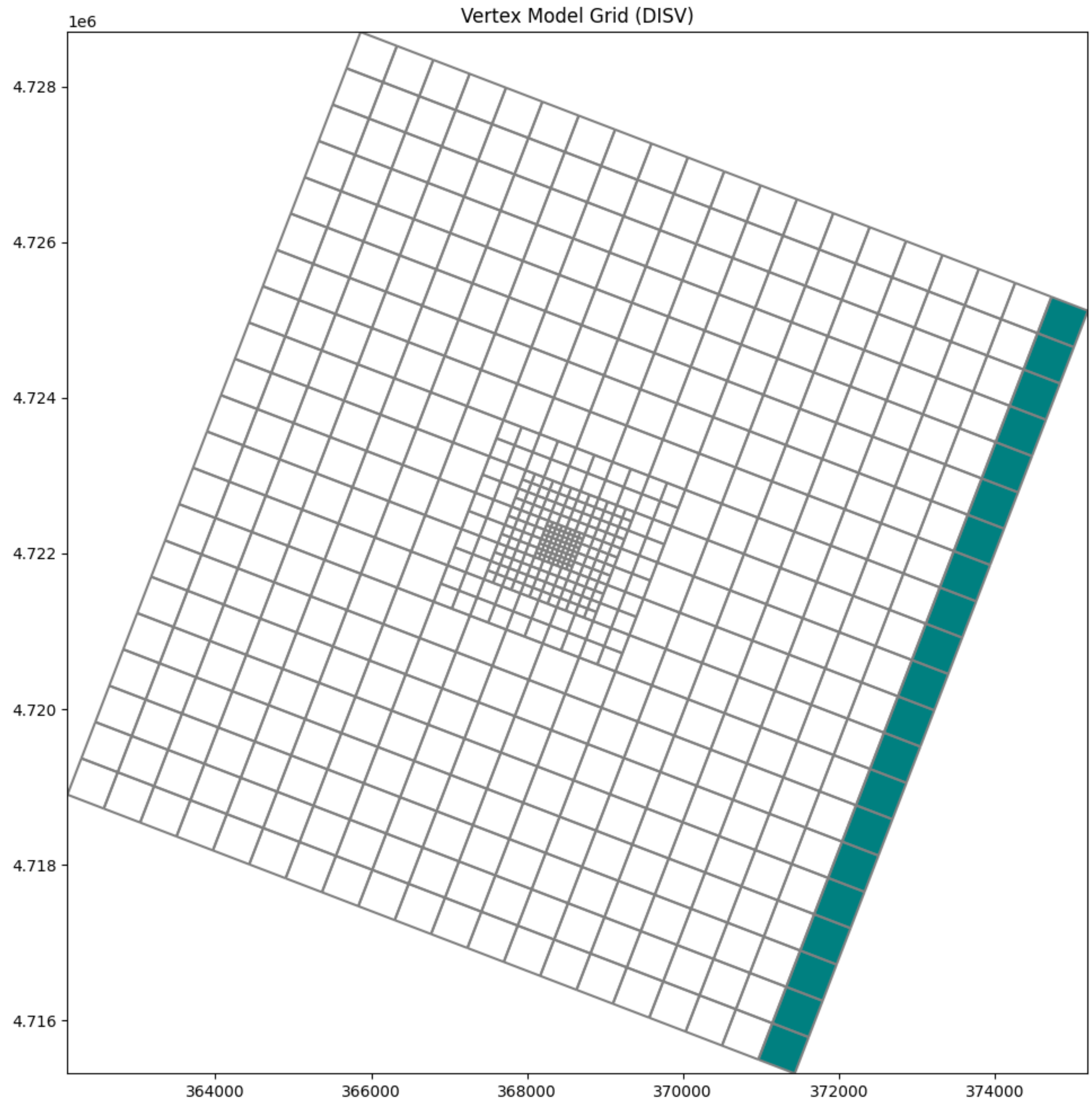
Plotting boundary conditions with Vertex Model grids

The `plot_bc()` method can be used to plot boundary conditions. It is setup to use the following dictionary to assign colors, however, these colors can be changed in the method call.

```
bc_color_dict = {'default': 'black', 'WEL': 'red', 'DRN': 'yellow',
                 'RIV': 'green', 'GHB': 'cyan', 'CHD': 'navy'}
```

Here we plot river (RIV) cell locations

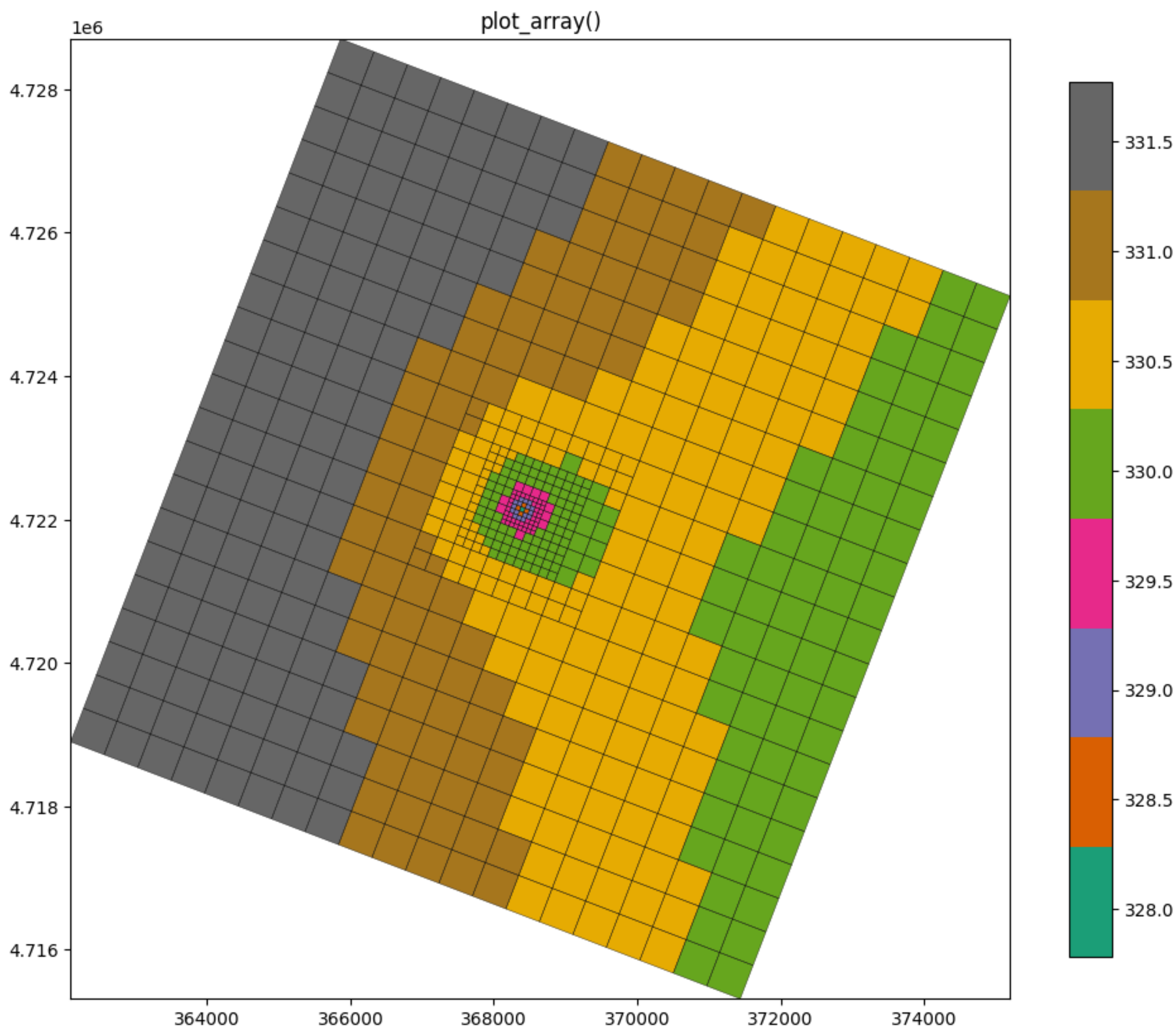
[31]:
```
fig = plt.figure(figsize=(12, 12))
ax = fig.add_subplot(1, 1, 1, aspect="equal")
ax.set_title("Vertex Model Grid (DISV)")

# use PlotMapView to plot a DISV (vertex) model
mapview = flopy.plot.PlotMapView(vertex_ml6, layer=0)
riv = mapview.plot_bc("RIV")
linecollection = mapview.plot_grid()
```



Plotting Arrays and Contouring with Vertex Model grids

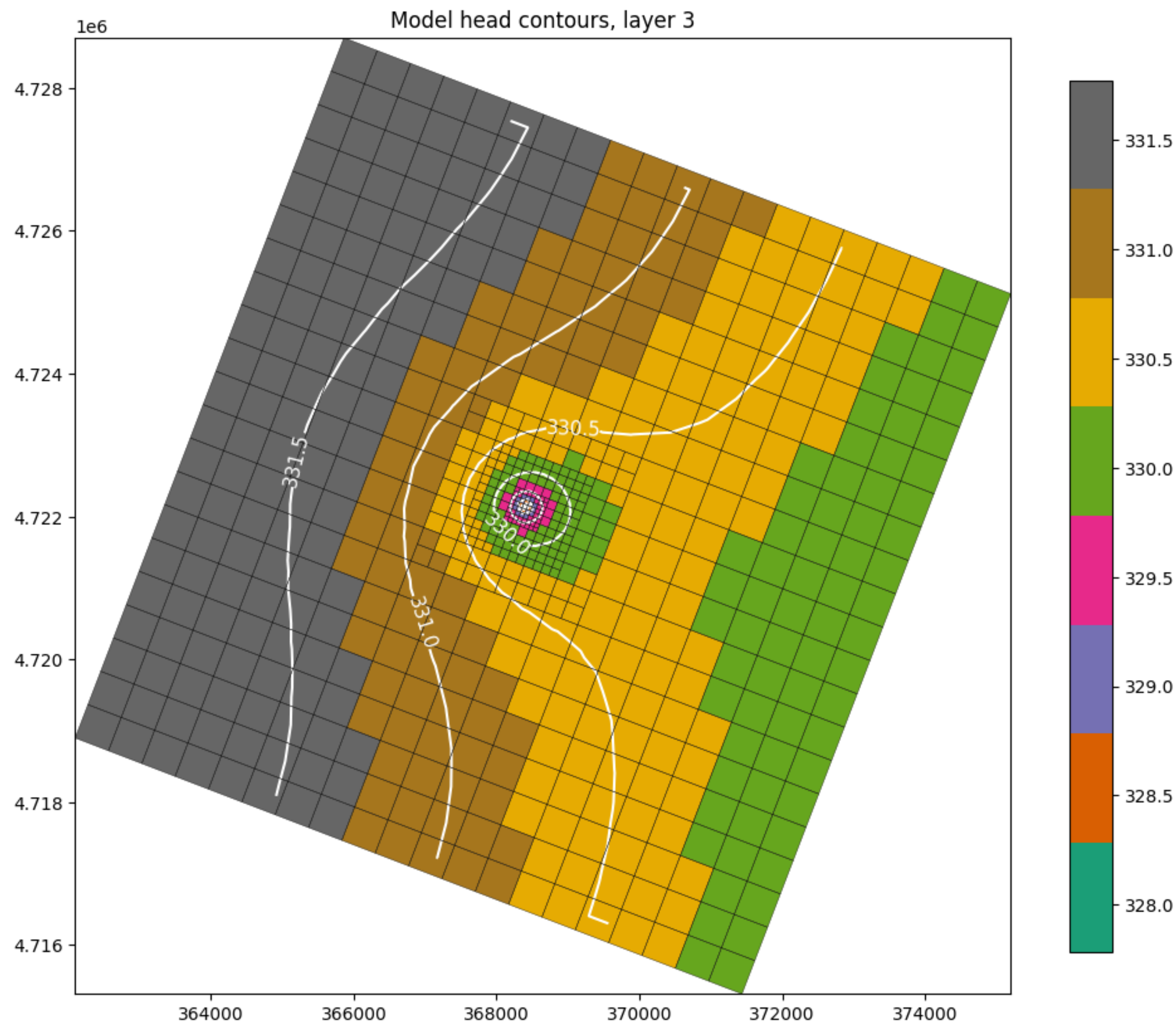
`PlotMapView` allows the user to plot arrays and contour with DISV based discretization. The `plot_array()` method is called in the same way as using a structured grid. The only difference is that `PlotMapView` builds a matplotlib patch collection for Vertex based grids.

[32]:
```
# get the head output for stress period 1 from the modflow6 head file
head = flopy.utils.HeadFile(os.path.join(modelpth, "mp7p2.hds"))
hdata = head.get_alldata()[0, :, :, :]

fig = plt.figure(figsize=(12, 12))
ax = fig.add_subplot(1, 1, aspect="equal")
ax.set_title("plot_array()")

mapview = flopy.plot.PlotMapView(model=vertex_ml6, layer=2)
patch_collection = mapview.plot_array(hdata, cmap="Dark2")
linecollection = mapview.plot_grid(lw=0.25, color="k")
cb = plt.colorbar(patch_collection, shrink=0.75)
```



The contour_array() method operates in the same way as the sturctured example.

[33]:
```
# plotting head array and then contouring the array!
levels = np.arange(327, 332, 0.5)

fig = plt.figure(figsize=(12, 12))
ax = fig.add_subplot(1, 1, 1, aspect="equal")
ax.set_title("Model head contours, layer 3")

mapview = flopy.plot.PlotMapView(model=vertex_ml6, layer=2)
pc = mapview.plot_array(hdata, cmap="Dark2")

# contouring the head array
contour_set = mapview.contour_array(hdata, levels=levels, colors="white")
plt.clabel(contour_set, fmt="%.1f", colors="white", fontsize=11)
linecollection = mapview.plot_grid(lw=0.25, color="k")

cb = plt.colorbar(pc, shrink=0.75, ax=ax)
```

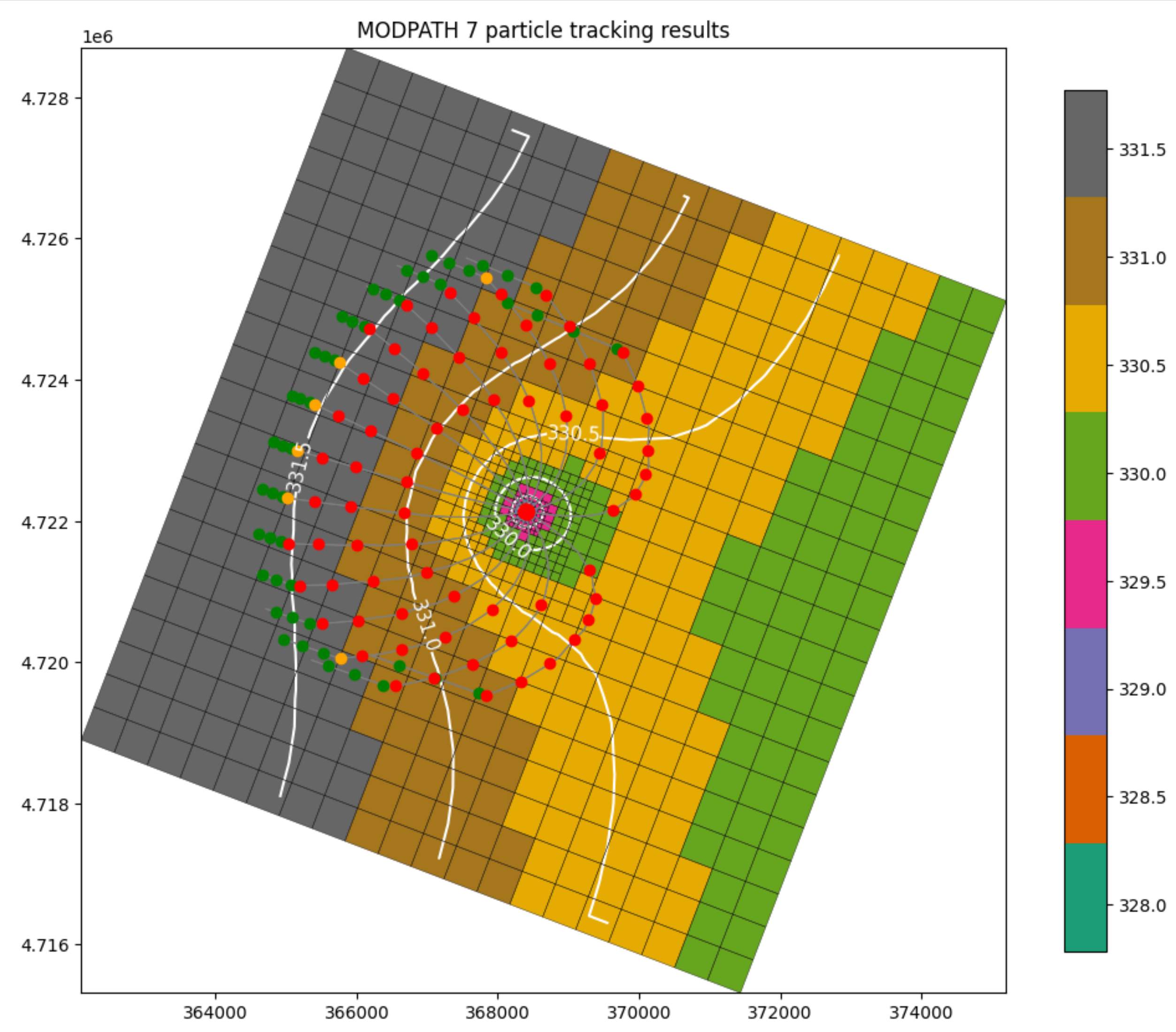


Plotting MODPATH 7 results on a vertex model

MODPATH-7 results can be plotted using the same built in methods as used previously to plot MODPATH-6 results. The `plot_pathline()` and `plot_timeseries()` methods are layered on the previous example to show modpath simulation results

[34]:
```
# load the MODPATH-7 results
mp_namea = "mp7p2a_mp"
fpth = os.path.join(modelpth, f"{mp_namea}.mppth")
p = flopy.utils.PathlineFile(fpth)
p0 = p.get_alldata()

fpth = os.path.join(modelpth, f"{mp_namea}.timeseries")
ts = flopy.utils.TimeseriesFile(fpth)
ts0 = ts.get_alldata()
```

[35]:
```
# setup the plot
fig = plt.figure(figsize=(12, 12))
ax = fig.add_subplot(1, 1, 1, aspect="equal")
ax.set_title("MODPATH 7 particle tracking results")

mapview = flopy.plot.PlotMapView(vertex_ml6, layer=2)

# plot and contour head arrays
pc = mapview.plot_array(hdata, cmap="Dark2")
contour_set = mapview.contour_array(hdata, levels=levels, colors="white")
plt.clabel(contour_set, fmt="%.1f", colors="white", fontsize=11)
linecollection = mapview.plot_grid(lw=0.25, color="k")
cb = plt.colorbar(pc, shrink=0.75, ax=ax)

# plot the modpath results
pline = mapview.plot_pathline(p0, layer="all", color="blue", lw=0.75)
colors = ["green", "orange", "red"]
for k in range(3):
    tseries = mapview.plot_timeseries(
        ts0, layer=k, marker="o", lw=0, color=colors[k]
    )
```



Plotting specific discharge vectors for DISV

MODFLOW-6 includes a the PLOT_SPECIFIC_DISCHARGE flag in the NPF package to calculate and store discharge vectors for easy plotting. The postprocessing module will translate the specific dischage into vector array and `PlotMapView` has the `plot_vector()` method to use this data. The specific discharge array is stored in the cell budget file.

[36]:
```
cbb = flopy.utils.CellBudgetFile(
    os.path.join(modelpth, "mp7p2.cbb"), precision="double"
)
spdis = cbb.get_data(text="SPDIS")[0]
qx, qy, qz = flopy.utils.postprocessing.get_specific_discharge(
    spdis, vertex_ml6
)

fig = plt.figure(figsize=(12, 12))
```

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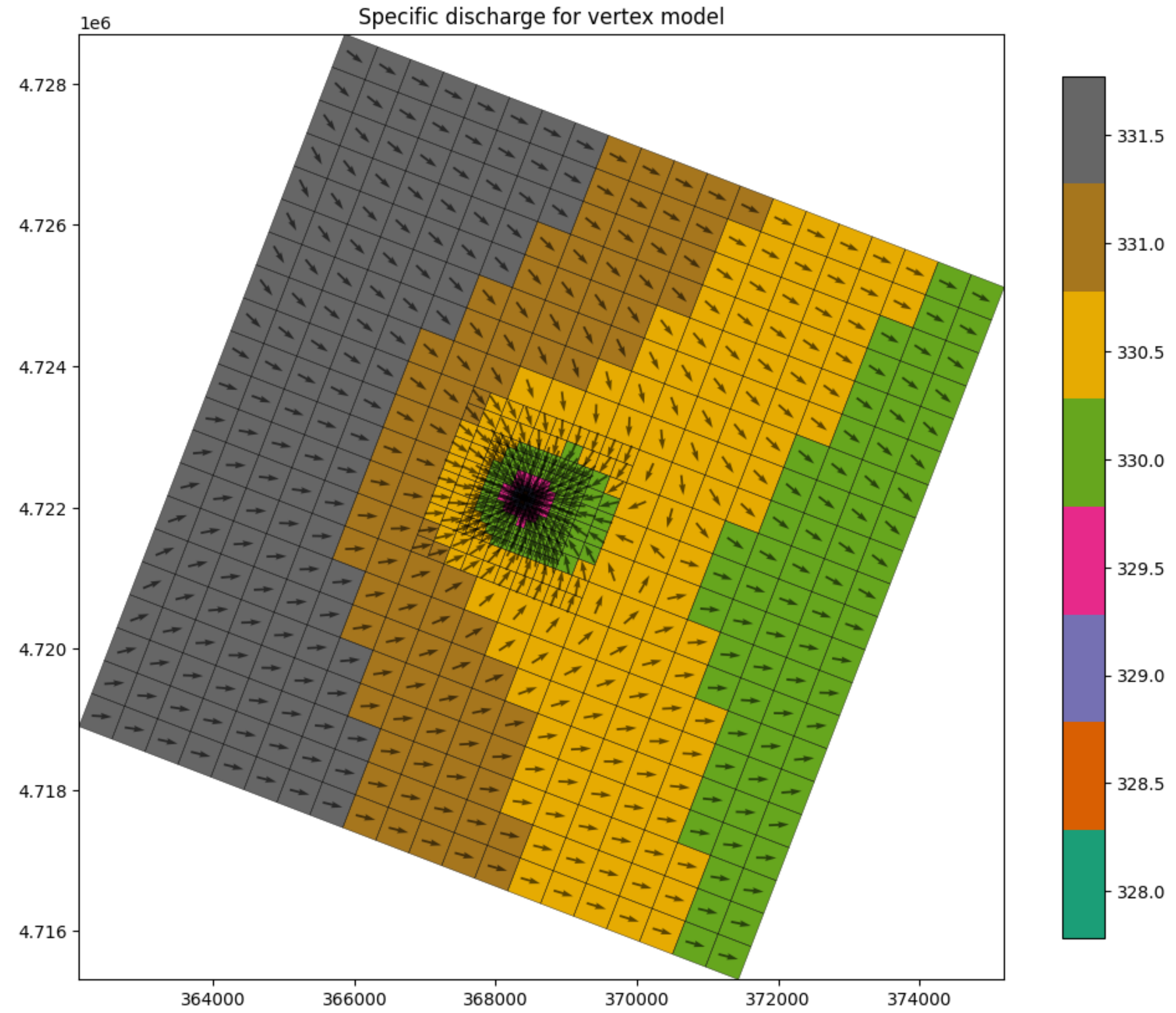
```
ax = fig.add_subplot(1, 1, 1, aspect="equal")
ax.set_title("Specific discharge for vertex model")

mapview = flopy.plot.PlotMapView(vertex_ml6, layer=2)
pc = mapview.plot_array(hdata, cmap="Dark2")
linecollection = mapview.plot_grid(lw=0.25, color="k")
cb = plt.colorbar(pc, shrink=0.75, ax=ax)

# plot specific discharge
quiver = mapview.plot_vector(qx, qy, normalize=True, alpha=0.60)
```



Unstructured grid (DISU) plotting with MODFLOW-USG and MODFLOW-6

Unstructured grid (DISU) plotting has support through the `PlotMapView` class and the `UnstructuredGrid` discretization object. The method calls are identical to those used for vertex (DISV) and structured (DIS) model grids. Let's run through a few unstructured grid examples

[37]:
```python
# set up the notebook for unstructured grid plotting
from flopy.discretization import UnstructuredGrid

# this is a folder containing some unstructured grids
datapth = str(prj_root / "examples" / "data" / "unstructured")


# simple functions to load vertices and incidence lists
def load_verts(fname):
    verts = np.genfromtxt(
        fname, dtype=[int, float, float], names=["iv", "x", "y"]
    )
    verts["iv"] -= 1  # zero based
    return verts


def load_iverts(fname):
    f = open(fname)
    iverts = []
    xc = []
    yc = []
    for line in f:
        ll = line.strip().split()
        iverts.append([int(i) - 1 for i in ll[4:]])
        xc.append(float(ll[1]))
        yc.append(float(ll[2]))
    return iverts, np.array(xc), np.array(yc)
```

[38]:
```python
# load vertices
fname = os.path.join(datapth, "ugrid_verts.dat")
verts = load_verts(fname)

# load the incidence list into iverts
fname = os.path.join(datapth, "ugrid_iverts.dat")
iverts, xc, yc = load_iverts(fname)
```

In this case, verts is just a 2-dimensional list of x,y vertex pairs. iverts is also a 2-dimensional list, where the outer list is of size ncells, and the inner list is a list of the vertex numbers that comprise the cell.

[39]:
```python
# Print the first 5 entries in verts and iverts
for ivert, v in enumerate(verts[:5]):
    print(f"Vertex coordinate pair for vertex {ivert}: {v}")
print("...\n")

for icell, vertlist in enumerate(iverts[:5]):
    print(f"List of vertices for cell {icell}: {vertlist}")
```

```
Vertex coordinate pair for vertex 0: (0, 0., 700.)
Vertex coordinate pair for vertex 1: (1, 100., 700.)
Vertex coordinate pair for vertex 2: (2, 100., 600.)
Vertex coordinate pair for vertex 3: (3, 0., 600.)
Vertex coordinate pair for vertex 4: (4, 200., 700.)
...

List of vertices for cell 0: [0, 1, 2, 3, 0]
List of vertices for cell 1: [1, 4, 5, 2, 1]
List of vertices for cell 2: [4, 6, 7, 5, 4]
List of vertices for cell 3: [6, 8, 9, 7, 6]
List of vertices for cell 4: [8, 10, 11, 9, 8]
```

A flopy `UnstructuredGrid` object can now be created using the vertices and incidence list. The `UnstructuredGrid` object is a key part of the plotting capabilities in flopy. In addition to the vertex information, the `UnstructuredGrid` object also needs to know how many cells are in each layer. This is specified in the ncpl variable, which is a list of cells per layer.

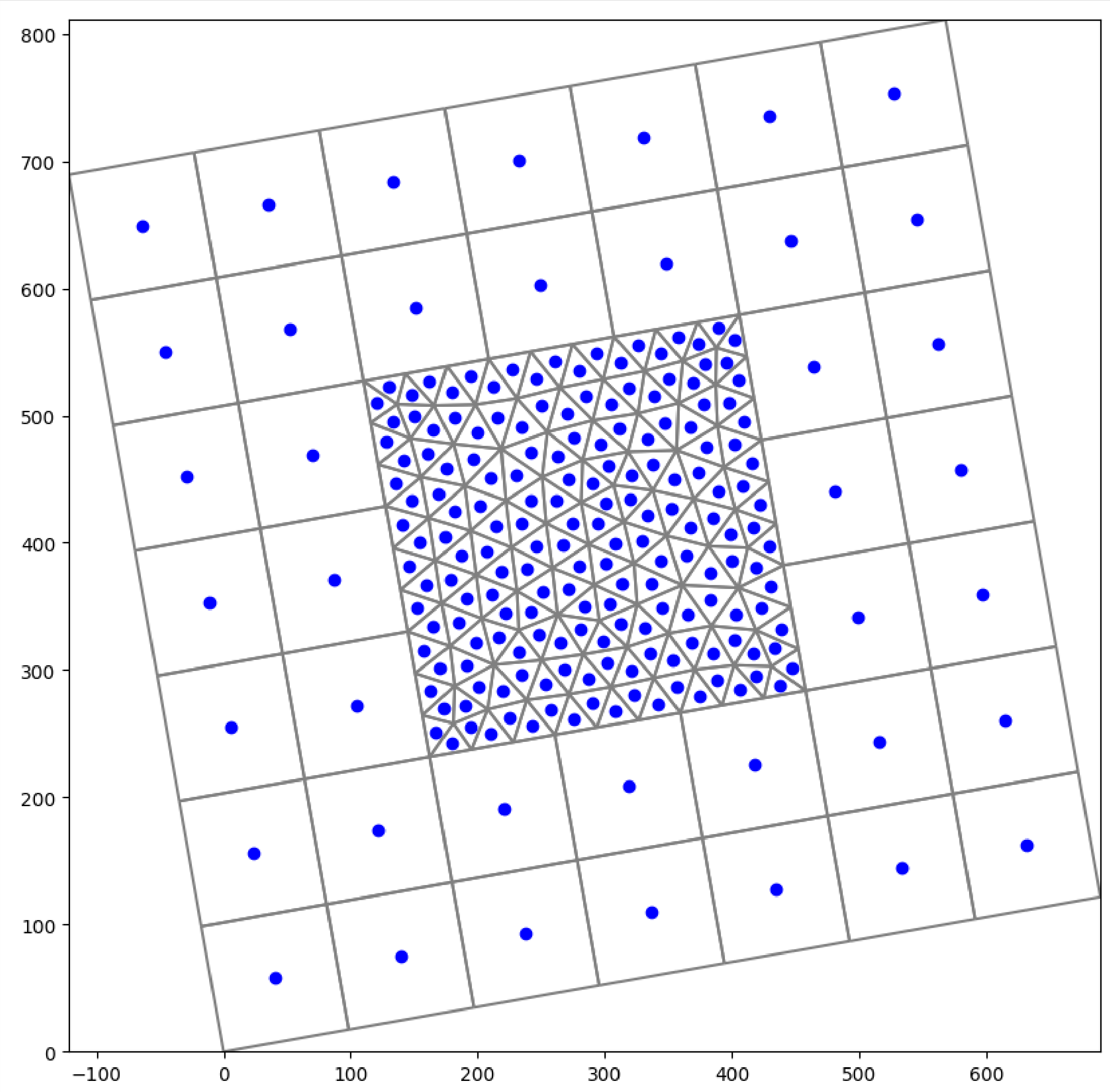
[40]:
```
ncpl = np.array(5 * [len(iverts)])
umg = UnstructuredGrid(verts, iverts, xc, yc, ncpl=ncpl, angrot=10)
print(ncpl)
print(umg)
```

```
[218 218 218 218 218]
xll:0.0; yll:0.0; rotation:10; units:undefined; lenuni:0
```

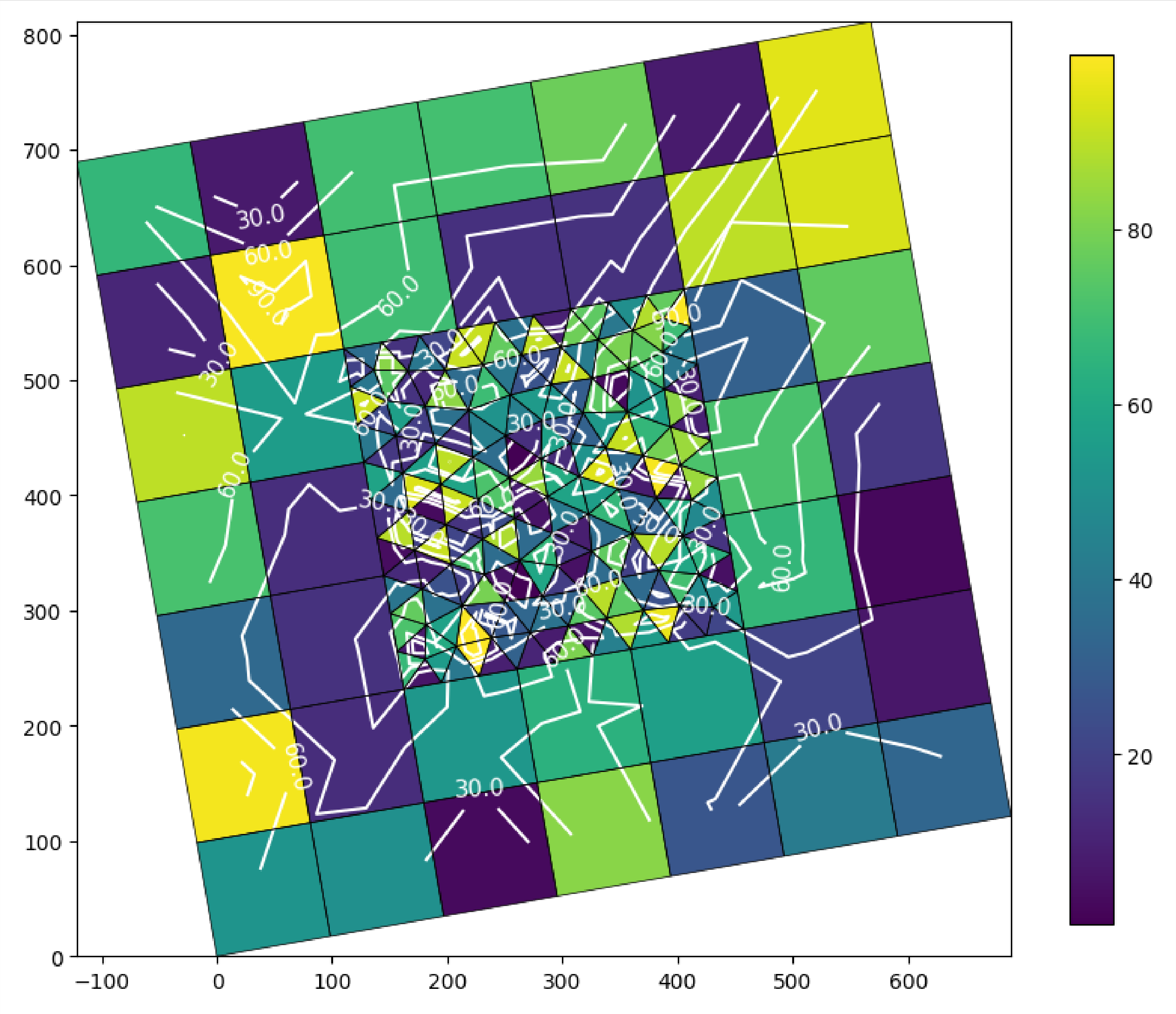
Now that we have an `UnstructuredGrid`, we can use the flopy `PlotMapView` object to create different types of plots, just like we do for structured grids.

[41]:
```
f = plt.figure(figsize=(10, 10))
mapview = flopy.plot.PlotMapView(modelgrid=umg)
mapview.plot_grid()
plt.plot(umg.xcellcenters, umg.ycellcenters, "bo")
```

[41]:
```
[<matplotlib.lines.Line2D at 0x7fbc40d83700>]
```

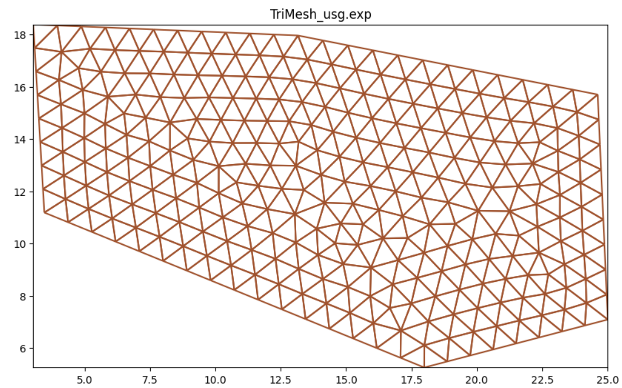


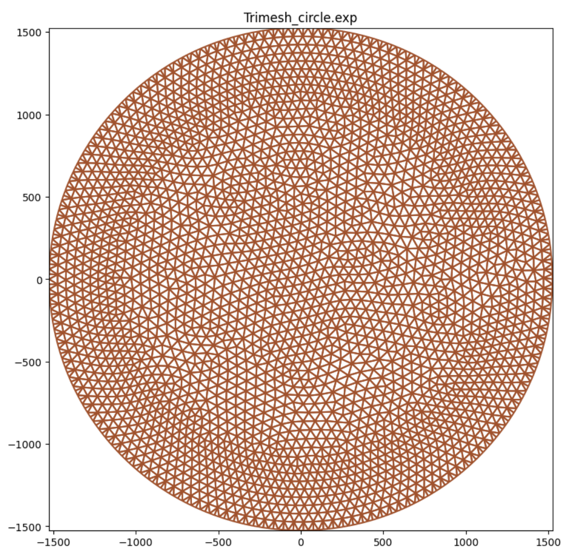
[42]:
```
# Create a random array for layer 0, and then plot it with a color flood and contours
f = plt.figure(figsize=(10, 10))

a = np.random.random(ncpl[0]) * 100
levels = np.arange(0, 100, 30)

mapview = flopy.plot.PlotMapView(modelgrid=umg)
pc = mapview.plot_array(a, cmap="viridis")
contour_set = mapview.contour_array(a, levels=levels, colors="white")
plt.clabel(contour_set, fmt="%.1f", colors="white", fontsize=11)
linecollection = mapview.plot_grid(color="k", lw=0.5)
colorbar = plt.colorbar(pc, shrink=0.75)
```

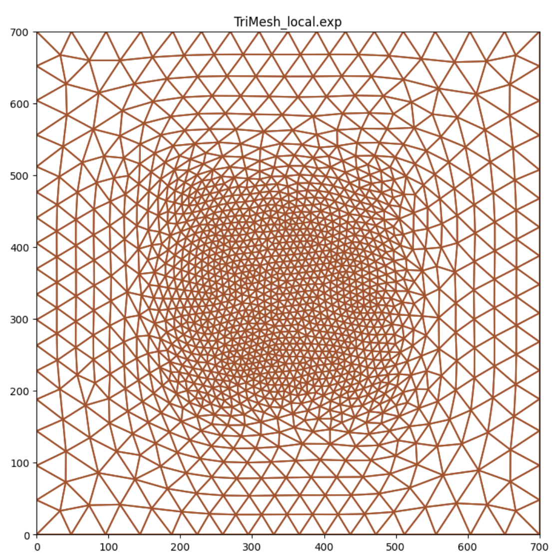


Here are some examples of some other types of grids. The data files for these grids are located in the datapth folder.

[43]:
```
from pathlib import Path

fig = plt.figure(figsize=(10, 30))
fnames = [fname for fname in os.listdir(datapth) if fname.endswith(".exp")]
nplot = len(fnames)
for i, f in enumerate(fnames):
    ax = fig.add_subplot(nplot, 1, i + 1, aspect="equal")
    fname = os.path.join(datapth, f)
    umga = UnstructuredGrid.from_argus_export(fname, nlay=1)
    mapview = flopy.plot.PlotMapView(modelgrid=umga, ax=ax)
    linecollection = mapview.plot_grid(colors="sienna")
    ax.set_title(Path(fname).name)
```


TriMesh_usg.exp
18
16
14
12
10
8
6
5.0
7.5
10.0
12.5
15.0
17.5
20.0
22.5
25.0


Trimesh_circle.exp
1500
1000
500
0
−500
−1000
−1500
−1500
−1000
−500
0
500
1000
1500

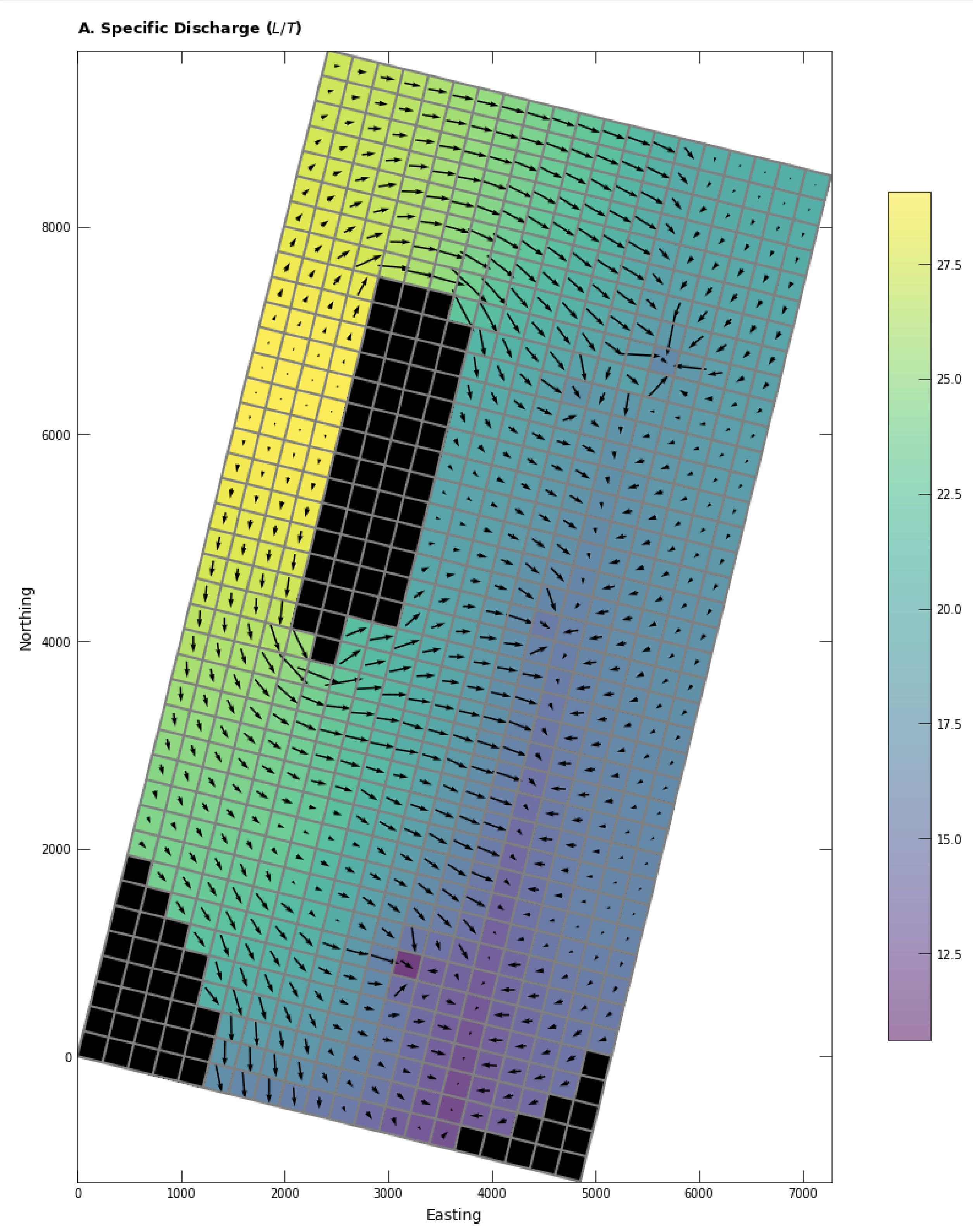

TriMesh_local.exp
700
600
500
400
300
200
100
0
0
100
200
300
400
500
600
700

Plotting using built in styles

FloPy's plotting routines can be used with built in styles from the `styles` module. The `styles` module takes advantage of matplotlib's temporary styling routines by reading in pre-built style sheets. Two different types of styles have been built for flopy: `USGSMap()` and `USGSPlot()` styles which can be used to create report quality figures. The styles module also contains a number of methods that can be used for adding axis labels, text, annotations, headings, removing tick lines, and updating the current font.

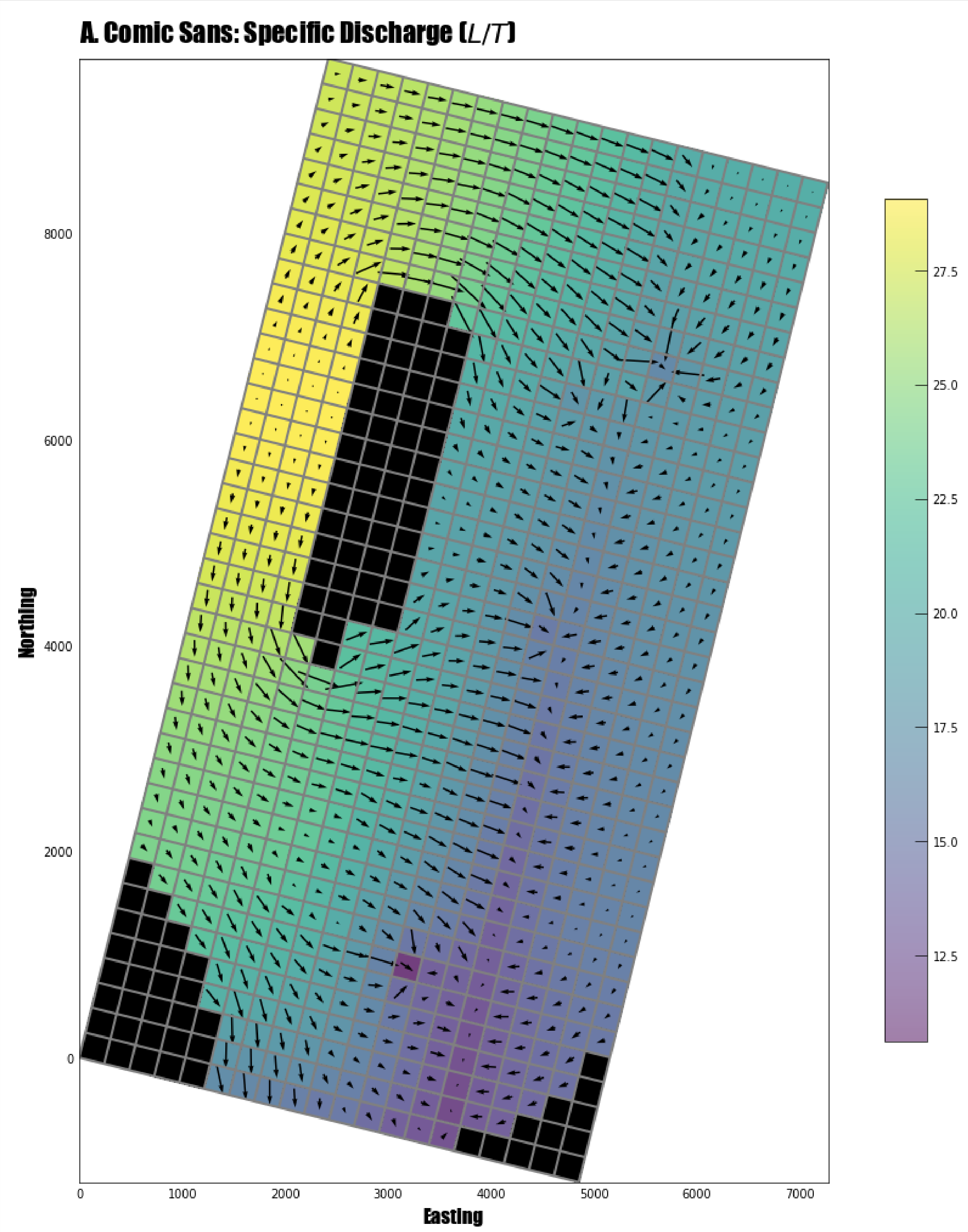
[44]:
```
# import flopy's styles
from flopy.plot import styles
```

[45]:
```
# get the specific discharge from the cell budget file
cbc_file = os.path.join(newpth, "freyberg.cbc")
cbc = flopy.utils.CellBudgetFile(cbc_file)
spdis = cbc.get_data(text="SPDIS")[0]

qx, qy, qz = flopy.utils.postprocessing.get_specific_discharge(spdis, ml6)

# get the head from the head file
head_file = os.path.join(newpth, "freyberg.hds")
head = flopy.utils.HeadFile(head_file)
hdata = head.get_alldata()[0]

# use USGSMap style to create a discharge figure:
with styles.USGSMap():
    fig = plt.figure(figsize=(12, 12))

    mapview = flopy.plot.PlotMapView(model=ml6, layer=0)
    linecollection = mapview.plot_grid()
    quadmesh = mapview.plot_array(a=hdata, alpha=0.5)
    quiver = mapview.plot_vector(qx, qy)
    inactive = mapview.plot_inactive()
    plt.colorbar(quadmesh, shrink=0.75)

    # use styles to add a heading, xlabel, ylabel
    styles.heading(
        letter="A.", heading="Specific Discharge (" + r"$L/T$" + ")"
    )
    styles.xlabel(label="Easting")
    styles.ylabel(label="Northing")
```



Here is a second example showing how to change the font type using `styles`

[46]:
```
# use USGSMap style, change font type, and plot without tick lines:
with styles.USGSMap():
    fig = plt.figure(figsize=(12, 12))

    mapview = flopy.plot.PlotMapView(model=ml6, layer=0)
    linecollection = mapview.plot_grid()
    quadmesh = mapview.plot_array(a=hdata, alpha=0.5)
    quiver = mapview.plot_vector(qx, qy)
    inactive = mapview.plot_inactive()
    plt.colorbar(quadmesh, shrink=0.75)

    # change the font type to comic sans
    styles.set_font_type(family="fantasy", fontname="Comic Sans MS"),

    # use styles to add a heading, xlabel, ylabel, and remove tick marks
    styles.heading(
        letter="A.",
        heading="Comic Sans: Specific Discharge (" + r"$L/T$" + ")",
        fontsize=16,
    )
    styles.xlabel(label="Easting", fontsize=12)
    styles.ylabel(label="Northing", fontsize=12)
    styles.remove_edge_ticks()
```


A. Comic Sans: Specific Discharge (L/T)
Northing
Easting
0
1000
2000
3000
4000
5000
6000
7000
8000
27.5
25.0
22.5
20.0
17.5
15.0
12.5

Summary

This notebook demonstrates some of the plotting functionality available with FloPy. Although not described here, the plotting functionality tries to be general by passing keyword arguments passed to `PlotMapView` methods down into the `matplotlib.pyplot` routines that do the actual plotting. For those looking to customize these plots, it may be necessary to search for the available keywords by understanding the types of objects that are created by the `PlotMapView` methods. The `PlotMapView` methods return these `matplotlib.collections` objects so that they could be fine-tuned later in the script before plotting.

Hope this gets you started!

[47]:
```
try:
    # ignore PermissionError on Windows
    tempdir.cleanup()
except:
    pass
```

6.3 Exporting data

6.3.1 Shapefile export demo

The goal of this notebook is to demonstrate ways to export model information to shapefiles. This example will cover: * basic exporting of information for a model, individual package, or dataset * custom exporting of combined data from different packages * general exporting and importing of geographic data from other sources

[1]:
```
import os
```

[2]:
```
import sys
from tempfile import TemporaryDirectory

import matplotlib as mpl
import matplotlib.pyplot as plt
import numpy as np
import pandas as pd

import flopy

print(sys.version)
print(f"numpy version: {np.__version__}")
print(f"matplotlib version: {mpl.__version__}")
print(f"flopy version: {flopy.__version__}")
```

```
3.8.18 (default, Aug 28 2023, 08:27:22)
[GCC 11.4.0]
numpy version: 1.24.4
matplotlib version: 3.7.4
flopy version: 3.5.0
```

[3]:
```
# temporary directory
temp_dir = TemporaryDirectory()
outdir = os.path.join(temp_dir.name, "shapefile_export")
```

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```
# load an existing model
model_ws = "../../examples/data/freyberg"
m = flopy.modflow.Modflow.load(
    "freyberg.nam",
    model_ws=model_ws,
    verbose=False,
    check=False,
    exe_name="mfnwt",
)
```

[4]:
```
m.get_package_list()
```

[4]:
```
['DIS', 'BAS6', 'LPF', 'WEL', 'RIV', 'RCH', 'OC', 'PCG']
```

set the model coordinate information

the coordinate information where the grid is located in a projected coordinate system (e.g. UTM)

[5]:
```
grid = m.modelgrid
grid.set_coord_info(xoff=273170, yoff=5088657, crs=26916)
```

[6]:
```
grid.extent
```

[6]:
```
(273170.0, 278170.0, 5088657.0, 5098657.0)
```

Declarative export using attached `.export()` methods

Export the whole model to a single shapefile

[7]:
```
fname = f"{outdir}/model.shp"
m.export(fname)
```

```
/opt/hostedtoolcache/Python/3.8.18/x64/lib/python3.8/site-packages/flopy/export/
↪shapefile_utils.py:318: UserWarning: Failed to get data for delc array, DIS package
  warn(
/opt/hostedtoolcache/Python/3.8.18/x64/lib/python3.8/site-packages/flopy/export/
↪shapefile_utils.py:318: UserWarning: Failed to get data for delr array, DIS package
  warn(
/opt/hostedtoolcache/Python/3.8.18/x64/lib/python3.8/site-packages/flopy/export/
↪shapefile_utils.py:318: UserWarning: Failed to get data for laycbd array, DIS package
  warn(
/opt/hostedtoolcache/Python/3.8.18/x64/lib/python3.8/site-packages/flopy/export/
↪shapefile_utils.py:318: UserWarning: Failed to get data for nstp array, DIS package
  warn(
/opt/hostedtoolcache/Python/3.8.18/x64/lib/python3.8/site-packages/flopy/export/
↪shapefile_utils.py:318: UserWarning: Failed to get data for perlen array, DIS package
  warn(
/opt/hostedtoolcache/Python/3.8.18/x64/lib/python3.8/site-packages/flopy/export/
↪shapefile_utils.py:318: UserWarning: Failed to get data for steady array, DIS package
```

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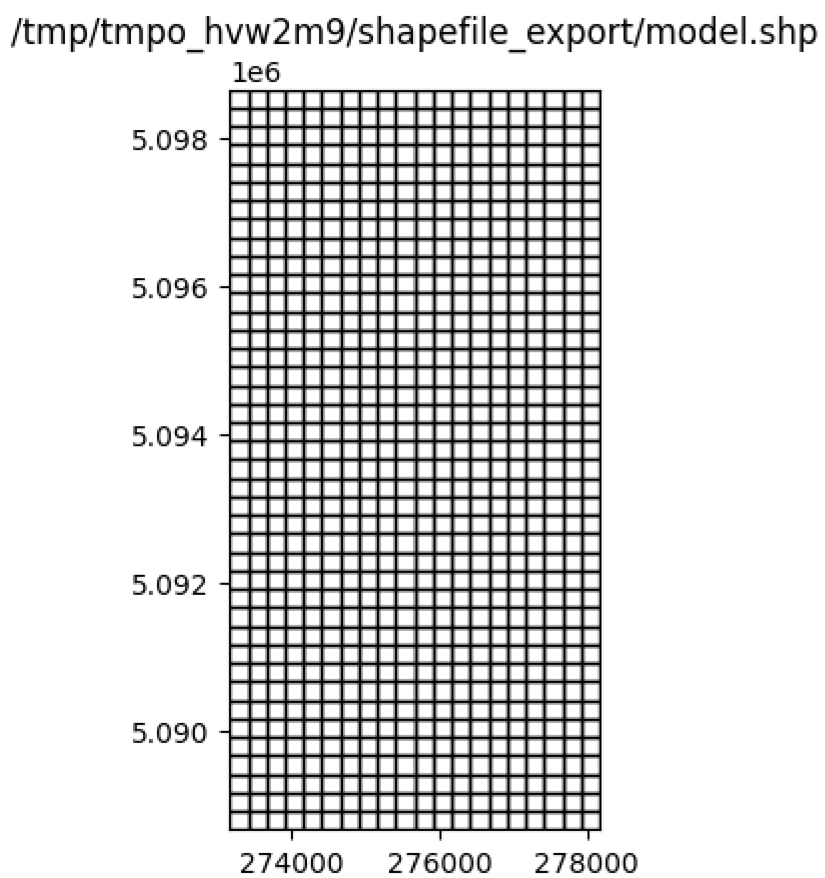
```
  warn(
/opt/hostedtoolcache/Python/3.8.18/x64/lib/python3.8/site-packages/flopy/export/
↪shapefile_utils.py:318: UserWarning: Failed to get data for tsmult array, DIS package
  warn(
/opt/hostedtoolcache/Python/3.8.18/x64/lib/python3.8/site-packages/flopy/export/
↪shapefile_utils.py:318: UserWarning: Failed to get data for chani array, LPF package
  warn(
/opt/hostedtoolcache/Python/3.8.18/x64/lib/python3.8/site-packages/flopy/export/
↪shapefile_utils.py:318: UserWarning: Failed to get data for layavg array, LPF package
  warn(
/opt/hostedtoolcache/Python/3.8.18/x64/lib/python3.8/site-packages/flopy/export/
↪shapefile_utils.py:318: UserWarning: Failed to get data for laytyp array, LPF package
  warn(
/opt/hostedtoolcache/Python/3.8.18/x64/lib/python3.8/site-packages/flopy/export/
↪shapefile_utils.py:318: UserWarning: Failed to get data for layvka array, LPF package
  warn(
/opt/hostedtoolcache/Python/3.8.18/x64/lib/python3.8/site-packages/flopy/export/
↪shapefile_utils.py:318: UserWarning: Failed to get data for laywet array, LPF package
  warn(
```

[8]:
```
ax = plt.subplot(1, 1, 1, aspect="equal")
extents = grid.extent
pc = flopy.plot.plot_shapefile(fname, ax=ax, edgecolor="k", facecolor="none")
ax.set_xlim(extents[0], extents[1])
ax.set_ylim(extents[2], extents[3])
ax.set_title(fname)
```

[8]:
```
Text(0.5, 1.0, '/tmp/tmpo_hvw2m9/shapefile_export/model.shp')
```




```
[9]: fname = f"{outdir}/wel.shp"
     m.wel.export(fname)
```

Export a package to a shapefile

Export a FloPy list or array object

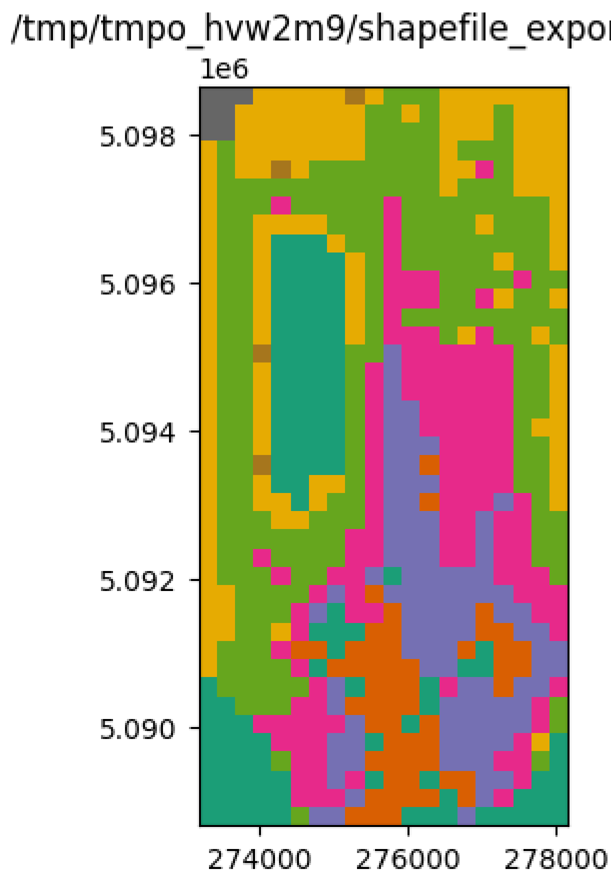
```
[10]: m.lpf.hk
```

```
[10]: <flopy.utils.util_array.Util3d at 0x7fb139266c10>
```

```
[11]: fname = f"{outdir}/hk.shp"
      m.lpf.hk.export(f"{outdir}/hk.shp")
```

```
[12]: ax = plt.subplot(1, 1, 1, aspect="equal")
      extents = grid.extent
      a = m.lpf.hk.array.ravel()
      pc = flopy.plot.plot_shapefile(fname, ax=ax, a=a)
      ax.set_xlim(extents[0], extents[1])
      ax.set_ylim(extents[2], extents[3])
      ax.set_title(fname)
```

[12]:
```
Text(0.5, 1.0, '/tmp/tmpo_hvw2m9/shapefile_export/hk.shp')
```



[13]:
```
m.riv.stress_period_data
```

[13]:
```
<flopy.utils.util_list.MfList at 0x7fb1391f7130>
```

[14]:
```
m.riv.stress_period_data.export(f"{outdir}/riv_spd.shp")
```

MfList.export() exports the whole grid by default, regardless of the locations of the boundary cells

sparse=True only exports the boundary cells in the MfList

[15]:
```
m.riv.stress_period_data.export(f"{outdir}/riv_spd.shp", sparse=True)
```

[16]:
```
m.wel.stress_period_data.export(f"{outdir}/wel_spd.shp", sparse=True)
```

Ad-hoc exporting using `recarray2shp`

- The main idea is to create a recarray with all of the attribute information, and a list of geometry features (one feature per row in the recarray)
- each geometry feature is an instance of the `Point`, `LineString` or `Polygon` classes in `flopy.utils.geometry`. The shapefile format requires all the features to be of the same type.
- We will use pandas dataframes for these examples because they are easy to work with, and then convert them to recarrays prior to exporting.

[17]:
```python
from flopy.export.shapefile_utils import recarray2shp
```

combining data from different packages

write a shapefile of RIV and WEL package cells

[18]:
```python
wellspd = pd.DataFrame(m.wel.stress_period_data[0])
rivspd = pd.DataFrame(m.riv.stress_period_data[0])
spd = pd.concat([wellspd, rivspd])
spd.head()
```

[18]:

	k	i	j	flux	iface	stage	cond	rbot
0	0	8	15	-0.00820	0.0	NaN	NaN	NaN
1	0	10	12	-0.00410	0.0	NaN	NaN	NaN
2	0	19	13	-0.00390	0.0	NaN	NaN	NaN
3	0	25	9	-0.00083	0.0	NaN	NaN	NaN
4	0	28	5	-0.00072	0.0	NaN	NaN	NaN

[19]:
```python
from flopy.utils.geometry import Polygon

vertices = []
for row, col in zip(spd.i, spd.j):
    vertices.append(grid.get_cell_vertices(row, col))
polygons = [Polygon(vrt) for vrt in vertices]
polygons
```

[19]:
```
[<flopy.utils.geometry.Polygon at 0x7fb136b06160>,
 <flopy.utils.geometry.Polygon at 0x7fb136b06130>,
 <flopy.utils.geometry.Polygon at 0x7fb136b06250>,
 <flopy.utils.geometry.Polygon at 0x7fb136b06ac0>,
 <flopy.utils.geometry.Polygon at 0x7fb136b06670>,
 <flopy.utils.geometry.Polygon at 0x7fb136b06e50>,
 <flopy.utils.geometry.Polygon at 0x7fb136b060d0>,
 <flopy.utils.geometry.Polygon at 0x7fb136b06ca0>,
 <flopy.utils.geometry.Polygon at 0x7fb136b069a0>,
 <flopy.utils.geometry.Polygon at 0x7fb136b06b80>,
 <flopy.utils.geometry.Polygon at 0x7fb136b33310>,
 <flopy.utils.geometry.Polygon at 0x7fb136b33fd0>,
 <flopy.utils.geometry.Polygon at 0x7fb136b33250>,
 <flopy.utils.geometry.Polygon at 0x7fb136b33430>,
 <flopy.utils.geometry.Polygon at 0x7fb136b33400>,
 <flopy.utils.geometry.Polygon at 0x7fb136b334c0>,
 <flopy.utils.geometry.Polygon at 0x7fb136b335e0>,
```

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```
<flopy.utils.geometry.Polygon at 0x7fb136b335b0>,
<flopy.utils.geometry.Polygon at 0x7fb136b33700>,
<flopy.utils.geometry.Polygon at 0x7fb136b33790>,
<flopy.utils.geometry.Polygon at 0x7fb136b337f0>,
<flopy.utils.geometry.Polygon at 0x7fb136b338b0>,
<flopy.utils.geometry.Polygon at 0x7fb136b33940>,
<flopy.utils.geometry.Polygon at 0x7fb136b33a60>,
<flopy.utils.geometry.Polygon at 0x7fb136b33a30>,
<flopy.utils.geometry.Polygon at 0x7fb136b33b50>,
<flopy.utils.geometry.Polygon at 0x7fb136b33be0>,
<flopy.utils.geometry.Polygon at 0x7fb136b33c70>,
<flopy.utils.geometry.Polygon at 0x7fb136b33dc0>,
<flopy.utils.geometry.Polygon at 0x7fb136b33d90>,
<flopy.utils.geometry.Polygon at 0x7fb136b33ee0>,
<flopy.utils.geometry.Polygon at 0x7fb136b33eb0>,
<flopy.utils.geometry.Polygon at 0x7fb136b33f40>,
<flopy.utils.geometry.Polygon at 0x7fb136b330d0>,
<flopy.utils.geometry.Polygon at 0x7fb136b33040>,
<flopy.utils.geometry.Polygon at 0x7fb136b331f0>,
<flopy.utils.geometry.Polygon at 0x7fb136b339a0>,
<flopy.utils.geometry.Polygon at 0x7fb136b33ac0>,
<flopy.utils.geometry.Polygon at 0x7fb136acf2e0>,
<flopy.utils.geometry.Polygon at 0x7fb136acf3a0>,
<flopy.utils.geometry.Polygon at 0x7fb136acf430>,
<flopy.utils.geometry.Polygon at 0x7fb136acf4c0>,
<flopy.utils.geometry.Polygon at 0x7fb136acf5b0>,
<flopy.utils.geometry.Polygon at 0x7fb136acf640>,
<flopy.utils.geometry.Polygon at 0x7fb136acf6d0>,
<flopy.utils.geometry.Polygon at 0x7fb136acf760>]
```

[20]:

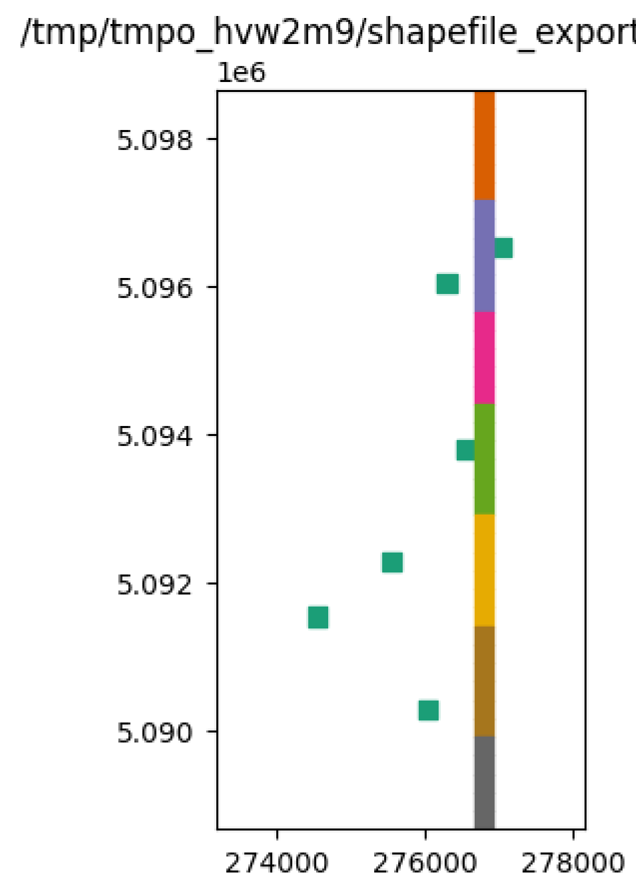
```
fname = f"{outdir}/bcs.shp"
recarray2shp(spd.to_records(), geoms=polygons, shpname=fname, crs=grid.epsg)
```

[21]:

```
ax = plt.subplot(1, 1, 1, aspect="equal")
extents = grid.extent
pc = flopy.plot.plot_shapefile(fname, ax=ax)
ax.set_xlim(extents[0], extents[1])
ax.set_ylim(extents[2], extents[3])
ax.set_title(fname)
```

[21]:

```
Text(0.5, 1.0, '/tmp/tmpo_hvw2m9/shapefile_export/bcs.shp')
```



exporting other data

Suppose we have some well data with actual locations that we want to export to a shapefile

[22]:
```
welldata = pd.DataFrame(
    {
        "wellID": np.arange(0, 10),
        "q": np.random.randn(10) * 100 - 1000,
        "x_utm": np.random.rand(10) * 5000 + grid.xoffset,
        "y_utm": grid.yoffset + np.random.rand(10) * 10000,
    }
)
welldata.head()
```

[22]:

	wellID	q	x_utm	y_utm
0	0	-1168.494405	278128.902835	5.096593e+06
1	1	-1172.156756	277799.340347	5.092081e+06
2	2	-982.272822	276529.150374	5.094145e+06
3	3	-1028.519743	276937.061580	5.095632e+06
4	4	-982.832406	276665.769787	5.096710e+06

[23]:
```
from flopy.utils.geometry import Point
```

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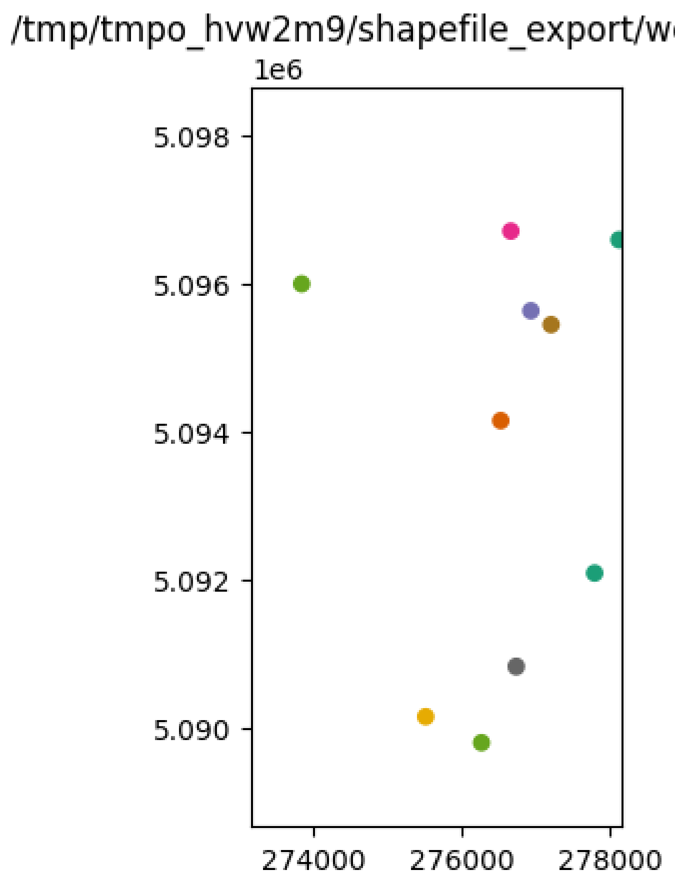
```
geoms = [Point(x, y) for x, y in zip(welldata.x_utm, welldata.y_utm)]

fname = f"{outdir}/wel_data.shp"
recarray2shp(welldata.to_records(), geoms=geoms, shpname=fname, crs=grid.epsg)
```

[24]:
```
ax = plt.subplot(1, 1, 1, aspect="equal")
extents = grid.extent
pc = flopy.plot.plot_shapefile(fname, ax=ax, radius=100)
ax.set_xlim(extents[0], extents[1])
ax.set_ylim(extents[2], extents[3])
ax.set_title(fname)
```

[24]:
```
Text(0.5, 1.0, '/tmp/tmpo_hvw2m9/shapefile_export/wel_data.shp')
```



Adding attribute data to an existing shapefile

Suppose we have a GIS coverage representing the river in the riv package

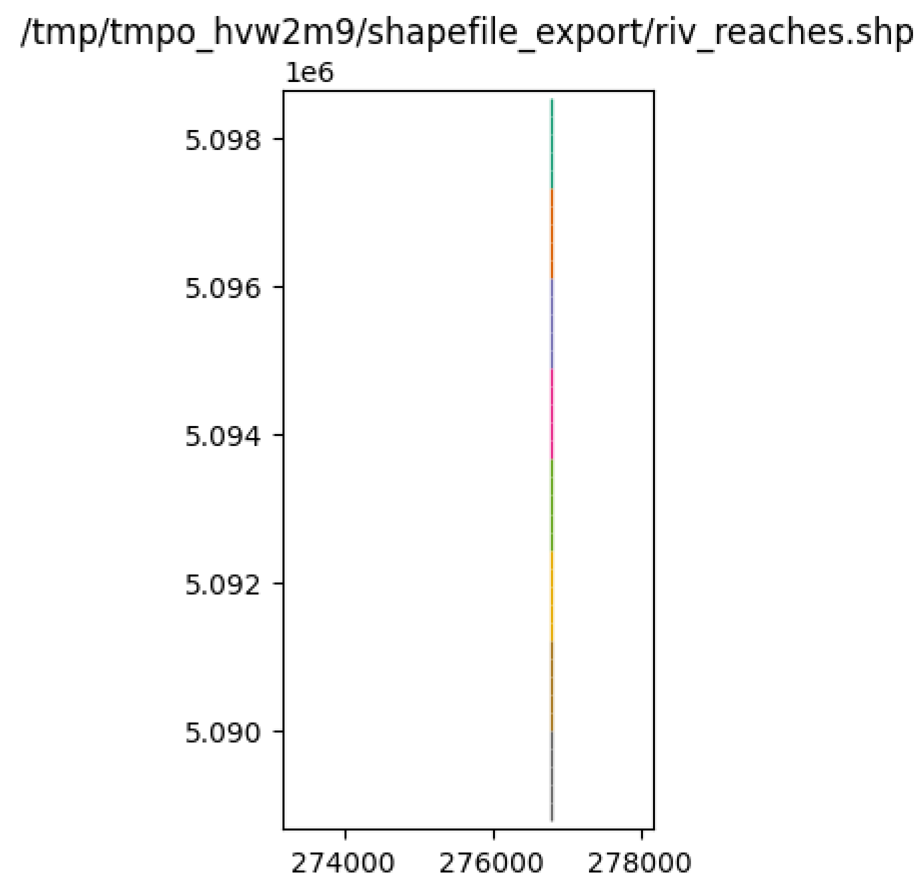
[25]:
```python
from flopy.utils.geometry import LineString

### make up a linestring shapefile of the river reaches
i, j = m.riv.stress_period_data[0].i, m.riv.stress_period_data[0].j
x0 = grid.xyzcellcenters[0][i[0], j[0]]
x1 = grid.xyzcellcenters[0][i[-1], j[-1]]
y0 = grid.xyzcellcenters[1][i[0], j[0]]
y1 = grid.xyzcellcenters[1][i[-1], j[-1]]
x = np.linspace(x0, x1, m.nrow + 1)
y = np.linspace(y0, y1, m.nrow + 1)
l0 = zip(list(zip(x[:-1], y[:-1])), list(zip(x[1:], y[1:])))
lines = [LineString(l) for l in l0]

rivdata = pd.DataFrame(m.riv.stress_period_data[0])
rivdata["reach"] = np.arange(len(lines))
lines_shapefile = f"{outdir}/riv_reaches.shp"
recarray2shp(
    rivdata.to_records(index=False),
    geoms=lines,
    shpname=lines_shapefile,
    crs=grid.epsg,
)
```

[26]:
```python
ax = plt.subplot(1, 1, 1, aspect="equal")
extents = grid.extent
pc = flopy.plot.plot_shapefile(lines_shapefile, ax=ax, radius=25)
ax.set_xlim(extents[0], extents[1])
ax.set_ylim(extents[2], extents[3])
ax.set_title(lines_shapefile)
```

[26]:
```
Text(0.5, 1.0, '/tmp/tmpo_hvw2m9/shapefile_export/riv_reaches.shp')
```



shp2recarray reads a shapefile into a numpy record array, which can easily be converted to a DataFrame

[27]:
```
from flopy.export.shapefile_utils import shp2recarray
```

[28]:
```
linesdata = shp2recarray(lines_shapefile)
linesdata = pd.DataFrame(linesdata)
linesdata.head()
```

[28]:
```
   k  i   j      stage  cond   rbot  iface  reach  \
0  0  0  14  20.100000  0.05  20.00    0.0      0
1  0  1  14  19.870001  0.05  19.75    0.0      1
2  0  2  14  19.650000  0.05  19.50    0.0      2
3  0  3  14  19.420000  0.05  19.25    0.0      3
4  0  4  14  19.190001  0.05  19.00    0.0      4

                                           geometry
0  <flopy.utils.geometry.LineString object at 0x7...
1  <flopy.utils.geometry.LineString object at 0x7...
2  <flopy.utils.geometry.LineString object at 0x7...
3  <flopy.utils.geometry.LineString object at 0x7...
4  <flopy.utils.geometry.LineString object at 0x7...
```

[29]:
```
# make up some fluxes between the river and aquifer at each reach
q = np.random.randn(len(linesdata)) + 1
```

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```
q
```

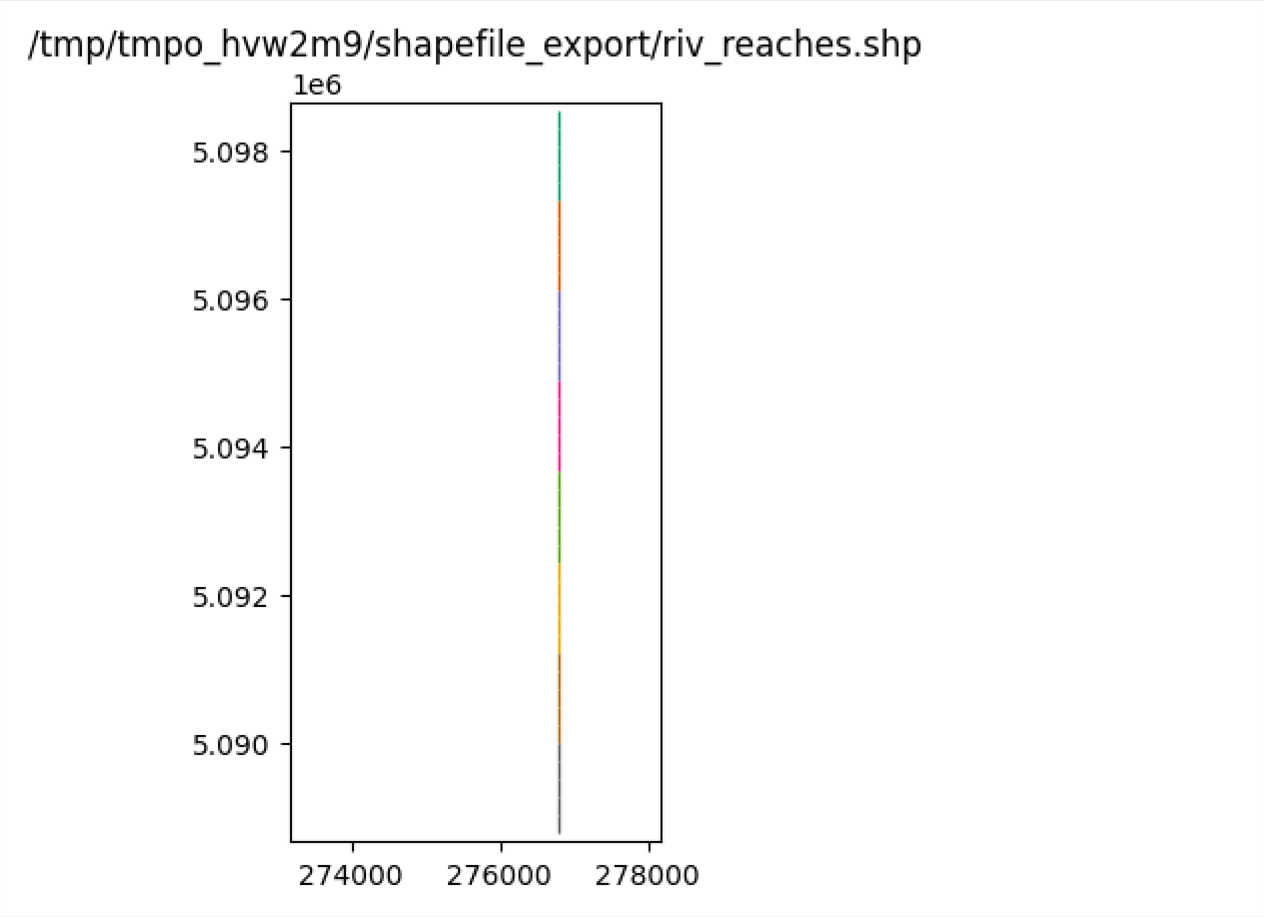
[29]:
```
array([ 2.59634437,  0.16396343,  2.10471095, -0.01260278,  1.37311779,
        1.13320485,  2.41679233,  1.28881834,  1.93272934,  1.024456  ,
        0.18296139, -0.36535417,  1.0496593 ,  0.36656188, -0.22184639,
        0.69776326,  0.15082364,  2.066711  ,  1.26057759,  1.56523207,
        2.5730076 ,  0.40086679,  0.15114441,  0.95177301,  2.93455291,
        1.26448037,  0.34874558,  1.14487655,  1.99608706,  1.88741144,
        2.32956875,  0.67947968, -0.20075081,  0.72891064,  1.96731829,
       -1.4715887 ,  1.35453759,  1.85204316,  0.07015399,  1.46340667])
```

[30]:
```
linesdata["qreach"] = q
linesdata["qstream"] = np.cumsum(q)
```

[31]:
```
recarray2shp(
    linesdata.drop("geometry", axis=1).to_records(),
    geoms=linesdata.geometry.values,
    shpname=lines_shapefile,
    crs=grid.epsg,
)
```

[32]:
```
ax = plt.subplot(1, 1, 1, aspect="equal")
extents = grid.extent
pc = flopy.plot.plot_shapefile(lines_shapefile, ax=ax, radius=25)
ax.set_xlim(extents[0], extents[1])
ax.set_ylim(extents[2], extents[3])
ax.set_title(lines_shapefile)
```

[32]:
```
Text(0.5, 1.0, '/tmp/tmpo_hvw2m9/shapefile_export/riv_reaches.shp')
```



Overriding the model's modelgrid with a user supplied modelgrid

In some cases it may be necessary to override the model's modelgrid instance with a seperate modelgrid. An example of this is if the model discretization is in feet and the user would like it projected in meters. Exporting can be accomplished by supplying a modelgrid as a `kwarg` in any of the `export()` methods within flopy. Below is an example:

[33]:
```
mg0 = m.modelgrid

# build a new modelgrid instance with discretization in meters
modelgrid = flopy.discretization.StructuredGrid(
    delc=mg0.delc * 0.3048,
    delr=mg0.delr * 0.3048,
    top=mg0.top,
    botm=mg0.botm,
    idomain=mg0.idomain,
    xoff=mg0.xoffset * 0.3048,
    yoff=mg0.yoffset * 0.3048,
)

# exporting an entire model
m.export(f"{outdir}/freyberg.shp", modelgrid=modelgrid)
```

```
No CRS information for writing a .prj file.
Supply an valid coordinate system reference to the attached modelgrid object or .
↪export() method.
No CRS information for writing a .prj file.
Supply an valid coordinate system reference to the attached modelgrid object or .
↪export() method.
```

```
/opt/hostedtoolcache/Python/3.8.18/x64/lib/python3.8/site-packages/flopy/export/
↪shapefile_utils.py:318: UserWarning: Failed to get data for delc array, DIS package
  warn(
/opt/hostedtoolcache/Python/3.8.18/x64/lib/python3.8/site-packages/flopy/export/
↪shapefile_utils.py:318: UserWarning: Failed to get data for delr array, DIS package
  warn(
/opt/hostedtoolcache/Python/3.8.18/x64/lib/python3.8/site-packages/flopy/export/
↪shapefile_utils.py:318: UserWarning: Failed to get data for laycbd array, DIS package
  warn(
/opt/hostedtoolcache/Python/3.8.18/x64/lib/python3.8/site-packages/flopy/export/
↪shapefile_utils.py:318: UserWarning: Failed to get data for nstp array, DIS package
  warn(
/opt/hostedtoolcache/Python/3.8.18/x64/lib/python3.8/site-packages/flopy/export/
↪shapefile_utils.py:318: UserWarning: Failed to get data for perlen array, DIS package
  warn(
/opt/hostedtoolcache/Python/3.8.18/x64/lib/python3.8/site-packages/flopy/export/
↪shapefile_utils.py:318: UserWarning: Failed to get data for steady array, DIS package
  warn(
/opt/hostedtoolcache/Python/3.8.18/x64/lib/python3.8/site-packages/flopy/export/
↪shapefile_utils.py:318: UserWarning: Failed to get data for tsmult array, DIS package
  warn(
/opt/hostedtoolcache/Python/3.8.18/x64/lib/python3.8/site-packages/flopy/export/
↪shapefile_utils.py:318: UserWarning: Failed to get data for chani array, LPF package
  warn(
/opt/hostedtoolcache/Python/3.8.18/x64/lib/python3.8/site-packages/flopy/export/
↪shapefile_utils.py:318: UserWarning: Failed to get data for layavg array, LPF package
  warn(
/opt/hostedtoolcache/Python/3.8.18/x64/lib/python3.8/site-packages/flopy/export/
↪shapefile_utils.py:318: UserWarning: Failed to get data for laytyp array, LPF package
  warn(
/opt/hostedtoolcache/Python/3.8.18/x64/lib/python3.8/site-packages/flopy/export/
↪shapefile_utils.py:318: UserWarning: Failed to get data for layvka array, LPF package
  warn(
/opt/hostedtoolcache/Python/3.8.18/x64/lib/python3.8/site-packages/flopy/export/
↪shapefile_utils.py:318: UserWarning: Failed to get data for laywet array, LPF package
  warn(
```

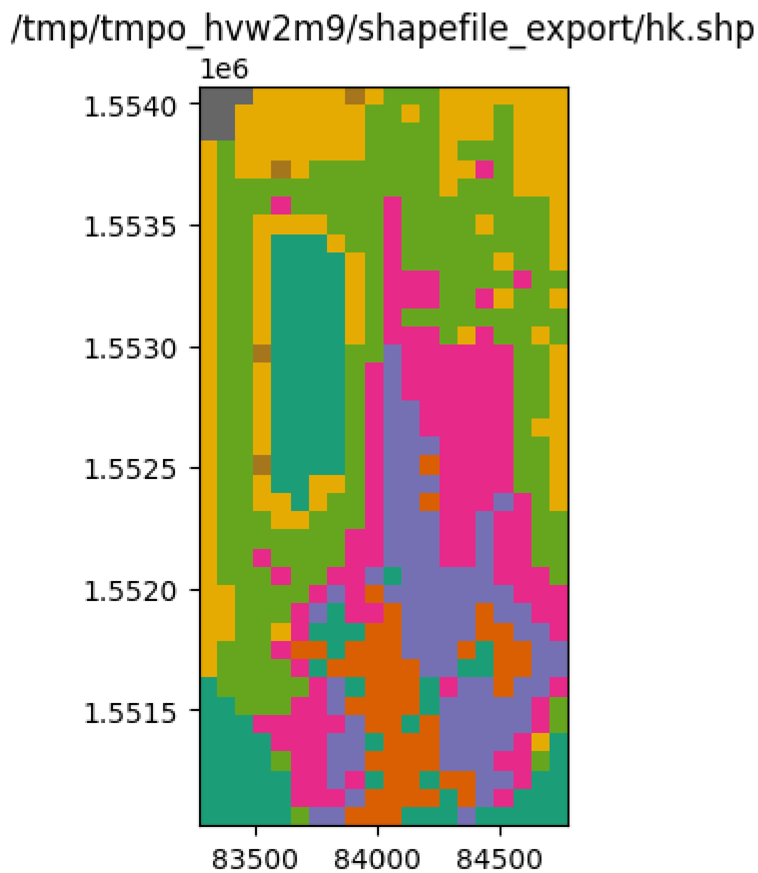
And for a specific parameter the method is the same

[34]:
```
fname = f"{outdir}/hk.shp"
m.lpf.hk.export(fname, modelgrid=modelgrid)
```

```
No CRS information for writing a .prj file.
Supply an valid coordinate system reference to the attached modelgrid object or .
↪export() method.
```

[35]:
```
ax = plt.subplot(1, 1, 1, aspect="equal")
extents = modelgrid.extent
a = m.lpf.hk.array.ravel()
pc = flopy.plot.plot_shapefile(fname, ax=ax, a=a)
ax.set_xlim(extents[0], extents[1])
ax.set_ylim(extents[2], extents[3])
ax.set_title(fname)
```

[35]:
```
Text(0.5, 1.0, '/tmp/tmpo_hvw2m9/shapefile_export/hk.shp')
```



[36]:
```
try:
    # ignore PermissionError on Windows
    temp_dir.cleanup()
except:
    pass
```

6.4 Other FloPy features

6.4.1 FloPy working stack demo

A short demonstration of core `flopy` functionality

[1]:
```
import sys
from pathlib import Path
from tempfile import TemporaryDirectory
```

[2]:
```
import matplotlib as mpl
import matplotlib.pyplot as plt
import numpy as np
import pandas as pd
```

[3]:
```
from IPython.display import clear_output, display

proj_root = Path.cwd().parent.parent

# run installed version of flopy or add local path
try:
    import flopy
except:
    sys.path.append(proj_root)
    import flopy

print(sys.version)
print(f"numpy version: {np.__version__}")
print(f"matplotlib version: {mpl.__version__}")
print(f"pandas version: {pd.__version__}")
print(f"flopy version: {flopy.__version__}")
```

```
3.8.18 (default, Aug 28 2023, 08:27:22)
[GCC 11.4.0]
numpy version: 1.24.4
matplotlib version: 3.7.4
pandas version: 2.0.3
flopy version: 3.5.0
```

Model Inputs

[4]:
```
# first lets load an existing model
model_ws = proj_root / "examples" / "data" / "freyberg_multilayer_transient"
ml = flopy.modflow.Modflow.load(
    "freyberg.nam",
    model_ws=model_ws,
    verbose=False,
    check=False,
    exe_name="mfnwt",
)
```

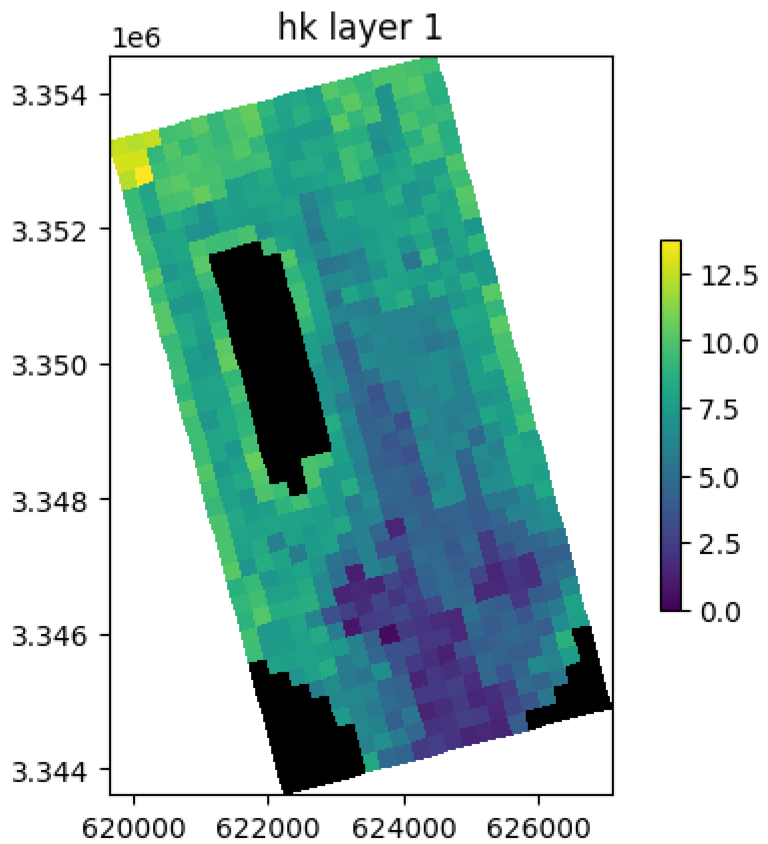
[5]:
```
ml.modelgrid
```

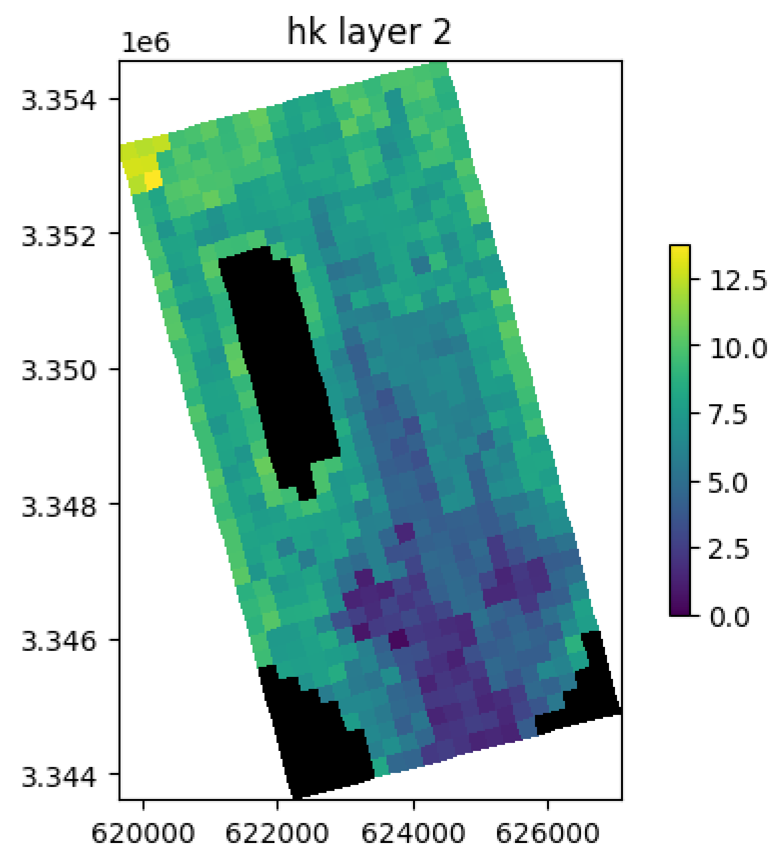
[5]:
```
xll:622241.1904510253; yll:3343617.741737109; rotation:15.0; crs:EPSG:32614; units:
↪meters; lenuni:2
```

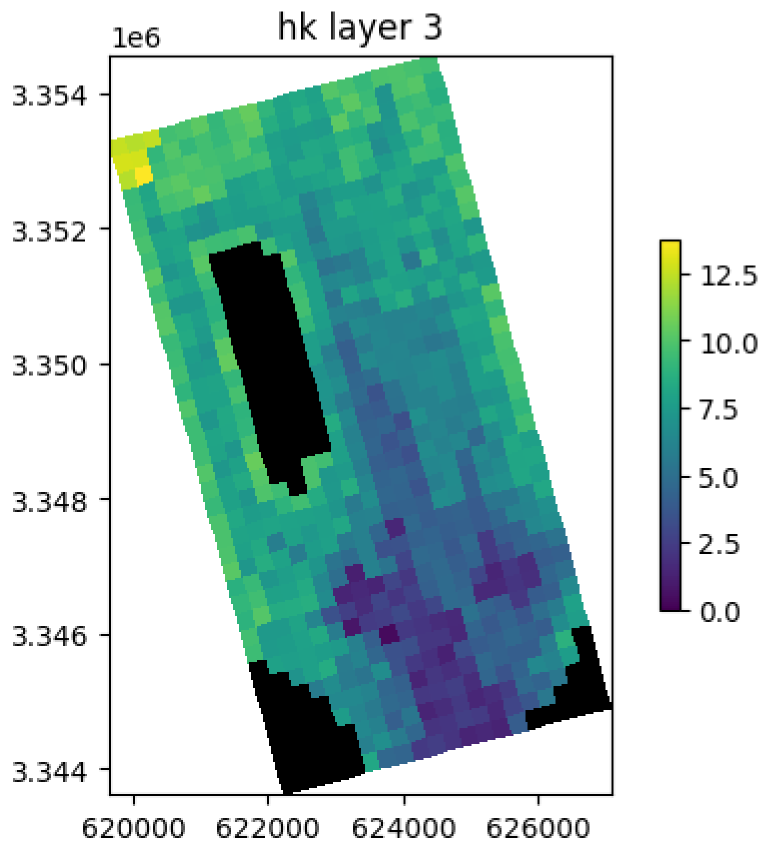
Let's looks at some plots

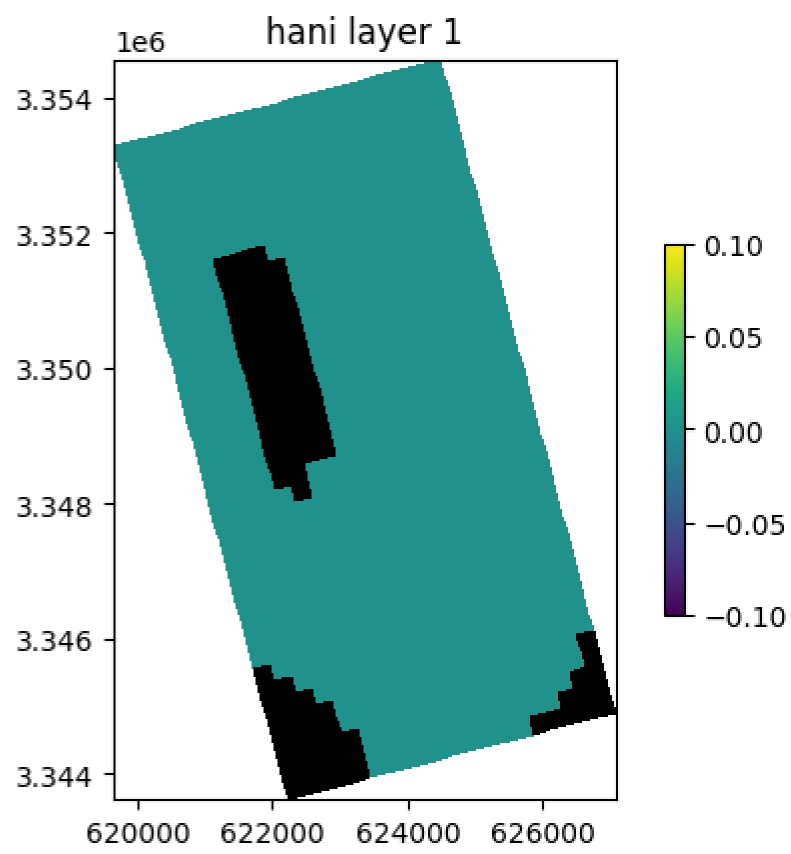
[6]:
```
ml.upw.plot()
```

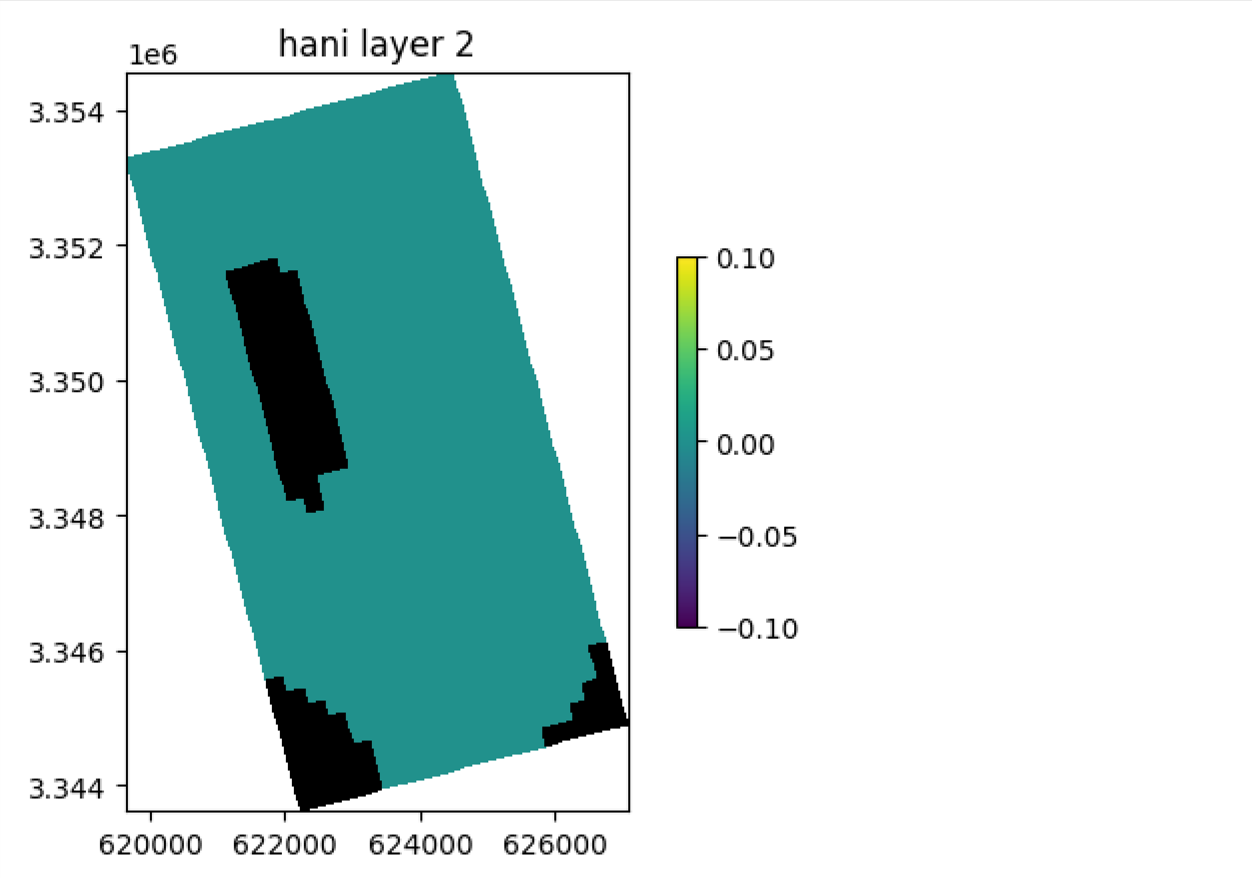
[6]:
```
[<Axes: title={'center': 'hk layer 1'}>,
 <Axes: title={'center': 'hk layer 2'}>,
 <Axes: title={'center': 'hk layer 3'}>,
 <Axes: title={'center': 'hani layer 1'}>,
 <Axes: title={'center': 'hani layer 2'}>,
 <Axes: title={'center': 'hani layer 3'}>,
 <Axes: title={'center': 'vka layer 1'}>,
 <Axes: title={'center': 'vka layer 2'}>,
 <Axes: title={'center': 'vka layer 3'}>,
 <Axes: title={'center': 'ss layer 1'}>,
 <Axes: title={'center': 'ss layer 2'}>,
 <Axes: title={'center': 'ss layer 3'}>,
 <Axes: title={'center': 'sy layer 1'}>,
 <Axes: title={'center': 'sy layer 2'}>,
 <Axes: title={'center': 'sy layer 3'}>,
 <Axes: title={'center': 'vkcb layer 1'}>,
 <Axes: title={'center': 'vkcb layer 2'}>,
 <Axes: title={'center': 'vkcb layer 3'}>]
```

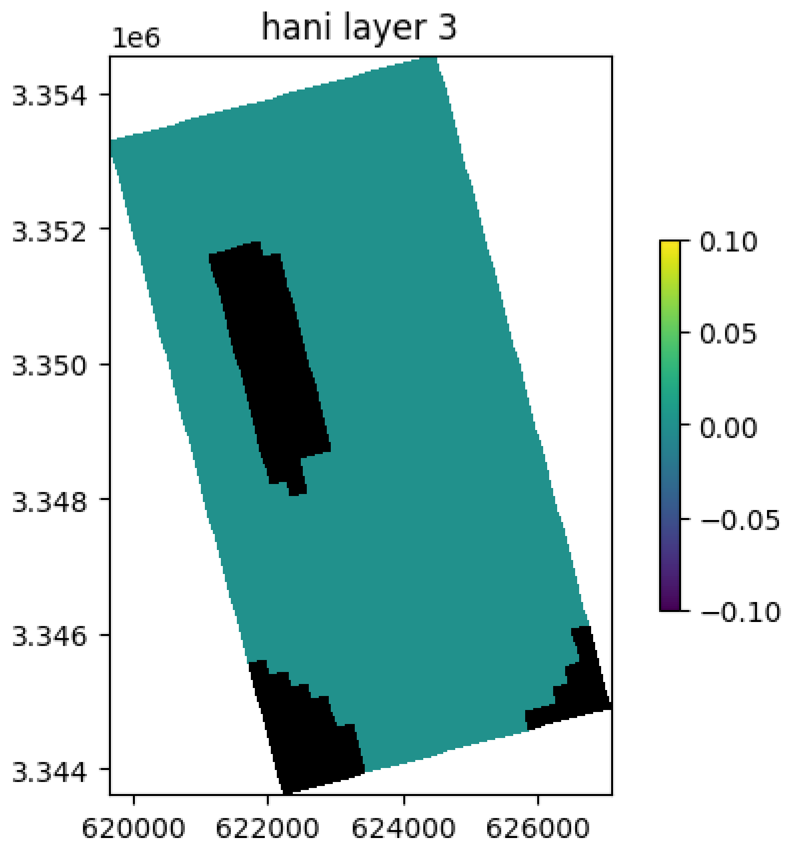

hk layer 1
1e6
3.354
3.352
3.350
3.348
3.346
3.344
620000
622000
624000
626000
12.5
10.0
7.5
5.0
2.5
0.0

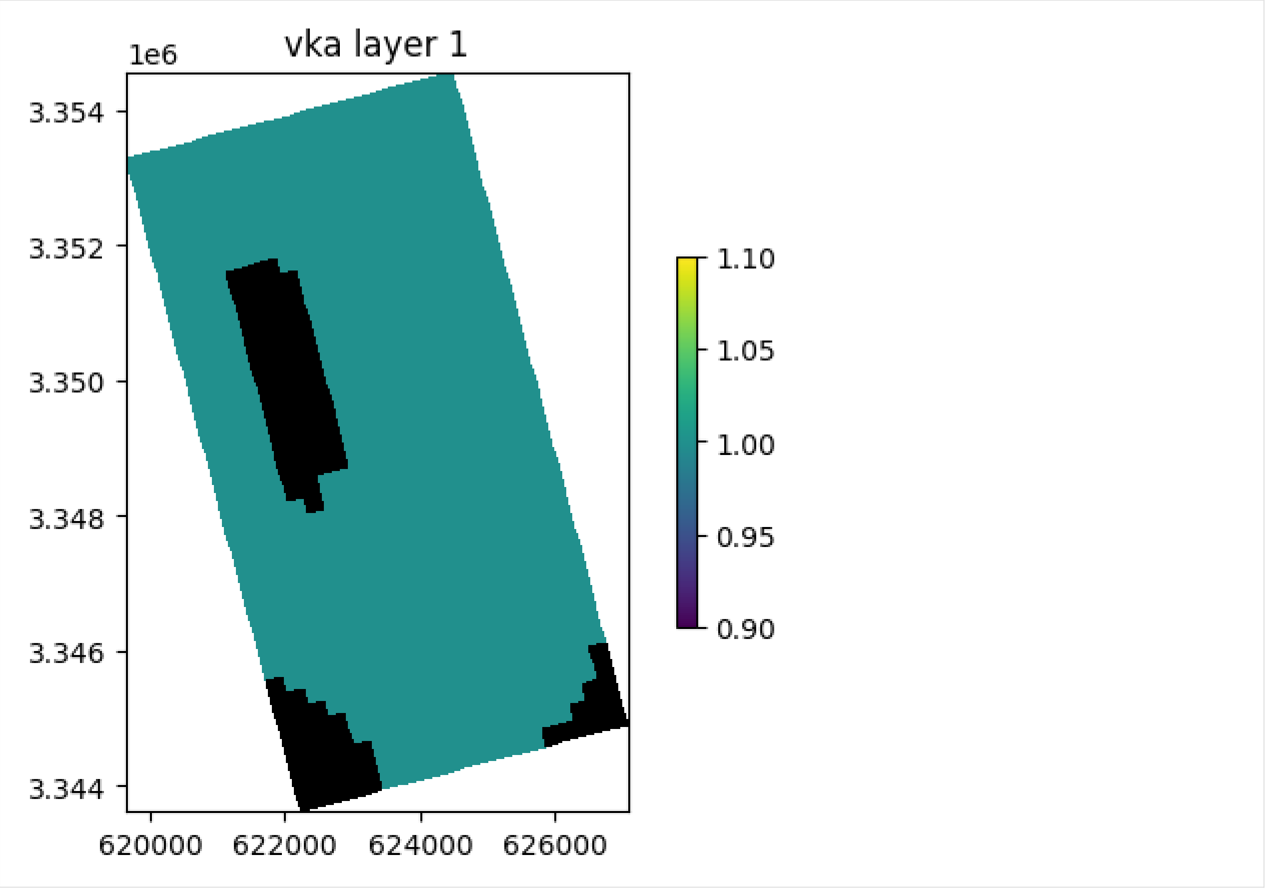

hk layer 2
1e6
3.354
3.352
3.350
3.348
3.346
3.344
620000
622000
624000
626000
12.5
10.0
7.5
5.0
2.5
0.0

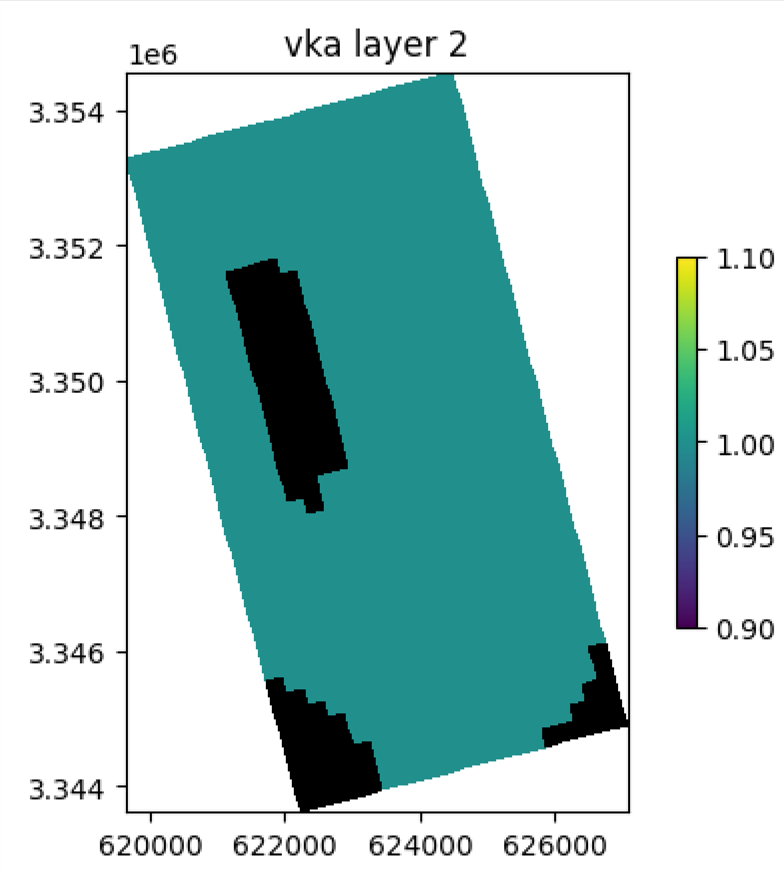

hk layer 3
1e6
3.354
3.352
3.350
3.348
3.346
3.344
620000
622000
624000
626000
12.5
10.0
7.5
5.0
2.5
0.0

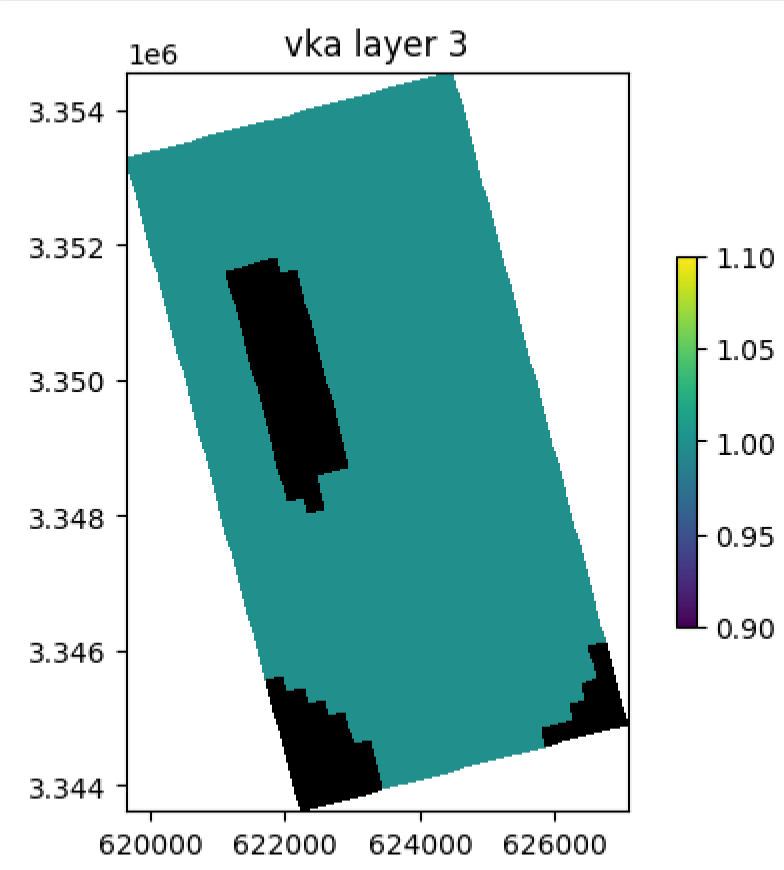

hani layer 1
1e6
3.354
3.352
3.350
3.348
3.346
3.344
620000
622000
624000
626000
0.10
0.05
0.00
−0.05
−0.10

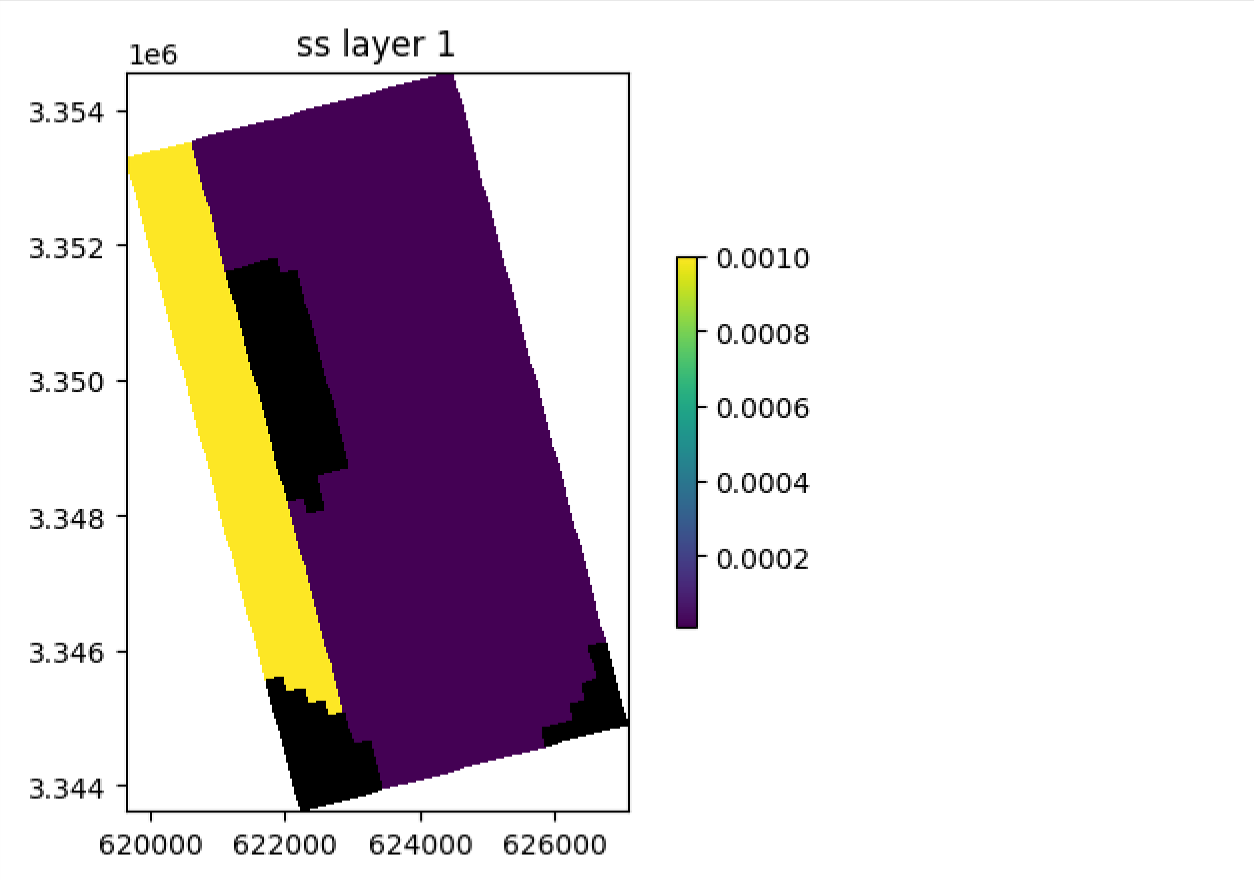

hani layer 2
1e6
3.354
3.352
3.350
3.348
3.346
3.344
620000
622000
624000
626000
0.10
0.05
0.00
−0.05
−0.10

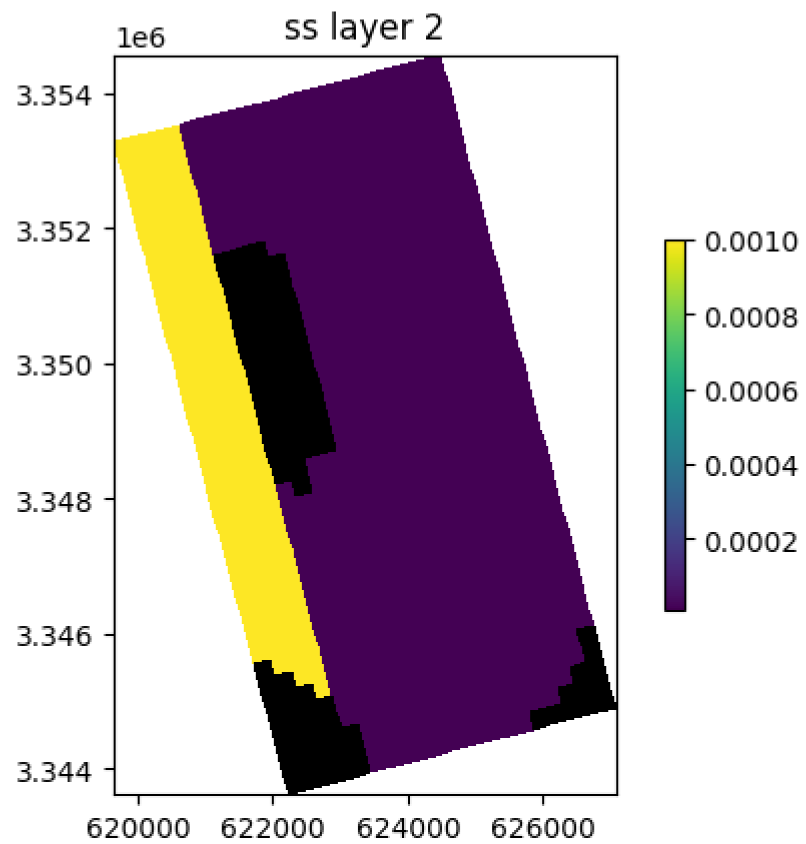

hani layer 3
1e6
3.354
3.352
3.350
3.348
3.346
3.344
620000
622000
624000
626000
0.10
0.05
0.00
−0.05
−0.10

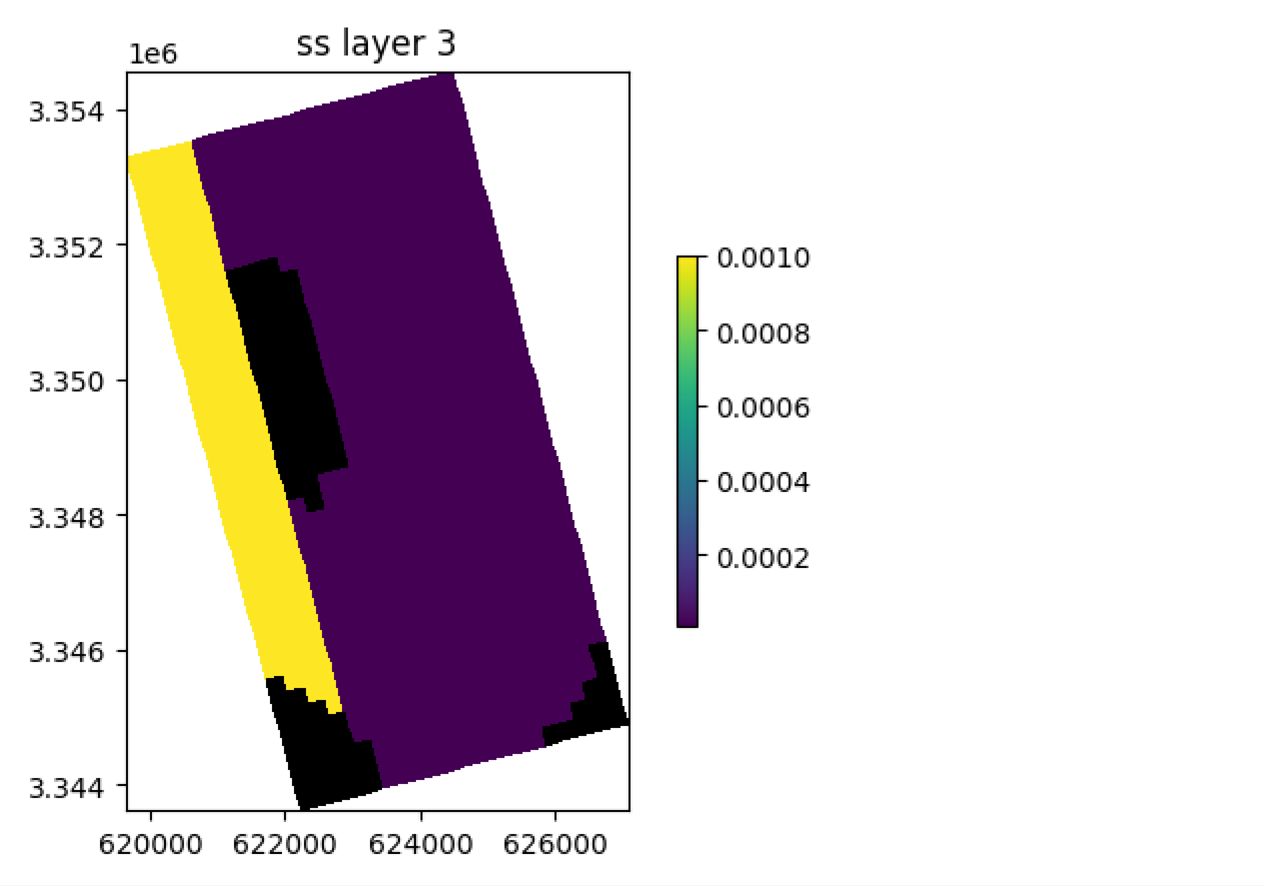

vka layer 1
1e6
3.354
3.352
3.350
3.348
3.346
3.344
620000
622000
624000
626000
1.10
1.05
1.00
0.95
0.90

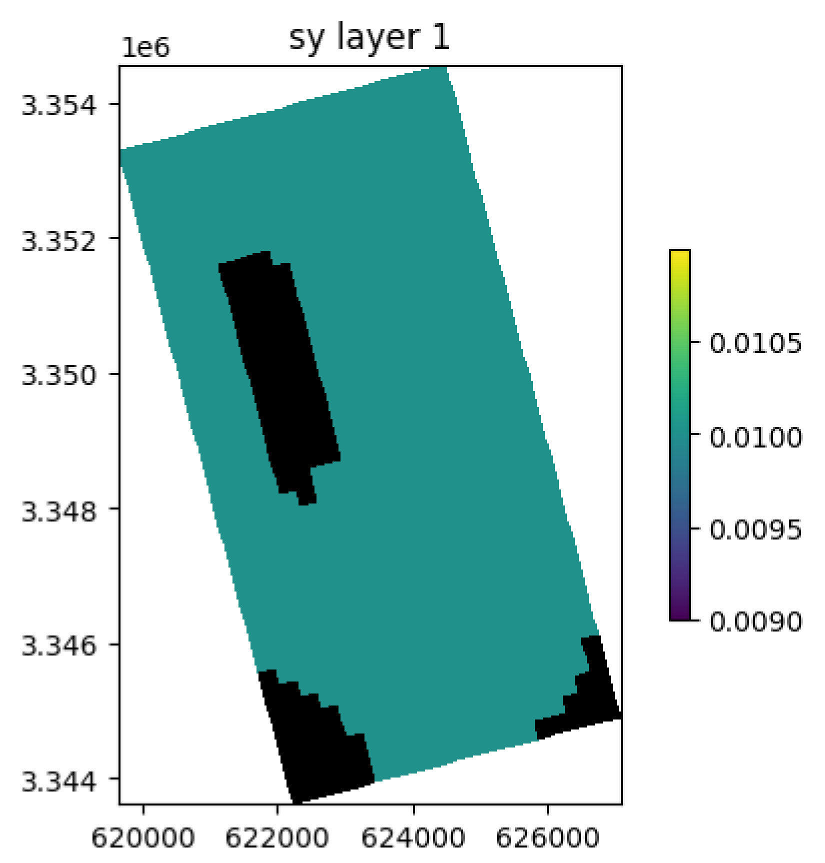

vka layer 2
1e6
3.354
3.352
3.350
3.348
3.346
3.344
620000
622000
624000
626000
1.10
1.05
1.00
0.95
0.90

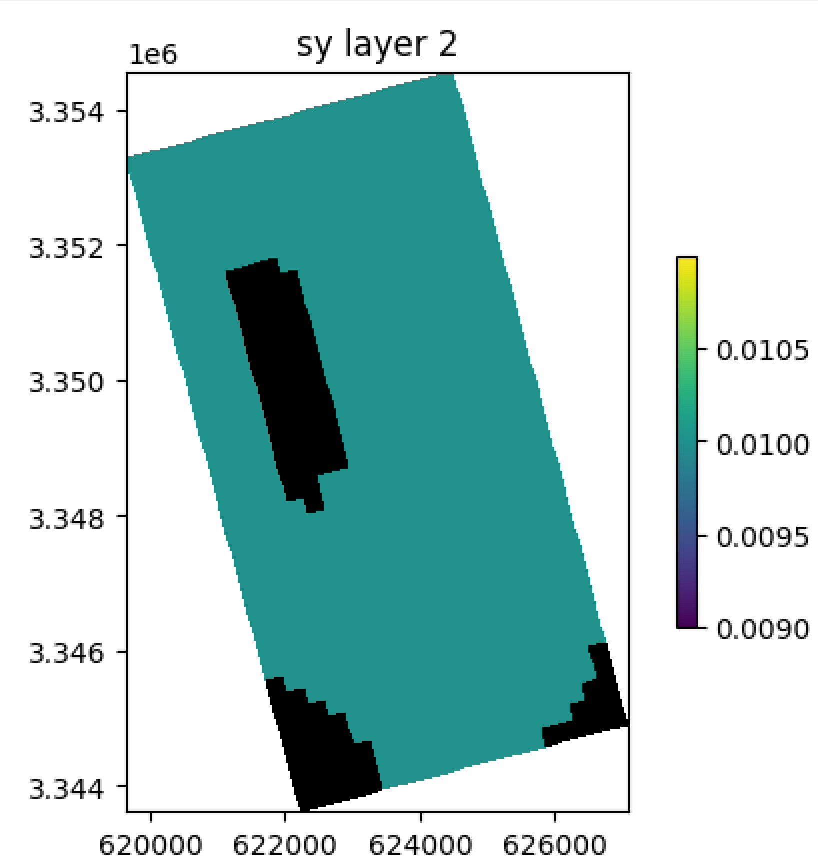

vka layer 3
1e6
3.354
3.352
3.350
3.348
3.346
3.344
620000
622000
624000
626000
1.10
1.05
1.00
0.95
0.90

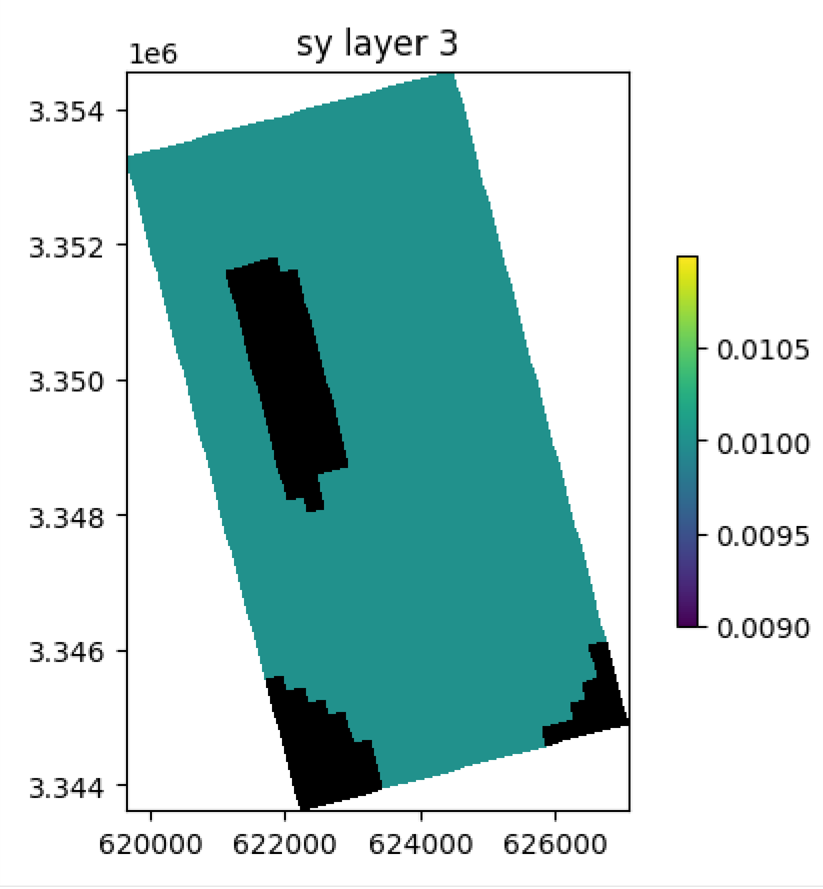

ss layer 1
1e6
3.354
3.352
3.350
3.348
3.346
3.344
620000
622000
624000
626000
0.0010
0.0008
0.0006
0.0004
0.0002

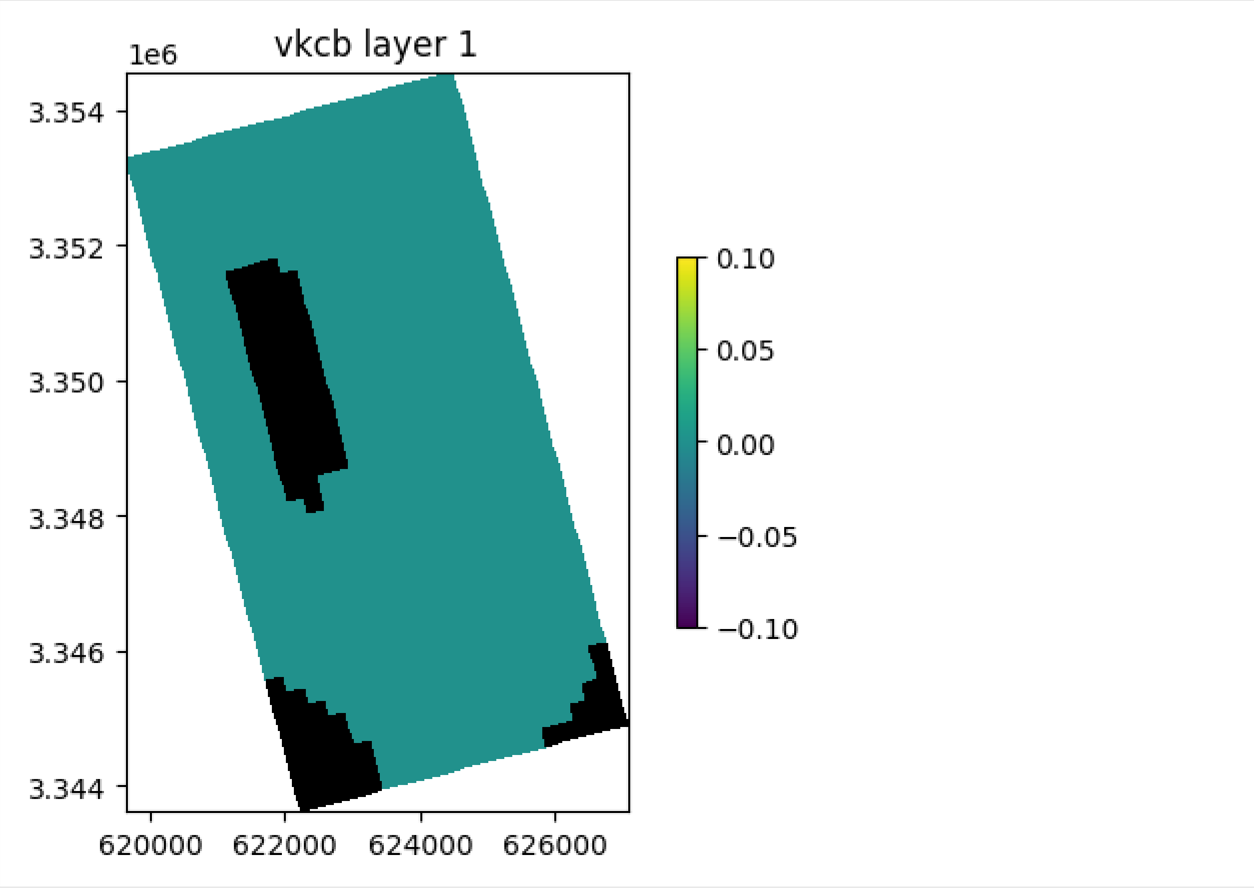

ss layer 2
1e6
3.354
3.352
3.350
3.348
3.346
3.344
620000
622000
624000
626000
0.0010
0.0008
0.0006
0.0004
0.0002

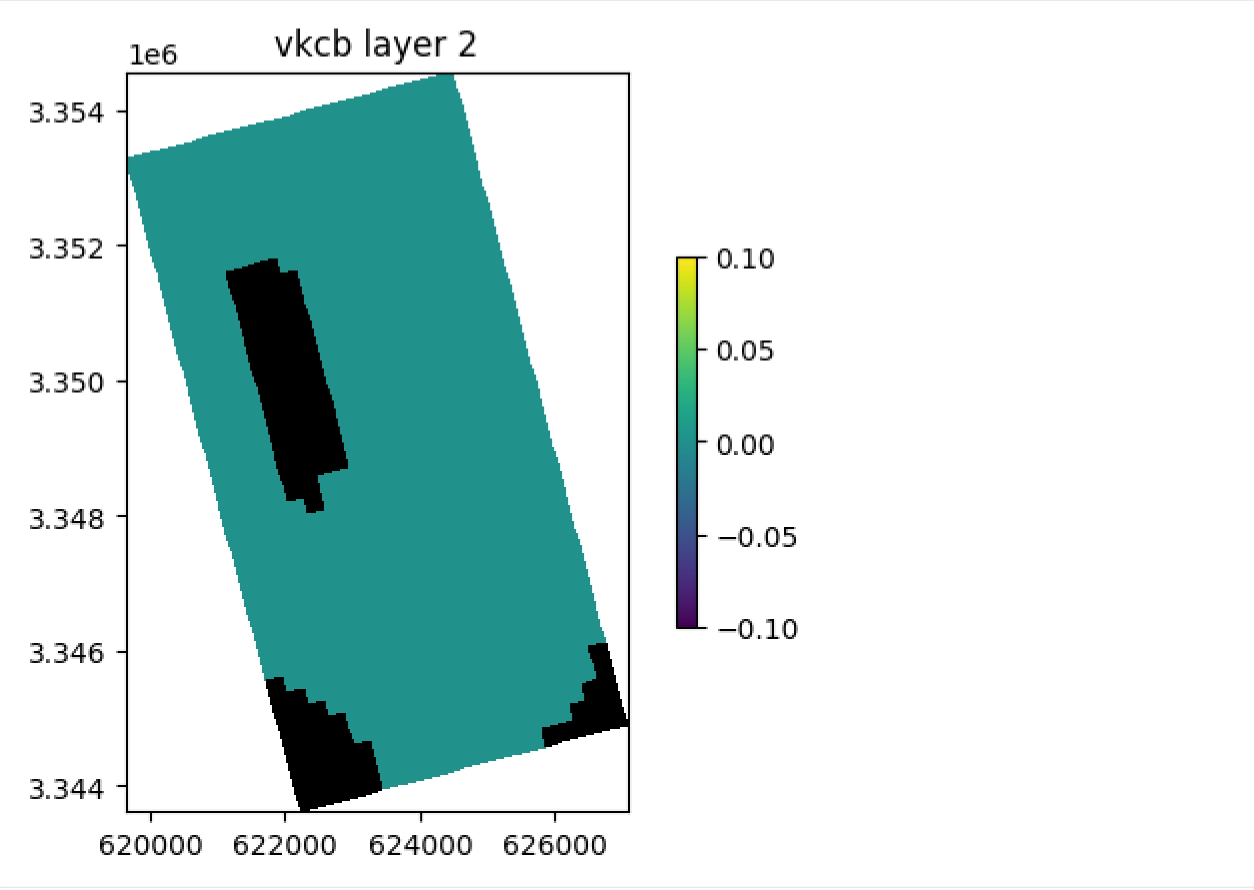

ss layer 3
1e6
3.354
3.352
3.350
3.348
3.346
3.344
620000
622000
624000
626000
0.0010
0.0008
0.0006
0.0004
0.0002

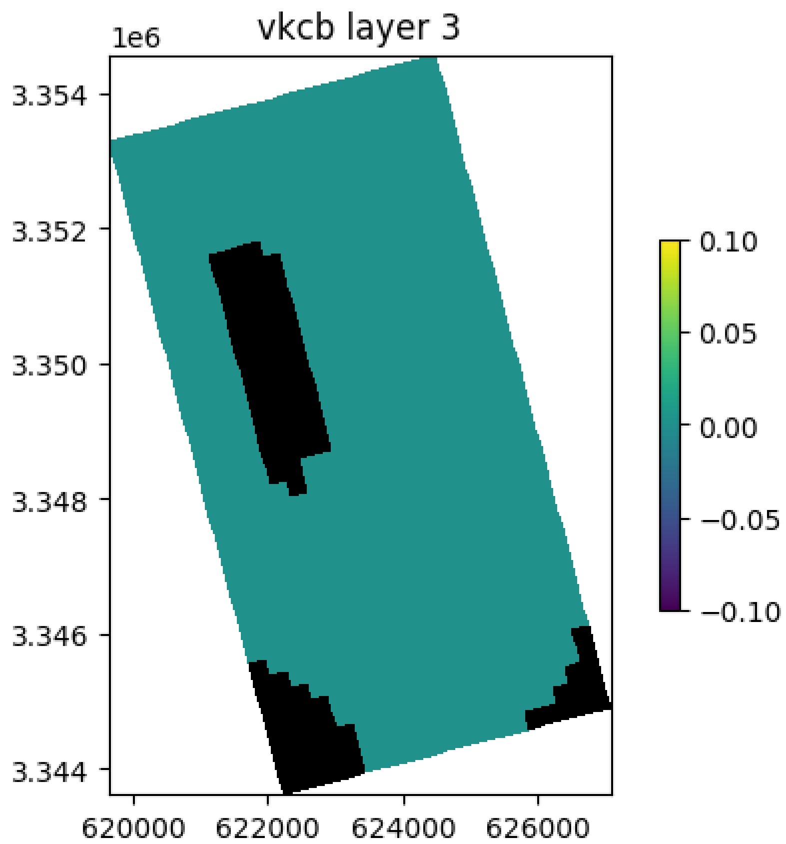

sy layer 1
1e6
3.354
3.352
3.350
3.348
3.346
3.344
620000
622000
624000
626000
0.0105
0.0100
0.0095
0.0090


sy layer 2
1e6
3.354
3.352
3.350
3.348
3.346
3.344
620000
622000
624000
626000
0.0105
0.0100
0.0095
0.0090


sy layer 3
1e6
3.354
3.352
3.350
3.348
3.346
3.344
620000
622000
624000
626000
0.0105
0.0100
0.0095
0.0090

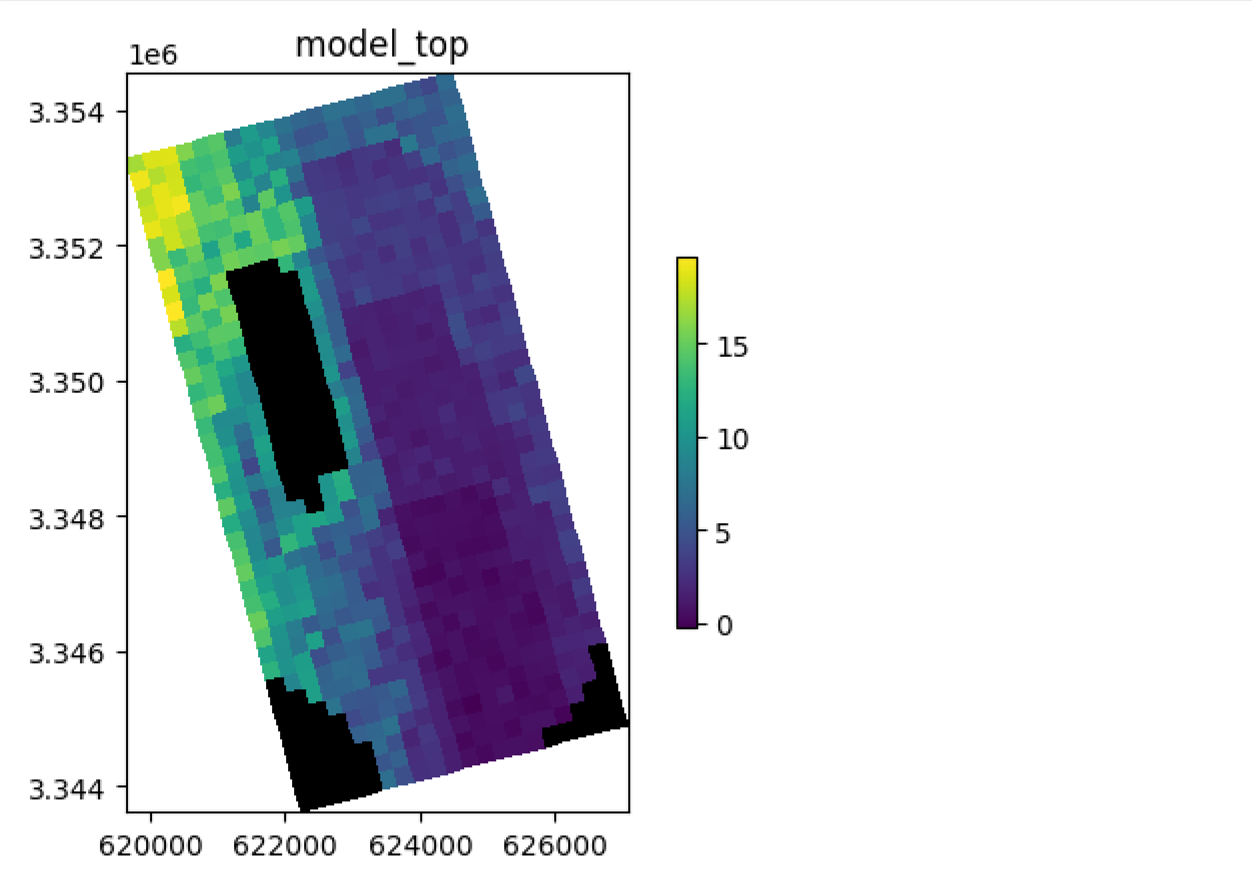

vkcb layer 1
1e6
3.354
3.352
3.350
3.348
3.346
3.344
620000
622000
624000
626000
0.10
0.05
0.00
−0.05
−0.10


vkcb layer 2
1e6
3.354
3.352
3.350
3.348
3.346
3.344
620000
622000
624000
626000
0.10
0.05
0.00
−0.05
−0.10



[7]:
```
ml.dis.plot()
```

[7]:
```
[<Axes: title={'center': ' model_top'}>,
 <Axes: title={'center': 'botm layer 1'}>,
 <Axes: title={'center': 'botm layer 2'}>,
 <Axes: title={'center': 'botm layer 3'}>]
```


model_top
1e6
3.354
3.352
3.350
3.348
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620000
622000
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15
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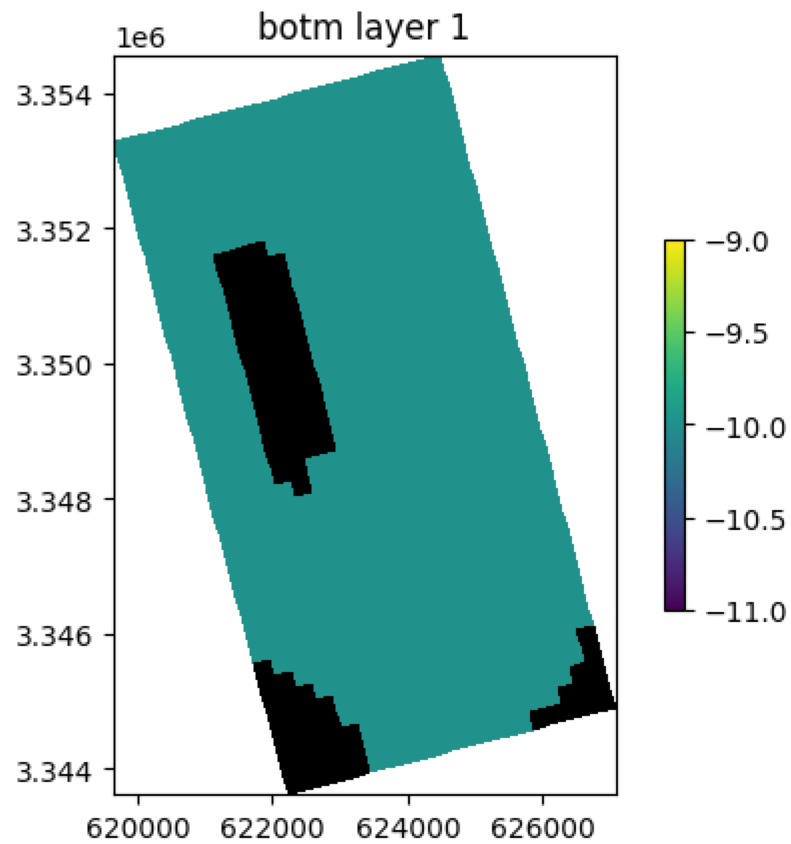
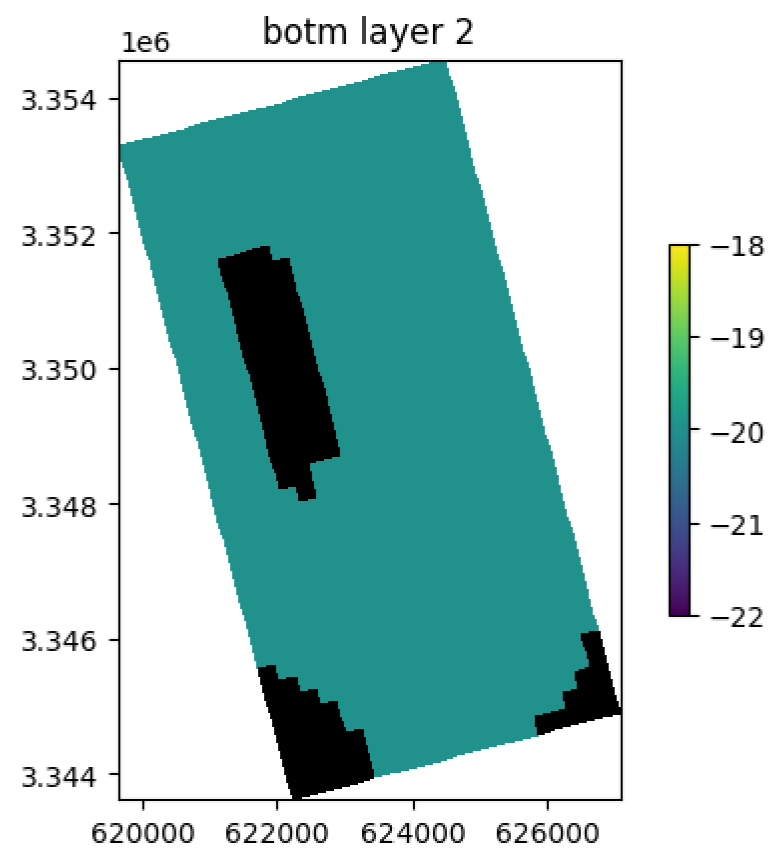
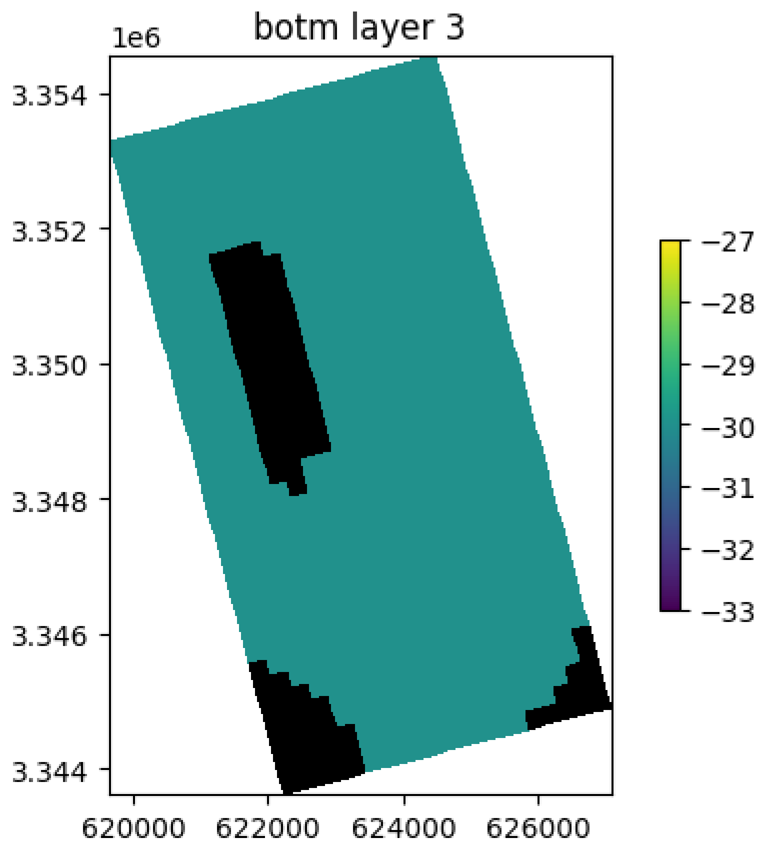
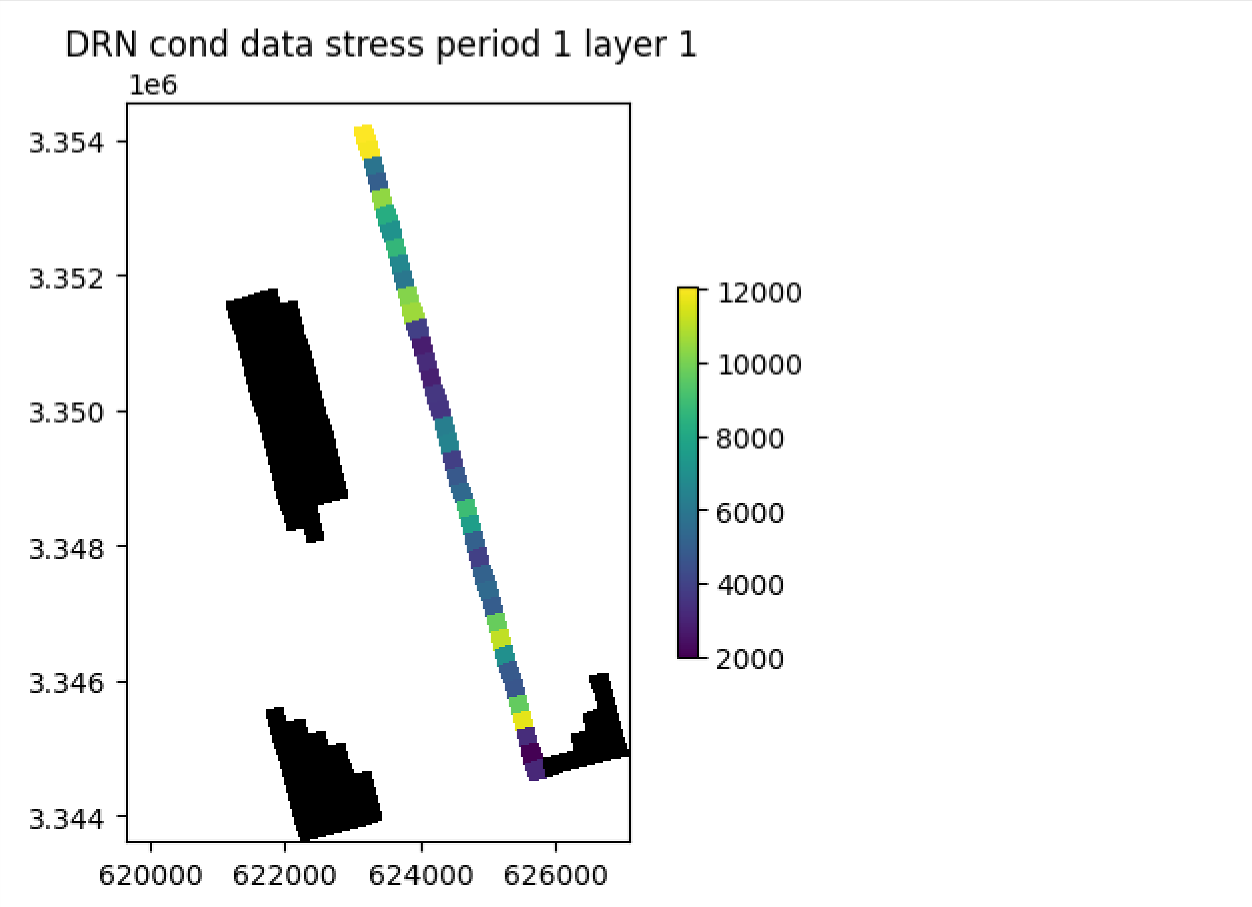

botm layer 1
1e6
3.354
3.352
3.350
3.348
3.346
3.344
620000
622000
624000
626000
−9.0
−9.5
−10.0
−10.5
−11.0

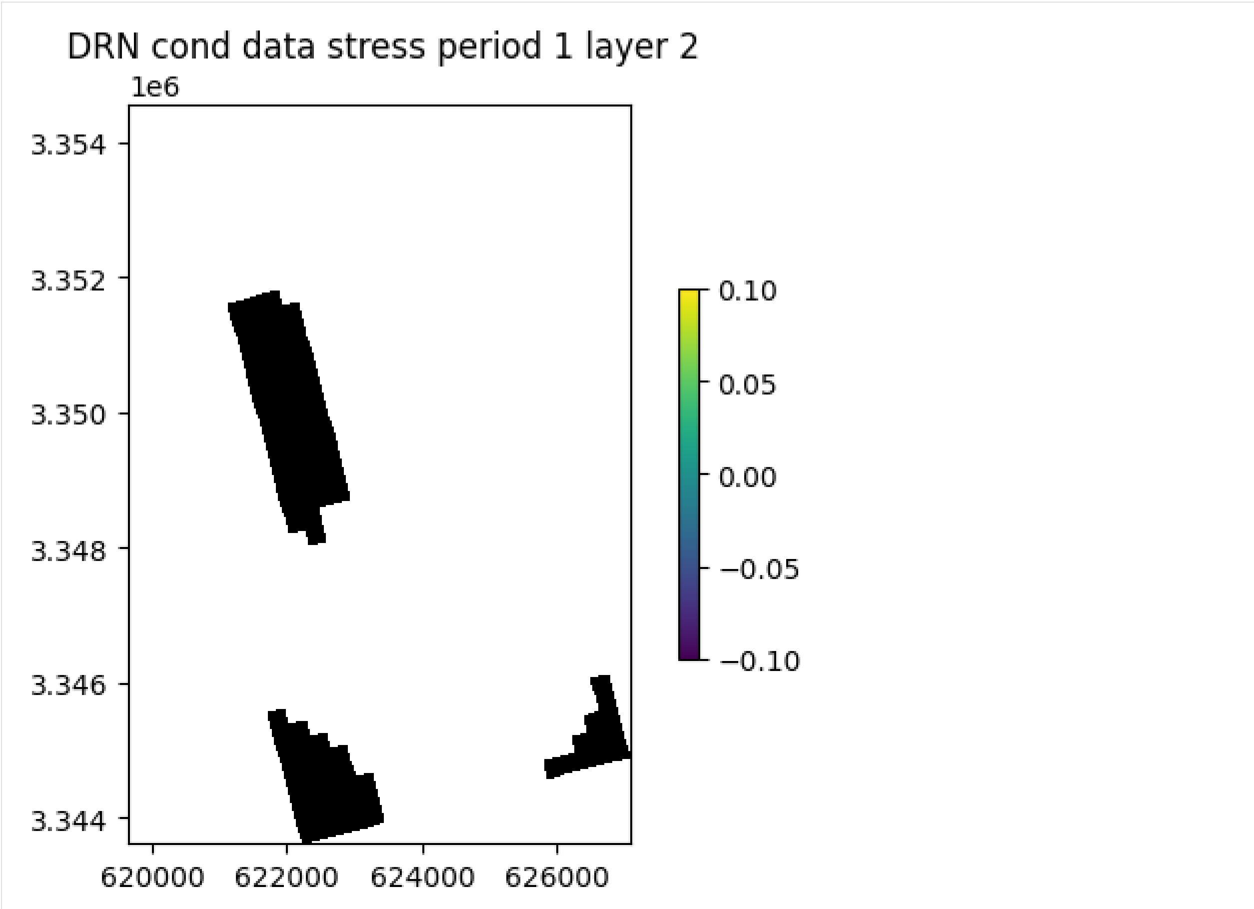

botm layer 2
1e6
3.354
3.352
3.350
3.348
3.346
3.344
620000
622000
624000
626000
−18
−19
−20
−21
−22



[8]:
```
ml.drn.plot(key="cond")
ml.drn.plot(key="elev")
```

[8]:
```
[<Axes: title={'center': ' DRN elev data stress period 1 layer 1'}>,
 <Axes: title={'center': ' DRN elev data stress period 1 layer 2'}>,
 <Axes: title={'center': ' DRN elev data stress period 1 layer 3'}>]
```


DRN cond data stress period 1 layer 1
1e6
3.354
3.352
3.350
3.348
3.346
3.344
620000
622000
624000
626000
12000
10000
8000
6000
4000
2000


DRN cond data stress period 1 layer 2
1e6
3.354
3.352
3.350
3.348
3.346
3.344
620000
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626000
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0.00
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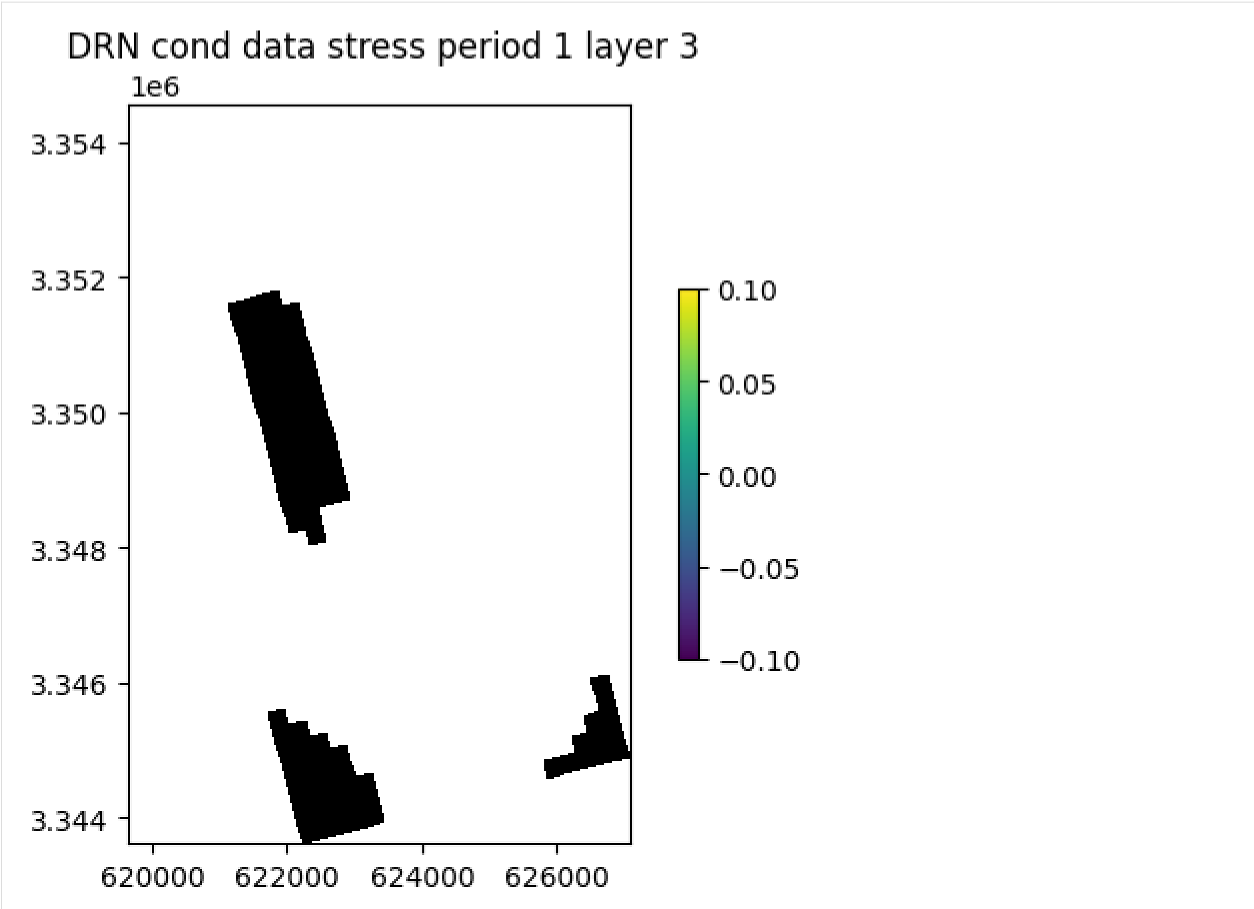
DRN cond data stress period 1 layer 3
1e6
3.354
3.352
3.350
3.348
3.346
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620000
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624000
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0.10
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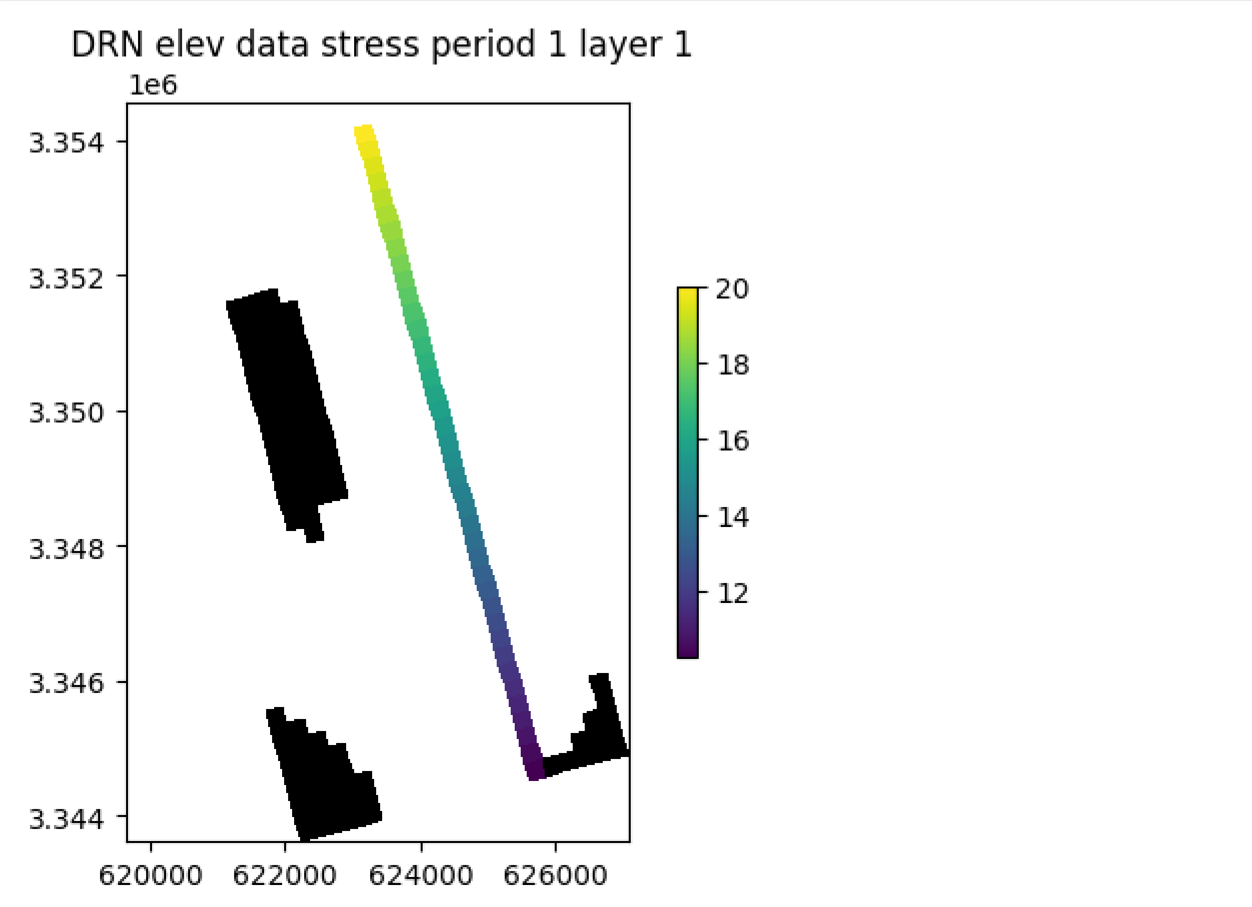
DRN elev data stress period 1 layer 1
1e6
3.354
3.352
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620000
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18
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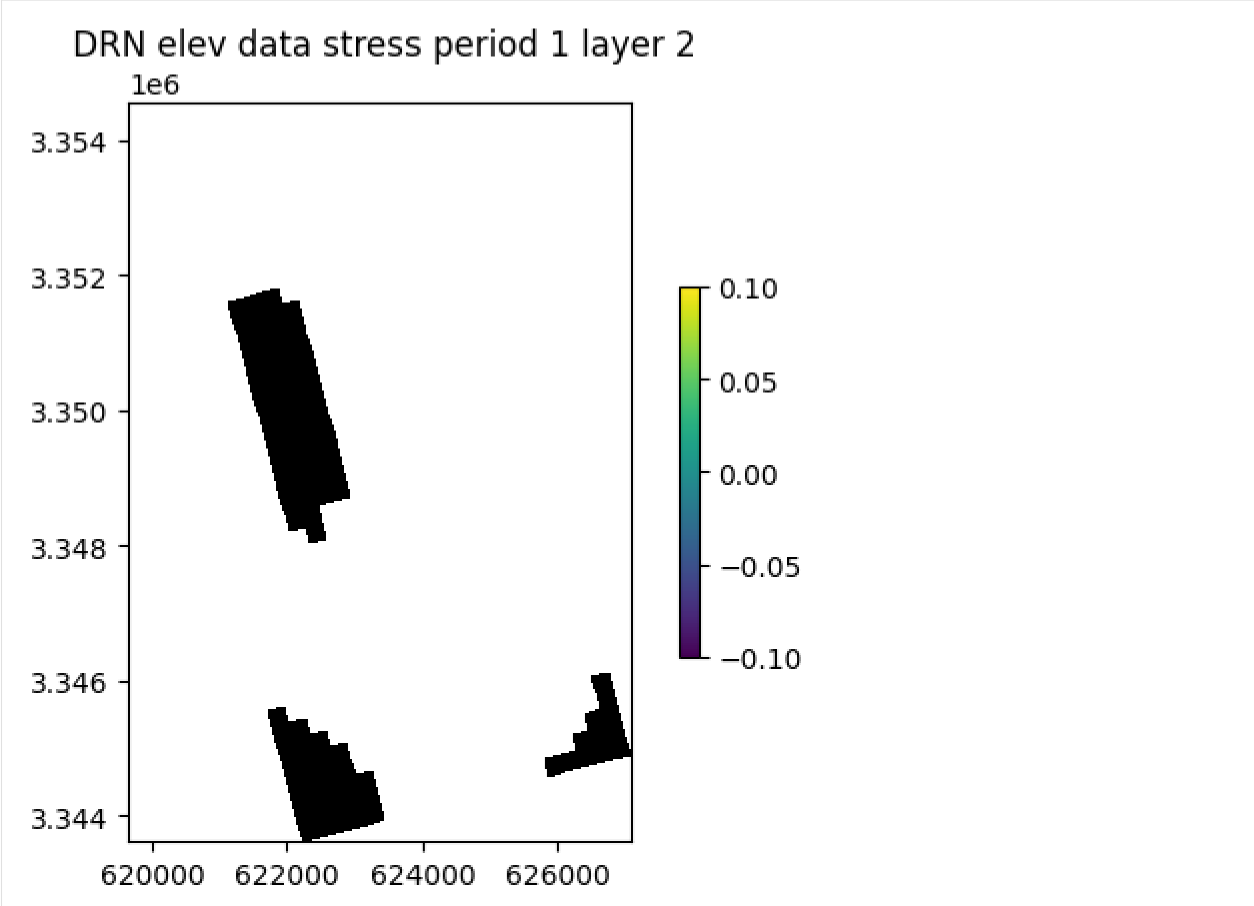
12


DRN elev data stress period 1 layer 2
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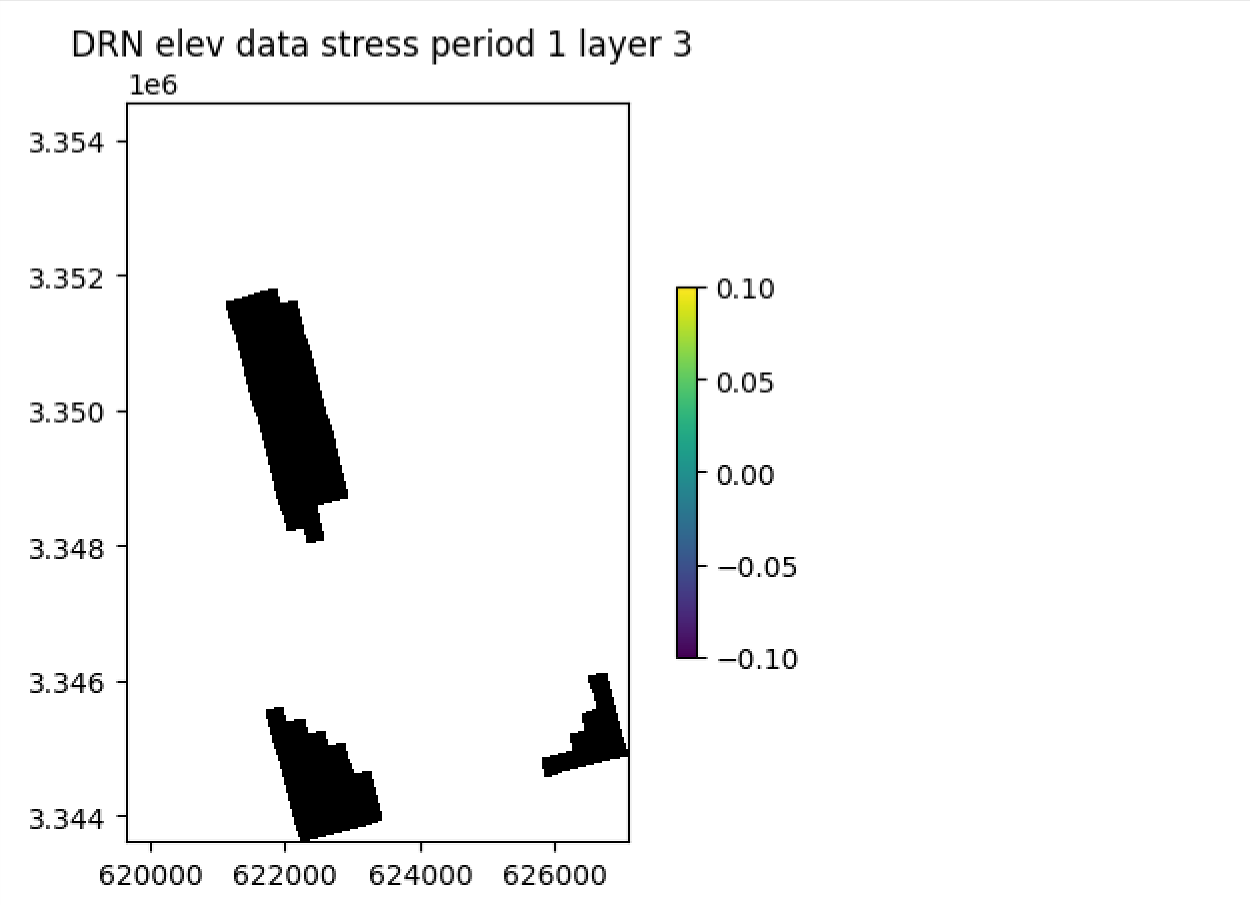

First create a temporary workspace.

[9]:
```
# create a temporary workspace
temp_dir = TemporaryDirectory()
workspace = Path(temp_dir.name)
```

Write a shapefile of the DIS package.

[10]:
```
# write the shapefile
ml.dis.export(workspace / "freyberg_dis.shp")
```

```
/opt/hostedtoolcache/Python/3.8.18/x64/lib/python3.8/site-packages/flopy/export/
↪shapefile_utils.py:318: UserWarning: Failed to get data for delc array, DIS package
  warn(
/opt/hostedtoolcache/Python/3.8.18/x64/lib/python3.8/site-packages/flopy/export/
↪shapefile_utils.py:318: UserWarning: Failed to get data for delr array, DIS package
  warn(
/opt/hostedtoolcache/Python/3.8.18/x64/lib/python3.8/site-packages/flopy/export/
↪shapefile_utils.py:318: UserWarning: Failed to get data for laycbd array, DIS package
  warn(
/opt/hostedtoolcache/Python/3.8.18/x64/lib/python3.8/site-packages/flopy/export/
↪shapefile_utils.py:318: UserWarning: Failed to get data for nstp array, DIS package
  warn(
/opt/hostedtoolcache/Python/3.8.18/x64/lib/python3.8/site-packages/flopy/export/
```

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```
↪shapefile_utils.py:318: UserWarning: Failed to get data for perlen array, DIS package
  warn(
/opt/hostedtoolcache/Python/3.8.18/x64/lib/python3.8/site-packages/flopy/export/
↪shapefile_utils.py:318: UserWarning: Failed to get data for steady array, DIS package
  warn(
/opt/hostedtoolcache/Python/3.8.18/x64/lib/python3.8/site-packages/flopy/export/
↪shapefile_utils.py:318: UserWarning: Failed to get data for tsmult array, DIS package
  warn(
```

Write a netCDF file with all model inputs.

```
[11]: ml.export(workspace / "freyberg.nc")
```

```
initialize_geometry::
model crs: EPSG:32614
initialize_geometry::nc_crs = EPSG:4326
transforming coordinates using = proj=pipeline step inv proj=utm zone=14 ellps=WGS84␣
↪step proj=unitconvert xy_in=rad xy_out=deg
```

```
[11]: <flopy.export.netcdf.NetCdf at 0x7fc4a5a66400>
```

Change model directory and external path, modify inputs and write new input files.

```
[12]: ml.external_path = workspace / "ref"
ml.model_ws = workspace
ml.write_input()
```

```
Util2d:delr: resetting 'how' to external
Util2d:delc: resetting 'how' to external
Util2d:model_top: resetting 'how' to external
Util2d:botm_layer_0: resetting 'how' to external
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Util2d:botm_layer_2: resetting 'how' to external
Util2d:ibound_layer_0: resetting 'how' to external
Util2d:ibound_layer_1: resetting 'how' to external
Util2d:ibound_layer_2: resetting 'how' to external
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Util2d:rech_1097: resetting 'how' to external
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Util2d:ss: resetting 'how' to external
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```

Now run the model.

[13]:
```
ml.run_model(silent=True)
```

[13]:
```
(True, [])
```

Inspecting outputs

First, let's look at the list file. The list file summarizes the model's results.

[14]:
```
mfl = flopy.utils.MfListBudget(model_ws / "freyberg.list")
df_flux, df_vol = mfl.get_dataframes(start_datetime="10-21-2015")
df_flux
```

[14]:
```
            STORAGE_IN  CONSTANT_HEAD_IN  WELLS_IN  DRAINS_IN  RECHARGE_IN  \
2015-10-22    0.000000          0.000000       0.0        0.0  6276.861816
2015-10-23  635.447998          0.000000       0.0        0.0  6428.198730
2015-10-24 1361.814941          0.000000       0.0        0.0  5397.295898
2015-10-25  677.577209          0.000000       0.0        0.0  5931.377441
2015-10-26  697.818298          0.000000       0.0        0.0  8378.572266
...                ...               ...       ...        ...          ...
2018-10-18 1298.433350         23.293699       0.0        0.0  4240.286133
2018-10-19  920.468689         25.997499       0.0        0.0  4082.749512
2018-10-20  496.671387         20.047001       0.0        0.0  5053.779297
2018-10-21  230.320999          9.045700       0.0        0.0  6168.920410
2018-10-22    0.000000        317.783386       0.0        0.0  5190.390625

              TOTAL_IN  STORAGE_OUT  CONSTANT_HEAD_OUT    WELLS_OUT  \
2015-10-22 6276.861816     0.000000        2446.318848     0.000000
2015-10-23 7063.646484    31.594000        2430.337891  1302.403198
2015-10-24 6759.110840     9.152200        2369.628174  1618.676392
2015-10-25 6608.954590   180.233307        2353.585449  1498.694702
2015-10-26 9076.390625  1051.897461        2417.248291  3119.501953
...                ...          ...                ...          ...
2018-10-18 5562.013184  1606.280396        1909.538574  1930.483154
2018-10-19 5029.215820  1659.194702        1892.605835  1279.166382
2018-10-20 5570.497559  2428.291016        1933.045898   794.582886
2018-10-21 6408.287109  2335.759521        2006.124268  1373.782593
2018-10-22 5508.173828     0.000000         745.363403  4762.799805

            DRAINS_OUT  RECHARGE_OUT    TOTAL_OUT    IN-OUT  \
2015-10-22 3830.650146           0.0  6276.968750 -0.106900
2015-10-23 3299.415039           0.0  7063.750000 -0.103500
2015-10-24 2761.639648           0.0  6759.096191  0.014648
2015-10-25 2576.461670           0.0  6608.975586 -0.020996
2015-10-26 2487.737305           0.0  9076.384766  0.005859
...                ...           ...          ...       ...
2018-10-18  115.724899           0.0  5562.026855 -0.013672
2018-10-19  198.258896           0.0  5029.225586 -0.009766
```

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```
2018-10-20   414.594513          0.0  5570.514648 -0.017090
2018-10-21   692.638123          0.0  6408.304688 -0.017578
2018-10-22     0.000000          0.0  5508.163086  0.010742

            PERCENT_DISCREPANCY
2015-10-22                 -0.0
2015-10-23                 -0.0
2015-10-24                  0.0
2015-10-25                 -0.0
2015-10-26                  0.0
...                         ...
2018-10-18                 -0.0
2018-10-19                 -0.0
2018-10-20                 -0.0
2018-10-21                 -0.0
2018-10-22                  0.0

[1097 rows x 14 columns]
```

[15]:

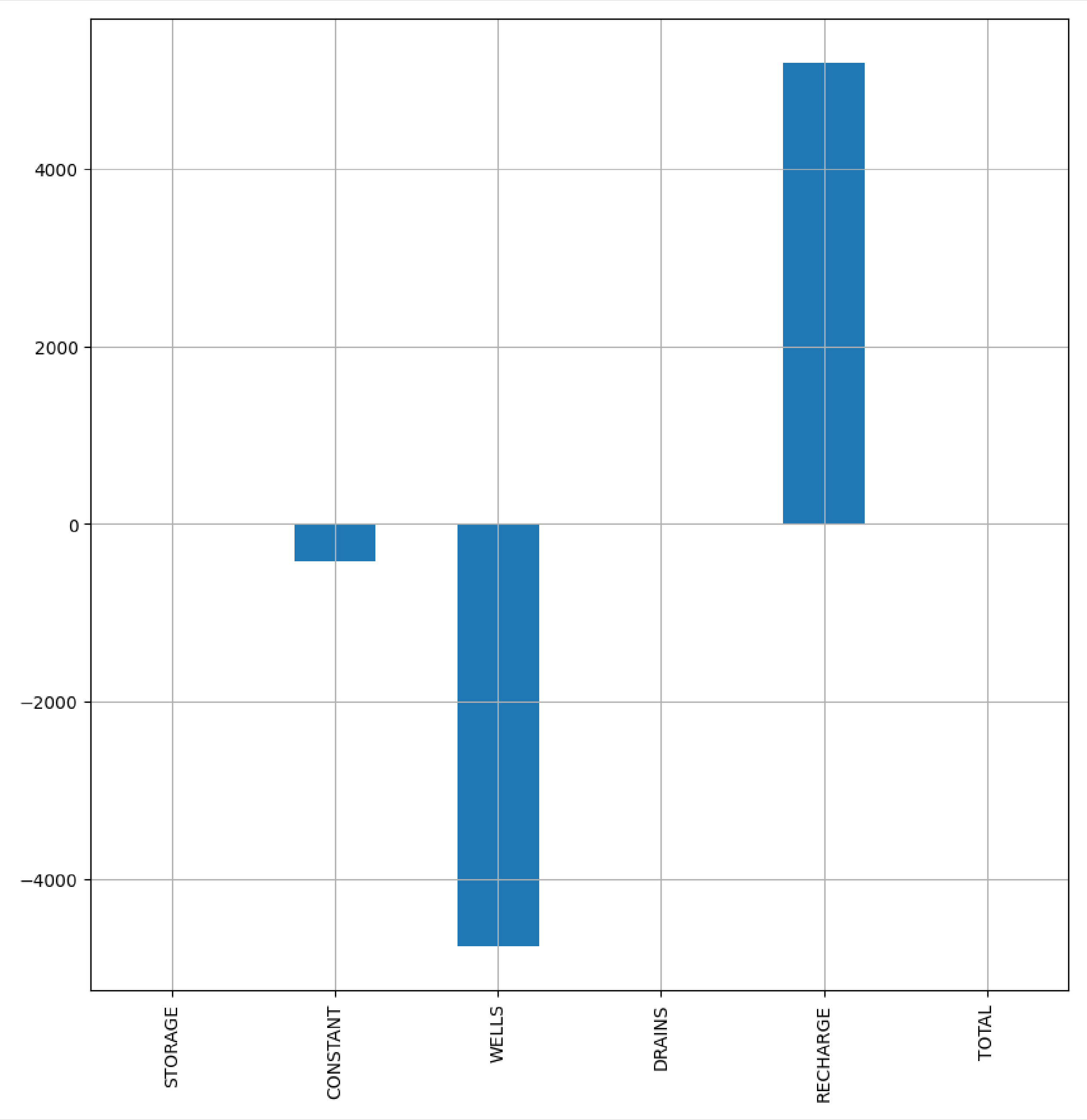
```
groups = df_flux.groupby(lambda x: x.split("_")[-1], axis=1).groups
df_flux_in = df_flux.loc[:, groups["IN"]]
df_flux_in.columns = df_flux_in.columns.map(lambda x: x.split("_")[0])

df_flux_out = df_flux.loc[:, groups["OUT"]]
df_flux_out.columns = df_flux_out.columns.map(lambda x: x.split("_")[0])


df_flux_delta = df_flux_in - df_flux_out
df_flux_delta.iloc[-1, :].plot(kind="bar", figsize=(10, 10), grid=True)
```

[15]:

```
<Axes: >
```



Now let's look at the simulated head.

[16]:
```python
# if you pass the model instance, then the plots will be offset and rotated
h = flopy.utils.HeadFile(model_ws / "freyberg.hds", model=ml)
h.times
```

[16]:
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945.0,
946.0,
947.0,
948.0,
949.0,
950.0,
951.0,
952.0,
953.0,
954.0,
955.0,
956.0,
957.0,
958.0,
959.0,
960.0,
961.0,
962.0,
963.0,
964.0,
965.0,
966.0,
967.0,
968.0,
969.0,
970.0,
971.0,
972.0,
973.0,
974.0,
975.0,
976.0,
977.0,
978.0,
979.0,
980.0,
981.0,
982.0,
983.0,
984.0,
985.0,
986.0,
987.0,
988.0,
989.0,
990.0,
991.0,
992.0,
993.0,
994.0,
```

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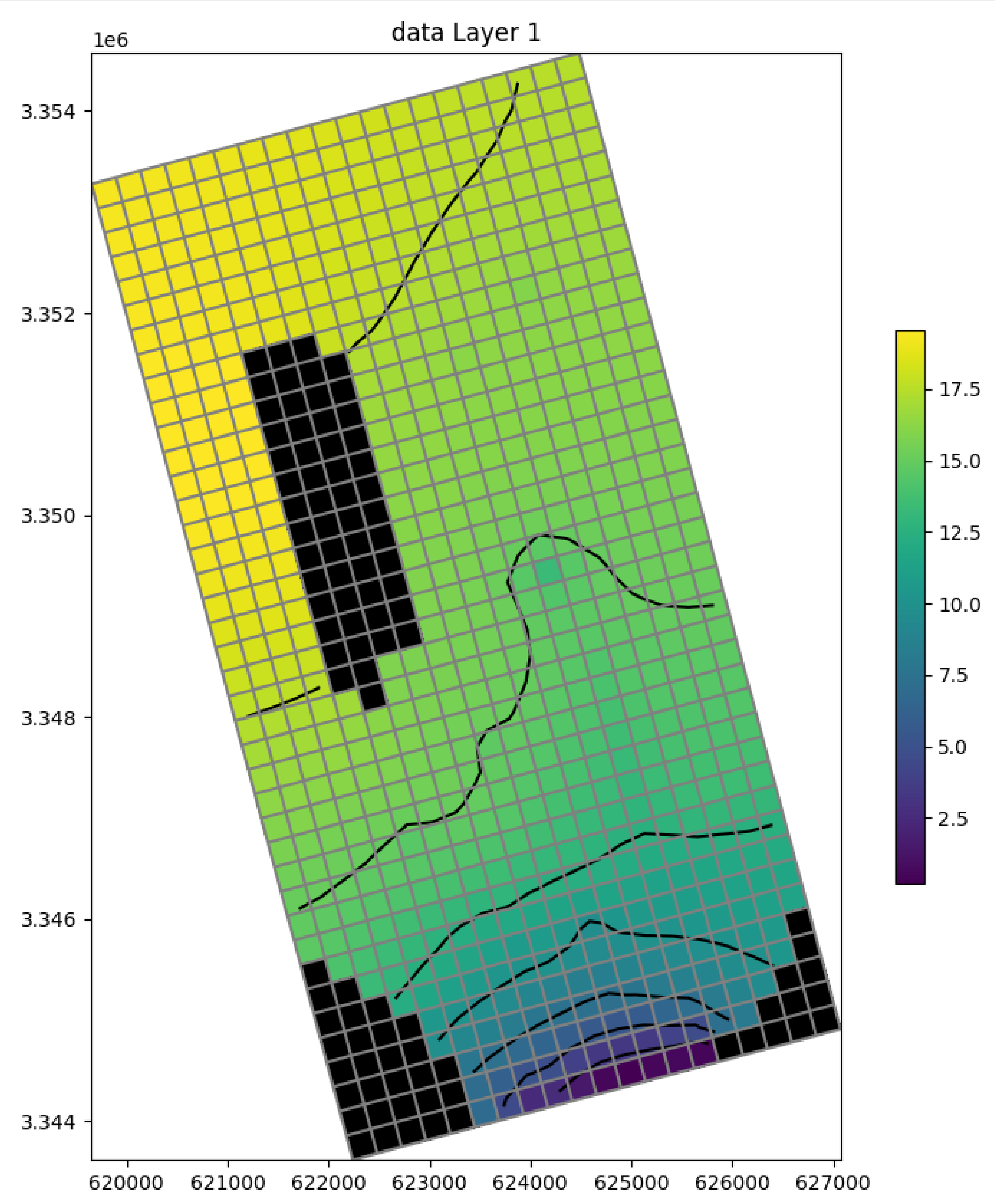
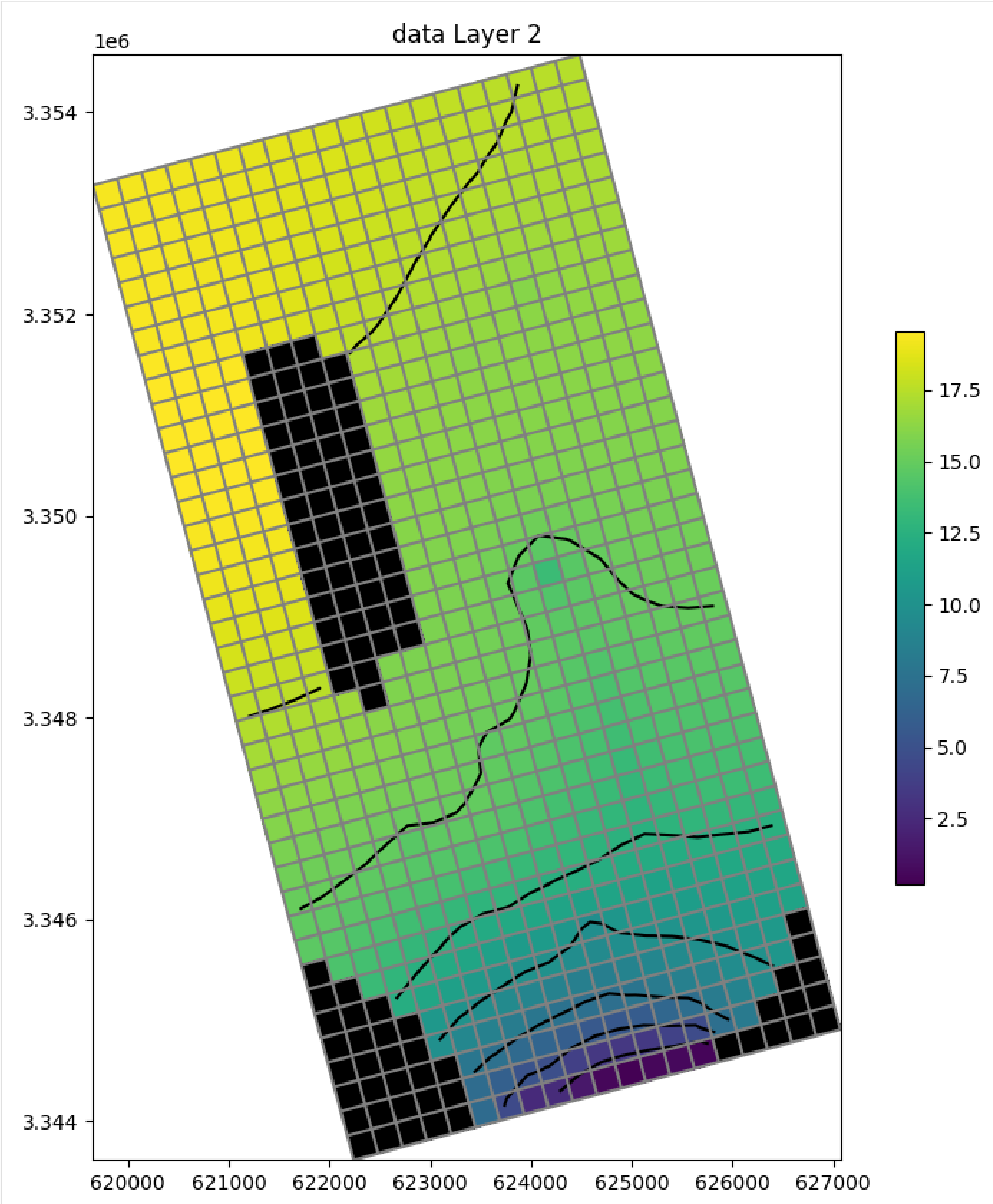
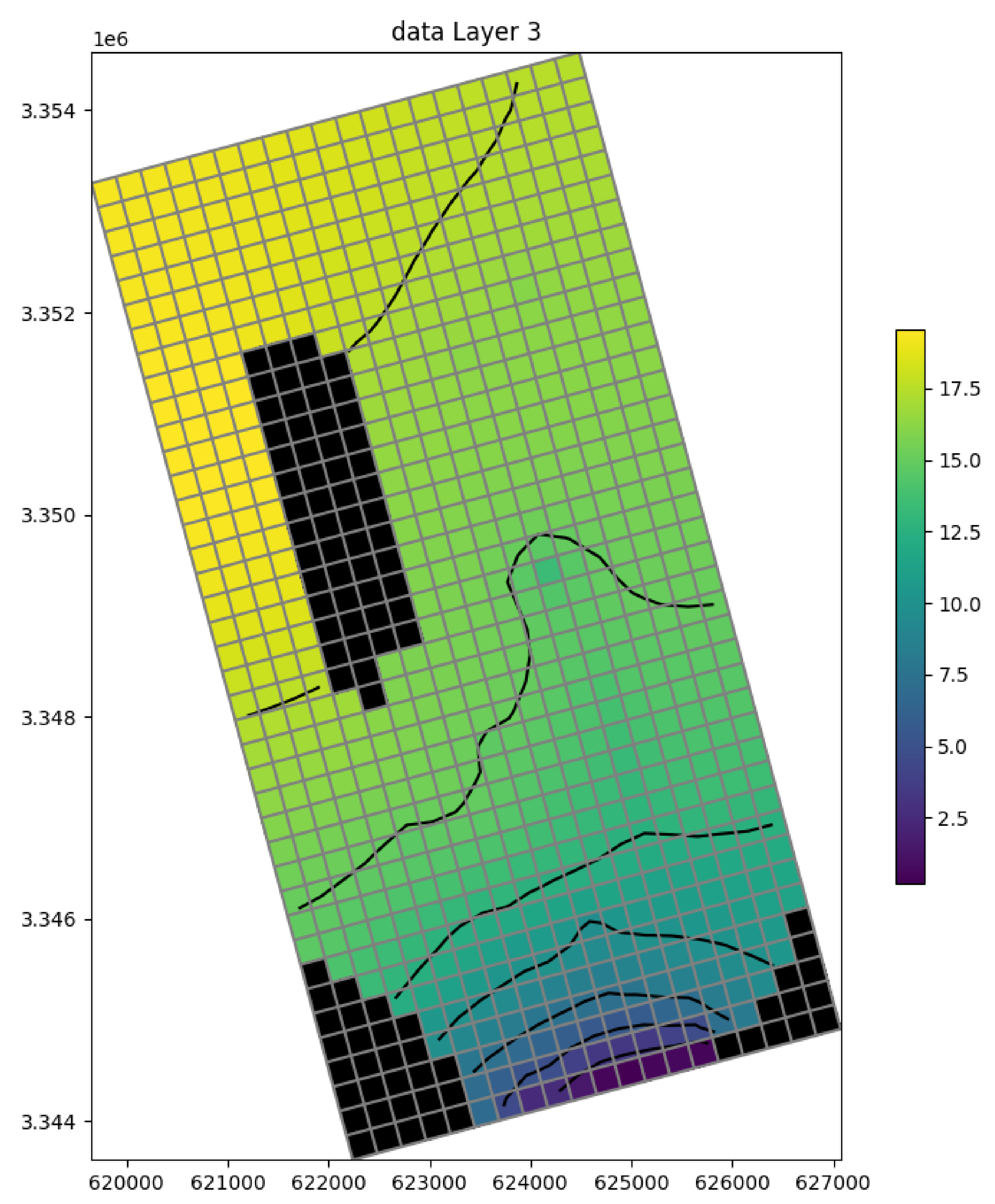
```
 995.0,
 996.0,
 997.0,
 998.0,
 999.0,
 1000.0,
 ...]
```

[17]:
```
h.plot(totim=900, contour=True, grid=True, colorbar=True, figsize=(10, 10))
```

[17]:
```
[<Axes: title={'center': 'data Layer 1'}>,
 <Axes: title={'center': 'data Layer 2'}>,
 <Axes: title={'center': 'data Layer 3'}>]
```


data Layer 1
1e6
3.354
3.352
3.350
3.348
3.346
3.344
620000
621000
622000
623000
624000
625000
626000
627000
17.5
15.0
12.5
10.0
7.5
5.0
2.5


data Layer 2
1e6
3.354
3.352
3.350
3.348
3.346
3.344
620000
621000
622000
623000
624000
625000
626000
627000
17.5
15.0
12.5
10.0
7.5
5.0
2.5



We can write the heads to a shapefile.

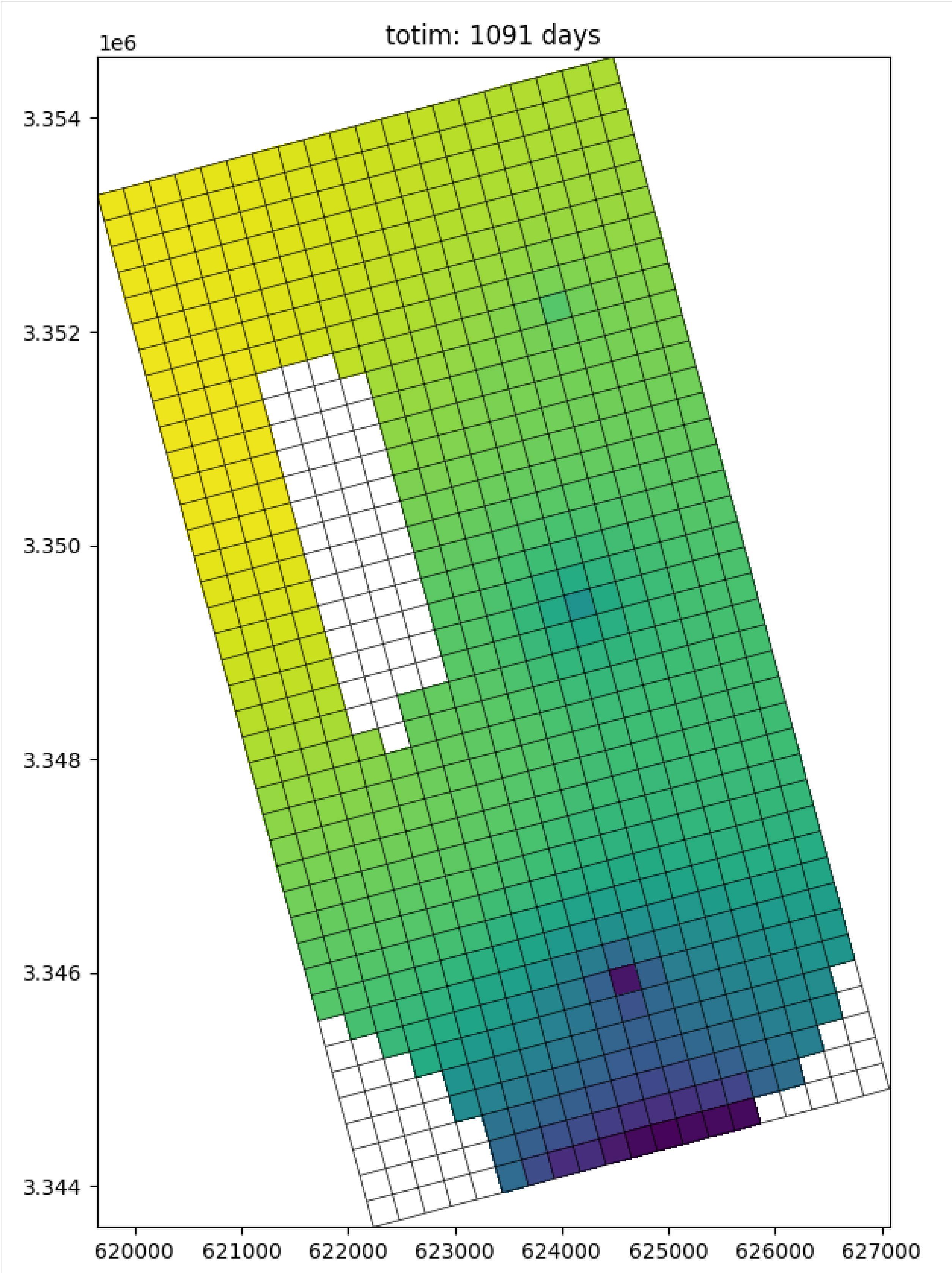
[18]:
```
h.to_shapefile(ml.model_ws / "freyburg_head.shp", verbose=False)
```

Finally, let's make an animation of the simulated head over the time domain.

[19]:
```
f = plt.figure(figsize=(10, 10))
ax = plt.subplot(1, 1, 1, aspect="equal")
for t in h.times[0:-1:10]:
    ax.cla()

    ax.set_title(f"totim: {t:4.0f} days")
    mm = flopy.plot.PlotMapView(model=ml, ax=ax)
    mm.plot_array(h.get_data(totim=t), vmin=0, vmax=20)
    mm.plot_grid(lw=0.5, color="black")

    display(f)
    clear_output(wait=True)
    plt.pause(0.1)
```


totim: 1091 days
1e6
3.354
3.352
3.350
3.348
3.346
3.344
620000
621000
622000
623000
624000
625000
626000
627000

[20]:
```
try:
    # ignore PermissionError on Windows
    temp_dir.cleanup()
except:
    pass
```

6.4.2 Computing transmissivity-weighted averages

Demonstration of `flopy.utils.get_transmissivities` method for computing open interval transmissivities (for weighted averages of heads or fluxes) In practice this method might be used to:

- compute vertically-averaged head target values representative of observation wells of varying open intervals (including variability in saturated thickness due to the position of the water table)
- apportion boundary fluxes (e.g. from an analytic element model) among model layers based on transmissivity.
- any other analysis where a distribution of transmissivity by layer is needed for a specified vertical interval of the model.

[1]:
```
import os
import sys
from tempfile import TemporaryDirectory

import matplotlib as mpl
import matplotlib.pyplot as plt
import numpy as np

import flopy

print(sys.version)
print(f"numpy version: {np.__version__}")
print(f"matplotlib version: {mpl.__version__}")
print(f"flopy version: {flopy.__version__}")
```

```
3.8.18 (default, Aug 28 2023, 08:27:22)
[GCC 11.4.0]
numpy version: 1.24.4
matplotlib version: 3.7.4
flopy version: 3.5.0
```

Make up some open interval tops and bottoms and some heads

- (these could be lists of observation well screen tops and bottoms)
- the heads array contains the simulated head in each model layer, at the location of each observation well (for example, what you would get back from HYDMOD if you had an entry for each layer at the location of each head target).
- make up a model grid with uniform horizontal k of 2.

[2]:
```
sctop = [-0.25, 0.5, 1.7, 1.5, 3.0, 2.5]  # screen tops
scbot = [-1.0, -0.5, 1.2, 0.5, 1.5, -0.2]  # screen bottoms
# head in each layer, for 6 head target locations
```

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```
heads = np.array(
    [
        [1.0, 2.0, 2.05, 3.0, 4.0, 2.5],
        [1.1, 2.1, 2.2, 2.0, 3.5, 3.0],
        [1.2, 2.3, 2.4, 0.6, 3.4, 3.2],
    ]
)
nl, nr = heads.shape
nc = nr
botm = np.ones((nl, nr, nc), dtype=float)
top = np.ones((nr, nc), dtype=float) * 2.1
hk = np.ones((nl, nr, nc), dtype=float) * 2.0
for i in range(nl):
    botm[nl - i - 1, :, :] = i
botm
```

[2]:
```
array([[[2., 2., 2., 2., 2., 2.],
        [2., 2., 2., 2., 2., 2.],
        [2., 2., 2., 2., 2., 2.],
        [2., 2., 2., 2., 2., 2.],
        [2., 2., 2., 2., 2., 2.],
        [2., 2., 2., 2., 2., 2.]],

       [[1., 1., 1., 1., 1., 1.],
        [1., 1., 1., 1., 1., 1.],
        [1., 1., 1., 1., 1., 1.],
        [1., 1., 1., 1., 1., 1.],
        [1., 1., 1., 1., 1., 1.],
        [1., 1., 1., 1., 1., 1.]],

       [[0., 0., 0., 0., 0., 0.],
        [0., 0., 0., 0., 0., 0.],
        [0., 0., 0., 0., 0., 0.],
        [0., 0., 0., 0., 0., 0.],
        [0., 0., 0., 0., 0., 0.],
        [0., 0., 0., 0., 0., 0.]]])
```

Make a flopy modflow model

[3]:
```
# temporary directory
temp_dir = TemporaryDirectory()
model_ws = temp_dir.name

m = flopy.modflow.Modflow("junk", version="mfnwt", model_ws=model_ws)
dis = flopy.modflow.ModflowDis(
    m, nlay=nl, nrow=nr, ncol=nc, botm=botm, top=top
)
upw = flopy.modflow.ModflowUpw(m, hk=hk)
```

Get transmissivities along the diagonal cells

- alternatively, if a model's coordinate information has been set up, the real-world x and y coordinates could be supplied with the x and y arguments
- if sctop and scbot arguments are given, the transmissivites are computed for the open intervals only (cells that are partially within the open interval have reduced thickness, cells outside of the open interval have transmissivities of 0). If no sctop or scbot arguments are supplied, trasmissivites reflect the full saturated thickness in each column of cells (see plot below, which shows different open intervals relative to the model layering)

[4]:
```
r, c = np.arange(nr), np.arange(nc)
T = flopy.utils.get_transmissivities(
    heads, m, r=r, c=c, sctop=sctop, scbot=scbot
)
np.round(T, 2)
```

[4]:
```
array([[0. , 0. , 0. , 0. , 0.2, 0.2],
       [0. , 0. , 1. , 1. , 1. , 2. ],
       [2. , 1. , 0. , 0.2, 0. , 2. ]])
```

[5]:
```
m.dis.botm.array[:, r, c]
```

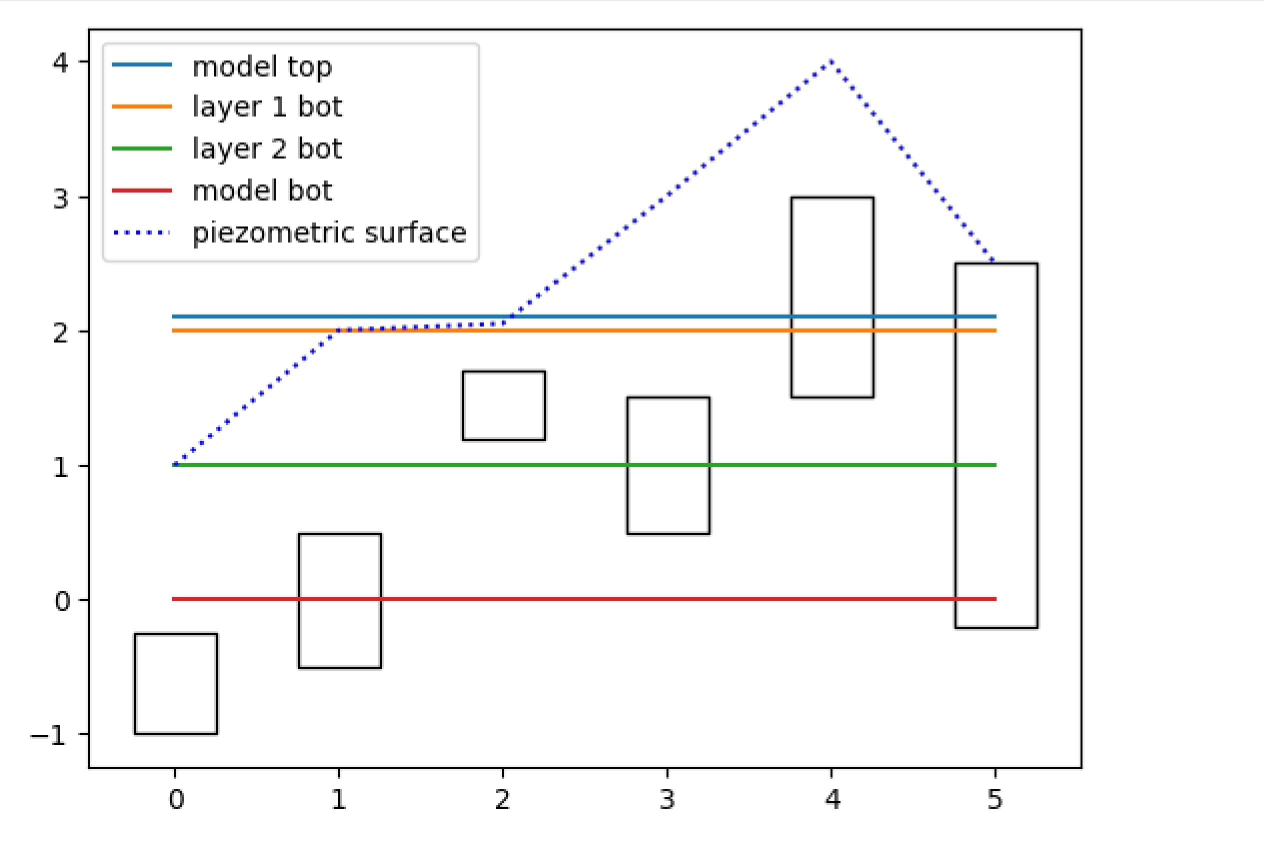
[5]:
```
array([[2., 2., 2., 2., 2., 2.],
       [1., 1., 1., 1., 1., 1.],
       [0., 0., 0., 0., 0., 0.]], dtype=float32)
```

Plot the model top and layer bottoms (colors)

open intervals are shown as boxes * well 0 has zero transmissivities for each layer, as it is below the model bottom * well 1 has T values of 0 for layers 1 and 2, and 1 for layer 3 (K=2 x 0.5 thickness)

[6]:
```
fig, ax = plt.subplots()
plt.plot(m.dis.top.array[r, c], label="model top")
for i, l in enumerate(m.dis.botm.array[:, r, c]):
    label = f"layer {i + 1} bot"
    if i == m.nlay - 1:
        label = "model bot"
    plt.plot(l, label=label)
plt.plot(heads[0], label="piezometric surface", color="b", linestyle=":")
for iw in range(len(sctop)):
    ax.fill_between(
        [iw - 0.25, iw + 0.25],
        scbot[iw],
        sctop[iw],
        facecolor="None",
        edgecolor="k",
    )
ax.legend(loc=2)
```

[6]:
```
<matplotlib.legend.Legend at 0x7f8326c98a00>
```



example of transmissivites without `sctop` and `scbot`

- well zero has T=0 in layer 1 because it is dry; T=0.2 in layer 2 because the sat. thickness there is only 0.1

[7]:
```
T = flopy.utils.get_transmissivities(heads, m, r=r, c=c)
np.round(T, 2)
```

[7]:
```
array([[0. , 0. , 0.1, 0.2, 0.2, 0.2],
       [0.2, 2. , 2. , 2. , 2. , 2. ],
       [2. , 2. , 2. , 1.2, 2. , 2. ]])
```

[8]:
```
try:
    # ignore PermissionError on Windows
    temp_dir.cleanup()
except:
    pass
```

6.4.3 Saving array data to MODFLOW-style binary files

[1]:
```
import os
import shutil
import sys
from tempfile import TemporaryDirectory

import matplotlib as mpl
import matplotlib.pyplot as plt
import numpy as np

# run installed version of flopy or add local path
try:
    import flopy
except:
    fpth = os.path.abspath(os.path.join("..", ".."))
    sys.path.append(fpth)
    import flopy

print(sys.version)
print(f"numpy version: {np.__version__}")
print(f"matplotlib version: {mpl.__version__}")
print(f"flopy version: {flopy.__version__}")
```

```
3.8.18 (default, Aug 28 2023, 08:27:22)
[GCC 11.4.0]
numpy version: 1.24.4
matplotlib version: 3.7.4
flopy version: 3.5.0
```

[2]:
```
nlay, nrow, ncol = 1, 20, 10

# temporary directory
temp_dir = TemporaryDirectory()
model_ws = os.path.join(temp_dir.name, "binary_data")

if os.path.exists(model_ws):
    shutil.rmtree(model_ws)

precision = "single"  # or 'double'
dtype = np.float32  # or np.float64

mf = flopy.modflow.Modflow(model_ws=model_ws)
dis = flopy.modflow.ModflowDis(
    mf, nlay=nlay, nrow=nrow, ncol=ncol, delr=20, delc=10
)
```

Create a linear data array

[3]:
```
# create the first row of data
b = np.linspace(10, 1, num=ncol, dtype=dtype).reshape(1, ncol)

# extend data to every row
```

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```
b = np.repeat(b, nrow, axis=0)

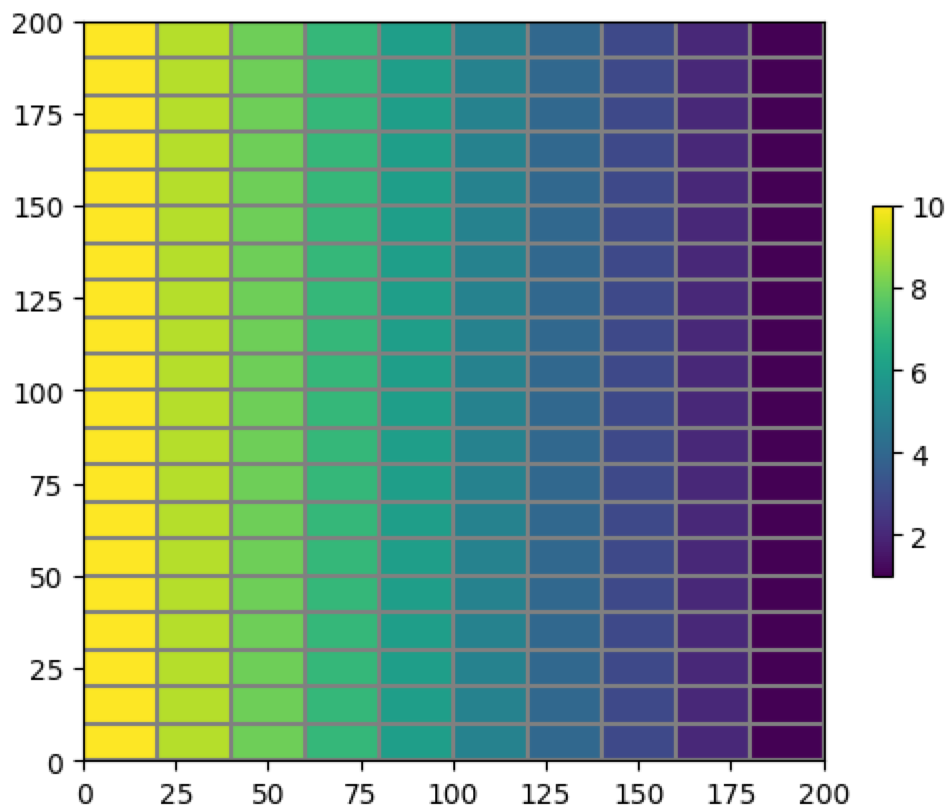
# print the shape and type of the data
print(b.shape)
```

```
(20, 10)
```

Plot the data array

```
[4]: pmv = flopy.plot.PlotMapView(model=mf)
v = pmv.plot_array(b)
pmv.plot_grid()
plt.colorbar(v, shrink=0.5)
```

```
[4]: <matplotlib.colorbar.Colorbar at 0x7f7e46b9c940>
```



Write the linear data array to a binary file

```
[5]: text = "head"

# write a binary data file
pertim = dtype(1.0)
header = flopy.utils.BinaryHeader.create(
    bintype=text,
    precision=precision,
    text=text,
    nrow=nrow,
```

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```
    ncol=ncol,
    ilay=1,
    pertim=pertim,
    totim=pertim,
    kstp=1,
    kper=1,
)
pth = os.path.join(model_ws, "bottom.bin")
flopy.utils.Util2d.write_bin(b.shape, pth, b, header_data=header)
```

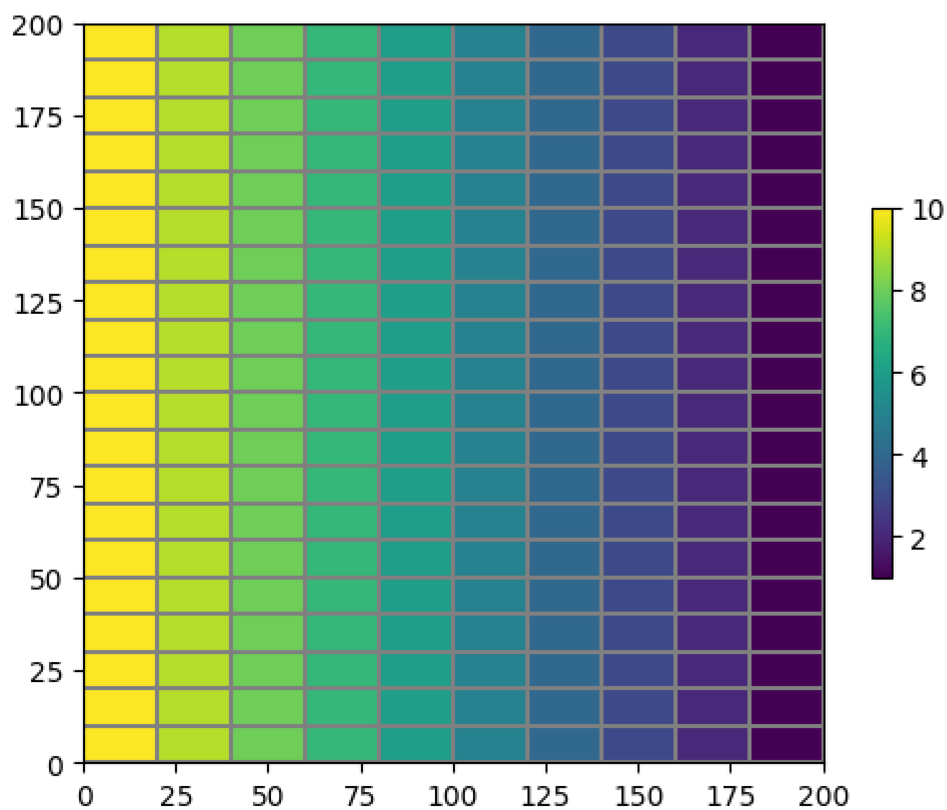
Read the binary data file

[6]:
```
bo = flopy.utils.HeadFile(pth, precision=precision)
br = bo.get_data(idx=0)
```

Plot the data that was read from the binary file

[7]:
```
pmv = flopy.plot.PlotMapView(model=mf)
v = pmv.plot_array(br)
pmv.plot_grid()
plt.colorbar(v, shrink=0.5)
```

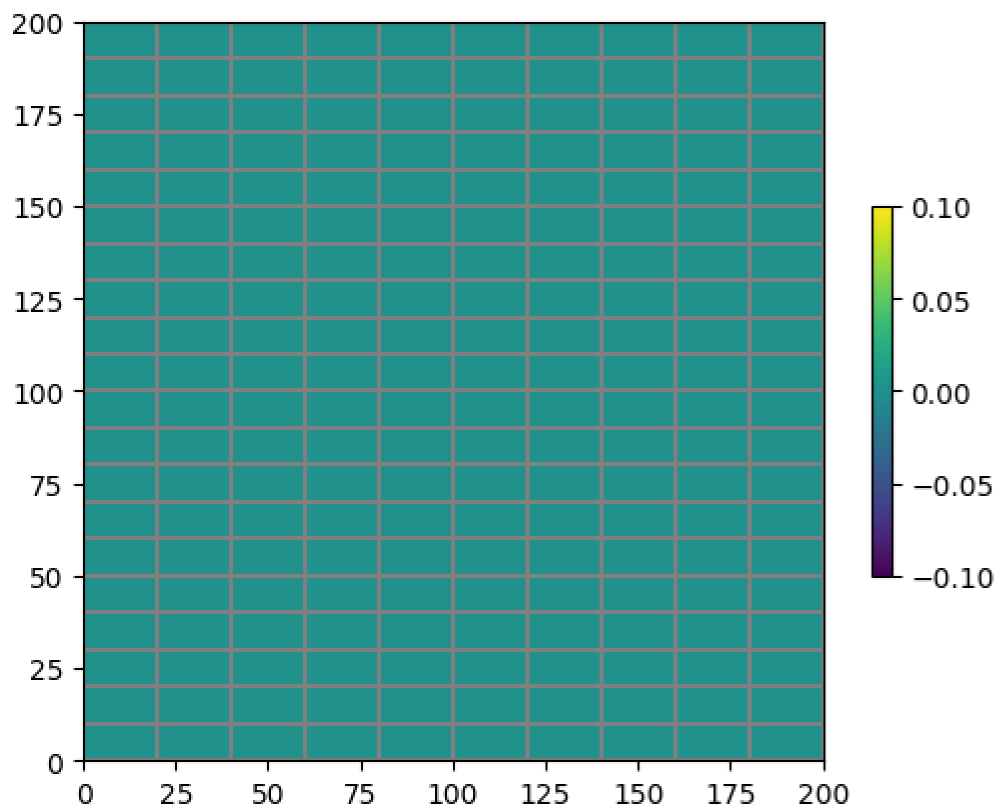
[7]:
```
<matplotlib.colorbar.Colorbar at 0x7f7e447f2b80>
```



Plot the difference in the two values

```
[8]: pmv = flopy.plot.PlotMapView(model=mf)
     v = pmv.plot_array(b - br)
     pmv.plot_grid()
     plt.colorbar(v, shrink=0.5)
```

```
[8]: <matplotlib.colorbar.Colorbar at 0x7f7e446d0df0>
```




```
[9]: try:
         # ignore PermissionError on Windows
         temp_dir.cleanup()
     except:
         pass
```

6.4.4 Working with shapefiles

This notebook shows some lower-level functionality in `flopy` for working with shapefiles including: * `recarray2shp` convience function for writing a numpy record array to a shapefile * `shp2recarray` convience function for quickly reading a shapefile into a numpy recarray * `utils.geometry` classes for writing shapefiles of model input/output. For example, quickly writing a shapefile of model cells with errors identified by the checker * examples of how the `Point` and `LineString` classes can be used to quickly plot pathlines and endpoints from MODPATH (these are also used by the `PathlineFile` and `EndpointFile` classes to write shapefiles of this output)

```
[1]: import os
     import shutil
     import sys
```

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```
import warnings
from tempfile import TemporaryDirectory

import matplotlib as mpl
import matplotlib.pyplot as plt
import numpy as np

import flopy
from flopy.export.shapefile_utils import recarray2shp, shp2recarray
from flopy.utils import geometry
from flopy.utils.geometry import LineString, Point, Polygon
from flopy.utils.modpathfile import EndpointFile, PathlineFile

warnings.simplefilter("ignore", UserWarning)
print(sys.version)
print(f"numpy version: {np.__version__}")
print(f"matplotlib version: {mpl.__version__}")
print(f"flopy version: {flopy.__version__}")
```

```
3.8.18 (default, Aug 28 2023, 08:27:22)
[GCC 11.4.0]
numpy version: 1.24.4
matplotlib version: 3.7.4
flopy version: 3.5.0
```

write a numpy record array to a shapefile

in this case, we want to visualize output from the checker first make a toy model

[2]:
```
temp_dir = TemporaryDirectory()
workspace = temp_dir.name

m = flopy.modflow.Modflow("toy_model", model_ws=workspace)
botm = np.zeros((2, 10, 10))
botm[0, :, :] = 1.5
botm[1, 5, 5] = 4  # negative layer thickness!
botm[1, 6, 6] = 4
dis = flopy.modflow.ModflowDis(
    nrow=10, ncol=10, nlay=2, delr=100, delc=100, top=3, botm=botm, model=m
)
```

set coordinate information

[3]:
```
grid = m.modelgrid
grid.set_coord_info(xoff=600000, yoff=5170000, crs="EPSG:26715", angrot=45)
```

[4]:
```
chk = dis.check()
chk.summary_array
```

```
DIS PACKAGE DATA VALIDATION:
  2 Errors:
    2 instances of zero or negative thickness

  Checks that passed:
    thin cells (less than checker threshold of 1.0)
    nan values in top array
    nan values in bottom array
```

[4]:
```
rec.array([('Error', 'DIS', 1, 5, 5, -2.5, 'zero or negative thickness'),
           ('Error', 'DIS', 1, 6, 6, -2.5, 'zero or negative thickness')],
          dtype=[('type', 'O'), ('package', 'O'), ('k', '<i8'), ('i', '<i8'), ('j', '<i8
↪'), ('value', '<f8'), ('desc', 'O')])
```

make geometry objects for the cells with errors

- geometry objects allow the shapefile writer to be simpler and agnostic about the kind of geometry

[5]:
```
get_vertices = (
    m.modelgrid.get_cell_vertices
)  # function to get the referenced vertices for a model cell
geoms = [Polygon(get_vertices(i, j)) for i, j in chk.summary_array[["i", "j"]]]
```

[6]:
```
geoms[0].type
```

[6]:
```
'Polygon'
```

[7]:
```
geoms[0].exterior
```

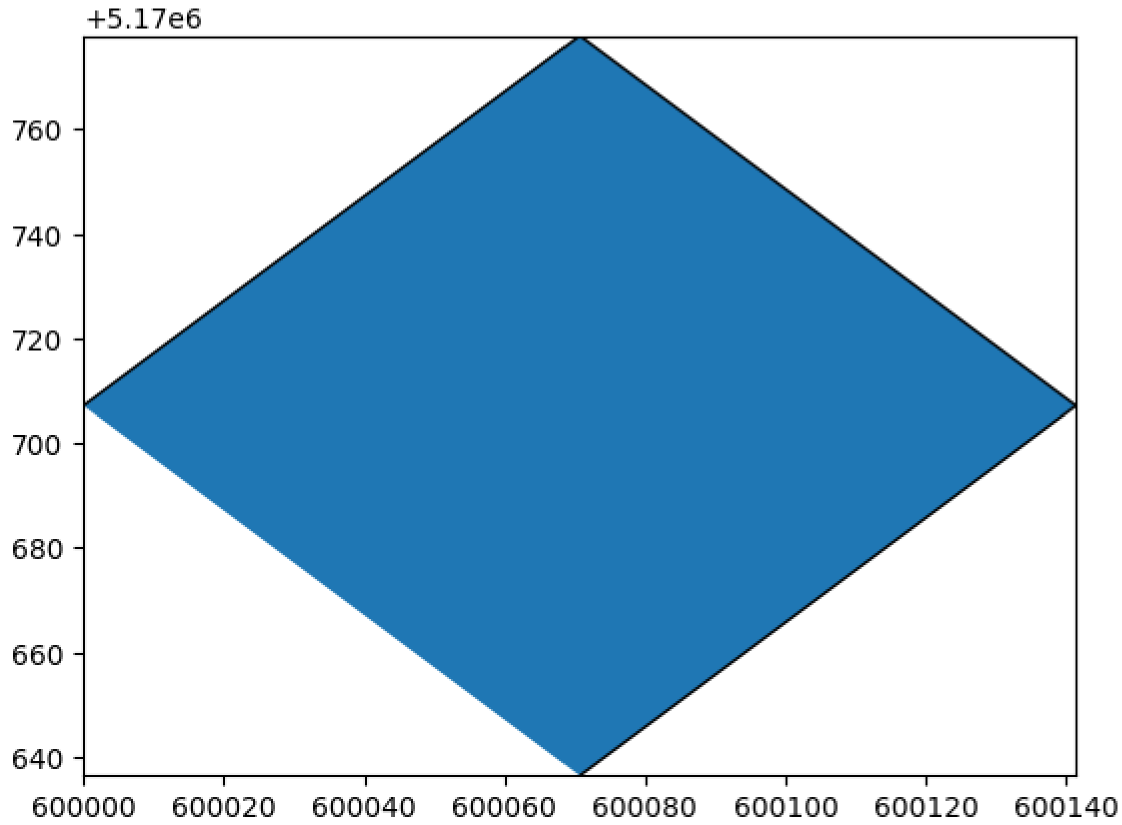
[7]:
```
((600000.0, 5170707.106781187),
 (600070.7106781186, 5170777.817459305),
 (600141.4213562373, 5170707.106781187),
 (600070.7106781186, 5170636.396103068))
```

[8]:
```
geoms[0].bounds
```

[8]:
```
(600000.0, 5170636.396103068, 600141.4213562373, 5170777.817459305)
```

[9]:
```
geoms[0].plot()  # this feature requires descartes
```

[9]:
```
<Axes: >
```



write the shapefile

- the projection (.prj) file can be written using an epsg code
- or copied from an existing .prj file

[10]:
```
from pathlib import Path

recarray2shp(
    chk.summary_array, geoms, os.path.join(workspace, "test.shp"), crs=26715
)
shape_path = os.path.join(workspace, "test.prj")
```

[11]:
```
shutil.copy(shape_path, os.path.join(workspace, "26715.prj"))
recarray2shp(
    chk.summary_array,
    geoms,
    os.path.join(workspace, "test.shp"),
    prjfile=os.path.join(workspace, "26715.prj"),
)
```

read it back in

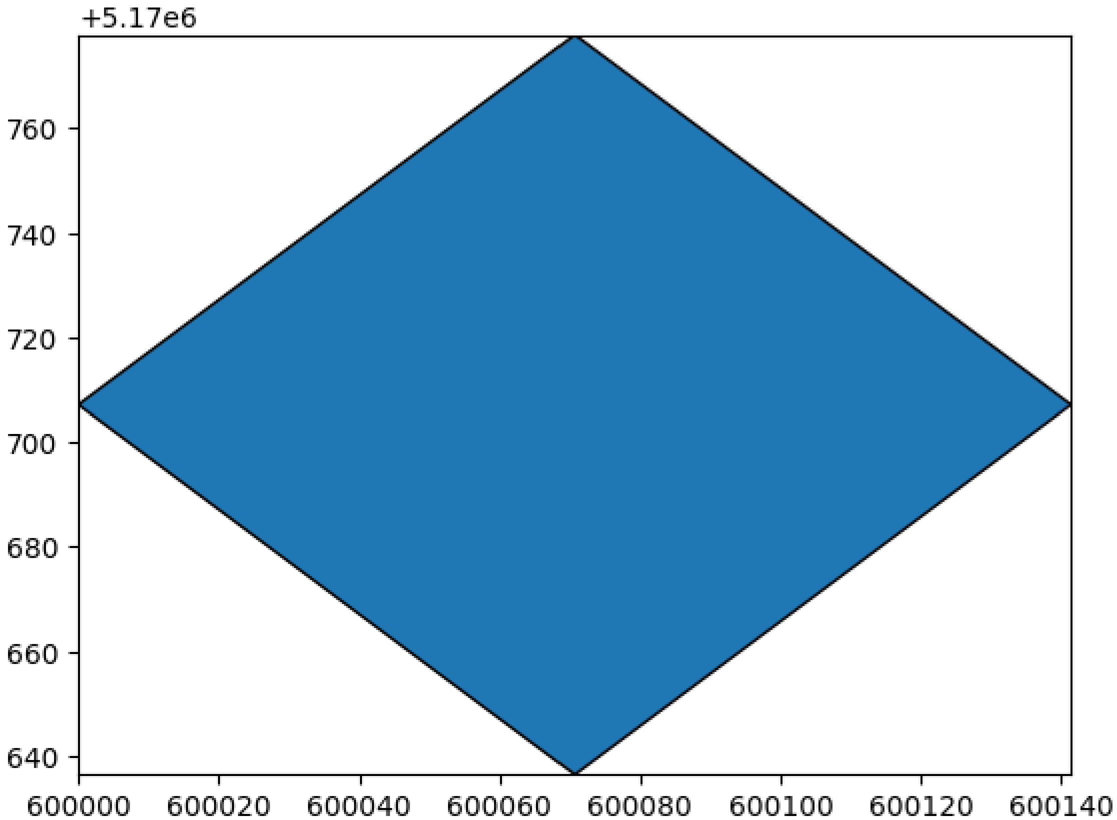
- flopy geometry objects representing the shapes are stored in the 'geometry' field

[12]:
```
ra = shp2recarray(os.path.join(workspace, "test.shp"))
ra
```

[12]:
```
rec.array([('Error', 'DIS', 1, 5, 5, -2.5, 'zero or negative thickness', <flopy.utils.
↪geometry.Polygon object at 0x7f8e03d395b0>),
           ('Error', 'DIS', 1, 6, 6, -2.5, 'zero or negative thickness', <flopy.utils.
↪geometry.Polygon object at 0x7f8e03d394f0>)],
          dtype=[('type', 'O'), ('package', 'O'), ('k', '<i8'), ('i', '<i8'), ('j', '<i8
↪'), ('value', '<f8'), ('desc', 'O'), ('geometry', 'O')])
```

[13]:
```
ra.geometry[0].plot()
```

[13]:
```
<Axes: >
```



Other geometry types

Linestring

- create geometry objects for pathlines from a MODPATH simulation
- plot the paths using the built in plotting method

[14]:
```
pthfile = PathlineFile("../../examples/data/mp6/EXAMPLE-3.pathline")
pthdata = pthfile._data.view(np.recarray)
```

[15]:
```
length_mult = 1.0  # multiplier to convert coordinates from model to real world
rot = 0  # grid rotation

particles = np.unique(pthdata.particleid)
geoms = []
for pid in particles:
    ra = pthdata[pthdata.particleid == pid]

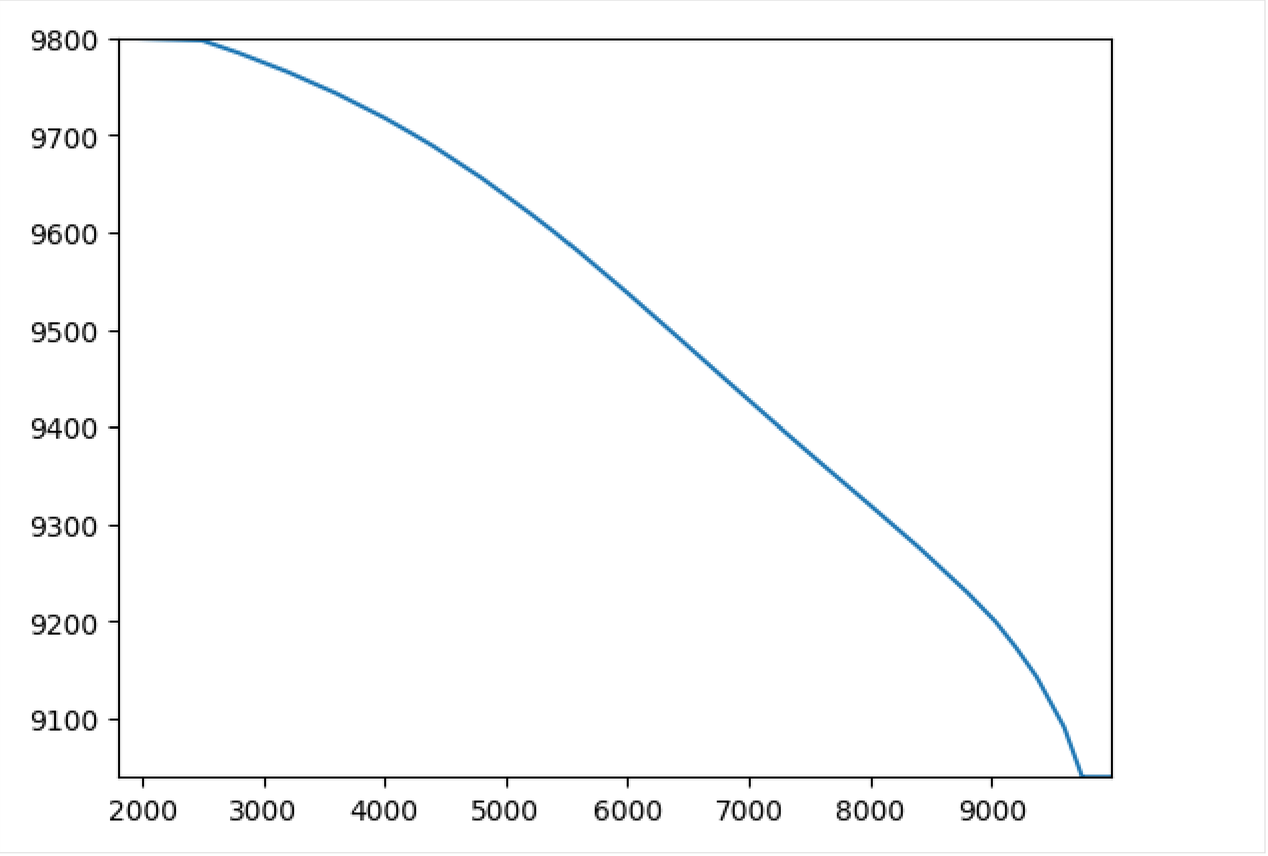
    x, y = geometry.rotate(
        ra.x * length_mult, ra.y * length_mult, grid.xoffset, grid.yoffset, rot
    )
    z = ra.z
    geoms.append(LineString(list(zip(x, y, z))))
```

[16]:
```
geoms[0]
```

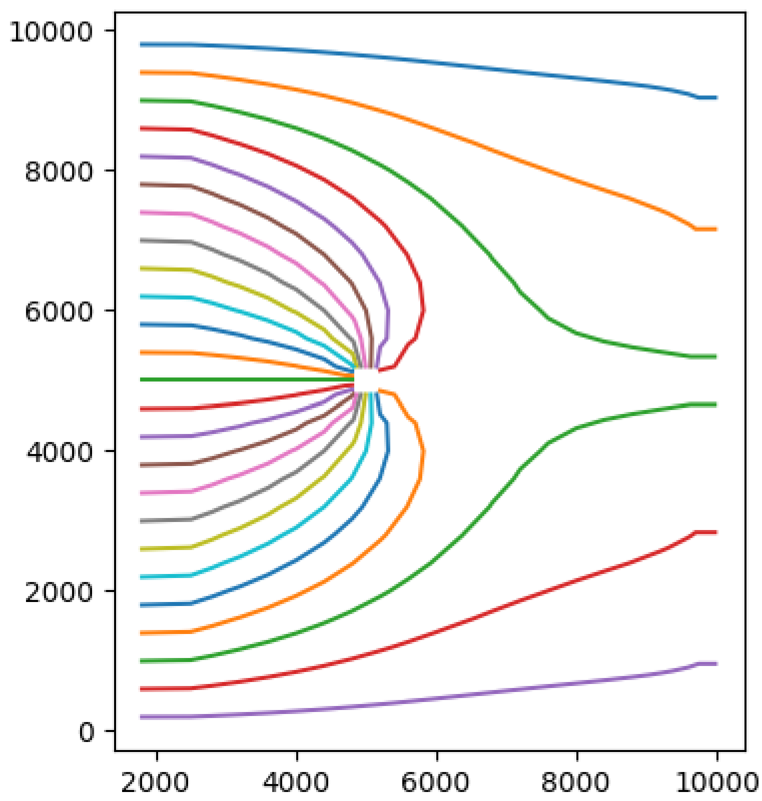
[16]:
```
<flopy.utils.geometry.LineString at 0x7f8e304add60>
```

[17]:
```
geoms[0].plot()
```

[17]:
```
<Axes: >
```



[18]:
```
fig, ax = plt.subplots()
for g in geoms:
    g.plot(ax=ax)
ax.autoscale()
ax.set_aspect(1)
```



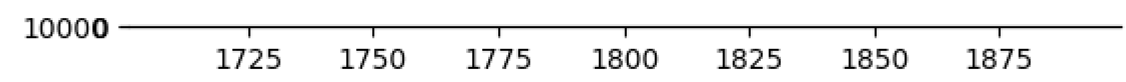
Points

[19]:
```
eptfile = EndpointFile("../../examples/data/mp6/EXAMPLE-3.endpoint")
eptdata = eptfile.get_alldata()
```

[20]:
```
x, y = geometry.rotate(
    eptdata["x0"] * length_mult,
    eptdata["y0"] * length_mult,
    grid.xoffset,
    grid.yoffset,
    rot,
)
z = eptdata["z0"]

geoms = [Point(x[i], y[i], z[i]) for i in range(len(eptdata))]
```

[21]:
```
fig, ax = plt.subplots()
for g in geoms:
    g.plot(ax=ax)
ax.autoscale()
ax.set_aspect(2e-6)
```



[22]:
```
try:
    # ignore PermissionError on Windows
    temp_dir.cleanup()
except:
    pass
```

6.5 MODFLOW 6 examples

6.5.1 Creating a Complex MODFLOW 6 Model with Flopy

The purpose of this notebook is to demonstrate the Flopy capabilities for building a more complex MODFLOW 6 model from scratch. This notebook will demonstrate the capabilities by replicating the advgw_tidal model that is distributed with MODFLOW 6.

Setup the Notebook Environment

[1]:
```
import os
```

[2]:
```
import sys
from tempfile import TemporaryDirectory

import matplotlib as mpl
import matplotlib.pyplot as plt
import numpy as np

# run installed version of flopy or add local path
try:
    import flopy
except:
    fpth = os.path.abspath(os.path.join("..", ".."))
    sys.path.append(fpth)
    import flopy

print(sys.version)
print(f"numpy version: {np.__version__}")
print(f"matplotlib version: {mpl.__version__}")
print(f"flopy version: {flopy.__version__}")
```

```
3.8.18 (default, Aug 28 2023, 08:27:22)
[GCC 11.4.0]
numpy version: 1.24.4
matplotlib version: 3.7.4
flopy version: 3.5.0
```

[3]:
```python
# For this example, we will set up a temporary workspace.
# Model input files and output files will reside here.
temp_dir = TemporaryDirectory()
model_name = "advgw_tidal"
workspace = os.path.join(temp_dir.name, model_name)
```

[4]:
```python
data_pth = os.path.join(
    "..",
    "..",
    "examples",
    "data",
    "mf6",
    "create_tests",
    "test005_advgw_tidal",
)
assert os.path.isdir(data_pth)
```

[5]:
```python
# create simulation
sim = flopy.mf6.MFSimulation(
    sim_name=model_name, version="mf6", exe_name="mf6", sim_ws=workspace
)

# create tdis package
tdis_rc = [(1.0, 1, 1.0), (10.0, 120, 1.0), (10.0, 120, 1.0), (10.0, 120, 1.0)]
tdis = flopy.mf6.ModflowTdis(
    sim, pname="tdis", time_units="DAYS", nper=4, perioddata=tdis_rc
)

# create gwf model
gwf = flopy.mf6.ModflowGwf(
    sim, modelname=model_name, model_nam_file=f"{model_name}.nam"
)
gwf.name_file.save_flows = True

# create iterative model solution and register the gwf model with it
ims = flopy.mf6.ModflowIms(
    sim,
    pname="ims",
    print_option="SUMMARY",
    complexity="SIMPLE",
    outer_dvclose=0.0001,
    outer_maximum=500,
    under_relaxation="NONE",
    inner_maximum=100,
    inner_dvclose=0.0001,
    rcloserecord=0.001,
    linear_acceleration="CG",
    scaling_method="NONE",
    reordering_method="NONE",
    relaxation_factor=0.97,
)
sim.register_ims_package(ims, [gwf.name])
```

[6]:
```
# discretization package
nlay = 3
nrow = 15
ncol = 10
botlay2 = {"factor": 1.0, "data": [-100 for x in range(150)]}
dis = flopy.mf6.ModflowGwfdis(
    gwf,
    pname="dis",
    nlay=nlay,
    nrow=nrow,
    ncol=ncol,
    delr=500.0,
    delc=500.0,
    top=50.0,
    botm=[5.0, -10.0, botlay2],
    filename=f"{model_name}.dis",
)

# initial conditions
ic = flopy.mf6.ModflowGwfic(
    gwf, pname="ic", strt=50.0, filename=f"{model_name}.ic"
)

# node property flow
npf = flopy.mf6.ModflowGwfnpf(
    gwf,
    pname="npf",
    save_flows=True,
    icelltype=[1, 0, 0],
    k=[5.0, 0.1, 4.0],
    k33=[0.5, 0.005, 0.1],
)

# output control
oc = flopy.mf6.ModflowGwfoc(
    gwf,
    pname="oc",
    budget_filerecord=f"{model_name}.cbb",
    head_filerecord=f"{model_name}.hds",
    headprintrecord=[("COLUMNS", 10, "WIDTH", 15, "DIGITS", 6, "GENERAL")],
    saverecord=[("HEAD", "ALL"), ("BUDGET", "ALL")],
    printrecord=[("HEAD", "FIRST"), ("HEAD", "LAST"), ("BUDGET", "LAST")],
)
```

[7]:
```
# storage package
sy = flopy.mf6.ModflowGwfsto.sy.empty(gwf, layered=True)
for layer in range(0, 3):
    sy[layer]["data"] = 0.2

ss = flopy.mf6.ModflowGwfsto.ss.empty(
    gwf, layered=True, default_value=0.000001
)
```

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```
sto = flopy.mf6.ModflowGwfsto(
    gwf,
    pname="sto",
    save_flows=True,
    iconvert=1,
    ss=ss,
    sy=sy,
    steady_state={0: True},
    transient={1: True},
)
```

[8]:
```
# well package
# test empty with aux vars, bound names, and time series
period_two = flopy.mf6.ModflowGwfwel.stress_period_data.empty(
    gwf,
    maxbound=3,
    aux_vars=["var1", "var2", "var3"],
    boundnames=True,
    timeseries=True,
)
period_two[0][0] = ((0, 11, 2), -50.0, -1, -2, -3, None)
period_two[0][1] = ((2, 4, 7), "well_1_rate", 1, 2, 3, "well_1")
period_two[0][2] = ((2, 3, 2), "well_2_rate", 4, 5, 6, "well_2")
period_three = flopy.mf6.ModflowGwfwel.stress_period_data.empty(
    gwf,
    maxbound=2,
    aux_vars=["var1", "var2", "var3"],
    boundnames=True,
    timeseries=True,
)
period_three[0][0] = ((2, 3, 2), "well_2_rate", 1, 2, 3, "well_2")
period_three[0][1] = ((2, 4, 7), "well_1_rate", 4, 5, 6, "well_1")
period_four = flopy.mf6.ModflowGwfwel.stress_period_data.empty(
    gwf,
    maxbound=5,
    aux_vars=["var1", "var2", "var3"],
    boundnames=True,
    timeseries=True,
)
period_four[0][0] = ((2, 4, 7), "well_1_rate", 1, 2, 3, "well_1")
period_four[0][1] = ((2, 3, 2), "well_2_rate", 4, 5, 6, "well_2")
period_four[0][2] = ((0, 11, 2), -10.0, 7, 8, 9, None)
period_four[0][3] = ((0, 2, 4), -20.0, 17, 18, 19, None)
period_four[0][4] = ((0, 13, 5), -40.0, 27, 28, 29, None)
stress_period_data = {}
stress_period_data[1] = period_two[0]
stress_period_data[2] = period_three[0]
stress_period_data[3] = period_four[0]
wel = flopy.mf6.ModflowGwfwel(
    gwf,
    pname="wel",
```

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```
    print_input=True,
    print_flows=True,
    auxiliary=[("var1", "var2", "var3")],
    maxbound=5,
    stress_period_data=stress_period_data,
    boundnames=True,
    save_flows=True,
)

# well ts package
ts_data = [
    (0.0, 0.0, 0.0, 0.0),
    (1.0, -200.0, 0.0, -100.0),
    (11.0, -1800.0, -500.0, -200.0),
    (21.0, -200.0, -400.0, -300.0),
    (31.0, 0.0, -600.0, -400.0),
]
wel.ts.initialize(
    filename="well-rates.ts",
    timeseries=ts_data,
    time_series_namerecord=[("well_1_rate", "well_2_rate", "well_3_rate")],
    interpolation_methodrecord=[("stepwise", "stepwise", "stepwise")],
)
```

[9]:
```
# Evapotranspiration
evt_period = flopy.mf6.ModflowGwfevt.stress_period_data.empty(gwf, 150, nseg=3)
for col in range(0, 10):
    for row in range(0, 15):
        evt_period[0][col * 15 + row] = (
            (0, row, col),
            50.0,
            0.0004,
            10.0,
            0.2,
            0.5,
            0.3,
            0.1,
            None,
        )
evt = flopy.mf6.ModflowGwfevt(
    gwf,
    pname="evt",
    print_input=True,
    print_flows=True,
    save_flows=True,
    maxbound=150,
    nseg=3,
    stress_period_data=evt_period,
)
```

[10]:
```
# General-Head Boundaries
ghb_period = {}
ghb_period_array = []
for layer, cond in zip(range(1, 3), [15.0, 1500.0]):
    for row in range(0, 15):
        ghb_period_array.append(((layer, row, 9), "tides", cond, "Estuary-L2"))
ghb_period[0] = ghb_period_array
ghb = flopy.mf6.ModflowGwfghb(
    gwf,
    pname="ghb",
    print_input=True,
    print_flows=True,
    save_flows=True,
    boundnames=True,
    maxbound=30,
    stress_period_data=ghb_period,
)
ts_recarray = []
fd = open(os.path.join(data_pth, "tides.txt"))
for line in fd:
    line_list = line.strip().split(",")
    ts_recarray.append((float(line_list[0]), float(line_list[1])))
ghb.ts.initialize(
    filename="tides.ts",
    timeseries=ts_recarray,
    time_series_namerecord="tides",
    interpolation_methodrecord="linear",
)
obs_recarray = {
    "ghb_obs.csv": [
        ("ghb-2-6-10", "GHB", (1, 5, 9)),
        ("ghb-3-6-10", "GHB", (2, 5, 9)),
    ],
    "ghb_flows.csv": [
        ("Estuary2", "GHB", "Estuary-L2"),
        ("Estuary3", "GHB", "Estuary-L3"),
    ],
}
ghb.obs.initialize(
    filename=f"{model_name}.ghb.obs",
    print_input=True,
    continuous=obs_recarray,
)
```

[11]:
```
obs_recarray = {
    "head_obs.csv": [("h1_13_8", "HEAD", (2, 12, 7))],
    "intercell_flow_obs1.csv": [
        ("ICF1_1.0", "FLOW-JA-FACE", (0, 4, 5), (0, 5, 5))
    ],
    "head-hydrographs.csv": [
        ("h3-13-9", "HEAD", (2, 12, 8)),
        ("h3-12-8", "HEAD", (2, 11, 7)),
```

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```
        ("h1-4-3", "HEAD", (0, 3, 2)),
        ("h1-12-3", "HEAD", (0, 11, 2)),
        ("h1-13-9", "HEAD", (0, 12, 8)),
    ],
}
obs_package = flopy.mf6.ModflowUtlobs(
    gwf,
    pname="head_obs",
    filename=f"{model_name}.obs",
    print_input=True,
    continuous=obs_recarray,
)
```

[12]:
```
# River
riv_period = {}
riv_period_array = [
    ((0, 2, 0), "river_stage_1", 1001.0, 35.9, None),
    ((0, 3, 1), "river_stage_1", 1002.0, 35.8, None),
    ((0, 4, 2), "river_stage_1", 1003.0, 35.7, None),
    ((0, 4, 3), "river_stage_1", 1004.0, 35.6, None),
    ((0, 5, 4), "river_stage_1", 1005.0, 35.5, None),
    ((0, 5, 5), "river_stage_1", 1006.0, 35.4, "riv1_c6"),
    ((0, 5, 6), "river_stage_1", 1007.0, 35.3, "riv1_c7"),
    ((0, 4, 7), "river_stage_1", 1008.0, 35.2, None),
    ((0, 4, 8), "river_stage_1", 1009.0, 35.1, None),
    ((0, 4, 9), "river_stage_1", 1010.0, 35.0, None),
    ((0, 9, 0), "river_stage_2", 1001.0, 36.9, "riv2_upper"),
    ((0, 8, 1), "river_stage_2", 1002.0, 36.8, "riv2_upper"),
    ((0, 7, 2), "river_stage_2", 1003.0, 36.7, "riv2_upper"),
    ((0, 6, 3), "river_stage_2", 1004.0, 36.6, None),
    ((0, 6, 4), "river_stage_2", 1005.0, 36.5, None),
    ((0, 5, 5), "river_stage_2", 1006.0, 36.4, "riv2_c6"),
    ((0, 5, 6), "river_stage_2", 1007.0, 36.3, "riv2_c7"),
    ((0, 6, 7), "river_stage_2", 1008.0, 36.2, None),
    ((0, 6, 8), "river_stage_2", 1009.0, 36.1),
    ((0, 6, 9), "river_stage_2", 1010.0, 36.0),
]
riv_period[0] = riv_period_array
riv = flopy.mf6.ModflowGwfriv(
    gwf,
    pname="riv",
    print_input=True,
    print_flows=True,
    save_flows=f"{model_name}.cbc",
    boundnames=True,
    maxbound=20,
    stress_period_data=riv_period,
)
ts_recarray = [
    (0.0, 40.0, 41.0),
    (1.0, 41.0, 41.5),
    (2.0, 43.0, 42.0),
```

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```
    (3.0, 45.0, 42.8),
    (4.0, 44.0, 43.0),
    (6.0, 43.0, 43.1),
    (9.0, 42.0, 42.4),
    (11.0, 41.0, 41.5),
    (31.0, 40.0, 41.0),
]
riv.ts.initialize(
    filename="river_stages.ts",
    timeseries=ts_recarray,
    time_series_namerecord=[("river_stage_1", "river_stage_2")],
    interpolation_methodrecord=[("linear", "stepwise")],
)
obs_recarray = {
    "riv_obs.csv": [
        ("rv1-3-1", "RIV", (0, 2, 0)),
        ("rv1-4-2", "RIV", (0, 3, 1)),
        ("rv1-5-3", "RIV", (0, 4, 2)),
        ("rv1-5-4", "RIV", (0, 4, 3)),
        ("rv1-6-5", "RIV", (0, 5, 4)),
        ("rv1-c6", "RIV", "riv1_c6"),
        ("rv1-c7", "RIV", "riv1_c7"),
        ("rv2-upper", "RIV", "riv2_upper"),
        ("rv-2-7-4", "RIV", (0, 6, 3)),
        ("rv2-8-5", "RIV", (0, 6, 4)),
        (
            "rv-2-9-6",
            "RIV",
            (
                0,
                5,
                5,
            ),
        ),
    ],
    "riv_flowsA.csv": [
        ("riv1-3-1", "RIV", (0, 2, 0)),
        ("riv1-4-2", "RIV", (0, 3, 1)),
        ("riv1-5-3", "RIV", (0, 4, 2)),
    ],
    "riv_flowsB.csv": [
        ("riv2-10-1", "RIV", (0, 9, 0)),
        ("riv-2-9-2", "RIV", (0, 8, 1)),
        ("riv2-8-3", "RIV", (0, 7, 2)),
    ],
}
riv.obs.initialize(
    filename=f"{model_name}.riv.obs",
    print_input=True,
    continuous=obs_recarray,
)
```

[13]:
```
# First recharge package
rch1_period = {}
rch1_period_array = []
col_range = {0: 3, 1: 4, 2: 5}
for row in range(0, 15):
    if row in col_range:
        col_max = col_range[row]
    else:
        col_max = 6
    for col in range(0, col_max):
        if (
            (row == 3 and col == 5)
            or (row == 2 and col == 4)
            or (row == 1 and col == 3)
            or (row == 0 and col == 2)
        ):
            mult = 0.5
        else:
            mult = 1.0
        if row == 0 and col == 0:
            bnd = "rch-1-1"
        elif row == 0 and col == 1:
            bnd = "rch-1-2"
        elif row == 1 and col == 2:
            bnd = "rch-2-3"
        else:
            bnd = None
        rch1_period_array.append(((0, row, col), "rch_1", mult, bnd))
rch1_period[0] = rch1_period_array
rch1 = flopy.mf6.ModflowGwfrch(
    gwf,
    filename=f"{model_name}_1.rch",
    pname="rch_1",
    fixed_cell=True,
    auxiliary="MULTIPLIER",
    auxmultname="MULTIPLIER",
    print_input=True,
    print_flows=True,
    save_flows=True,
    boundnames=True,
    maxbound=84,
    stress_period_data=rch1_period,
)
ts_data = [
    (0.0, 0.0015),
    (1.0, 0.0010),
    (11.0, 0.0015),
    (21.0, 0.0025),
    (31.0, 0.0015),
]
rch1.ts.initialize(
    filename="recharge_rates_1.ts",
    timeseries=ts_data,
```
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```
    time_series_namerecord="rch_1",
    interpolation_methodrecord="stepwise",
)
```

[14]:
```
# Second recharge package
rch2_period = {}
rch2_period_array = [
    ((0, 0, 2), "rch_2", 0.5),
    ((0, 0, 3), "rch_2", 1.0),
    ((0, 0, 4), "rch_2", 1.0),
    ((0, 0, 5), "rch_2", 1.0),
    ((0, 0, 6), "rch_2", 1.0),
    ((0, 0, 7), "rch_2", 1.0),
    ((0, 0, 8), "rch_2", 1.0),
    ((0, 0, 9), "rch_2", 0.5),
    ((0, 1, 3), "rch_2", 0.5),
    ((0, 1, 4), "rch_2", 1.0),
    ((0, 1, 5), "rch_2", 1.0),
    ((0, 1, 6), "rch_2", 1.0),
    ((0, 1, 7), "rch_2", 1.0),
    ((0, 1, 8), "rch_2", 0.5),
    ((0, 2, 4), "rch_2", 0.5),
    ((0, 2, 5), "rch_2", 1.0),
    ((0, 2, 6), "rch_2", 1.0),
    ((0, 2, 7), "rch_2", 0.5),
    ((0, 3, 5), "rch_2", 0.5),
    ((0, 3, 6), "rch_2", 0.5),
]
rch2_period[0] = rch2_period_array
rch2 = flopy.mf6.ModflowGwfrch(
    gwf,
    filename=f"{model_name}_2.rch",
    pname="rch_2",
    fixed_cell=True,
    auxiliary="MULTIPLIER",
    auxmultname="MULTIPLIER",
    print_input=True,
    print_flows=True,
    save_flows=True,
    maxbound=20,
    stress_period_data=rch2_period,
)
ts_data = [
    (0.0, 0.0016),
    (1.0, 0.0018),
    (11.0, 0.0019),
    (21.0, 0.0016),
    (31.0, 0.0018),
]
rch2.ts.initialize(
    filename="recharge_rates_2.ts",
    timeseries=ts_data,
```

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```
    time_series_namerecord="rch_2",
    interpolation_methodrecord="linear",
)
```

[15]:
```
# Third recharge package
rch3_period = {}
rch3_period_array = []
col_range = {0: 9, 1: 8, 2: 7}
for row in range(0, 15):
    if row in col_range:
        col_min = col_range[row]
    else:
        col_min = 6
    for col in range(col_min, 10):
        if (
            (row == 0 and col == 9)
            or (row == 1 and col == 8)
            or (row == 2 and col == 7)
            or (row == 3 and col == 6)
        ):
            mult = 0.5
        else:
            mult = 1.0
        rch3_period_array.append(((0, row, col), "rch_3", mult))
rch3_period[0] = rch3_period_array
rch3 = flopy.mf6.ModflowGwfrch(
    gwf,
    filename=f"{model_name}_3.rch",
    pname="rch_3",
    fixed_cell=True,
    auxiliary="MULTIPLIER",
    auxmultname="MULTIPLIER",
    print_input=True,
    print_flows=True,
    save_flows=True,
    maxbound=54,
    stress_period_data=rch3_period,
)
ts_data = [
    (0.0, 0.0017),
    (1.0, 0.0020),
    (11.0, 0.0017),
    (21.0, 0.0018),
    (31.0, 0.0020),
]
rch3.ts.initialize(
    filename="recharge_rates_3.ts",
    timeseries=ts_data,
    time_series_namerecord="rch_3",
    interpolation_methodrecord="linear",
)
```

Create the MODFLOW 6 Input Files and Run the Model

Once all the flopy objects are created, it is very easy to create all of the input files and run the model.

[16]:
```
# write simulation to new location
sim.write_simulation()
```

```
writing simulation...
  writing simulation name file...
  writing simulation tdis package...
  writing solution package ims...
  writing model advgw_tidal...
    writing model name file...
    writing package dis...
    writing package ic...
    writing package npf...
    writing package oc...
    writing package sto...
    writing package wel...
    writing package ts_0...
    writing package evt...
    writing package ghb...
    writing package ts_1...
    writing package obs_0...
    writing package head_obs...
    writing package riv...
    writing package ts_2...
    writing package obs_1...
    writing package rch_1...
    writing package ts_3...
    writing package rch_2...
    writing package ts_4...
    writing package rch_3...
    writing package ts_5...
```

[17]:
```
# Print a list of the files that were created
# in workspace
print(os.listdir(workspace))
```

```
['advgw_tidal.obs', 'advgw_tidal.ims', 'advgw_tidal.evt', 'advgw_tidal.oc', 'recharge_
↪rates_3.ts', 'advgw_tidal.riv.obs', 'advgw_tidal_2.rch', 'advgw_tidal.ghb.obs', 'advgw_
↪tidal.npf', 'advgw_tidal.nam', 'advgw_tidal.wel', 'advgw_tidal.ghb', 'tides.ts',
↪'advgw_tidal.sto', 'well-rates.ts', 'advgw_tidal.riv', 'recharge_rates_2.ts', 'advgw_
↪tidal_1.rch', 'advgw_tidal.tdis', 'advgw_tidal.dis', 'recharge_rates_1.ts', 'river_
↪stages.ts', 'advgw_tidal_3.rch', 'advgw_tidal.ic', 'mfsim.nam']
```

Run the Simulation

We can also run the simulation from the notebook, but only if the MODFLOW 6 executable is available. The executable can be made available by putting the executable in a folder that is listed in the system path variable. Another option is to just put a copy of the executable in the simulation folder, though this should generally be avoided. A final option is to provide a full path to the executable when the simulation is constructed. This would be done by specifying exe_name with the full path.

[18]:
```
# Run the simulation
success, buff = sim.run_simulation(silent=True, report=True)
if success:
    for line in buff:
        print(line)
else:
    raise ValueError("Failed to run.")
```

```
                                   MODFLOW 6
                U.S. GEOLOGICAL SURVEY MODULAR HYDROLOGIC MODEL
                            VERSION 6.4.2 06/28/2023

   MODFLOW 6 compiled Jul 05 2023 20:29:14 with Intel(R) Fortran Intel(R) 64
   Compiler Classic for applications running on Intel(R) 64, Version 2021.7.0
                             Build 20220726_000000

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and distribution information.


 Run start date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:29:53

 Writing simulation list file: mfsim.lst
 Using Simulation name file: mfsim.nam

    Solving:  Stress period:     1    Time step:     1
    Solving:  Stress period:     2    Time step:     1
    Solving:  Stress period:     2    Time step:     2
    Solving:  Stress period:     2    Time step:     3
    Solving:  Stress period:     2    Time step:     4
    Solving:  Stress period:     2    Time step:     5
    Solving:  Stress period:     2    Time step:     6
    Solving:  Stress period:     2    Time step:     7
    Solving:  Stress period:     2    Time step:     8
    Solving:  Stress period:     2    Time step:     9
    Solving:  Stress period:     2    Time step:    10
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 Run end date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:29:54
 Elapsed run time:  1.249 Seconds

 Normal termination of simulation.
```

Post-Process Head Results

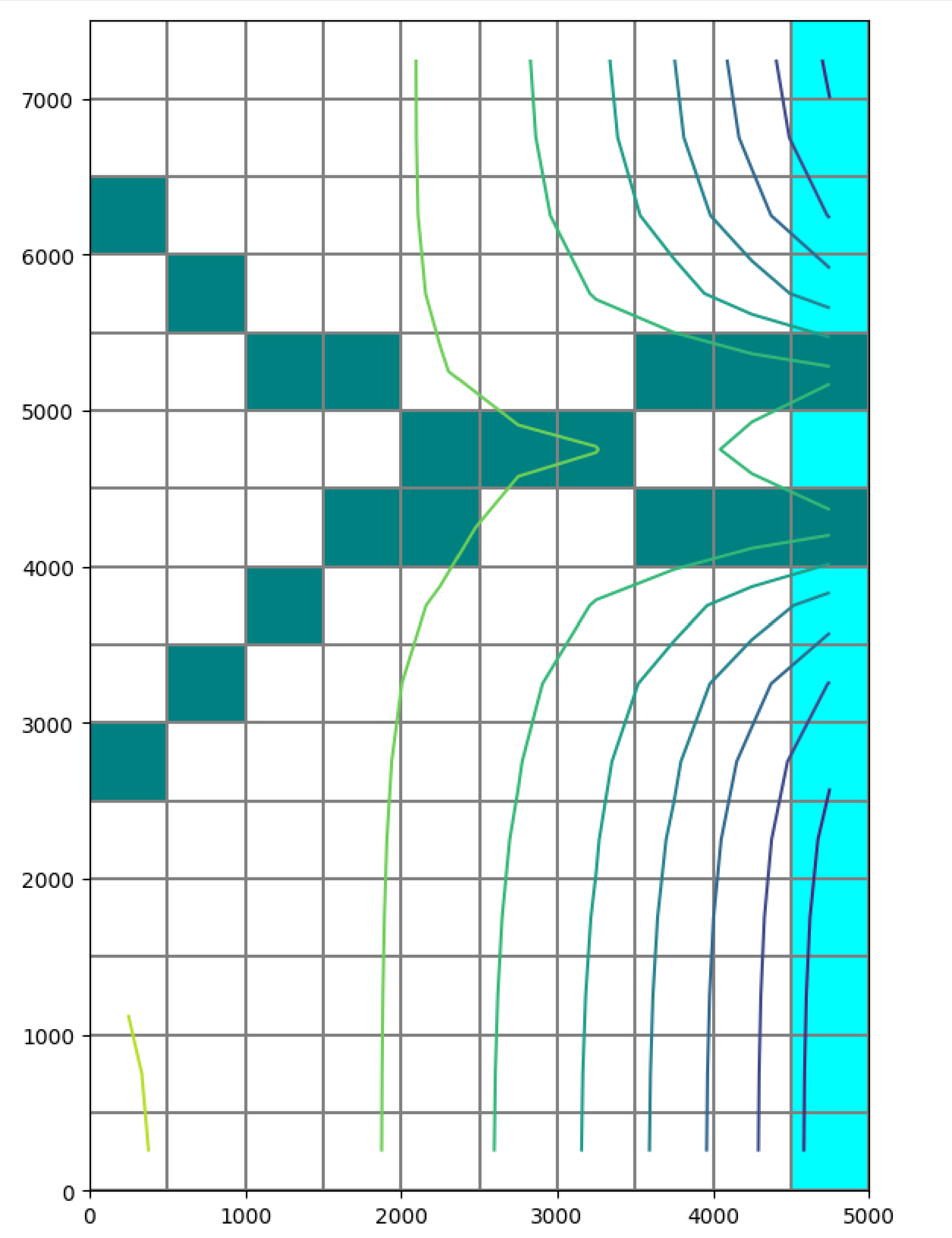
First, we get the simulated head data using the `.output.head()` method and the `get_data` function, by specifying, in this case, the step number and period number for which we want to retrieve data. A three-dimensional array is returned of size `nlay, nrow, ncol`. FloPy plotting methods are used to make contours of the head in a specific layer (in this case, layer 1). FloPy plotting methods are also used to plot the model grid and the location of GHB cells in the model domain.

[19]:
```
# Retrieve the head data using the .output() method
h = gwf.output.head().get_data(kstpkper=(0, 0))
```

[20]:
```
fig = plt.figure(figsize=(10, 10))
ax = fig.add_subplot(1, 1, 1, aspect="equal")

# Next we create an instance of the ModelMap class
modelmap = flopy.plot.PlotMapView(model=gwf, ax=ax)

ghb_quadmesh = modelmap.plot_bc(name="ghb", plotAll=True)
riv_quadmesh = modelmap.plot_bc(name="riv", plotAll=True)
linecollection = modelmap.plot_grid()
contours = modelmap.contour_array(h[0])
```


7000
6000
5000
4000
3000
2000
1000
0
0
1000
2000
3000
4000
5000

Post-Process Flows

MODFLOW 6 writes a binary grid file, which contains information about the model grid. MODFLOW 6 also writes a binary budget file, which contains flow information. Both of these files can be read using FloPy methods. The `MfGrdFile` class in FloPy can be used to read the binary grid file, which contains the cell connectivity (`ia` and `ja`). The `output.budget()` method in FloPy can be used to read the binary budget file written by MODFLOW 6.

[21]:
```
fname = os.path.join(workspace, f"{model_name}.dis.grb")
bgf = flopy.mf6.utils.MfGrdFile(fname)
ia, ja = bgf.ia, bgf.ja
```

[22]:
```
flowja = gwf.output.budget().get_data(text="FLOW-JA-FACE")[0].squeeze()
```

[23]:
```
# By having the ia and ja arrays and the flow-ja-face we can look at
# the flows for any cell and process them in the follow manner. Note
# layer, row, column locations are zero-based.
k = 2
i = 11
j = 2
cell_nodes = gwf.modelgrid.get_node([(k, i, j)])

for celln in cell_nodes:
    print(f"Printing flows for cell {celln}")
    for ipos in range(ia[celln] + 1, ia[celln + 1]):
        cellm = ja[ipos]
        print(f"Cell {celln} flow with cell {cellm} is {flowja[ipos]}")
```

```
Printing flows for cell 412
Cell 412 flow with cell 262 is 251.46262091207623
Cell 412 flow with cell 402 is 0.7176346498656017
Cell 412 flow with cell 411 is 439.8629968543804
Cell 412 flow with cell 413 is -693.4212447574185
Cell 412 flow with cell 422 is 1.3779378787739915
```

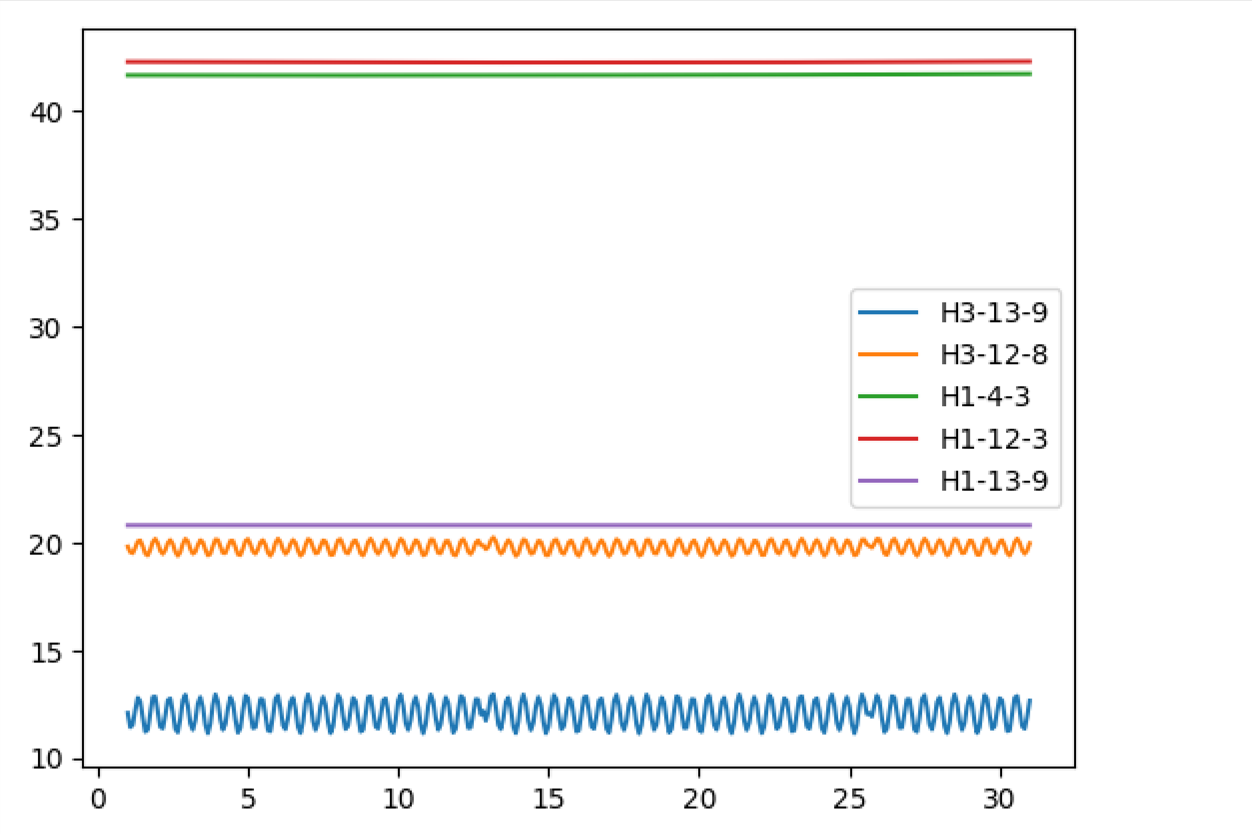
Post-Process Head Observations

MODFLOW 6 observations can be read using the `output.obs()` method in FloPy.

[24]:
```
csv = gwf.head_obs.output.obs(f="head-hydrographs.csv").get_data()

for name in csv.dtype.names[1:]:
    plt.plot(csv["totim"], csv[name], label=name)
plt.legend()
```

[24]:
```
<matplotlib.legend.Legend at 0x7f7ea65b06d0>
```




```
[25]: try:
          # ignore PermissionError on Windows
          temp_dir.cleanup()
      except:
          pass
```

6.5.2 Model splitting for parallel and serial MODFLOW 6

The model splitting functionality for MODFLOW 6 is shown in this notebook. Model splitting via the `Mf6Splitter()` class can be performed on groundwater flow models as well as combined groundwater flow and transport models. The `Mf6Splitter()` class maps a model's connectivity and then builds new models, with exchanges and movers between the new models, based on a user defined array of model numbers.

The `Mf6Splitter()` class supports Structured, Vertex, and Unstructured Grid models.

```
[1]: import os
     import sys
```

```
[2]: try:
         import flopy
     except:
         fpth = os.path.abspath(os.path.join("..", ".."))
         sys.path.append(fpth)
         import flopy
```

[3]:
```
from pathlib import Path
from tempfile import TemporaryDirectory
```

[4]:
```
import matplotlib.pyplot as plt
import numpy as np
```

[5]:
```
from flopy.mf6.utils import Mf6Splitter
from flopy.plot import styles
from flopy.utils.geometry import LineString, Polygon
```

[6]:
```
sys.path.append("../common")
from notebook_utils import geometries, string2geom
```

Example 1: splitting a simple structured grid model

This example shows the basics of using the `Mf6Splitter()` class and applies the method to the Freyberg (1988) model.

[7]:
```
simulation_ws = Path("../../examples/data/mf6-freyberg")
sim = flopy.mf6.MFSimulation.load(sim_ws=simulation_ws)
```

```
loading simulation...
  loading simulation name file...
  loading tdis package...
  loading model gwf6...
    loading package dis...
    loading package ic...
WARNING: Block "options" is not a valid block name for file type ic.
    loading package oc...
    loading package npf...
    loading package sto...
    loading package chd...
    loading package riv...
    loading package wel...
    loading package rch...
  loading solution package freyberg...
```

Create a temporary directory for this example and run the Freyberg (1988) model.

[8]:
```
temp_dir = TemporaryDirectory()
workspace = Path(temp_dir.name)
```

[9]:
```
sim.set_sim_path(workspace)
sim.write_simulation()
success, buff = sim.run_simulation(silent=True)
assert success
```

```
writing simulation...
  writing simulation name file...
  writing simulation tdis package...
  writing solution package freyberg...
  writing model freyberg...
    writing model name file...
```

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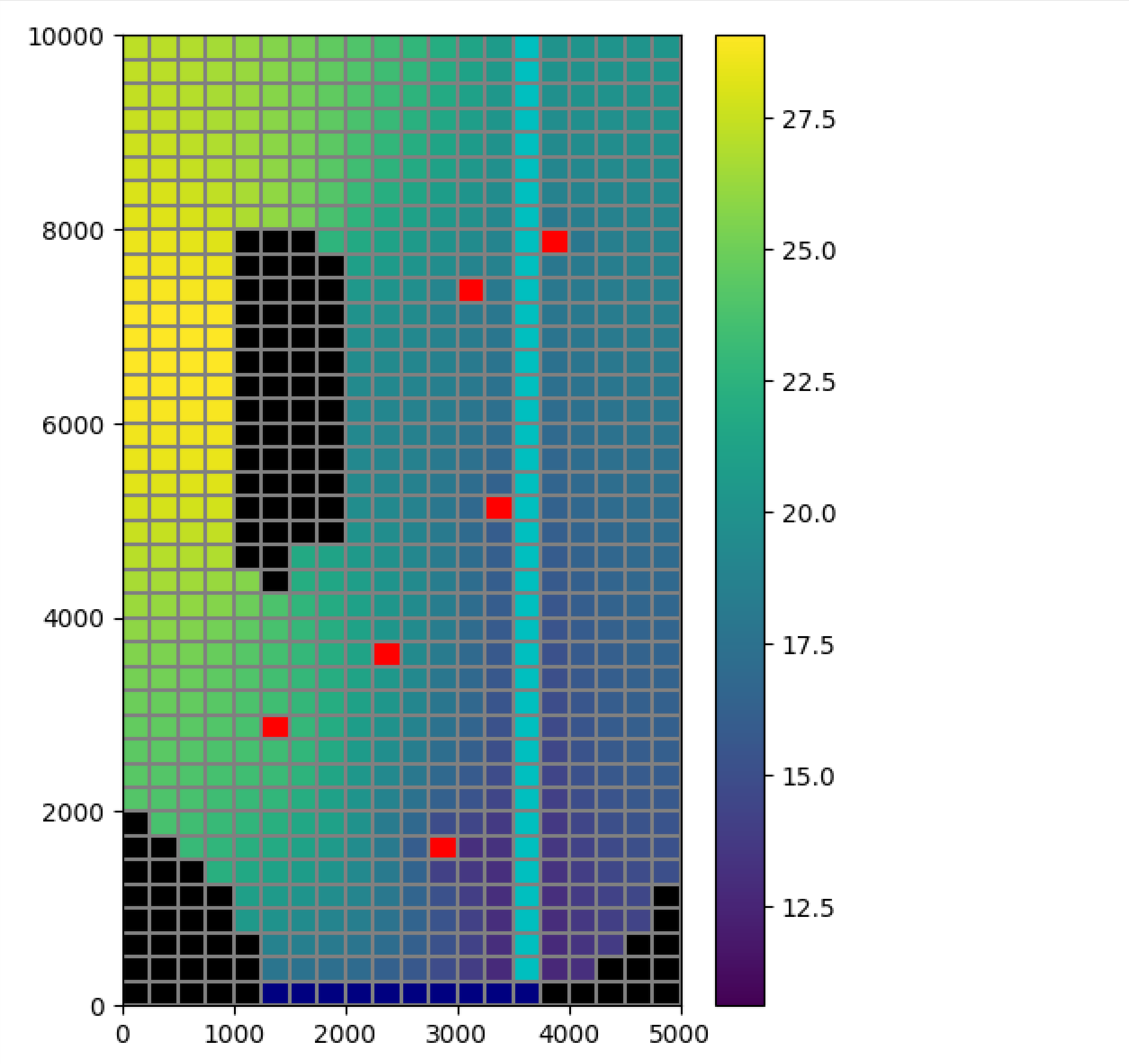
```
    writing package dis...
    writing package ic...
    writing package oc...
    writing package npf...
    writing package sto...
    writing package chd-1...
    writing package riv-1...
    writing package wel-1...
    writing package rch-1...
```

Visualize the head results and boundary conditions from this model.

[10]:
```
gwf = sim.get_model()
head = gwf.output.head().get_alldata()[-1]
```

[11]:
```
fig, ax = plt.subplots(figsize=(5, 7))
pmv = flopy.plot.PlotMapView(gwf, ax=ax)
heads = gwf.output.head().get_alldata()[-1]
heads = np.where(heads == 1e30, np.nan, heads)
vmin = np.nanmin(heads)
vmax = np.nanmax(heads)
pc = pmv.plot_array(heads, vmin=vmin, vmax=vmax)
pmv.plot_bc("WEL")
pmv.plot_bc("RIV", color="c")
pmv.plot_bc("CHD")
pmv.plot_grid()
pmv.plot_ibound()
plt.colorbar(pc)
```

[11]:
```
<matplotlib.colorbar.Colorbar at 0x7fd8a5f08580>
```



Creating an array that defines the new models

In order to split models, the model domain must be discretized using unique model numbers. Any number of models can be created, however all of the cells within each model must be contiguous.

The `Mf6Splitter()` class accept arrays that are equal in size to the number of cells per layer (`StructuredGrid` and `VertexGrid`) or the number of model nodes (`UnstructuredGrid`).

In this example, the model is split diagonally into two model domains.

[12]:
```
modelgrid = gwf.modelgrid
```

[13]:
```
array = np.ones((modelgrid.nrow, modelgrid.ncol), dtype=int)
ncol = 1
```

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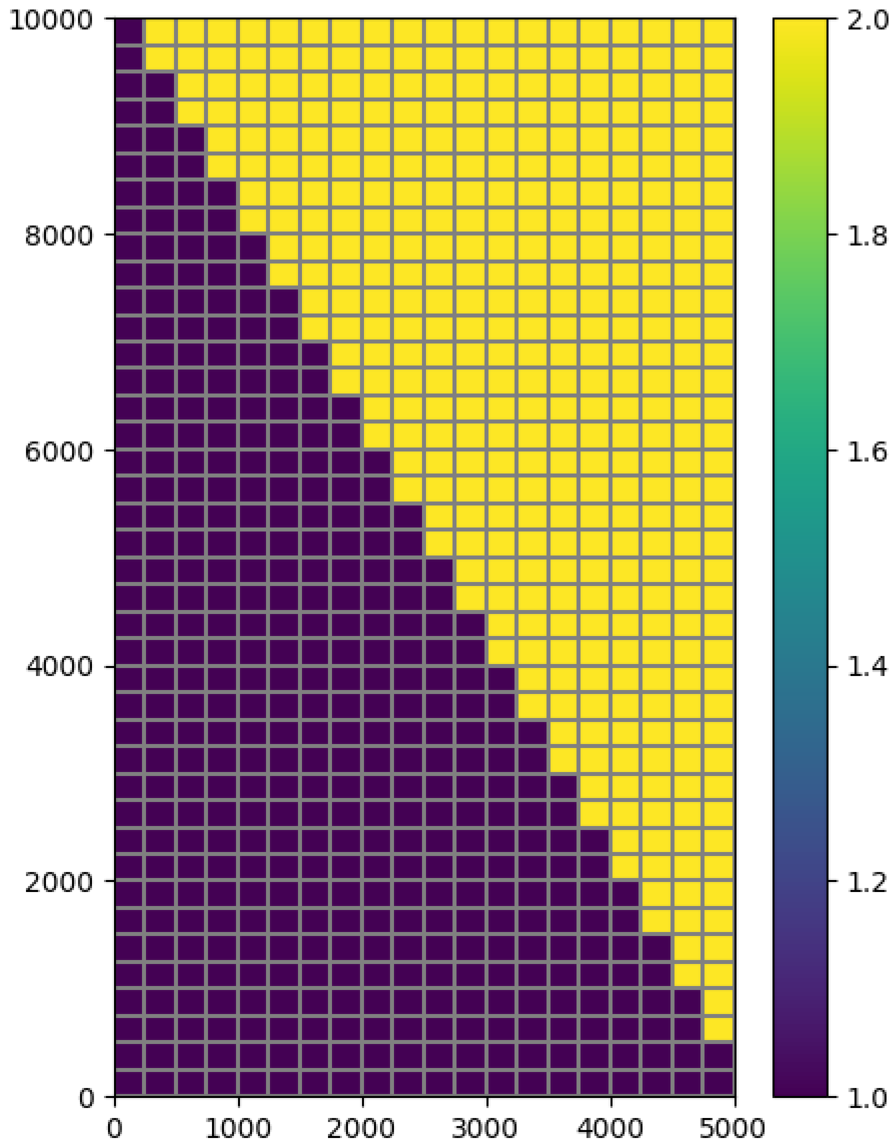
```
for row in range(modelgrid.nrow):
    if row != 0 and row % 2 == 0:
        ncol += 1
    array[row, ncol:] = 2
```

Plot the two domains that the model will be split into

[14]:
```
fig, ax = plt.subplots(figsize=(5, 7))
pmv = flopy.plot.PlotMapView(gwf, ax=ax)
pc = pmv.plot_array(array)
lc = pmv.plot_grid()
plt.colorbar(pc)
plt.show()
```



Splitting the model using `Mf6Splitter()`

The `Mf6Splitter()` class accepts one required parameter and one optional parameter. These parameters are: - `sim`: A flopy.mf6.MFSimulation object - `modelname`: optional, the name of the model being split. If omitted Mf6Splitter grabs the first groundwater flow model listed in the simulation

[15]:
```
mfsplit = Mf6Splitter(sim)
```

The model splitting is then performed by calling the `split_model()` function. `split_model()` accepts an array that is either the same size as the number of cells per layer (`StructuredGrid` and `VertexGrid`) model or the number of nodes in the model (`UnstructuredGrid`).

This function returns a new `MFSimulation` object that contains the split models and exchanges between them

[16]:
```
new_sim = mfsplit.split_model(array)
```

[17]:
```
# now to write and run the simulation
new_sim.set_sim_path(workspace / "split_model")
new_sim.write_simulation()
success, buff = new_sim.run_simulation(silent=True)
assert success
```

```
writing simulation...
  writing simulation name file...
  writing simulation tdis package...
  writing solution package ims_-1...
  writing package sim_1_2.gwfgwf...
  writing model freyberg_1...
    writing model name file...
    writing package dis...
    writing package ic...
    writing package oc...
    writing package npf...
    writing package sto...
    writing package chd-1...
    writing package riv-1...
    writing package wel-1...
    writing package rch-1...
  writing model freyberg_2...
    writing model name file...
    writing package dis...
    writing package ic...
    writing package oc...
    writing package npf...
    writing package sto...
    writing package riv-1...
    writing package wel-1...
    writing package rch-1...
```

Visualize and reassemble model output

Both models are visualized side by side

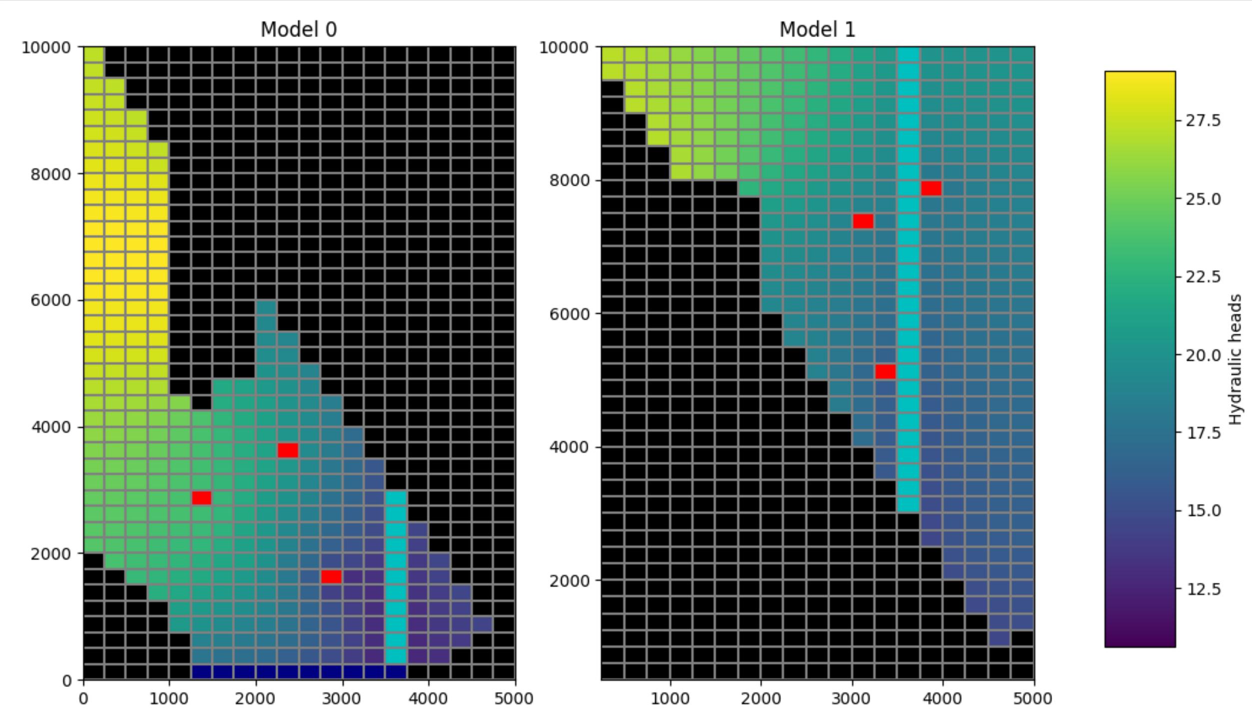
[18]:
```
# visualizing both models side by side
ml0 = new_sim.get_model("freyberg_1")
ml1 = new_sim.get_model("freyberg_2")
```

[19]:
```
heads0 = ml0.output.head().get_alldata()[-1]
heads1 = ml1.output.head().get_alldata()[-1]
```

[20]:
```
fig, (ax0, ax1) = plt.subplots(1, 2, figsize=(12, 7))
pmv = flopy.plot.PlotMapView(ml0, ax=ax0)
pmv.plot_array(heads0, vmin=vmin, vmax=vmax)
pmv.plot_ibound()
pmv.plot_grid()
pmv.plot_bc("WEL")
pmv.plot_bc("RIV", color="c")
pmv.plot_bc("CHD")
ax0.set_title("Model 0")

pmv = flopy.plot.PlotMapView(ml1, ax=ax1)
pc = pmv.plot_array(heads1, vmin=vmin, vmax=vmax)
pmv.plot_ibound()
pmv.plot_bc("WEL")
pmv.plot_bc("RIV", color="c")
pmv.plot_grid()
ax1.set_title("Model 1")

fig.subplots_adjust(right=0.8)
cbar_ax = fig.add_axes([0.85, 0.15, 0.05, 0.7])
cbar = fig.colorbar(pc, cax=cbar_ax, label="Hydraulic heads")
```



Array based model output can be assembled into the original model's shape by using the `reconstruct_array()` method

`reconstruct_array` accepts a dictionary of array data. This data is assembled as {model_number: array_from_model}.

[21]:
```
array_dict = {1: heads0, 2: heads1}
```

[22]:
```
new_head_array = mfsplit.reconstruct_array(array_dict)
```

Recarray based model inputs and outputs can also be assembled into the original model's shape by using the `reconstruct_recarray()` method

The code below demonstratess how to join the input recarrays for the WEL, RIV, and CHD package and plot them as boundary condition arrays.

[23]:
```
models = [ml0, ml1]
```

[24]:
```
pkgs = ["wel", "riv", "chd"]
d = {}
for pkg in pkgs:
    rarrays = {}
    for ix, model in enumerate(models):
        pak = model.get_package(pkg)
        try:
            rarrays[ix + 1] = pak.stress_period_data.data[0]
```

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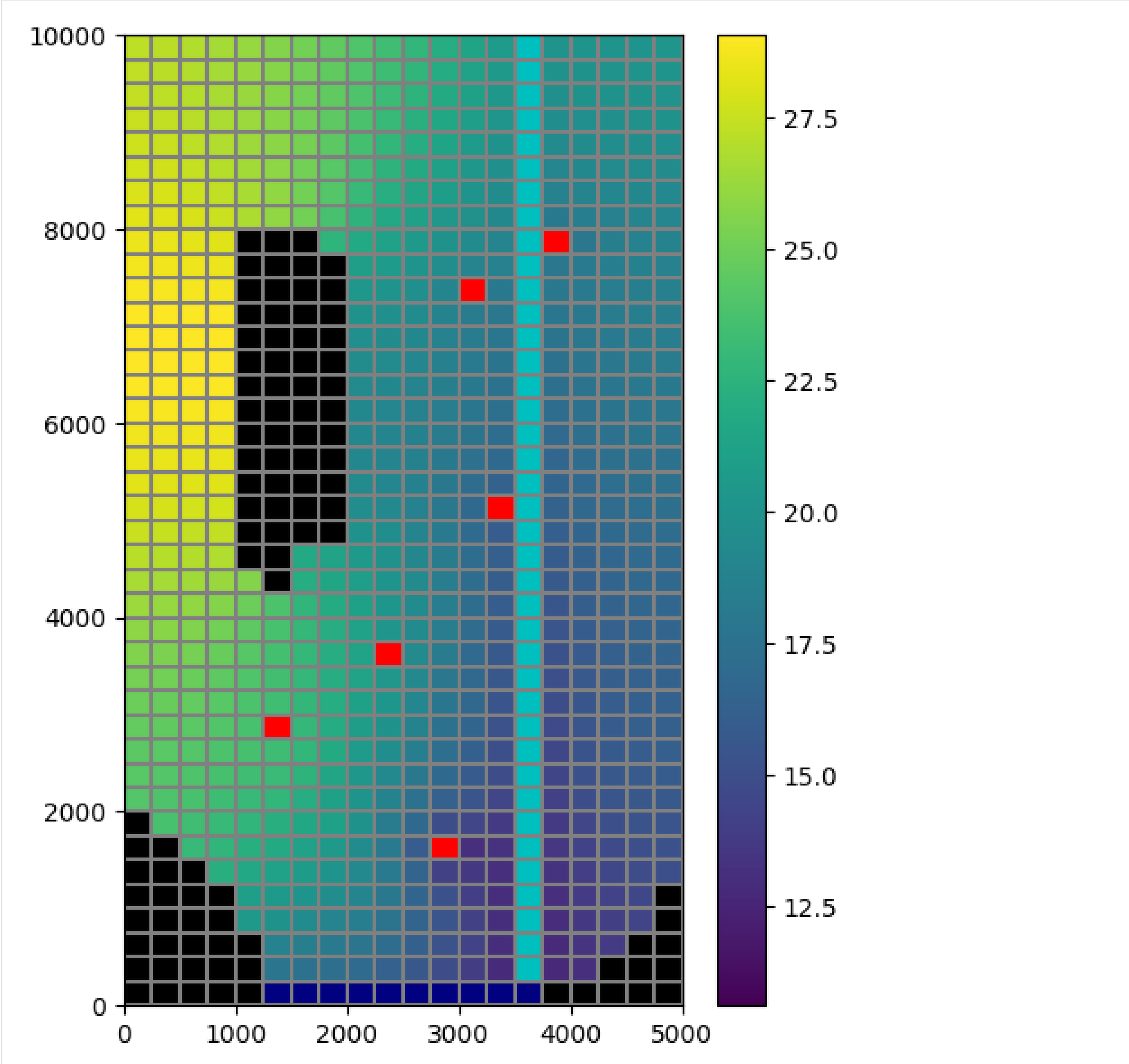
```
        except (TypeError, AttributeError):
            pass
    recarray = mfsplit.reconstruct_recarray(rarrays)
    if pkg == "riv":
        color = "c"
        bc_array, kwargs = mfsplit.recarray_bc_array(recarray, color="c")
    else:
        bc_array, kwargs = mfsplit.recarray_bc_array(recarray, pkgtype=pkg)
    d[pkg] = {"bc_array": bc_array, "kwargs": kwargs}
```

[25]:
```
fig, ax = plt.subplots(figsize=(5, 7))
pmv = flopy.plot.PlotMapView(gwf, ax=ax)
pc = pmv.plot_array(new_head_array, vmin=vmin, vmax=vmax)
pmv.plot_ibound()
pmv.plot_grid()
pmv.plot_array(d["wel"]["bc_array"], **d["wel"]["kwargs"])
pmv.plot_array(d["riv"]["bc_array"], **d["riv"]["kwargs"])
pmv.plot_array(d["chd"]["bc_array"], **d["chd"]["kwargs"])
plt.colorbar(pc)
plt.show()
```



Example 2: a more comprehensive example with the watershed model from Hughes and others 2023

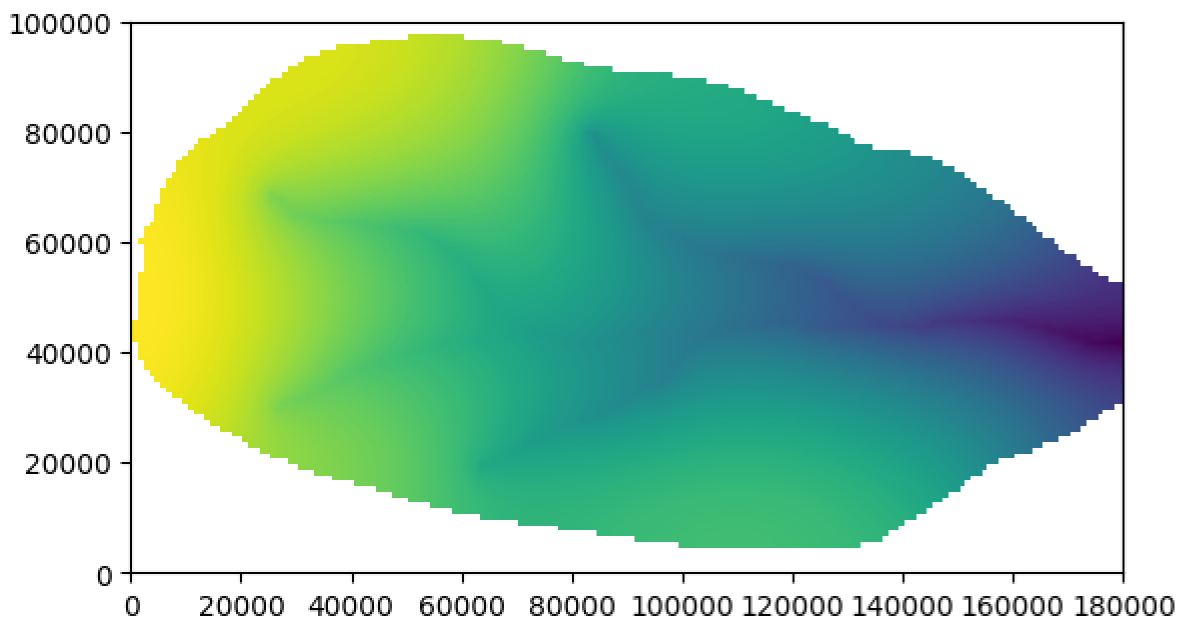
In this example, a basin model is created and is split into many models. From Hughes, Joseph D., Langevin, Christian D., Paulinski, Scott R., Larsen, Joshua D., and Brakenhoff, David, 2023, FloPy Workflows for Creating Structured and Unstructured MODFLOW Models: Groundwater, https://doi.org/10.1111/gwat.13327

Create the model

Load an ASCII raster file

[26]:
```
ascii_file = Path("../../examples/data/geospatial/fine_topo.asc")
```

[27]:
```
fine_topo = flopy.utils.Raster.load(ascii_file)
fine_topo.plot()
```



[27]:
```
<Axes: >
```

[28]:
```
Lx = 180000
Ly = 100000
extent = (0, Lx, 0, Ly)
levels = np.arange(10, 110, 10)
vmin, vmax = 0.0, 100.0
```

[29]:
```
temp_dir = TemporaryDirectory()
workspace = Path(temp_dir.name)
```

[30]:
```
boundary_polygon = string2geom(geometries["boundary"])
boundary_polygon.append(boundary_polygon[0])
bp = np.array(boundary_polygon)
```

[31]:
```
# define stream segment locations
segs = [string2geom(geometries[f"streamseg{i}"]) for i in range(1, 5)]
```

Plot the model boundary and the individual stream segments for the RIV package

[32]:
```
fig = plt.figure(figsize=(8, 8))
ax = fig.add_subplot()
```

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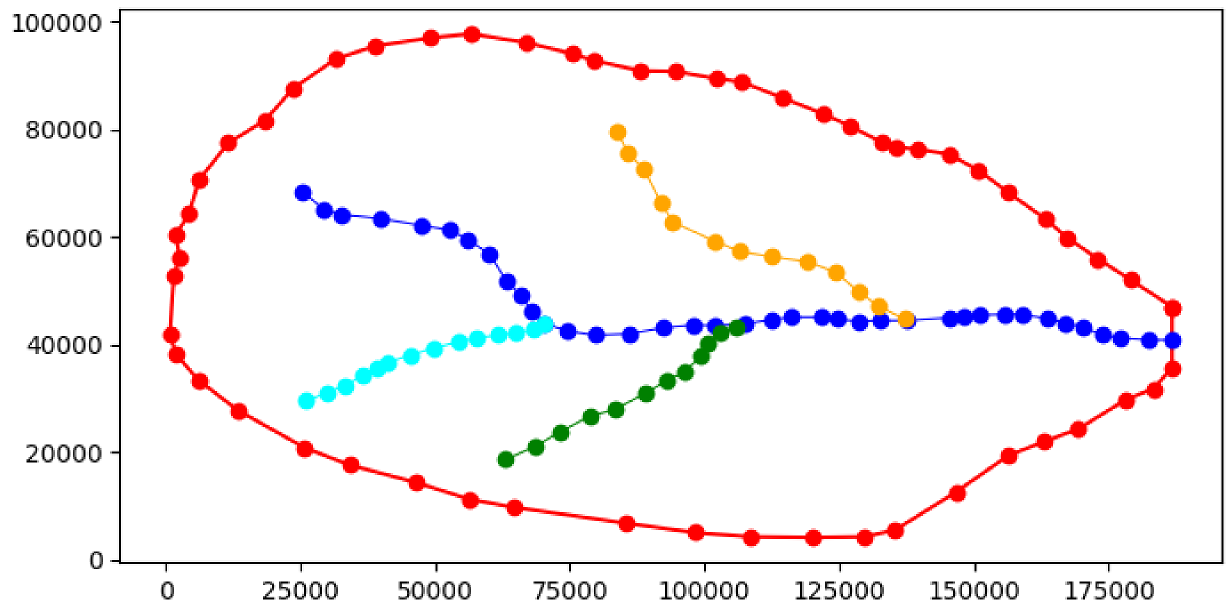
```
ax.set_aspect("equal")
riv_colors = ("blue", "cyan", "green", "orange", "red")
ax.plot(bp[:, 0], bp[:, 1], "ro-")
for idx, seg in enumerate(segs):
    sa = np.array(seg)
    ax.plot(sa[:, 0], sa[:, 1], color=riv_colors[idx], lw=0.75, marker="o")
```



Create a MODFLOW model grid

[33]:
```
dx = dy = 5000
dv0 = 5.0
nlay = 1
nrow = int(Ly / dy) + 1
ncol = int(Lx / dx) + 1
delr = np.array(ncol * [dx])
delc = np.array(nrow * [dy])
top = np.ones((nrow, ncol)) * 1000.0
botm = np.ones((nlay, nrow, ncol)) * -100.0
modelgrid = flopy.discretization.StructuredGrid(
    nlay=nlay, delr=delr, delc=delc, xoff=0, yoff=0, top=top, botm=botm
)
```

Crop the raster, resample it for the top elevation, and create an ibound array

[34]:
```
new_top = fine_topo.resample_to_grid(
    modelgrid, band=fine_topo.bands[0], method="min", extrapolate_edges=True
)
```

[35]:
```
# calculate and set idomain
ix = flopy.utils.GridIntersect(modelgrid, method="vertex", rtree=True)
result = ix.intersect(Polygon(boundary_polygon))
idxs = tuple(zip(*result.cellids))
```

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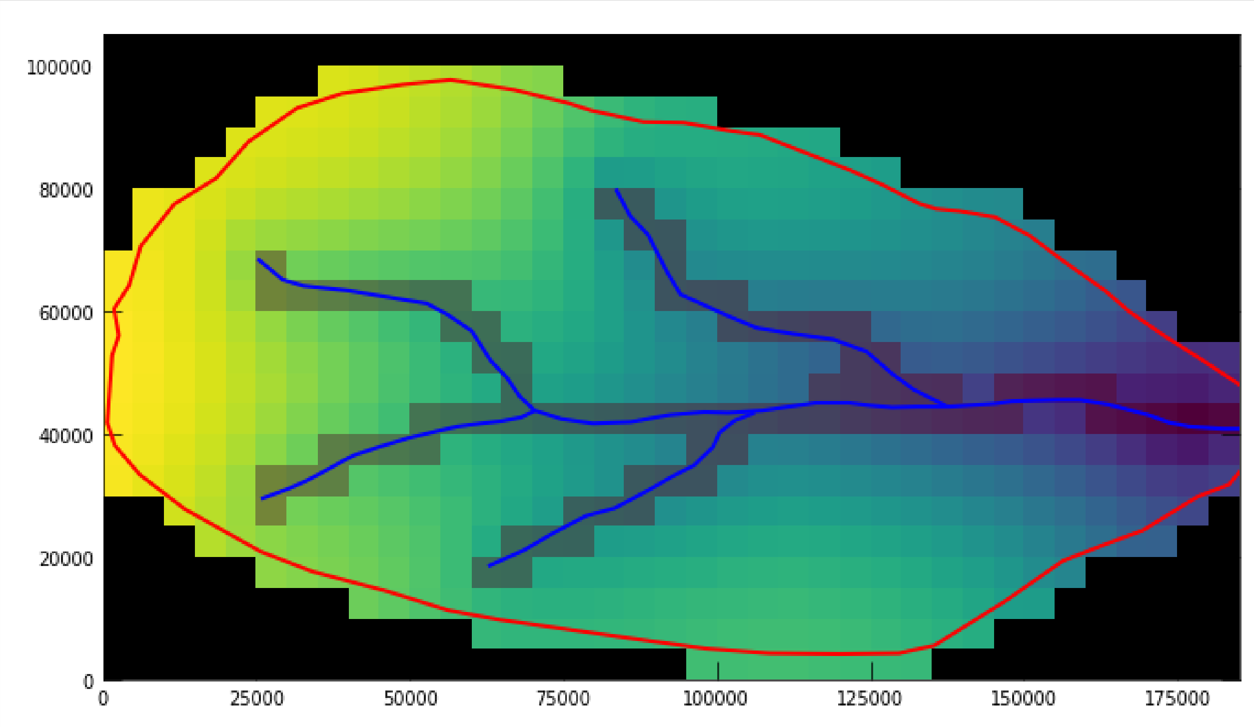
```
idomain = np.zeros((nrow, ncol), dtype=int)
idomain[idxs] = 1
```

[36]:
```
# set this idomain and top to the modelgrid
modelgrid._idomain = idomain
modelgrid._top = new_top
```

Intersect the stream segments with the modelgrid

[37]:
```
ixs = flopy.utils.GridIntersect(modelgrid, method="structured")
cellids = []
for seg in segs:
    v = ixs.intersect(LineString(seg), sort_by_cellid=True)
    cellids += v["cellids"].tolist()
intersection_rg = np.zeros(modelgrid.shape[1:])
for loc in cellids:
    intersection_rg[loc] = 1
```

[38]:
```
with styles.USGSMap():
    fig, ax = plt.subplots(figsize=(8, 8))
    pmv = flopy.plot.PlotMapView(modelgrid=modelgrid)
    ax.set_aspect("equal")
    pmv.plot_array(modelgrid.top)
    pmv.plot_array(
        intersection_rg,
        masked_values=[
            0,
        ],
        alpha=0.2,
        cmap="Reds_r",
    )
    pmv.plot_inactive()
    ax.plot(bp[:, 0], bp[:, 1], "r-")
    for seg in segs:
        sa = np.array(seg)
        ax.plot(sa[:, 0], sa[:, 1], "b-")
```



Calculate drain conductance, set simulation options, and begin building model arrays

[39]:
```
# Set number of model layers to 2
nlay = 2
```

[40]:
```
# intersect stream segs to simulate as drains
ixs = flopy.utils.GridIntersect(modelgrid, method="structured")
drn_cellids = []
drn_lengths = []
for seg in segs:
    v = ixs.intersect(LineString(seg), sort_by_cellid=True)
    drn_cellids += v["cellids"].tolist()
    drn_lengths += v["lengths"].tolist()
```

[41]:
```
leakance = 1.0 / (0.5 * dv0)  # kv / b
drn_data = []
for (r, c), length in zip(drn_cellids, drn_lengths):
    x = modelgrid.xcellcenters[r, c]
    width = 5.0 + (14.0 / Lx) * (Lx - x)
    conductance = leakance * length * width
    drn_data.append((0, r, c, modelgrid.top[r, c], conductance))
drn_data[:10]
```

[41]:
```
[(0, 12, 36, 3.6404473781585693, 9622.185546471488),
 (0, 12, 35, 1.111111044883728, 10478.844160380193),
 (0, 12, 34, 3.8888888359069824, 11731.97414523631),
 (0, 12, 33, 6.666666507720947, 12346.648887868123),
 (0, 12, 32, 9.44444465637207, 6006.996161832478),
 (0, 11, 32, 10.555556297302246, 6942.175535223257),
```

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```
 (0, 11, 31, 12.222222328186035, 13534.73438485134),
 (0, 11, 30, 15.0, 14284.510735821312),
 (0, 11, 29, 17.77777862548828, 13441.64541297737),
 (0, 12, 29, 20.0, 1699.7820641189026)]
```

[42]:

```
# groundwater discharge to surface
idomain = modelgrid.idomain.copy()
index = tuple(zip(*drn_cellids))
idomain[index] = -1

gw_discharge_data = []
for r in range(nrow):
    for c in range(ncol):
        if idomain[r, c] < 1:
            continue
        conductance = leakance * dx * dy
        gw_discharge_data.append(
            (0, r, c, modelgrid.top[r, c] - 0.5, conductance, 1.0)
        )
gw_discharge_data[:10]
```

[42]:

```
[(0, 1, 7, 99.99099731445312, 10000000.0, 1.0),
 (0, 1, 8, 98.9864730834961, 10000000.0, 1.0),
 (0, 1, 9, 97.68162536621094, 10000000.0, 1.0),
 (0, 1, 10, 96.02616882324219, 10000000.0, 1.0),
 (0, 1, 11, 93.93696594238281, 10000000.0, 1.0),
 (0, 1, 12, 91.06060028076172, 10000000.0, 1.0),
 (0, 1, 13, 87.65284729003906, 10000000.0, 1.0),
 (0, 1, 14, 86.53125, 10000000.0, 1.0),
 (0, 2, 5, 100.72657012939453, 10000000.0, 1.0),
 (0, 2, 6, 100.33457946777344, 10000000.0, 1.0)]
```

[43]:

```
botm = np.zeros((nlay, nrow, ncol))
botm[0] = modelgrid.top - dv0
for ix in range(1, nlay):
    dv0 *= 1.5
    botm[ix] = botm[ix - 1] - dv0
```

[44]:

```
idomain = np.zeros((nlay, nrow, ncol), dtype=int)
idomain[:] = modelgrid.idomain

strt = np.zeros((nlay, nrow, ncol))
strt[:] = modelgrid.top
```

Create the watershed model using Flopy

[45]:

```
temp_dir = TemporaryDirectory()
workspace = Path(temp_dir.name) / "basin"
```

[46]:

```
sim = flopy.mf6.MFSimulation(
    sim_name="basin",
    sim_ws=workspace,
```

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```
    exe_name="mf6",
)

tdis = flopy.mf6.ModflowTdis(sim)
ims = flopy.mf6.ModflowIms(
    sim,
    complexity="simple",
    print_option="SUMMARY",
    linear_acceleration="bicgstab",
    outer_maximum=1000,
    inner_maximum=100,
    outer_dvclose=1e-5,
    inner_dvclose=1e-6,
)
gwf = flopy.mf6.ModflowGwf(
    sim,
    save_flows=True,
    newtonoptions="NEWTON UNDER_RELAXATION",
)

dis = flopy.mf6.ModflowGwfdis(
    gwf,
    nlay=nlay,
    nrow=nrow,
    ncol=ncol,
    delr=dx,
    delc=dy,
    idomain=idomain,
    top=modelgrid.top,
    botm=botm,
    xorigin=0.0,
    yorigin=0.0,
)

ic = flopy.mf6.ModflowGwfic(gwf, strt=strt)
npf = flopy.mf6.ModflowGwfnpf(
    gwf,
    save_specific_discharge=True,
    icelltype=1,
    k=1.0,
)
sto = flopy.mf6.ModflowGwfsto(
    gwf,
    iconvert=1,
    ss=1e-5,
    sy=0.2,
    steady_state=True,
)
rch = flopy.mf6.ModflowGwfrcha(
    gwf,
    recharge=0.000001,
)
```

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```
drn = flopy.mf6.ModflowGwfdrn(
    gwf,
    stress_period_data=drn_data,
    pname="river",
)
drn_gwd = flopy.mf6.ModflowGwfdrn(
    gwf,
    auxiliary=["depth"],
    auxdepthname="depth",
    stress_period_data=gw_discharge_data,
    pname="gwd",
)
oc = flopy.mf6.ModflowGwfoc(
    gwf,
    head_filerecord=f"{gwf.name}.hds",
    budget_filerecord=f"{gwf.name}.cbc",
    saverecord=[("HEAD", "ALL"), ("BUDGET", "ALL")],
    printrecord=[("BUDGET", "ALL")],
)
```

[47]:
```
sim.write_simulation()
success, buff = sim.run_simulation(silent=True)
assert success
```

```
writing simulation...
  writing simulation name file...
  writing simulation tdis package...
  writing solution package ims_-1...
  writing model model...
    writing model name file...
    writing package dis...
    writing package ic...
    writing package npf...
    writing package sto...
    writing package rcha_0...
    writing package river...
INFORMATION: maxbound in ('gwf6', 'drn', 'dimensions') changed to 88 based on size of␣
↪stress_period_data
    writing package gwd...
INFORMATION: maxbound in ('gwf6', 'drn', 'dimensions') changed to 470 based on size of␣
↪stress_period_data
    writing package oc...
```

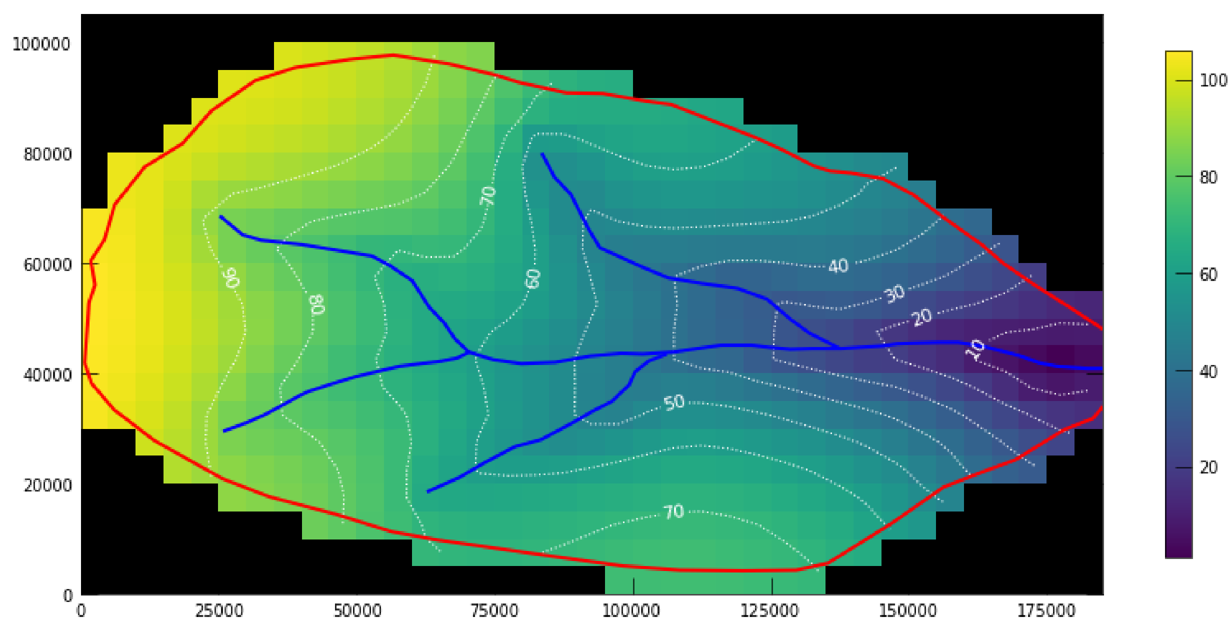
Plot the model results

[48]:
```
water_table = flopy.utils.postprocessing.get_water_table(
    gwf.output.head().get_data()
)
heads = gwf.output.head().get_data()
hmin, hmax = water_table.min(), water_table.max()
contours = np.arange(0, 100, 10)
hmin, hmax
```

[48]:
```
(1.1351828297118696, 105.96803703036794)
```

[49]:
```
with styles.USGSMap():
    fig = plt.figure(figsize=(10, 8))
    ax = fig.add_subplot()
    ax.set_xlim(0, Lx)
    ax.set_ylim(0, Ly)
    ax.set_aspect("equal")
    pmv = flopy.plot.PlotMapView(modelgrid=gwf.modelgrid, ax=ax)
    h = pmv.plot_array(heads, vmin=hmin, vmax=hmax)
    c = pmv.contour_array(
        water_table,
        levels=contours,
        colors="white",
        linewidths=0.75,
        linestyles=":",
    )
    plt.clabel(c, fontsize=8)
    pmv.plot_inactive()
    plt.colorbar(h, ax=ax, shrink=0.5)

    ax.plot(bp[:, 0], bp[:, 1], "r-")
    for seg in segs:
        sa = np.array(seg)
        ax.plot(sa[:, 0], sa[:, 1], "b-")
```



Split the watershed model

Build a splitting array and split this model into many models for parallel modflow runs

[50]:
```
nrow_blocks, ncol_blocks = 2, 4
row_inc, col_inc = int(nrow / nrow_blocks), int(ncol / ncol_blocks)
row_inc, col_inc
```

[50]:
```
(10, 9)
```

[51]:
```
icnt = 0
row_blocks = [icnt]
for i in range(nrow_blocks):
    icnt += row_inc
    row_blocks.append(icnt)
if row_blocks[-1] < nrow:
    row_blocks[-1] = nrow
row_blocks
```

[51]:
```
[0, 10, 21]
```

[52]:
```
icnt = 0
col_blocks = [icnt]
for i in range(ncol_blocks):
    icnt += col_inc
    col_blocks.append(icnt)
if col_blocks[-1] < ncol:
    col_blocks[-1] = ncol
col_blocks
```

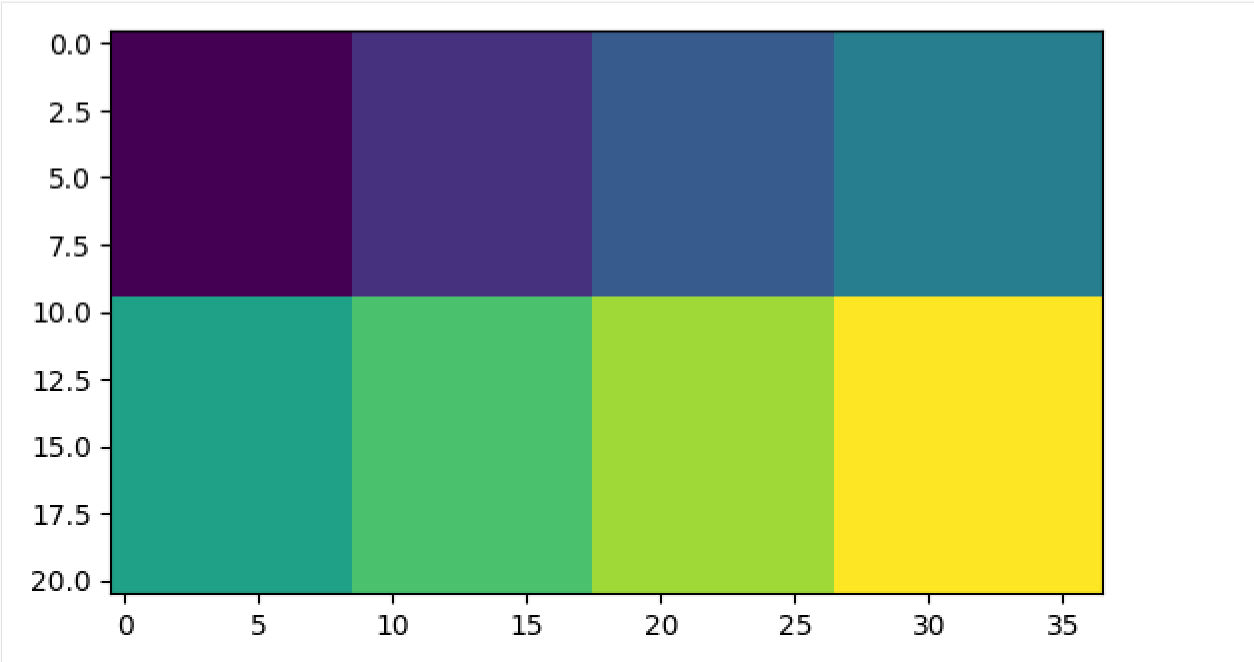
[52]:
```
[0, 9, 18, 27, 37]
```

[53]:
```
mask = np.zeros((nrow, ncol), dtype=int)
```

[54]:
```
# create masking array
ival = 1
model_row_col_offset = {}
for idx in range(len(row_blocks) - 1):
    for jdx in range(len(col_blocks) - 1):
        mask[
            row_blocks[idx] : row_blocks[idx + 1],
            col_blocks[jdx] : col_blocks[jdx + 1],
        ] = ival
        model_row_col_offset[ival - 1] = (row_blocks[idx], col_blocks[jdx])
        # increment model number
        ival += 1
```

[55]:
```
plt.imshow(mask)
```

[55]:
```
<matplotlib.image.AxesImage at 0x7fd88a03e1c0>
```



Now split the model into many models using `Mf6Splitter()`

[56]:
```
mfsplit = Mf6Splitter(sim)
new_sim = mfsplit.split_model(mask)
```

[57]:
```
new_ws = workspace / "split_models"
new_sim.set_sim_path(new_ws)
new_sim.write_simulation()
success, buff = new_sim.run_simulation(silent=True)
assert success
```

```
writing simulation...
  writing simulation name file...
  writing simulation tdis package...
  writing solution package ims_-1...
  writing package sim_1_2.gwfgwf...
  writing package sim_1_5.gwfgwf...
  writing package sim_2_3.gwfgwf...
  writing package sim_2_6.gwfgwf...
  writing package sim_3_4.gwfgwf...
  writing package sim_3_7.gwfgwf...
  writing package sim_4_8.gwfgwf...
  writing package sim_5_6.gwfgwf...
  writing package sim_6_7.gwfgwf...
  writing package sim_7_8.gwfgwf...
  writing model model_1...
    writing model name file...
    writing package dis...
    writing package ic...
    writing package npf...
```

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```
    writing package sto...
    writing package rcha_0...
    writing package river...
    writing package gwd...
    writing package oc...
  writing model model_2...
    writing model name file...
    writing package dis...
    writing package ic...
    writing package npf...
    writing package sto...
    writing package rcha_0...
    writing package river...
    writing package gwd...
    writing package oc...
  writing model model_3...
    writing model name file...
    writing package dis...
    writing package ic...
    writing package npf...
    writing package sto...
    writing package rcha_0...
    writing package river...
    writing package gwd...
    writing package oc...
  writing model model_4...
    writing model name file...
    writing package dis...
    writing package ic...
    writing package npf...
    writing package sto...
    writing package rcha_0...
    writing package gwd...
    writing package oc...
  writing model model_5...
    writing model name file...
    writing package dis...
    writing package ic...
    writing package npf...
    writing package sto...
    writing package rcha_0...
    writing package river...
    writing package gwd...
    writing package oc...
  writing model model_6...
    writing model name file...
    writing package dis...
    writing package ic...
    writing package npf...
    writing package sto...
    writing package rcha_0...
    writing package river...
```

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```
    writing package gwd...
    writing package oc...
  writing model model_7...
    writing model name file...
    writing package dis...
    writing package ic...
    writing package npf...
    writing package sto...
    writing package rcha_0...
    writing package river...
    writing package gwd...
    writing package oc...
  writing model model_8...
    writing model name file...
    writing package dis...
    writing package ic...
    writing package npf...
    writing package sto...
    writing package rcha_0...
    writing package river...
    writing package gwd...
    writing package oc...
```

Reassemble the heads to the original model shape for plotting

Create a dictionary of model number : heads and use the `reconstruct_array()` method to get a numpy array that is the original shape of the unsplit model.

[58]:
```
model_names = list(new_sim.model_names)
head_dict = {}
for modelname in model_names:
    mnum = int(modelname.split("_")[-1])
    head = new_sim.get_model(modelname).output.head().get_alldata()[-1]
    head_dict[mnum] = head
```

[59]:
```
ra_heads = mfsplit.reconstruct_array(head_dict)
ra_watertable = flopy.utils.postprocessing.get_water_table(ra_heads)
```

[60]:
```
with styles.USGSMap():
    fig, axs = plt.subplots(nrows=3, figsize=(8, 12))
    diff = ra_heads - heads
    hv = [ra_heads, heads, diff]
    titles = ["Multiple models", "Single model", "Multiple - single"]
    for idx, ax in enumerate(axs):
        ax.set_aspect("equal")
        ax.set_title(titles[idx])

        if idx < 2:
            levels = contours
            vmin = hmin
```

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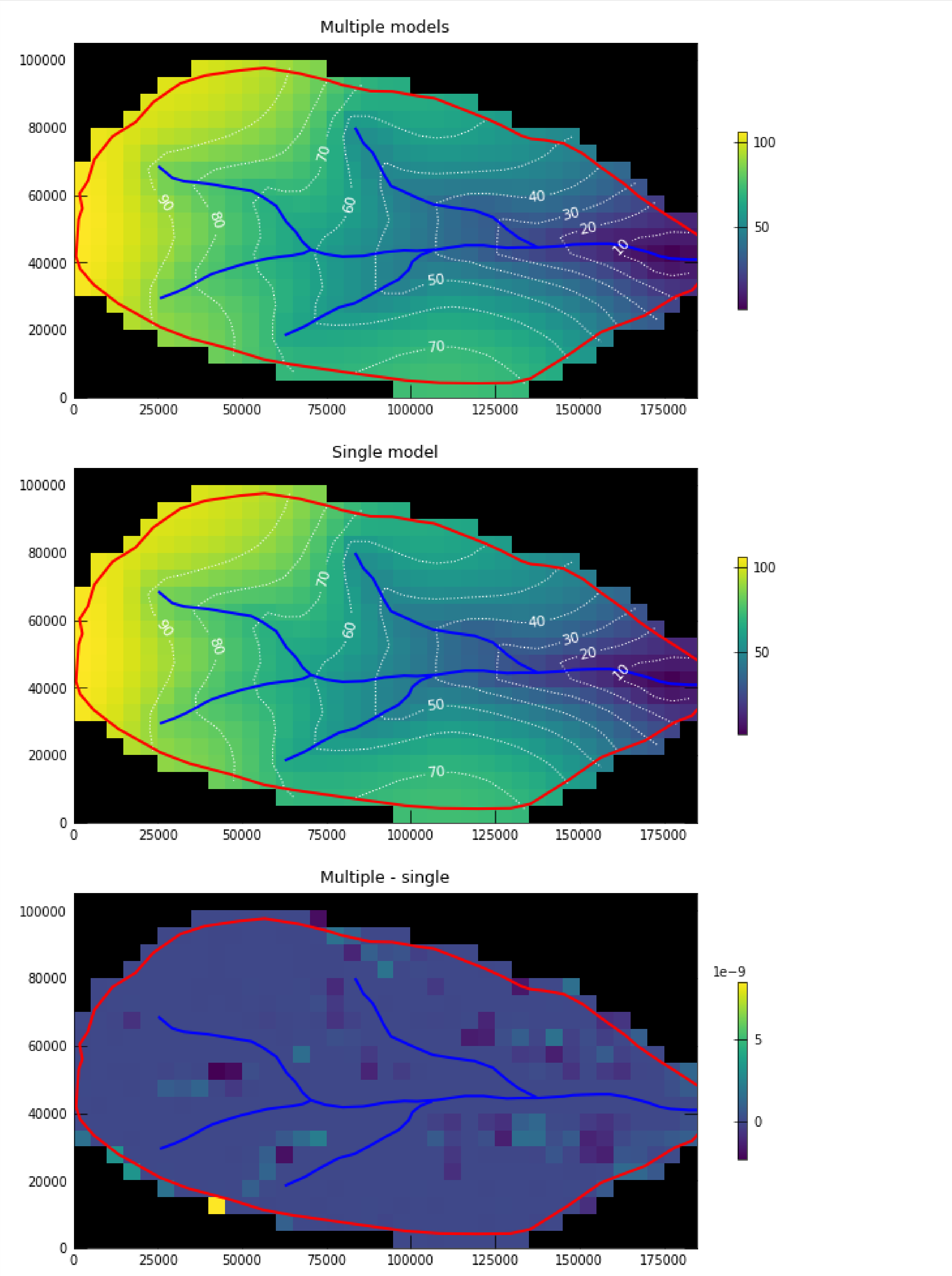
```
            vmax = hmax
        else:
            levels = None
            vmin = None
            vmax = None

        pmv = flopy.plot.PlotMapView(modelgrid=gwf.modelgrid, ax=ax, layer=0)
        h = pmv.plot_array(hv[idx], vmin=vmin, vmax=vmax)
        if levels is not None:
            c = pmv.contour_array(
                hv[idx],
                levels=levels,
                colors="white",
                linewidths=0.75,
                linestyles=":",
            )
            plt.clabel(c, fontsize=8)
        pmv.plot_inactive()
        plt.colorbar(h, ax=ax, shrink=0.5)

        ax.plot(bp[:, 0], bp[:, 1], "r-")
        for seg in segs:
            sa = np.array(seg)
            ax.plot(sa[:, 0], sa[:, 1], "b-")
```


Multiple models
Single model
Multiple - single
100000
80000
60000
40000
20000
0
25000
50000
75000
100000
125000
150000
175000
90
80
70
60
50
40
30
20
10
100
50
1e−9
5
0

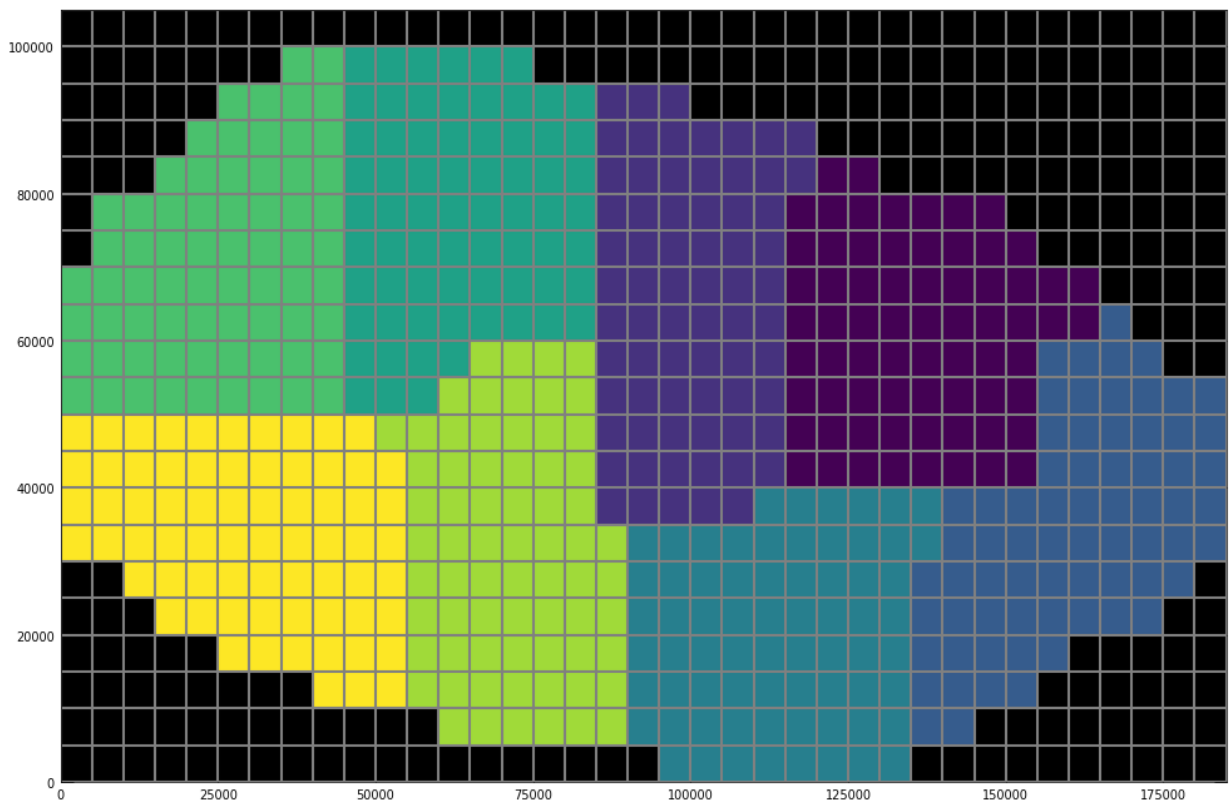
Example 3: create an optimized splitting mask for a model

In the previous examples, the watershed model splitting mask was defined by the user. `Mf6Splitter` also has a method called `optimize_splitting_mask` that creates a mask based on the number of models the user would like to generate.

The `optimize_splitting_mask()` method generates a vertex weighted adjacency graph, based on the number active and inactive nodes in all layers of the model. This adjacency graph is then provided to `pymetis` which does the work for us and returns a membership array for each node.

[61]:
```python
# Split the watershed model into many models
mfsplit = Mf6Splitter(sim)
split_array = mfsplit.optimize_splitting_mask(nparts=8)

with styles.USGSMap():
    fig, ax = plt.subplots(figsize=(12, 8))
    pmv = flopy.plot.PlotMapView(gwf, ax=ax)
    pmv.plot_array(split_array)
    pmv.plot_inactive()
    pmv.plot_grid()
```



[62]:
```python
new_sim = mfsplit.split_model(split_array)

temp_dir = TemporaryDirectory()
workspace = Path("temp")

new_ws = workspace / "opt_split_models"
new_sim.set_sim_path(new_ws)
```

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```
new_sim.write_simulation()
success, buff = new_sim.run_simulation(silent=True)
assert success
```

```
writing simulation...
  writing simulation name file...
  writing simulation tdis package...
  writing solution package ims_-1...
  writing package sim_0_1.gwfgwf...
  writing package sim_0_2.gwfgwf...
  writing package sim_0_3.gwfgwf...
  writing package sim_1_3.gwfgwf...
  writing package sim_1_4.gwfgwf...
  writing package sim_1_6.gwfgwf...
  writing package sim_2_3.gwfgwf...
  writing package sim_3_6.gwfgwf...
  writing package sim_4_5.gwfgwf...
  writing package sim_4_6.gwfgwf...
  writing package sim_4_7.gwfgwf...
  writing package sim_5_7.gwfgwf...
  writing package sim_6_7.gwfgwf...
  writing model model_0...
    writing model name file...
    writing package dis...
    writing package ic...
    writing package npf...
    writing package sto...
    writing package rcha_0...
    writing package river...
    writing package gwd...
    writing package oc...
  writing model model_1...
    writing model name file...
    writing package dis...
    writing package ic...
    writing package npf...
    writing package sto...
    writing package rcha_0...
    writing package river...
    writing package gwd...
    writing package oc...
  writing model model_2...
    writing model name file...
    writing package dis...
    writing package ic...
    writing package npf...
    writing package sto...
    writing package rcha_0...
    writing package river...
    writing package gwd...
    writing package oc...
  writing model model_3...
```

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```
    writing model name file...
    writing package dis...
    writing package ic...
    writing package npf...
    writing package sto...
    writing package rcha_0...
    writing package river...
    writing package gwd...
    writing package oc...
  writing model model_4...
    writing model name file...
    writing package dis...
    writing package ic...
    writing package npf...
    writing package sto...
    writing package rcha_0...
    writing package river...
    writing package gwd...
    writing package oc...
  writing model model_5...
    writing model name file...
    writing package dis...
    writing package ic...
    writing package npf...
    writing package sto...
    writing package rcha_0...
    writing package river...
    writing package gwd...
    writing package oc...
  writing model model_6...
    writing model name file...
    writing package dis...
    writing package ic...
    writing package npf...
    writing package sto...
    writing package rcha_0...
    writing package river...
    writing package gwd...
    writing package oc...
  writing model model_7...
    writing model name file...
    writing package dis...
    writing package ic...
    writing package npf...
    writing package sto...
    writing package rcha_0...
    writing package river...
    writing package gwd...
    writing package oc...
```

Reassemble the heads and plot results

[63]:
```
model_names = list(new_sim.model_names)
head_dict = {}
for modelname in model_names:
    mnum = int(modelname.split("_")[-1])
    head = new_sim.get_model(modelname).output.head().get_alldata()[-1]
    head_dict[mnum] = head
```

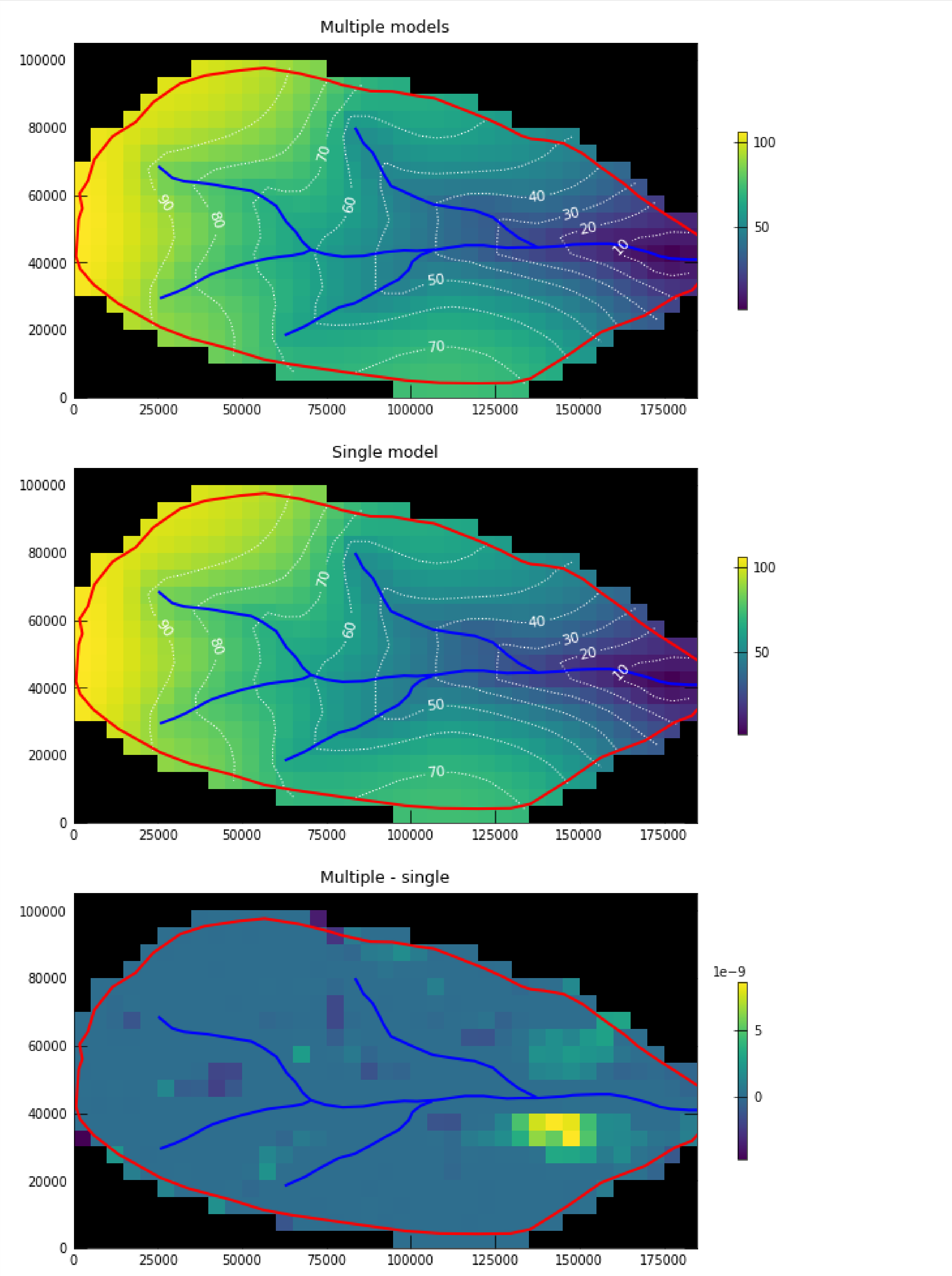
[64]:
```
ra_heads = mfsplit.reconstruct_array(head_dict)
ra_watertable = flopy.utils.postprocessing.get_water_table(ra_heads)
```

[65]:
```
with styles.USGSMap():
    fig, axs = plt.subplots(nrows=3, figsize=(8, 12))
    diff = ra_heads - heads
    hv = [ra_heads, heads, diff]
    titles = ["Multiple models", "Single model", "Multiple - single"]
    for idx, ax in enumerate(axs):
        ax.set_aspect("equal")
        ax.set_title(titles[idx])

        if idx < 2:
            levels = contours
            vmin = hmin
            vmax = hmax
        else:
            levels = None
            vmin = None
            vmax = None

        pmv = flopy.plot.PlotMapView(modelgrid=gwf.modelgrid, ax=ax, layer=0)
        h = pmv.plot_array(hv[idx], vmin=vmin, vmax=vmax)
        if levels is not None:
            c = pmv.contour_array(
                hv[idx],
                levels=levels,
                colors="white",
                linewidths=0.75,
                linestyles=":",
            )
            plt.clabel(c, fontsize=8)
        pmv.plot_inactive()
        plt.colorbar(h, ax=ax, shrink=0.5)

        ax.plot(bp[:, 0], bp[:, 1], "r-")
        for seg in segs:
            sa = np.array(seg)
            ax.plot(sa[:, 0], sa[:, 1], "b-")
```


Multiple models
Single model
Multiple - single
1e−9

6.5.3 Creating a Simple MODFLOW 6 Model with Flopy

The purpose of this notebook is to demonstrate the Flopy capabilities for building a simple MODFLOW 6 model from scratch, running the model, and viewing the results. This notebook will demonstrate the capabilities using a simple lake example. A separate notebook is also available in which the same lake example is created for MODFLOW-2005 (flopy3_lake_example.ipynb).

Setup the Notebook Environment

[1]:
```
import os
```

[2]:
```
import sys
from tempfile import TemporaryDirectory

import matplotlib as mpl
import matplotlib.pyplot as plt
import numpy as np

# run installed version of flopy or add local path
try:
    import flopy
except:
    fpth = os.path.abspath(os.path.join("..", ".."))
    sys.path.append(fpth)
    import flopy

print(sys.version)
print(f"numpy version: {np.__version__}")
print(f"matplotlib version: {mpl.__version__}")
print(f"flopy version: {flopy.__version__}")
```

```
3.8.18 (default, Aug 28 2023, 08:27:22)
[GCC 11.4.0]
numpy version: 1.24.4
matplotlib version: 3.7.4
flopy version: 3.5.0
```

[3]:
```
# For this example, we will set up a temporary workspace.
# Model input files and output files will reside here.
temp_dir = TemporaryDirectory()
workspace = os.path.join(temp_dir.name, "mf6lake")
```

Create the Flopy Model Objects

We are creating a square model with a specified head equal to `h1` along all boundaries. The head at the cell in the center in the top layer is fixed to `h2`. First, set the name of the model and the parameters of the model: the number of layers `Nlay`, the number of rows and columns `N`, lengths of the sides of the model `L`, aquifer thickness `H`, hydraulic conductivity `k`

[4]:
```
name = "mf6lake"
h1 = 100
```

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```
h2 = 90
Nlay = 10
N = 101
L = 400.0
H = 50.0
k = 1.0
```

One big difference between MODFLOW 6 and previous MODFLOW versions is that MODFLOW 6 is based on the concept of a simulation. A simulation consists of the following:

- Temporal discretization (TDIS)
- One or more models (GWF is the only model supported at present)
- Zero or more exchanges (instructions for how models are coupled)
- Solutions

For this simple lake example, the simulation consists of the temporal discretization (TDIS) package (TDIS), a groundwater flow (GWF) model, and an iterative model solution (IMS), which controls how the GWF model is solved.

[5]:
```
# Create the Flopy simulation object
sim = flopy.mf6.MFSimulation(
    sim_name=name, exe_name="mf6", version="mf6", sim_ws=workspace
)

# Create the Flopy temporal discretization object
tdis = flopy.mf6.modflow.mftdis.ModflowTdis(
    sim, pname="tdis", time_units="DAYS", nper=1, perioddata=[(1.0, 1, 1.0)]
)

# Create the Flopy groundwater flow (gwf) model object
model_nam_file = f"{name}.nam"
gwf = flopy.mf6.ModflowGwf(sim, modelname=name, model_nam_file=model_nam_file)

# Create the Flopy iterative model solver (ims) Package object
ims = flopy.mf6.modflow.mfims.ModflowIms(sim, pname="ims", complexity="SIMPLE")
```

Now that the overall simulation is set up, we can focus on building the groundwater flow model. The groundwater flow model will be built by adding packages to it that describe the model characteristics.

Define the discretization of the model. All layers are given equal thickness. The `bot` array is build from `H` and the `Nlay` values to indicate top and bottom of each layer, and `delrow` and `delcol` are computed from model size `L` and number of cells `N`. Once these are all computed, the Discretization file is built.

[6]:
```
# Create the discretization package
bot = np.linspace(-H / Nlay, -H, Nlay)
delrow = delcol = L / (N - 1)
dis = flopy.mf6.modflow.mfgwfdis.ModflowGwfdis(
    gwf,
    pname="dis",
    nlay=Nlay,
    nrow=N,
    ncol=N,
    delr=delrow,
```

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```
    delc=delcol,
    top=0.0,
    botm=bot,
)
```

[7]:
```
# Create the initial conditions package
start = h1 * np.ones((Nlay, N, N))
ic = flopy.mf6.modflow.mfgwfic.ModflowGwfic(gwf, pname="ic", strt=start)
```

[8]:
```
# Create the node property flow package
npf = flopy.mf6.modflow.mfgwfnpf.ModflowGwfnpf(
    gwf, pname="npf", icelltype=1, k=k, save_flows=True
)
```

[9]:
```
# Create the constant head package.
# List information is created a bit differently for
# MODFLOW 6 than for other MODFLOW versions.  The
# cellid (layer, row, column, for a regular grid)
# must be entered as a tuple as the first entry.
# Remember that these must be zero-based indices!
chd_rec = []
chd_rec.append(((0, int(N / 2), int(N / 2)), h2))
for layer in range(0, Nlay):
    for row_col in range(0, N):
        chd_rec.append(((layer, row_col, 0), h1))
        chd_rec.append(((layer, row_col, N - 1), h1))
        if row_col != 0 and row_col != N - 1:
            chd_rec.append(((layer, 0, row_col), h1))
            chd_rec.append(((layer, N - 1, row_col), h1))
chd = flopy.mf6.modflow.mfgwfchd.ModflowGwfchd(
    gwf,
    pname="chd",
    maxbound=len(chd_rec),
    stress_period_data=chd_rec,
    save_flows=True,
)
```

[10]:
```
# The chd package stored the constant heads in a structured
# array, also called a recarray.  We can get a pointer to the
# recarray for the first stress period (iper = 0) as follows.
iper = 0
ra = chd.stress_period_data.get_data(key=iper)
ra
```

[10]:
```
rec.array([((0, 50, 50),  90), ((0, 0, 0), 100), ((0, 0, 100), 100), ...,
           ((9, 100, 99), 100), ((9, 100, 0), 100), ((9, 100, 100), 100)],
          dtype=[('cellid', 'O'), ('head', '<i8')])
```

[11]:
```
# We can make a quick plot to show where our constant
# heads are located by creating an integer array
# that starts with ones everywhere, but is assigned
```

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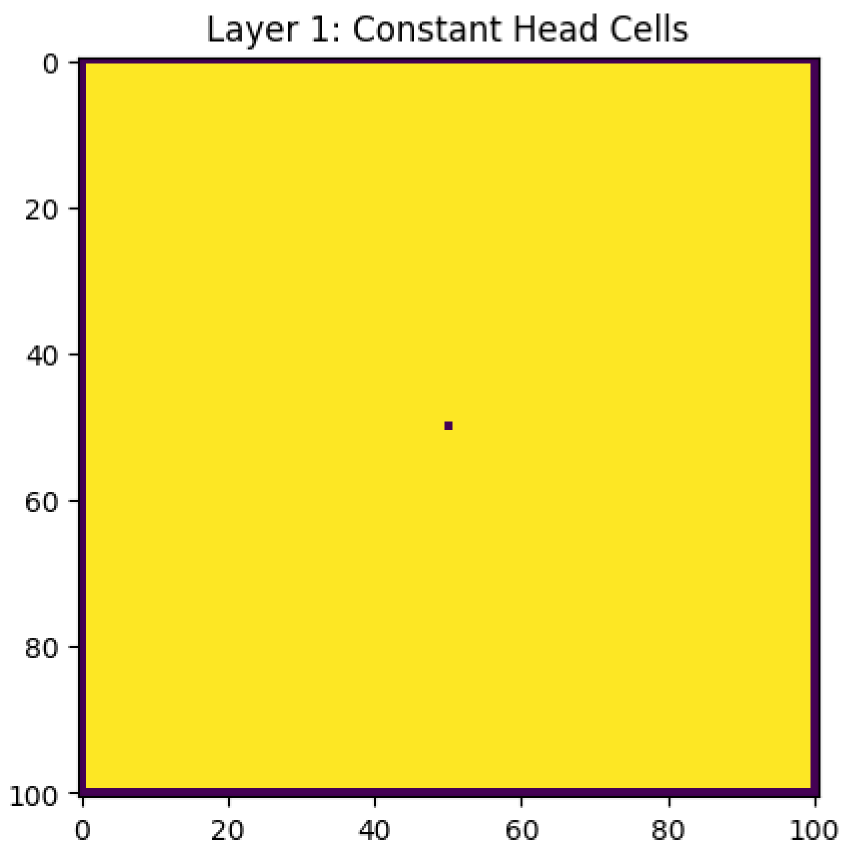
```
# a -1 where chds are located
ibd = np.ones((Nlay, N, N), dtype=int)
for k, i, j in ra["cellid"]:
    ibd[k, i, j] = -1

ilay = 0
plt.imshow(ibd[ilay, :, :], interpolation="none")
plt.title(f"Layer {ilay + 1}: Constant Head Cells")
```

[11]:

```
Text(0.5, 1.0, 'Layer 1: Constant Head Cells')
```



[12]:

```
# Create the output control package
headfile = f"{name}.hds"
head_filerecord = [headfile]
budgetfile = f"{name}.cbb"
budget_filerecord = [budgetfile]
saverecord = [("HEAD", "ALL"), ("BUDGET", "ALL")]
printrecord = [("HEAD", "LAST")]
oc = flopy.mf6.modflow.mfgwfoc.ModflowGwfoc(
    gwf,
    pname="oc",
    saverecord=saverecord,
    head_filerecord=head_filerecord,
    budget_filerecord=budget_filerecord,
```

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```
    printrecord=printrecord,
)
```

[13]:
```
# Note that help can always be found for a package
# using either forms of the following syntax
help(oc)
# help(flopy.mf6.modflow.mfgwfoc.ModflowGwfoc)
```

```
Help on ModflowGwfoc in module flopy.mf6.modflow.mfgwfoc object:

class ModflowGwfoc(flopy.mf6.mfpackage.MFPackage)
 |  ModflowGwfoc(model, loading_package=False, budget_filerecord=None, budgetcsv_
↪filerecord=None, head_filerecord=None, headprintrecord=None, saverecord=None,␣
↪printrecord=None, filename=None, pname=None, **kwargs)
 |
 |  ModflowGwfoc defines a oc package within a gwf6 model.
 |
 |  Parameters
 |  ----------
 |  model : MFModel
 |      Model that this package is a part of. Package is automatically
 |      added to model when it is initialized.
 |  loading_package : bool
 |      Do not set this parameter. It is intended for debugging and internal
 |      processing purposes only.
 |  budget_filerecord : [budgetfile]
 |      * budgetfile (string) name of the output file to write budget
 |        information.
 |  budgetcsv_filerecord : [budgetcsvfile]
 |      * budgetcsvfile (string) name of the comma-separated value (CSV) output
 |        file to write budget summary information. A budget summary record
 |        will be written to this file for each time step of the simulation.
 |  head_filerecord : [headfile]
 |      * headfile (string) name of the output file to write head information.
 |  headprintrecord : [columns, width, digits, format]
 |      * columns (integer) number of columns for writing data.
 |      * width (integer) width for writing each number.
 |      * digits (integer) number of digits to use for writing a number.
 |      * format (string) write format can be EXPONENTIAL, FIXED, GENERAL, or
 |        SCIENTIFIC.
 |  saverecord : [rtype, ocsetting]
 |      * rtype (string) type of information to save or print. Can be BUDGET or
 |        HEAD.
 |      * ocsetting (keystring) specifies the steps for which the data will be
 |        saved.
 |          all : [keyword]
 |              * all (keyword) keyword to indicate save for all time steps in
 |                period.
 |          first : [keyword]
 |              * first (keyword) keyword to indicate save for first step in
 |                period. This keyword may be used in conjunction with other
 |                keywords to print or save results for multiple time steps.
```

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```
|          last : [keyword]
|              * last (keyword) keyword to indicate save for last step in
|                period. This keyword may be used in conjunction with other
|                keywords to print or save results for multiple time steps.
|          frequency : [integer]
|              * frequency (integer) save at the specified time step
|                frequency. This keyword may be used in conjunction with other
|                keywords to print or save results for multiple time steps.
|          steps : [integer]
|              * steps (integer) save for each step specified in STEPS. This
|                keyword may be used in conjunction with other keywords to
|                print or save results for multiple time steps.
|  printrecord : [rtype, ocsetting]
|      * rtype (string) type of information to save or print. Can be BUDGET or
|        HEAD.
|      * ocsetting (keystring) specifies the steps for which the data will be
|        saved.
|          all : [keyword]
|              * all (keyword) keyword to indicate save for all time steps in
|                period.
|          first : [keyword]
|              * first (keyword) keyword to indicate save for first step in
|                period. This keyword may be used in conjunction with other
|                keywords to print or save results for multiple time steps.
|          last : [keyword]
|              * last (keyword) keyword to indicate save for last step in
|                period. This keyword may be used in conjunction with other
|                keywords to print or save results for multiple time steps.
|          frequency : [integer]
|              * frequency (integer) save at the specified time step
|                frequency. This keyword may be used in conjunction with other
|                keywords to print or save results for multiple time steps.
|          steps : [integer]
|              * steps (integer) save for each step specified in STEPS. This
|                keyword may be used in conjunction with other keywords to
|                print or save results for multiple time steps.
|  filename : String
|      File name for this package.
|  pname : String
|      Package name for this package.
|  parent_file : MFPackage
|      Parent package file that references this package. Only needed for
|      utility packages (mfutl*). For example, mfutllaktab package must have
|      a mfgwflak package parent_file.
|
|  Method resolution order:
|      ModflowGwfoc
|      flopy.mf6.mfpackage.MFPackage
|      flopy.mf6.mfbase.PackageContainer
|      flopy.pakbase.PackageInterface
|      builtins.object
|
```

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```
|  Methods defined here:
|
|  __init__(self, model, loading_package=False, budget_filerecord=None, budgetcsv_
↪filerecord=None, head_filerecord=None, headprintrecord=None, saverecord=None,␣
↪printrecord=None, filename=None, pname=None, **kwargs)
|      Initialize self.  See help(type(self)) for accurate signature.
|
|  ----------------------------------------------------------------------
|  Data and other attributes defined here:
|
|  budget_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator o...
|
|  budgetcsv_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerato...
|
|  dfn = [['header'], ['block options', 'name budget_filerecord', 'type r...
|
|  dfn_file_name = 'gwf-oc.dfn'
|
|  head_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator obj...
|
|  headprintrecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator obj...
|
|  package_abbr = 'gwfoc'
|
|  printrecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>
|
|  saverecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>
|
|  ----------------------------------------------------------------------
|  Methods inherited from flopy.mf6.mfpackage.MFPackage:
|
|  __repr__(self)
|      Return repr(self).
|
|  __setattr__(self, name, value)
|      Implement setattr(self, name, value).
|
|  __str__(self)
|      Return str(self).
|
|  build_child_package(self, pkg_type, data, parameter_name, filerecord)
|      Builds a child package.  This method is only intended for FloPy
|      internal use.
|
|  build_child_packages_container(self, pkg_type, filerecord)
|      Builds a container object for any child packages.  This method is
|      only intended for FloPy internal use.
|
|  build_mfdata(self, var_name, data=None)
|      Returns the appropriate data type object (mfdatalist, mfdataarray,
|      or mfdatascalar) given that object the appropriate structure (looked
|      up based on var_name) and any data supplied.  This method is for
```

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```
|       internal FloPy library use only.
|
|       Parameters
|       ----------
|       var_name : str
|           Variable name
|
|       data : many supported types
|           Data contained in this object
|
|       Returns
|       -------
|       data object : MFData subclass
|
|   check(self, f=None, verbose=True, level=1, checktype=None)
|       Data check, returns True on success.
|
|   create_package_dimensions(self)
|       Creates a package dimensions object.  For internal FloPy library
|       use.
|
|       Returns
|       -------
|       package dimensions : PackageDimensions
|
|   export(self, f, **kwargs)
|       Method to export a package to netcdf or shapefile based on the
|       extension of the file name (.shp for shapefile, .nc for netcdf)
|
|       Parameters
|       ----------
|       f : str
|           Filename
|       kwargs : keyword arguments
|           modelgrid : flopy.discretization.Grid instance
|               User supplied modelgrid which can be used for exporting
|               in lieu of the modelgrid associated with the model object
|
|       Returns
|       -------
|           None or Netcdf object
|
|   get_file_path(self)
|       Returns the package file's path.
|
|       Returns
|       -------
|       file path : str
|
|   inspect_cells(self, cell_list, stress_period=None)
|       Inspect model cells.  Returns package data associated with cells.
|
```

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```
|      Parameters
|      ----------
|      cell_list : list of tuples
|          List of model cells.  Each model cell is a tuple of integers.
|          ex: [(1,1,1), (2,4,3)]
|      stress_period : int
|          For transient data, only return data from this stress period.  If
|          not specified or None, all stress period data will be returned.
|
|      Returns
|      -------
|      output : array
|          Array containing inspection results
|
|  is_valid(self)
|      Returns whether or not this package is valid.
|
|      Returns
|      -------
|      is valid : bool
|
|  load(self, strict=True)
|      Loads the package from file.
|
|      Parameters
|      ----------
|      strict : bool
|          Enforce strict checking of data.
|
|      Returns
|      -------
|      success : bool
|
|  plot(self, **kwargs)
|      Plot 2-D, 3-D, transient 2-D, and stress period list (MfList)
|      package input data
|
|      Parameters
|      ----------
|      **kwargs : dict
|          filename_base : str
|              Base file name that will be used to automatically generate
|              file names for output image files. Plots will be exported as
|              image files if file_name_base is not None. (default is None)
|          file_extension : str
|              Valid matplotlib.pyplot file extension for savefig(). Only
|              used if filename_base is not None. (default is 'png')
|          mflay : int
|              MODFLOW zero-based layer number to return.  If None, then all
|              all layers will be included. (default is None)
|          kper : int
|              MODFLOW zero-based stress period number to return. (default is
```

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```
 |              zero)
 |          key : str
 |              MfList dictionary key. (default is None)
 |
 |      Returns
 |      ----------
 |      axes : list
 |          Empty list is returned if filename_base is not None. Otherwise
 |          a list of matplotlib.pyplot.axis are returned.
 |
 |  remove(self)
 |      Removes this package from the simulation/model it is currently a
 |      part of.
 |
 |  set_all_data_external(self, check_data=True, external_data_folder=None)
 |      Sets the package's list and array data to be stored externally.
 |
 |      Parameters
 |      ----------
 |          check_data : bool
 |              Determine if data error checking is enabled
 |          external_data_folder
 |              Folder where external data will be stored
 |
 |  set_all_data_internal(self, check_data=True)
 |      Sets the package's list and array data to be stored internally.
 |
 |      Parameters
 |      ----------
 |          check_data : bool
 |              Determine if data error checking is enabled
 |
 |  set_model_relative_path(self, model_ws)
 |      Sets the model path relative to the simulation's path.
 |
 |      Parameters
 |      ----------
 |      model_ws : str
 |          Model path relative to the simulation's path.
 |
 |  write(self, ext_file_action=<ExtFileAction.copy_relative_paths: 3>)
 |      Writes the package to a file.
 |
 |      Parameters
 |      ----------
 |      ext_file_action : ExtFileAction
 |          How to handle pathing of external data files.
 |
 |  ----------------------------------------------------------------------
 |  Class methods inherited from flopy.mf6.mfpackage.MFPackage:
 |
 |  __init_subclass__() from builtins.type
```

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```
 |      Register package type
 |
 |  ----------------------------------------------------------------------
 |  Readonly properties inherited from flopy.mf6.mfpackage.MFPackage:
 |
 |  data_list
 |      List of data in this package.
 |
 |  output
 |      Method to get output associated with a specific package
 |
 |      Returns
 |      -------
 |          MF6Output object
 |
 |  package_type
 |      String describing type of package
 |
 |  plottable
 |      If package is plottable
 |
 |  quoted_filename
 |      Package's file name with quotes if there is a space.
 |
 |  ----------------------------------------------------------------------
 |  Data descriptors inherited from flopy.mf6.mfpackage.MFPackage:
 |
 |  filename
 |      Package's file name.
 |
 |  name
 |      Name of package
 |
 |  parent
 |      Parent package
 |
 |  ----------------------------------------------------------------------
 |  Methods inherited from flopy.mf6.mfbase.PackageContainer:
 |
 |  get_package(self, name=None)
 |      Finds a package by package name, package key, package type, or partial
 |      package name. returns either a single package, a list of packages,
 |      or None.
 |
 |      Parameters
 |      ----------
 |      name : str
 |          Name of the package, 'RIV', 'LPF', etc.
 |
 |      Returns
 |      -------
 |      pp : Package object
```

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```
|
|  register_package(self, package)
|      Base method for registering a package.  Should be overridden.
|
|  ----------------------------------------------------------------------
|  Static methods inherited from flopy.mf6.mfbase.PackageContainer:
|
|  get_module_val(module, item, attrb)
|      Static method that returns a python class module value.  For
|      internal FloPy use only, not intended for end users.
|
|  model_factory(model_type)
|      Static method that returns the appropriate model type object based
|      on the model_type string. For internal FloPy use only, not intended
|      for end users.
|
|      Parameters
|      ----------
|          model_type : str
|              Type of model that package is a part of
|
|      Returns
|      -------
|          model : MFModel subclass
|
|  package_factory(package_type: str, model_type: str)
|      Static method that returns the appropriate package type object based
|      on the package_type and model_type strings.  For internal FloPy use
|      only, not intended for end users.
|
|      Parameters
|      ----------
|          package_type : str
|              Type of package to create
|          model_type : str
|              Type of model that package is a part of
|
|      Returns
|      -------
|          package : MFPackage subclass
|
|  package_list()
|      Static method that returns the list of available packages.
|      For internal FloPy use only, not intended for end users.
|
|      Returns a list of MFPackage subclasses
|
|  ----------------------------------------------------------------------
|  Readonly properties inherited from flopy.mf6.mfbase.PackageContainer:
|
|  package_dict
|      Returns a copy of the package name dictionary.
```

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```
 |
 |  package_key_dict
 |
 |  package_names
 |      Returns a list of package names.
 |
 |  ----------------------------------------------------------------------
 |  Data descriptors inherited from flopy.mf6.mfbase.PackageContainer:
 |
 |  __dict__
 |      dictionary for instance variables (if defined)
 |
 |  __weakref__
 |      list of weak references to the object (if defined)
 |
 |  ----------------------------------------------------------------------
 |  Data and other attributes inherited from flopy.mf6.mfbase.PackageContainer:
 |
 |  models_by_type = {'gwf': <class 'flopy.mf6.modflow.mfgwf.ModflowGwf'>,...
 |
 |  modflow_models = [<class 'flopy.mf6.modflow.mfgwf.ModflowGwf'>, <class...
 |
 |  modflow_packages = [<class 'flopy.mf6.modflow.mfnam.ModflowNam'>, <cla...
 |
 |  packages_by_abbr = {'ems': <class 'flopy.mf6.modflow.mfems.ModflowEms'...
 |
 |  ----------------------------------------------------------------------
 |  Readonly properties inherited from flopy.pakbase.PackageInterface:
 |
 |  has_stress_period_data
```

Create the MODFLOW 6 Input Files and Run the Model

Once all the flopy objects are created, it is very easy to create all of the input files and run the model.

[14]:
```
# Write the datasets
sim.write_simulation()
```

```
writing simulation...
  writing simulation name file...
  writing simulation tdis package...
  writing solution package ims...
  writing model mf6lake...
    writing model name file...
    writing package dis...
    writing package ic...
    writing package npf...
    writing package chd...
    writing package oc...
```

```
[15]: # Print a list of the files that were created
      # in workspace
      print(os.listdir(workspace))
```

```
['mf6lake.nam', 'mf6lake.oc', 'mf6lake.dis', 'mf6lake.npf', 'mf6lake.chd', 'mf6lake.ic',
↪'mf6lake.ims', 'mf6lake.tdis', 'mfsim.nam']
```

Run the Simulation

We can also run the simulation from the notebook, but only if the MODFLOW 6 executable is available. The executable can be made available by putting the executable in a folder that is listed in the system path variable. Another option is to just put a copy of the executable in the simulation folder, though this should generally be avoided. A final option is to provide a full path to the executable when the simulation is constructed. This would be done by specifying exe_name with the full path.

```
[16]: # Run the simulation
      success, buff = sim.run_simulation(silent=True, report=True)
      if success:
          for line in buff:
              print(line)
      else:
          raise ValueError("Failed to run.")
```

```
                                   MODFLOW 6
                U.S. GEOLOGICAL SURVEY MODULAR HYDROLOGIC MODEL
                            VERSION 6.4.2 06/28/2023

   MODFLOW 6 compiled Jul 05 2023 20:29:14 with Intel(R) Fortran Intel(R) 64
   Compiler Classic for applications running on Intel(R) 64, Version 2021.7.0
                             Build 20220726_000000

This software has been approved for release by the U.S. Geological
Survey (USGS). Although the software has been subjected to rigorous
review, the USGS reserves the right to update the software as needed
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authorized or unauthorized use. Also refer to the USGS Water
Resources Software User Rights Notice for complete use, copyright,
and distribution information.


 Run start date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:30:13

 Writing simulation list file: mfsim.lst
 Using Simulation name file: mfsim.nam

    Solving:  Stress period:     1    Time step:     1

 Run end date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:30:14
```

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```
Elapsed run time:  0.429 Seconds

Normal termination of simulation.
```

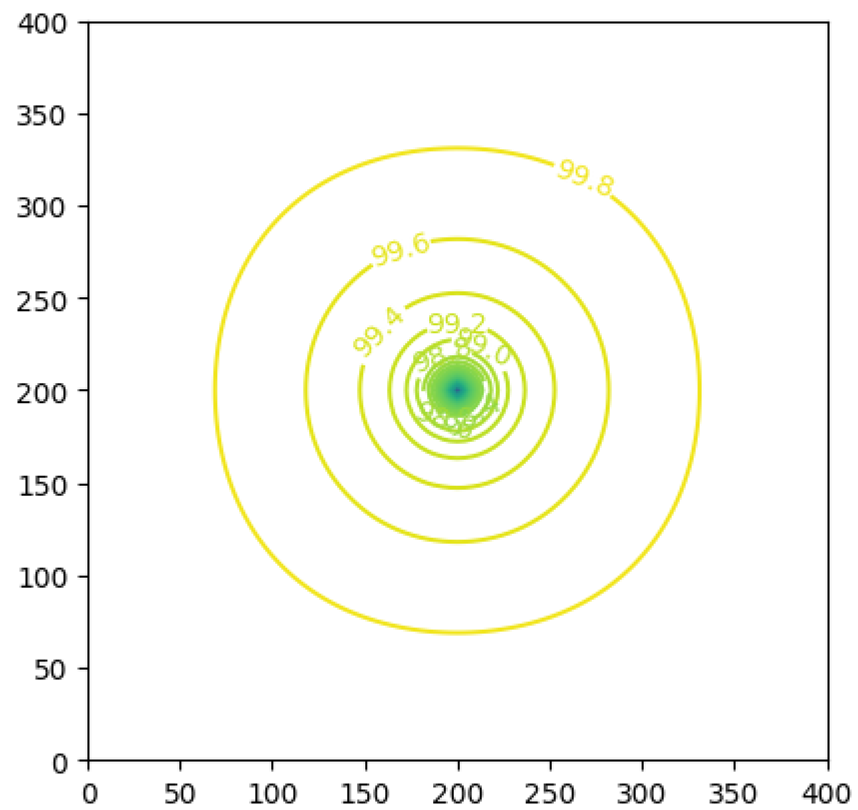
Post-Process Head Results

Post-processing MODFLOW 6 results is still a work in progress. There aren't any Flopy plotting functions built in yet, like they are for other MODFLOW versions. So we need to plot the results using general Flopy capabilities. We can also use some of the Flopy ModelMap capabilities for MODFLOW 6, but in order to do so, we need to manually create a SpatialReference object, that is needed for the plotting. Examples of both approaches are shown below.

First, a link to the heads file is created with `HeadFile`. The link can then be accessed with the `get_data` function, by specifying, in this case, the step number and period number for which we want to retrieve data. A three-dimensional array is returned of size `nlay, nrow, ncol`. Matplotlib contouring functions are used to make contours of the layers or a cross-section.

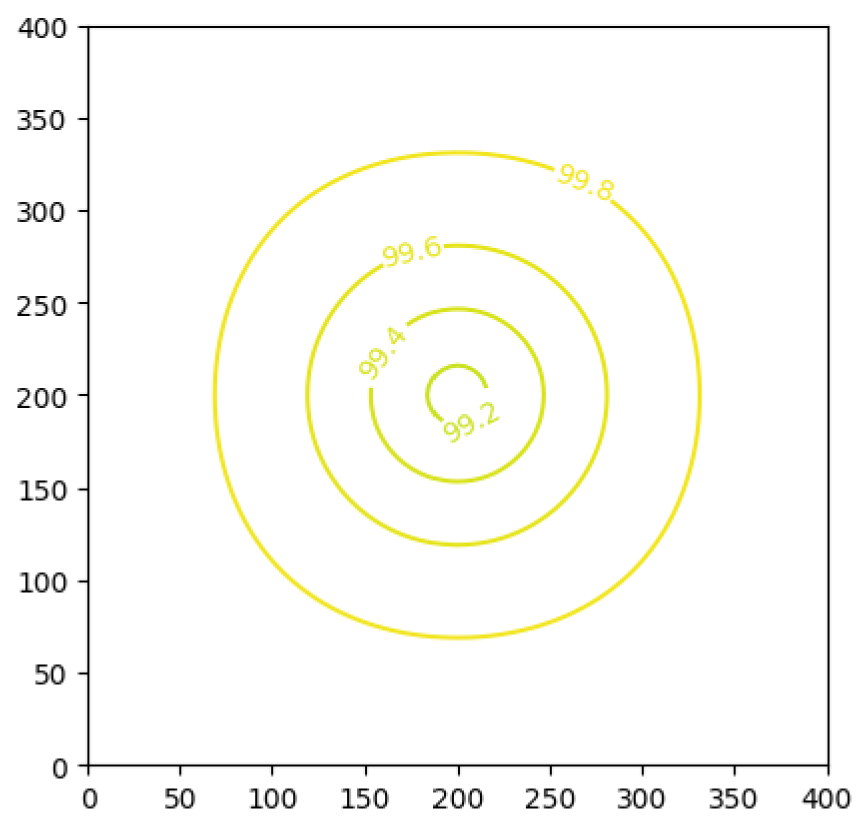
[17]:
```
# Read the binary head file and plot the results
# We can use the existing Flopy HeadFile class because
# the format of the headfile for MODFLOW 6 is the same
# as for previous MODFLOW verions
fname = os.path.join(workspace, headfile)
hds = flopy.utils.binaryfile.HeadFile(fname)
h = hds.get_data(kstpkper=(0, 0))
x = y = np.linspace(0, L, N)
y = y[::-1]
c = plt.contour(x, y, h[0], np.arange(90, 100.1, 0.2))
plt.clabel(c, fmt="%2.1f")
plt.axis("scaled")
```

[17]:
```
(0.0, 400.0, 0.0, 400.0)
```



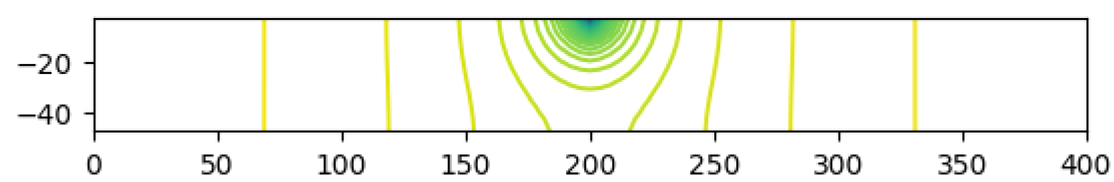
[18]:
```
x = y = np.linspace(0, L, N)
y = y[::-1]
c = plt.contour(x, y, h[-1], np.arange(90, 100.1, 0.2))
plt.clabel(c, fmt="%1.1f")
plt.axis("scaled")
```

[18]:
```
(0.0, 400.0, 0.0, 400.0)
```



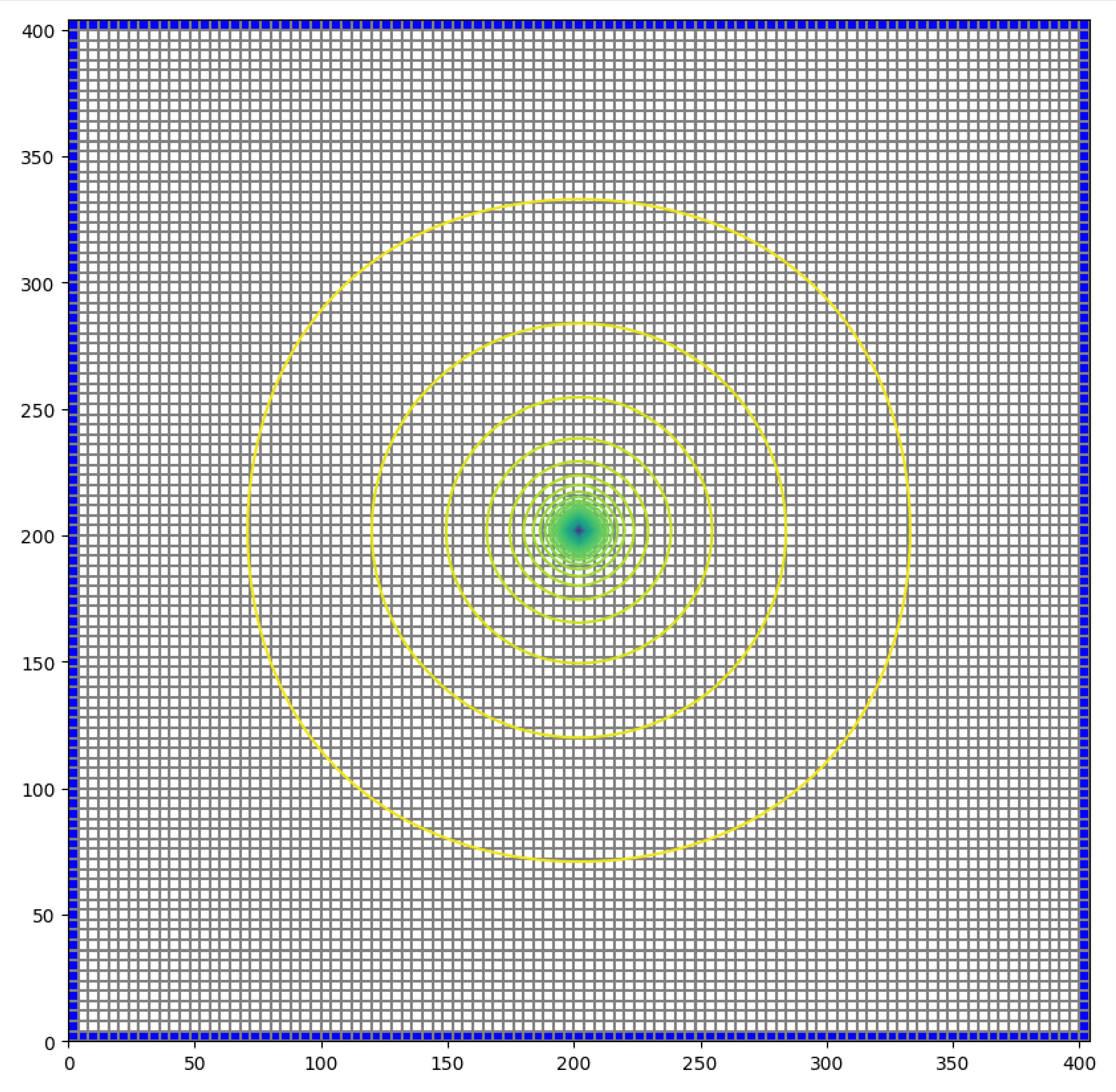
[19]:
```
z = np.linspace(-H / Nlay / 2, -H + H / Nlay / 2, Nlay)
c = plt.contour(x, z, h[:, 50, :], np.arange(90, 100.1, 0.2))
plt.axis("scaled")
```

[19]:
```
(0.0, 400.0, -47.5, -2.5)
```



[20]:
```
# We can also use the Flopy PlotMapView capabilities for MODFLOW 6
fig = plt.figure(figsize=(10, 10))
ax = fig.add_subplot(1, 1, 1, aspect="equal")
modelmap = flopy.plot.PlotMapView(model=gwf, ax=ax)

# Then we can use the plot_grid() method to draw the grid
# The return value for this function is a matplotlib LineCollection object,
# which could be manipulated (or used) later if necessary.
quadmesh = modelmap.plot_ibound(ibound=ibd)
linecollection = modelmap.plot_grid()
contours = modelmap.contour_array(h[0], levels=np.arange(90, 100.1, 0.2))
```



[21]:
```
# We can also use the Flopy PlotMapView capabilities for MODFLOW 6
fig = plt.figure(figsize=(10, 10))
ax = fig.add_subplot(1, 1, 1, aspect="equal")

# Next we create an instance of the ModelMap class
modelmap = flopy.plot.PlotMapView(model=gwf, ax=ax)

# Then we can use the plot_grid() method to draw the grid
# The return value for this function is a matplotlib LineCollection object,
# which could be manipulated (or used) later if necessary.
quadmesh = modelmap.plot_ibound(ibound=ibd)
linecollection = modelmap.plot_grid()
pa = modelmap.plot_array(h[0])
```

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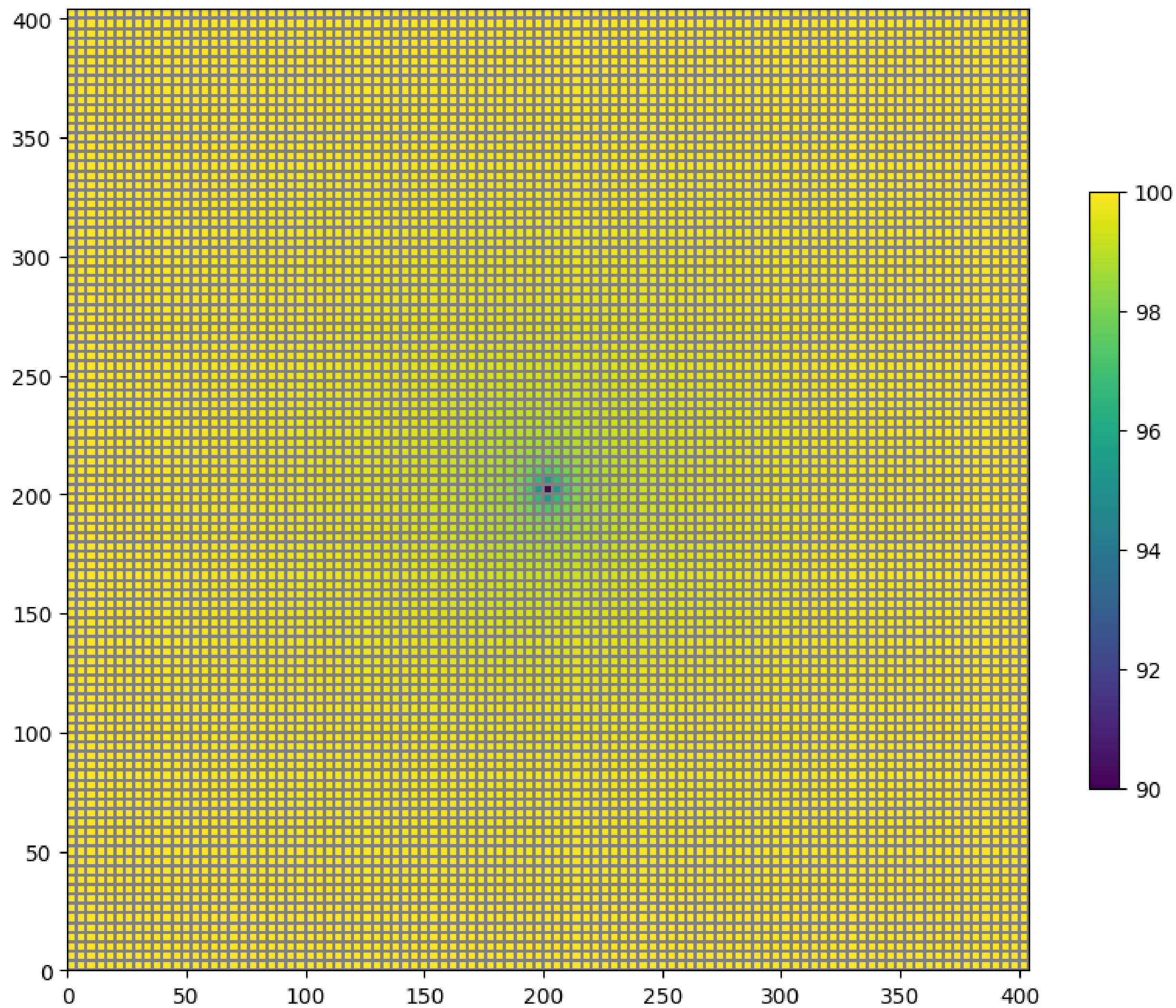
```
cb = plt.colorbar(pa, shrink=0.5)
```



Post-Process Flows

MODFLOW 6 writes a binary grid file, which contains information about the model grid. MODFLOW 6 also writes a binary budget file, which contains flow information. Both of these files can be read using Flopy capabilities. The MfGrdFile class in Flopy can be used to read the binary grid file. The CellBudgetFile class in Flopy can be used to read the binary budget file written by MODFLOW 6.

[22]:
```
# read the binary grid file
fname = os.path.join(workspace, f"{name}.dis.grb")
bgf = flopy.mf6.utils.MfGrdFile(fname)

# data read from the binary grid file is stored in a dictionary
bgf._datadict
```

[22]:
```
{'NCELLS': 102010,
 'NLAY': 10,
 'NROW': 101,
 'NCOL': 101,
 'NJA': 689628,
 'XORIGIN': 0.0,
 'YORIGIN': 0.0,
 'ANGROT': 0.0,
 'DELR': array([4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4.,
        4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4.,
        4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4.,
        4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4.,
        4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4.,
        4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4.]),
 'DELC': array([4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4.,
        4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4.,
        4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4.,
        4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4.,
        4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4.,
        4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4., 4.]),
 'TOP': array([0., 0., 0., ..., 0., 0., 0.]),
 'BOTM': array([ -5.,  -5.,  -5., ..., -50., -50., -50.]),
 'IA': array([     1,      5,     10, ..., 689620, 689625, 689629], dtype=int32),
 'JA': array([     1,      2,    102, ...,  91809, 101909, 102009], dtype=int32),
 'IDOMAIN': array([1, 1, 1, ..., 1, 1, 1], dtype=int32),
 'ICELLTYPE': array([1, 1, 1, ..., 1, 1, 1], dtype=int32)}
```

[23]:
```
# read the cell budget file
fname = os.path.join(workspace, f"{name}.cbb")
cbb = flopy.utils.CellBudgetFile(fname, precision="double")
cbb.list_records()

flowja = cbb.get_data(text="FLOW-JA-FACE")[0][0, 0, :]
chdflow = cbb.get_data(text="CHD")[0]
```

```
(1, 1, b'    FLOW-JA-FACE', 689628, 1, -1, 1, 1., 1., 1., b'', b'', b'', b'')
(1, 1, b'             CHD', 101, 101, -10, 6, 1., 1., 1., b'MF6LAKE         ', b'MF6LAKE␣
↪         ', b'MF6LAKE         ', b'CHD             ')
```

[24]:
```
# By having the ia and ja arrays and the flow-ja-face we can look at
# the flows for any cell and process them in the follow manner.
k = 5
i = 50
j = 50
celln = k * N * N + i * N + j
ia, ja = bgf.ia, bgf.ja
print(f"Printing flows for cell {celln}")
for ipos in range(ia[celln] + 1, ia[celln + 1]):
    cellm = ja[ipos]
    print(f"Cell {celln} flow with cell {cellm} is {flowja[ipos]}")
```

```
Printing flows for cell 56105
Cell 56105 flow with cell 45904 is -0.5173461773371856
```

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```
Cell 56105 flow with cell 56004 is 0.04821245255698159
Cell 56105 flow with cell 56104 is 0.04821245255698159
Cell 56105 flow with cell 56106 is 0.04827345085914203
Cell 56105 flow with cell 56206 is 0.04827345085914203
Cell 56105 flow with cell 66306 is 0.32526484558511587
```

[25]:
```python
try:
    # ignore PermissionError on Windows
    temp_dir.cleanup()
except:
    pass
```

6.5.4 Flopy MODFLOW 6 (MF6) Support

The Flopy library contains classes for creating, saving, running, loading, and modifying MF6 simulations. The MF6 portion of the flopy library is located in the `flopy.mf6` module.

Conceptual model

While there are a number of classes in `flopy.mf6`, to get started you only need to use the main classes summarized below:

`flopy.mf6.MFSimulation`

MODFLOW Simulation Class. Entry point into any MODFLOW simulation.

`flopy.mf6.ModflowGwf`

MODFLOW Groundwater Flow Model Class. Represents a single model in a simulation.

`flopy.mf6.Modflow[pc]`

MODFLOW package classes where [pc] is the abbreviation of the package name. Each package is a separate class.

For packages that are part of a groundwater flow model, the abbreviation begins with `Gwf`. For example, `flopy.mf6.ModflowGwfdis` is the Discretization package.

Creating a simulation

A MF6 simulation is created by first creating a simulation object “MFSimulation”. When you create the simulation object you can define the simulation’s name, version, executable name, workspace path, and the name of the tdis file. All of these are optional parameters, and if not defined each one will default to the following:

- `sim_name`: ‘modflowtest’
- `version`: ‘mf6’
- `exe_name`: ‘mf6’

- sim_ws: os.curdir ('.')
- sim_tdis_file: 'modflow6.tdis'

The sim_ws parameter accepts str or os.PathLike arguments.

[1]:
```python
import os
import sys
from pathlib import Path
from shutil import copyfile
from tempfile import TemporaryDirectory

proj_root = Path.cwd().parent.parent

# run installed version of flopy or add local path
try:
    import flopy
except:
    sys.path.append(proj_root)
    import flopy

# temporary directory
temp_dir = TemporaryDirectory()
sim_name = "example_sim"
sim_path = Path(temp_dir.name) / "example_project"
sim = flopy.mf6.MFSimulation(
    sim_name=sim_name, version="mf6", exe_name="mf6", sim_ws=sim_path
)
```

The next step is to create a tdis package object "ModflowTdis". The first parameter of the ModflowTdis class is a simulation object, which ties a ModflowTdis object to a specific simulation. The other parameters and their definitions can be found in the docstrings.

[2]:
```python
tdis = flopy.mf6.ModflowTdis(
    sim,
    pname="tdis",
    time_units="DAYS",
    nper=2,
    perioddata=[(1.0, 1, 1.0), (10.0, 5, 1.0)],
)
```

Next one or more models are created using the ModflowGwf class. The first parameter of the ModflowGwf class is the simulation object that the model will be a part of.

[3]:
```python
model_name = "example_model"
model = flopy.mf6.ModflowGwf(
    sim, modelname=model_name, model_nam_file=f"{model_name}.nam"
)
```

Next create one or more Iterative Model Solution (IMS) files.

[4]:
```python
ims_package = flopy.mf6.ModflowIms(
    sim,
    pname="ims",
    print_option="ALL",
```

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```
    complexity="SIMPLE",
    outer_dvclose=0.00001,
    outer_maximum=50,
    under_relaxation="NONE",
    inner_maximum=30,
    inner_dvclose=0.00001,
    linear_acceleration="CG",
    preconditioner_levels=7,
    preconditioner_drop_tolerance=0.01,
    number_orthogonalizations=2,
)
```

Each ModflowGwf object needs to be associated with an ModflowIms object. This is done by calling the MFSimulation object's "register_ims_package" method. The first parameter in this method is the ModflowIms object and the second parameter is a list of model names (strings) for the models to be associated with the ModflowIms object.

[5]:
```
sim.register_ims_package(ims_package, [model_name])
```

Next add packages to each model. The first package added needs to be a spatial discretization package since flopy uses information from the spatial discretization package to help you build other packages. There are three spatial discretization packages to choose from:

- DIS (`ModflowGwfDis`): Structured discretization
- DISV (`ModflowGwfdisv`): Discretization with vertices
- DISU (`ModflowGwfdisu`): Unstructured discretization

[6]:
```
dis_package = flopy.mf6.ModflowGwfdis(
    model,
    pname="dis",
    length_units="FEET",
    nlay=2,
    nrow=2,
    ncol=5,
    delr=500.0,
    delc=500.0,
    top=100.0,
    botm=[50.0, 20.0],
    filename=f"{model_name}.dis",
)
```

Accessing namefiles

Namefiles are automatically built for you by flopy. However, there are some options contained in the namefiles that you may want to set. To get the namefile object access the name_file attribute in either a simulation or model object to get the simulation or model namefile.

[7]:
```
# set the nocheck property in the simulation namefile
sim.name_file.nocheck = True
# set the print_input option in the model namefile
model.name_file.print_input = True
```

Specifying options

Option that appear alone are assigned a boolean value, like the print_input option above. Options that have additional optional parameters are assigned using a tuple, with the entries containing the names of the optional parameters to turn on. Use a tuple with an empty string to indicate no optional parameters and use a tuple with None to turn the option off.

[8]:
```
# Turn Newton option on with under relaxation
model.name_file.newtonoptions = "UNDER_RELAXATION"
# Turn Newton option on without under relaxation
model.name_file.newtonoptions = ""
# Turn off Newton option
model.name_file.newtonoptions = None
```

MFArray templates

Lastly define all other packages needed.

Note that flopy supports a number of ways to specify data for a package. A template, which defines the data array shape for you, can be used to specify the data. Templates are built by calling the empty of the data type you are building. For example, to build a template for k in the npf package you would call:

```
ModflowGwfnpf.k.empty()
```

The empty method for `MFArray` data templates (data templates whose size is based on the structure of the model grid) take up to four parameters:

- `model`: The model object that the data is a part of. A valid model object with a discretization package is required in order to build the proper array dimensions. This parameter is required.
- `layered`: True or false whether the data is layered or not.
- `data_storage_type_list`: List of data storage types, one for each model layer. If the template is not layered, only one data storage type needs to be specified. There are three data storage types supported, internal_array, internal_constant, and external_file.
- `default_value`: The initial value for the array.

[9]:
```
# build a data template for k that stores the first layer as an internal array and the␣
↪second
# layer as a constant with the default value of k for all layers set to 100.0
layer_storage_types = [
    flopy.mf6.data.mfdatastorage.DataStorageType.internal_array,
    flopy.mf6.data.mfdatastorage.DataStorageType.internal_constant,
]
k_template = flopy.mf6.ModflowGwfnpf.k.empty(
    model, True, layer_storage_types, 100.0
)
# change the value of the second layer to 50.0
k_template[0]["data"] = [
    65.0,
    60.0,
    55.0,
    50.0,
    45.0,
```

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```
    40.0,
    35.0,
    30.0,
    25.0,
    20.0,
]
k_template[0]["factor"] = 1.5
print(k_template)
# create npf package using the k template to define k
npf_package = flopy.mf6.ModflowGwfnpf(
    model, pname="npf", save_flows=True, icelltype=1, k=k_template
)
```

```
[{'factor': 1.5, 'iprn': 1, 'data': [65.0, 60.0, 55.0, 50.0, 45.0, 40.0, 35.0, 30.0, 25.
↪0, 20.0]}, 100.0]
```

Specifying MFArray Data

MFArray data can also be specified as a numpy array, a list of values, or a single value. Below strt (starting heads) are defined as a single value, 100.0, which is interpreted as an internal constant storage type of value 100.0. Strt could also be defined as a list defining a value for every model cell:

```
strt=[100.0, 100.0, 100.0, 100.0, 100.0, 100.0, 100.0, 100.0, 100.0, 100.0,
      90.0, 90.0, 90.0, 90.0, 90.0, 90.0, 90.0, 90.0, 90.0, 90.0]
```

Or as a list defining a value or values for each model layer:

```
strt=[100.0, 90.0]
```

or:

```
strt=[[100.0], [90.0, 90.0, 90.0, 90.0, 90.0, 90.0, 90.0, 90.0, 90.0, 90.0]]
```

MFArray data can also be stored in an external file by using a dictionary using the keys 'filename' to specify the file name relative to the model folder and 'data' to specific the data. The optional 'factor', 'iprn', and 'binary' keys may also be used.

```
strt={'filename': 'strt.txt', 'factor':1.0, 'data':[100.0, 100.0, 100.0, 100.0, 100.0,␣
↪100.0, 100.0, 100.0, 100.0, 100.0,
      90.0, 90.0, 90.0, 90.0, 90.0, 90.0, 90.0, 90.0, 90.0, 90.0], 'binary': 'True'}
```

If the 'data' key is omitted from the dictionary flopy will try to read the data from an existing file 'filename'. Any relative paths for loading data from a file should specified relative to the MF6 simulation folder.

[10]:
```
strt = {
    "filename": "strt.txt",
    "factor": 1.0,
    "data": [
        100.0,
        100.0,
        100.0,
        100.0,
```

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```
        100.0,
        100.0,
        100.0,
        100.0,
        100.0,
        100.0,
        90.0,
        90.0,
        90.0,
        90.0,
        90.0,
        90.0,
        90.0,
        90.0,
        90.0,
        90.0,
    ],
    "binary": "True",
}
ic_package = flopy.mf6.ModflowGwfic(
    model, pname="ic", strt=strt, filename=f"{model_name}.ic"
)
# move external file data into model folder
icv_data_path = os.path.join(
    "..", "..", "examples", "data", "mf6", "notebooks", "iconvert.txt"
)
copyfile(icv_data_path, os.path.join(sim_path, "iconvert.txt"))
# create storage package
sto_package = flopy.mf6.ModflowGwfsto(
    model,
    pname="sto",
    save_flows=True,
    iconvert={"filename": "iconvert.txt"},
    ss=[0.000001, 0.000002],
    sy=[
        0.15,
        0.14,
        0.13,
        0.12,
        0.11,
        0.11,
        0.12,
        0.13,
        0.14,
        0.15,
        0.15,
        0.14,
        0.13,
        0.12,
        0.11,
        0.11,
        0.12,
```

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```
        0.13,
        0.14,
        0.15,
    ],
)
```

MFList Templates

Flopy supports specifying record and recarray `MFList` data in a number of ways. Templates can be created that define the shape of the data. The empty method for `MFList` data templates take up to 7 parameters.

- `model`: The model object that the data is a part of. A valid model object with a discretization package is required in order to build the proper array dimensions. This parameter is required.
- `maxbound`: The number of rows in the recarray. If not specified one row is returned.
- `aux_vars`: List of auxiliary variable names. If not specified auxiliary variables are not used.
- `boundnames`: True/False if boundnames is to be used.
- `nseg`: Number of segments (only relevant for a few data types)
- `timeseries`: True/False indicates that time series data will be used.
- `stress_periods`: List of integer stress periods to be used (transient MFList data only). If not specified for transient data, template will only be defined for stress period 1.

MFList transient data templates are numpy recarrays stored in a dictionary with the dictionary key an integer zero based stress period value (stress period - 1).

In the code below the well package is set up using a transient MFList template to help build the well's stress_periods.

[11]:
```
maxbound = 2
# build a stress_period_data template with 2 wells over stress periods 1 and 2 with␣
↪boundnames
# and three aux variables
wel_periodrec = flopy.mf6.ModflowGwfwel.stress_period_data.empty(
    model,
    maxbound=maxbound,
    boundnames=True,
    aux_vars=["var1", "var2", "var3"],
    stress_periods=[0, 1],
)
# define the two wells for stress period one
wel_periodrec[0][0] = ((0, 1, 2), -50.0, -1, -2, -3, "First Well")
wel_periodrec[0][1] = ((1, 1, 4), -25.0, 2, 3, 4, "Second Well")
# define the two wells for stress period two
wel_periodrec[1][0] = ((0, 1, 2), -200.0, -1, -2, -3, "First Well")
wel_periodrec[1][1] = ((1, 1, 4), -4000.0, 2, 3, 4, "Second Well")
# build the well package
wel_package = flopy.mf6.ModflowGwfwel(
    model,
    pname="wel",
    print_input=True,
    print_flows=True,
```

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```
    auxiliary=["var1", "var2", "var3"],
    maxbound=maxbound,
    stress_period_data=wel_periodrec,
    boundnames=True,
    save_flows=True,
)
```

Cell IDs

Cell IDs always appear as tuples in an MFList. For a structured grid cell IDs appear as:

(<layer>, <row>, <column>)

For vertice based grid cells IDs appear as:

(<layer>, <intralayer_cell_id>)

Unstructured grid cell IDs appear as:

(<cell_id>)

Specifying MFList Data

MFList data can also be defined as a list of tuples, with each tuple being a row of the recarray. For transient data the list of tuples can be stored in a dictionary with the dictionary key an integer zero based stress period value. If only a list of tuples is specified for transient data, the data is assumed to apply to stress period 1. Additional stress periods can be added with the add_transient_key method. The code below defines saverecord and printrecord as a list of tuples.

[12]:
```
# printrecord data as a list of tuples.  since no stress
# period is specified it will default to stress period 1
printrec_tuple_list = [("HEAD", "ALL"), ("BUDGET", "ALL")]
# saverecord data as a dictionary of lists of tuples for
# stress periods 1 and 2.
saverec_dict = {
    0: [("HEAD", "ALL"), ("BUDGET", "ALL")],
    1: [("HEAD", "ALL"), ("BUDGET", "ALL")],
}
# create oc package
oc_package = flopy.mf6.ModflowGwfoc(
    model,
    pname="oc",
    budget_filerecord=[(f"{model_name}.cbc",)],
    head_filerecord=[(f"{model_name}.hds",)],
    saverecord=saverec_dict,
    printrecord=printrec_tuple_list,
)
# add stress period two to the print record
oc_package.printrecord.add_transient_key(1)
# set the data for stress period two in the print record
oc_package.printrecord.set_data([("HEAD", "ALL"), ("BUDGET", "ALL")], 1)
```

Specifying MFList Data in an External File

MFList data can be specified in an external file using a dictionary with the 'filename' key. If the 'data' key is also included in the dictionary and is not None, flopy will create the file with the data contained in the 'data' key. The 'binary' key can be used to save data to a binary file (`'binary': True`). The code below creates a chd package which creates and references an external file containing data for stress period 1 and stores the data internally in the chd package file for stress period 2.

[13]:
```
stress_period_data = {
    0: {"filename": "chd_sp1.dat", "data": [[(0, 0, 0), 70.0]]},
    1: [[(0, 0, 0), 60.0]],
}
chd = flopy.mf6.ModflowGwfchd(
    model, maxbound=1, stress_period_data=stress_period_data
)
```

Packages that Support both List-based and Array-based Data

The recharge and evapotranspiration packages can be specified using list-based or array-based input. The array packages have an "a" on the end of their name:

- `ModflowGwfrch`: list based recharge package
- `ModflowGwfrcha`: array based recharge package
- `ModflowGwfevt`: list based evapotranspiration package
- `ModflowGwfevta`: array based evapotranspiration package

[14]:
```
rch_recarray = {
    0: [((0, 0, 0), "rch_1"), ((1, 1, 1), "rch_2")],
    1: [((0, 0, 0), "rch_1"), ((1, 1, 1), "rch_2")],
}
rch_package = flopy.mf6.ModflowGwfrch(
    model,
    pname="rch",
    fixed_cell=True,
    print_input=True,
    maxbound=2,
    stress_period_data=rch_recarray,
)
```

Utility Files (TS, TAS, OBS, TAB)

Utility files, MF6 formatted files that reference by packages, include time series, time array series, observation, and tab files. The file names for utility files are specified using the package that references them. The utility files can be created in several ways. A simple case is demonstrated below. More detail is given in the flopy3_mf6_obs_ts_tas notebook.

[15]:
```
# build a time series array for the recharge package
ts_data = [
    (0.0, 0.015, 0.0017),
    (1.0, 0.016, 0.0019),
    (2.0, 0.012, 0.0015),
```

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```
    (3.0, 0.020, 0.0014),
    (4.0, 0.015, 0.0021),
    (5.0, 0.013, 0.0012),
    (6.0, 0.022, 0.0012),
    (7.0, 0.016, 0.0014),
    (8.0, 0.013, 0.0011),
    (9.0, 0.021, 0.0011),
    (10.0, 0.017, 0.0016),
    (11.0, 0.012, 0.0015),
]
rch_package.ts.initialize(
    time_series_namerecord=["rch_1", "rch_2"],
    timeseries=ts_data,
    filename="recharge_rates.ts",
    interpolation_methodrecord=["stepwise", "stepwise"],
)

# build an recharge observation package that outputs the western recharge to a binary␣
↪file and the eastern
# recharge to a text file
obs_data = {
    ("rch_west.csv", "binary"): [
        ("rch_1_1_1", "RCH", (0, 0, 0)),
        ("rch_1_2_1", "RCH", (0, 1, 0)),
    ],
    "rch_east.csv": [
        ("rch_1_1_5", "RCH", (0, 0, 4)),
        ("rch_1_2_5", "RCH", (0, 1, 4)),
    ],
}
rch_package.obs.initialize(
    filename="example_model.rch.obs",
    digits=10,
    print_input=True,
    continuous=obs_data,
)
```

Saving and Running a MF6 Simulation

Saving and running a simulation are done with the MFSimulation class's write_simulation and run_simulation methods.

[16]:
```
# write simulation to new location
sim.write_simulation()

# run simulation
success, buff = sim.run_simulation(silent=True, report=True)
assert success, "Failed to run"
for line in buff:
    print(line)
```

```
writing simulation...
  writing simulation name file...
  writing simulation tdis package...
  writing solution package ims...
  writing model example_model...
    writing model name file...
    writing package dis...
    writing package npf...
    writing package ic...
    writing package sto...
    writing package wel...
    writing package oc...
    writing package chd_0...
    writing package rch...
    writing package ts_0...
    writing package obs_0...
                                   MODFLOW 6
                U.S. GEOLOGICAL SURVEY MODULAR HYDROLOGIC MODEL
                            VERSION 6.4.2 06/28/2023

   MODFLOW 6 compiled Jul 05 2023 20:29:14 with Intel(R) Fortran Intel(R) 64
   Compiler Classic for applications running on Intel(R) 64, Version 2021.7.0
                             Build 20220726_000000

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 Run start date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:30:19

 Writing simulation list file: mfsim.lst
 Using Simulation name file: mfsim.nam

    Solving:  Stress period:     1    Time step:     1
    Solving:  Stress period:     2    Time step:     1
    Solving:  Stress period:     2    Time step:     2
    Solving:  Stress period:     2    Time step:     3
    Solving:  Stress period:     2    Time step:     4
    Solving:  Stress period:     2    Time step:     5

 Run end date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:30:19
 Elapsed run time:  0.029 Seconds
```

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```
Normal termination of simulation.
```

Exporting a MF6 Model

Exporting a MF6 model to a shapefile or netcdf is the same as exporting a MF2005 model.

[17]:
```
# make directory
pth = Path(temp_dir.name) / "netCDF_export"
pth.mkdir(exist_ok=True)

# export the dis package to a netcdf file
model.dis.export(pth / "dis.nc")

# export the botm array to a shapefile
model.dis.botm.export(str(pth / "botm.shp"))  # supports os.PathLike or str
```

```
initialize_geometry::
model crs: None
initialize_geometry::nc_crs = EPSG:4326
No CRS information for writing a .prj file.
Supply an valid coordinate system reference to the attached modelgrid object or .
↪export() method.
```

Loading an Existing MF6 Simulation

Loading a simulation can be done with the flopy.mf6.MFSimulation.load static method.

[18]:
```
# load the simulation
loaded_sim = flopy.mf6.MFSimulation.load(sim_name, "mf6", "mf6", sim_path)
```

```
loading simulation...
  loading simulation name file...
  loading tdis package...
  loading model gwf6...
    loading package dis...
    loading package npf...
    loading package ic...
    loading package sto...
    loading package wel...
    loading package oc...
    loading package chd...
    loading package rch...
  loading solution package example_model...
```

Retrieving Data and Modifying an Existing MF6 Simulation

Data can be easily retrieved from a simulation. Data can be retrieved using two methods. One method is to retrieve the data object from a master simulation dictionary that keeps track of all the data. The master simulation dictionary is accessed by accessing a simulation's "simulation_data" property and then the "mfdata" property:

```
sim.simulation_data.mfdata[(model_name, package_name, block_name, variable_name)]
```

The data path is the path to the data stored as a tuple containing the model name, package name, block name, and data name.

The second method is to get the data from the package object. If you do not already have the package object, you can work your way down the simulation structure, from the simulation to the correct model, to the correct package, and finally to the data object.

These methods are demonstrated in the code below.

[19]:
```
# get hydraulic conductivity data object from the data dictionary
hk = sim.simulation_data.mfdata[(model_name, "npf", "griddata", "k")]

# get specific yield data object from the storage package
sy = sto_package.sy

# get the model object from the simulation object using the get_model method,
# which takes a string with the model's name and returns the model object
mdl = sim.get_model(model_name)
# get the package object from the model mobject using the get_package method,
# which takes a string with the package's name or type
ic = mdl.get_package("ic")
# get the data object from the initial condition package object
strt = ic.strt
```

Once you have the appropriate data object there are a number methods to retrieve data from that object. Data retrieved can either be the data as it appears in the model file or the data with any factor specified in the model file applied to it. To get the raw data without applying a factor use the get_data method. To get the data with the factor already applied use .array.

Note that MFArray data is always a copy of the data stored by flopy. Modifying the copy of the flopy data will have no affect on the data stored in flopy. Non-constant internal MFList data is returned as a reference to a numpy recarray. Modifying this recarray will modify the data stored in flopy.

[20]:
```
# get the data without applying any factor
hk_data_no_factor = hk.get_data()
print(f"Data without factor:\n{hk_data_no_factor}\n")

# get data with factor applied
hk_data_factor = hk.array
print(f"Data with factor:\n{hk_data_factor}\n")
```

```
Data without factor:
[[[ 65.   60.   55.   50.   45.]
  [ 40.   35.   30.   25.   20.]]

 [[100. 100. 100. 100. 100.]
  [100. 100. 100. 100. 100.]]]
```

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```
Data with factor:
[[[ 97.5  90.   82.5  75.   67.5]
  [ 60.   52.5  45.   37.5  30. ]]

 [[100.  100.  100.  100.  100. ]
  [100.  100.  100.  100.  100. ]]]
```

Data can also be retrieved from the data object using []. For unlayered data the [] can be used to slice the data.

[21]:
```
# slice layer one row two
print(f"SY slice of layer on row two\n{sy[0, :, 2]}\n")
```

```
SY slice of layer on row two
[0.13 0.13]
```

For layered data specify the layer number within the brackets. This will return a "LayerStorage" object which let's you change attributes of an individual layer.

[22]:
```
# get layer one LayerStorage object
hk_layer_one = hk[0]
# change the print code and factor for layer one
hk_layer_one.iprn = "2"
hk_layer_one.factor = 1.1
print(f"Layer one data without factor:\n{hk_layer_one.get_data()}\n")
print(f"Data with new factor:\n{hk.array}\n")
```

```
Layer one data without factor:
[[65. 60. 55. 50. 45.]
 [40. 35. 30. 25. 20.]]

Data with new factor:
[[[ 71.5  66.   60.5  55.   49.5]
  [ 44.   38.5  33.   27.5  22. ]]

 [[100.  100.  100.  100.  100. ]
  [100.  100.  100.  100.  100. ]]]
```

Modifying Data

Data can be modified in several ways. One way is to set data for a given layer within a LayerStorage object, like the one accessed in the code above. Another way is to set the data attribute to the new data. Yet another way is to call the data object's set_data method.

[23]:
```
# set data within a LayerStorage object
hk_layer_one.set_data(
    [120.0, 100.0, 80.0, 70.0, 60.0, 50.0, 40.0, 30.0, 25.0, 20.0]
)
print(f"New HK data no factor:\n{hk.get_data()}\n")
# set data attribute to new data
```

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```
ic_package.strt = 150.0
print(f"New strt values:\n{ic_package.strt.array}\n")
# call set_data
sto_package.ss.set_data([0.000003, 0.000004])
print(f"New ss values:\n{sto_package.ss.array}\n")
```

```
New HK data no factor:
[[[120. 100.  80.  70.  60.]
  [ 50.  40.  30.  25.  20.]]

 [[100. 100. 100. 100. 100.]
  [100. 100. 100. 100. 100.]]]

New strt values:
[[[150. 150. 150. 150. 150.]
  [150. 150. 150. 150. 150.]]

 [[150. 150. 150. 150. 150.]
  [150. 150. 150. 150. 150.]]]

New ss values:
[[[3.e-06 3.e-06 3.e-06 3.e-06 3.e-06]
  [3.e-06 3.e-06 3.e-06 3.e-06 3.e-06]]

 [[4.e-06 4.e-06 4.e-06 4.e-06 4.e-06]
  [4.e-06 4.e-06 4.e-06 4.e-06 4.e-06]]]
```

Modifying the Simulation Path

The simulation path folder can be changed by using the set_sim_path method in the MFFileMgmt object. The MFFileMgmt object can be obtained from the simulation object through properties:

```
sim.simulation_data.mfpath
```

[24]:
```
save_folder = sim_path / "sim_modified"  # define path
save_folder.mkdir(exist_ok=True)  # ensure path exists
sim.set_sim_path(save_folder)  # change simulation path
```

The `sim_path` property is a shortcut for `simulation_data.mfpath.get_sim_path()`:

[25]:
```
assert sim.sim_path == sim.simulation_data.mfpath.get_sim_path()
```

Adding a Model Relative Path

A model relative path lets you put all of the files associated with a model in a folder relative to the simulation folder. Warning, this will override all of your file paths to model package files and will also override any relative file paths to external model data files.

[26]:
```python
# Change path of model files relative to the simulation folder
model.set_model_relative_path("model_folder")
model_folder = save_folder / "model_folder"
model_folder.mkdir(exist_ok=True)

# write simulation to new folder
sim.write_simulation()

# run simulation from new folder
success, buff = sim.run_simulation(silent=True, report=True)
assert success, "Failed to run"
for line in buff:
    print(line)
```

```
writing simulation...
  writing simulation name file...
  writing simulation tdis package...
  writing solution package ims...
  writing model example_model...
    writing model name file...
    writing package dis...
    writing package npf...
    writing package ic...
    writing package sto...
    writing package wel...
    writing package oc...
    writing package chd_0...
    writing package rch...
    writing package ts_0...
    writing package obs_0...
                                   MODFLOW 6
                U.S. GEOLOGICAL SURVEY MODULAR HYDROLOGIC MODEL
                            VERSION 6.4.2 06/28/2023

   MODFLOW 6 compiled Jul 05 2023 20:29:14 with Intel(R) Fortran Intel(R) 64
   Compiler Classic for applications running on Intel(R) 64, Version 2021.7.0
                             Build 20220726_000000

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```

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```
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 Run start date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:30:19

 Writing simulation list file: mfsim.lst
 Using Simulation name file: mfsim.nam

    Solving:  Stress period:     1    Time step:     1
    Solving:  Stress period:     2    Time step:     1
    Solving:  Stress period:     2    Time step:     2
    Solving:  Stress period:     2    Time step:     3
    Solving:  Stress period:     2    Time step:     4
    Solving:  Stress period:     2    Time step:     5

 Run end date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:30:19
 Elapsed run time:  0.031 Seconds

 Normal termination of simulation.
```
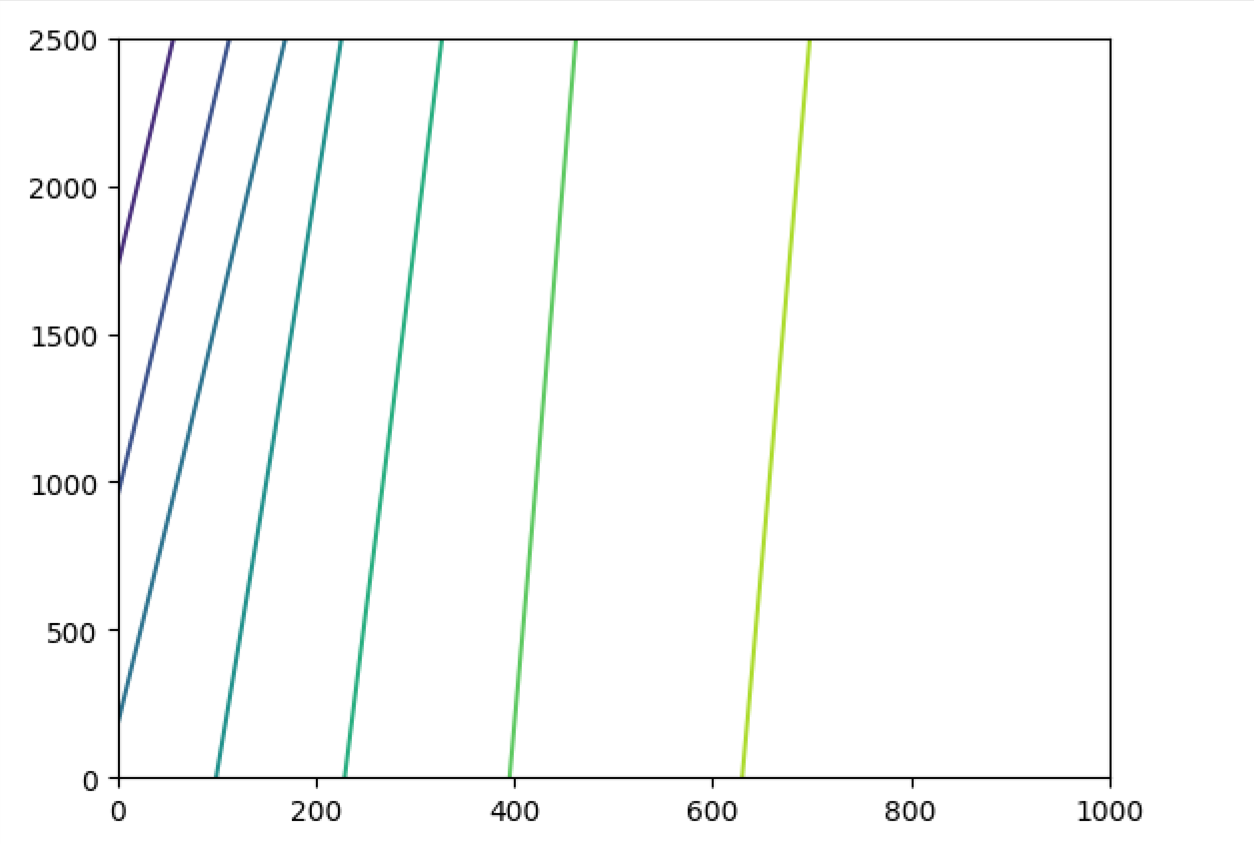

Post-Processing the Results

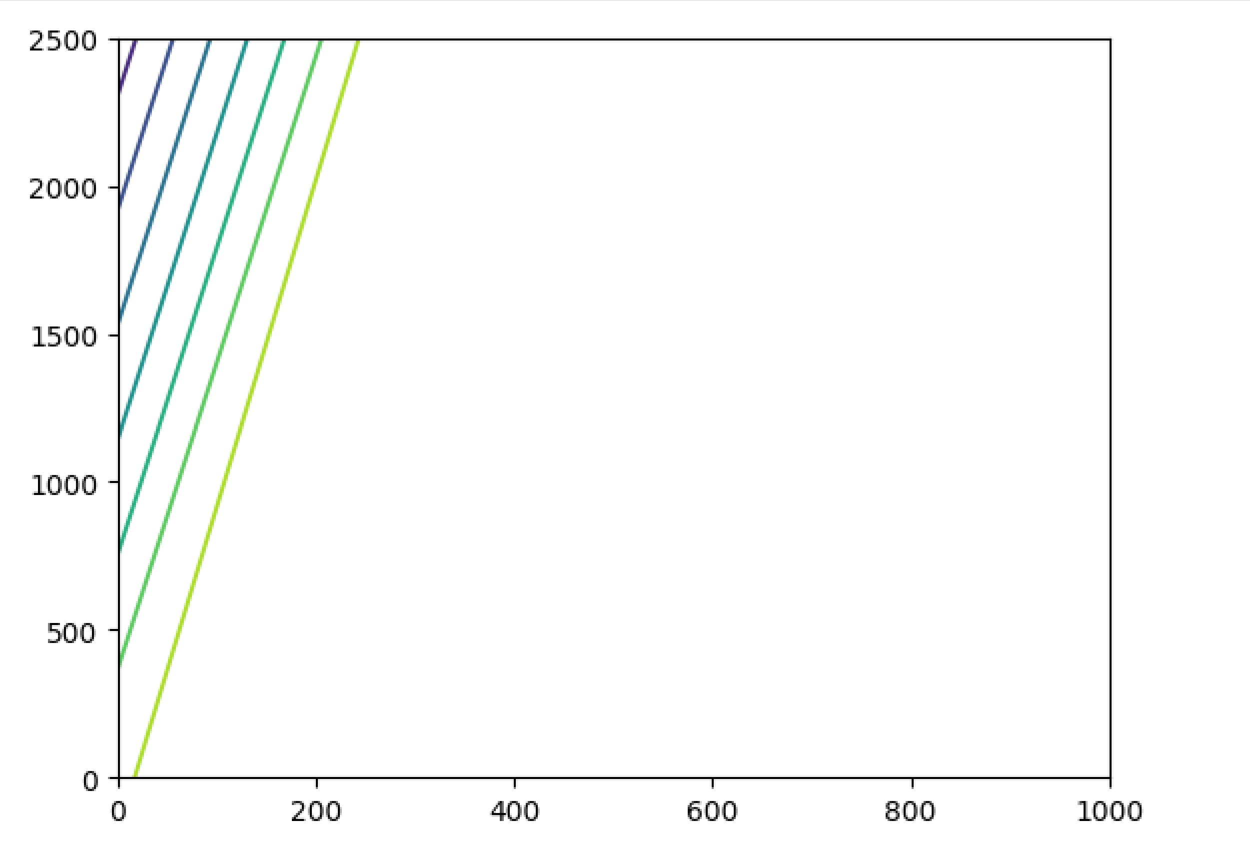
Results can be retrieved using the `output` method available on each groundwater flow and transport model.

[27]:
```python
import matplotlib.pyplot as plt
import numpy as np

# get all head data
head = model.output.head().get_alldata()
# get the head data from the end of the model run
head_end = head[-1]
# plot the head data from the end of the model run
levels = np.arange(160, 162, 1)
extent = (0.0, 1000.0, 2500.0, 0.0)
plt.contour(head_end[0, :, :], extent=extent)
plt.show()
```



Results can also be retrieved using the existing binaryfile method.

[28]:
```
# get head data using old flopy method
hds_path = sim_path / f"{model_name}.hds"
hds = flopy.utils.HeadFile(hds_path)
# get heads after 1.0 days
head = hds.get_data(totim=1.0)
# plot head data
plt.contour(head[0, :, :], extent=extent)
plt.show()
```



Clean up the temporary workspace.

[29]:
```
try:
    # ignore PermissionError on Windows
    temp_dir.cleanup()
except:
    pass
```

6.6 MODFLOW USG examples

6.6.1 MODFLOW-USG CLN package demo

This example problem demonstrates use of the CLN process for simulating flow to a well pumping from two aquifers seperated by an impermeable confining unit. A structured finite-difference grid with 100 rows and 100 columns was used. Each square cells is 470m by 470 m in extent. Initial heads are 10m in aquifer 1 and 30m in aquifer 2.

[1]:
```
import os
import shutil
from tempfile import TemporaryDirectory

import matplotlib.pyplot as plt
import numpy as np
```

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```
import flopy
```

```
[2]: # temporary directory
temp_dir = TemporaryDirectory()
cln_ws = temp_dir.name
```

Loading Example 03_conduit_confined

The elevation of the top of layer 1 is -100 m, the bottom of layer 1 is -110 m, the top of layer 2 is -120 m and the bottom of layer 2 is -130 m. The confining unit between layers1 and 2 is impermeable and is represented using a quasi-three-dimensional approach. The only way a stress from one aquifer can be propagated to another is through the cln well that penetrates both aquifers.

The hydraulic conductivity values of the upper and lower aquifers are 100 and 400 m/d, respectively. Both aquifers have a primaey storage coefficient of 0.0001 and a specific yield of 0.01.

A vertical conduit well is located at the center of the domain and has a radius of 0.5 m. The well pumps 62,840 m3/d and is open fully to both aquifers from top to bottom. The CLN Process was used with a circular conduit geometry type to discretize the well bore with two conduit cells, one in each layer. The WEL Package was used to pump from the bottom CLN cell.

```
[3]: model_ws = os.path.join(
    "../../examples/data/mfusg_test", "03_conduit_confined"
)
mf = flopy.mfusg.MfUsg.load(
    "ex3.nam", model_ws=model_ws, exe_name="mfusg", check=False, verbose=True
)
```

```
Creating new model with name: ex3
--------------------------------------------------

Parsing the namefile --> ../../examples/data/mfusg_test/03_conduit_confined/ex3.nam
could not set filehandle to ex3.lst
could not set filehandle to ex3.cbb
could not set filehandle to ex3.hds
could not set filehandle to ex3.ddn
could not set filehandle to ex3.clncbb
could not set filehandle to ex3.clnhds

--------------------------------------------------
External unit dictionary:
{7: filename:../../examples/data/mfusg_test/03_conduit_confined/ex3.lst, filetype:LIST,␣
↪1: filename:../../examples/data/mfusg_test/03_conduit_confined/ex3.bas, filetype:BAS6,␣
↪14: filename:../../examples/data/mfusg_test/03_conduit_confined/ex3.wel, filetype:WEL,␣
↪12: filename:../../examples/data/mfusg_test/03_conduit_confined/ex3.dis, filetype:DIS,␣
↪11: filename:../../examples/data/mfusg_test/03_conduit_confined/ex3.bcf, filetype:BCF6,
↪ 13: filename:../../examples/data/mfusg_test/03_conduit_confined/ex3.cln, filetype:CLN,
↪ 22: filename:../../examples/data/mfusg_test/03_conduit_confined/ex3.oc, filetype:OC,␣
↪19: filename:../../examples/data/mfusg_test/03_conduit_confined/ex3.sms, filetype:SMS,␣
↪50: filename:../../examples/data/mfusg_test/03_conduit_confined/ex3.cbb, filetype:
```

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```
↪DATA(BINARY), 30: filename:../../examples/data/mfusg_test/03_conduit_confined/ex3.hds,␣
↪filetype:DATA(BINARY), 31: filename:../../examples/data/mfusg_test/03_conduit_confined/
↪ex3.ddn, filetype:DATA(BINARY), 35: filename:../../examples/data/mfusg_test/03_conduit_
↪confined/ex3.clncbb, filetype:DATA(BINARY), 36: filename:../../examples/data/mfusg_
↪test/03_conduit_confined/ex3.clnhds, filetype:DATA(BINARY)}
--------------------------------------------------

ModflowBas6 free format:True

loading dis package file...
   Loading dis package with:
      2 layers, 100 rows, 100 columns, and 1 stress periods
   loading laycbd...
   loading delr...
   loading delc...
   loading top...
   loading botm...
      for 2 layers and 1 confining beds
   loading stress period data...
       for 1 stress periods
adding Package:  DIS
   DIS  package load...success
   LIST package load...skipped
loading bas6 package file...
adding Package:  BAS6
   BAS6 package load...success
loading wel package file...
   loading <class 'flopy.mfusg.mfusgwel.MfUsgWel'> for kper     1
   implicit itmp_cln of 0 in ../../examples/data/mfusg_test/03_conduit_confined/ex3.wel
Adding ex3.cbc (unit=50) to the output list.
adding Package:  WEL
   WEL  package load...success
loading bcf package file...
   loading ipakcb, HDRY, IWDFLG, WETFCT, IWETIT, IHDWET...
   loading LAYCON...
   loading TRPY...
   loading sf1 layer   1...
   loading hy layer   1...
   loading vcont layer   1...
   loading sf2 layer   1...
   loading sf1 layer   2...
   loading hy layer   2...
   loading sf2 layer   2...
adding Package:  BCF6
   BCF6 package load...success
loading CLN package file...

   ncln 1
   iclnnds -1
    iclncb 35
   iclnhd 36
    iclndd 0
```

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```
   iclnib 0
    nclngwc 2
   TRANSIENT False
    PRINTIAJA False
   RECTANGULAR 0
    BHEDETAIL False
   SAVECLNCON 0
    SAVECLNMAS 0
   GRAVITY None
    VISCOSITY None
   Reading nndcln...
  Reading node_prop...
   Reading cln_gwc...
   Reading cln_circ...
   Reading ibound...
   Reading strt...
Adding ex3.clncbb (unit=35) to the output list.
Adding ex3.clnhds (unit=36) to the output list.
adding Package:  CLN
   CLN  package load...success
loading oc package file...
Adding ex3.hds (unit=30) to the output list.
Adding ex3.ddn (unit=31) to the output list.
adding Package:  OC
   OC   package load...success
loading sms package file...
   loading HCLOSE HICLOSE MXITER ITER1 IPRSMS NONLINMETH LINMETH...
   HCLOSE 0.001
   HICLOSE 1e-05
   MXITER 220
   ITER1 600
   IPRSMS 1
   NONLINMETH 2
   LINMETH 1
   loading THETA AKAPPA GAMMA AMOMENTUM NUMTRACK BTOL BREDUC RESLIM...
   THETA 0.9
   AKAPPA 0.07
   GAMMA 0.1
   AMOMENTUM 0.0
   NUMTRACK 200
   BTOL 1.1
   BREDUC 0.2
   RESLIM 1.0
   loading IACL NORDER LEVEL NORTH IREDSYS RRCTOL IDROPTOL EPSRN
   IACL 2
   NORDER 1
   LEVEL 3
   NORTH 14
   IREDSYS 0
   RRCTOL 0.0
   IDROPTOL 0
   EPSRN 0.001
```

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```
adding Package:  SMS
   SMS  package load...success
   DATA(BINARY) package load...skipped
      ex3.cbb
   DATA(BINARY) package load...skipped
      ex3.hds
   DATA(BINARY) package load...skipped
      ex3.ddn
   DATA(BINARY) package load...skipped
      ex3.clncbb
   DATA(BINARY) package load...skipped
      ex3.clnhds

WARNING:
    External file unit 0 does not exist in ext_unit_dict.

   The following 7 packages were successfully loaded.
      ex3.dis
      ex3.bas
      ex3.wel
      ex3.bcf
      ex3.cln
      ex3.oc
      ex3.sms
   The following 1 packages were not loaded.
      ex3.lst
```

[4]:
```
# output control
mf.remove_package("OC")

spd = {}
for i in range(mf.nper):
    for j in range(mf.dis.nstp[i]):
        spd[(i, j)] = ["save head", "save budget"]

oc = flopy.modflow.ModflowOc(
    mf, stress_period_data=spd, unitnumber=[22, 30, 31, 50]
)
```

```
removing Package:  ['OC']
adding Package:  OC
```

[5]:
```
model_ws = os.path.join(cln_ws, "ex03")

if os.path.exists(model_ws):
    shutil.rmtree(model_ws)
os.mkdir(model_ws)

mf.model_ws = model_ws
```

```
changing model workspace...
   ../../../../../../../../tmp/tmpt3x301w5/ex03
```

[6]:
```python
mf.write_input()
success, buff = mf.run_model(silent=True, report=True)
if success:
    for line in buff:
        print(line)
else:
    raise ValueError("Failed to run.")
```

```
Writing packages:
   Package:  DIS
   Package:  BAS6
   Package:  WEL
   Package:  BCF6
   Package:  CLN
   Package:  SMS
   Package:  OC


                                  MODFLOW-USG
    U.S. GEOLOGICAL SURVEY MODULAR FINITE-DIFFERENCE GROUNDWATER FLOW MODEL
                             Version 1.5.00 02/27/2019

 Using NAME file: ex3.nam
 Run start date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:30:25

 Solving:  Stress period:     1    Time step:     1    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:     2    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:     3    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:     4    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:     5    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:     6    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:     7    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:     8    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:     9    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    10    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    11    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    12    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    13    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    14    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    15    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    16    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    17    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    18    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    19    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    20    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    21    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    22    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    23    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    24    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    25    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    26    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    27    Groundwater Flow Eqn.
```

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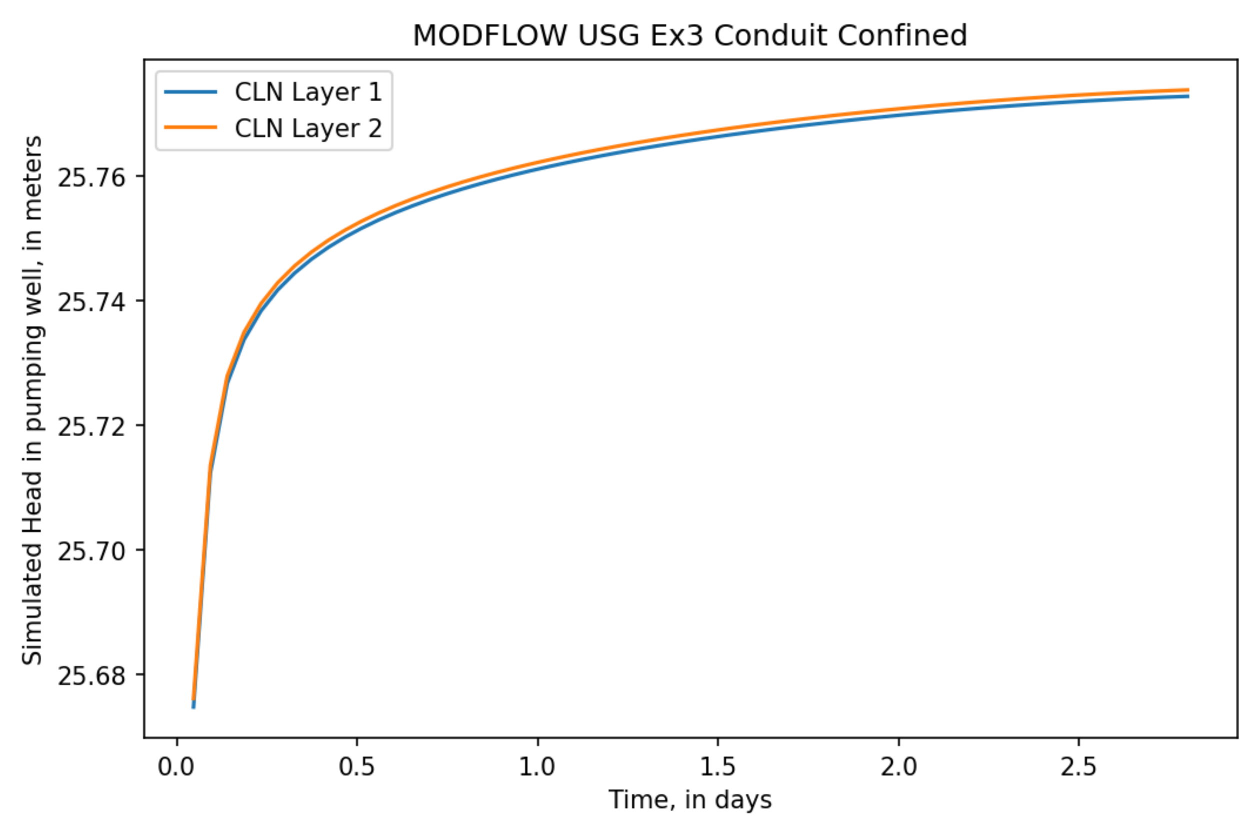
```
 Solving:  Stress period:     1    Time step:    28    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    29    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    30    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    31    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    32    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    33    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    34    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    35    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    36    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    37    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    38    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    39    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    40    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    41    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    42    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    43    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    44    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    45    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    46    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    47    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    48    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    49    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    50    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    51    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    52    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    53    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    54    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    55    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    56    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    57    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    58    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    59    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    60    Groundwater Flow Eqn.
 Run end date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:30:27
 Elapsed run time:  1.288 Seconds

  Normal termination of simulation
```

[7]:
```
head_file = os.path.join(mf.model_ws, "ex3.clnhds")
headobj = flopy.utils.HeadFile(head_file)
```

[8]:
```
simtimes = headobj.get_times()

nper = len(simtimes)

nnode = mf.cln.nclnnds

simhead = np.zeros((1, 1, nnode, nper))
for i in range(nper):
    simhead[:, :, :, i] = headobj.get_data(kstpkper=(i, 0))
simhead = np.squeeze(simhead)
```

[9]:
```python
fig = plt.figure(figsize=(8, 5), dpi=150)
ax = fig.add_subplot(111)
ax.plot(simtimes, simhead[0], label="CLN Layer 1")
ax.plot(simtimes, simhead[1], label="CLN Layer 2")
ax.set_xlabel("Time, in days")
ax.set_ylabel("Simulated Head in pumping well, in meters")
ax.set_title("MODFLOW USG Ex3 Conduit Confined")
ax.legend()
```

[9]:
```
<matplotlib.legend.Legend at 0x7f5b91fb95b0>
```



[10]:
```python
cbb_file = os.path.join(mf.model_ws, "ex3.clncbb")
cbb = flopy.utils.CellBudgetFile(cbb_file)
# cbb.list_records()

simflow = cbb.get_data(kstpkper=(0, 0), text="GWF")[0]
for i in range(nper - 1):
    simflow = np.append(
        simflow, cbb.get_data(kstpkper=(i + 1, 0), text="GWF")[0]
    )
simflow1 = simflow[simflow["node"] == 1]["q"]
simflow2 = simflow[simflow["node"] == 2]["q"]
```

[11]:
```python
fig = plt.figure(figsize=(8, 11), dpi=150)
ax1 = fig.add_subplot(211)
ax1.plot(simtimes, simflow1, label="CLN Layer 1")
```

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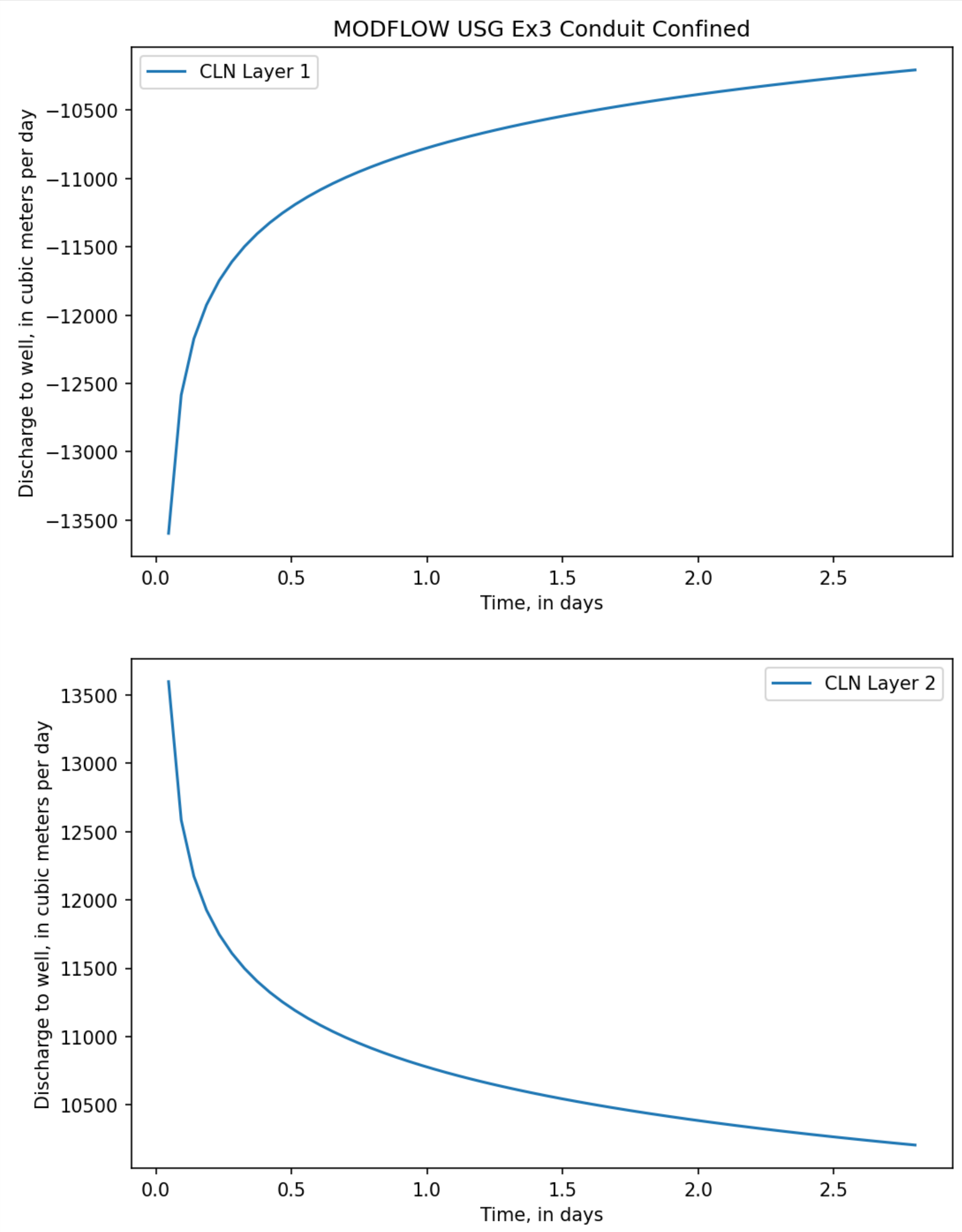
```
ax1.set_xlabel("Time, in days")
ax1.set_ylabel("Discharge to well, in cubic meters per day")
ax1.set_title("MODFLOW USG Ex3 Conduit Confined")
ax1.legend()

ax2 = fig.add_subplot(212)
ax2.plot(simtimes, simflow2, label="CLN Layer 2")
ax2.set_xlabel("Time, in days")
ax2.set_ylabel("Discharge to well, in cubic meters per day")
ax2.legend()
```

[11]:

```
<matplotlib.legend.Legend at 0x7f5b91bbb970>
```


MODFLOW USG Ex3 Conduit Confined
CLN Layer 1
Discharge to well, in cubic meters per day
−10500
−11000
−11500
−12000
−12500
−13000
−13500
0.0
0.5
1.0
1.5
2.0
2.5
Time, in days
CLN Layer 2
Discharge to well, in cubic meters per day
13500
13000
12500
12000
11500
11000
10500
0.0
0.5
1.0
1.5
2.0
2.5
Time, in days

Create example 03A_conduit_unconfined of mfusg 1.5

An unconfined example was simulated with this problem setup. The same simulation setup of previous example is used. However, the elevation of the top of layer 1 is 10 m, the bottom of layer 1 is 0 m, the top of layer 2 is -10 m, and the bottom of layer 2 is -20 m. The CLN domain is discretized using two vertical conduit cells. It depicts the behavior of unconfined flow in the conduit when the CLN cell in layer 1 becomes dry.

[12]:
```python
modelname = "ex03a"
model_ws = os.path.join(cln_ws, modelname)
mf = flopy.mfusg.MfUsg(
    modelname=modelname, model_ws=model_ws, exe_name="mfusg", verbose=True
)
```

[13]:
```python
ipakcb = 50

nlay = 2
nrow = 100
ncol = 100
laycbd = [1, 0]

delr = 470.000
delc = 470.000

ztop = 10.0
botm = [0.0, -10.0, -20.0]

perlen = 160
nstp = 160

dis = flopy.modflow.ModflowDis(
    mf,
    nlay,
    nrow,
    ncol,
    delr=delr,
    delc=delc,
    laycbd=laycbd,
    top=ztop,
    botm=botm,
    perlen=perlen,
    nstp=nstp,
    steady=False,
    lenuni=0,
)

bas = flopy.modflow.ModflowBas(mf, ibound=1, strt=[10.0, 30.0])

bcf = flopy.mfusg.MfUsgBcf(
    mf,
    ipakcb=ipakcb,
    laycon=4,
    wetfct=1.0,
    iwetit=5,
```

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```
    hy=[100.0, 400.0],
    vcont=0.0,
    sf1=1e-4,
    sf2=0.01,
)

sms = flopy.mfusg.MfUsgSms(
    mf,
    hclose=1.0e-3,
    hiclose=1.0e-5,
    mxiter=220,
    iter1=600,
    iprsms=1,
    nonlinmeth=2,
    linmeth=1,
    theta=0.9,
    akappa=0.07,
    gamma=0.1,
    amomentum=0.0,
    numtrack=200,
    btol=1.1,
    breduc=0.2,
    reslim=1.0,
    iacl=2,
    norder=1,
    level=3,
    north=14,
)
```

```
adding Package:  DIS
adding Package:  BAS6
Adding ex03a.cbc (unit=50) to the output list.
adding Package:  BCF6
adding Package:  SMS
```

[14]:

```
# output control
spd = {}
for i in range(mf.nper):
    for j in range(mf.dis.nstp[i]):
        spd[(i, j)] = ["save head", "save budget"]

oc = flopy.modflow.ModflowOc(mf, stress_period_data=spd)
```

```
Adding ex03a.hds (unit=51) to the output list.
adding Package:  OC
```

[15]:

```
unitnumber = [71, 35, 36, 0, 0, 0, 0]

node_prop = [
    [1, 1, 0, 10.0, 0.0, 1.57, 0, 0],
    [2, 1, 0, 10.0, -20.0, 1.57, 0, 0],
]
```

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```
cln_gwc = [
    [1, 1, 50, 50, 0, 0, 10.0, 1.0, 0],
    [2, 2, 50, 50, 0, 0, 10.0, 1.0, 0],
]

nconduityp = 1
cln_circ = [[1, 0.5, 3.23e10]]

strt = [10.0, 30.0]
cln = flopy.mfusg.MfUsgCln(
    mf,
    ncln=1,
    iclnnds=-1,
    nndcln=2,
    nclngwc=2,
    node_prop=node_prop,
    cln_gwc=cln_gwc,
    cln_circ=cln_circ,
    strt=strt,
    unitnumber=unitnumber,
)
```

```
Adding ex03a.clncb (unit=35) to the output list.
Adding ex03a.clnhd (unit=36) to the output list.
adding Package:  CLN
```

[16]:

```
options = []
options.append("autoflowreduce")
cln_stress_period_data = {0: [[1, -62840.0]]}

wel = flopy.mfusg.MfUsgWel(
    mf,
    ipakcb=ipakcb,
    options=options,
    cln_stress_period_data=cln_stress_period_data,
)
```

```
adding Package:  WEL
```

[17]:

```
wel.cln_stress_period_data.data
```

[17]:

```
{0: rec.array([(1, -62840.)],
           dtype=[('node', '<i8'), ('flux', '<f4')])}
```

[18]:

```
mf.write_input()
success, buff = mf.run_model(silent=True, report=True)
if success:
    for line in buff:
        print(line)
else:
    raise ValueError("Failed to run.")
```

```
Writing packages:
   Package:  DIS
   Package:  BAS6
   Package:  BCF6
   Package:  SMS
   Package:  OC
   Package:  CLN
   Package:  WEL


                                  MODFLOW-USG
    U.S. GEOLOGICAL SURVEY MODULAR FINITE-DIFFERENCE GROUNDWATER FLOW MODEL
                             Version 1.5.00 02/27/2019

 Using NAME file: ex03a.nam
 Run start date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:30:27

 Solving:  Stress period:     1    Time step:     1    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:     2    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:     3    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:     4    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:     5    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:     6    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:     7    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:     8    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:     9    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    10    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    11    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    12    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    13    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    14    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    15    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    16    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    17    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    18    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    19    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    20    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    21    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    22    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    23    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    24    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    25    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    26    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    27    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    28    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    29    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    30    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    31    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    32    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    33    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    34    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    35    Groundwater Flow Eqn.
```

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```
Solving:  Stress period:     1    Time step:    36    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    37    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    38    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    39    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    40    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    41    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    42    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    43    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    44    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    45    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    46    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    47    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    48    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    49    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    50    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    51    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    52    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    53    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    54    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    55    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    56    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    57    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    58    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    59    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    60    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    61    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    62    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    63    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    64    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    65    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    66    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    67    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    68    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    69    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    70    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    71    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    72    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    73    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    74    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    75    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    76    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    77    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    78    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    79    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    80    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    81    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    82    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    83    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    84    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    85    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    86    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    87    Groundwater Flow Eqn.
```

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```
Solving:  Stress period:     1    Time step:    88    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    89    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    90    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    91    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    92    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    93    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    94    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    95    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    96    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    97    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    98    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    99    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   100    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   101    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   102    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   103    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   104    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   105    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   106    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   107    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   108    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   109    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   110    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   111    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   112    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   113    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   114    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   115    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   116    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   117    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   118    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   119    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   120    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   121    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   122    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   123    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   124    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   125    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   126    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   127    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   128    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   129    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   130    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   131    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   132    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   133    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   134    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   135    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   136    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   137    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   138    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   139    Groundwater Flow Eqn.
```

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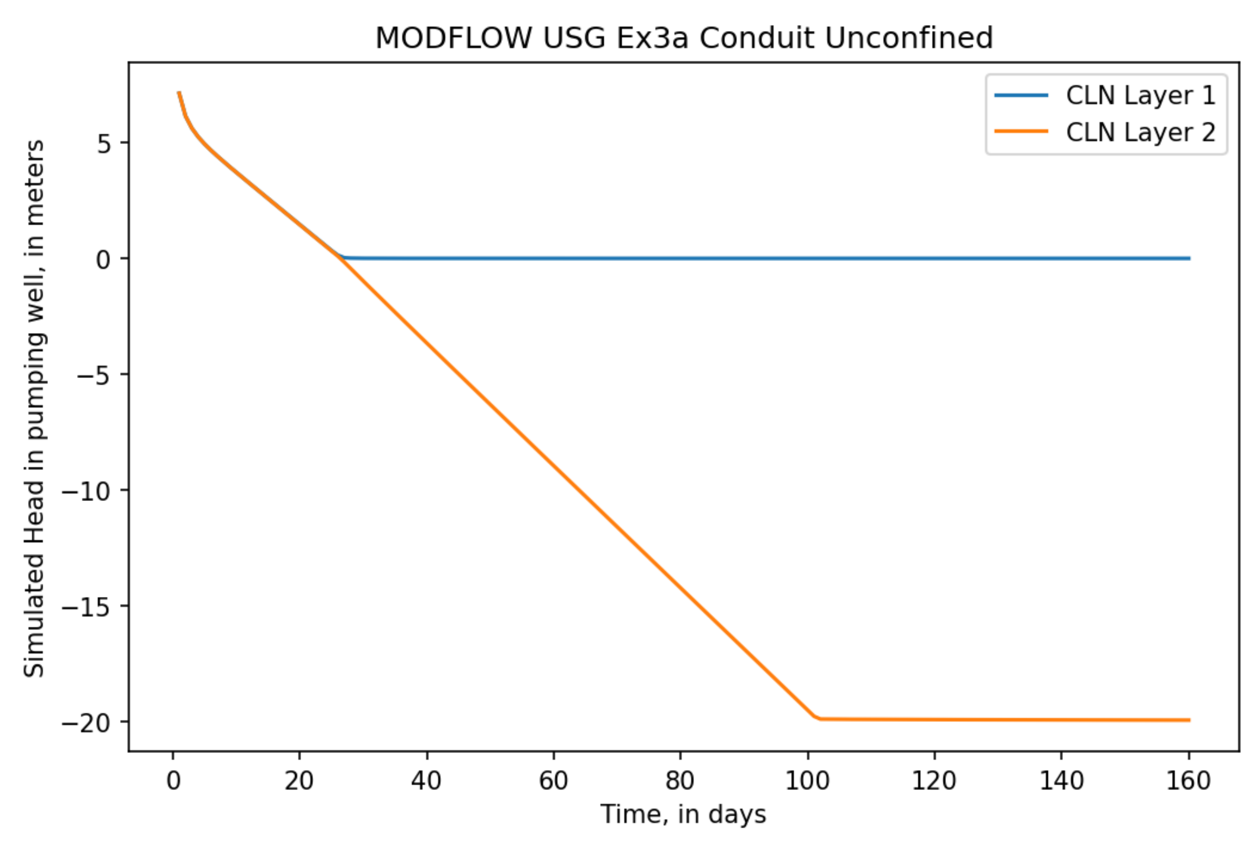
```
Solving:  Stress period:     1    Time step:   140    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   141    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   142    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   143    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   144    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   145    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   146    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   147    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   148    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   149    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   150    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   151    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   152    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   153    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   154    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   155    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   156    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   157    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   158    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   159    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   160    Groundwater Flow Eqn.
Run end date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:30:37
Elapsed run time:  9.809 Seconds

 Normal termination of simulation
```

[19]:
```
head_file = os.path.join(mf.model_ws, f"{modelname}.clnhd")
headobj = flopy.utils.HeadFile(head_file)

simtimes = headobj.get_times()
nper = len(simtimes)
nnode = mf.cln.nclnnds

simhead = np.zeros((1, 1, nnode, nper))
for i in range(nper):
    simhead[:, :, :, i] = headobj.get_data(kstpkper=(i, 0))

head_case1 = np.squeeze(simhead)
```

[20]:
```
fig = plt.figure(figsize=(8, 5), dpi=150)
ax = fig.add_subplot(111)
ax.plot(simtimes, head_case1[0], label="CLN Layer 1")
ax.plot(simtimes, head_case1[1], label="CLN Layer 2")
ax.set_xlabel("Time, in days")
ax.set_ylabel("Simulated Head in pumping well, in meters")
ax.set_title("MODFLOW USG Ex3a Conduit Unconfined")
ax.legend()
```

[20]:
```
<matplotlib.legend.Legend at 0x7f5b91ae7160>
```



[21]:
```
cbb_file = os.path.join(mf.model_ws, f"{modelname}.clncb")
cbb = flopy.utils.CellBudgetFile(cbb_file)
# cbb.list_records()

simflow = cbb.get_data(kstpkper=(0, 0), text="GWF")[0]
for i in range(nper - 1):
    simflow = np.append(
        simflow, cbb.get_data(kstpkper=(i + 1, 0), text="GWF")[0]
    )

flow_case1 = simflow
```

Modify CLN amd WEL package to example create 03B_conduit_unconfined of mfusg 1.5

The problem is solved using only one CLN conduit cell to represent the well connecting both aquifer layers. This is conceptually equivalent to the MNW methodology and does not colve for flow within the well. The behavior of unconfined flow between the well and layer 1 negalects the dry-cell condition whereby head in the well is below the bottom of layer 1.

[22]:
```
modelname = "ex03b"
model_ws = os.path.join(cln_ws, modelname)

mf.model_ws = model_ws
mf._set_name(modelname)
```

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```
for i, fname in enumerate(mf.output_fnames):
    mf.output_fnames[i] = modelname + os.path.splitext(fname)[1]
```

```
creating model workspace...
   ../../../../../../../tmp/tmpt3x301w5/ex03b

changing model workspace...
   ../../../../../../../tmp/tmpt3x301w5/ex03b
```

[23]:
```
mf.remove_package("CLN")

node_prop = [[1, 1, 0, 30.0, -20.0, 1.57]]
cln_gwc = [
    [1, 1, 50, 50, 0, 0, 10.0, 1.0, 0],
    [1, 2, 50, 50, 0, 0, 10.0, 1.0, 0],
]

strt = 20.0
cln = flopy.mfusg.MfUsgCln(
    mf,
    ncln=1,
    iclnnds=-1,
    nndcln=1,
    nclngwc=2,
    node_prop=node_prop,
    cln_gwc=cln_gwc,
    cln_circ=cln_circ,
    strt=strt,
    unitnumber=unitnumber,
)
```

```
removing Package:  ['CLN']
adding Package:  CLN
```

[24]:
```
mf.remove_package("WEL")

options = []
options.append("autoflowreduce")
options.append("iunitafr 55")
cln_stress_period_data = {0: [[0, -62840.0]]}

wel = flopy.mfusg.MfUsgWel(
    mf,
    ipakcb=ipakcb,
    options=options,
    cln_stress_period_data=cln_stress_period_data,
)
```

```
removing Package:  ['WEL']
Adding ex03b.afr (unit=55) to the output list.
adding Package:  WEL
```

[25]:
```python
mf.write_input()
success, buff = mf.run_model(silent=True, report=True)
if success:
    for line in buff:
        print(line)
else:
    raise ValueError("Failed to run.")
```

```
Writing packages:
   Package:  DIS
   Package:  BAS6
   Package:  BCF6
   Package:  SMS
   Package:  OC
   Package:  CLN
   Package:  WEL


                                  MODFLOW-USG
    U.S. GEOLOGICAL SURVEY MODULAR FINITE-DIFFERENCE GROUNDWATER FLOW MODEL
                             Version 1.5.00 02/27/2019

 Using NAME file: ex03b.nam
 Run start date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:30:38

 Solving:  Stress period:     1    Time step:     1    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:     2    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:     3    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:     4    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:     5    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:     6    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:     7    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:     8    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:     9    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    10    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    11    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    12    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    13    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    14    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    15    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    16    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    17    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    18    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    19    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    20    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    21    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    22    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    23    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    24    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    25    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    26    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    27    Groundwater Flow Eqn.
```

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```
Solving:  Stress period:     1    Time step:    28    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    29    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    30    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    31    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    32    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    33    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    34    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    35    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    36    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    37    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    38    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    39    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    40    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    41    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    42    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    43    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    44    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    45    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    46    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    47    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    48    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    49    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    50    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    51    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    52    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    53    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    54    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    55    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    56    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    57    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    58    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    59    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    60    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    61    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    62    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    63    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    64    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    65    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    66    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    67    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    68    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    69    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    70    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    71    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    72    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    73    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    74    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    75    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    76    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    77    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    78    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    79    Groundwater Flow Eqn.
```

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```
Solving:  Stress period:     1    Time step:    80    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    81    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    82    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    83    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    84    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    85    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    86    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    87    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    88    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    89    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    90    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    91    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    92    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    93    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    94    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    95    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    96    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    97    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    98    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    99    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   100    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   101    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   102    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   103    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   104    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   105    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   106    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   107    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   108    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   109    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   110    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   111    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   112    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   113    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   114    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   115    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   116    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   117    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   118    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   119    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   120    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   121    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   122    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   123    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   124    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   125    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   126    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   127    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   128    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   129    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   130    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   131    Groundwater Flow Eqn.
```

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```
 Solving:  Stress period:     1    Time step:   132    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:   133    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:   134    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:   135    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:   136    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:   137    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:   138    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:   139    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:   140    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:   141    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:   142    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:   143    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:   144    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:   145    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:   146    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:   147    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:   148    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:   149    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:   150    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:   151    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:   152    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:   153    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:   154    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:   155    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:   156    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:   157    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:   158    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:   159    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:   160    Groundwater Flow Eqn.
 Run end date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:30:45
 Elapsed run time:  7.263 Seconds

  Normal termination of simulation
```

[26]:
```
head_file = os.path.join(mf.model_ws, f"{modelname}.clnhd")
headobj = flopy.utils.HeadFile(head_file)

simtimes = headobj.get_times()
nper = len(simtimes)
nnode = mf.cln.nclnnds

simhead = np.zeros((1, 1, nnode, nper))
for i in range(nper):
    simhead[:, :, :, i] = headobj.get_data(kstpkper=(i, 0))

head_case2 = np.squeeze(simhead)
```

[27]:
```
fig = plt.figure(figsize=(8, 5), dpi=150)
ax = fig.add_subplot(111)
ax.plot(simtimes, head_case2)
ax.set_xlabel("Time, in days")
```

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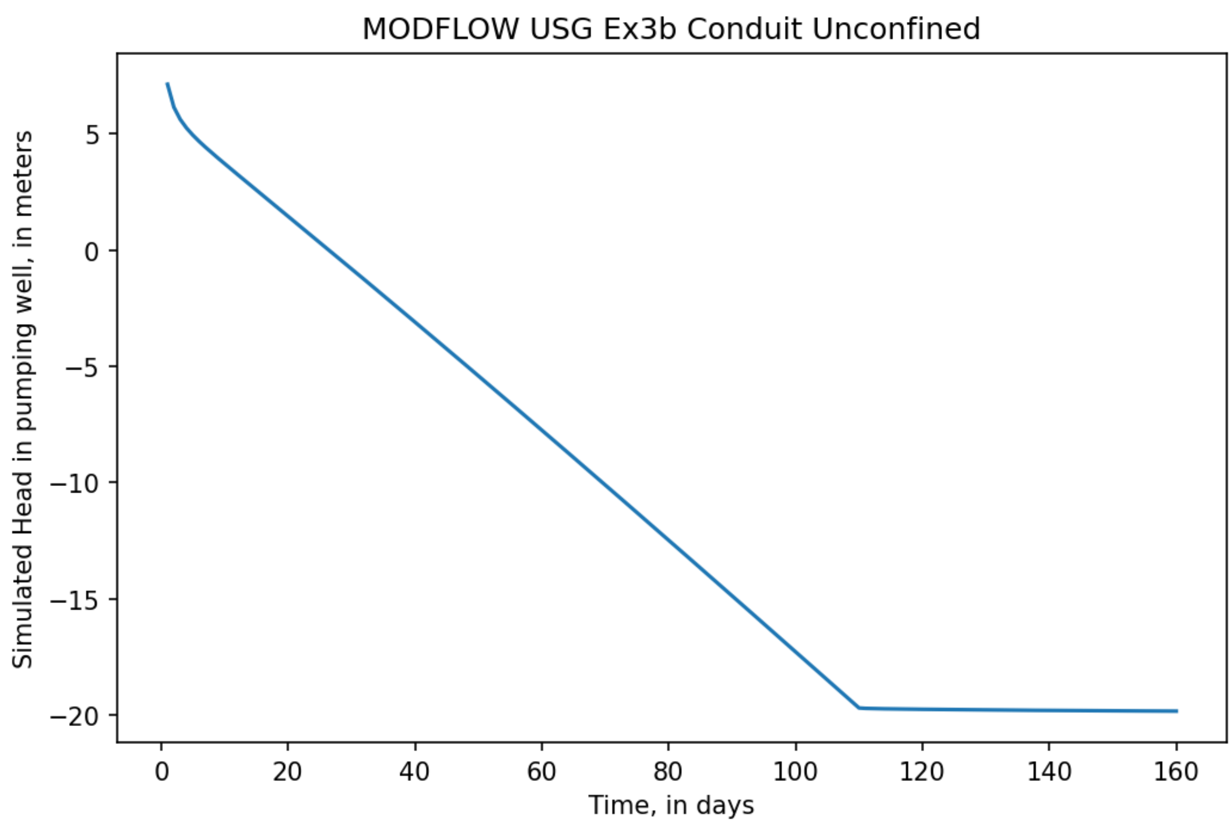
```
ax.set_ylabel("Simulated Head in pumping well, in meters")
ax.set_title("MODFLOW USG Ex3b Conduit Unconfined")
```

[27]:
```
Text(0.5, 1.0, 'MODFLOW USG Ex3b Conduit Unconfined')
```



[28]:
```
cbb_file = os.path.join(mf.model_ws, f"{modelname}.clncb")
cbb = flopy.utils.CellBudgetFile(cbb_file)
# cbb.list_records()

simflow = cbb.get_data(kstpkper=(0, 0), text="GWF")[0]
for i in range(nper - 1):
    simflow = np.append(
        simflow, cbb.get_data(kstpkper=(i + 1, 0), text="GWF")[0]
    )

flow_case2 = simflow
```

Modify CLN amd WEL package to example create 03C_conduit_unconfined of mfusg 1.5

The CLN well is discretized using two conduit geometry CLN cells but with the confined option for flow winthin the conduit and between CLN and GWF domains.

[29]:
```
modelname = "ex03c"
model_ws = os.path.join(cln_ws, modelname)

mf.model_ws = model_ws
mf._set_name(modelname)
for i, fname in enumerate(mf.output_fnames):
    mf.output_fnames[i] = modelname + os.path.splitext(fname)[1]
```

```
creating model workspace...
   ../../../../../../../tmp/tmpt3x301w5/ex03c

changing model workspace...
   ../../../../../../../tmp/tmpt3x301w5/ex03c
```

[30]:
```
mf.remove_package("CLN")

node_prop = [
    [1, 1, 0, 10.0, 0.0, 1.57, 1, 0],
    [2, 1, 0, 10.0, -20.0, 1.57, 1, 0],
]
cln_gwc = [
    [1, 1, 50, 50, 0, 0, 10.0, 1.0, 0],
    [2, 2, 50, 50, 0, 0, 10.0, 1.0, 0],
]

strt = [10.0, 30.0]

cln = flopy.mfusg.MfUsgCln(
    mf,
    ncln=1,
    iclnnds=-1,
    nndcln=2,
    nclngwc=2,
    node_prop=node_prop,
    cln_gwc=cln_gwc,
    cln_circ=cln_circ,
    strt=strt,
    unitnumber=unitnumber,
)
```

```
removing Package:  ['CLN']
adding Package:  CLN
```

[31]:
```
mf.remove_package("WEL")

cln_stress_period_data = {0: [[1, -62840.0]]}

wel = flopy.mfusg.MfUsgWel(
```

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```
    mf,
    ipakcb=ipakcb,
    options=options,
    cln_stress_period_data=cln_stress_period_data,
)
```

```
removing Package:  ['WEL']
adding Package:  WEL
```

[32]:
```
mf.write_input()
success, buff = mf.run_model(silent=True, report=True)
if success:
    for line in buff:
        print(line)
else:
    raise ValueError("Failed to run.")
```

```

Writing packages:
   Package:  DIS
   Package:  BAS6
   Package:  BCF6
   Package:  SMS
   Package:  OC
   Package:  CLN
   Package:  WEL


                                  MODFLOW-USG
    U.S. GEOLOGICAL SURVEY MODULAR FINITE-DIFFERENCE GROUNDWATER FLOW MODEL
                             Version 1.5.00 02/27/2019

 Using NAME file: ex03c.nam
 Run start date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:30:46

 Solving:  Stress period:     1    Time step:     1    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:     2    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:     3    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:     4    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:     5    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:     6    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:     7    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:     8    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:     9    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    10    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    11    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    12    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    13    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    14    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    15    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    16    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    17    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:    18    Groundwater Flow Eqn.
```

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```
Solving:  Stress period:     1    Time step:    19    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    20    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    21    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    22    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    23    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    24    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    25    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    26    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    27    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    28    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    29    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    30    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    31    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    32    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    33    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    34    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    35    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    36    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    37    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    38    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    39    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    40    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    41    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    42    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    43    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    44    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    45    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    46    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    47    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    48    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    49    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    50    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    51    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    52    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    53    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    54    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    55    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    56    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    57    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    58    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    59    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    60    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    61    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    62    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    63    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    64    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    65    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    66    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    67    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    68    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    69    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    70    Groundwater Flow Eqn.
```

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Solving:  Stress period:     1    Time step:    71    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:    72    Groundwater Flow Eqn.
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Solving:  Stress period:     1    Time step:   122    Groundwater Flow Eqn.
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 Solving:  Stress period:     1    Time step:   123    Groundwater Flow Eqn.
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 Solving:  Stress period:     1    Time step:   159    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:   160    Groundwater Flow Eqn.
 Run end date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:30:54
 Elapsed run time:  8.651 Seconds

  Normal termination of simulation
```

[33]:
```python
head_file = os.path.join(mf.model_ws, f"{modelname}.clnhd")
headobj = flopy.utils.HeadFile(head_file)

simtimes = headobj.get_times()
nper = len(simtimes)
nnode = mf.cln.nclnnds

simhead = np.zeros((1, 1, nnode, nper))
for i in range(nper):
```

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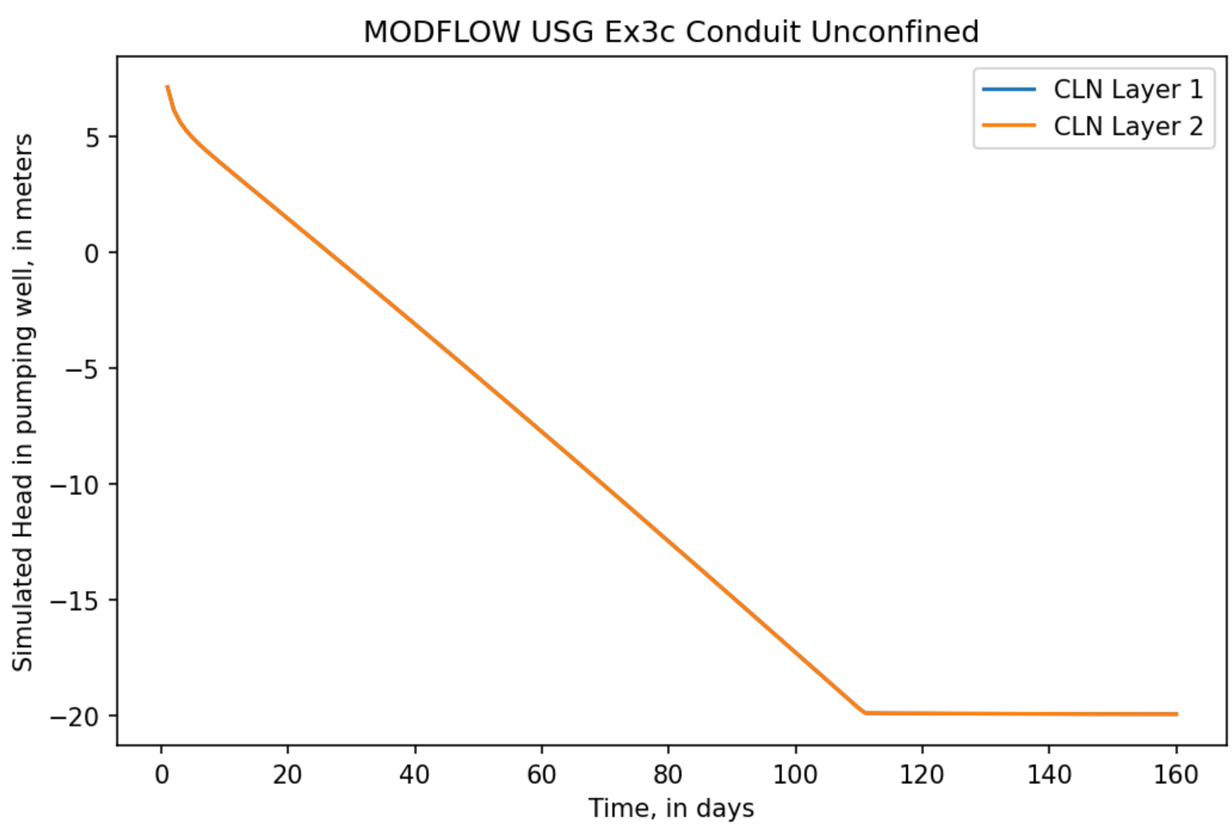
```
    simhead[:, :, :, i] = headobj.get_data(kstpkper=(i, 0))

head_case3 = np.squeeze(simhead)
```

[34]:
```
fig = plt.figure(figsize=(8, 5), dpi=150)
ax = fig.add_subplot(111)
ax.plot(simtimes, head_case3[0], label="CLN Layer 1")
ax.plot(simtimes, head_case3[1], label="CLN Layer 2")
ax.set_xlabel("Time, in days")
ax.set_ylabel("Simulated Head in pumping well, in meters")
ax.set_title("MODFLOW USG Ex3c Conduit Unconfined")
ax.legend()
```

[34]:
```
<matplotlib.legend.Legend at 0x7f5b915ac0a0>
```



[35]:
```
cbb_file = os.path.join(mf.model_ws, f"{modelname}.clncb")
cbb = flopy.utils.CellBudgetFile(cbb_file)
# cbb.list_records()

simflow = cbb.get_data(kstpkper=(0, 0), text="GWF")[0]
for i in range(nper - 1):
    simflow = np.append(
        simflow, cbb.get_data(kstpkper=(i + 1, 0), text="GWF")[0]
    )
```

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```
flow_case3 = simflow
```

Modify CLN amd WEL package to example create 03D_conduit_unconfined of mfusg 1.5

Only one CLN cell to discretize the well but includes the "flow-to-dry-cell" option to limit flow in layer 1 when the head in the CLN cell is below the bottom of the layer.

[36]:
```
modelname = "ex03d"
model_ws = os.path.join(cln_ws, modelname)

mf.model_ws = model_ws
mf._set_name(modelname)
for i, fname in enumerate(mf.output_fnames):
    mf.output_fnames[i] = modelname + os.path.splitext(fname)[1]
```

```
creating model workspace...
   ../../../../../../../../tmp/tmpt3x301w5/ex03d

changing model workspace...
   ../../../../../../../../tmp/tmpt3x301w5/ex03d
```

[37]:
```
mf.remove_package("CLN")

node_prop = [[1, 1, 0, 30.0, -20.0, 1.57]]
cln_gwc = [
    [1, 1, 50, 50, 0, 0, 10.0, 1.0, 1],
    [1, 2, 50, 50, 0, 0, 10.0, 1.0, 1],
]

strt = 20.0

cln = flopy.mfusg.MfUsgCln(
    mf,
    ncln=1,
    iclnnds=-1,
    nndcln=1,
    nclngwc=2,
    node_prop=node_prop,
    cln_gwc=cln_gwc,
    cln_circ=cln_circ,
    strt=strt,
    unitnumber=unitnumber,
)
```

```
removing Package:  ['CLN']
adding Package:  CLN
```

[38]:
```
mf.remove_package("WEL")

cln_stress_period_data = {0: [[0, -62840.0]]}
```

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```
wel = flopy.mfusg.MfUsgWel(
    mf,
    ipakcb=ipakcb,
    options=options,
    cln_stress_period_data=cln_stress_period_data,
)
```

```
removing Package:  ['WEL']
adding Package:  WEL
```

[39]:

```
mf.write_input()
success, buff = mf.run_model(silent=True, report=True)
if success:
    for line in buff:
        print(line)
else:
    raise ValueError("Failed to run.")
```

```

Writing packages:
   Package:  DIS
   Package:  BAS6
   Package:  BCF6
   Package:  SMS
   Package:  OC
   Package:  CLN
   Package:  WEL


                                  MODFLOW-USG
    U.S. GEOLOGICAL SURVEY MODULAR FINITE-DIFFERENCE GROUNDWATER FLOW MODEL
                             Version 1.5.00 02/27/2019

 Using NAME file: ex03d.nam
 Run start date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:30:55

 Solving:  Stress period:     1    Time step:     1    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:     2    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:     3    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:     4    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:     5    Groundwater Flow Eqn.
 Solving:  Stress period:     1    Time step:     6    Groundwater Flow Eqn.
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 Solving:  Stress period:     1    Time step:    16    Groundwater Flow Eqn.
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Solving:  Stress period:     1    Time step:    17    Groundwater Flow Eqn.
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Solving:  Stress period:     1    Time step:   156    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   157    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   158    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   159    Groundwater Flow Eqn.
Solving:  Stress period:     1    Time step:   160    Groundwater Flow Eqn.
Run end date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:31:02
Elapsed run time:  7.193 Seconds

 Normal termination of simulation
```

[40]:
```
head_file = os.path.join(mf.model_ws, f"{modelname}.clnhd")
headobj = flopy.utils.HeadFile(head_file)

simtimes = headobj.get_times()
nper = len(simtimes)
nnode = mf.cln.nclnnds
```

(continues on next page)

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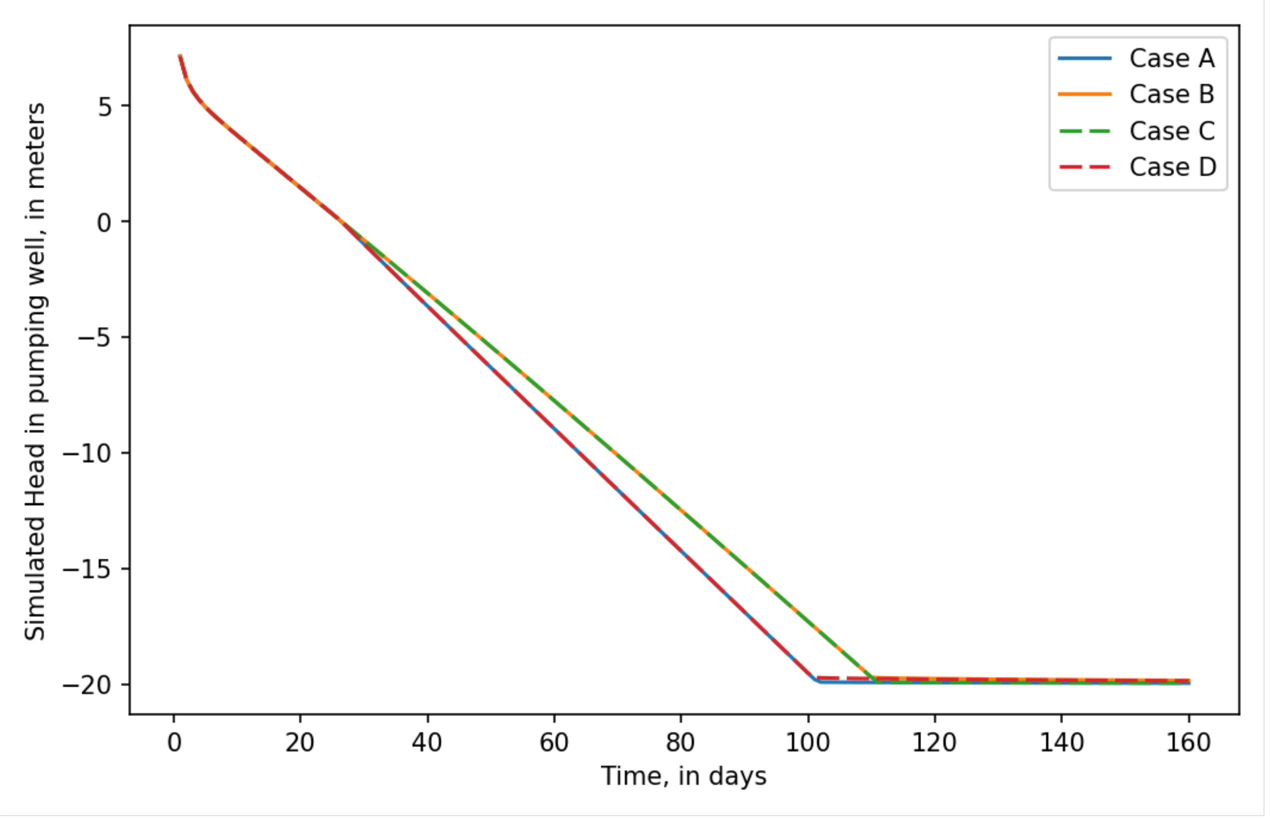
```
simhead = np.zeros((1, 1, nnode, nper))
for i in range(nper):
    simhead[:, :, :, i] = headobj.get_data(kstpkper=(i, 0))

head_case4 = np.squeeze(simhead)
```

[41]:
```
cbb_file = os.path.join(mf.model_ws, f"{modelname}.clncb")
cbb = flopy.utils.CellBudgetFile(cbb_file)
# cbb.list_records()

simflow = cbb.get_data(kstpkper=(0, 0), text="GWF")[0]
for i in range(nper - 1):
    simflow = np.append(
        simflow, cbb.get_data(kstpkper=(i + 1, 0), text="GWF")[0]
    )

flow_case4 = simflow
```

Comparing four cases

[42]:
```
fig = plt.figure(figsize=(8, 5), dpi=150)
ax = fig.add_subplot(111)
ax.plot(simtimes, head_case1[1], label="Case A")
ax.plot(simtimes, head_case2, label="Case B")
ax.plot(simtimes, head_case3[1], dashes=[6, 2], label="Case C")
ax.plot(simtimes, head_case4, dashes=[6, 2], label="Case D")

ax.set_xlabel("Time, in days")
ax.set_ylabel("Simulated Head in pumping well, in meters")
ax.legend()
```

[42]:
```
<matplotlib.legend.Legend at 0x7f5b9145d280>
```



[43]:
```
fig = plt.figure(figsize=(8, 11), dpi=150)
ax1 = fig.add_subplot(211)
ax1.plot(
    simtimes,
    flow_case1[::2,]["q"],
    label="Case A",
)
ax1.plot(
    simtimes,
    flow_case2[::2,]["q"],
    label="Case B",
)
ax1.plot(
    simtimes,
    flow_case3[::2,]["q"],
    dashes=[6, 2],
    label="Case C",
)
ax1.plot(
    simtimes,
    flow_case4[::2,]["q"],
    dashes=[6, 2],
    label="Case D",
)
ax1.set_xlabel("Time, in days")
ax1.set_ylabel("Layer 1 flow to well")
```

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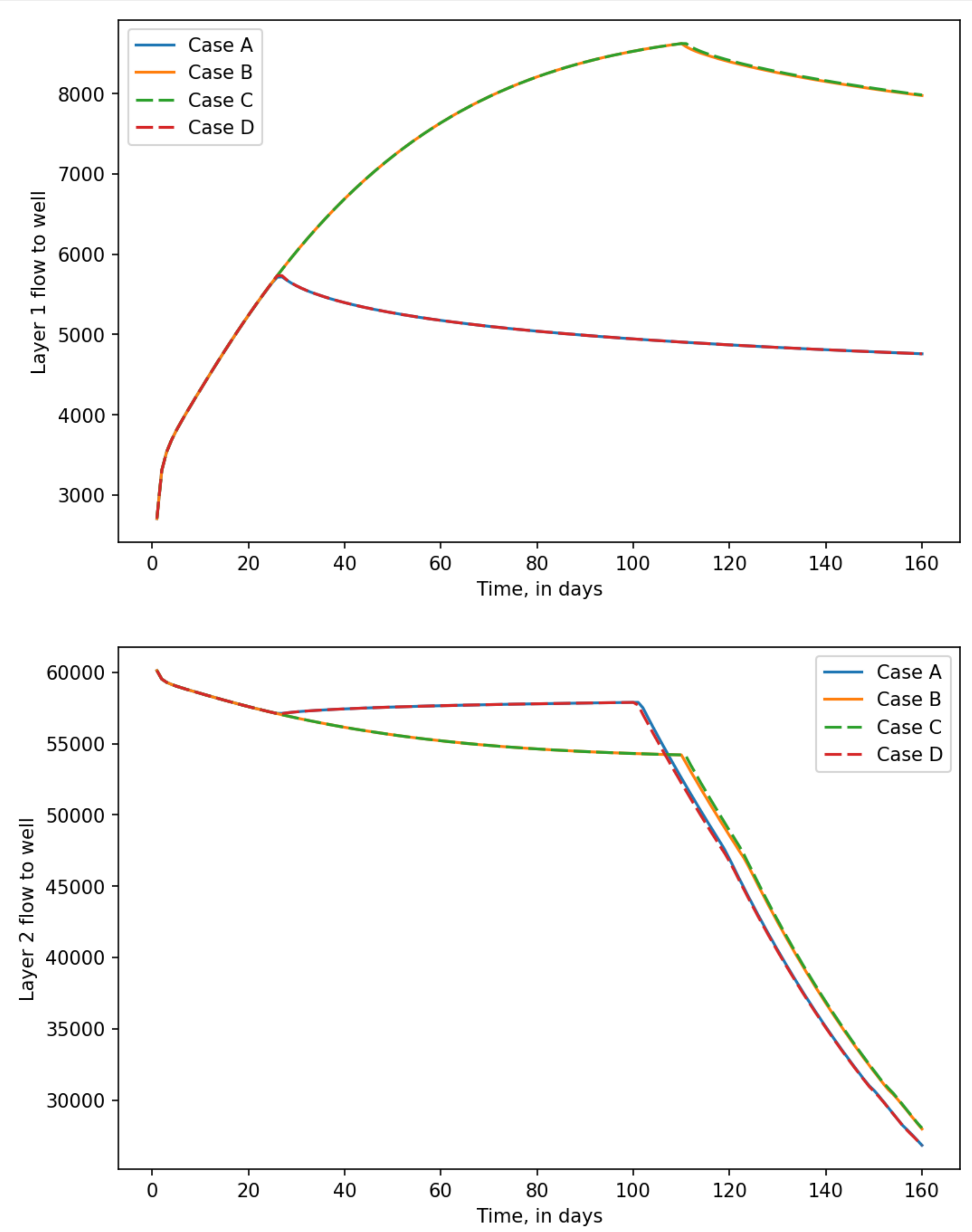
```
ax1.legend()

ax2 = fig.add_subplot(212)
ax2.plot(
    simtimes,
    flow_case1[1::2,]["q"],
    label="Case A",
)
ax2.plot(
    simtimes,
    flow_case2[1::2,]["q"],
    label="Case B",
)
ax2.plot(
    simtimes,
    flow_case3[1::2,]["q"],
    dashes=[6, 2],
    label="Case C",
)
ax2.plot(
    simtimes,
    flow_case4[1::2,]["q"],
    dashes=[6, 2],
    label="Case D",
)
ax2.set_xlabel("Time, in days")
ax2.set_ylabel("Layer 2 flow to well")
ax2.legend()
```

[43]:
```
<matplotlib.legend.Legend at 0x7f5b91518250>
```


Case A
Case B
Case C
Case D
8000
7000
6000
5000
4000
3000
Layer 1 flow to well
0
20
40
60
80
100
120
140
160
Time, in days
60000
55000
50000
45000
40000
35000
30000
Layer 2 flow to well
Case A
Case B
Case C
Case D
0
20
40
60
80
100
120
140
160
Time, in days

6.6.2 MODFLOW-USG Freyberg demo

This example demonstrates a MODFLOW USG Freyberg model, including construction of an `UnstructuredGrid` from a specification file and plotting head data in cross-section.

First we locate the model directory.

[1]:
```python
from pathlib import Path

import flopy

root_name = "freyberg.usg"
model_ws = Path.cwd().parent / "../examples/data" / root_name.replace(".", "_")
```

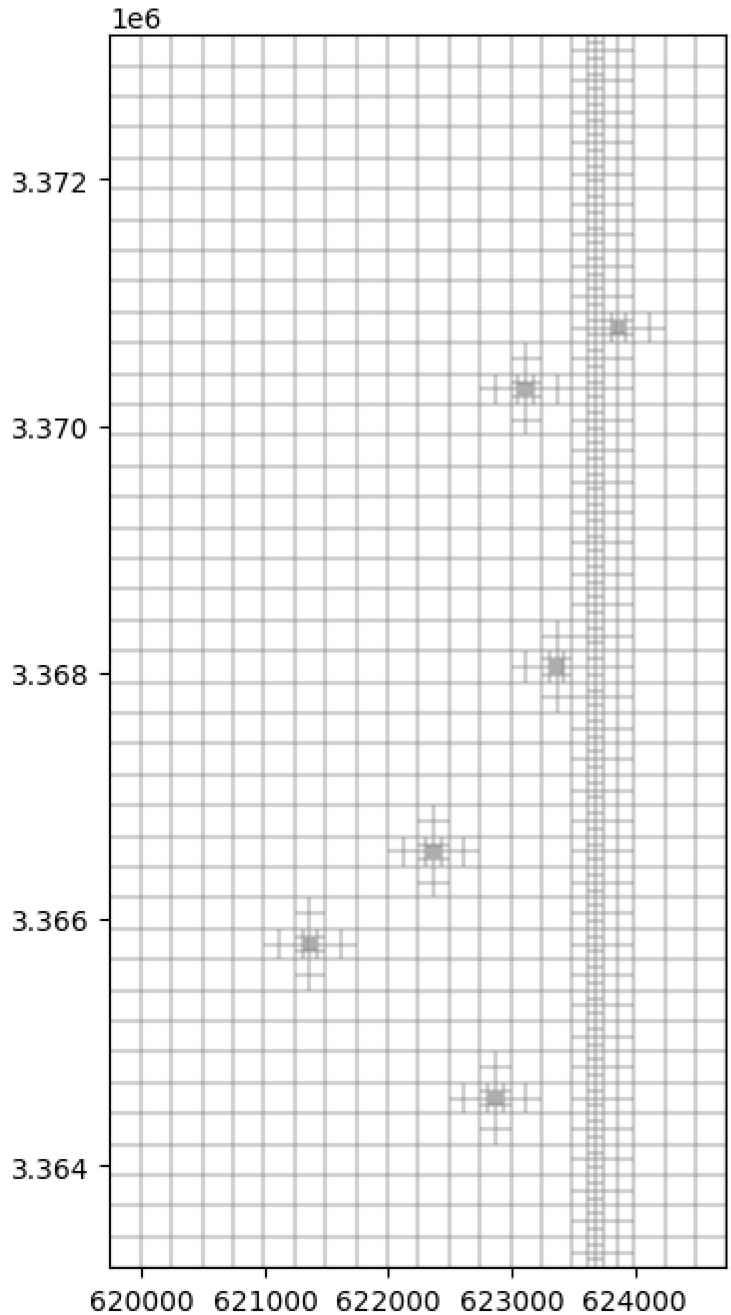
Now construct an `UnstructuredGrid` from a grid specification file.

[2]:
```python
from flopy.discretization import UnstructuredGrid

mfgrid = UnstructuredGrid.from_gridspec(str(model_ws / f"{root_name}.gsf"))
```

Plot the grid in map view.

[3]:
```python
import matplotlib.pyplot as plt

fig = plt.figure(figsize=(8, 8))
ax = fig.add_subplot(1, 1, 1, aspect="equal")
pmv = flopy.plot.PlotMapView(modelgrid=mfgrid, ax=ax)
pmv.plot_grid(alpha=0.1)
```

[3]:
```
<matplotlib.collections.LineCollection at 0x7ff939516820>
```



Create cross-section lines.

[4]:
```python
from flopy.utils.geometry import LineString

lines = [
    LineString(ls)
    for ls in [
        [(623000, 3364000), (623000, 3372000)],
        [(623650, 3364000), (623650, 3372000)],
```

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```
    ]
]
```

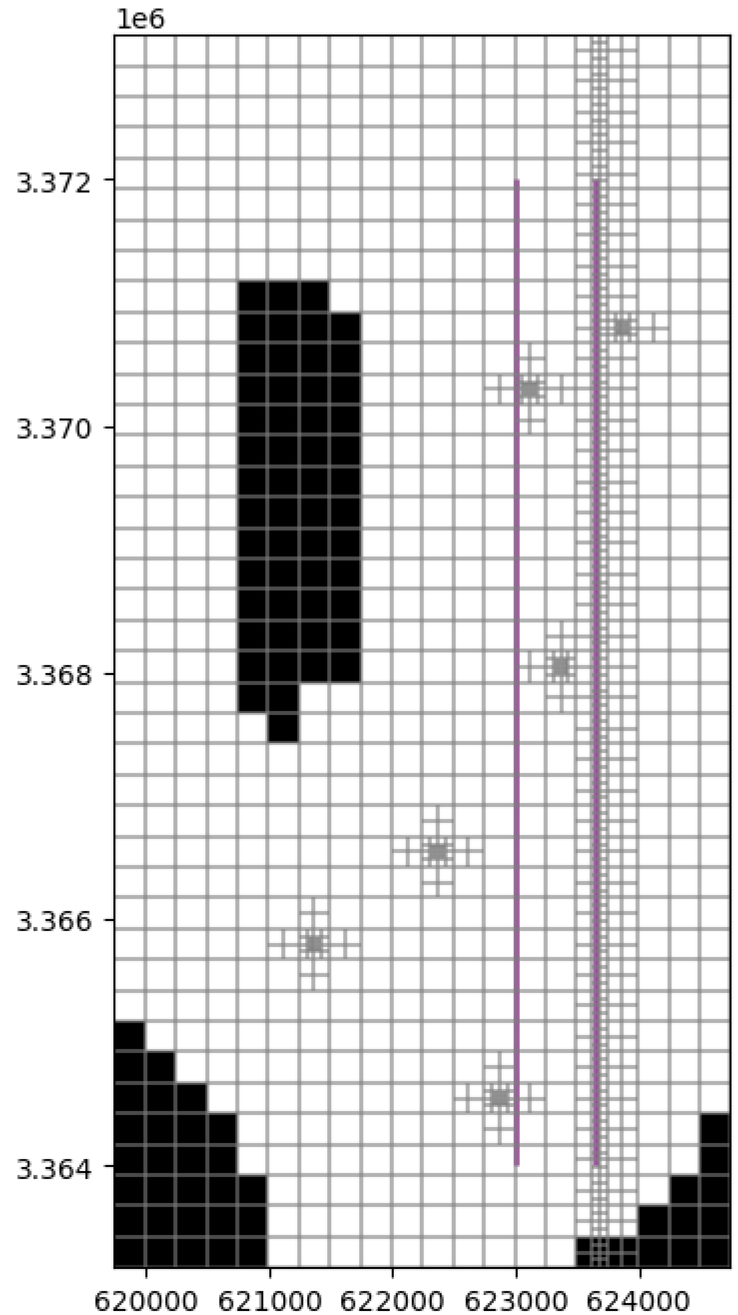
Load the model and retrieve inactive cells.

[5]:
```
gwf = flopy.mfusg.MfUsg.load(
    f"{root_name}.nam",
    model_ws=str(model_ws),
    verbose=False,
    check=False,
    exe_name="mfusg",
)

bas6 = gwf.get_package("bas6")
ibound = bas6.ibound.array
```

Show the map view again with cross-section lines and inactive cells.

[6]:
```
fig = plt.figure(figsize=(8, 8))
ax = fig.add_subplot(1, 1, 1, aspect="equal")
pmv = flopy.plot.PlotMapView(modelgrid=mfgrid, ax=ax)
grid = pmv.plot_grid(alpha=0.2)
shps = pmv.plot_shapes(lines, edgecolor="purple", lw=2, alpha=0.7)
inac = pmv.plot_inactive(ibound=ibound)
```



Next, we can run the model and plot cross-sections of the resulting head. We will run the model in a temporary workspace to avoid altering the example data.

[7]:
```
from tempfile import TemporaryDirectory

# temporary directory
temp_dir = TemporaryDirectory()
work_dir = Path(temp_dir.name) / "freyberg_usg"
```

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```
gwf.change_model_ws(str(work_dir))
gwf.write_name_file()
gwf.write_input()
success, buff = gwf.run_model(silent=True, report=True)
if success:
    for line in buff:
        print(line)
else:
    raise ValueError("Failed to run.")
```

```
creating model workspace...
   ../../../../../../../tmp/tmpw2apvwqg/freyberg_usg

                                 MODFLOW-USG
    U.S. GEOLOGICAL SURVEY MODULAR FINITE-DIFFERENCE GROUNDWATER FLOW MODEL
                            Version 1.5.00 02/27/2019

 Using NAME file: freyberg.usg.nam
 Run start date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:31:08

 Solving:  Stress period:     1    Time step:     1    Groundwater Flow Eqn.
 Solving:  Stress period:     2    Time step:     1    Groundwater Flow Eqn.
 Solving:  Stress period:     3    Time step:     1    Groundwater Flow Eqn.
 Solving:  Stress period:     4    Time step:     1    Groundwater Flow Eqn.
 Solving:  Stress period:     5    Time step:     1    Groundwater Flow Eqn.
 Solving:  Stress period:     6    Time step:     1    Groundwater Flow Eqn.
 Solving:  Stress period:     7    Time step:     1    Groundwater Flow Eqn.
 Solving:  Stress period:     8    Time step:     1    Groundwater Flow Eqn.
 Solving:  Stress period:     9    Time step:     1    Groundwater Flow Eqn.
 Solving:  Stress period:    10    Time step:     1    Groundwater Flow Eqn.
 Solving:  Stress period:    11    Time step:     1    Groundwater Flow Eqn.
 Solving:  Stress period:    12    Time step:     1    Groundwater Flow Eqn.
 Solving:  Stress period:    13    Time step:     1    Groundwater Flow Eqn.
 Solving:  Stress period:    14    Time step:     1    Groundwater Flow Eqn.
 Solving:  Stress period:    15    Time step:     1    Groundwater Flow Eqn.
 Solving:  Stress period:    16    Time step:     1    Groundwater Flow Eqn.
 Solving:  Stress period:    17    Time step:     1    Groundwater Flow Eqn.
 Solving:  Stress period:    18    Time step:     1    Groundwater Flow Eqn.
 Solving:  Stress period:    19    Time step:     1    Groundwater Flow Eqn.
 Solving:  Stress period:    20    Time step:     1    Groundwater Flow Eqn.
 Solving:  Stress period:    21    Time step:     1    Groundwater Flow Eqn.
 Solving:  Stress period:    22    Time step:     1    Groundwater Flow Eqn.
 Solving:  Stress period:    23    Time step:     1    Groundwater Flow Eqn.
 Solving:  Stress period:    24    Time step:     1    Groundwater Flow Eqn.
 Solving:  Stress period:    25    Time step:     1    Groundwater Flow Eqn.
 Run end date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:31:08
 Elapsed run time:  0.273 Seconds

  Normal termination of simulation
```

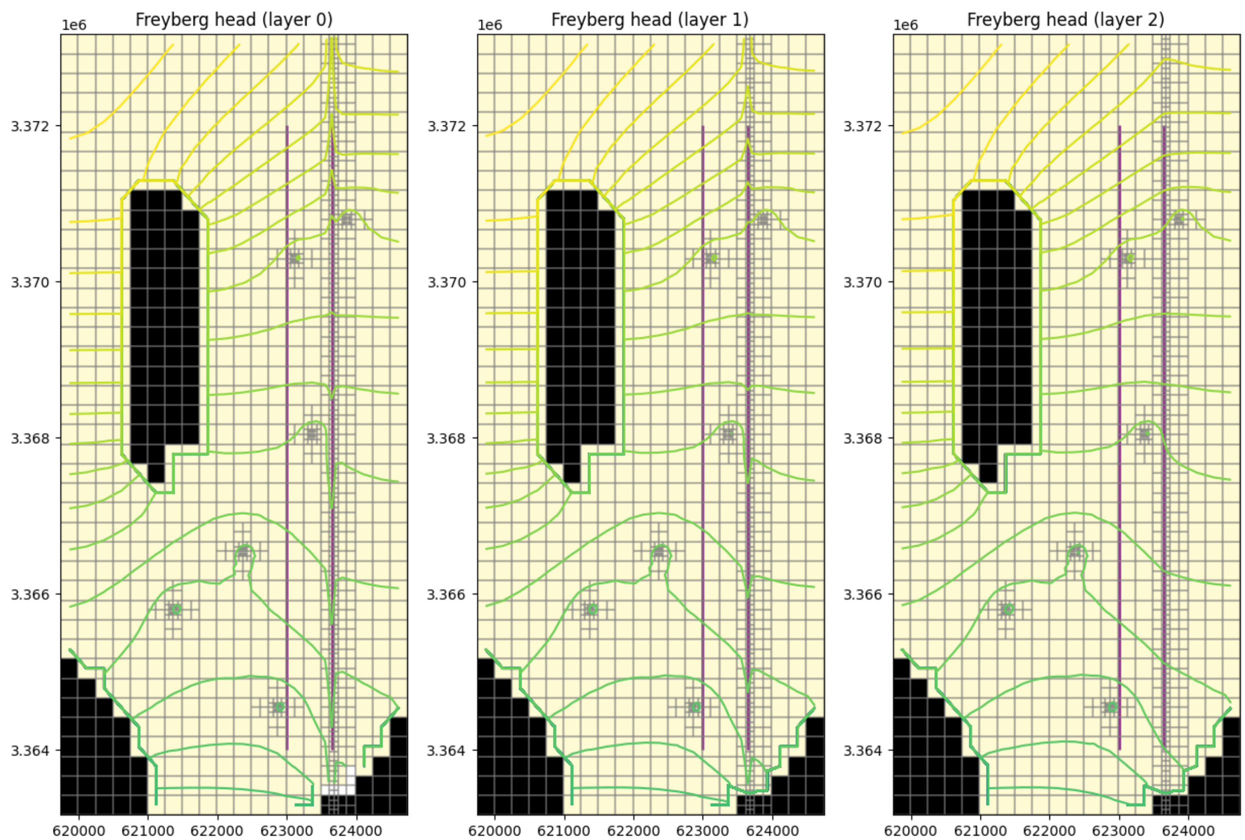
Load head data from the output files:

[8]:
```python
import numpy as np

hds = flopy.utils.HeadUFile(str(work_dir / f"{root_name}.hds"), model=gwf)
times = hds.get_times()
head = np.array(hds.get_data())
print(head.shape)
```

```
(3, 1499)
```

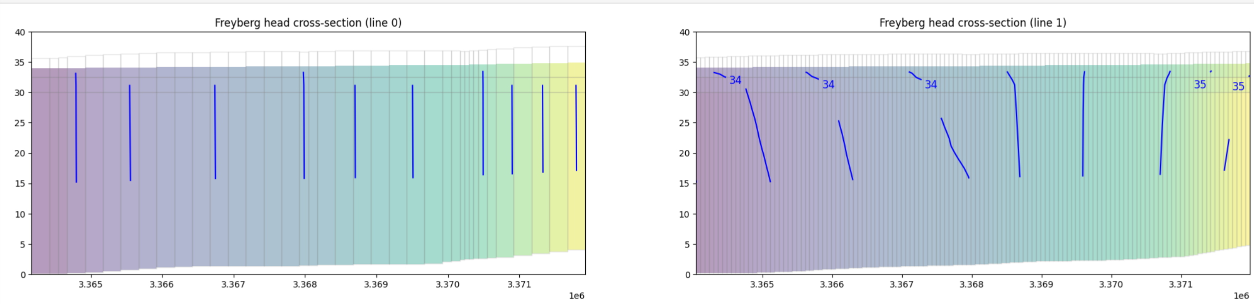
Plot the head colormap and contours for each layer.

[9]:
```python
levels = np.arange(30, 35.4, 0.1)
fig = plt.figure(figsize=(15, 10))

for layer, h in enumerate(head):
    ax = fig.add_subplot(1, len(head), layer + 1)
    ax.set_title(f"Freyberg head (layer {layer})")
    pmv = flopy.plot.PlotMapView(modelgrid=mfgrid, ax=ax)
    mesh = pmv.plot_array(h, alpha=0.2)
    grid = pmv.plot_grid(alpha=0.2)
    shps = pmv.plot_shapes(lines, edgecolor="purple", lw=2, alpha=0.8)
    inac = pmv.plot_inactive(ibound=ibound)
    ctrs = pmv.contour_array(h, levels=levels)
```



A head argument can be provided to `CrossSectionPlot.contour_array()` to show the phreatic surface.

[10]:
```
fig = plt.figure(figsize=(25, 5))

for i, line in enumerate(lines):
    ax = fig.add_subplot(1, len(lines), i + 1)
    ax.set_title(f"Freyberg head cross-section (line {i})")
    xsect = flopy.plot.PlotCrossSection(
        modelgrid=mfgrid,
        ax=ax,
        line={"line": lines[i]},
        geographic_coords=True,
    )
    xsect.plot_array(head, head=head, alpha=0.4)
    xsect.plot_ibound(ibound=ibound, head=head)
    xsect.plot_inactive(ibound=ibound)
    contours = xsect.contour_array(
        head,
        masked_values=[999.0],
        head=head,
        levels=levels,
        alpha=1.0,
        colors="blue",
    )
    plt.clabel(contours, fmt="%.0f", colors="blue", fontsize=12)
    xsect.plot_grid(alpha=0.2)
    ax.set_ylim([0, 40])  # set y axis range to ignore low elevations
```



The head argument can be a 1D array or a 2D array matching the shape of the grid (i.e., `head.shape == (layer count, ncpl)`).

[11]:
```
line = lines[0]

for time in times[0:3]:
    head = np.array(hds.get_data(totim=time))
    head2 = np.hstack(head)

    fig = plt.figure(figsize=(25, 5))
    ax = fig.add_subplot(1, 3, 1)
    ax.set_title(f"Freyberg cross-section (t = {int(time)}, no head)")
    xsect = flopy.plot.PlotCrossSection(
        modelgrid=mfgrid, ax=ax, line={"line": line}, geographic_coords=True
    )
    cmap = xsect.plot_array(
        head2,
```

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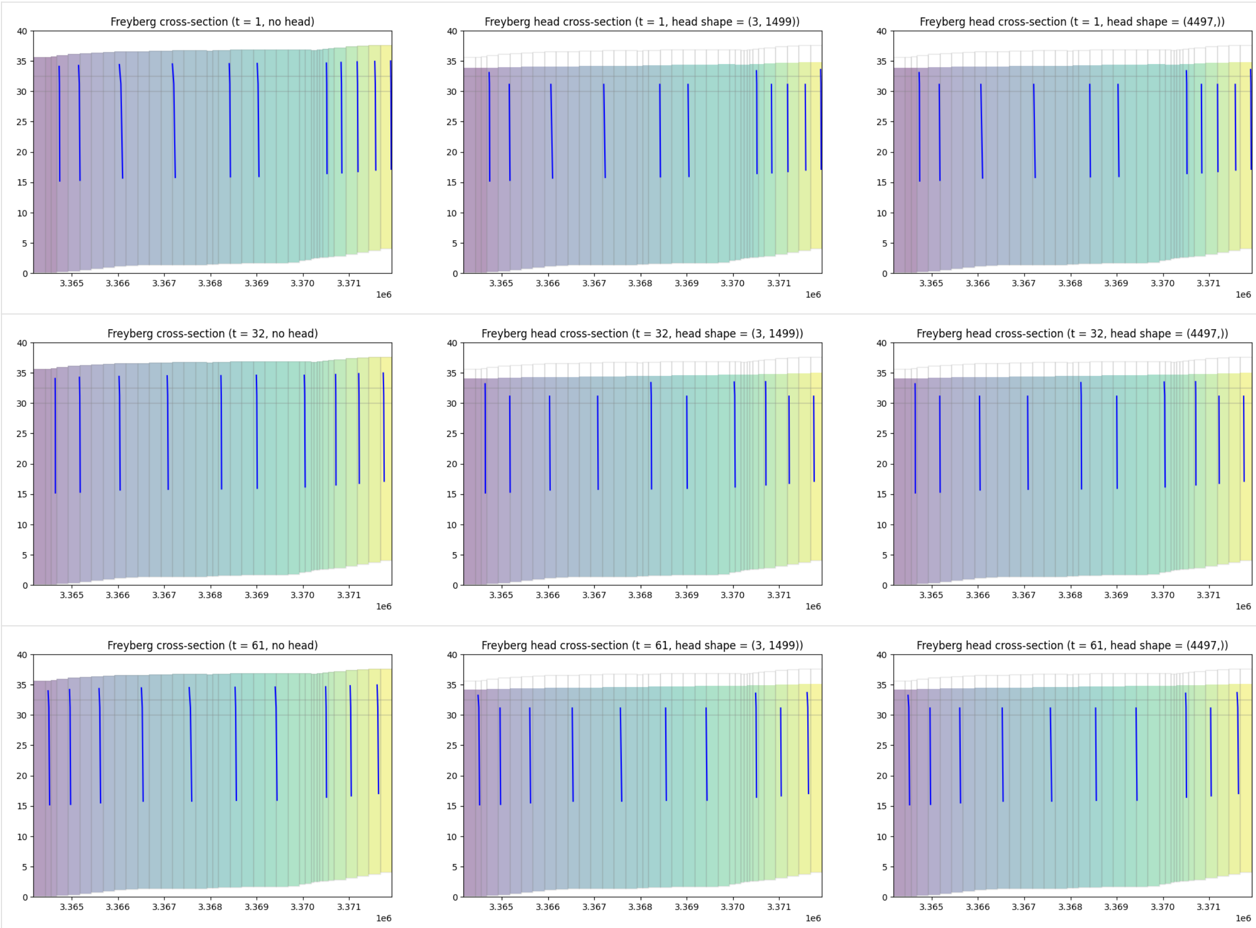
```
        masked_values=[-999.99],
        alpha=0.4,
    )
    contours = xsect.contour_array(
        head2, levels=levels, alpha=1.0, colors="blue"
    )
    xsect.plot_inactive(ibound=ibound, color_noflow=(0.8, 0.8, 0.8))
    xsect.plot_grid(alpha=0.2)
    ax.set_ylim([0, 40])  # set y axis range to ignore low elevations

    ax = fig.add_subplot(1, 3, 2)
    ax.set_title(
        f"Freyberg head cross-section (t = {int(time)}, head shape = {head.shape})"
    )
    xsect = flopy.plot.PlotCrossSection(
        modelgrid=mfgrid, ax=ax, line={"line": line}, geographic_coords=True
    )
    cmap = xsect.plot_array(
        head,
        masked_values=[-999.99],
        head=head,
        alpha=0.4,
    )
    contours = xsect.contour_array(
        head, head=head, levels=levels, alpha=1.0, colors="blue"
    )
    xsect.plot_inactive(ibound=ibound, color_noflow=(0.8, 0.8, 0.8))
    xsect.plot_grid(alpha=0.2)
    ax.set_ylim([0, 40])

    ax = fig.add_subplot(1, 3, 3)
    ax.set_title(
        f"Freyberg head cross-section (t = {int(time)}, head shape = {head2.shape})"
    )
    xsect = flopy.plot.PlotCrossSection(
        modelgrid=mfgrid, ax=ax, line={"line": line}, geographic_coords=True
    )
    cmap = xsect.plot_array(
        head2,
        masked_values=[-999.99],
        head=head2,
        alpha=0.4,
    )
    contours = xsect.contour_array(
        head2, head=head2, levels=levels, alpha=1.0, colors="blue"
    )
    xsect.plot_inactive(ibound=ibound, color_noflow=(0.8, 0.8, 0.8))
    xsect.plot_grid(alpha=0.2)
    ax.set_ylim([0, 40])
```



[12]:
```
try:
    # ignore PermissionError on Windows
    temp_dir.cleanup()
except:
    pass
```

6.6.3 MODFLOW-USG: Discontinuous water table configuration over a stairway impervious base

One of the most challenging numerical cases for MODFLOW arises from drying-rewetting problems often associated with abrupt changes in the elevations of impervious base of a thin unconfined aquifer. This problem simulates a discontinuous water table configuration over a stairway impervious base and flow between constant-head boundaries in column 1 and 200. This problem is based on

Zaidel, J. (2013), Discontinuous Steady-State Analytical Solutions of the Boussinesq Equation and Their Numerical Representation by Modflow. Groundwater, 51: 952–959. doi: 10.1111/gwat.12019

The model consistes of a grid of 200 columns, 1 row, and 1 layer; a bottom altitude of ranging from 20 to 0 m; constant heads of 23 and 5 m in column 1 and 200, respectively; and a horizontal hydraulic conductivity of $1x10^{-4}$ m/d. The discretization is 5 m in the row direction for all cells.

In this example results from MODFLOW-USG will be evaluated.

[1]:
```
import sys
from pathlib import Path
from tempfile import TemporaryDirectory

import matplotlib as mpl
import matplotlib.pyplot as plt
import numpy as np

import flopy

print(sys.version)
print(f"numpy version: {np.__version__}")
print(f"matplotlib version: {mpl.__version__}")
print(f"flopy version: {flopy.__version__}")
```

```
3.8.18 (default, Aug 28 2023, 08:27:22)
[GCC 11.4.0]
numpy version: 1.24.4
matplotlib version: 3.7.4
flopy version: 3.5.0
```

[2]:
```
# Set temporary workspace and MODFLOW executable
# (assume executable is in users' path variable)
mfexe = "mfusg"
modelname = "zaidel"
temp_dir = TemporaryDirectory()
workspace = Path(temp_dir.name) / modelname
workspace.mkdir()
```

Model parameters

[3]:
```
# model dimensions
nlay, nrow, ncol = 1, 1, 200
delr = 50.0
delc = 1.0

# boundary heads
h1 = 23.0
h2 = 5.0

# cell centroid locations
x = np.arange(0.0, float(ncol) * delr, delr) + delr / 2.0

# ibound
ibound = np.ones((nlay, nrow, ncol), dtype=int)
ibound[:, :, 0] = -1
ibound[:, :, -1] = -1

# bottom of the model
botm = 25 * np.ones((nlay + 1, nrow, ncol), dtype=float)
base = 20.0
```

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```
for j in range(ncol):
    botm[1, :, j] = base
    # if j > 0 and j % 40 == 0:
    if j + 1 in [40, 80, 120, 160]:
        base -= 5

# starting heads
strt = h1 * np.ones((nlay, nrow, ncol), dtype=float)
strt[:, :, -1] = h2
```

Create and run the MODFLOW-USG model

[4]:
```
# make the flopy model
mf = flopy.mfusg.MfUsg(modelname=modelname, exe_name=mfexe, model_ws=workspace)
dis = flopy.modflow.ModflowDis(
    mf,
    nlay,
    nrow,
    ncol,
    delr=delr,
    delc=delc,
    top=botm[0, :, :],
    botm=botm[1:, :, :],
    perlen=1,
    nstp=1,
    steady=True,
)
bas = flopy.modflow.ModflowBas(mf, ibound=ibound, strt=strt)
lpf = flopy.mfusg.MfUsgLpf(mf, hk=0.0001, laytyp=4)
oc = flopy.modflow.ModflowOc(
    mf,
    stress_period_data={
        (0, 0): ["print budget", "print head", "save head", "save budget"]
    },
)
sms = flopy.mfusg.MfUsgSms(
    mf,
    nonlinmeth=1,
    linmeth=1,
    numtrack=50,
    btol=1.1,
    breduc=0.70,
    reslim=0.0,
    theta=0.85,
    akappa=0.0001,
    gamma=0.0,
    amomentum=0.1,
    iacl=2,
    norder=0,
    level=5,
```

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```
    north=7,
    iredsys=0,
    rrctol=0.0,
    idroptol=1,
    epsrn=1.0e-5,
    mxiter=500,
    hclose=1.0e-3,
    hiclose=1.0e-3,
    iter1=50,
)
mf.write_input()

# remove any existing head files
try:
    (workspace / f"{modelname}.hds").unlink(missing_ok=True)
except:
    pass

# run the model
success, buff = mf.run_model(silent=True, report=True)
assert success, "Failed to run"
for line in buff:
    print(line)
```

```
                                  MODFLOW-USG
    U.S. GEOLOGICAL SURVEY MODULAR FINITE-DIFFERENCE GROUNDWATER FLOW MODEL
                             Version 1.5.00 02/27/2019

 Using NAME file: zaidel.nam
 Run start date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:30:02

 Solving:  Stress period:     1    Time step:     1    Groundwater Flow Eqn.
 Run end date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:30:02
 Elapsed run time:  0.003 Seconds

  Normal termination of simulation
```

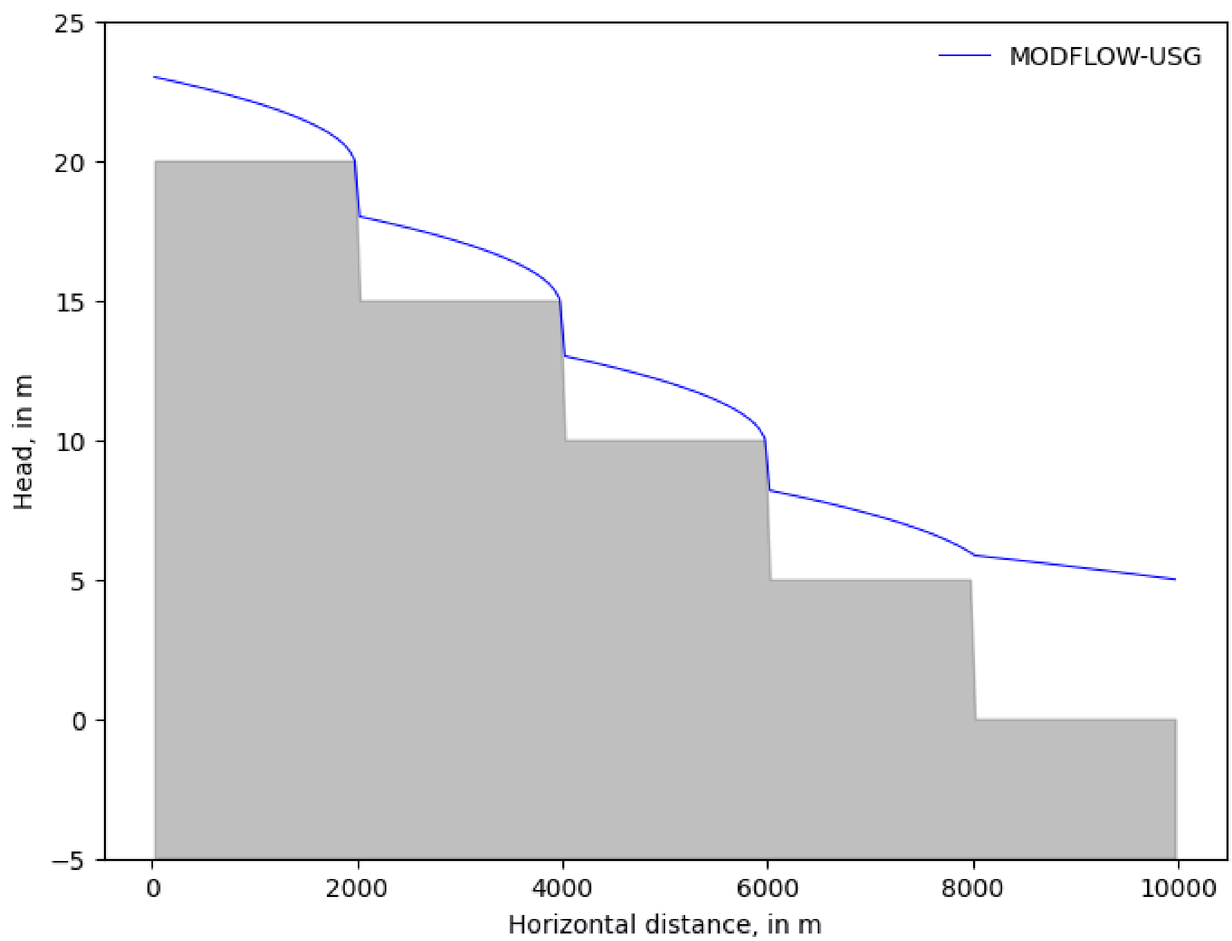
Read the simulated MODFLOW-USG model results

[5]:
```
# Create the mfusg headfile object
headfile = workspace / f"{modelname}.hds"
headobj = flopy.utils.HeadFile(headfile)
times = headobj.get_times()
mfusghead = headobj.get_data(totim=times[-1])
```

Plot MODFLOW-USG results

[6]:
```
fig = plt.figure(figsize=(8, 6))
fig.subplots_adjust(
    left=None, bottom=None, right=None, top=None, wspace=0.25, hspace=0.25
)
ax = fig.add_subplot(1, 1, 1)
ax.plot(
    x, mfusghead[0, 0, :], linewidth=0.75, color="blue", label="MODFLOW-USG"
)
ax.fill_between(x, y1=botm[1, 0, :], y2=-5, color="0.5", alpha=0.5)
leg = ax.legend(loc="upper right")
leg.draw_frame(False)
ax.set_xlabel("Horizontal distance, in m")
ax.set_ylabel("Head, in m")
ax.set_ylim(-5, 25)
```

[6]:
```
(-5.0, 25.0)
```



[7]:
```
try:
    # ignore PermissionError on Windows
    temp_dir.cleanup()
```

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```
except:
    pass
```

6.7 MODFLOW-2005/MODFLOW-NWT examples

6.7.1 Flopy Drain Return (DRT) capabilities

[1]:
```
import os
```

[2]:
```
import sys
from tempfile import TemporaryDirectory

import matplotlib as mpl
import matplotlib.pyplot as plt
import numpy as np

import flopy

print(sys.version)
print(f"numpy version: {np.__version__}")
print(f"matplotlib version: {mpl.__version__}")
print(f"flopy version: {flopy.__version__}")
```

```
3.8.18 (default, Aug 28 2023, 08:27:22)
[GCC 11.4.0]
numpy version: 1.24.4
matplotlib version: 3.7.4
flopy version: 3.5.0
```

[3]:
```
# temporary directory
temp_dir = TemporaryDirectory()
modelpth = temp_dir.name

# creat the model package
m = flopy.modflow.Modflow(
    "drt_test",
    model_ws=modelpth,
    exe_name="mfnwt",
    version="mfnwt",
)
d = flopy.modflow.ModflowDis(
    m,
    nlay=1,
    nrow=10,
    ncol=10,
    nper=1,
    perlen=1,
    top=10,
    botm=0,
```

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```
    steady=True,
)
b = flopy.modflow.ModflowBas(m, strt=10, ibound=1)
u = flopy.modflow.ModflowUpw(m, hk=10)
n = flopy.modflow.ModflowNwt(m)
o = flopy.modflow.ModflowOc(m)
```

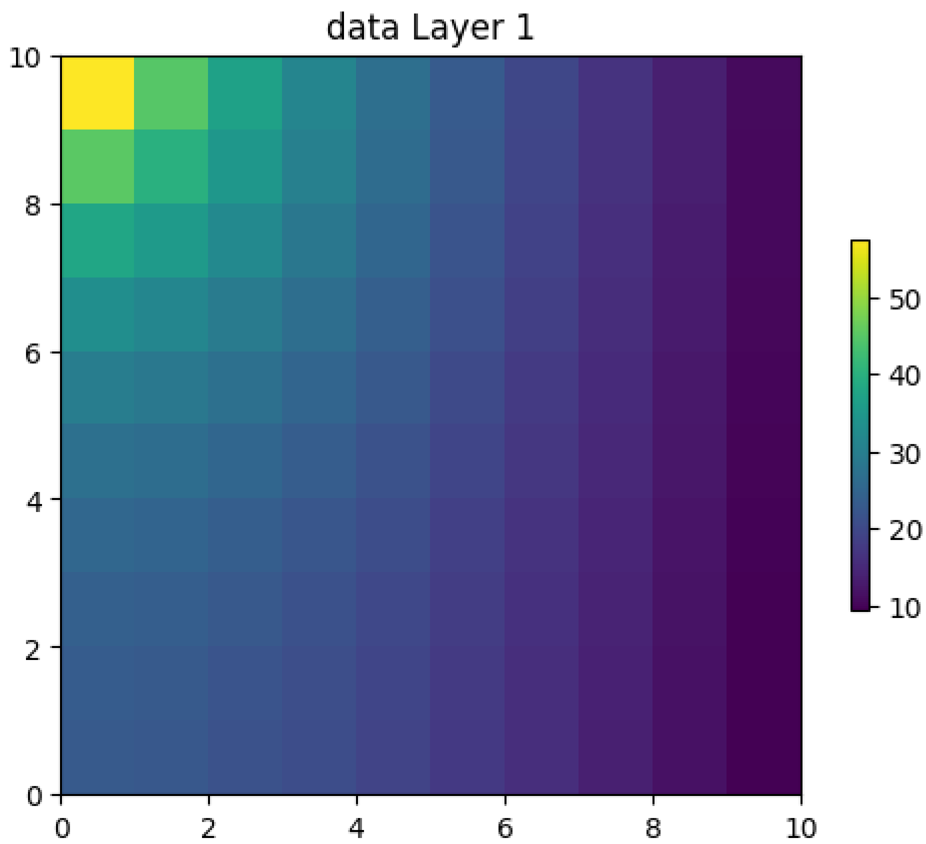
[4]:
```
# create the drt package
spd = []
for i in range(m.nrow):
    spd.append([0, i, m.ncol - 1, 5.0, 50.0, 1, 1, 1, 1.0])
d = flopy.modflow.ModflowDrt(m, stress_period_data={0: spd})
```

[5]:
```
# run the drt model
m.write_input()
success, buff = m.run_model(silent=True, report=True)
if success:
    for line in buff:
        print(line)
else:
    raise ValueError("Failed to run.")
```

```
                                  MODFLOW-NWT-SWR1
    U.S. GEOLOGICAL SURVEY MODULAR FINITE-DIFFERENCE GROUNDWATER-FLOW MODEL
                             WITH NEWTON FORMULATION
                             Version 1.3.0 07/01/2022
                    BASED ON MODFLOW-2005 Version 1.12.0 02/03/2017

                    SWR1 Version 1.05.0 03/10/2022

 Using NAME file: drt_test.nam
 Run start date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:27:41

 Solving:  Stress period:     1    Time step:     1    Groundwater-Flow Eqn.
 Run end date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:27:41
 Elapsed run time:  0.001 Seconds

  Normal termination of simulation
```

[6]:
```
# plot heads for the drt model
hds = flopy.utils.HeadFile(os.path.join(m.model_ws, f"{m.name}.hds"))
hds.plot(colorbar=True)
```

[6]:
```
<Axes: title={'center': 'data Layer 1'}>
```




```
[7]: # remove the drt package and create a standard drain file
spd = []
for i in range(m.nrow):
    spd.append([0, i, m.ncol - 1, 5.0, 1.0])
m.remove_package("DRT")
d = flopy.modflow.ModflowDrn(m, stress_period_data={0: spd})
```

```
[8]: # run the drain model
m.write_input()
success, buff = m.run_model(silent=True, report=True)
if success:
    for line in buff:
        print(line)
else:
    raise ValueError("Failed to run.")
```

```
                                  MODFLOW-NWT-SWR1
    U.S. GEOLOGICAL SURVEY MODULAR FINITE-DIFFERENCE GROUNDWATER-FLOW MODEL
                             WITH NEWTON FORMULATION
                             Version 1.3.0 07/01/2022
                    BASED ON MODFLOW-2005 Version 1.12.0 02/03/2017

                    SWR1 Version 1.05.0 03/10/2022
```

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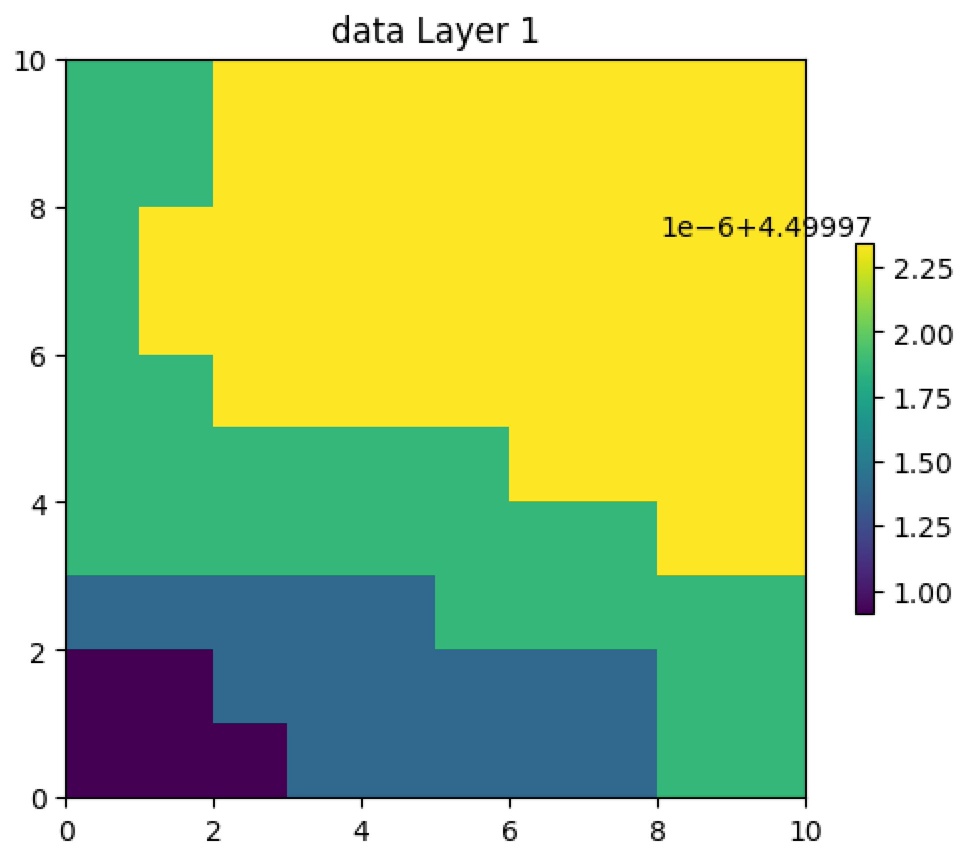
```
Using NAME file: drt_test.nam
Run start date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:27:42

Solving:  Stress period:     1    Time step:     1    Groundwater-Flow Eqn.
Run end date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:27:42
Elapsed run time:  0.001 Seconds

 Normal termination of simulation
```

[9]:
```
# plot the heads for the model with the drain
hds = flopy.utils.HeadFile(os.path.join(m.model_ws, f"{m.name}.hds"))
hds.plot(colorbar=True)
```

[9]:
```
<Axes: title={'center': 'data Layer 1'}>
```



[10]:
```
try:
    # ignore PermissionError on Windows
    temp_dir.cleanup()
except:
    pass
```

6.7.2 Lake Package Example

First set the path and import the required packages. The flopy path doesn't have to be set if you install flopy from a binary installer. If you want to run this notebook, you have to set the path to your own flopy path.

[1]:
```
import os
import sys
from tempfile import TemporaryDirectory

import matplotlib as mpl
import matplotlib.pyplot as plt
import numpy as np

# run installed version of flopy or add local path
try:
    import flopy
except:
    fpth = os.path.abspath(os.path.join("..", ".."))
    sys.path.append(fpth)
    import flopy

# temporary directory
temp_dir = TemporaryDirectory()
workspace = temp_dir.name

print(sys.version)
print(f"numpy version: {np.__version__}")
print(f"matplotlib version: {mpl.__version__}")
print(f"flopy version: {flopy.__version__}")
```

```
3.8.18 (default, Aug 28 2023, 08:27:22)
[GCC 11.4.0]
numpy version: 1.24.4
matplotlib version: 3.7.4
flopy version: 3.5.0
```

We are creating a square model with a specified head equal to `h1` along all boundaries. The head at the cell in the center in the top layer is fixed to `h2`. First, set the name of the model and the parameters of the model: the number of layers `Nlay`, the number of rows and columns `N`, lengths of the sides of the model `L`, aquifer thickness `H`, hydraulic conductivity `k`

[2]:
```
name = "lake_example"
h1 = 100
h2 = 90
Nlay = 10
N = 101
L = 400.0
H = 50.0
k = 1.0
```

Create a MODFLOW model and store it (in this case in the variable `ml`, but you can call it whatever you want). The modelname will be the name given to all MODFLOW files (input and output). The exe_name should be the full path to your MODFLOW executable. The version is either 'mf2k' for MODFLOW2000 or 'mf2005'for MODFLOW2005.

[3]:
```
ml = flopy.modflow.Modflow(
    modelname=name, exe_name="mf2005", version="mf2005", model_ws=workspace
)
```

Define the discretization of the model. All layers are given equal thickness. The `bot` array is build from the `Hlay` values to indicate top and bottom of each layer, and `delrow` and `delcol` are computed from model size `L` and number of cells `N`. Once these are all computed, the Discretization file is built.

[4]:
```
bot = np.linspace(-H / Nlay, -H, Nlay)
delrow = delcol = L / (N - 1)
dis = flopy.modflow.ModflowDis(
    ml,
    nlay=Nlay,
    nrow=N,
    ncol=N,
    delr=delrow,
    delc=delcol,
    top=0.0,
    botm=bot,
    laycbd=0,
)
```

Next we specify the boundary conditions and starting heads with the Basic package. The `ibound` array will be `1` in all cells in all layers, except for along the boundary and in the cell at the center in the top layer where it is set to `-1` to indicate fixed heads. The starting heads are used to define the heads in the fixed head cells (this is a steady simulation, so none of the other starting values matter). So we set the starting heads to `h1` everywhere, except for the head at the center of the model in the top layer.

[5]:
```
Nhalf = int((N - 1) / 2)
ibound = np.ones((Nlay, N, N), dtype=int)
ibound[:, 0, :] = -1
ibound[:, -1, :] = -1
ibound[:, :, 0] = -1
ibound[:, :, -1] = -1
ibound[0, Nhalf, Nhalf] = -1
start = h1 * np.ones((N, N))
start[Nhalf, Nhalf] = h2
bas = flopy.modflow.ModflowBas(ml, ibound=ibound, strt=start)
```

The aquifer properties (really only the hydraulic conductivity) are defined with the LPF package.

[6]:
```
lpf = flopy.modflow.ModflowLpf(ml, hk=k)
```

Finally, we need to specify the solver we want to use (PCG with default values), and the output control (using the default values). Then we are ready to write all MODFLOW input files and run MODFLOW.

[7]:
```
pcg = flopy.modflow.ModflowPcg(ml)
oc = flopy.modflow.ModflowOc(ml)
ml.write_input()
success, buff = ml.run_model(silent=True, report=True)
if success:
    for line in buff:
        print(line)
```

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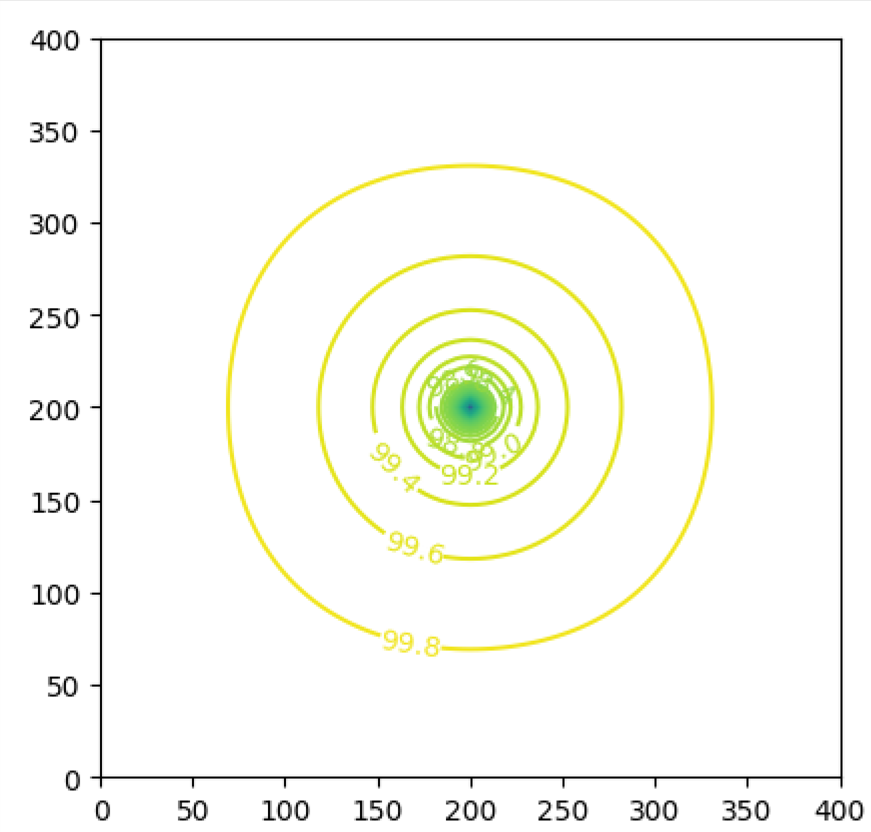
```
else:
    raise ValueError("Failed to run.")
```

```
                                  MODFLOW-2005
    U.S. GEOLOGICAL SURVEY MODULAR FINITE-DIFFERENCE GROUND-WATER FLOW MODEL
                             Version 1.12.00 2/3/2017

 Using NAME file: lake_example.nam
 Run start date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:29:52

 Solving:  Stress period:     1    Time step:     1    Ground-Water Flow Eqn.
 Run end date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:29:52
 Elapsed run time:  0.263 Seconds

  Normal termination of simulation
```

Once the model has terminated normally, we can read the heads file. First, a link to the heads file is created with `HeadFile`. The link can then be accessed with the `get_data` function, by specifying, in this case, the step number and period number for which we want to retrieve data. A three-dimensional array is returned of size `nlay, nrow, ncol`. Matplotlib contouring functions are used to make contours of the layers or a cross-section.

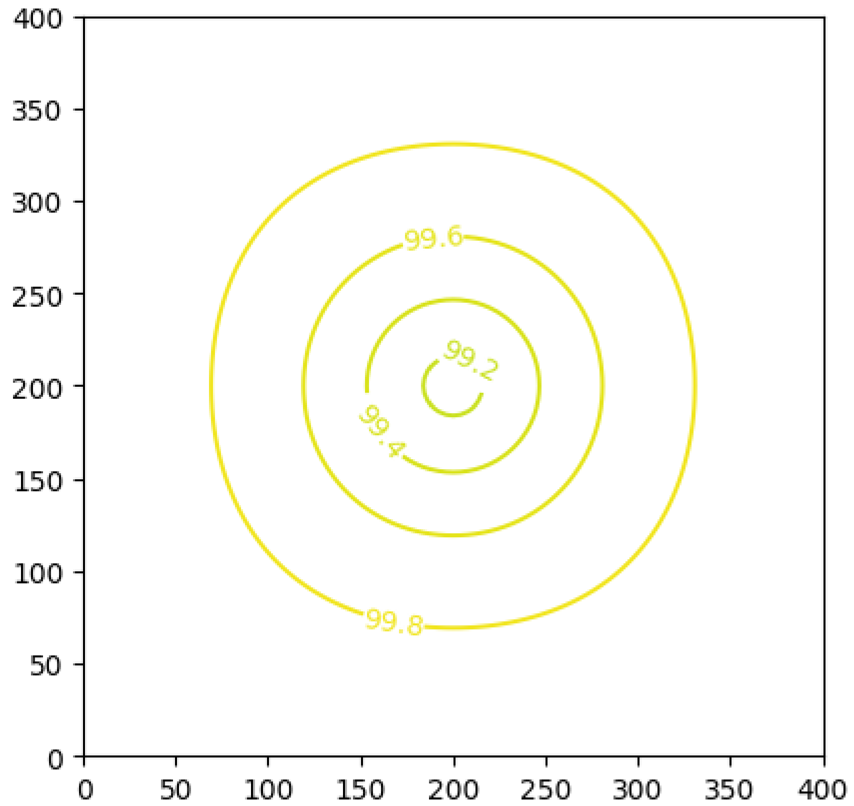
[8]:
```
hds = flopy.utils.HeadFile(os.path.join(workspace, f"{name}.hds"))
h = hds.get_data(kstpkper=(0, 0))
x = y = np.linspace(0, L, N)
c = plt.contour(x, y, h[0], np.arange(90, 100.1, 0.2))
plt.clabel(c, fmt="%2.1f")
plt.axis("scaled")
```

[8]:
```
(0.0, 400.0, 0.0, 400.0)
```



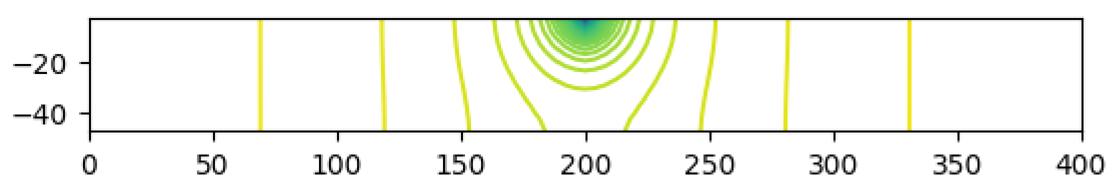
[9]:
```
x = y = np.linspace(0, L, N)
c = plt.contour(x, y, h[-1], np.arange(90, 100.1, 0.2))
plt.clabel(c, fmt="%1.1f")
plt.axis("scaled")
```

[9]:
```
(0.0, 400.0, 0.0, 400.0)
```



[10]:
```
z = np.linspace(-H / Nlay / 2, -H + H / Nlay / 2, Nlay)
c = plt.contour(x, z, h[:, 50, :], np.arange(90, 100.1, 0.2))
plt.axis("scaled")
```

[10]:
```
(0.0, 400.0, -47.5, -2.5)
```



[11]:
```
try:
    # ignore PermissionError on Windows
    temp_dir.cleanup()
except:
    pass
```

6.7.3 Simple water-table solution with recharge

This problem is an unconfined system with a uniform recharge rate, a horizontal bottom, and flow between constant-head boundaries in column 1 and 100. MODFLOW models cannot match the analytical solution exactly because they do not allow recharge to constant-head cells. Constant-head cells in column 1 and 100 were made very thin (0.1 m) in the direction of flow to minimize the effect of recharge applied to them. The analytical solution for this problem can be written as:

$$h = \sqrt{b_1^2 - \frac{x}{L}(b_1^2 - b_2^2) + (\frac{Rx}{K}(L - x))} + z_{bottom}$$

where R is the recharge rate, K is the the hydraulic conductivity in the horizontal direction, b_1 is the specified saturated thickness at the left boundary, b_2 is the specified saturated thickness at the right boundary, x is the distance from the left boundary L is the length of the model domain, and z_{bottom} is the elebation of the bottom of the aquifer.

The model consistes of a grid of 100 columns, 1 row, and 1 layer; a bottom altitude of 0 m; constant heads of 20 and 11m in column 1 and 100, respectively; a recharge rate of 0.001 m/d; and a horizontal hydraulic conductivity of 50 m/d. The discretization is 0.1 m in the row direction for the constant-head cells (column 1 and 100) and 50 m for all other cells.

[1]:
```python
import sys
from pathlib import Path
from tempfile import TemporaryDirectory

import matplotlib as mpl
import matplotlib.pyplot as plt
import numpy as np

import flopy

print(sys.version)
print(f"numpy version: {np.__version__}")
print(f"matplotlib version: {mpl.__version__}")
print(f"flopy version: {flopy.__version__}")
```

```
3.8.18 (default, Aug 28 2023, 08:27:22)
[GCC 11.4.0]
numpy version: 1.24.4
matplotlib version: 3.7.4
flopy version: 3.5.0
```

[2]:
```python
# Set name of MODFLOW exe
#  assumes executable is in users path statement
exe_name = "mfnwt"
mfexe = exe_name
```

Create a temporary workspace.

[3]:
```python
temp_dir = TemporaryDirectory()
workspace = Path(temp_dir.name)
workspace.mkdir(exist_ok=True)
modelname = "watertable"
```

Define a function to calculate the analytical solution at specified points in an aquifer.

[4]:
```
def analytical_water_table_solution(h1, h2, z, R, K, L, x):
    h = np.zeros((x.shape[0]), float)
    # dx = x[1] - x[0]
    # x -= dx
    b1 = h1 - z
    b2 = h2 - z
    h = (
        np.sqrt(
            b1**2 - (x / L) * (b1**2 - b2**2) + (R * x / K) * (L - x)
        )
        + z
    )
    return h
```

Define model data required to create input files and calculate the analytical solution.

[5]:
```
# model dimensions
nlay, nrow, ncol = 1, 1, 100

# cell spacing
delr = 50.0
delc = 1.0

# domain length
L = 5000.0

# boundary heads
h1 = 20.0
h2 = 11.0

# ibound
ibound = np.ones((nlay, nrow, ncol), dtype=int)

# starting heads
strt = np.zeros((nlay, nrow, ncol), dtype=float)
strt[0, 0, 0] = h1
strt[0, 0, -1] = h2

# top of the aquifer
top = 25.0

# bottom of the aquifer
botm = 0.0

# hydraulic conductivity
hk = 50.0

# location of cell centroids
x = np.arange(0.0, L, delr) + (delr / 2.0)

# location of cell edges
xa = np.arange(0, L + delr, delr)
```

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```
# recharge rate
rchrate = 0.001

# calculate the head at the cell centroids using the analytical solution function
hac = analytical_water_table_solution(h1, h2, botm, rchrate, hk, L, x)

# calculate the head at the cell edges using the analytical solution function
ha = analytical_water_table_solution(h1, h2, botm, rchrate, hk, L, xa)

# ghbs
# ghb conductance
b1, b2 = 0.5 * (h1 + hac[0]), 0.5 * (h2 + hac[-1])
c1, c2 = hk * b1 * delc / (0.5 * delr), hk * b2 * delc / (0.5 * delr)
# dtype
ghb_dtype = flopy.modflow.ModflowGhb.get_default_dtype()
print(ghb_dtype)
# build ghb recarray
stress_period_data = np.zeros((2), dtype=ghb_dtype)
stress_period_data = stress_period_data.view(np.recarray)
print("stress_period_data: ", stress_period_data)
print("type is: ", type(stress_period_data))
# fill ghb recarray
stress_period_data[0] = (0, 0, 0, h1, c1)
stress_period_data[1] = (0, 0, ncol - 1, h2, c2)
```

```
[('k', '<i8'), ('i', '<i8'), ('j', '<i8'), ('bhead', '<f4'), ('cond', '<f4')]
stress_period_data:  [(0, 0, 0, 0., 0.) (0, 0, 0, 0., 0.)]
type is:  <class 'numpy.recarray'>
```

Create and run the MODFLOW-NWT model.

[6]:
```
mf = flopy.modflow.Modflow(
    modelname=modelname, exe_name=mfexe, model_ws=workspace, version="mfnwt"
)
dis = flopy.modflow.ModflowDis(
    mf,
    nlay,
    nrow,
    ncol,
    delr=delr,
    delc=delc,
    top=top,
    botm=botm,
    perlen=1,
    nstp=1,
    steady=True,
)
bas = flopy.modflow.ModflowBas(mf, ibound=ibound, strt=strt)
lpf = flopy.modflow.ModflowUpw(mf, hk=hk, laytyp=1)
ghb = flopy.modflow.ModflowGhb(mf, stress_period_data=stress_period_data)
rch = flopy.modflow.ModflowRch(mf, rech=rchrate, nrchop=1)
oc = flopy.modflow.ModflowOc(mf)
nwt = flopy.modflow.ModflowNwt(mf, linmeth=2, iprnwt=1, options="COMPLEX")
```

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```
mf.write_input()

# remove existing heads results, if necessary
try:
    (workspace / f"{modelname}.hds").unlink(missing_ok=True)
except:
    pass
# run existing model
success, buff = mf.run_model(silent=True, report=True)
assert success, "Failed to run"
for line in buff:
    print(line)
```

```
                                  MODFLOW-NWT-SWR1
    U.S. GEOLOGICAL SURVEY MODULAR FINITE-DIFFERENCE GROUNDWATER-FLOW MODEL
                             WITH NEWTON FORMULATION
                             Version 1.3.0 07/01/2022
                    BASED ON MODFLOW-2005 Version 1.12.0 02/03/2017

                    SWR1 Version 1.05.0 03/10/2022

 Using NAME file: watertable.nam
 Run start date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:30:22

 Solving:  Stress period:     1    Time step:     1    Groundwater-Flow Eqn.
 Run end date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:30:22
 Elapsed run time:  0.007 Seconds

  Normal termination of simulation
```

Read the simulation's results.

```
[7]: # Create the headfile object
headfile = workspace / f"{modelname}.hds"
headobj = flopy.utils.HeadFile(headfile, precision="single")
times = headobj.get_times()
head = headobj.get_data(totim=times[-1])
```

Plot the MODFLOW-NWT results and compare to the analytical solution.

```
[8]: fig = plt.figure(figsize=(16, 6))
fig.subplots_adjust(
    left=None, bottom=None, right=None, top=None, wspace=0.25, hspace=0.25
)

ax = fig.add_subplot(1, 3, 1)
ax.plot(xa, ha, linewidth=8, color="0.5", label="analytical solution")
ax.plot(x, head[0, 0, :], color="red", label="MODFLOW-2015")
leg = ax.legend(loc="lower left")
leg.draw_frame(False)
ax.set_xlabel("Horizontal distance, in m")
ax.set_ylabel("Head, in m")
```

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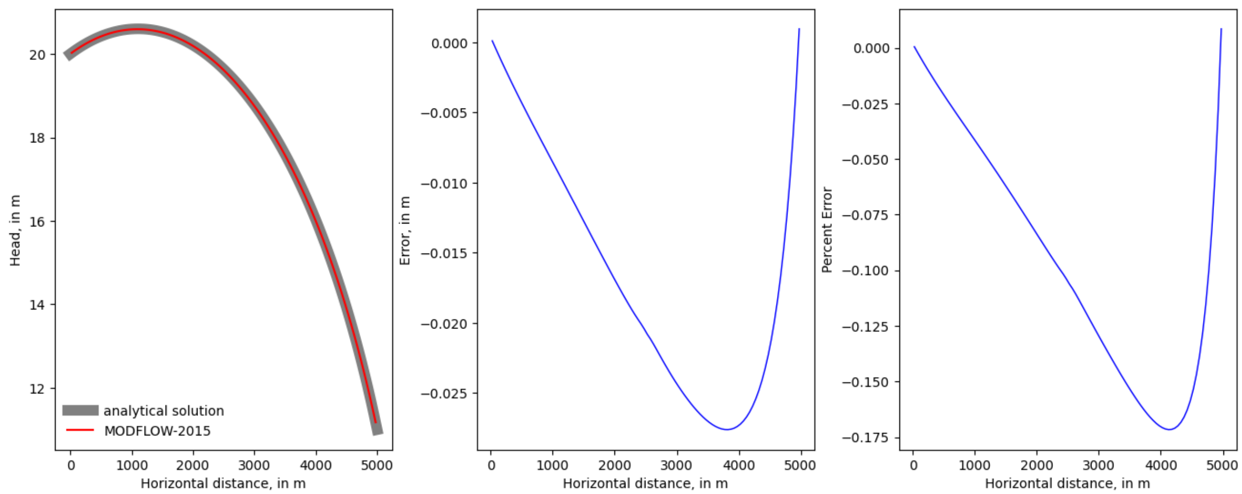
```
ax = fig.add_subplot(1, 3, 2)
ax.plot(x, head[0, 0, :] - hac, linewidth=1, color="blue")
ax.set_xlabel("Horizontal distance, in m")
ax.set_ylabel("Error, in m")

ax = fig.add_subplot(1, 3, 3)
ax.plot(x, 100.0 * (head[0, 0, :] - hac) / hac, linewidth=1, color="blue")
ax.set_xlabel("Horizontal distance, in m")
ax.set_ylabel("Percent Error")
```

[8]:
```
Text(0, 0.5, 'Percent Error')
```



[9]:
```
try:
    # ignore PermissionError on Windows
    temp_dir.cleanup()
except:
    pass
```

6.7.4 Postprocessing head results from MODFLOW

[1]:
```
import os
import sys
from tempfile import TemporaryDirectory

import matplotlib as mpl
import matplotlib.pyplot as plt
import numpy as np

import flopy
import flopy.utils.binaryfile as bf
from flopy.utils.postprocessing import (
    get_gradients,
    get_transmissivities,
```

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```
    get_water_table,
)

print(sys.version)
print(f"numpy version: {np.__version__}")
print(f"matplotlib version: {mpl.__version__}")
print(f"flopy version: {flopy.__version__}")
```

```
3.8.18 (default, Aug 28 2023, 08:27:22)
[GCC 11.4.0]
numpy version: 1.24.4
matplotlib version: 3.7.4
flopy version: 3.5.0
```

[2]:
```
mfnam = "EXAMPLE.nam"
model_ws = "../../examples/data/mp6/"
heads_file = "EXAMPLE.HED"

# temporary directory
temp_dir = TemporaryDirectory()
workspace = temp_dir.name
```

Load example model and head results

[3]:
```
m = flopy.modflow.Modflow.load(mfnam, model_ws=model_ws)
```

[4]:
```
hdsobj = bf.HeadFile(model_ws + heads_file)
hds = hdsobj.get_data(kstpkper=(0, 2))
hds.shape
```

[4]:
```
(5, 25, 25)
```

Plot heads in each layer; export the heads and head contours for viewing in a GIS

for more information about GIS export, type `help(export_array)`, for example

[5]:
```
fig, axes = plt.subplots(2, 3, figsize=(11, 8.5))
axes = axes.flat
grid = m.modelgrid
for i, hdslayer in enumerate(hds):
    im = axes[i].imshow(hdslayer, vmin=hds.min(), vmax=hds.max())
    axes[i].set_title(f"Layer {i + 1}")
    ctr = axes[i].contour(hdslayer, colors="k", linewidths=0.5)

    # export head rasters
    # (GeoTiff export requires the rasterio package; for ascii grids, just change the
↪extension to *.asc)
    flopy.export.utils.export_array(
        grid, os.path.join(workspace, f"heads{i + 1}.tif"), hdslayer
    )
```

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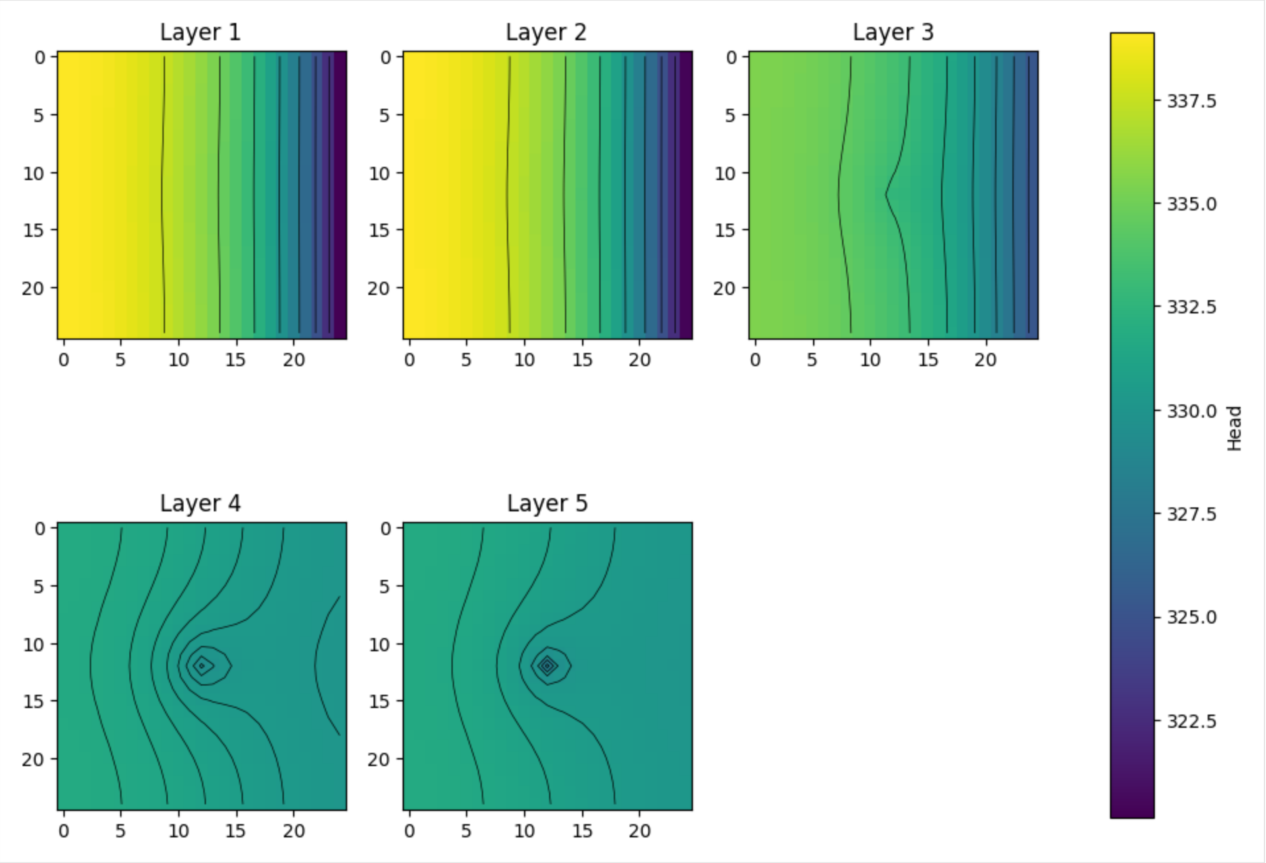
```
    # export head contours to a shapefile
    flopy.export.utils.export_array_contours(
        grid, os.path.join(workspace, f"heads{i + 1}.shp"), hdslayer
    )

fig.delaxes(axes[-1])
fig.subplots_adjust(right=0.8)
cbar_ax = fig.add_axes([0.85, 0.15, 0.03, 0.7])
fig.colorbar(im, cax=cbar_ax, label="Head")
```

```
No CRS information for writing a .prj file.
Supply an valid coordinate system reference to the attached modelgrid object or .
↪export() method.
No CRS information for writing a .prj file.
Supply an valid coordinate system reference to the attached modelgrid object or .
↪export() method.
No CRS information for writing a .prj file.
Supply an valid coordinate system reference to the attached modelgrid object or .
↪export() method.
No CRS information for writing a .prj file.
Supply an valid coordinate system reference to the attached modelgrid object or .
↪export() method.
No CRS information for writing a .prj file.
Supply an valid coordinate system reference to the attached modelgrid object or .
↪export() method.
```

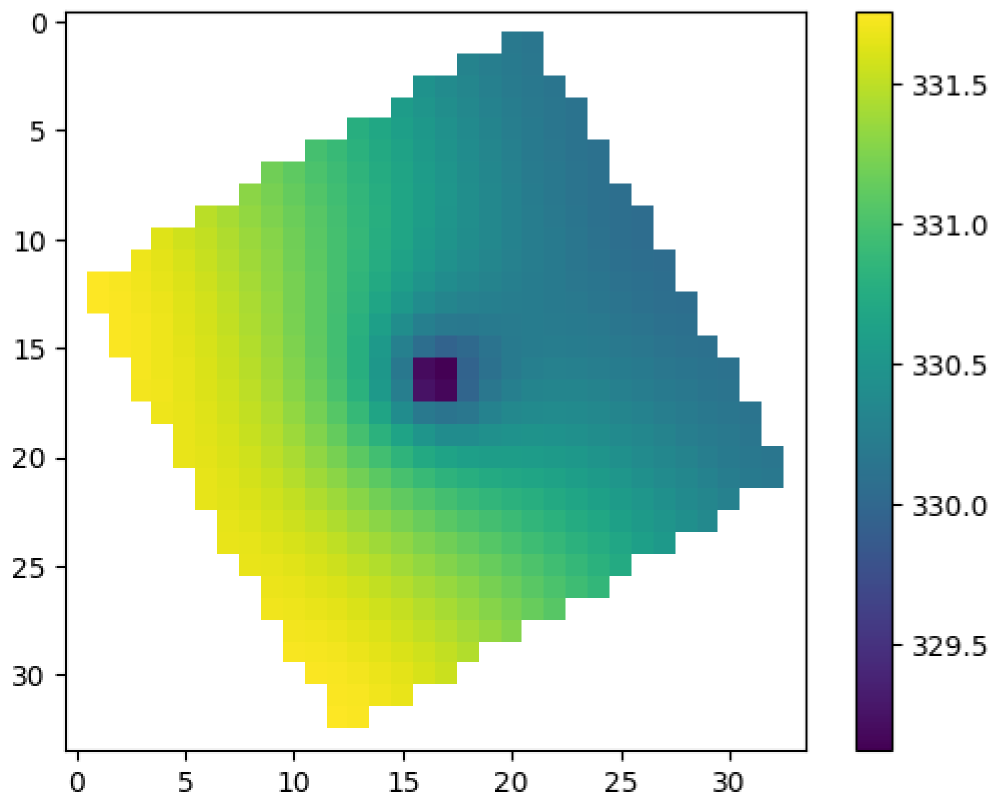
[5]:
```
<matplotlib.colorbar.Colorbar at 0x7f2d1d35a490>
```



Compare rotated arc-ascii and GeoTiff output

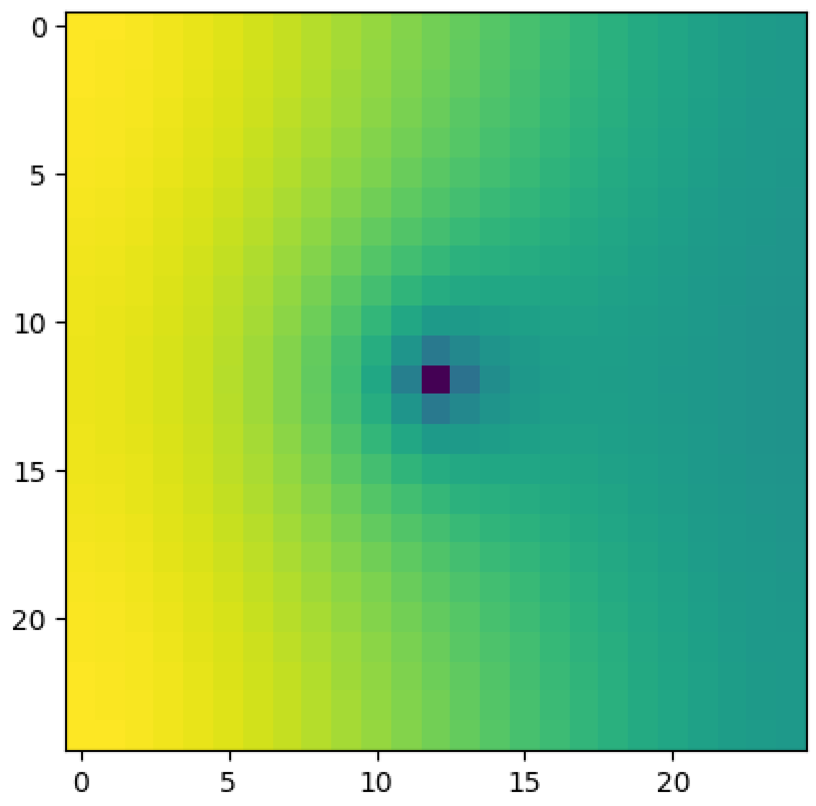
[6]:
```
grid.set_coord_info(angrot=30.0)
nodata = 0.0
flopy.export.utils.export_array(
    grid, os.path.join(workspace, "heads5_rot.asc"), hdslayer, nodata=nodata
)
flopy.export.utils.export_array(
    grid, os.path.join(workspace, "heads5_rot.tif"), hdslayer, nodata=nodata
)

results = np.loadtxt(os.path.join(workspace, f"heads5_rot.asc"), skiprows=6)
results[results == nodata] = np.nan
plt.imshow(results)
plt.colorbar()
```

[6]:
```
<matplotlib.colorbar.Colorbar at 0x7f2d07d3fdc0>
```



[7]:
```
try:
    import rasterio
except:
    rasterio = None
    print("install rasterio to create GeoTiff output")
if rasterio is not None:
    with rasterio.open(os.path.join(workspace, "heads5_rot.tif")) as src:
        print(src.meta)
        plt.imshow(src.read(1))
```

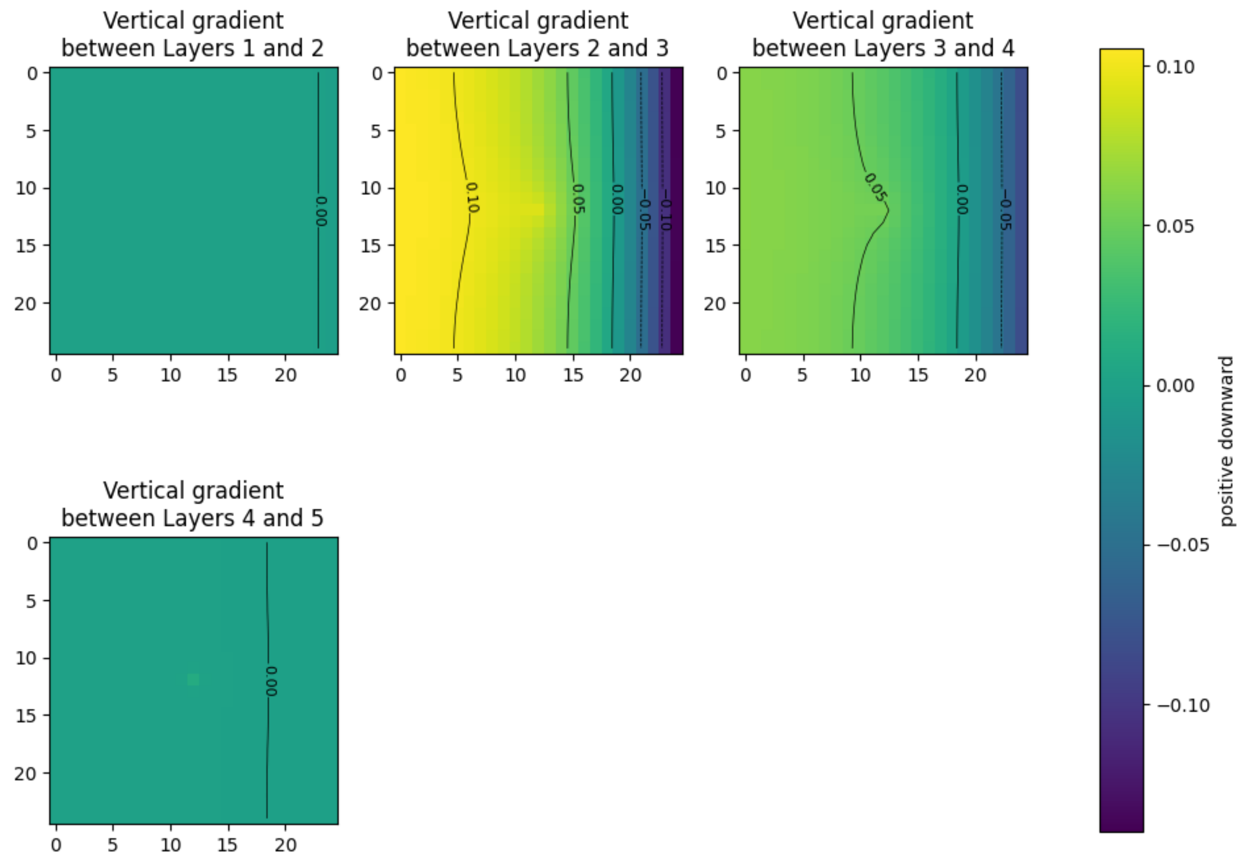
```
{'driver': 'GTiff', 'dtype': 'float32', 'nodata': 0.0, 'width': 25, 'height': 25, 'count
↪': 1, 'crs': None, 'transform': Affine(346.4101615137755, 199.99999999999997, -4999.
↪999999999999,
       199.99999999999997, -346.4101615137755, 8660.254037844386)}
```



Get the vertical head gradients between layers

[8]:
```
grad = get_gradients(hds, m, nodata=-999)

fig, axes = plt.subplots(2, 3, figsize=(11, 8.5))
axes = axes.flat

for i, vertical_gradient in enumerate(grad):
    im = axes[i].imshow(vertical_gradient, vmin=grad.min(), vmax=grad.max())
    axes[i].set_title(f"Vertical gradient\nbetween Layers {i + 1} and {i + 2}")
    ctr = axes[i].contour(
        vertical_gradient,
        levels=[-0.1, -0.05, 0.0, 0.05, 0.1],
        colors="k",
        linewidths=0.5,
    )
    plt.clabel(ctr, fontsize=8, inline=1)

fig.delaxes(axes[-2])
fig.delaxes(axes[-1])
fig.subplots_adjust(right=0.8)
cbar_ax = fig.add_axes([0.85, 0.15, 0.03, 0.7])
fig.colorbar(im, cax=cbar_ax, label="positive downward")
```

[8]:
```
<matplotlib.colorbar.Colorbar at 0x7f2d07a7e760>
```

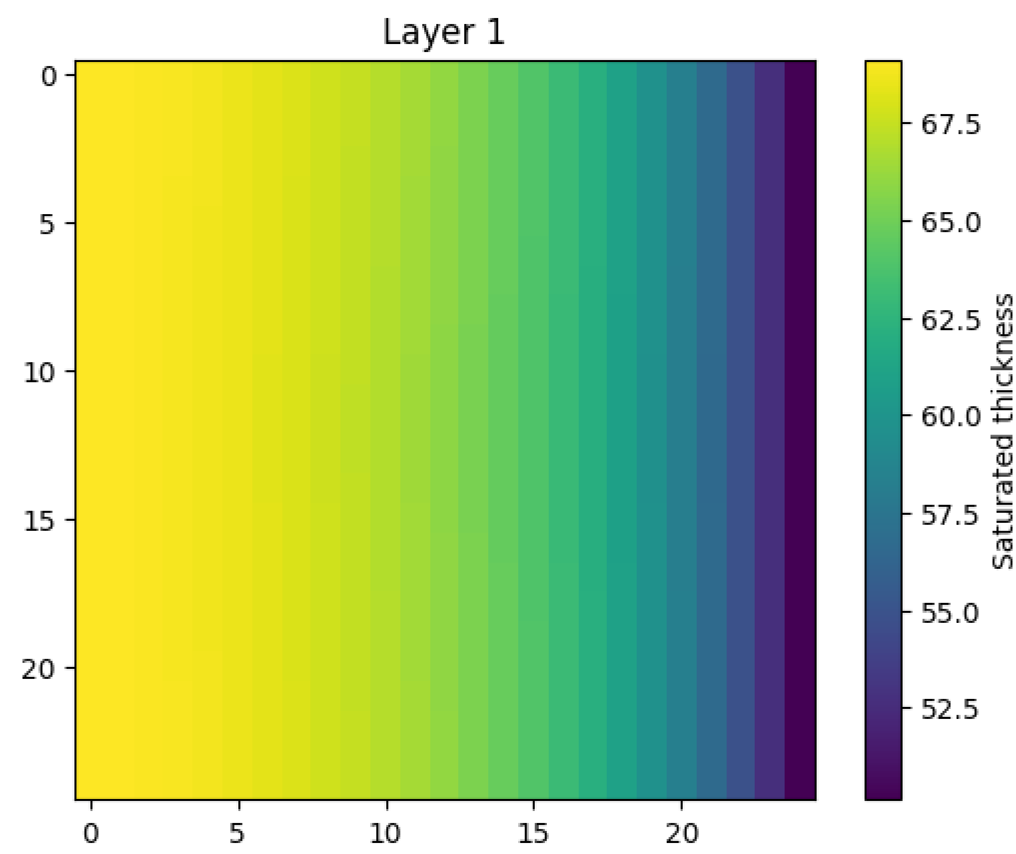


Get the saturated thickness of a layer

`m.modelgrid.saturated_thickness()` returns an nlay, nrow, ncol array of saturated thicknesses.

[9]:
```python
st = m.modelgrid.saturated_thickness(hds, mask=-9999.0)

plt.imshow(st[0])
plt.colorbar(label="Saturated thickness")
plt.title("Layer 1")
```

[9]:
```
Text(0.5, 1.0, 'Layer 1')
```

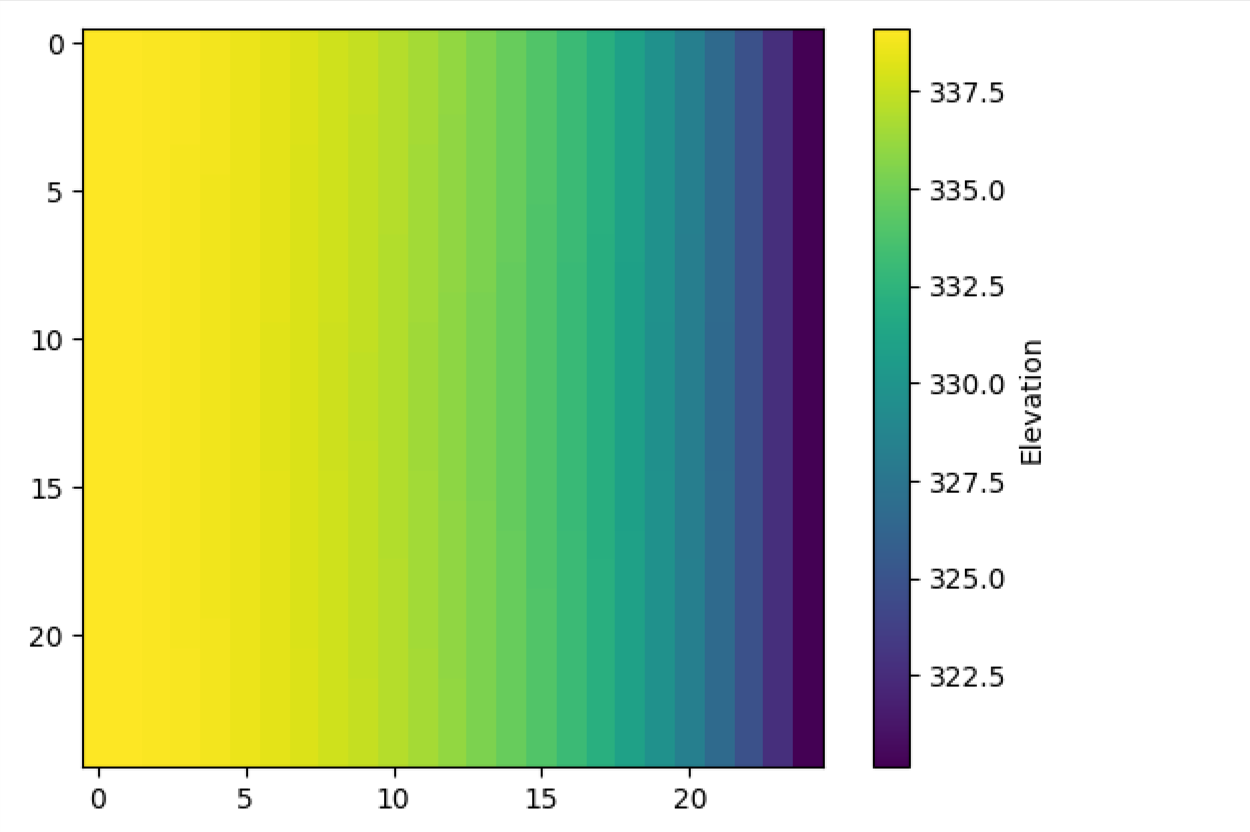


Get the water table

`get_water_table()` returns an nrow, ncol array of the water table elevation. This method can be useful when HDRY is turned on and the water table is in multiple layers.

[10]:
```
wt = get_water_table(heads=hds, hdry=-9999)

plt.imshow(wt)
plt.colorbar(label="Elevation")
```

[10]:
```
<matplotlib.colorbar.Colorbar at 0x7f2d078d0850>
```



Get layer transmissivities at arbitrary locations, accounting for the position of the water table

- for this method, the heads input is an nlay x nobs array of head results, which could be constructed using the Hydmod package with an observation in each layer at each observation location, for example .
- x, y values in real-world coordinates can be used in lieu of row, column, provided a correct coordinate information is supplied to the flopy model object's grid.
- open interval tops and bottoms can be supplied at each location for computing transmissivity-weighted average heads
- this method can also be used for apportioning boundary fluxes for an inset from a 2-D regional model
- see `**flopy3_get_transmissivities_example.ipynb**` for more details on how this method works

[11]:
```
r = [20, 5]
c = [5, 20]
headresults = hds[:, r, c]
get_transmissivities(headresults, m, r=r, c=c)
```

[11]:
```
array([[3.42867432e+03, 2.91529083e+03],
       [2.50000000e+03, 2.50000000e+03],
       [1.99999996e-01, 1.99999996e-01],
       [2.00000000e+04, 2.00000000e+04],
       [2.00000000e+04, 2.00000000e+04]])
```

[12]:
```
r = [20, 5]
c = [5, 20]
sctop = [340, 320]  # top of open interval at each location
scbot = [210, 150]  # top of bottom interval at each location
headresults = hds[:, r, c]
tr = get_transmissivities(headresults, m, r=r, c=c, sctop=sctop, scbot=scbot)
tr
```

[12]:
```
array([[3.42867432e+03, 2.50000000e+03],
       [2.50000000e+03, 2.50000000e+03],
       [9.99999978e-02, 1.99999996e-01],
       [0.00000000e+00, 1.00000000e+04],
       [0.00000000e+00, 0.00000000e+00]])
```

convert to transmissivity fractions

[13]:
```
trfrac = tr / tr.sum(axis=0)
trfrac
```

[13]:
```
array([[5.78310817e-01, 1.66664444e-01],
       [4.21672316e-01, 1.66664444e-01],
       [1.68668923e-05, 1.33331553e-05],
       [0.00000000e+00, 6.66657778e-01],
       [0.00000000e+00, 0.00000000e+00]])
```

Layer 3 contributes almost no transmissivity because of its K-value

[14]:
```
m.lpf.hk.array[:, r, c]
```

[14]:
```
array([[5.e+01, 5.e+01],
       [5.e+01, 5.e+01],
       [1.e-02, 1.e-02],
       [2.e+02, 2.e+02],
       [2.e+02, 2.e+02]], dtype=float32)
```

[15]:
```
m.modelgrid.cell_thickness[:, r, c]
```

[15]:
```
array([[130., 130.],
       [ 50.,  50.],
       [ 20.,  20.],
       [100., 100.],
       [100., 100.]])
```

[16]:
```
try:
    # ignore PermissionError on Windows
    temp_dir.cleanup()
except:
    pass
```

6.7.5 SFR package Prudic and others (2004) example

Demonstrates functionality of Flopy SFR module using the example documented by Prudic and others (2004):

Problem description:

- Grid dimensions: 1 Layer, 15 Rows, 10 Columns
- Stress periods: 1 steady
- Flow package: LPF
- Stress packages: SFR, GHB, EVT, RCH
- Solver: SIP

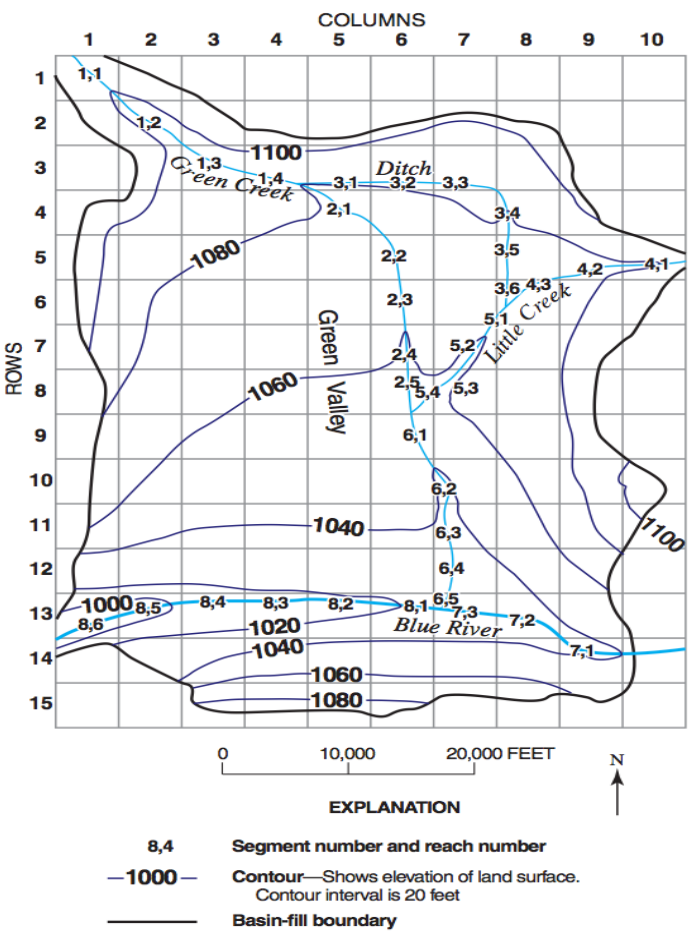


Figure 6. Hypothetical basin-fill aquifer with model grid, land-surface contours, and stream segment and reach numbering scheme for test simulation 1.

[1]:
```python
import glob
import os
import shutil
```

[2]:
```python
import sys
from tempfile import TemporaryDirectory
```

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```
import matplotlib as mpl
import matplotlib.pyplot as plt
import numpy as np
import pandas as pd

import flopy
import flopy.utils.binaryfile as bf
from flopy.utils.sfroutputfile import SfrFile

mpl.rcParams["figure.figsize"] = (11, 8.5)

print(sys.version)
print(f"numpy version: {np.__version__}")
print(f"pandas version: {pd.__version__}")
print(f"matplotlib version: {mpl.__version__}")
print(f"flopy version: {flopy.__version__}")
```

```
3.8.18 (default, Aug 28 2023, 08:27:22)
[GCC 11.4.0]
numpy version: 1.24.4
pandas version: 2.0.3
matplotlib version: 3.7.4
flopy version: 3.5.0
```

[3]:
```
# Set name of MODFLOW exe
#  assumes executable is in users path statement
exe_name = "mf2005"
```

copy over the example files to the working directory

[4]:
```
# temporary directory
temp_dir = TemporaryDirectory()
path = temp_dir.name

gpth = os.path.join("..", "..", "examples", "data", "mf2005_test", "test1ss.*")
for f in glob.glob(gpth):
    shutil.copy(f, path)
gpth = os.path.join("..", "..", "examples", "data", "mf2005_test", "test1tr.*")
for f in glob.glob(gpth):
    shutil.copy(f, path)
```

Load example dataset, skipping the SFR package

[5]:
```python
m = flopy.modflow.Modflow.load(
    "test1ss.nam",
    version="mf2005",
    exe_name=exe_name,
    model_ws=path,
    load_only=["ghb", "evt", "rch", "dis", "bas6", "oc", "sip", "lpf"],
)
```

[6]:
```python
oc = m.oc
oc.stress_period_data
```

[6]:
```
{(-1, -1): [],
 (0, 0): ['print budget', 'print head', 'save head', 'save budget']}
```

Read pre-prepared reach and segment data into numpy recarrays using numpy.genfromtxt()

Reach data (Item 2 in the SFR input instructions), are input and stored in a numpy record array https://numpy.org/doc/stable/reference/generated/numpy.recarray.html This allows for reach data to be indexed by their variable names, as described in the SFR input instructions.

For more information on Item 2, see the Online Guide to MODFLOW: https://water.usgs.gov/nrp/gwsoftware/modflow2000/MFDOC/sfr.html

[7]:
```python
rpth = os.path.join(
    "..", "..", "examples", "data", "sfr_examples", "test1ss_reach_data.csv"
)
reach_data = np.genfromtxt(rpth, delimiter=",", names=True)
reach_data
```

[7]:
```
array([(0.,  0., 0., 1., 1., 4500.), (0.,  1., 1., 1., 2., 7000.),
       (0.,  2., 2., 1., 3., 6000.), (0.,  2., 3., 1., 4., 5550.),
       (0.,  3., 4., 2., 1., 6500.), (0.,  4., 5., 2., 2., 5000.),
       (0.,  5., 5., 2., 3., 5000.), (0.,  6., 5., 2., 4., 5000.),
       (0.,  7., 5., 2., 5., 5000.), (0.,  2., 4., 3., 1., 5000.),
       (0.,  2., 5., 3., 2., 5000.), (0.,  2., 6., 3., 3., 4500.),
       (0.,  3., 7., 3., 4., 6000.), (0.,  4., 7., 3., 5., 5000.),
       (0.,  5., 7., 3., 6., 2000.), (0.,  4., 9., 4., 1., 2500.),
       (0.,  4., 8., 4., 2., 5000.), (0.,  5., 7., 4., 3., 3500.),
       (0.,  5., 7., 5., 1., 4000.), (0.,  6., 6., 5., 2., 5000.),
       (0.,  7., 6., 5., 3., 3500.), (0.,  7., 5., 5., 4., 2500.),
       (0.,  8., 5., 6., 1., 5000.), (0.,  9., 6., 6., 2., 5000.),
       (0., 10., 6., 6., 3., 5000.), (0., 11., 6., 6., 4., 5000.),
       (0., 12., 6., 6., 5., 2000.), (0., 13., 8., 7., 1., 5000.),
       (0., 12., 7., 7., 2., 5500.), (0., 12., 6., 7., 3., 5000.),
       (0., 12., 5., 8., 1., 5000.), (0., 12., 4., 8., 2., 5000.),
       (0., 12., 3., 8., 3., 5000.), (0., 12., 2., 8., 4., 5000.),
       (0., 12., 1., 8., 5., 5000.), (0., 12., 0., 8., 6., 3000.)],
      dtype=[('k', '<f8'), ('i', '<f8'), ('j', '<f8'), ('iseg', '<f8'), ('ireach', '<f8
↪'), ('rchlen', '<f8')])
```

Segment Data structure

Segment data are input and stored in a dictionary of record arrays, which

[8]:
```
spth = os.path.join(
    "..", "..", "examples", "data", "sfr_examples", "test1ss_segment_data.csv"
)
ss_segment_data = np.genfromtxt(spth, delimiter=",", names=True)
segment_data = {0: ss_segment_data}
segment_data[0][0:1]["width1"]
```

[8]:
```
array([0.])
```

define dataset 6e (channel flow data) for segment 1

dataset 6e is stored in a nested dictionary keyed by stress period and segment, with a list of the following lists defined for each segment with icalc == 4 FLOWTAB(1) FLOWTAB(2) … FLOWTAB(NSTRPTS) DPTHTAB(1) DPTHTAB(2) … DPTHTAB(NSTRPTS) WDTHTAB(1) WDTHTAB(2) … WDTHTAB(NSTRPTS)

[9]:
```
channel_flow_data = {
    0: {
        1: [
            [0.5, 1.0, 2.0, 4.0, 7.0, 10.0, 20.0, 30.0, 50.0, 75.0, 100.0],
            [0.25, 0.4, 0.55, 0.7, 0.8, 0.9, 1.1, 1.25, 1.4, 1.7, 2.6],
            [3.0, 3.5, 4.2, 5.3, 7.0, 8.5, 12.0, 14.0, 17.0, 20.0, 22.0],
        ]
    }
}
```

define dataset 6d (channel geometry data) for segments 7 and 8

dataset 6d is stored in a nested dictionary keyed by stress period and segment, with a list of the following lists defined for each segment with icalc == 4 FLOWTAB(1) FLOWTAB(2) … FLOWTAB(NSTRPTS) DPTHTAB(1) DPTHTAB(2) … DPTHTAB(NSTRPTS) WDTHTAB(1) WDTHTAB(2) … WDTHTAB(NSTRPTS)

[10]:
```
channel_geometry_data = {
    0: {
        7: [
            [0.0, 10.0, 80.0, 100.0, 150.0, 170.0, 240.0, 250.0],
            [20.0, 13.0, 10.0, 2.0, 0.0, 10.0, 13.0, 20.0],
        ],
        8: [
            [0.0, 10.0, 80.0, 100.0, 150.0, 170.0, 240.0, 250.0],
            [25.0, 17.0, 13.0, 4.0, 0.0, 10.0, 16.0, 20.0],
        ],
    }
}
```

Define SFR package variables

[11]:
```
nstrm = len(reach_data)  # number of reaches
nss = len(segment_data[0])  # number of segments
nsfrpar = 0  # number of parameters (not supported)
nparseg = 0
const = 1.486  # constant for manning's equation, units of cfs
dleak = 0.0001  # closure tolerance for stream stage computation
ipakcb = 53  # flag for writing SFR output to cell-by-cell budget (on unit 53)
istcb2 = 81  # flag for writing SFR output to text file
dataset_5 = {0: [nss, 0, 0]}  # dataset 5 (see online guide)
```

Instantiate SFR package

Input arguments generally follow the variable names defined in the Online Guide to MODFLOW

[12]:
```
sfr = flopy.modflow.ModflowSfr2(
    m,
    nstrm=nstrm,
    nss=nss,
    const=const,
    dleak=dleak,
    ipakcb=ipakcb,
    istcb2=istcb2,
    reach_data=reach_data,
    segment_data=segment_data,
    channel_geometry_data=channel_geometry_data,
    channel_flow_data=channel_flow_data,
    dataset_5=dataset_5,
    unit_number=15,
)
```

[13]:
```
sfr.reach_data[0:1]
```

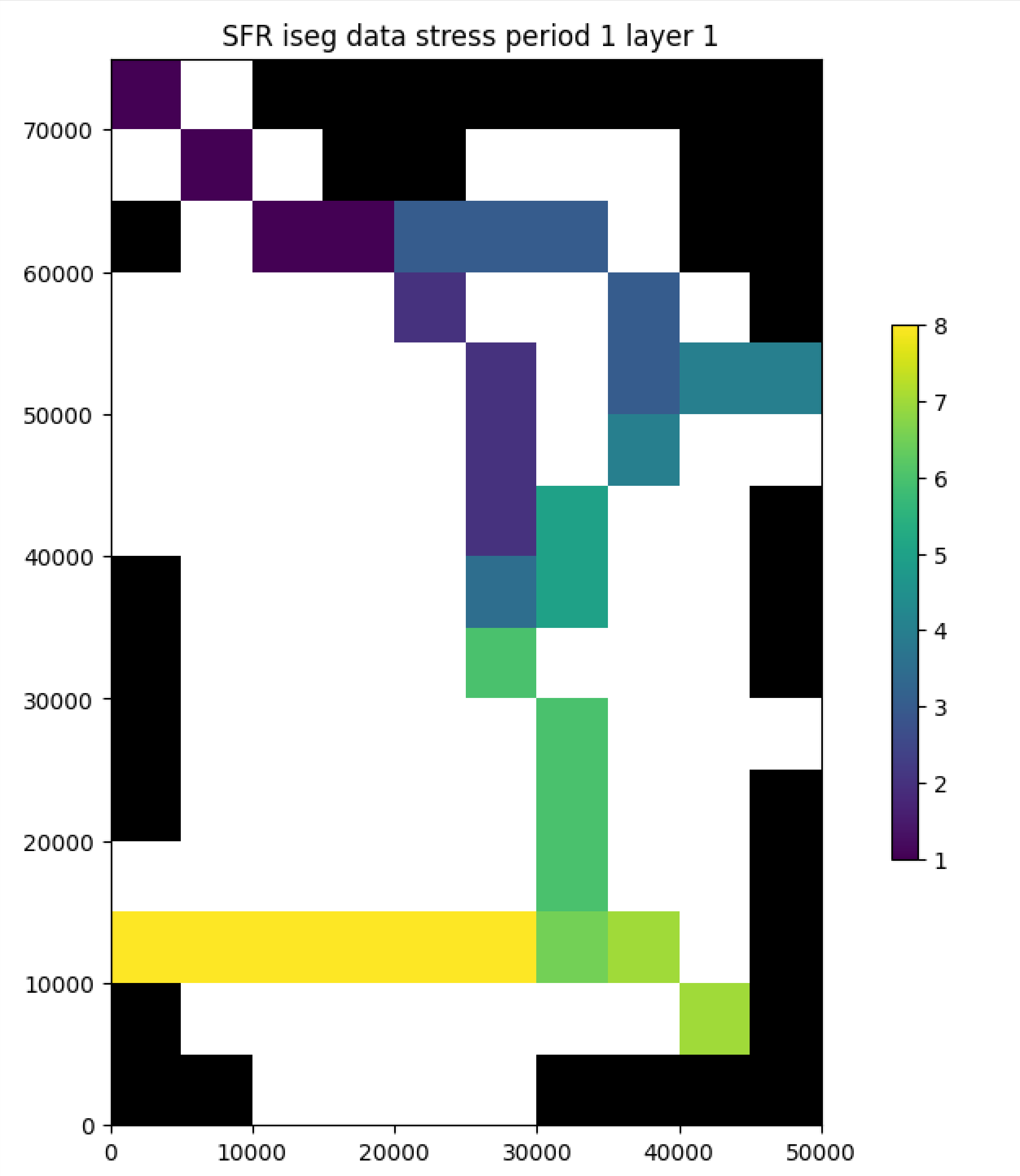
[13]:
```
rec.array([(0, 0, 0, 0, 1, 1, 4500., 0., 0., 0., 0., 0., 0., 0., 0., 1, 2)],
          dtype=[('node', '<i8'), ('k', '<i8'), ('i', '<i8'), ('j', '<i8'), ('iseg', '<i8
↪'), ('ireach', '<i8'), ('rchlen', '<f4'), ('strtop', '<f4'), ('slope', '<f4'), (
↪'strthick', '<f4'), ('strhc1', '<f4'), ('thts', '<f4'), ('thti', '<f4'), ('eps', '<f4
↪'), ('uhc', '<f4'), ('reachID', '<i8'), ('outreach', '<i8')])
```

Plot the SFR segments

any column in the reach_data array can be plotted using the key argument

[14]:
```
sfr.plot(key="iseg")
```

[14]:
```
[<Axes: title={'center': ' SFR iseg data stress period 1 layer 1'}>]
```


SFR iseg data stress period 1 layer 1
70000
60000
50000
40000
30000
20000
10000
0
0
10000
20000
30000
40000
50000
8
7
6
5
4
3
2
1

Check the SFR dataset for errors

[15]:
```python
chk = sfr.check()
```

```
passed.

Checking for continuity in segment and reach numbering...
passed.

Checking for increasing segment numbers in downstream direction...
passed.

Checking for circular routing...
passed.

Checking reach connections for proximity...
0 segments with non-adjacent reaches found.
At segments:


0 segments with non-adjacent reaches found.
At segments:



Checking for model cells with multiple non-zero SFR conductances...
3 model cells with multiple non-zero SFR conductances found.
This may lead to circular routing between collocated reaches.
Nodes with overlapping conductances:
k       i       j       iseg    ireach  rchlen  strthick        strhc1
0       7       5       2       5       5000.0  3.0     2.9999999242136255e-05
0       5       7       3       6       2000.0  2.0     2.9999999242136255e-05
0       5       7       4       3       3500.0  3.0     2.9999999242136255e-05
0       5       7       5       1       4000.0  3.0     2.9999999242136255e-05
0       7       5       5       4       2500.0  3.0     2.9999999242136255e-05
0       12      6       6       5       2000.0  3.0     2.9999999242136255e-05
0       12      6       7       3       5000.0  3.0     5.999999848427251e-05

Checking for streambed tops of less than -10...
strtop not specified for isfropt=0
passed.

Checking for streambed tops of greater than 15000...
strtop not specified for isfropt=0
passed.

Checking segment_data for downstream rises in streambed elevation...
passed.

Checking reach_data for downstream rises in streambed elevation...
Reach strtop not specified for nstrm=36, reachinput=False and isfropt=0
passed.
```

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```
Checking reach_data for inconsistencies between streambed elevations and the model␣
↪grid...
Reach strtop, strthick not specified for nstrm=36, reachinput=False and isfropt=0
passed.

Checking segment_data for inconsistencies between segment end elevations and the model␣
↪grid...
passed.

Checking for streambed slopes of less than 0.0001...
slope not specified for isfropt=0
passed.

Checking for streambed slopes of greater than 1.0...
slope not specified for isfropt=0
passed.
```

[16]:
```
m.external_fnames = [os.path.split(f)[1] for f in m.external_fnames]
m.external_fnames
```

[16]:
```
['test1ss.sg1',
 'test1ss.sg2',
 'test1ss.sg3',
 'test1ss.sg4',
 'test1ss.sg5',
 'test1ss.sg6',
 'test1ss.sg7',
 'test1ss.sg8',
 'test1ss.dvsg9']
```

[17]:
```
m.write_input()
```

[18]:
```
success, buff = m.run_model(silent=True, report=True)
if success:
    for line in buff:
        print(line)
else:
    raise ValueError("Failed to run.")
```

```
                                  MODFLOW-2005
    U.S. GEOLOGICAL SURVEY MODULAR FINITE-DIFFERENCE GROUND-WATER FLOW MODEL
                             Version 1.12.00 2/3/2017

 Using NAME file: test1ss.nam
 Run start date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:33:37

 Solving:  Stress period:     1    Time step:     1    Ground-Water Flow Eqn.
 Run end date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:33:37
 Elapsed run time:  0.010 Seconds
```

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```
Normal termination of simulation
```

Load SFR formated water balance output into pandas dataframe using the `SfrFile` class

[19]:
```python
sfr_outfile = os.path.join(
    "..", "..", "examples", "data", "sfr_examples", "test1ss.flw"
)
sfrout = SfrFile(sfr_outfile)
df = sfrout.get_dataframe()
df.head()
```

[19]:

	layer	row	column	segment	reach	Qin	Qaquifer	Qout	Qovr	\
0	1	1	1	1	1	25.0000	0.7923	24.2080	0.0	
1	1	2	2	1	2	24.2080	2.1408	22.0670	0.0	
2	1	3	3	1	3	22.0670	2.9909	19.0760	0.0	
3	1	3	4	1	4	19.0760	2.5538	16.5220	0.0	
4	1	4	5	2	1	6.5222	2.7058	3.8163	0.0	

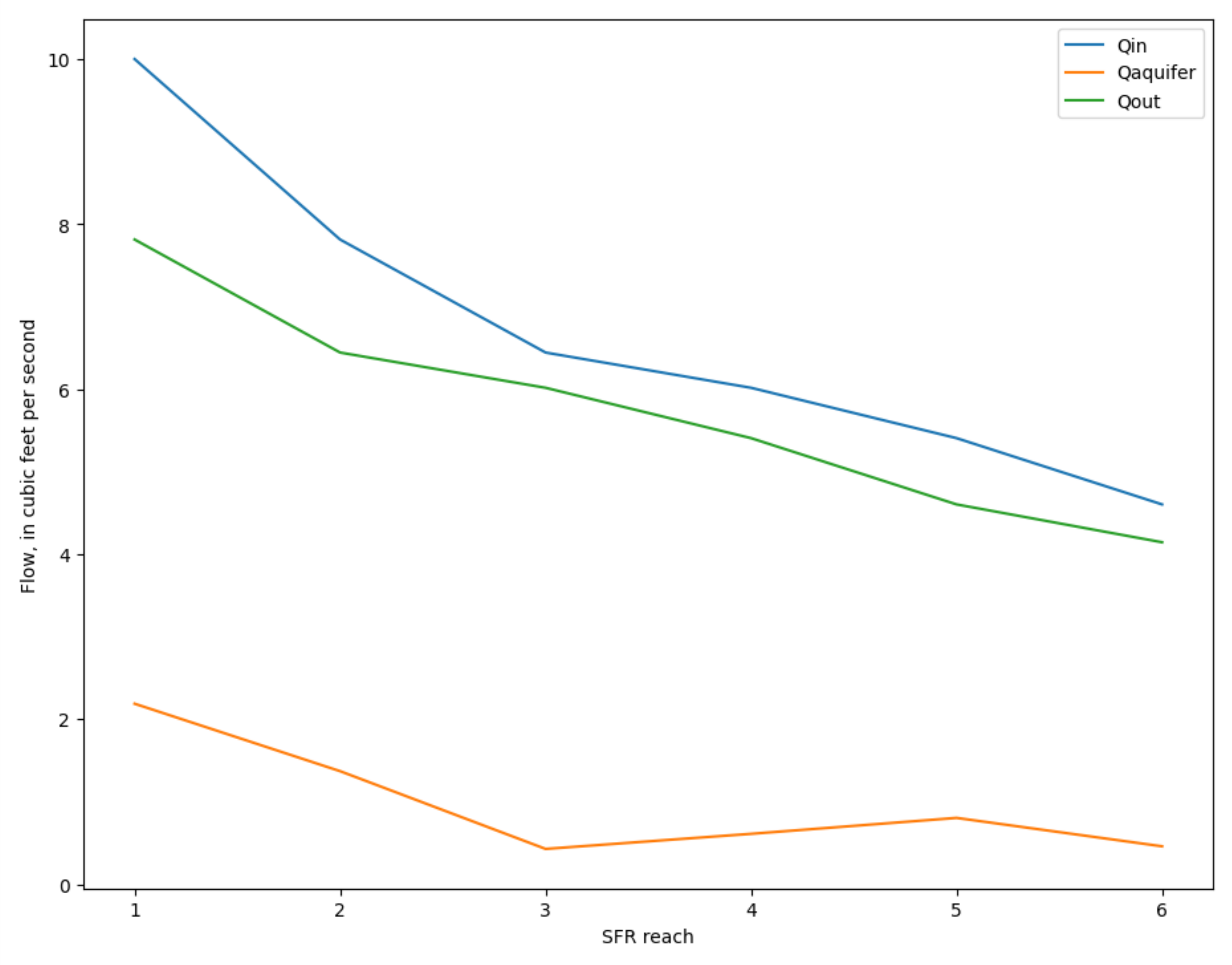
	Qprecip	Qet	stage	depth	width	Cond	gradient	kstpkper	k	i	j
0	0.0	0.0	1094.22	1.174	12.98	0.5843	0.4520	(0, 0)	0	0	0
1	0.0	0.0	1089.21	1.152	12.68	0.8878	0.8038	(0, 0)	0	1	1
2	0.0	0.0	1083.53	1.110	12.13	0.7278	1.3700	(0, 0)	0	2	2
3	0.0	0.0	1078.47	1.064	11.32	0.6285	1.3550	(0, 0)	0	2	3
4	0.0	0.0	1072.40	0.469	12.00	0.7800	1.1560	(0, 0)	0	3	4

Plot streamflow and stream/aquifer interactions for a segment

[20]:
```python
inds = df.segment == 3
print(df.reach[inds].astype(str))
# ax = df.ix[inds, ['Qin', 'Qaquifer', 'Qout']].plot(x=df.reach[inds])
ax = df.loc[inds, ["reach", "Qin", "Qaquifer", "Qout"]].plot(x="reach")
ax.set_ylabel("Flow, in cubic feet per second")
ax.set_xlabel("SFR reach")
```

```
9     1
10    2
11    3
12    4
13    5
14    6
Name: reach, dtype: object
```

[20]:
```
Text(0.5, 0, 'SFR reach')
```



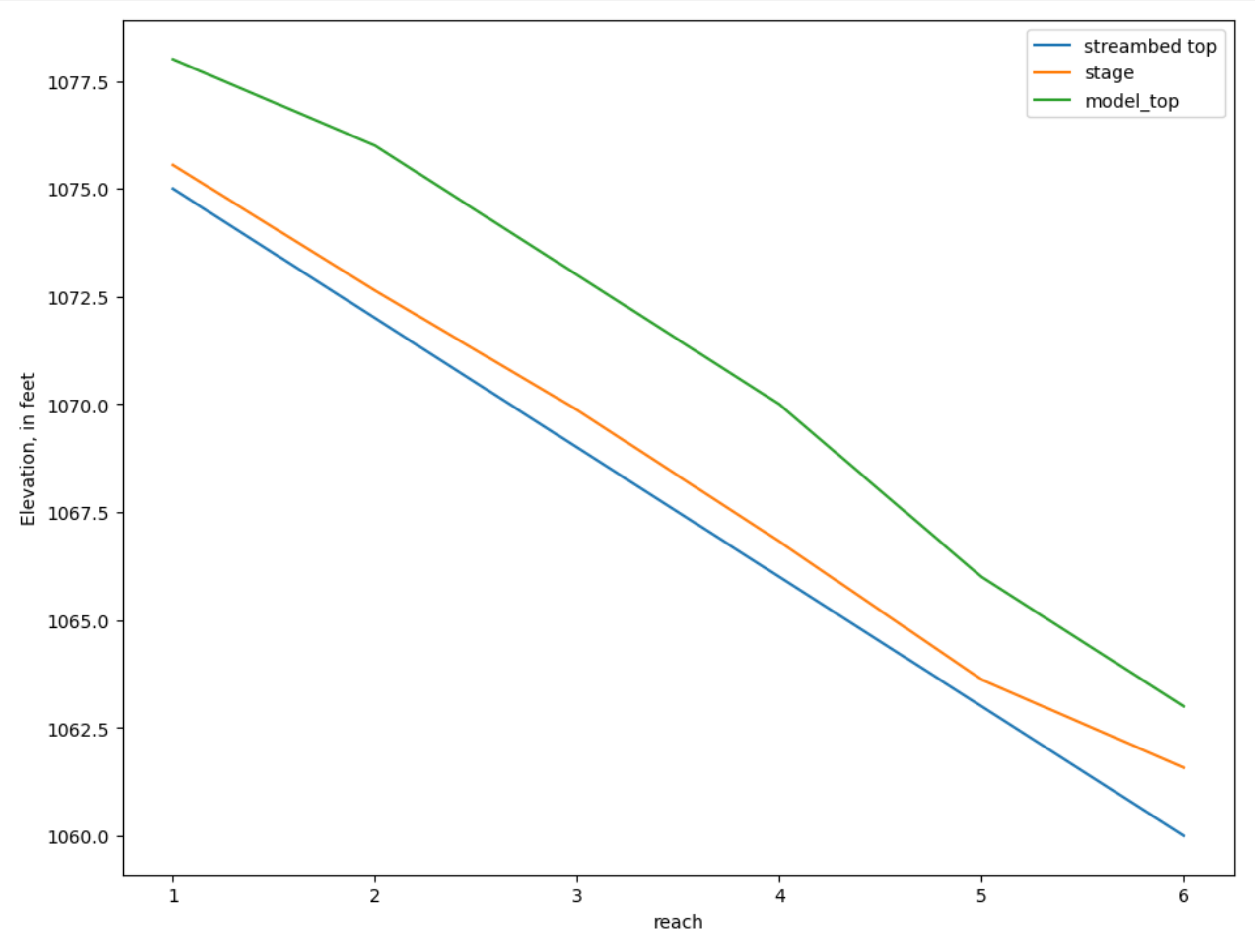
Look at stage, model top, and streambed top

[21]:
```
streambed_top = m.sfr.segment_data[0][m.sfr.segment_data[0].nseg == 3][
    ["elevup", "elevdn"]
][0]
streambed_top
```

[21]:
```
(1075., 1060.)
```

[22]:
```
df["model_top"] = m.dis.top.array[df.row.values - 1, df.column.values - 1]
fig, ax = plt.subplots()
plt.plot([1, 6], list(streambed_top), label="streambed top")
# ax = df.loc[inds, ['stage', 'model_top']].plot(ax=ax, x=df.reach[inds])
ax = df.loc[inds, ["reach", "stage", "model_top"]].plot(ax=ax, x="reach")
ax.set_ylabel("Elevation, in feet")
plt.legend()
```

[22]:
```
<matplotlib.legend.Legend at 0x7f8af5e65220>
```



Get SFR leakage results from cell budget file

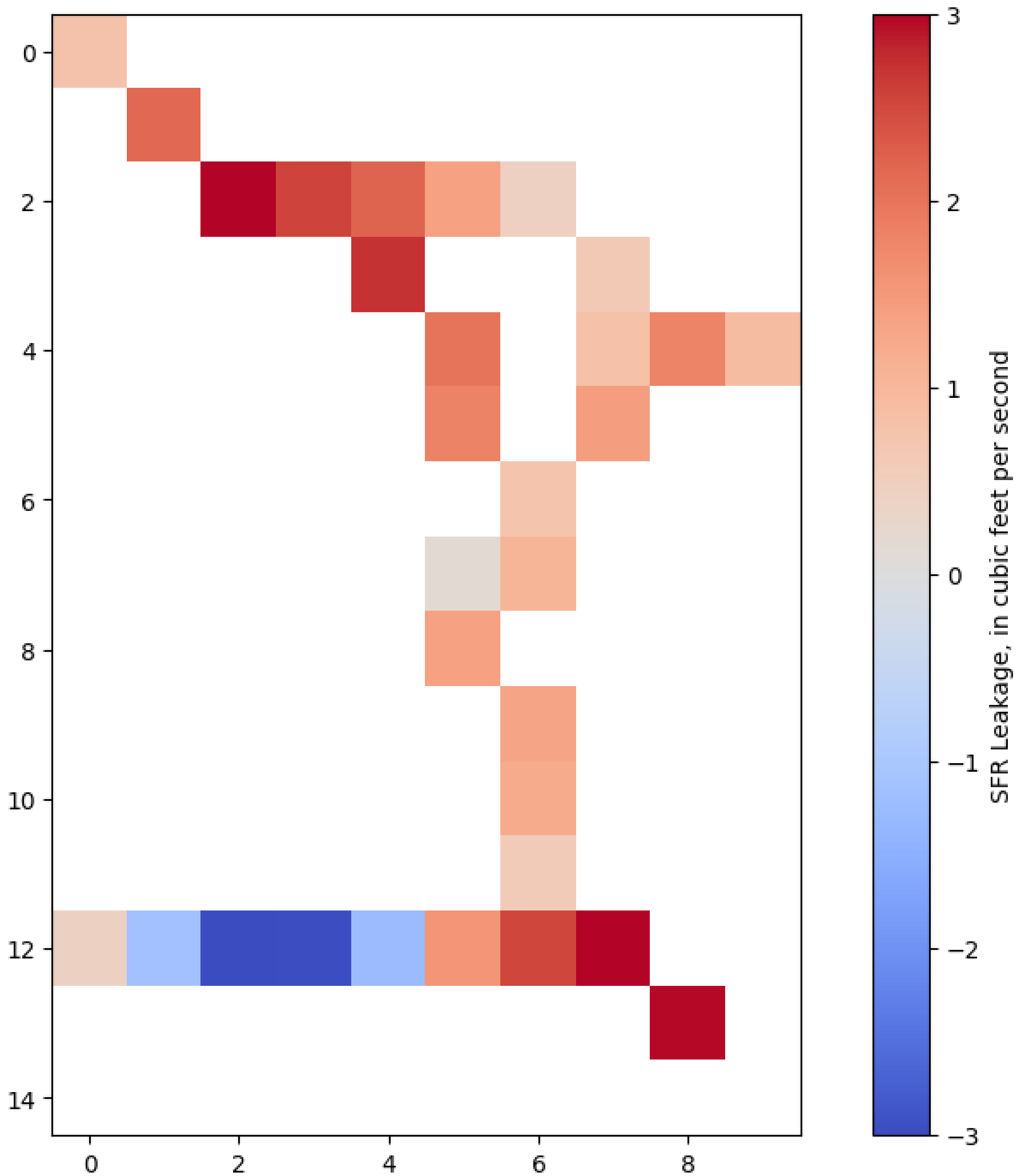
[23]:
```
bpth = os.path.join(path, "test1ss.cbc")
cbbobj = bf.CellBudgetFile(bpth)
cbbobj.list_records()
```

```
(1, 1, b'  STREAM LEAKAGE', 10, 15, 1, 0, 0., 0., -1., b'', b'', b'', b'')
```

[24]:
```
sfrleak = cbbobj.get_data(text="  STREAM LEAKAGE")[0]
sfrleak[sfrleak == 0] = np.nan  # remove zero values
```

Plot leakage in plan view

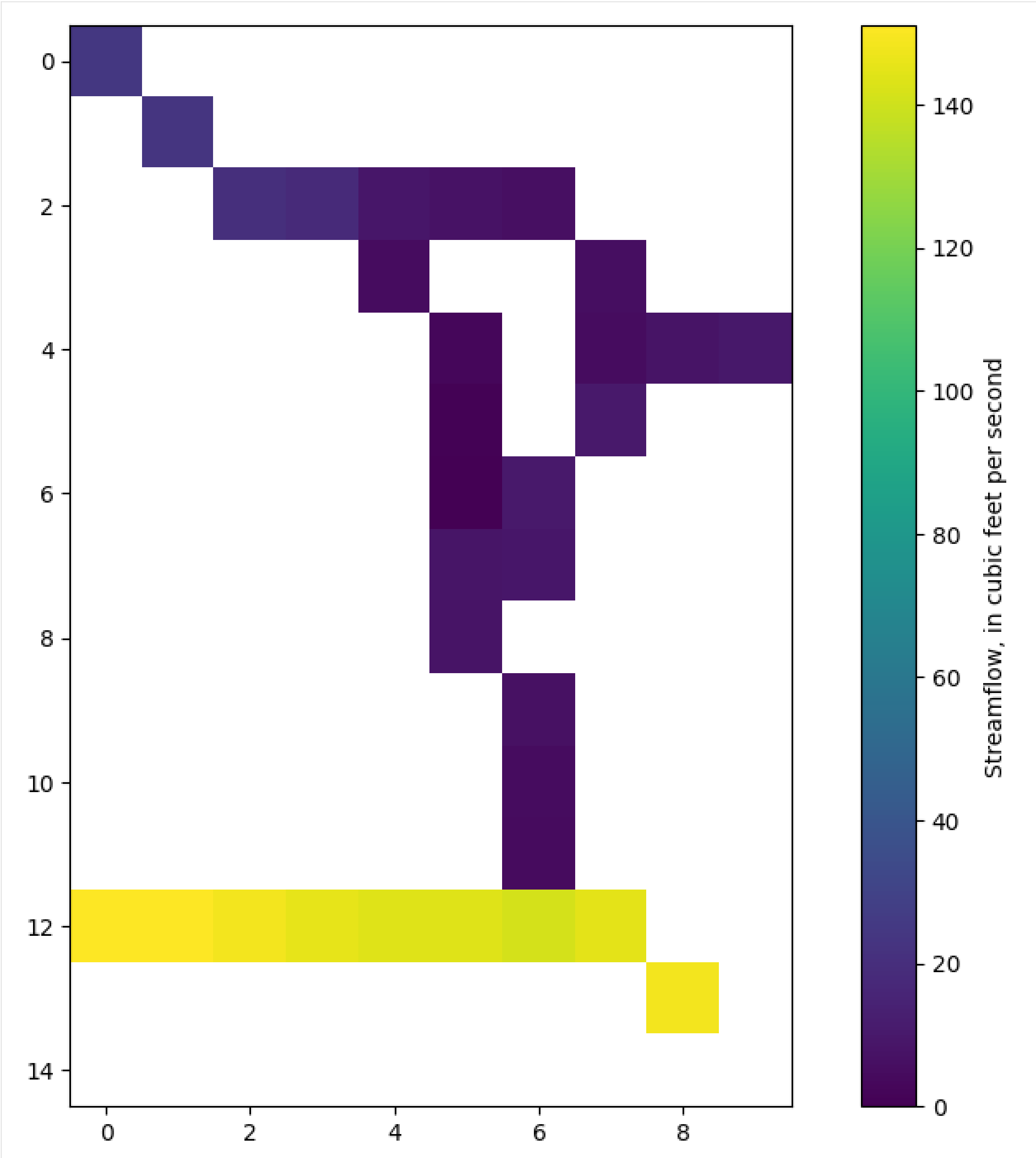
[25]:
```
im = plt.imshow(
    sfrleak[0], interpolation="none", cmap="coolwarm", vmin=-3, vmax=3
)
cb = plt.colorbar(im, label="SFR Leakage, in cubic feet per second")
```



Plot total streamflow

[26]:
```
sfrQ = sfrleak[0].copy()
sfrQ[sfrQ == 0] = np.nan
sfrQ[df.row.values - 1, df.column.values - 1] = (
    df[["Qin", "Qout"]].mean(axis=1).values
)
im = plt.imshow(sfrQ, interpolation="none")
plt.colorbar(im, label="Streamflow, in cubic feet per second")
```

[26]:
```
<matplotlib.colorbar.Colorbar at 0x7f8af5cd9d00>
```


0
2
4
6
8
10
12
14
0
2
4
6
8
0
20
40
60
80
100
120
140
Streamflow, in cubic feet per second

Reading transient SFR formatted output

The `SfrFile` class handles this the same way

Files for the transient version of the above example were already copied to the `data` folder in the third cell above. First run the transient model to get the output:

```
>mf2005 test1tr.nam
```

[27]:
```
flopy.run_model(exe_name, "test1tr.nam", model_ws=path, silent=True)
```

[27]:
```
(True, [])
```

[28]:
```
sfrout_tr = SfrFile(os.path.join(path, "test1tr.flw"))
dftr = sfrout_tr.get_dataframe()
dftr.head()
```

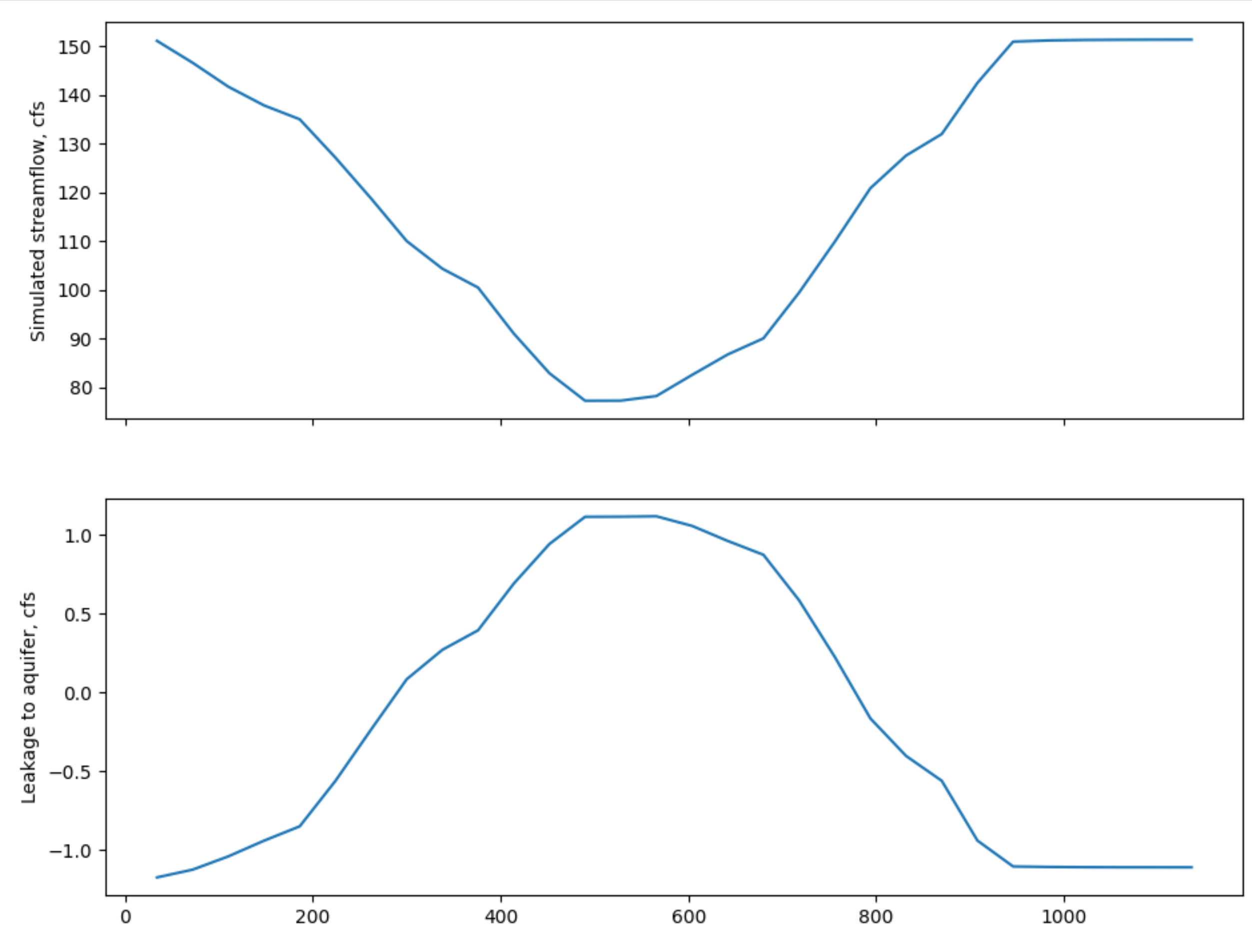
[28]:
```
   layer  row  column  segment  reach      Qin  Qaquifer     Qout  Qovr  \
0      1    1       1        1      1  25.0000   0.77759  24.2220   0.0
1      1    2       2        1      2  24.2220   2.21540  22.0070   0.0
2      1    3       3        1      3  22.0070   2.98700  19.0200   0.0
3      1    3       4        1      4  19.0200   2.54940  16.4710   0.0
4      1    4       5        2      1   6.4706   2.70370   3.7669   0.0

   Qprecip  Qet    stage   depth  width    Cond  gradient kstpkper  k  i  j
0      0.0  0.0  1094.22  1.1740  12.98  0.5843    0.4436   (0, 0)  0  0  0
1      0.0  0.0  1089.21  1.1510  12.68  0.8875    0.8321   (0, 0)  0  1  1
2      0.0  0.0  1083.53  1.1090  12.12  0.7270    1.3700   (0, 0)  0  2  2
3      0.0  0.0  1078.47  1.0630  11.31  0.6275    1.3540   (0, 0)  0  2  3
4      0.0  0.0  1072.40  0.4663  12.00  0.7800    1.1550   (0, 0)  0  3  4
```

plot a hydrograph

plot `Qout` (simulated streamflow) and `Qaquifer` (simulated stream leakage) through time

[29]:
```
fig, axes = plt.subplots(2, 1, sharex=True)
dftr8 = dftr.loc[(dftr.segment == 8) & (dftr.reach == 5)]
dftr8.Qout.plot(ax=axes[0])
axes[0].set_ylabel("Simulated streamflow, cfs")
dftr8.Qaquifer.plot(ax=axes[1])
axes[1].set_ylabel("Leakage to aquifer, cfs")
```

[29]:
```
Text(0, 0.5, 'Leakage to aquifer, cfs')
```



[30]:
```python
try:
    # ignore PermissionError on Windows
    temp_dir.cleanup()
except:
    pass
```

6.7.6 SWI2 Example 1. Rotating Interface

This example problem is the first example problem in the SWI2 documentation (https://pubs.usgs.gov/tm/6a46/) and simulates transient movement of a freshwater:nbsphinx-math:`seawater `interface separating two density zones in a two-dimensional vertical plane. The problem domain is 250 m long, 40 m high, and 1 m wide. The aquifer is confined, storage changes are not considered (all MODFLOW stress periods are steady-state), and the top and bottom of the aquifer are horizontal and impermeable.

The domain is discretized into 50 columns, 1 row, and 1 layer, with respective cell dimensions of 5 m (DELR), 1 m (DELC), and 40 m. A constant head of 0 m is specified for column 50. The hydraulic conductivity is 2 m/d and the effective porosity (SSZ) is 0.2. A flow of 1 m^3/d of seawater is specified in column 1 and causes groundwater to flow from left to right in the model domain.

The domain contains one freshwater zone and one seawater zone, separated by an active ZETA surface between the zones (NSRF=1) that approximates the 50-percent seawater salinity contour. A 400-day period is simulated using a constant time step of 2 days. Fluid density is represented using the stratified option (ISTRAT=1) and the elevation of the interface is output every 100 days (every 50 time steps). The densities, ρ, of the freshwater and saltwater are 1,000 and 1,025 kg/m^3, respectively. Hence, the dimensionless densities, ν, of the freshwater and saltwater are 0.0 and 0.025, respectively. The maximum slope of the toe and tip is specified as 0.2 (`TOESLOPE=TIPSLOPE=0.2`), and default tip/toe parameters are used (`ALPHA=BETA=0.1`). Initially, the interface is at a 45° angle from (x,z) = (80,0) to (x,z) = (120,-40). The source/sink terms (`ISOURCE`) are specified to be freshwater everywhere (`ISOURCE=1`) except in cell 1 where saltwater enters the model and `ISOURCE` equals 2. A comparison of results for SWI2 and the exact Dupuit solution of Wilson and Sa Da Costa (1982) are presented below. The constant flow from left to right results in an average velocity of 0.125 m/d. The exact Dupuit solution is a rotating straight interface of which the center moves to the right with this velocity

Import `numpy` and `matplotlib`, set all figures to be inline, import `flopy.modflow` and `flopy.utils`.

[1]:
```python
import os
import sys
from tempfile import TemporaryDirectory

import matplotlib as mpl
import matplotlib.pyplot as plt
import numpy as np

import flopy

print(sys.version)
print(f"numpy version: {np.__version__}")
print(f"matplotlib version: {mpl.__version__}")
print(f"flopy version: {flopy.__version__}")
```

```
3.8.18 (default, Aug 28 2023, 08:27:22)
[GCC 11.4.0]
numpy version: 1.24.4
matplotlib version: 3.7.4
flopy version: 3.5.0
```

Define model name of your model and the location of MODFLOW executable. All MODFLOW files and output will be stored in the subdirectory defined by the workspace. Create a model named `ml` and specify that this is a MODFLOW-2005 model.

[2]:
```python
modelname = "swiex1"

# Set name of MODFLOW exe
#  assumes executable is in users path statement
exe_name = "mf2005"

temp_dir = TemporaryDirectory()
workspace = temp_dir.name

ml = flopy.modflow.Modflow(
    modelname, version="mf2005", exe_name=exe_name, model_ws=workspace
)
```

Define the number of layers, rows and columns, and the cell size along the rows (`delr`) and along the columns (`delc`). Then create a discretization file. Specify the top and bottom of the aquifer. The heads are computed quasi-steady state (hence a steady MODFLOW run) while the interface will move. There is one stress period with a length of 400 days and 200 steps (so one step is 2 days).

[3]:
```python
nlay = 1
nrow = 1
ncol = 50
delr = 5.0
delc = 1.0
nper, perlen, nstp = 1, 400.0, 200
discret = flopy.modflow.ModflowDis(
    ml,
    nlay=nlay,
    nrow=nrow,
    ncol=ncol,
    delr=delr,
    delc=delc,
    top=0,
    botm=-40.0,
    steady=True,
    nper=nper,
    perlen=perlen,
    nstp=nstp,
)
```

All cells are active (`ibound=1`), while the last cell is fixed head (`ibound=-1`). The starting values of the head are not important, as the heads are computed every time with a steady run.

[4]:
```python
ibound = np.ones((nrow, ncol))
ibound[0, -1] = -1
bas = flopy.modflow.ModflowBas(ml, ibound=ibound, strt=0.0)
```

Define the hydraulic conductivity. The aquifer is confined (`laytype=0`) and the intercell hydraulic conductivity is the harmonic meand (`layavg=0`).

[5]:
```python
lpf = flopy.modflow.ModflowLpf(ml, hk=2.0, laytyp=0, layavg=0)
```

Inflow on the right side of the model is 1 m^3/d (layer 0, row 0, column 0, discharge 1)

[6]:
```python
wel = flopy.modflow.ModflowWel(ml, stress_period_data={0: [[0, 0, 0, 1]]})
```

Define the output control to save heads and interface every 50 steps, and define the pcg solver with default arguments.

[7]:
```python
spd = {}
for istp in range(49, nstp + 1, 50):
    spd[(0, istp)] = ["save head", "print budget"]
    spd[(0, istp + 1)] = []

oc = flopy.modflow.ModflowOc(ml, stress_period_data=spd)
pcg = flopy.modflow.ModflowPcg(ml)
```

The intial interface is straight. The isource is one everywhere (inflow and outflow is fresh (zone 1)) except for the first cell (index=0) which has saltwater inflow (zone 2).

[8]:
```python
z = np.zeros((nrow, ncol), float)
z[0, 16:24] = np.arange(-2.5, -40, -5)
z[0, 24:] = -40
z = [z]  # zeta needs to be
```

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```
isource = np.ones((nrow, ncol), int)
isource[0, 0] = 2
#
swi = flopy.modflow.ModflowSwi2(
    ml,
    nsrf=1,
    istrat=1,
    toeslope=0.2,
    tipslope=0.2,
    nu=[0, 0.025],
    zeta=z,
    ssz=0.2,
    isource=isource,
    nsolver=1,
    iswizt=55,
)
```

Write the MODFLOW input files and run the model

[9]:
```
ml.write_input()
success, buff = ml.run_model(silent=True, report=True)
if success:
    for line in buff:
        print(line)
else:
    raise ValueError("Failed to run.")
```

```
                                  MODFLOW-2005
    U.S. GEOLOGICAL SURVEY MODULAR FINITE-DIFFERENCE GROUND-WATER FLOW MODEL
                             Version 1.12.00 2/3/2017

 Using NAME file: swiex1.nam
 Run start date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:33:51

 Solving:  Stress period:     1    Time step:     1    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:     2    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:     3    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:     4    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:     5    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:     6    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:     7    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:     8    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:     9    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:    10    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:    11    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:    12    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:    13    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:    14    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:    15    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:    16    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:    17    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:    18    Ground-Water Flow Eqn.
```

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```
 Solving:  Stress period:     1    Time step:    19    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:    20    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:    21    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:    22    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:    23    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:    24    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:    25    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:    26    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:    27    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:    28    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:    29    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:    30    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:    31    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:    32    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:    33    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:    34    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:    35    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:    36    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:    37    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:    38    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:    39    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:    40    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:    41    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:    42    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:    43    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:    44    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:    45    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:    46    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:    47    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:    48    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:    49    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:    50    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:    51    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:    52    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:    53    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:    54    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:    55    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:    56    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:    57    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:    58    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:    59    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:    60    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:    61    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:    62    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:    63    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:    64    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:    65    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:    66    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:    67    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:    68    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:    69    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:    70    Ground-Water Flow Eqn.
```

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```
Solving:  Stress period:     1    Time step:    71    Ground-Water Flow Eqn.
Solving:  Stress period:     1    Time step:    72    Ground-Water Flow Eqn.
Solving:  Stress period:     1    Time step:    73    Ground-Water Flow Eqn.
Solving:  Stress period:     1    Time step:    74    Ground-Water Flow Eqn.
Solving:  Stress period:     1    Time step:    75    Ground-Water Flow Eqn.
Solving:  Stress period:     1    Time step:    76    Ground-Water Flow Eqn.
Solving:  Stress period:     1    Time step:    77    Ground-Water Flow Eqn.
Solving:  Stress period:     1    Time step:    78    Ground-Water Flow Eqn.
Solving:  Stress period:     1    Time step:    79    Ground-Water Flow Eqn.
Solving:  Stress period:     1    Time step:    80    Ground-Water Flow Eqn.
Solving:  Stress period:     1    Time step:    81    Ground-Water Flow Eqn.
Solving:  Stress period:     1    Time step:    82    Ground-Water Flow Eqn.
Solving:  Stress period:     1    Time step:    83    Ground-Water Flow Eqn.
Solving:  Stress period:     1    Time step:    84    Ground-Water Flow Eqn.
Solving:  Stress period:     1    Time step:    85    Ground-Water Flow Eqn.
Solving:  Stress period:     1    Time step:    86    Ground-Water Flow Eqn.
Solving:  Stress period:     1    Time step:    87    Ground-Water Flow Eqn.
Solving:  Stress period:     1    Time step:    88    Ground-Water Flow Eqn.
Solving:  Stress period:     1    Time step:    89    Ground-Water Flow Eqn.
Solving:  Stress period:     1    Time step:    90    Ground-Water Flow Eqn.
Solving:  Stress period:     1    Time step:    91    Ground-Water Flow Eqn.
Solving:  Stress period:     1    Time step:    92    Ground-Water Flow Eqn.
Solving:  Stress period:     1    Time step:    93    Ground-Water Flow Eqn.
Solving:  Stress period:     1    Time step:    94    Ground-Water Flow Eqn.
Solving:  Stress period:     1    Time step:    95    Ground-Water Flow Eqn.
Solving:  Stress period:     1    Time step:    96    Ground-Water Flow Eqn.
Solving:  Stress period:     1    Time step:    97    Ground-Water Flow Eqn.
Solving:  Stress period:     1    Time step:    98    Ground-Water Flow Eqn.
Solving:  Stress period:     1    Time step:    99    Ground-Water Flow Eqn.
Solving:  Stress period:     1    Time step:   100    Ground-Water Flow Eqn.
Solving:  Stress period:     1    Time step:   101    Ground-Water Flow Eqn.
Solving:  Stress period:     1    Time step:   102    Ground-Water Flow Eqn.
Solving:  Stress period:     1    Time step:   103    Ground-Water Flow Eqn.
Solving:  Stress period:     1    Time step:   104    Ground-Water Flow Eqn.
Solving:  Stress period:     1    Time step:   105    Ground-Water Flow Eqn.
Solving:  Stress period:     1    Time step:   106    Ground-Water Flow Eqn.
Solving:  Stress period:     1    Time step:   107    Ground-Water Flow Eqn.
Solving:  Stress period:     1    Time step:   108    Ground-Water Flow Eqn.
Solving:  Stress period:     1    Time step:   109    Ground-Water Flow Eqn.
Solving:  Stress period:     1    Time step:   110    Ground-Water Flow Eqn.
Solving:  Stress period:     1    Time step:   111    Ground-Water Flow Eqn.
Solving:  Stress period:     1    Time step:   112    Ground-Water Flow Eqn.
Solving:  Stress period:     1    Time step:   113    Ground-Water Flow Eqn.
Solving:  Stress period:     1    Time step:   114    Ground-Water Flow Eqn.
Solving:  Stress period:     1    Time step:   115    Ground-Water Flow Eqn.
Solving:  Stress period:     1    Time step:   116    Ground-Water Flow Eqn.
Solving:  Stress period:     1    Time step:   117    Ground-Water Flow Eqn.
Solving:  Stress period:     1    Time step:   118    Ground-Water Flow Eqn.
Solving:  Stress period:     1    Time step:   119    Ground-Water Flow Eqn.
Solving:  Stress period:     1    Time step:   120    Ground-Water Flow Eqn.
Solving:  Stress period:     1    Time step:   121    Ground-Water Flow Eqn.
Solving:  Stress period:     1    Time step:   122    Ground-Water Flow Eqn.
```

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```
 Solving:  Stress period:     1    Time step:   123    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:   124    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:   125    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:   126    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:   127    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:   128    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:   129    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:   130    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:   131    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:   132    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:   133    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:   134    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:   135    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:   136    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:   137    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:   138    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:   139    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:   140    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:   141    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:   142    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:   143    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:   144    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:   145    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:   146    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:   147    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:   148    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:   149    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:   150    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:   151    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:   152    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:   153    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:   154    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:   155    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:   156    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:   157    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:   158    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:   159    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:   160    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:   161    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:   162    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:   163    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:   164    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:   165    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:   166    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:   167    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:   168    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:   169    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:   170    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:   171    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:   172    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:   173    Ground-Water Flow Eqn.
 Solving:  Stress period:     1    Time step:   174    Ground-Water Flow Eqn.
```

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```
Solving:  Stress period:     1    Time step:    175    Ground-Water Flow Eqn.
Solving:  Stress period:     1    Time step:    176    Ground-Water Flow Eqn.
Solving:  Stress period:     1    Time step:    177    Ground-Water Flow Eqn.
Solving:  Stress period:     1    Time step:    178    Ground-Water Flow Eqn.
Solving:  Stress period:     1    Time step:    179    Ground-Water Flow Eqn.
Solving:  Stress period:     1    Time step:    180    Ground-Water Flow Eqn.
Solving:  Stress period:     1    Time step:    181    Ground-Water Flow Eqn.
Solving:  Stress period:     1    Time step:    182    Ground-Water Flow Eqn.
Solving:  Stress period:     1    Time step:    183    Ground-Water Flow Eqn.
Solving:  Stress period:     1    Time step:    184    Ground-Water Flow Eqn.
Solving:  Stress period:     1    Time step:    185    Ground-Water Flow Eqn.
Solving:  Stress period:     1    Time step:    186    Ground-Water Flow Eqn.
Solving:  Stress period:     1    Time step:    187    Ground-Water Flow Eqn.
Solving:  Stress period:     1    Time step:    188    Ground-Water Flow Eqn.
Solving:  Stress period:     1    Time step:    189    Ground-Water Flow Eqn.
Solving:  Stress period:     1    Time step:    190    Ground-Water Flow Eqn.
Solving:  Stress period:     1    Time step:    191    Ground-Water Flow Eqn.
Solving:  Stress period:     1    Time step:    192    Ground-Water Flow Eqn.
Solving:  Stress period:     1    Time step:    193    Ground-Water Flow Eqn.
Solving:  Stress period:     1    Time step:    194    Ground-Water Flow Eqn.
Solving:  Stress period:     1    Time step:    195    Ground-Water Flow Eqn.
Solving:  Stress period:     1    Time step:    196    Ground-Water Flow Eqn.
Solving:  Stress period:     1    Time step:    197    Ground-Water Flow Eqn.
Solving:  Stress period:     1    Time step:    198    Ground-Water Flow Eqn.
Solving:  Stress period:     1    Time step:    199    Ground-Water Flow Eqn.
Solving:  Stress period:     1    Time step:    200    Ground-Water Flow Eqn.
Run end date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:33:51
Elapsed run time:  0.013 Seconds

 Normal termination of simulation
```

Load the head and zeta data from the file

[10]:
```python
# read model heads
hfile = flopy.utils.HeadFile(os.path.join(ml.model_ws, f"{modelname}.hds"))
head = hfile.get_alldata()
# read model zeta
zfile = flopy.utils.CellBudgetFile(
    os.path.join(ml.model_ws, f"{modelname}.zta")
)
kstpkper = zfile.get_kstpkper()
zeta = []
for kk in kstpkper:
    zeta.append(zfile.get_data(kstpkper=kk, text="ZETASRF  1")[0])
zeta = np.array(zeta)
```

Make a graph and add the solution of Wilson and Sa da Costa

[11]:
```python
plt.figure(figsize=(16, 6))
# define x-values of xcells and plot interface
x = np.arange(0, ncol * delr, delr) + delr / 2.0
label = [
```

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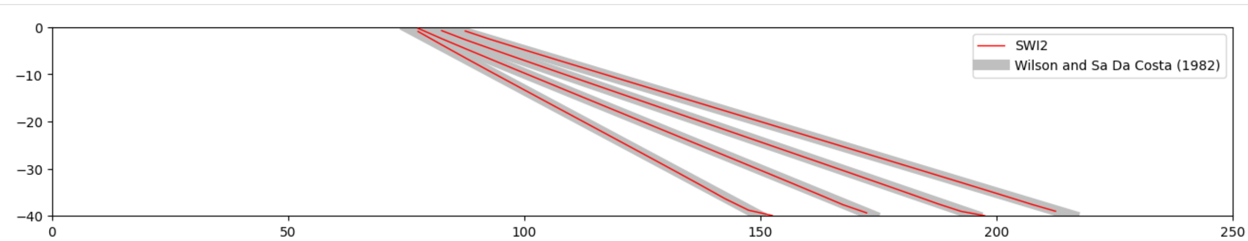
```
    "SWI2",
    "_",
    "_",
    "_",
]  # labels with an underscore are not added to legend
for i in range(4):
    zt = np.ma.masked_outside(zeta[i, 0, 0, :], -39.99999, -0.00001)
    plt.plot(x, zt, "r-", lw=1, zorder=10, label=label[i])
# Data for the Wilson - Sa da Costa solution
k = 2.0
n = 0.2
nu = 0.025
H = 40.0
tzero = H * n / (k * nu) / 4.0
Ltoe = np.zeros(4)
v = 0.125
t = np.arange(100, 500, 100)
label = [
    "Wilson and Sa Da Costa (1982)",
    "_",
    "_",
    "_",
]  # labels with an underscore are not added to legend
for i in range(4):
    Ltoe[i] = H * np.sqrt(k * nu * (t[i] + tzero) / n / H)
    plt.plot(
        [100 - Ltoe[i] + v * t[i], 100 + Ltoe[i] + v * t[i]],
        [0, -40],
        "0.75",
        lw=8,
        zorder=0,
        label=label[i],
    )
# Scale figure and add legend
plt.axis("scaled")
plt.xlim(0, 250)
plt.ylim(-40, 0)
plt.legend(loc="best")
```

[11]:

```
<matplotlib.legend.Legend at 0x7f65f8b6c6d0>
```



Use ModelCrossSection plotting class and plot_surface() method to plot zeta surfaces.

[12]:

```
fig = plt.figure(figsize=(16, 3))
ax = fig.add_subplot(1, 1, 1)
```

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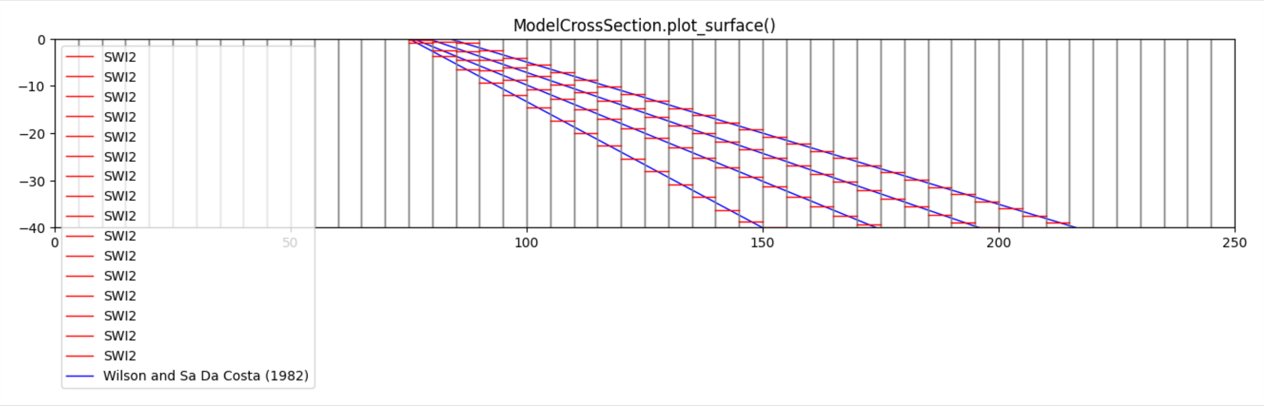
```
modelxsect = flopy.plot.PlotCrossSection(model=ml, line={"Row": 0})
label = ["SWI2", "_", "_", "_"]
for k in range(zeta.shape[0]):
    modelxsect.plot_surface(
        zeta[k, :, :, :],
        masked_values=[0, -40.0],
        color="red",
        lw=1,
        label=label[k],
    )
linecollection = modelxsect.plot_grid()
ax.set_title("ModelCrossSection.plot_surface()")
# Data for the Wilson - Sa da Costa solution
k = 2.0
n = 0.2
nu = 0.025
H = 40.0
tzero = H * n / (k * nu) / 4.0
Ltoe = np.zeros(4)
v = 0.125
t = np.arange(100, 500, 100)
label = [
    "Wilson and Sa Da Costa (1982)",
    "_",
    "_",
    "_",
]  # labels with an underscore are not added to legend
for i in range(4):
    Ltoe[i] = H * np.sqrt(k * nu * (t[i] + tzero) / n / H)
    ax.plot(
        [100 - Ltoe[i] + v * t[i], 100 + Ltoe[i] + v * t[i]],
        [0, -40],
        "blue",
        lw=1,
        zorder=0,
        label=label[i],
    )
# Scale figure and add legend
ax.axis("scaled")
ax.set_xlim(0, 250)
ax.set_ylim(-40, 0)
ax.legend(loc="best")
```

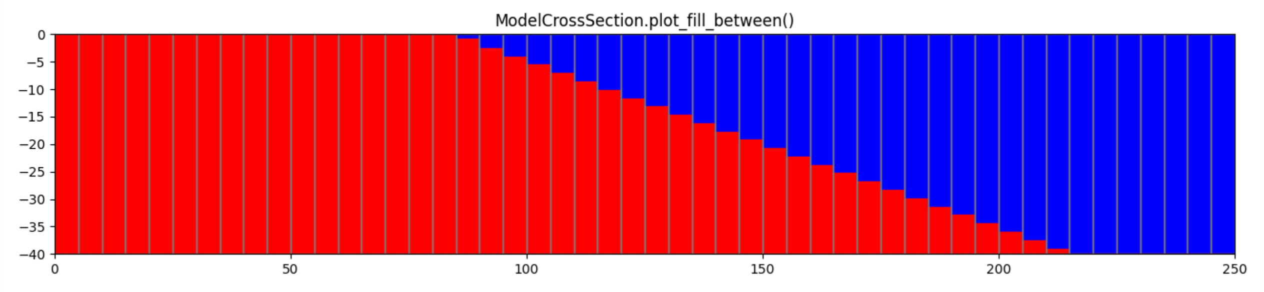
[12]:
```
<matplotlib.legend.Legend at 0x7f66605e9ef10>
```



Use ModelCrossSection plotting class and plot_fill_between() method to fill between zeta surfaces.

[13]:
```
fig = plt.figure(figsize=(16, 3))
ax = fig.add_subplot(1, 1, 1)
modelxsect = flopy.plot.PlotCrossSection(model=ml, line={"Row": 0})
modelxsect.plot_fill_between(zeta[3, :, :, :])
linecollection = modelxsect.plot_grid()
ax.set_title("ModelCrossSection.plot_fill_between()")
```

[13]:
```
Text(0.5, 1.0, 'ModelCrossSection.plot_fill_between()')
```

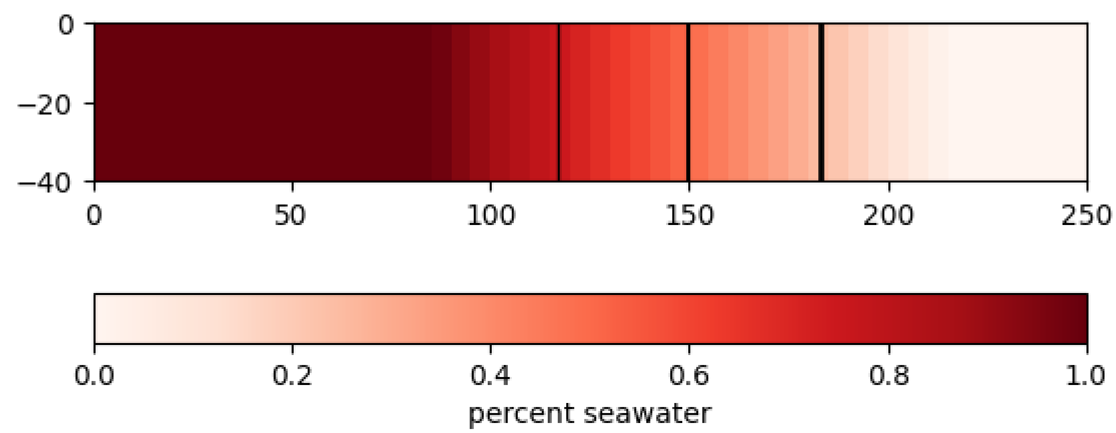


Convert zeta surfaces to relative seawater concentrations

[14]:
```
X, Y = np.meshgrid(x, [0, -40])
zc = flopy.plot.SwiConcentration(model=ml)
conc = zc.calc_conc(zeta={0: zeta[3, :, :, :]}) / 0.025
print(conc[0, 0, :])
v = np.vstack((conc[0, 0, :], conc[0, 0, :]))
plt.imshow(v, extent=[0, 250, -40, 0], cmap="Reds")
cb = plt.colorbar(orientation="horizontal")
cb.set_label("percent seawater")
plt.contour(X, Y, v, [0.25, 0.5, 0.75], linewidths=[2, 1.5, 1], colors="black")
```

```
[1.00000001 1.00000001 1.00000001 1.00000001 1.00000001 1.00000001
 1.00000001 1.00000001 1.00000001 1.00000001 1.00000001 1.00000001
 1.00000001 1.00000001 1.00000001 1.00000001 1.00000001 0.97957368
 0.93777831 0.89900599 0.8606122  0.82240776 0.78431243 0.74628681
 0.70830902 0.6703652  0.63244558 0.59454289 0.55665098 0.5187645
 0.4808785  0.44298783 0.40508729 0.36717053 0.32923027 0.29125705
 0.25323816 0.21515508 0.17697897 0.13865538 0.10004826 0.06099987
 0.02483263 0.         0.         0.         0.         0.
 0.         0.        ]
```

[14]:
```
<matplotlib.contour.QuadContourSet at 0x7f660596f340>
```



[15]:
```python
try:
    # ignore PermissionError on Windows
    temp_dir.cleanup()
except:
    pass
```

6.7.7 SWI2 Example 2. Rotating Brackish Zone

This example problem modifies the rotating interface problem, with 3 zones, no boundary inflow, impermeable aquifer top and bottoms, and ignoring storage changes. The problem domain is 300m long, 40m high, and 1m wide. The aquifer is confined. At x=0, there is a constant head of 0m.

The grid discretization has 60 columns, 1 row, and 1 layer, and delr of 5m, delc 1m, and 40m height. The time discretization is a single period with 1000 time steps, each of 2 days.

There are three groundwater zones: freshwater, brackish, and seawater. The zones are separated by two active ZETA surfaces representing the 25% and 75% seawater salinity contours. Fluid density is represented using the stratified option (ISTRAT=1). The maximum slope of the toe and tip is specified as 0.4, and default tip and toe parameters are used (ALPHA=BETA=0.1). At time t = 0, both interfaces are straight and oriented 45° from horizontal. Initial ZETA surfaces 1 and 2 extend from (x,z) = (150,0) to (x,z) = (190,-40), and from (x,z) = (110,0) to (x,z) = (150,-40), respectively. The brackish zone rotates toward a horizontal position over time.

Import dependencies.

[1]:
```python
import os
import sys
from pathlib import Path
from tempfile import TemporaryDirectory

import matplotlib as mpl
import matplotlib.pyplot as plt
import numpy as np

import flopy

print(sys.version)
```

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```
print(f"numpy version: {np.__version__}")
print(f"matplotlib version: {mpl.__version__}")
print(f"flopy version: {flopy.__version__}")
```

```
3.8.18 (default, Aug 28 2023, 08:27:22)
[GCC 11.4.0]
numpy version: 1.24.4
matplotlib version: 3.7.4
flopy version: 3.5.0
```

[2]:
```
# Modify default matplotlib settings.
updates = {
    "font.family": ["Arial"],
    "mathtext.default": "regular",
    "pdf.compression": 0,
    "pdf.fonttype": 42,
    "legend.fontsize": 7,
    "axes.labelsize": 8,
    "xtick.labelsize": 7,
    "ytick.labelsize": 7,
}
plt.rcParams.update(updates)
```

Define model name and the location of the MODFLOW executable (assumed available on the path).

[3]:
```
modelname = "swiex2"
exe_name = "mf2005"
```

Create a temporary workspace.

[4]:
```
temp_dir = TemporaryDirectory()
workspace = temp_dir.name
```

Create nested working directories.

[5]:
```
dirs = [os.path.join(workspace, "SWI2"), os.path.join(workspace, "SEAWAT")]
for d in dirs:
    if not os.path.exists(d):
        os.mkdir(d)
```

Define model discretization information.

[6]:
```
nper = 1
perlen = 2000
nstp = 1000
nlay, nrow, ncol = 1, 1, 60
delr = 5.0
nsurf = 2
x = np.arange(0.5 * delr, ncol * delr, delr)
xedge = np.linspace(0, float(ncol) * delr, len(x) + 1)
ibound = np.ones((nrow, ncol), int)
ibound[0, 0] = -1
```

Define SWI2 data.

[7]:
```
z0 = np.zeros((nlay, nrow, ncol), float)
z1 = np.zeros((nlay, nrow, ncol), float)
z0[0, 0, 30:38] = np.arange(-2.5, -40, -5)
z0[0, 0, 38:] = -40
z1[0, 0, 22:30] = np.arange(-2.5, -40, -5)
z1[0, 0, 30:] = -40
z = []
z.append(z0)
z.append(z1)
ssz = 0.2
isource = np.ones((nrow, ncol), "int")
isource[0, 0] = 2
```

Create a stratified model and specify that it is a MODFLOW 2005 model.

[8]:
```
modelname = "swiex2_strat"
print("creating...", modelname)
ml = flopy.modflow.Modflow(
    modelname, version="mf2005", exe_name=exe_name, model_ws=dirs[0]
)
discret = flopy.modflow.ModflowDis(
    ml,
    nlay=1,
    ncol=ncol,
    nrow=nrow,
    delr=delr,
    delc=1,
    top=0,
    botm=[-40.0],
    nper=nper,
    perlen=perlen,
    nstp=nstp,
)
bas = flopy.modflow.ModflowBas(ml, ibound=ibound, strt=0.05)
bcf = flopy.modflow.ModflowBcf(ml, laycon=0, tran=2 * 40)
swi = flopy.modflow.ModflowSwi2(
    ml,
    iswizt=55,
    nsrf=nsurf,
    istrat=1,
    toeslope=0.2,
    tipslope=0.2,
    nu=[0, 0.0125, 0.025],
    zeta=z,
    ssz=ssz,
    isource=isource,
    nsolver=1,
)
oc = flopy.modflow.ModflowOc(ml, stress_period_data={(0, 999): ["save head"]})
pcg = flopy.modflow.ModflowPcg(ml)
```

```
creating... swiex2_strat
```

Write input files and run the stratified model.

[9]:
```
ml.write_input()
success, buff = ml.run_model(silent=True, report=True)
assert success, "Failed to run."
```

Load results from the stratified model.

[10]:
```
zetafile = os.path.join(dirs[0], f"{modelname}.zta")
zobj = flopy.utils.CellBudgetFile(zetafile)
zkstpkper = zobj.get_kstpkper()
zeta = zobj.get_data(kstpkper=zkstpkper[-1], text="ZETASRF  1")[0]
zeta2 = zobj.get_data(kstpkper=zkstpkper[-1], text="ZETASRF  2")[0]
```

Define VD model.

[11]:
```
modelname = "swiex2_vd"
print("creating...", modelname)
ml = flopy.modflow.Modflow(
    modelname, version="mf2005", exe_name=exe_name, model_ws=dirs[0]
)
discret = flopy.modflow.ModflowDis(
    ml,
    nlay=1,
    ncol=ncol,
    nrow=nrow,
    delr=delr,
    delc=1,
    top=0,
    botm=[-40.0],
    nper=nper,
    perlen=perlen,
    nstp=nstp,
)
bas = flopy.modflow.ModflowBas(ml, ibound=ibound, strt=0.05)
bcf = flopy.modflow.ModflowBcf(ml, laycon=0, tran=2 * 40)
swi = flopy.modflow.ModflowSwi2(
    ml,
    iswizt=55,
    nsrf=nsurf,
    istrat=0,
    toeslope=0.2,
    tipslope=0.2,
    nu=[0, 0, 0.025, 0.025],
    zeta=z,
    ssz=ssz,
    isource=isource,
    nsolver=1,
)
oc = flopy.modflow.ModflowOc(ml, stress_period_data={(0, 999): ["save head"]})
pcg = flopy.modflow.ModflowPcg(ml)
```

```
creating... swiex2_vd
```

Write input files and run VD model.

[12]:
```
ml.write_input()
success, buff = ml.run_model(silent=True, report=True)
assert success, "Failed to run."
```

Load VD model results.

[13]:
```
zetafile = os.path.join(dirs[0], f"{modelname}.zta")
zobj = flopy.utils.CellBudgetFile(zetafile)
zkstpkper = zobj.get_kstpkper()
zetavd = zobj.get_data(kstpkper=zkstpkper[-1], text="ZETASRF  1")[0]
zetavd2 = zobj.get_data(kstpkper=zkstpkper[-1], text="ZETASRF  2")[0]
```

Define SEAWAT model.

[14]:
```
swtexe_name = "swtv4"
modelname = "swiex2_swt"
print("creating...", modelname)
swt_xmax = 300.0
swt_zmax = 40.0
swt_delr = 1.0
swt_delc = 1.0
swt_delz = 0.5
swt_ncol = int(swt_xmax / swt_delr)  # 300
swt_nrow = 1
swt_nlay = int(swt_zmax / swt_delz)  # 80
print(swt_nlay, swt_nrow, swt_ncol)
swt_ibound = np.ones((swt_nlay, swt_nrow, swt_ncol), int)
# swt_ibound[0, swt_ncol-1, 0] = -1
swt_ibound[0, 0, 0] = -1
swt_x = np.arange(0.5 * swt_delr, swt_ncol * swt_delr, swt_delr)
swt_xedge = np.linspace(0, float(ncol) * delr, len(swt_x) + 1)
swt_top = 0.0
z0 = swt_top
swt_botm = np.zeros((swt_nlay), float)
swt_z = np.zeros((swt_nlay), float)
zcell = -swt_delz / 2.0
for ilay in range(0, swt_nlay):
    z0 -= swt_delz
    swt_botm[ilay] = z0
    swt_z[ilay] = zcell
    zcell -= swt_delz
# swt_X, swt_Z = np.meshgrid(swt_x, swt_botm)
swt_X, swt_Z = np.meshgrid(swt_x, swt_z)
# mt3d
# mt3d boundary array set to all active
icbund = np.ones((swt_nlay, swt_nrow, swt_ncol), int)
# create initial concentrations for MT3D
sconc = np.ones((swt_nlay, swt_nrow, swt_ncol), float)
sconcp = np.zeros((swt_nlay, swt_ncol), float)
xsb = 110
xbf = 150
for ilay in range(0, swt_nlay):
    for icol in range(0, swt_ncol):
```

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```
        if swt_x[icol] > xsb:
            sconc[ilay, 0, icol] = 0.5
        if swt_x[icol] > xbf:
            sconc[ilay, 0, icol] = 0.0
    for icol in range(0, swt_ncol):
        sconcp[ilay, icol] = sconc[ilay, 0, icol]
    xsb += swt_delz
    xbf += swt_delz

# ssm data
itype = flopy.mt3d.Mt3dSsm.itype_dict()
ssm_data = {0: [0, 0, 0, 35.0, itype["BAS6"]]}

# print sconcp
# mt3d print times
timprs = (np.arange(5) + 1) * 2000.0
nprs = len(timprs)
# create the MODFLOW files
m = flopy.seawat.Seawat(modelname, exe_name=swtexe_name, model_ws=dirs[1])
discret = flopy.modflow.ModflowDis(
    m,
    nrow=swt_nrow,
    ncol=swt_ncol,
    nlay=swt_nlay,
    delr=swt_delr,
    delc=swt_delc,
    laycbd=0,
    top=swt_top,
    botm=swt_botm,
    nper=nper,
    perlen=perlen,
    nstp=1,
    steady=False,
)
bas = flopy.modflow.ModflowBas(m, ibound=swt_ibound, strt=0.05)
lpf = flopy.modflow.ModflowLpf(
    m, hk=2.0, vka=2.0, ss=0.0, sy=0.0, laytyp=0, layavg=0
)
oc = flopy.modflow.ModflowOc(m, save_every=1, save_types=["save head"])
pcg = flopy.modflow.ModflowPcg(m)
# Create the MT3DMS model files
adv = flopy.mt3d.Mt3dAdv(
    m,
    mixelm=-1,  # -1 is TVD
    percel=0.05,
    nadvfd=0,
    # 0 or 1 is upstream; 2 is central in space
    # particle based methods
    nplane=4,
    mxpart=1e7,
    itrack=2,
    dceps=1e-4,
```

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```
    npl=16,
    nph=16,
    npmin=8,
    npmax=256,
)
btn = flopy.mt3d.Mt3dBtn(
    m,
    icbund=1,
    prsity=ssz,
    sconc=sconc,
    ifmtcn=-1,
    chkmas=False,
    nprobs=10,
    nprmas=10,
    dt0=0.0,
    ttsmult=1.2,
    ttsmax=100.0,
    ncomp=1,
    nprs=nprs,
    timprs=timprs,
    mxstrn=1e8,
)
dsp = flopy.mt3d.Mt3dDsp(m, al=0.0, trpt=1.0, trpv=1.0, dmcoef=0.0)
gcg = flopy.mt3d.Mt3dGcg(
    m, mxiter=1, iter1=50, isolve=3, cclose=1e-6, iprgcg=5
)
ssm = flopy.mt3d.Mt3dSsm(m, stress_period_data=ssm_data)
# Create the SEAWAT model files
vdf = flopy.seawat.SeawatVdf(
    m,
    nswtcpl=1,
    iwtable=0,
    densemin=0,
    densemax=0,
    denseref=1000.0,
    denseslp=25.0,
    firstdt=1.0e-03,
)
```

```
creating... swiex2_swt
80 1 300
```

Write input files and run SEAWAT model.

[15]:
```
m.write_input()
success, buff = m.run_model(silent=True, report=True)
assert success, "Failed to run."
```

Load SEAWAT model results.

[16]:
```
ucnfile = os.path.join(dirs[1], "MT3D001.UCN")
uobj = flopy.utils.UcnFile(ucnfile)
times = uobj.get_times()
```

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```
print(times)
ukstpkper = uobj.get_kstpkper()
print(ukstpkper)
c = uobj.get_data(totim=times[-1])
conc = np.zeros((swt_nlay, swt_ncol), float)
for icol in range(0, swt_ncol):
    for ilay in range(0, swt_nlay):
        conc[ilay, icol] = c[ilay, 0, icol]
```

```
[2000.0]
[(0, 0)]
```

Create plots.

[17]:
```
# figure
fwid = 7.0  # 6.50
fhgt = 4.5  # 6.75
flft = 0.125
frgt = 0.95
fbot = 0.125
ftop = 0.925

print("creating  cross-section figure...")
xsf, axes = plt.subplots(3, 1, figsize=(fwid, fhgt), facecolor="w")
xsf.subplots_adjust(
    wspace=0.25, hspace=0.25, left=flft, right=frgt, bottom=fbot, top=ftop
)
# plot initial conditions
ax = axes[0]
ax.text(
    -0.075,
    1.05,
    "A",
    transform=ax.transAxes,
    va="center",
    ha="center",
    size="8",
)
# text(.975, .1, '(a)', transform = ax.transAxes, va = 'center', ha = 'center')
ax.plot([110, 150], [0, -40], "k")
ax.plot([150, 190], [0, -40], "k")
ax.set_xlim(0, 300)
ax.set_ylim(-40, 0)
ax.set_yticks(np.arange(-40, 1, 10))
ax.text(50, -20, "salt", va="center", ha="center")
ax.text(150, -20, "brackish", va="center", ha="center")
ax.text(250, -20, "fresh", va="center", ha="center")
ax.set_ylabel("Elevation, in meters")
# plot stratified swi2 and seawat results
ax = axes[1]
ax.text(
    -0.075,
    1.05,
```

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```
    "B",
    transform=ax.transAxes,
    va="center",
    ha="center",
    size="8",
)
#
zp = zeta[0, 0, :]
p = (zp < 0.0) & (zp > -40.0)
ax.plot(x[p], zp[p], "b", linewidth=1.5, drawstyle="steps-mid")
zp = zeta2[0, 0, :]
p = (zp < 0.0) & (zp > -40.0)
ax.plot(x[p], zp[p], "b", linewidth=1.5, drawstyle="steps-mid")
# seawat data
cc = ax.contour(
    swt_X,
    swt_Z,
    conc,
    levels=[0.25, 0.75],
    colors="k",
    linestyles="solid",
    linewidths=0.75,
    zorder=101,
)
# fake figures
ax.plot([-100.0, -100], [-100.0, -100], "b", linewidth=1.5, label="SWI2")
ax.plot([-100.0, -100], [-100.0, -100], "k", linewidth=0.75, label="SEAWAT")
# legend
leg = ax.legend(loc="lower left", numpoints=1)
leg._drawFrame = False
# axes
ax.set_xlim(0, 300)
ax.set_ylim(-40, 0)
ax.set_yticks(np.arange(-40, 1, 10))
ax.set_ylabel("Elevation, in meters")
# plot vd model
ax = axes[2]
ax.text(
    -0.075,
    1.05,
    "C",
    transform=ax.transAxes,
    va="center",
    ha="center",
    size="8",
)
dr = zeta[0, 0, :]
ax.plot(x, dr, "b", linewidth=1.5, drawstyle="steps-mid")
dr = zeta2[0, 0, :]
ax.plot(x, dr, "b", linewidth=1.5, drawstyle="steps-mid")
dr = zetavd[0, 0, :]
ax.plot(x, dr, "r", linewidth=0.75, drawstyle="steps-mid")
```

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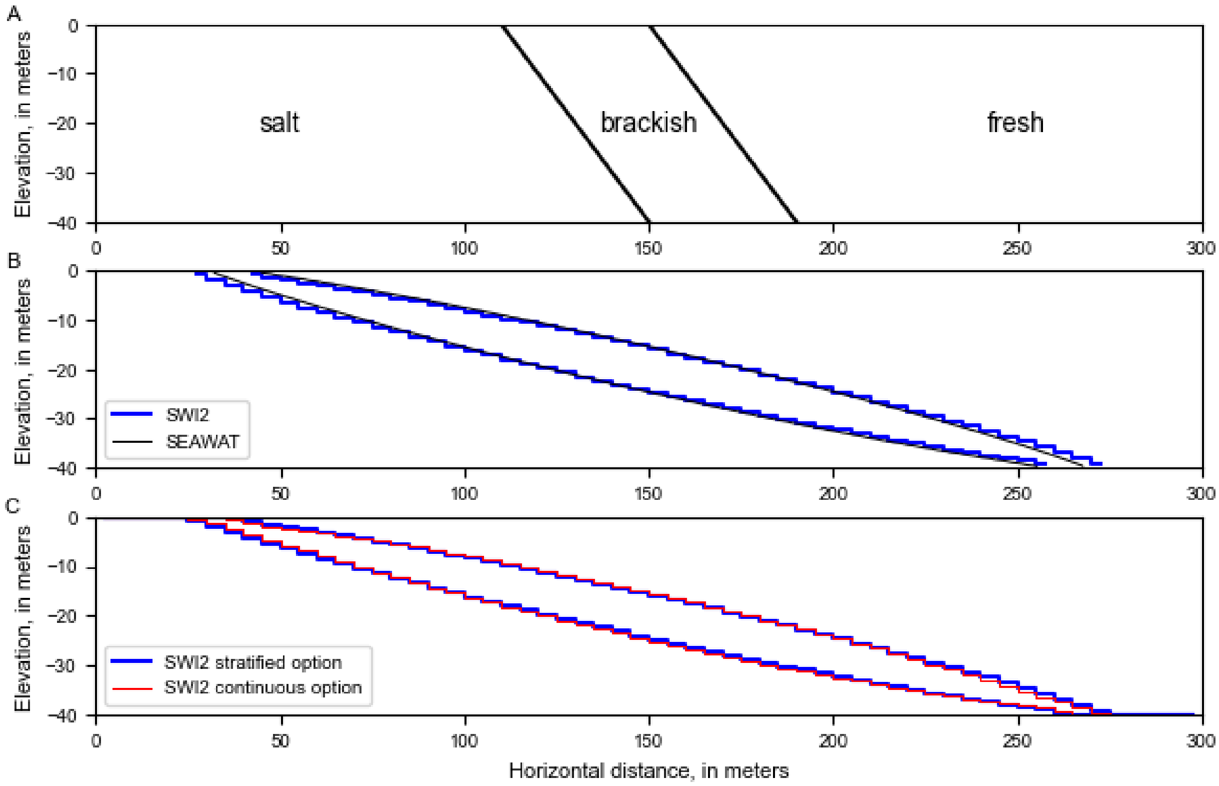
```
dr = zetavd2[0, 0, :]
ax.plot(x, dr, "r", linewidth=0.75, drawstyle="steps-mid")
# fake figures
ax.plot(
    [-100.0, -100],
    [-100.0, -100],
    "b",
    linewidth=1.5,
    label="SWI2 stratified option",
)
ax.plot(
    [-100.0, -100],
    [-100.0, -100],
    "r",
    linewidth=0.75,
    label="SWI2 continuous option",
)
# legend
leg = ax.legend(loc="lower left", numpoints=1)
leg._drawFrame = False
# axes
ax.set_xlim(0, 300)
ax.set_ylim(-40, 0)
ax.set_yticks(np.arange(-40, 1, 10))
ax.set_xlabel("Horizontal distance, in meters")
ax.set_ylabel("Elevation, in meters")
```

```
creating  cross-section figure...
```

[17]:
```
Text(0, 0.5, 'Elevation, in meters')
```



Clean up the temporary workspace.

[18]:
```
try:
    # ignore PermissionError on Windows
    temp_dir.cleanup()
except:
    pass
```

6.7.8 SWI2 Example 3. Freshwater-seawater interface movement in a two-aquifer coastal system

This example problem simulates transient movement of the freshwater-seawater interface in response to changing freshwater inflow in a two-aquifer coastal aquifer system. The problem domain is 4,000m long, 41m high, and 1m wide. Both aquifers are 20m thick and are separated by a leaky layer 1m thick. The aquifers are confined, storage changes are not considered (all MODFLOW stress periods are steady-state), and the top and bottom of each aquifer is horizontal. The top of the upper aquifer and bottom of the lower aquifer are impermeable.

The domain is discretized into 200 columns that are each 20m long (DELR), 1 row that is 1m wide (DELC), and 3 layers that are 20, 1, and 20m thick. A total of 2,000 years are simulated using two 1,000-year stress periods and a constant time step of 2 years. The hydraulic conductivity of the top and bottom aquifer are 2 and 4 m/d, respectively, and the horizon- tal and vertical hydraulic conductivity of the confining unit are 1 and 0.01 m/d, respectively. The effective porosity is 0.2 for all model layers.

The left 600 m of the model domain extends offshore and the ocean boundary is represented as a general head boundary condition (GHB) at the top of model layer 1. A freshwater head of 0 m is specified at the ocean bottom in all general head boundaries. The GHB conductance that controls outflow from the aquifer into the ocean is 0.4 square meter per day (m2/d) and corresponds to a leakance of 0.02 d-1 (or a resistance of 50 days).

The groundwater is divided into a freshwater zone and a seawater zone, separated by an active ZETA surface, 2, between the zones (NSRF=1) that approximates the 50-percent seawater salinity contour. Fluid density is represented using the stratified density option (ISTRAT=1). The dimensionless densities, v, of the freshwater and saltwater are 0.0 and 0.025. The tip and toe tracking parameters are a TOESLOPE of 0.02 and a TIPSLOPE of 0.04, a default ALPHA of 0.1, and a default BETA of 0.1. Initially, the interface between freshwater and seawater is straight, is at the top of aquifer 1 at x = -100, and has a slope of -0.025 m/m. The SWI2 ISOURCE parameter is set to -2 in cells having GHBs so that water that infiltrates into the aquifer from the GHB cells is saltwater (zone 2), whereas water that flows out of the model at the GHB cells is of the same type as the water at the top of the aquifer. In all other cells, the SWI2 ISOURCE parameter is set to 0, indicating boundary conditions have water that is identical to water at the top of the aquifer.

Initially, the net freshwater inflow rate of 0.03 m3/d specified at the right boundary causes flow to occur towards the ocean. The flow in each layer is distributed in proportion to the aquifer transmissivities. During the first 1,000-year stress period, a freshwater source of 0.01 m3/d is specified in the right-most cell (column 200) of the top aquifer, and a freshwater source of 0.02 m3/d is specified in the right-most cell (column 200) of the bottom aquifer. During the second 1,000-year stress period, these values are halved to reduce the net freshwater inflow to 0.015 m3/d, which is distributed in proportion to the transmissivities of both aquifers at the right boundary.

Import dependencies.

[1]:
```python
import os
import sys
from tempfile import TemporaryDirectory

import matplotlib as mpl
import matplotlib.pyplot as plt
import numpy as np

import flopy

print(sys.version)
print(f"numpy version: {np.__version__}")
print(f"matplotlib version: {mpl.__version__}")
print(f"flopy version: {flopy.__version__}")
```

```
3.8.18 (default, Aug 28 2023, 08:27:22)
[GCC 11.4.0]
numpy version: 1.24.4
matplotlib version: 3.7.4
flopy version: 3.5.0
```

[2]:
```python
# Modify default matplotlib settings
updates = {
    "font.family": ["Arial"],
    "mathtext.default": "regular",
    "pdf.compression": 0,
    "pdf.fonttype": 42,
    "legend.fontsize": 7,
    "axes.labelsize": 8,
    "xtick.labelsize": 7,
    "ytick.labelsize": 7,
}
plt.rcParams.update(updates)
```

Define some utility functions.

[3]:
```
def MergeData(ndim, zdata, tb):
    sv = 0.05
    md = np.empty((ndim), float)
    md.fill(np.nan)
    found = np.empty((ndim), bool)
    found.fill(False)
    for idx, layer in enumerate(zdata):
        for jdx, z in enumerate(layer):
            if found[jdx] == True:
                continue
            t0 = tb[idx][0] - sv
            t1 = tb[idx][1] + sv
            if z < t0 and z > t1:
                md[jdx] = z
                found[jdx] = True
    return md
```

[4]:
```
def LegBar(ax, x0, y0, t0, dx, dy, dt, cc):
    for c in cc:
        ax.plot([x0, x0 + dx], [y0, y0], color=c, linewidth=4)
        ctxt = f"{t0:=3d} years"
        ax.text(x0 + 2.0 * dx, y0 + dy / 2.0, ctxt, size=5)
        y0 += dy
        t0 += dt
```

Define model name and the location of the MODFLOW executable (assumed available on the path).

[5]:
```
modelname = "swiex3"
exe_name = "mf2005"
```

Create a temporary workspace.

[6]:
```
temp_dir = TemporaryDirectory()
workspace = temp_dir.name
```

Define model discretization.

[7]:
```
nlay = 3
nrow = 1
ncol = 200
delr = 20.0
delc = 1.0
```

Define well data.

[8]:
```
lrcQ1 = np.array([(0, 0, 199, 0.01), (2, 0, 199, 0.02)])
lrcQ2 = np.array([(0, 0, 199, 0.01 * 0.5), (2, 0, 199, 0.02 * 0.5)])
```

Define general head boundary data.

[9]:
```
lrchc = np.zeros((30, 5))
lrchc[:, [0, 1, 3, 4]] = [0, 0, 0.0, 0.8 / 2.0]
lrchc[:, 2] = np.arange(0, 30)
```

Define SWI2 data.

```
[10]: zini = np.hstack(
          (-9 * np.ones(24), np.arange(-9, -50, -0.5), -50 * np.ones(94))
      )[np.newaxis, :]
      iso = np.zeros((1, 200), dtype=int)
      iso[:, :30] = -2
```

Create the flow model.

```
[11]: ml = flopy.modflow.Modflow(
          modelname, version="mf2005", exe_name=exe_name, model_ws=workspace
      )
      discret = flopy.modflow.ModflowDis(
          ml,
          nrow=nrow,
          ncol=ncol,
          nlay=3,
          delr=delr,
          delc=delc,
          laycbd=[0, 0, 0],
          top=-9.0,
          botm=[-29, -30, -50],
          nper=2,
          perlen=[365 * 1000, 1000 * 365],
          nstp=[500, 500],
      )
      bas = flopy.modflow.ModflowBas(ml, ibound=1, strt=1.0)
      bcf = flopy.modflow.ModflowBcf(
          ml, laycon=[0, 0, 0], tran=[40.0, 1, 80.0], vcont=[0.005, 0.005]
      )
      wel = flopy.modflow.ModflowWel(ml, stress_period_data={0: lrcQ1, 1: lrcQ2})
      ghb = flopy.modflow.ModflowGhb(ml, stress_period_data={0: lrchc})
      swi = flopy.modflow.ModflowSwi2(
          ml,
          iswizt=55,
          nsrf=1,
          istrat=1,
          toeslope=0.01,
          tipslope=0.04,
          nu=[0, 0.025],
          zeta=[zini, zini, zini],
          ssz=0.2,
          isource=iso,
          nsolver=1,
      )
      oc = flopy.modflow.ModflowOc(ml, save_every=100, save_types=["save head"])
      pcg = flopy.modflow.ModflowPcg(ml)
```

Write the model input files.

```
[12]: ml.write_input()
```

Run the model.

[13]:
```python
success, buff = ml.run_model(silent=True, report=True)
assert success, "Failed to run."
```

Load results.

[14]:
```python
headfile = os.path.join(workspace, f"{modelname}.hds")
hdobj = flopy.utils.HeadFile(headfile)
head = hdobj.get_data(totim=3.65000e05)
```

[15]:
```python
zetafile = os.path.join(workspace, f"{modelname}.zta")
zobj = flopy.utils.CellBudgetFile(zetafile)
zkstpkper = zobj.get_kstpkper()
zeta = []
for kk in zkstpkper:
    zeta.append(zobj.get_data(kstpkper=kk, text="ZETASRF  1")[0])
zeta = np.array(zeta)
```

[16]:
```python
fwid, fhgt = 7.00, 4.50
flft, frgt, fbot, ftop = 0.125, 0.95, 0.125, 0.925
```

Plot results.

[17]:
```python
colormap = plt.cm.plasma  # winter
cc = []
icolor = 11
cr = np.linspace(0.0, 0.9, icolor)
for idx in cr:
    cc.append(colormap(idx))
lw = 0.5

x = np.arange(-30 * delr + 0.5 * delr, (ncol - 30) * delr, delr)
xedge = np.linspace(-30.0 * delr, (ncol - 30.0) * delr, len(x) + 1)
zedge = [[-9.0, -29.0], [-29.0, -30.0], [-30.0, -50.0]]

fig = plt.figure(figsize=(fwid, fhgt), facecolor="w")
fig.subplots_adjust(
    wspace=0.25, hspace=0.25, left=flft, right=frgt, bottom=fbot, top=ftop
)

ax = fig.add_subplot(311)
ax.text(
    -0.075,
    1.05,
    "A",
    transform=ax.transAxes,
    va="center",
    ha="center",
    size="8",
)
# confining unit
ax.fill(
    [-600, 3400, 3400, -600],
    [-29, -29, -30, -30],
```

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```
    fc=[0.8, 0.8, 0.8],
    ec=[0.8, 0.8, 0.8],
)
#
z = np.copy(zini[0, :])
zr = z.copy()
p = (zr < -9.0) & (zr > -50.0)
ax.plot(x[p], zr[p], color=cc[0], linewidth=lw, drawstyle="steps-mid")
#
for i in range(5):
    zt = MergeData(
        ncol, [zeta[i, 0, 0, :], zeta[i, 1, 0, :], zeta[i, 2, 0, :]], zedge
    )
    dr = zt.copy()
    ax.plot(x, dr, color=cc[i + 1], linewidth=lw, drawstyle="steps-mid")
# Manufacture a legend bar
LegBar(ax, -200.0, -33.75, 0, 25, -2.5, 200, cc[0:6])
# axes
ax.set_ylim(-50, -9)
ax.set_ylabel("Elevation, in meters")
ax.set_xlim(-250.0, 2500.0)

ax = fig.add_subplot(312)
ax.text(
    -0.075,
    1.05,
    "B",
    transform=ax.transAxes,
    va="center",
    ha="center",
    size="8",
)
# confining unit
ax.fill(
    [-600, 3400, 3400, -600],
    [-29, -29, -30, -30],
    fc=[0.8, 0.8, 0.8],
    ec=[0.8, 0.8, 0.8],
)
#
for i in range(4, 10):
    zt = MergeData(
        ncol, [zeta[i, 0, 0, :], zeta[i, 1, 0, :], zeta[i, 2, 0, :]], zedge
    )
    dr = zt.copy()
    ax.plot(x, dr, color=cc[i + 1], linewidth=lw, drawstyle="steps-mid")
# Manufacture a legend bar
LegBar(ax, -200.0, -33.75, 1000, 25, -2.5, 200, cc[5:11])
# axes
ax.set_ylim(-50, -9)
ax.set_ylabel("Elevation, in meters")
ax.set_xlim(-250.0, 2500.0)
```

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```
ax = fig.add_subplot(313)
ax.text(
    -0.075,
    1.05,
    "C",
    transform=ax.transAxes,
    va="center",
    ha="center",
    size="8",
)
# confining unit
ax.fill(
    [-600, 3400, 3400, -600],
    [-29, -29, -30, -30],
    fc=[0.8, 0.8, 0.8],
    ec=[0.8, 0.8, 0.8],
)
#
zt = MergeData(
    ncol, [zeta[4, 0, 0, :], zeta[4, 1, 0, :], zeta[4, 2, 0, :]], zedge
)
ax.plot(
    x,
    zt,
    marker="o",
    markersize=3,
    linewidth=0.0,
    markeredgecolor="blue",
    markerfacecolor="None",
)
# ghyben herzberg
zeta1 = -9 - 40.0 * (head[0, 0, :])
gbh = np.empty(len(zeta1), float)
gbho = np.empty(len(zeta1), float)
for idx, z1 in enumerate(zeta1):
    if z1 >= -9.0 or z1 <= -50.0:
        gbh[idx] = np.nan
        gbho[idx] = 0.0
    else:
        gbh[idx] = z1
        gbho[idx] = z1
ax.plot(x, gbh, "r")
np.savetxt(os.path.join(workspace, "Ghyben-Herzberg.out"), gbho)
# fake figures
ax.plot([-100.0, -100], [-100.0, -100], "r", label="Ghyben-Herzberg")
ax.plot(
    [-100.0, -100],
    [-100.0, -100],
    "bo",
    markersize=3,
    markeredgecolor="blue",
```

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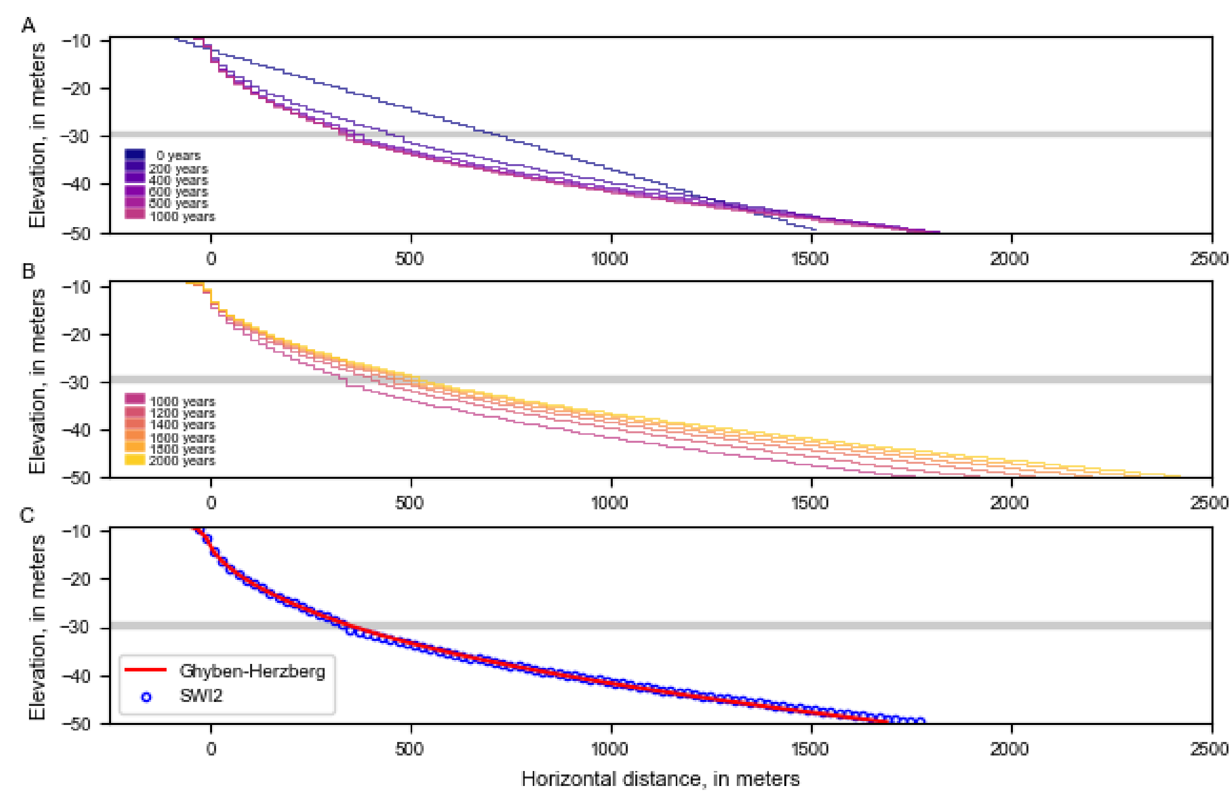
```
    markerfacecolor="None",
    label="SWI2",
)
# legend
leg = ax.legend(loc="lower left", numpoints=1)
leg._drawFrame = False
# axes
ax.set_ylim(-50, -9)
ax.set_xlabel("Horizontal distance, in meters")
ax.set_ylabel("Elevation, in meters")
ax.set_xlim(-250.0, 2500.0)
```

[17]:

```
(-250.0, 2500.0)
```



Clean up the temporary workspace.

[18]:

```
try:
    temp_dir.cleanup()
except (PermissionError, NotADirectoryError):
    pass
```

6.7.9 SWI2 Example 4. Upconing Below a Pumping Well in a Two-Aquifer Island System

This example problem is the fourth example problem in the SWI2 documentation (https://pubs.usgs.gov/tm/6a46/) and simulates transient movement of the freshwater-seawater interface beneath an island in response to recharge and groundwater withdrawals. The island is 2,050$:nbsphinx-math:`times`$2,050 m and consists of two 20-m thick aquifers that extend below sea level. The aquifers are confined, storage changes are not considered (all MODFLOW stress periods are steady-state), and the top and bottom of each aquifer is horizontal. The top of the upper aquifer and the bottom of the lower aquifer are impermeable.

The domain is discretized into 61 columns, 61 rows, and 2 layers, with respective cell dimensions of 50 m (`DELR`), 50 m (`DELC`), and 20 m. A total of 230 years is simulated using three stress periods with lengths of 200, 12, and 18 years, with constant time steps of 0.2, 0.1, and 0.1 years, respectively.

The horizontal and vertical hydraulic conductivity of both aquifers are 10 m/d and 0.2 m/d, respectively. The effective porosity is 0.2 for both aquifers. The model is extended 500 m offshore along all sides and the ocean boundary is represented as a general head boundary condition (GHB) in model layer 1. A freshwater head of 0 m is specified at the ocean bottom in all general head boundaries. The GHB conductance that controls outflow from the aquifer into the ocean is 62.5 m^2/d and corresponds to a leakance of 0.025 d^{-1} (or a resistance of 40 days).

The groundwater is divided into a freshwater zone and a seawater zone, separated by an active ZETA surface between the zones (`NSRF=1`) that approximates the 50-percent seawater salinity contour. Fluid density is represented using the stratified density option (`ISTRAT=1`). The dimensionless density difference (ν) between freshwater and saltwater is 0.025. The tip and toe tracking parameters are a `TOESLOPE` and `TIPSLOPE` of 0.005, a default `ALPHA` of 0.1, and a default `BETA` of 0.1. Initially, the interface between freshwater and saltwater is 1 m below land surface on the island and at the top of the upper aquifer offshore. The SWI2 `ISOURCE` parameter is set to -2 in cells having GHBs so that water that infiltrates into the aquifer from the GHB cells is saltwater (zone 2), whereas water that flows out of the model at the GHB cells is identical to water at the top of the aquifer. `ISOURCE` in layer 2, row 31, column 36 is set to 2 so that a saltwater well may be simulated in the third stress period of simulation 2. In all other cells, the SWI2 `ISOURCE` parameter is set to 0, indicating boundary conditions have water that is identical to water at the top of the aquifer and can be either freshwater or saltwater, depending on the elevation of the active `ZETA` surface in the cell.

A constant recharge rate of 0.4 millimeters per day (mm/d) is used in all three stress periods. The development of the freshwater lens is simulated for 200 years, after which a pumping well having a withdrawal rate of 250 m^3/d is started in layer 1, row 31, column 36. For the first simulation (simulation 1), the well pumps for 30 years, after which the interface almost reaches the top of the upper aquifer layer. In the second simulation (simulation 2), an additional well withdrawing saltwater at a rate of 25 m^3/d is simulated below the freshwater well in layer 2 , row 31, column 36, 12 years after the freshwater groundwater withdrawal begins in the well in layer 1. The saltwater well is intended to prevent the interface from upconing into the upper aquifer (model layer).

Import `numpy` and `matplotlib`, set all figures to be inline, import `flopy.modflow` and `flopy.utils`.

[1]:
```python
import os
import sys
from tempfile import TemporaryDirectory

import matplotlib as mpl
import matplotlib.pyplot as plt
import numpy as np

import flopy

print(sys.version)
print(f"numpy version: {np.__version__}")
print(f"matplotlib version: {mpl.__version__}")
print(f"flopy version: {flopy.__version__}")
```

```
3.8.18 (default, Aug 28 2023, 08:27:22)
[GCC 11.4.0]
numpy version: 1.24.4
matplotlib version: 3.7.4
flopy version: 3.5.0
```

Define model name of your model and the location of MODFLOW executable. All MODFLOW files and output will be stored in the subdirectory defined by the workspace. Create a model named `ml` and specify that this is a MODFLOW-2005 model.

[2]:
```
# Set name of MODFLOW exe
#  assumes executable is in users path statement
exe_name = "mf2005"

temp_dir = TemporaryDirectory()
workspace = temp_dir.name
```

Define the number of layers, rows and columns. The heads are computed quasi-steady state (hence a steady MODFLOW run) while the interface will move. There are three stress periods with a length of 200, 12, and 18 years and 1,000, 120, and 180 steps.

[3]:
```
ncol = 61
nrow = 61
nlay = 2

nper = 3
perlen = [365.25 * 200.0, 365.25 * 12.0, 365.25 * 18.0]
nstp = [1000, 120, 180]
save_head = [200, 60, 60]
steady = True
```

Specify the cell size along the rows (`delr`) and along the columns (`delc`) and the top and bottom of the aquifer for the `DIS` package.

[4]:
```
# dis data
delr, delc = 50.0, 50.0
botm = np.array([-10.0, -30.0, -50.0])
```

Define the `IBOUND` array and starting heads for the `BAS` package. The corners of the model are defined to be inactive.

[5]:
```
# bas data
# ibound - active except for the corners
ibound = np.ones((nlay, nrow, ncol), dtype=int)
ibound[:, 0, 0] = 0
ibound[:, 0, -1] = 0
ibound[:, -1, 0] = 0
ibound[:, -1, -1] = 0
# initial head data
ihead = np.zeros((nlay, nrow, ncol), dtype=float)
```

Define the layers to be confined and define the horizontal and vertical hydraulic conductivity of the aquifer for the `LPF` package.

[6]:
```
# lpf data
laytyp = 0
hk = 10.0
vka = 0.2
```

Define the boundary condition data for the model

[7]:
```
# boundary condition data
# ghb data
colcell, rowcell = np.meshgrid(np.arange(0, ncol), np.arange(0, nrow))
index = np.zeros((nrow, ncol), dtype=int)
index[:, :10] = 1
index[:, -10:] = 1
index[:10, :] = 1
index[-10:, :] = 1
nghb = np.sum(index)
lrchc = np.zeros((nghb, 5))
lrchc[:, 0] = 0
lrchc[:, 1] = rowcell[index == 1]
lrchc[:, 2] = colcell[index == 1]
lrchc[:, 3] = 0.0
lrchc[:, 4] = 50.0 * 50.0 / 40.0
# create ghb dictionary
ghb_data = {0: lrchc}

# recharge data
rch = np.zeros((nrow, ncol), dtype=float)
rch[index == 0] = 0.0004
# create recharge dictionary
rch_data = {0: rch}

# well data
nwells = 2
lrcq = np.zeros((nwells, 4))
lrcq[0, :] = np.array((0, 30, 35, 0))
lrcq[1, :] = np.array([1, 30, 35, 0])
lrcqw = lrcq.copy()
lrcqw[0, 3] = -250
lrcqsw = lrcq.copy()
lrcqsw[0, 3] = -250.0
lrcqsw[1, 3] = -25.0
# create well dictionary
base_well_data = {0: lrcq, 1: lrcqw}
swwells_well_data = {0: lrcq, 1: lrcqw, 2: lrcqsw}
```

[8]:
```
# swi2 data
nadptmx = 10
nadptmn = 1
nu = [0, 0.025]
numult = 5.0
toeslope = nu[1] / numult  # 0.005
tipslope = nu[1] / numult  # 0.005
z1 = -10.0 * np.ones((nrow, ncol))
```

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```
z1[index == 0] = -11.0
z = np.array([[z1, z1]])
iso = np.zeros((nlay, nrow, ncol), dtype=int)
iso[0, :, :][index == 0] = 1
iso[0, :, :][index == 1] = -2
iso[1, 30, 35] = 2
ssz = 0.2
# swi2 observations
obsnam = ["layer1_", "layer2_"]
obslrc = [[0, 30, 35], [1, 30, 35]]
nobs = len(obsnam)
iswiobs = 1051
```

Create output control (OC) data using words

[9]:
```
# oc data
spd = {
    (0, 199): ["print budget", "save head"],
    (0, 200): [],
    (0, 399): ["print budget", "save head"],
    (0, 400): [],
    (0, 599): ["print budget", "save head"],
    (0, 600): [],
    (0, 799): ["print budget", "save head"],
    (0, 800): [],
    (0, 999): ["print budget", "save head"],
    (1, 0): [],
    (1, 59): ["print budget", "save head"],
    (1, 60): [],
    (1, 119): ["print budget", "save head"],
    (1, 120): [],
    (2, 0): [],
    (2, 59): ["print budget", "save head"],
    (2, 60): [],
    (2, 119): ["print budget", "save head"],
    (2, 120): [],
    (2, 179): ["print budget", "save head"],
}
```

Create the model with the freshwater well (Simulation 1)

[10]:
```
modelname = "swiex4_s1"
ml = flopy.modflow.Modflow(
    modelname, version="mf2005", exe_name=exe_name, model_ws=workspace
)

discret = flopy.modflow.ModflowDis(
    ml,
    nlay=nlay,
    nrow=nrow,
    ncol=ncol,
    laycbd=0,
```

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```
    delr=delr,
    delc=delc,
    top=botm[0],
    botm=botm[1:],
    nper=nper,
    perlen=perlen,
    nstp=nstp,
)
bas = flopy.modflow.ModflowBas(ml, ibound=ibound, strt=ihead)
lpf = flopy.modflow.ModflowLpf(ml, laytyp=laytyp, hk=hk, vka=vka)
wel = flopy.modflow.ModflowWel(ml, stress_period_data=base_well_data)
ghb = flopy.modflow.ModflowGhb(ml, stress_period_data=ghb_data)
rch = flopy.modflow.ModflowRch(ml, rech=rch_data)
swi = flopy.modflow.ModflowSwi2(
    ml,
    nsrf=1,
    istrat=1,
    toeslope=toeslope,
    tipslope=tipslope,
    nu=nu,
    zeta=z,
    ssz=ssz,
    isource=iso,
    nsolver=1,
    nadptmx=nadptmx,
    nadptmn=nadptmn,
    nobs=nobs,
    iswiobs=iswiobs,
    obsnam=obsnam,
    obslrc=obslrc,
    iswizt=55,
)
oc = flopy.modflow.ModflowOc(ml, stress_period_data=spd)
pcg = flopy.modflow.ModflowPcg(
    ml, hclose=1.0e-6, rclose=3.0e-3, mxiter=100, iter1=50
)
```

```
ModflowSwi2: specification of nobs is deprecated.
```

Write the simulation 1 MODFLOW input files and run the model

[11]:
```
ml.write_input()
ml.run_model(silent=True)
```

[11]:
```
(True, [])
```

Create the model with the saltwater well (Simulation 2)

[12]:
```
modelname2 = "swiex4_s2"
ml2 = flopy.modflow.Modflow(
    modelname2, version="mf2005", exe_name=exe_name, model_ws=workspace
)
```

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```
discret = flopy.modflow.ModflowDis(
    ml2,
    nlay=nlay,
    nrow=nrow,
    ncol=ncol,
    laycbd=0,
    delr=delr,
    delc=delc,
    top=botm[0],
    botm=botm[1:],
    nper=nper,
    perlen=perlen,
    nstp=nstp,
)
bas = flopy.modflow.ModflowBas(ml2, ibound=ibound, strt=ihead)
lpf = flopy.modflow.ModflowLpf(ml2, laytyp=laytyp, hk=hk, vka=vka)
wel = flopy.modflow.ModflowWel(ml2, stress_period_data=swwells_well_data)
ghb = flopy.modflow.ModflowGhb(ml2, stress_period_data=ghb_data)
rch = flopy.modflow.ModflowRch(ml2, rech=rch_data)
swi = flopy.modflow.ModflowSwi2(
    ml2,
    nsrf=1,
    istrat=1,
    toeslope=toeslope,
    tipslope=tipslope,
    nu=nu,
    zeta=z,
    ssz=ssz,
    isource=iso,
    nsolver=1,
    nadptmx=nadptmx,
    nadptmn=nadptmn,
    nobs=nobs,
    iswiobs=iswiobs,
    obsnam=obsnam,
    obslrc=obslrc,
    iswizt=55,
)
oc = flopy.modflow.ModflowOc(ml2, stress_period_data=spd)
pcg = flopy.modflow.ModflowPcg(
    ml2, hclose=1.0e-6, rclose=3.0e-3, mxiter=100, iter1=50
)
```

```
ModflowSwi2: specification of nobs is deprecated.
```

Write the simulation 2 MODFLOW input files and run the model

[13]:
```
ml2.write_input()
ml2.run_model(silent=True)
```

[13]:
```
(True, [])
```

Load the simulation 1 ZETA data and ZETA observations.

[14]:
```
# read base model zeta
zfile = flopy.utils.CellBudgetFile(
    os.path.join(ml.model_ws, f"{modelname}.zta")
)
kstpkper = zfile.get_kstpkper()
zeta = []
for kk in kstpkper:
    zeta.append(zfile.get_data(kstpkper=kk, text="ZETASRF  1")[0])
zeta = np.array(zeta)
# read swi obs
zobs = np.genfromtxt(
    os.path.join(ml.model_ws, f"{modelname}.zobs.out"), names=True
)
```

Load the simulation 2 ZETA data and ZETA observations.

[15]:
```
# read saltwater well model zeta
zfile2 = flopy.utils.CellBudgetFile(
    os.path.join(ml2.model_ws, f"{modelname2}.zta")
)
kstpkper = zfile2.get_kstpkper()
zeta2 = []
for kk in kstpkper:
    zeta2.append(zfile2.get_data(kstpkper=kk, text="ZETASRF  1")[0])
zeta2 = np.array(zeta2)
# read swi obs
zobs2 = np.genfromtxt(
    os.path.join(ml2.model_ws, f"{modelname2}.zobs.out"), names=True
)
```

Create arrays for the x-coordinates and the output years

[16]:
```
x = np.linspace(-1500, 1500, 61)
xcell = np.linspace(-1500, 1500, 61) + delr / 2.0
xedge = np.linspace(-1525, 1525, 62)
years = [40, 80, 120, 160, 200, 6, 12, 18, 24, 30]
```

Define figure dimensions and colors used for plotting ZETA surfaces

[17]:
```
# figure dimensions
fwid, fhgt = 8.00, 5.50
flft, frgt, fbot, ftop = 0.125, 0.95, 0.125, 0.925

# line color definition
icolor = 5
colormap = plt.cm.jet  # winter
cc = []
cr = np.linspace(0.9, 0.0, icolor)
for idx in cr:
    cc.append(colormap(idx))
```

Recreate **Figure 9** from the SWI2 documentation (https://pubs.usgs.gov/tm/6a46/).

[18]:
```
plt.rcParams.update({"legend.fontsize": 6, "legend.frameon": False})
fig = plt.figure(figsize=(fwid, fhgt), facecolor="w")
fig.subplots_adjust(
    wspace=0.25, hspace=0.25, left=flft, right=frgt, bottom=fbot, top=ftop
)
# first plot
ax = fig.add_subplot(2, 2, 1)
# axes limits
ax.set_xlim(-1500, 1500)
ax.set_ylim(-50, -10)
for idx in range(5):
    # layer 1
    ax.plot(
        xcell,
        zeta[idx, 0, 30, :],
        drawstyle="steps-mid",
        linewidth=0.5,
        color=cc[idx],
        label=f"{years[idx]:2d} years",
    )
    # layer 2
    ax.plot(
        xcell,
        zeta[idx, 1, 30, :],
        drawstyle="steps-mid",
        linewidth=0.5,
        color=cc[idx],
        label="_None",
    )
ax.plot([-1500, 1500], [-30, -30], color="k", linewidth=1.0)
# legend
plt.legend(loc="lower left")
# axes labels and text
ax.set_xlabel("Horizontal distance, in meters")
ax.set_ylabel("Elevation, in meters")
ax.text(
    0.025,
    0.55,
    "Layer 1",
    transform=ax.transAxes,
    va="center",
    ha="left",
    size="7",
)
ax.text(
    0.025,
    0.45,
    "Layer 2",
    transform=ax.transAxes,
    va="center",
    ha="left",
    size="7",
)
```

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```
ax.text(
    0.975,
    0.1,
    "Recharge conditions",
    transform=ax.transAxes,
    va="center",
    ha="right",
    size="8",
)

# second plot
ax = fig.add_subplot(2, 2, 2)
# axes limits
ax.set_xlim(-1500, 1500)
ax.set_ylim(-50, -10)
for idx in range(5, len(years)):
    # layer 1
    ax.plot(
        xcell,
        zeta[idx, 0, 30, :],
        drawstyle="steps-mid",
        linewidth=0.5,
        color=cc[idx - 5],
        label=f"{years[idx]:2d} years",
    )
    # layer 2
    ax.plot(
        xcell,
        zeta[idx, 1, 30, :],
        drawstyle="steps-mid",
        linewidth=0.5,
        color=cc[idx - 5],
        label="_None",
    )
ax.plot([-1500, 1500], [-30, -30], color="k", linewidth=1.0)
# legend
plt.legend(loc="lower left")
# axes labels and text
ax.set_xlabel("Horizontal distance, in meters")
ax.set_ylabel("Elevation, in meters")
ax.text(
    0.025,
    0.55,
    "Layer 1",
    transform=ax.transAxes,
    va="center",
    ha="left",
    size="7",
)
ax.text(
    0.025,
    0.45,
```

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```
    "Layer 2",
    transform=ax.transAxes,
    va="center",
    ha="left",
    size="7",
)
ax.text(
    0.975,
    0.1,
    "Freshwater well withdrawal",
    transform=ax.transAxes,
    va="center",
    ha="right",
    size="8",
)

# third plot
ax = fig.add_subplot(2, 2, 3)
# axes limits
ax.set_xlim(-1500, 1500)
ax.set_ylim(-50, -10)
for idx in range(5, len(years)):
    # layer 1
    ax.plot(
        xcell,
        zeta2[idx, 0, 30, :],
        drawstyle="steps-mid",
        linewidth=0.5,
        color=cc[idx - 5],
        label=f"{years[idx]:2d} years",
    )
    # layer 2
    ax.plot(
        xcell,
        zeta2[idx, 1, 30, :],
        drawstyle="steps-mid",
        linewidth=0.5,
        color=cc[idx - 5],
        label="_None",
    )
ax.plot([-1500, 1500], [-30, -30], color="k", linewidth=1.0)
# legend
plt.legend(loc="lower left")
# axes labels and text
ax.set_xlabel("Horizontal distance, in meters")
ax.set_ylabel("Elevation, in meters")
ax.text(
    0.025,
    0.55,
    "Layer 1",
    transform=ax.transAxes,
    va="center",
```

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```
    ha="left",
    size="7",
)
ax.text(
    0.025,
    0.45,
    "Layer 2",
    transform=ax.transAxes,
    va="center",
    ha="left",
    size="7",
)
ax.text(
    0.975,
    0.1,
    "Freshwater and saltwater\nwell withdrawals",
    transform=ax.transAxes,
    va="center",
    ha="right",
    size="8",
)

# fourth plot
ax = fig.add_subplot(2, 2, 4)
# axes limits
ax.set_xlim(0, 30)
ax.set_ylim(-50, -10)
t = zobs["TOTIM"][999:] / 365 - 200.0
tz2 = zobs["layer1_001"][999:]
tz3 = zobs2["layer1_001"][999:]
for i in range(len(t)):
    if zobs["layer2_001"][i + 999] < -30.0 - 0.1:
        tz2[i] = zobs["layer2_001"][i + 999]
    if zobs2["layer2_001"][i + 999] < 20.0 - 0.1:
        tz3[i] = zobs2["layer2_001"][i + 999]
ax.plot(
    t,
    tz2,
    linestyle="solid",
    color="r",
    linewidth=0.75,
    label="Freshwater well",
)
ax.plot(
    t,
    tz3,
    linestyle="dotted",
    color="r",
    linewidth=0.75,
    label="Freshwater and saltwater well",
)
ax.plot([0, 30], [-30, -30], "k", linewidth=1.0, label="_None")
```

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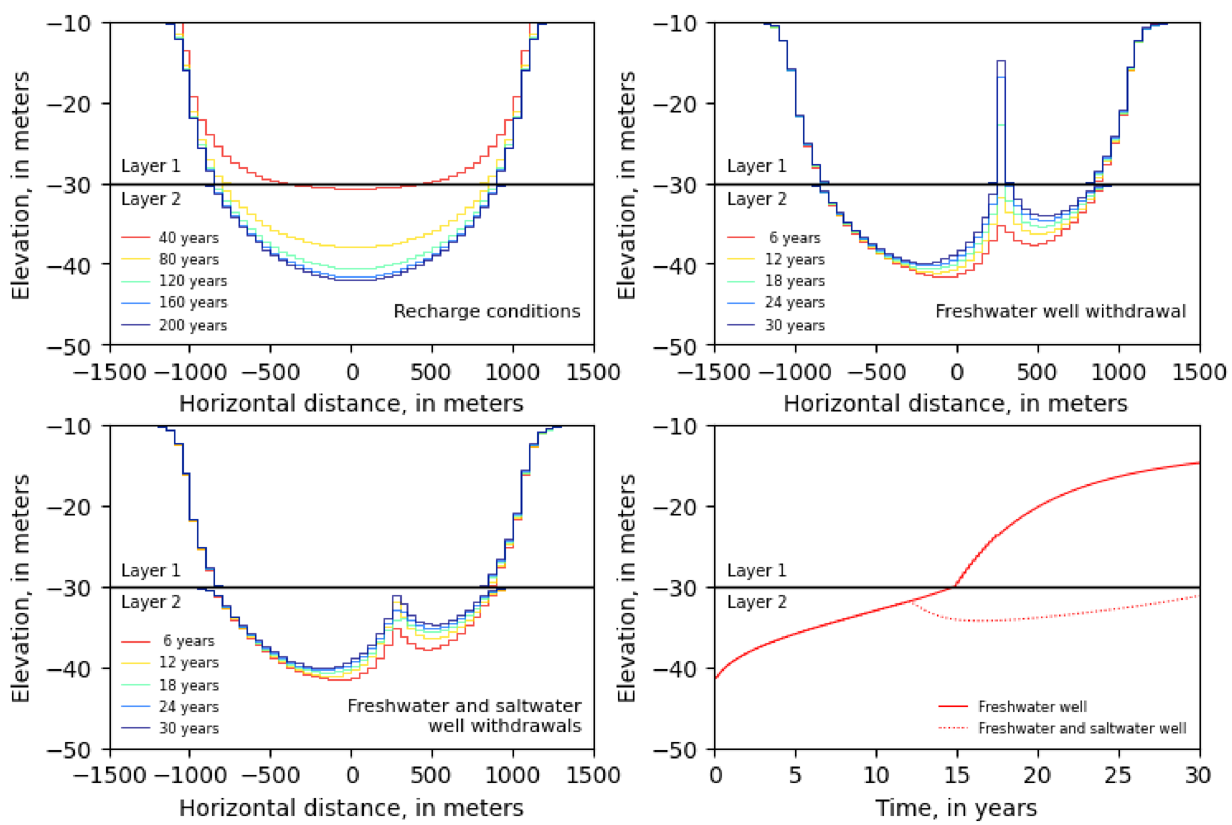
```
# legend
leg = plt.legend(loc="lower right", numpoints=1)
# axes labels and text
ax.set_xlabel("Time, in years")
ax.set_ylabel("Elevation, in meters")
ax.text(
    0.025,
    0.55,
    "Layer 1",
    transform=ax.transAxes,
    va="center",
    ha="left",
    size="7",
)
ax.text(
    0.025,
    0.45,
    "Layer 2",
    transform=ax.transAxes,
    va="center",
    ha="left",
    size="7",
)
```

[18]:

```
Text(0.025, 0.45, 'Layer 2')
```



Use `ModelCrossSection` plotting class and `plot_fill_between()` method to fill between zeta surfaces.

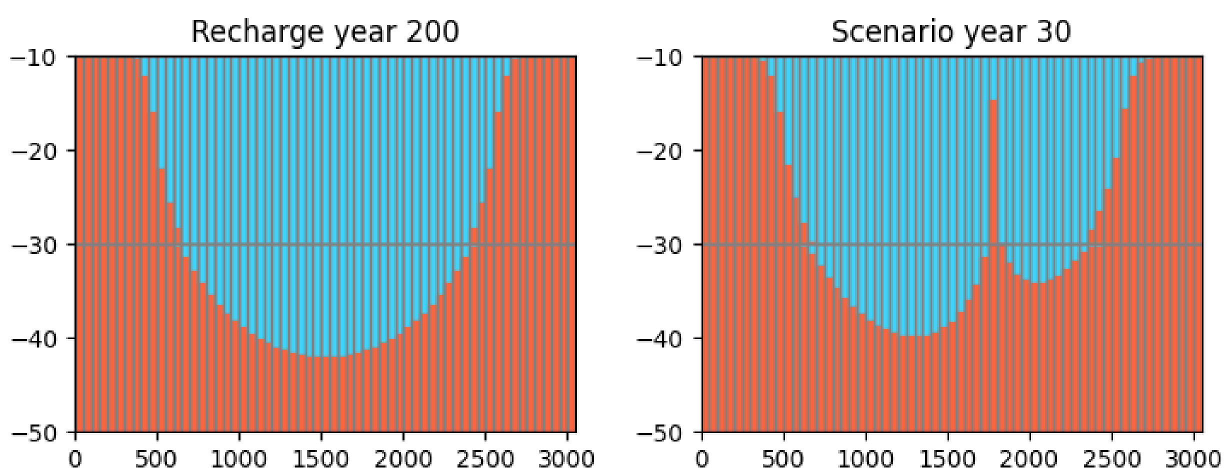
[19]:
```python
fig = plt.figure(figsize=(fwid, fhgt / 2))
fig.subplots_adjust(
    wspace=0.25, hspace=0.25, left=flft, right=frgt, bottom=fbot, top=ftop
)

colors = ["#40d3f7", "#F76541"]

ax = fig.add_subplot(1, 2, 1)
modelxsect = flopy.plot.PlotCrossSection(
    model=ml, line={"Row": 30}, extent=(0, 3050, -50, -10)
)
modelxsect.plot_fill_between(
    zeta[4, :, :, :], colors=colors, ax=ax, edgecolors="none"
)
linecollection = modelxsect.plot_grid(ax=ax)
ax.set_title(f"Recharge year {years[4]}")

ax = fig.add_subplot(1, 2, 2)
ax.set_xlim(0, 3050)
ax.set_ylim(-50, -10)
modelxsect.plot_fill_between(zeta[-1, :, :, :], colors=colors, ax=ax)
linecollection = modelxsect.plot_grid(ax=ax)
ax.set_title(f"Scenario year {years[-1]}")
```

[19]:
```
Text(0.5, 1.0, 'Scenario year 30')
```



[20]:
```python
try:
    # ignore PermissionError on Windows
    temp_dir.cleanup()
except:
    pass
```

6.7.10 SWI2 Example 5. Radial Upconing Problem

This example problem simulates transient movement of the freshwater-seawater interface in response to groundwater withdrawals and is based on the problem of Zhou and others (2005). The aquifer is 120-m thick, confined, storage changes are not considered (because all MODFLOW stress periods are steady-state), and the top and bottom of the aquifer are horizontal and impermeable.

The domain is discretized into a radial flow domain, centered on a pumping well, having 113 columns, 1 row, and 6 layers, with respective cell dimensions of 25m (DELR), 1m (DELC), and 20m. A total of 8 years is simulated using two 4-year stress periods and a constant 1-day time step.

The horizontal and vertical hydraulic conductivity of the aquifer are 21.7 and 8.5 m/d, respectively, and the effective porosity of the aquifer is 0.2. The hydraulic conductivity and effective porosity values applied in the model are based on the approach of logarithmic averaging of interblock transmissivity (LAYAVG=1) to better approximate analytical solutions for radial flow problems (Langevin, 2008). Constant heads were specified at the edge of the model domain (column 113) in all 6 layers, with specified freshwater heads of 0.0m.

The groundwater is divided into a freshwater zone and a seawater zone, separated by an active ZETA surface, 2, between the zones (NSRF=1) that approximates the 50-percent seawater salinity contour. Fluid density is represented using the stratified density option (ISTRAT=1). The dimensionless density difference between freshwater and saltwater is 0.025. The tip and toe tracking parameters are a TOESLOPE and TIPSLOPE of 0.025, a default ALPHA of 0.1, and a default BETA of 0.1. Initially, the interface between freshwater and saltwater is at an elevation of -100m. The SWI2 ISOURCE parameter is set to 1 in the constant head cells in layers 1-5 and to 2 in the constant head cell in layer 6. This ensures that inflow from the constant head cells in model layers 1-5 and 6 is freshwater and saltwater, respectively. In all other cells, the SWI2 ISOURCE parameter was set to 0, indicating boundary conditions have water that is identical to water at the top of the aquifer.

A pumping well screened from 0 to -20m with a withdrawal rate of 2,400 m3/d is simulated for stress period 1 at the left side of the model (column 1) in the first layer. To simulate recovery, the pumping well withdrawal rate was set to 0 m3/d for stress period 2.

The simulated position of the interface is shown at 1-year increments for the withdrawal (stress period 1) and recovery (stress period 2) periods. During the withdrawal period, the interface steadily rises from its initial elevation of -100m to a maximum elevation of -87m after 4 years. During the recovery period, the interface elevation decreases to -96m at the end of year 5 but does not return to the initial elevation of -100m at the end of year 8.

Import dependencies.

[1]:
```python
import math
import os
import sys
from tempfile import TemporaryDirectory

import matplotlib as mpl
import matplotlib.pyplot as plt
import numpy as np

import flopy

print(sys.version)
print(f"numpy version: {np.__version__}")
print(f"matplotlib version: {mpl.__version__}")
print(f"flopy version: {flopy.__version__}")
```

```
3.8.18 (default, Aug 28 2023, 08:27:22)
[GCC 11.4.0]
numpy version: 1.24.4
```

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```
matplotlib version: 3.7.4
flopy version: 3.5.0
```

[2]:
```
# Modify default matplotlib settings.
updates = {
    "font.family": ["Arial"],
    "mathtext.default": "regular",
    "pdf.compression": 0,
    "pdf.fonttype": 42,
    "legend.fontsize": 7,
    "axes.labelsize": 8,
    "xtick.labelsize": 7,
    "ytick.labelsize": 7,
}
plt.rcParams.update(updates)
```

Create a temporary workspace.

[3]:
```
temp_dir = TemporaryDirectory()
workspace = temp_dir.name
```

Make working subdirectories.

[4]:
```
dirs = [os.path.join(workspace, "SWI2"), os.path.join(workspace, "SEAWAT")]
for d in dirs:
    if not os.path.exists(d):
        os.mkdir(d)
```

Define grid discretization.

[5]:
```
nlay = 6
nrow = 1
ncol = 113
delr = np.zeros((ncol), float)
delc = 1.0
r = np.zeros((ncol), float)
x = np.zeros((ncol), float)
edge = np.zeros((ncol), float)
dx = 25.0
for i in range(0, ncol):
    delr[i] = dx
r[0] = delr[0] / 2.0
for i in range(1, ncol):
    r[i] = r[i - 1] + (delr[i - 1] + delr[i]) / 2.0
x[0] = delr[0] / 2.0
for i in range(1, ncol):
    x[i] = x[i - 1] + (delr[i - 1] + delr[i]) / 2.0
edge[0] = delr[0]
for i in range(1, ncol):
    edge[i] = edge[i - 1] + delr[i]
```

Define time discretization.

[6]:
```
nper = 2
perlen = [1460, 1460]
nstp = [1460, 1460]
steady = True
```

Define more shared model parameters.

[7]:
```
nsave_zeta = 8
ndecay = 4
ibound = np.ones((nlay, nrow, ncol), int)
for k in range(0, nlay):
    ibound[k, 0, ncol - 1] = -1
bot = np.zeros((nlay, nrow, ncol), float)
dz = 100.0 / float(nlay - 1)
zall = -np.arange(0, 100 + dz, dz)
zall = np.append(zall, -120.0)
tb = -np.arange(dz, 100 + dz, dz)
tb = np.append(tb, -120.0)
for k in range(0, nlay):
    for i in range(0, ncol):
        bot[k, 0, i] = tb[k]
isource = np.zeros((nlay, nrow, ncol), int)
isource[:, 0, ncol - 1] = 1
isource[nlay - 1, 0, ncol - 1] = 2

khb = (0.0000000000256 * 1000.0 * 9.81 / 0.001) * 60 * 60 * 24
kvb = (0.0000000000100 * 1000.0 * 9.81 / 0.001) * 60 * 60 * 24
ssb = 1e-5
sszb = 0.2
kh = np.zeros((nlay, nrow, ncol), float)
kv = np.zeros((nlay, nrow, ncol), float)
ss = np.zeros((nlay, nrow, ncol), float)
ssz = np.zeros((nlay, nrow, ncol), float)
for k in range(0, nlay):
    for i in range(0, ncol):
        f = r[i] * 2.0 * math.pi
        kh[k, 0, i] = khb * f
        kv[k, 0, i] = kvb * f
        ss[k, 0, i] = ssb * f
        ssz[k, 0, i] = sszb * f
z = np.ones((nlay), float)
z = -100.0 * z

nwell = 1
for k in range(0, nlay):
    if zall[k] > -20.0 and zall[k + 1] <= -20:
        nwell = k + 1
print(f"nlay={nlay} dz={dz} nwell={nwell}")
wellQ = -2400.0
wellbtm = -20.0
wellQpm = wellQ / abs(wellbtm)
well_data = {}
for ip in range(0, nper):
```

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```
    welllist = np.zeros((nwell, 4), float)
    for iw in range(0, nwell):
        if ip == 0:
            b = zall[iw] - zall[iw + 1]
            if zall[iw + 1] < wellbtm:
                b = zall[iw] - wellbtm
            q = wellQpm * b
        else:
            q = 0.0
        welllist[iw, 0] = iw
        welllist[iw, 1] = 0
        welllist[iw, 2] = 0
        welllist[iw, 3] = q
    well_data[ip] = welllist.copy()

ihead = np.zeros((nlay), float)

ocspd = {}
for i in range(0, nper):
    icnt = 0
    for j in range(0, nstp[i]):
        icnt += 1
        if icnt == 365:
            ocspd[(i, j)] = ["save head"]
            icnt = 0
        else:
            ocspd[(i, j)] = []

solver2params = {
    "mxiter": 100,
    "iter1": 20,
    "npcond": 1,
    "zclose": 1.0e-6,
    "rclose": 3e-3,
    "relax": 1.0,
    "nbpol": 2,
    "damp": 1.0,
    "dampt": 1.0,
}
```

```
nlay=6 dz=20.0 nwell=1
```

Define SWI2 model name and MODFLOW executable name.

[8]:
```
modelname = "swi2ex5"
mf_name = "mf2005"
```

Define the SWI2 model.

[9]:
```
ml = flopy.modflow.Modflow(
    modelname, version="mf2005", exe_name=mf_name, model_ws=dirs[0]
)
discret = flopy.modflow.ModflowDis(
```

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```
    ml,
    nrow=nrow,
    ncol=ncol,
    nlay=nlay,
    delr=delr,
    delc=delc,
    top=0,
    botm=bot,
    laycbd=0,
    nper=nper,
    perlen=perlen,
    nstp=nstp,
    steady=steady,
)
bas = flopy.modflow.ModflowBas(ml, ibound=ibound, strt=ihead)
lpf = flopy.modflow.ModflowLpf(
    ml, hk=kh, vka=kv, ss=ss, sy=ssz, vkcb=0, laytyp=0, layavg=1
)
wel = flopy.modflow.ModflowWel(ml, stress_period_data=well_data)
swi = flopy.modflow.ModflowSwi2(
    ml,
    iswizt=55,
    nsrf=1,
    istrat=1,
    toeslope=0.025,
    tipslope=0.025,
    nu=[0, 0.025],
    zeta=z,
    ssz=ssz,
    isource=isource,
    nsolver=2,
    solver2params=solver2params,
)
oc = flopy.modflow.ModflowOc(ml, stress_period_data=ocspd)
pcg = flopy.modflow.ModflowPcg(
    ml, hclose=1.0e-6, rclose=3.0e-3, mxiter=100, iter1=50
)
```

Write input files and run the SWI2 model.

[10]:
```
ml.write_input()
success, buff = ml.run_model(silent=True, report=True)
assert success, "Failed to run."
```

[11]:
```
# Load model results.
get_stp = [364, 729, 1094, 1459, 364, 729, 1094, 1459]
get_per = [0, 0, 0, 0, 1, 1, 1, 1]
nswi_times = len(get_per)
zetafile = os.path.join(dirs[0], f"{modelname}.zta")
zobj = flopy.utils.CellBudgetFile(zetafile)
zeta = []
for kk in zip(get_stp, get_per):
```

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```
    zeta.append(zobj.get_data(kstpkper=kk, text="ZETASRF  1")[0])
zeta = np.array(zeta)
```

Redefine input data for SEAWAT.

[12]:
```
nlay_swt = 120
# mt3d print times
timprs = (np.arange(8) + 1) * 365.0
nprs = len(timprs)
ndecay = 4
ibound = np.ones((nlay_swt, nrow, ncol), "int")
for k in range(0, nlay_swt):
    ibound[k, 0, ncol - 1] = -1
bot = np.zeros((nlay_swt, nrow, ncol), float)
zall = [0, -20.0, -40.0, -60.0, -80.0, -100.0, -120.0]
dz = 120.0 / nlay_swt
tb = np.arange(nlay_swt) * -dz - dz
sconc = np.zeros((nlay_swt, nrow, ncol), float)
icbund = np.ones((nlay_swt, nrow, ncol), int)
strt = np.zeros((nlay_swt, nrow, ncol), float)
pressure = 0.0
g = 9.81
z = -dz / 2.0  # cell center
for k in range(0, nlay_swt):
    for i in range(0, ncol):
        bot[k, 0, i] = tb[k]
    if bot[k, 0, 0] >= -100.0:
        sconc[k, 0, :] = 0.0 / 3.0 * 0.025 * 1000.0 / 0.7143
    else:
        sconc[k, 0, :] = 3.0 / 3.0 * 0.025 * 1000.0 / 0.7143
        icbund[k, 0, -1] = -1

    dense = 1000.0 + 0.7143 * sconc[k, 0, 0]
    pressure += 0.5 * dz * dense * g
    if k > 0:
        z = z - dz
        denseup = 1000.0 + 0.7143 * sconc[k - 1, 0, 0]
        pressure += 0.5 * dz * denseup * g
    strt[k, 0, :] = z + pressure / dense / g
    # print z, pressure, strt[k, 0, 0], sconc[k, 0, 0]

khb = (0.0000000000256 * 1000.0 * 9.81 / 0.001) * 60 * 60 * 24
kvb = (0.0000000000100 * 1000.0 * 9.81 / 0.001) * 60 * 60 * 24
ssb = 1e-5
sszb = 0.2
kh = np.zeros((nlay_swt, nrow, ncol), float)
kv = np.zeros((nlay_swt, nrow, ncol), float)
ss = np.zeros((nlay_swt, nrow, ncol), float)
ssz = np.zeros((nlay_swt, nrow, ncol), float)
for k in range(0, nlay_swt):
    for i in range(0, ncol):
        f = r[i] * 2.0 * math.pi
```

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```
        kh[k, 0, i] = khb * f
        kv[k, 0, i] = kvb * f
        ss[k, 0, i] = ssb * f
        ssz[k, 0, i] = sszb * f
# wells and ssm data
itype = flopy.mt3d.Mt3dSsm.itype_dict()
nwell = 1
for k in range(0, nlay_swt):
    if bot[k, 0, 0] >= -20.0:
        nwell = k + 1
print(f"nlay_swt={nlay_swt} dz={dz} nwell={nwell}")
well_data = {}
ssm_data = {}
wellQ = -2400.0
wellbtm = -20.0
wellQpm = wellQ / abs(wellbtm)
for ip in range(0, nper):
    welllist = np.zeros((nwell, 4), float)
    ssmlist = []
    for iw in range(0, nwell):
        if ip == 0:
            q = wellQpm * dz
        else:
            q = 0.0
        welllist[iw, 0] = iw
        welllist[iw, 1] = 0
        welllist[iw, 2] = 0
        welllist[iw, 3] = q
        ssmlist.append([iw, 0, 0, 0.0, itype["WEL"]])
    well_data[ip] = welllist.copy()
    ssm_data[ip] = ssmlist
```

```
nlay_swt=120 dz=1.0 nwell=20
```

Define model name and exe for SEAWAT model.

[13]:
```
modelname = "swi2ex5_swt"
swtexe_name = "swtv4"
```

Create the SEAWAT model.

[14]:
```
m = flopy.seawat.Seawat(modelname, exe_name=swtexe_name, model_ws=dirs[1])
discret = flopy.modflow.ModflowDis(
    m,
    nrow=nrow,
    ncol=ncol,
    nlay=nlay_swt,
    delr=delr,
    delc=delc,
    top=0,
    botm=bot,
    laycbd=0,
    nper=nper,
```

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```
    perlen=perlen,
    nstp=nstp,
    steady=True,
)
bas = flopy.modflow.ModflowBas(m, ibound=ibound, strt=strt)
lpf = flopy.modflow.ModflowLpf(
    m, hk=kh, vka=kv, ss=ss, sy=ssz, vkcb=0, laytyp=0, layavg=1
)
wel = flopy.modflow.ModflowWel(m, stress_period_data=well_data)
oc = flopy.modflow.ModflowOc(m, save_every=365, save_types=["save head"])
pcg = flopy.modflow.ModflowPcg(
    m, hclose=1.0e-5, rclose=3.0e-3, mxiter=100, iter1=50
)
# Create the basic MT3DMS model data
adv = flopy.mt3d.Mt3dAdv(
    m,
    mixelm=-1,
    percel=0.5,
    nadvfd=0,
    # 0 or 1 is upstream; 2 is central in space
    # particle based methods
    nplane=4,
    mxpart=1e7,
    itrack=2,
    dceps=1e-4,
    npl=16,
    nph=16,
    npmin=8,
    npmax=256,
)
btn = flopy.mt3d.Mt3dBtn(
    m,
    icbund=icbund,
    prsity=ssz,
    ncomp=1,
    sconc=sconc,
    ifmtcn=-1,
    chkmas=False,
    nprobs=10,
    nprmas=10,
    dt0=1.0,
    ttsmult=1.0,
    nprs=nprs,
    timprs=timprs,
    mxstrn=1e8,
)
dsp = flopy.mt3d.Mt3dDsp(m, al=0.0, trpt=1.0, trpv=1.0, dmcoef=0.0)
gcg = flopy.mt3d.Mt3dGcg(m, mxiter=1, iter1=50, isolve=1, cclose=1e-7)
ssm = flopy.mt3d.Mt3dSsm(m, stress_period_data=ssm_data)
# Create the SEAWAT model data
vdf = flopy.seawat.SeawatVdf(
    m,
```

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```
    iwtable=0,
    densemin=0,
    densemax=0,
    denseref=1000.0,
    denseslp=0.7143,
    firstdt=1e-3,
)
```

Write SEAWAT model input files.

[15]:
```
m.write_input()
```

Run the SEAWAT model.

[16]:
```
success, buff = m.run_model(silent=True, report=True)
assert success, "Failed to run."
```

Load SEAWAT model results.

[17]:
```
ucnfile = os.path.join(dirs[1], "MT3D001.UCN")
uobj = flopy.utils.UcnFile(ucnfile)
times = uobj.get_times()
print(times)
conc = np.zeros((len(times), nlay_swt, ncol), float)
for idx, tt in enumerate(times):
    c = uobj.get_data(totim=tt)
    for ilay in range(0, nlay_swt):
        for jcol in range(0, ncol):
            conc[idx, ilay, jcol] = c[ilay, 0, jcol]
```

```
[365.0, 730.0, 1095.0, 1460.0, 1825.0, 2190.0, 2555.0, 2920.0]
```

Define some spatial data for plots.

[18]:
```
# swi2
bot = np.zeros((1, ncol, nlay), float)
dz = 100.0 / float(nlay - 1)
zall = -np.arange(0, 100 + dz, dz)
zall = np.append(zall, -120.0)
tb = -np.arange(dz, 100 + dz, dz)
tb = np.append(tb, -120.0)
for k in range(0, nlay):
    for i in range(0, ncol):
        bot[0, i, k] = tb[k]
# seawat
swt_dz = 120.0 / nlay_swt
swt_tb = np.zeros((nlay_swt), float)
zc = -swt_dz / 2.0
for klay in range(0, nlay_swt):
    swt_tb[klay] = zc
    zc -= swt_dz
X, Z = np.meshgrid(x, swt_tb)
```

Plot results.

[19]:
```
fwid, fhgt = 6.5, 6.5
flft, frgt, fbot, ftop = 0.125, 0.95, 0.125, 0.925

eps = 1.0e-3

lc = ["r", "c", "g", "b", "k"]
cfig = ["A", "B", "C", "D", "E", "F", "G", "H"]
inc = 1.0e-3

xsf, axes = plt.subplots(4, 2, figsize=(fwid, fhgt), facecolor="w")
xsf.subplots_adjust(
    wspace=0.25, hspace=0.25, left=flft, right=frgt, bottom=fbot, top=ftop
)
# withdrawal and recovery titles
ax = axes.flatten()[0]
ax.text(
    0.0,
    1.03,
    "Withdrawal",
    transform=ax.transAxes,
    va="bottom",
    ha="left",
    size="8",
)
ax = axes.flatten()[1]
ax.text(
    0.0,
    1.03,
    "Recovery",
    transform=ax.transAxes,
    va="bottom",
    ha="left",
    size="8",
)
# dummy items for legend
ax = axes.flatten()[2]
ax.plot(
    [-1, -1],
    [-1, -1],
    "bo",
    markersize=3,
    markeredgecolor="blue",
    markerfacecolor="None",
    label="SWI2 interface",
)
ax.plot(
    [-1, -1],
    [-1, -1],
    color="k",
    linewidth=0.75,
    linestyle="solid",
    label="SEAWAT 50% seawater",
)
```

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```
ax.plot(
    [-1, -1],
    [-1, -1],
    marker="s",
    color="k",
    linewidth=0,
    linestyle="none",
    markeredgecolor="w",
    markerfacecolor="0.75",
    label="SEAWAT 5-95% seawater",
)
leg = ax.legend(
    loc="upper left",
    numpoints=1,
    ncol=1,
    labelspacing=0.5,
    borderaxespad=1,
    handlelength=3,
)
leg._drawFrame = False
# data items
for itime in range(0, nswi_times):
    zb = np.zeros((ncol), float)
    zs = np.zeros((ncol), float)
    for icol in range(0, ncol):
        for klay in range(0, nlay):
            # top and bottom of layer
            ztop = float(f"{zall[klay]:10.3e}")
            zbot = float(f"{zall[klay + 1]:10.3e}")
            # fresh-salt zeta surface
            zt = zeta[itime, klay, 0, icol]
            if (ztop - zt) > eps:
                zs[icol] = zt
    if itime < ndecay:
        ic = itime
        isp = ic * 2
        ax = axes.flatten()[isp]
    else:
        ic = itime - ndecay
        isp = (ic * 2) + 1
        ax = axes.flatten()[isp]
    # figure title
    ax.text(
        -0.15,
        1.025,
        cfig[itime],
        transform=ax.transAxes,
        va="center",
        ha="center",
        size="8",
    )
```

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```
    # swi2
    ax.plot(
        x,
        zs,
        "bo",
        markersize=3,
        markeredgecolor="blue",
        markerfacecolor="None",
        label="_None",
    )

    # seawat
    sc = ax.contour(
        X,
        Z,
        conc[itime, :, :],
        levels=[17.5],
        colors="k",
        linestyles="solid",
        linewidths=0.75,
        zorder=30,
    )
    cc = ax.contourf(
        X,
        Z,
        conc[itime, :, :],
        levels=[0.0, 1.75, 33.250],
        colors=["w", "0.75", "w"],
    )
    # set graph limits
    ax.set_xlim(0, 500)
    ax.set_ylim(-100, -65)
    if itime < ndecay:
        ax.set_ylabel("Elevation, in meters")

# x labels
ax = axes.flatten()[6]
ax.set_xlabel("Horizontal distance, in meters")
ax = axes.flatten()[7]
ax.set_xlabel("Horizontal distance, in meters")

# simulation time titles
for itime in range(0, nswi_times):
    if itime < ndecay:
        ic = itime
        isp = ic * 2
        ax = axes.flatten()[isp]
    else:
        ic = itime - ndecay
        isp = (ic * 2) + 1
        ax = axes.flatten()[isp]
    iyr = itime + 1
```

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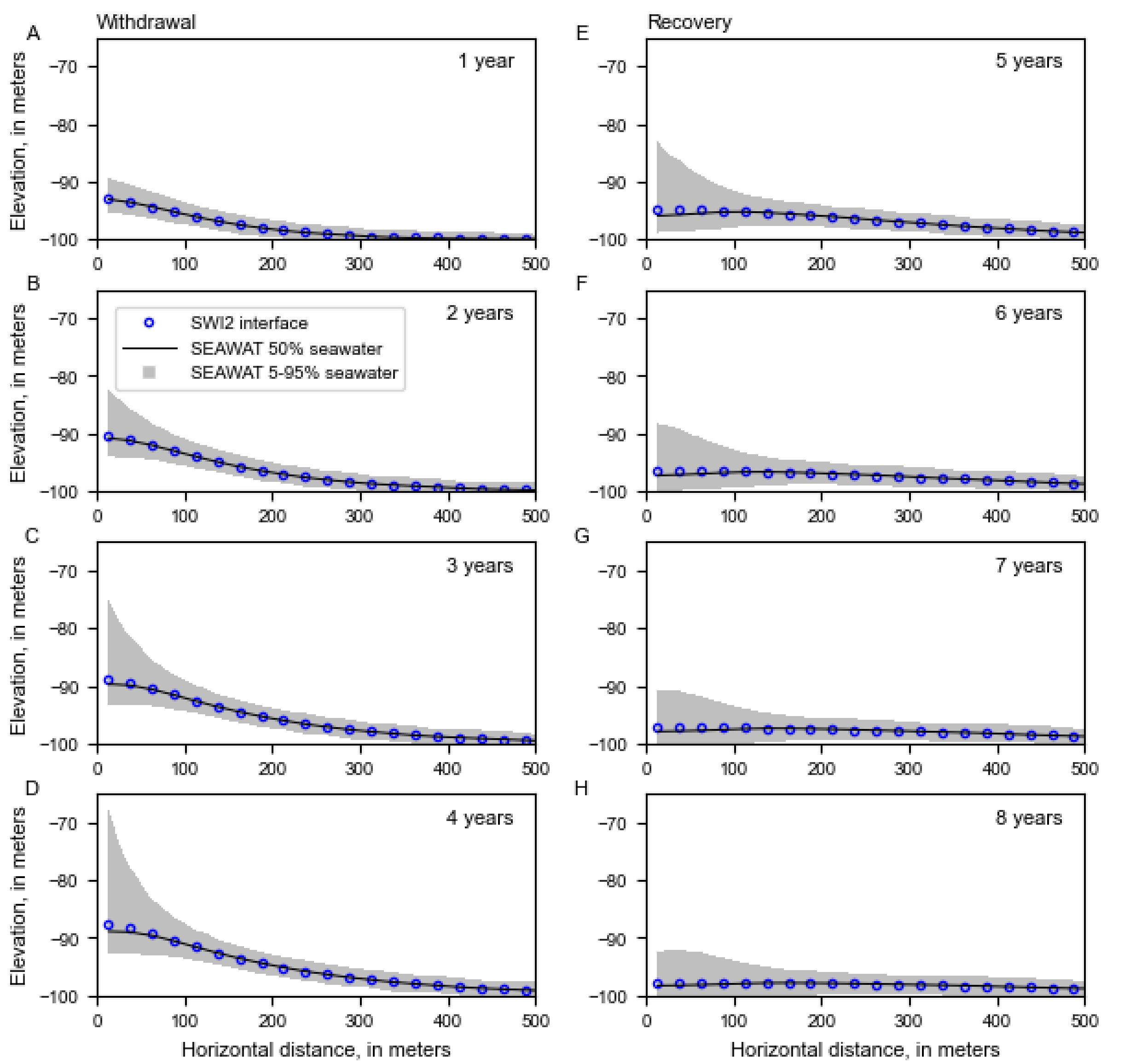
```
    if iyr > 1:
        ctxt = f"{iyr} years"
    else:
        ctxt = f"{iyr} year"
    ax.text(
        0.95,
        0.925,
        ctxt,
        transform=ax.transAxes,
        va="top",
        ha="right",
        size="8",
    )

plt.show()
```



Clean up the temporary workspace.

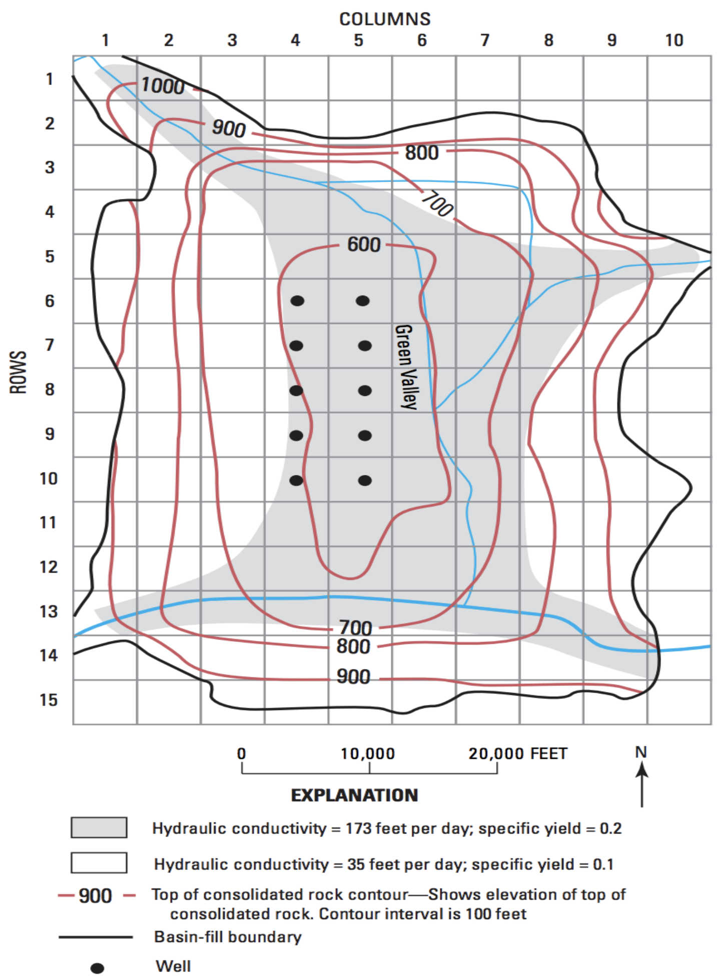
[20]:
```
try:
    temp_dir.cleanup()
except (PermissionError, NotADirectoryError):
    pass
```

6.7.11 Unsaturated Zone Flow (UZF) Package demo

Demonstrates functionality of the flopy UZF module using the example from Niswonger and others (2006). This is the same as the SFR example problem from Prudic and others (2004; p. 13–19), except the UZF package replaces the ET and RCH packages.

Problem description:

- Grid dimensions: 1 Layer, 15 Rows, 10 Columns
- Stress periods: 12
- Units are in seconds and days
- Flow package: LPF
- Stress packages: SFR, GHB, UZF
- Solver: SIP



[1]:
```
import glob
```

[2]:
```
import os
import shutil
import sys
from pathlib import Path
from tempfile import TemporaryDirectory

import matplotlib as mpl
import matplotlib.pyplot as plt
import numpy as np
import pandas as pd

proj_root = Path.cwd().parent.parent

import flopy
from flopy.utils import flopy_io

print(sys.version)
print(f"numpy version: {np.__version__}")
print(f"matplotlib version: {mpl.__version__}")
```

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```
print(f"pandas version: {pd.__version__}")
print(f"flopy version: {flopy.__version__}")
```

```
3.8.18 (default, Aug 28 2023, 08:27:22)
[GCC 11.4.0]
numpy version: 1.24.4
matplotlib version: 3.7.4
pandas version: 2.0.3
flopy version: 3.5.0
```

[3]:
```
# Set name of MODFLOW exe
#  assumes executable is in users path statement
exe_name = "mf2005"
```

Set up a temporary workspace.

[4]:
```
temp_dir = TemporaryDirectory()
path = Path(temp_dir.name)

gpth = proj_root / "examples" / "data" / "mf2005_test" / "UZFtest2.*"
for f in glob.glob(str(gpth)):
    shutil.copy(f, path)
```

Load example dataset, skipping the UZF package.

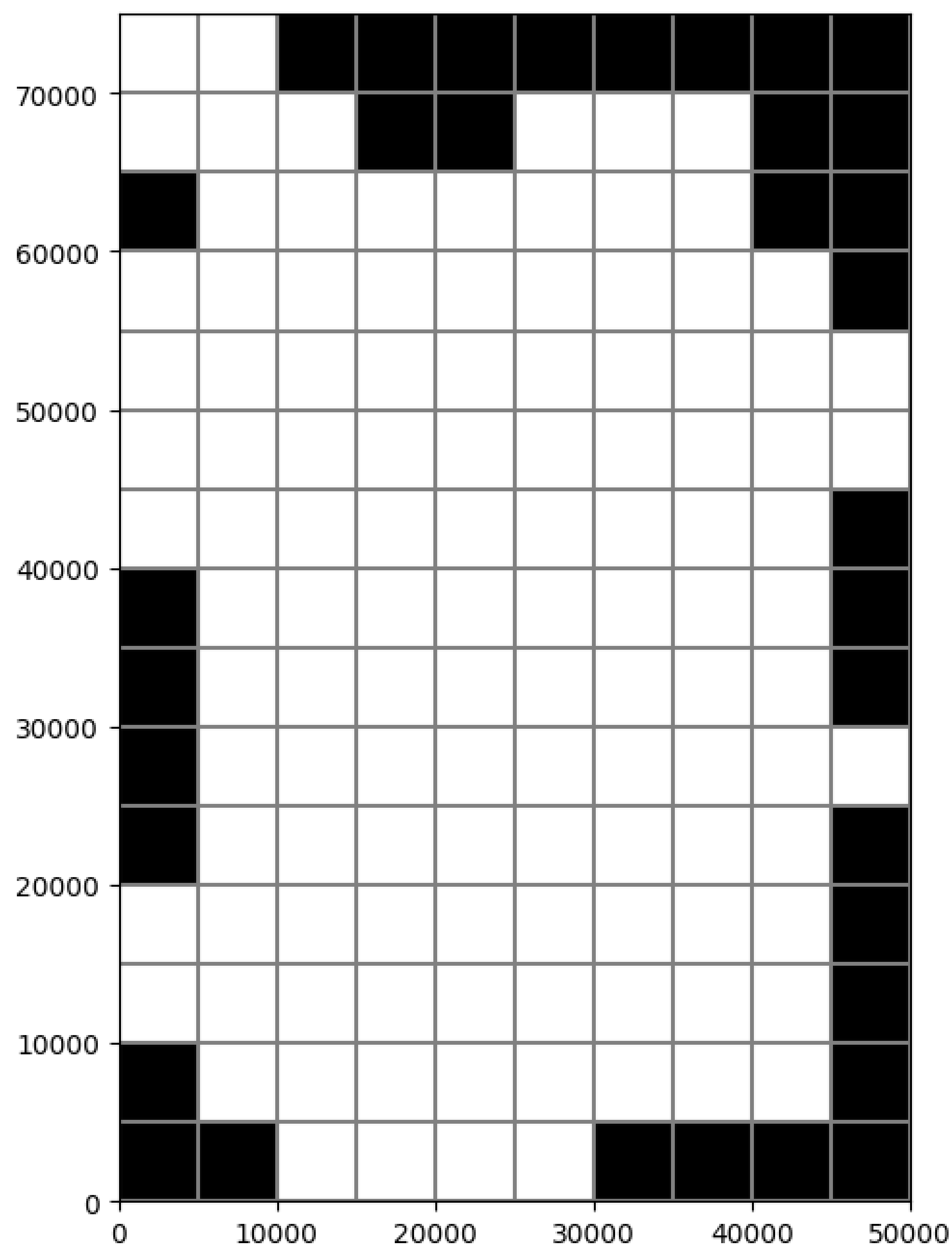
[5]:
```
m = flopy.modflow.Modflow.load(
    "UZFtest2.nam",
    version="mf2005",
    exe_name=exe_name,
    model_ws=path,
    load_only=["ghb", "dis", "bas6", "oc", "sip", "lpf", "sfr"],
)
```

Remove previous UZF external file references so they don't conflict with the ones made by FloPy.

[6]:
```
rm = [True if ".uz" in f else False for f in m.external_fnames]
m.external_fnames = [f for i, f in enumerate(m.external_fnames) if not rm[i]]
m.external_binflag = [f for i, f in enumerate(m.external_binflag) if not rm[i]]
m.external_output = [f for i, f in enumerate(m.external_output) if not rm[i]]
m.external_units = [f for i, f in enumerate(m.external_output) if not rm[i]]
```

Define the `izufbnd` array. In the example, the UZF package **izufbnd** array is the same as the ibound.

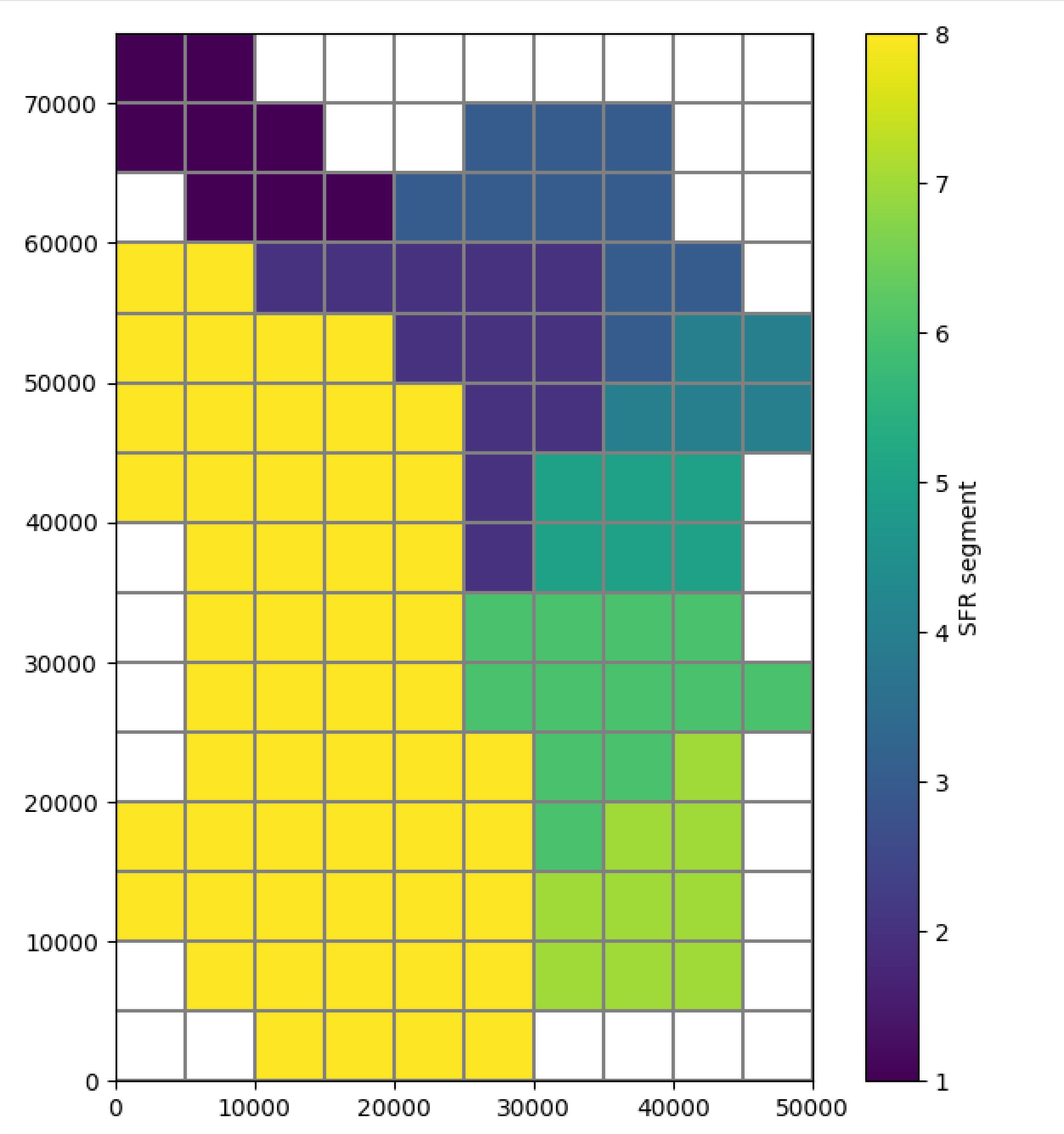
[7]:
```
fig = plt.figure(figsize=(8, 8))
ax = fig.add_subplot(1, 1, 1, aspect="equal")
mapview = flopy.plot.PlotMapView(model=m)
quadmesh = mapview.plot_ibound()
linecollection = mapview.plot_grid()
```



Read the `irunbnd` array from an external file.

[8]:
```
irnbndpth = proj_root / "examples" / "data" / "uzf_examples" / "irunbnd.dat"
irunbnd = np.loadtxt(irnbndpth)

fig = plt.figure(figsize=(8, 8))
ax = fig.add_subplot(1, 1, 1, aspect="equal")
mapview = flopy.plot.PlotMapView(model=m)
irunbndplt = mapview.plot_array(irunbnd)
plt.colorbar(irunbndplt, ax=ax, label="SFR segment")
linecollection = mapview.plot_grid()
```



Define the vks (unsaturated zone vertical hydraulic conductivity) array.

[9]:
```
vksbndpth = proj_root / "examples" / "data" / "uzf_examples" / "vks.dat"
vks = np.loadtxt(vksbndpth)

fig = plt.figure(figsize=(8, 8))
ax = fig.add_subplot(1, 1, 1, aspect="equal")
mapview = flopy.plot.PlotMapView(model=m)
vksplt = mapview.plot_array(vks)
plt.colorbar(vksplt, ax=ax, label="Layer 1 Kv")
```

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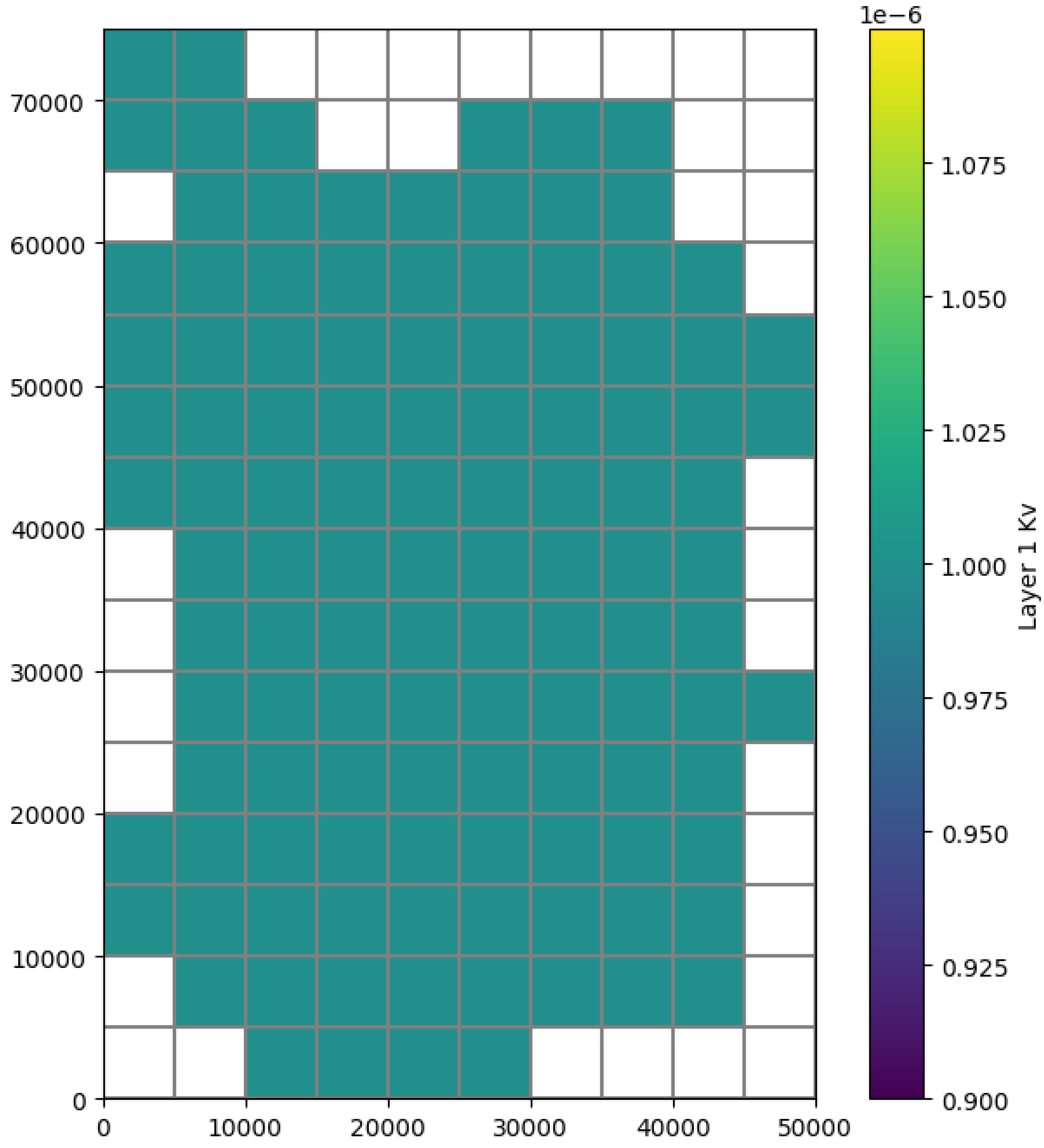
```
linecollection = mapview.plot_grid()
```



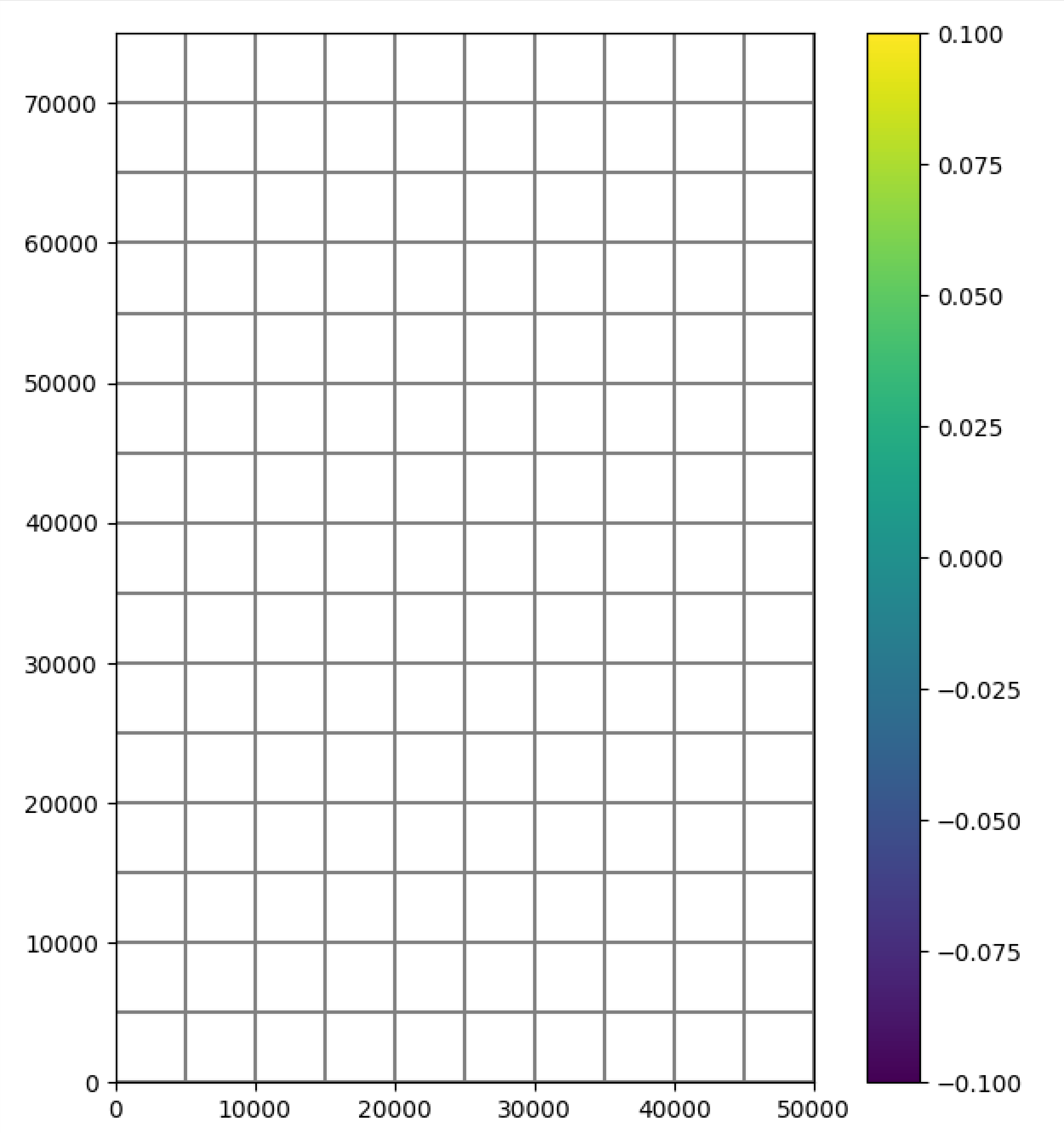
Define the `finf` array: * load infiltration rates from a file into a 3D array * `finf` can be submitted to FloPy as a 3D array, list of 2D arrays, list of numeric values, or single numeric value

[10]:
```
m.nrow_ncol_nlay_nper
```

[10]:
```
(15, 10, 1, 12)
```

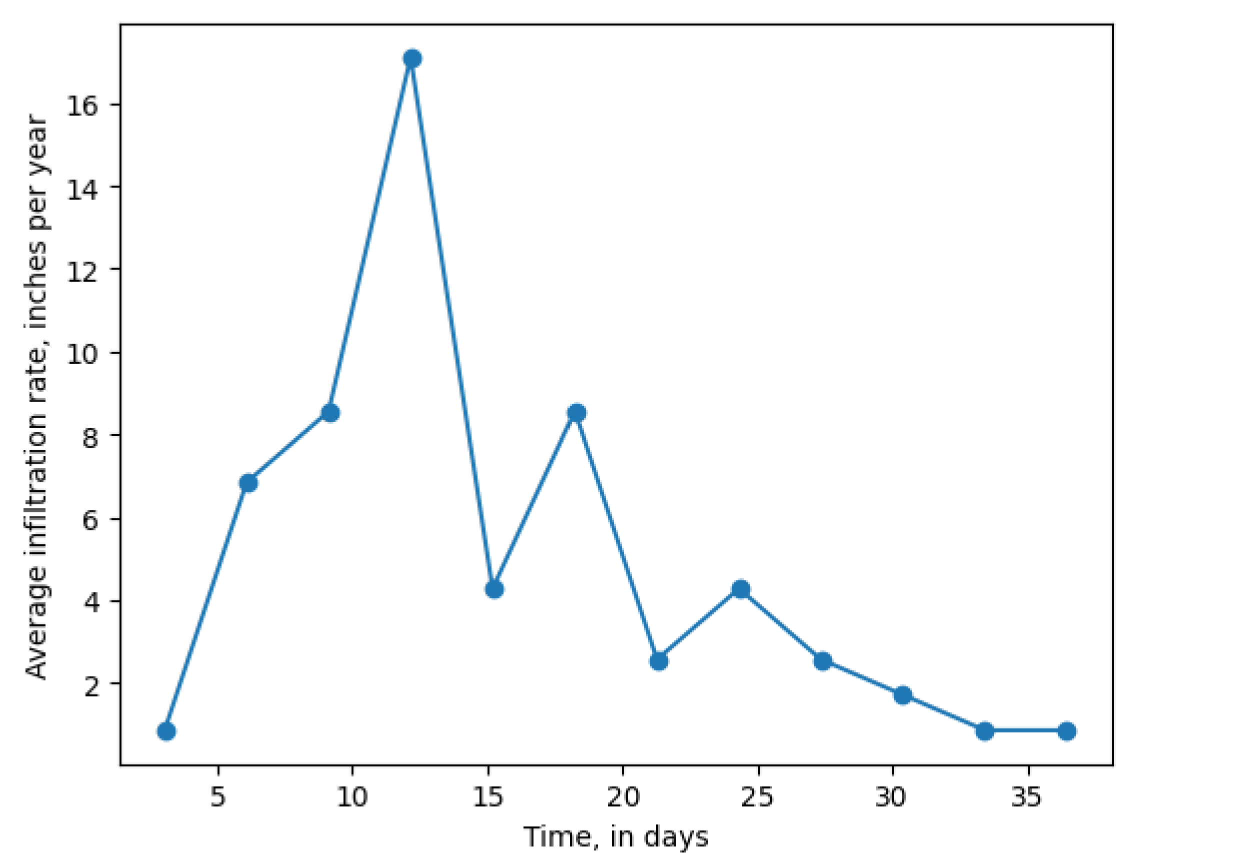
[11]:
```python
finf = np.loadtxt(
    proj_root / "examples" / "data" / "uzf_examples" / "finf.dat"
)
finf = np.reshape(finf, (m.nper, m.nrow, m.ncol))
finf = {i: finf[i] for i in range(finf.shape[0])}

# plot using PlotMapView
fig = plt.figure(figsize=(8, 8))
ax = fig.add_subplot(1, 1, 1, aspect="equal")
mapview = flopy.plot.PlotMapView(model=m)
quadmesh = mapview.plot_array(finf[0])
plt.colorbar(quadmesh)
linecollection = mapview.plot_grid()
```



[12]:
```
plt.plot(
    m.dis.perlen.array.cumsum() / 864600,
    [a.mean() * 86400 * 365 * 12 for a in finf.values()],
    marker="o",
)
plt.xlabel("Time, in days")
plt.ylabel("Average infiltration rate, inches per year")
```

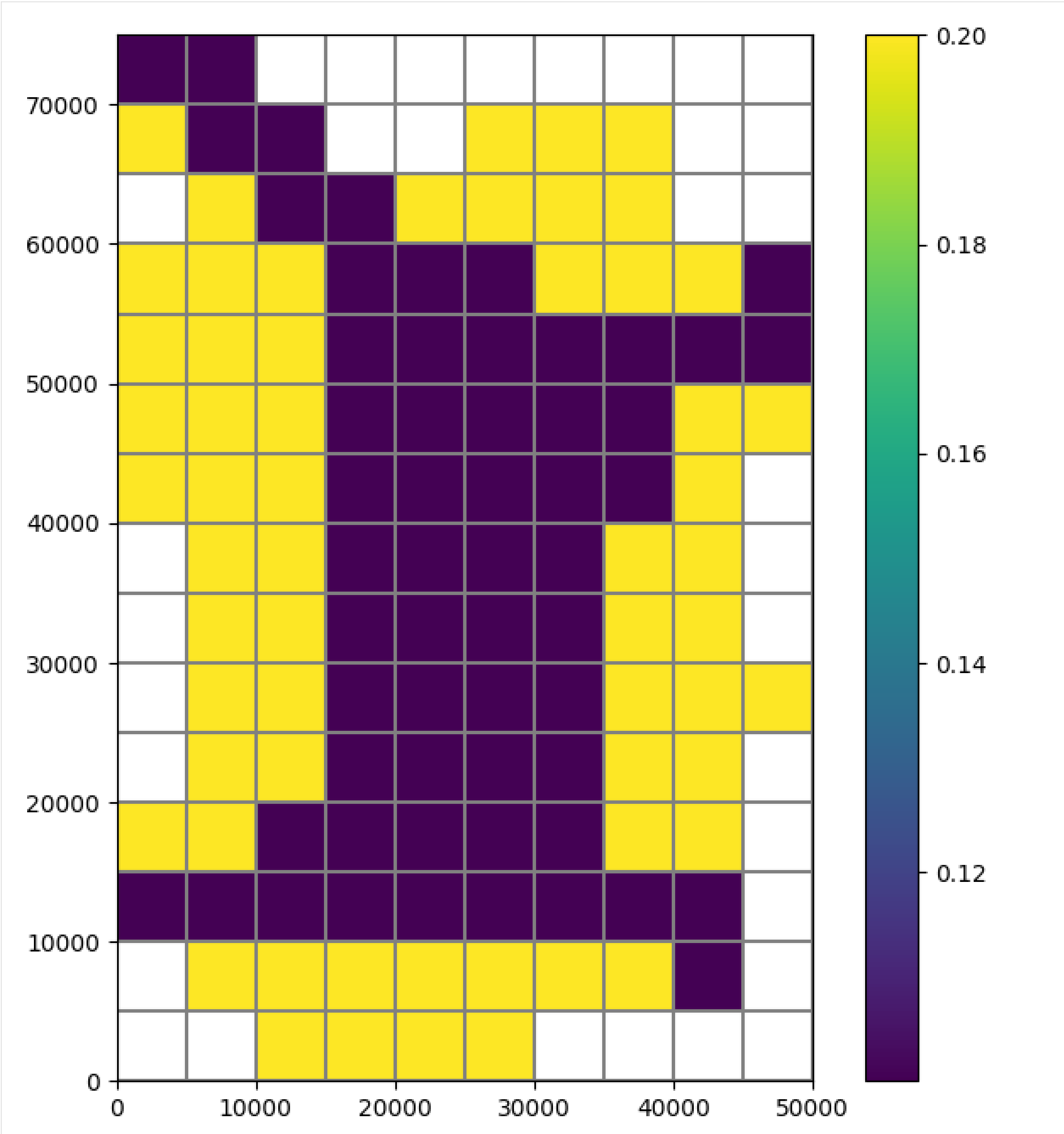
[12]:
```
Text(0, 0.5, 'Average infiltration rate, inches per year')
```



Define extwc (extinction water content) array.

[13]:
```
extwc = np.loadtxt(
    proj_root / "examples" / "data" / "uzf_examples" / "extwc.dat"
)

fig = plt.figure(figsize=(8, 8))
ax = fig.add_subplot(1, 1, 1, aspect="equal")
mapview = flopy.plot.PlotMapView(model=m)
quadmesh = mapview.plot_array(extwc)
plt.colorbar(quadmesh)
linecollection = mapview.plot_grid()
```


70000
60000
50000
40000
30000
20000
10000
0
0
10000
20000
30000
40000
50000
0.20
0.18
0.16
0.14
0.12

Set up the gages (observation points)

- supplied as a dictionary keyed by IFTUNIT
- A positive value [of IFTUNIT] is for output of individual cells whereas a negative value is for output that is summed over all model cells.
- values are a list of [IUZROW, IUZCOL, IFTUNIT, IUZOPT]
- IUZROW and IUZCOL are zero based

[14]:
```
uzgag = {
    -68: [-68],
    65: [
        2,
        5,
        65,
        1,
    ],  # Print time, head, uz thickness and cum. vols of infiltration, recharge,␣
↪storage, change in storage and ground-water discharge to land surface.
    66: [
        5,
        2,
        66,
        2,
    ],  # Same as option 1 except rates of infiltration, recharge, change in storage,␣
↪and ground-water discharge also are printed.
    67: [9, 4, 67, 3],
}  # Prints time, ground-water head, thickness of unsaturated zone, followed by a series␣
↪of depths and water contents in the unsaturated zone.
```

Make the UZF package.

[15]:
```
uzf = flopy.modflow.ModflowUzf1(
    m,
    nuztop=1,
    iuzfopt=1,
    irunflg=1,
    ietflg=1,
    ipakcb=0,
    iuzfcb2=61,  # binary output of recharge and groundwater discharge
    ntrail2=25,
    nsets=20,
    surfdep=1.0,
    uzgag=uzgag,
    iuzfbnd=m.bas6.ibound.array,
    irunbnd=irunbnd,
    vks=vks,  # saturated vertical hydraulic conductivity of the uz
    finf=finf,  # infiltration rates
    eps=3.5,  # Brooks-Corey relation of water content to hydraulic conductivity␣
↪(epsilon)
    thts=0.35,  # saturated water content of the uz in units of volume of water to total␣
↪volume
    pet=5.000000e-08,  # potential ET
    extdp=15.0,  # ET extinction depth(s)
```

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```
    extwc=extwc,  # extinction water content below which ET cannot be removed from the␣
↪unsaturated zone
    unitnumber=19,
)
```

Write model input files.

[16]:
```
m.write_input()
```

Run the model.

[17]:
```
success, buff = m.run_model()
assert success, f"{m.name} failed to run"
```

```
FloPy is using the following executable to run the model: ../../home/runner/.local/bin/
↪modflow/mf2005

                                  MODFLOW-2005
    U.S. GEOLOGICAL SURVEY MODULAR FINITE-DIFFERENCE GROUND-WATER FLOW MODEL
                             Version 1.12.00 2/3/2017

 Using NAME file: UZFtest2.nam
 Run start date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:36:31

 Solving:  Stress period:     1    Time step:     1    Ground-Water Flow Eqn.
 Solving:  Stress period:     2    Time step:     1    Ground-Water Flow Eqn.
 Solving:  Stress period:     2    Time step:     2    Ground-Water Flow Eqn.
 Solving:  Stress period:     2    Time step:     3    Ground-Water Flow Eqn.
 Solving:  Stress period:     2    Time step:     4    Ground-Water Flow Eqn.
 Solving:  Stress period:     2    Time step:     5    Ground-Water Flow Eqn.
 Solving:  Stress period:     2    Time step:     6    Ground-Water Flow Eqn.
 Solving:  Stress period:     2    Time step:     7    Ground-Water Flow Eqn.
 Solving:  Stress period:     2    Time step:     8    Ground-Water Flow Eqn.
 Solving:  Stress period:     2    Time step:     9    Ground-Water Flow Eqn.
 Solving:  Stress period:     2    Time step:    10    Ground-Water Flow Eqn.
 Solving:  Stress period:     2    Time step:    11    Ground-Water Flow Eqn.
 Solving:  Stress period:     2    Time step:    12    Ground-Water Flow Eqn.
 Solving:  Stress period:     2    Time step:    13    Ground-Water Flow Eqn.
 Solving:  Stress period:     2    Time step:    14    Ground-Water Flow Eqn.
 Solving:  Stress period:     2    Time step:    15    Ground-Water Flow Eqn.
 Solving:  Stress period:     3    Time step:     1    Ground-Water Flow Eqn.
 Solving:  Stress period:     3    Time step:     2    Ground-Water Flow Eqn.
 Solving:  Stress period:     3    Time step:     3    Ground-Water Flow Eqn.
 Solving:  Stress period:     3    Time step:     4    Ground-Water Flow Eqn.
 Solving:  Stress period:     3    Time step:     5    Ground-Water Flow Eqn.
 Solving:  Stress period:     3    Time step:     6    Ground-Water Flow Eqn.
 Solving:  Stress period:     3    Time step:     7    Ground-Water Flow Eqn.
 Solving:  Stress period:     3    Time step:     8    Ground-Water Flow Eqn.
 Solving:  Stress period:     3    Time step:     9    Ground-Water Flow Eqn.
 Solving:  Stress period:     3    Time step:    10    Ground-Water Flow Eqn.
 Solving:  Stress period:     3    Time step:    11    Ground-Water Flow Eqn.
 Solving:  Stress period:     3    Time step:    12    Ground-Water Flow Eqn.
 Solving:  Stress period:     3    Time step:    13    Ground-Water Flow Eqn.
```

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```
Solving:  Stress period:     3    Time step:    14    Ground-Water Flow Eqn.
Solving:  Stress period:     3    Time step:    15    Ground-Water Flow Eqn.
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Solving:  Stress period:     4    Time step:    14    Ground-Water Flow Eqn.
Solving:  Stress period:     4    Time step:    15    Ground-Water Flow Eqn.
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Solving:  Stress period:     7    Time step:     5    Ground-Water Flow Eqn.
```

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```
Solving:  Stress period:     7    Time step:     6    Ground-Water Flow Eqn.
Solving:  Stress period:     7    Time step:     7    Ground-Water Flow Eqn.
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Solving:  Stress period:     9    Time step:    14    Ground-Water Flow Eqn.
Solving:  Stress period:     9    Time step:    15    Ground-Water Flow Eqn.
Solving:  Stress period:    10    Time step:     1    Ground-Water Flow Eqn.
Solving:  Stress period:    10    Time step:     2    Ground-Water Flow Eqn.
Solving:  Stress period:    10    Time step:     3    Ground-Water Flow Eqn.
Solving:  Stress period:    10    Time step:     4    Ground-Water Flow Eqn.
Solving:  Stress period:    10    Time step:     5    Ground-Water Flow Eqn.
Solving:  Stress period:    10    Time step:     6    Ground-Water Flow Eqn.
Solving:  Stress period:    10    Time step:     7    Ground-Water Flow Eqn.
Solving:  Stress period:    10    Time step:     8    Ground-Water Flow Eqn.
Solving:  Stress period:    10    Time step:     9    Ground-Water Flow Eqn.
Solving:  Stress period:    10    Time step:    10    Ground-Water Flow Eqn.
Solving:  Stress period:    10    Time step:    11    Ground-Water Flow Eqn.
Solving:  Stress period:    10    Time step:    12    Ground-Water Flow Eqn.
```

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```
Solving:  Stress period:    10    Time step:    13    Ground-Water Flow Eqn.
Solving:  Stress period:    10    Time step:    14    Ground-Water Flow Eqn.
Solving:  Stress period:    10    Time step:    15    Ground-Water Flow Eqn.
Solving:  Stress period:    11    Time step:     1    Ground-Water Flow Eqn.
Solving:  Stress period:    11    Time step:     2    Ground-Water Flow Eqn.
Solving:  Stress period:    11    Time step:     3    Ground-Water Flow Eqn.
Solving:  Stress period:    11    Time step:     4    Ground-Water Flow Eqn.
Solving:  Stress period:    11    Time step:     5    Ground-Water Flow Eqn.
Solving:  Stress period:    11    Time step:     6    Ground-Water Flow Eqn.
Solving:  Stress period:    11    Time step:     7    Ground-Water Flow Eqn.
Solving:  Stress period:    11    Time step:     8    Ground-Water Flow Eqn.
Solving:  Stress period:    11    Time step:     9    Ground-Water Flow Eqn.
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Solving:  Stress period:    11    Time step:    15    Ground-Water Flow Eqn.
Solving:  Stress period:    12    Time step:     1    Ground-Water Flow Eqn.
Solving:  Stress period:    12    Time step:     2    Ground-Water Flow Eqn.
Solving:  Stress period:    12    Time step:     3    Ground-Water Flow Eqn.
Solving:  Stress period:    12    Time step:     4    Ground-Water Flow Eqn.
Solving:  Stress period:    12    Time step:     5    Ground-Water Flow Eqn.
Solving:  Stress period:    12    Time step:     6    Ground-Water Flow Eqn.
Solving:  Stress period:    12    Time step:     7    Ground-Water Flow Eqn.
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Solving:  Stress period:    12    Time step:     9    Ground-Water Flow Eqn.
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Solving:  Stress period:    12    Time step:    11    Ground-Water Flow Eqn.
Solving:  Stress period:    12    Time step:    12    Ground-Water Flow Eqn.
Solving:  Stress period:    12    Time step:    13    Ground-Water Flow Eqn.
Solving:  Stress period:    12    Time step:    14    Ground-Water Flow Eqn.
Solving:  Stress period:    12    Time step:    15    Ground-Water Flow Eqn.
Run end date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:36:36
Elapsed run time:  4.619 Seconds

 Normal termination of simulation
```

Inspecting results

First, look at the budget output.

[18]:
```python
fpth = path / "UZFtest2.uzfcb2.bin"
avail = os.path.isfile(fpth)
if avail:
    uzfbdobjct = flopy.utils.CellBudgetFile(fpth)
    uzfbdobjct.list_records()
else:
    print(f'"{fpth}" is not available')
```

```
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↪'')
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(5, 10, b'       HORT+DUNN', 10, 15, -1, 4, 121100.21, 504971.6, 24156966., b'', b'', b'
↪', b'')
(5, 10, b'  STORAGE CHANGE', 10, 15, -1, 4, 121100.21, 504971.6, 24156966., b'', b'', b'
↪', b'')
(10, 10, b'           GW ET', 10, 15, -1, 4, 195033.11, 1318233.4, 24970228., b'', b'', b
↪'', b'')
(10, 10, b'    UZF RECHARGE', 10, 15, -1, 4, 195033.11, 1318233.4, 24970228., b'', b'', b
↪'', b'')
(10, 10, b' SURFACE LEAKAGE', 10, 15, -1, 4, 195033.11, 1318233.4, 24970228., b'', b'', b
↪'', b'')
(10, 10, b'       HORT+DUNN', 10, 15, -1, 4, 195033.11, 1318233.4, 24970228., b'', b'', b
↪'', b'')
(10, 10, b'  STORAGE CHANGE', 10, 15, -1, 4, 195033.11, 1318233.4, 24970228., b'', b'', b
↪'', b'')
(15, 10, b'           GW ET', 10, 15, -1, 4, 314102.8, 2627999.8, 26279994., b'', b'', b'
↪', b'')
(15, 10, b'    UZF RECHARGE', 10, 15, -1, 4, 314102.8, 2627999.8, 26279994., b'', b'', b'
↪', b'')
(15, 10, b' SURFACE LEAKAGE', 10, 15, -1, 4, 314102.8, 2627999.8, 26279994., b'', b'', b'
↪', b'')
(15, 10, b'       HORT+DUNN', 10, 15, -1, 4, 314102.8, 2627999.8, 26279994., b'', b'', b'
↪', b'')
(15, 10, b'  STORAGE CHANGE', 10, 15, -1, 4, 314102.8, 2627999.8, 26279994., b'', b'', b'
↪', b'')
(5, 11, b'           GW ET', 10, 15, -1, 4, 121100.21, 504971.6, 26784966., b'', b'', b'
↪', b'')
(5, 11, b'    UZF RECHARGE', 10, 15, -1, 4, 121100.21, 504971.6, 26784966., b'', b'', b'
↪', b'')
(5, 11, b' SURFACE LEAKAGE', 10, 15, -1, 4, 121100.21, 504971.6, 26784966., b'', b'', b'
↪', b'')
(5, 11, b'       HORT+DUNN', 10, 15, -1, 4, 121100.21, 504971.6, 26784966., b'', b'', b'
↪', b'')
(5, 11, b'  STORAGE CHANGE', 10, 15, -1, 4, 121100.21, 504971.6, 26784966., b'', b'', b'
↪', b'')
(10, 11, b'           GW ET', 10, 15, -1, 4, 195033.11, 1318233.4, 27598228., b'', b'', b
↪'', b'')
(10, 11, b'    UZF RECHARGE', 10, 15, -1, 4, 195033.11, 1318233.4, 27598228., b'', b'', b
```

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```
↪'', b'')
(10, 11, b' SURFACE LEAKAGE', 10, 15, -1, 4, 195033.11, 1318233.4, 27598228., b'', b'', b
↪'', b'')
(10, 11, b'       HORT+DUNN', 10, 15, -1, 4, 195033.11, 1318233.4, 27598228., b'', b'', b
↪'', b'')
(10, 11, b'  STORAGE CHANGE', 10, 15, -1, 4, 195033.11, 1318233.4, 27598228., b'', b'', b
↪'', b'')
(15, 11, b'           GW ET', 10, 15, -1, 4, 314102.8, 2627999.8, 28907994., b'', b'', b'
↪', b'')
(15, 11, b'    UZF RECHARGE', 10, 15, -1, 4, 314102.8, 2627999.8, 28907994., b'', b'', b'
↪', b'')
(15, 11, b' SURFACE LEAKAGE', 10, 15, -1, 4, 314102.8, 2627999.8, 28907994., b'', b'', b'
↪', b'')
(15, 11, b'       HORT+DUNN', 10, 15, -1, 4, 314102.8, 2627999.8, 28907994., b'', b'', b'
↪', b'')
(15, 11, b'  STORAGE CHANGE', 10, 15, -1, 4, 314102.8, 2627999.8, 28907994., b'', b'', b'
↪', b'')
(5, 12, b'           GW ET', 10, 15, -1, 4, 121100.21, 504971.6, 29412966., b'', b'', b'
↪', b'')
(5, 12, b'    UZF RECHARGE', 10, 15, -1, 4, 121100.21, 504971.6, 29412966., b'', b'', b'
↪', b'')
(5, 12, b' SURFACE LEAKAGE', 10, 15, -1, 4, 121100.21, 504971.6, 29412966., b'', b'', b'
↪', b'')
(5, 12, b'       HORT+DUNN', 10, 15, -1, 4, 121100.21, 504971.6, 29412966., b'', b'', b'
↪', b'')
(5, 12, b'  STORAGE CHANGE', 10, 15, -1, 4, 121100.21, 504971.6, 29412966., b'', b'', b'
↪', b'')
(10, 12, b'           GW ET', 10, 15, -1, 4, 195033.11, 1318233.4, 30226228., b'', b'', b
↪'', b'')
(10, 12, b'    UZF RECHARGE', 10, 15, -1, 4, 195033.11, 1318233.4, 30226228., b'', b'', b
↪'', b'')
(10, 12, b' SURFACE LEAKAGE', 10, 15, -1, 4, 195033.11, 1318233.4, 30226228., b'', b'', b
↪'', b'')
(10, 12, b'       HORT+DUNN', 10, 15, -1, 4, 195033.11, 1318233.4, 30226228., b'', b'', b
↪'', b'')
(10, 12, b'  STORAGE CHANGE', 10, 15, -1, 4, 195033.11, 1318233.4, 30226228., b'', b'', b
↪'', b'')
(15, 12, b'           GW ET', 10, 15, -1, 4, 314102.8, 2627999.8, 31535994., b'', b'', b'
↪', b'')
(15, 12, b'    UZF RECHARGE', 10, 15, -1, 4, 314102.8, 2627999.8, 31535994., b'', b'', b'
↪', b'')
(15, 12, b' SURFACE LEAKAGE', 10, 15, -1, 4, 314102.8, 2627999.8, 31535994., b'', b'', b'
↪', b'')
(15, 12, b'       HORT+DUNN', 10, 15, -1, 4, 314102.8, 2627999.8, 31535994., b'', b'', b'
↪', b'')
(15, 12, b'  STORAGE CHANGE', 10, 15, -1, 4, 314102.8, 2627999.8, 31535994., b'', b'', b'
↪', b'')
```

[19]:
```python
if success and avail:
    r = uzfbdobjct.get_data(text="UZF RECHARGE")
    et = uzfbdobjct.get_data(text="GW ET")
```

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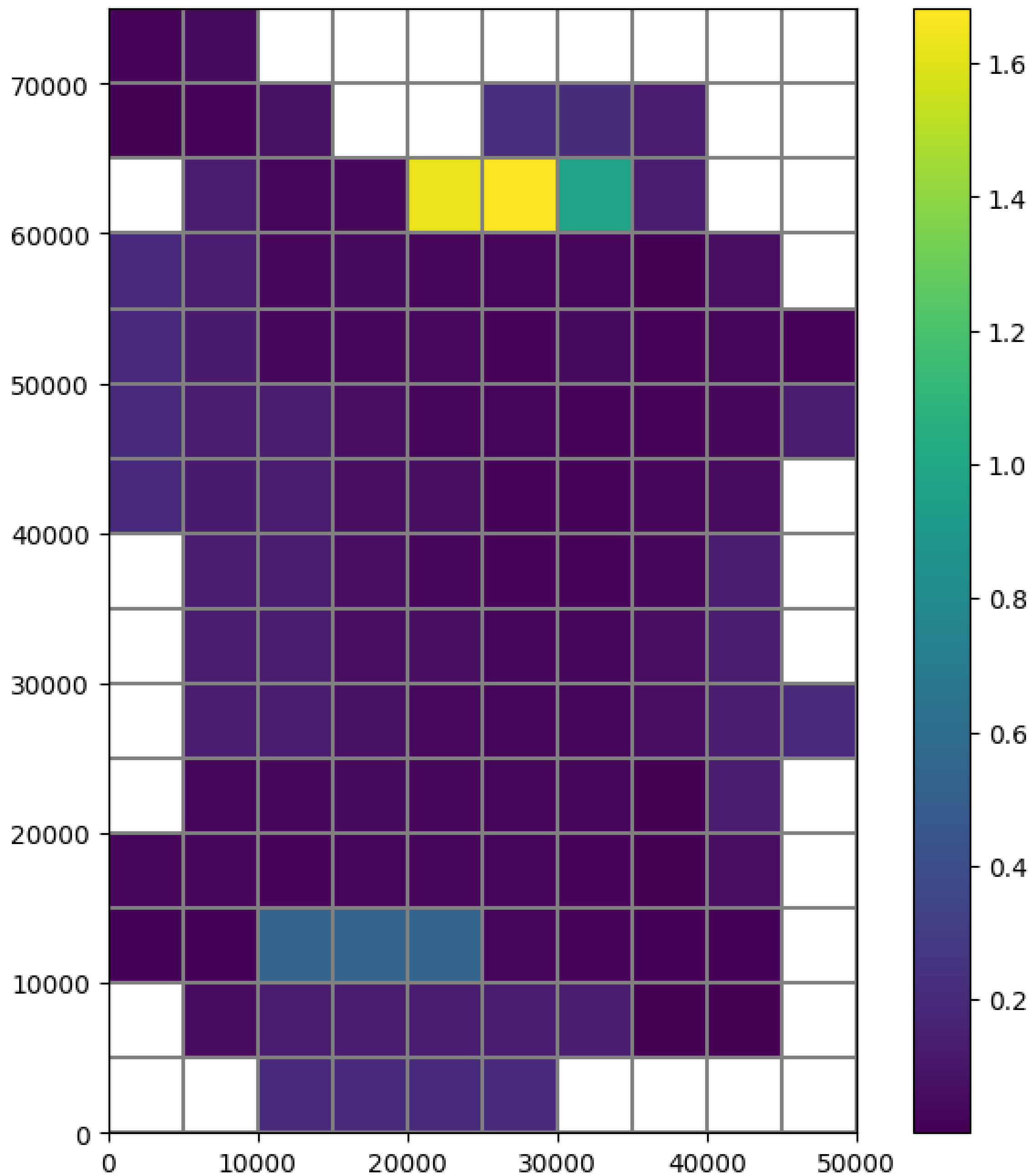
```
    fig = plt.figure(figsize=(8, 8))
    ax = fig.add_subplot(1, 1, 1, aspect="equal")
    mapview = flopy.plot.PlotMapView(model=m)
    quadmesh = mapview.plot_array(r[6])
    plt.colorbar(quadmesh)
    linecollection = mapview.plot_grid()
```



[20]:
```
if avail:
    rtot = [rp.sum() for rp in r]
    ettot = [etp.sum() for etp in et]
```

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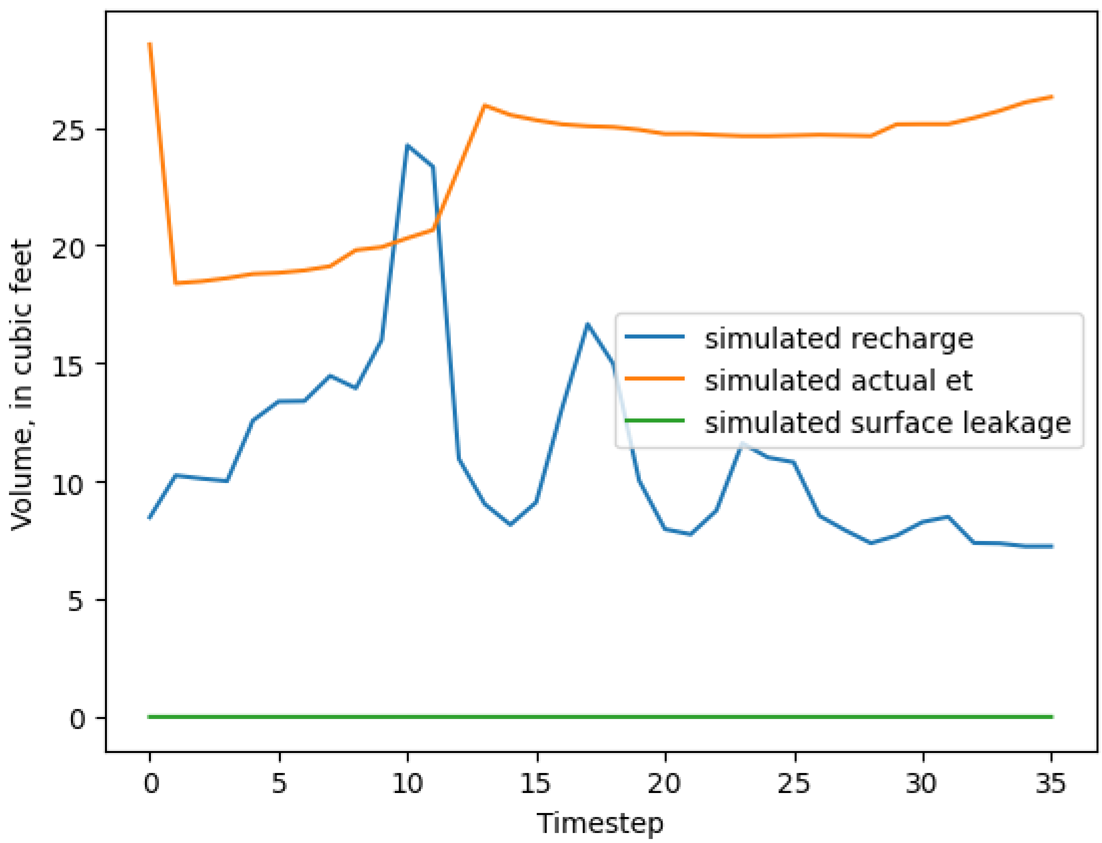
```
    sltot = [sl.sum() for sl in uzfbdobjct.get_data(text="SURFACE LEAKAGE")]

    plt.plot(rtot, label="simulated recharge")
    plt.plot(np.abs(ettot), label="simulated actual et")
    plt.plot(np.abs(sltot), label="simulated surface leakage")
    plt.xlabel("Timestep")
    plt.ylabel("Volume, in cubic feet")
    plt.legend()
```



Look at the gages.

[21]:
```
fpth = path / "UZFtest2.uzf68.out"
avail = os.path.isfile(fpth)
if avail:
    dtype = [
        ("TIME", float),
        ("APPLIED-INFIL", float),
        ("RUNOFF", float),
        ("ACTUAL-INFIL", float),
        ("SURFACE-LEAK", float),
        ("UZ-ET", float),
        ("GW-ET", float),
        ("UZSTOR-CHANGE", float),
        ("RECHARGE", float),
```

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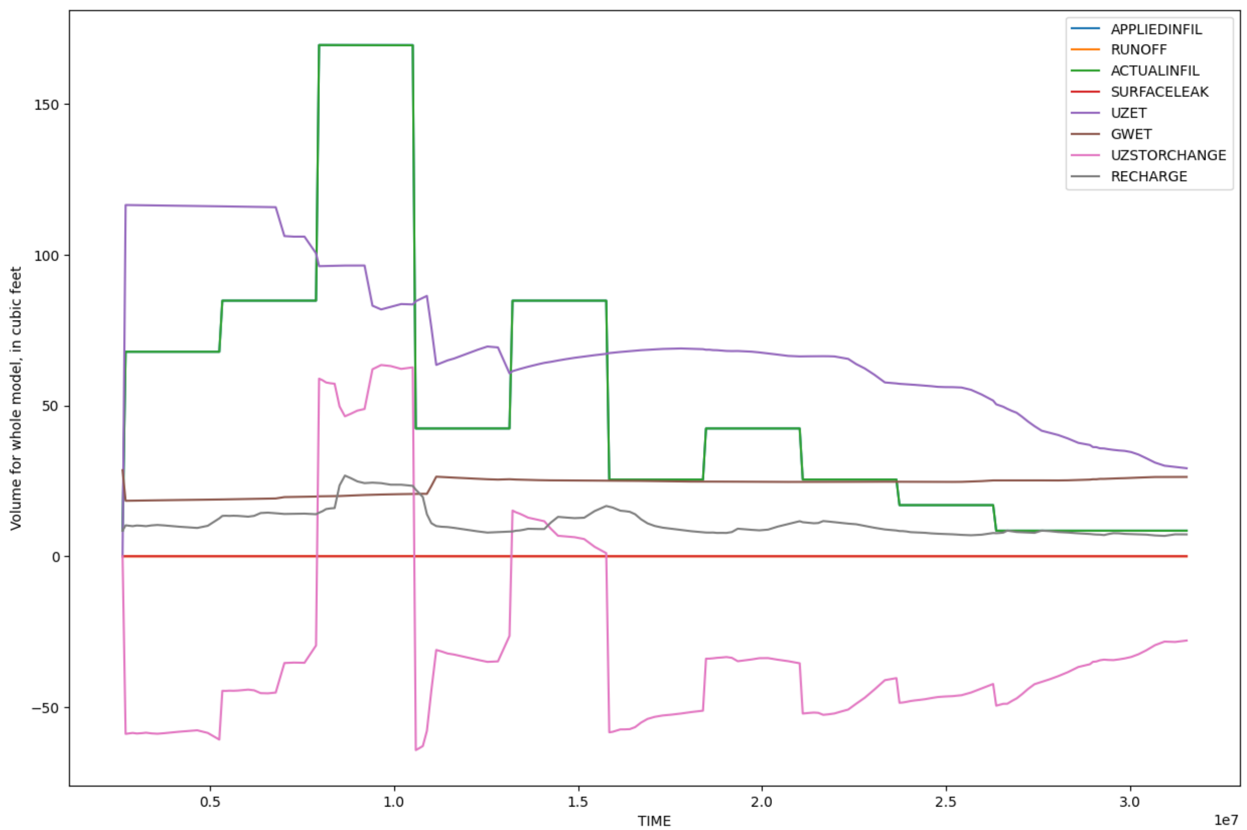
```
    ]
    # read data from file
    df = np.genfromtxt(fpth, skip_header=3, dtype=dtype)
    # convert numpy recarray to pandas dataframe
    df = pd.DataFrame(data=df)
    # set index to the time column
    df.set_index(["TIME"], inplace=True)
    # plot the data
    ax = df.plot(legend=False, figsize=(15, 10))
    patches, labels = ax.get_legend_handles_labels()
    ax.legend(patches, labels, loc=1)
    ax.set_ylabel("Volume for whole model, in cubic feet")
```



Plot water content profile through time at row 10, column 5.

[22]:
```
fpth = path / "UZFtest2.uzf67.out"
avail = os.path.isfile(fpth)
if avail:
    data = []
    with open(fpth) as input:
        for i in range(3):
            next(input)
        for line in input:
            line = line.strip().split()
            if len(line) == 6:
```

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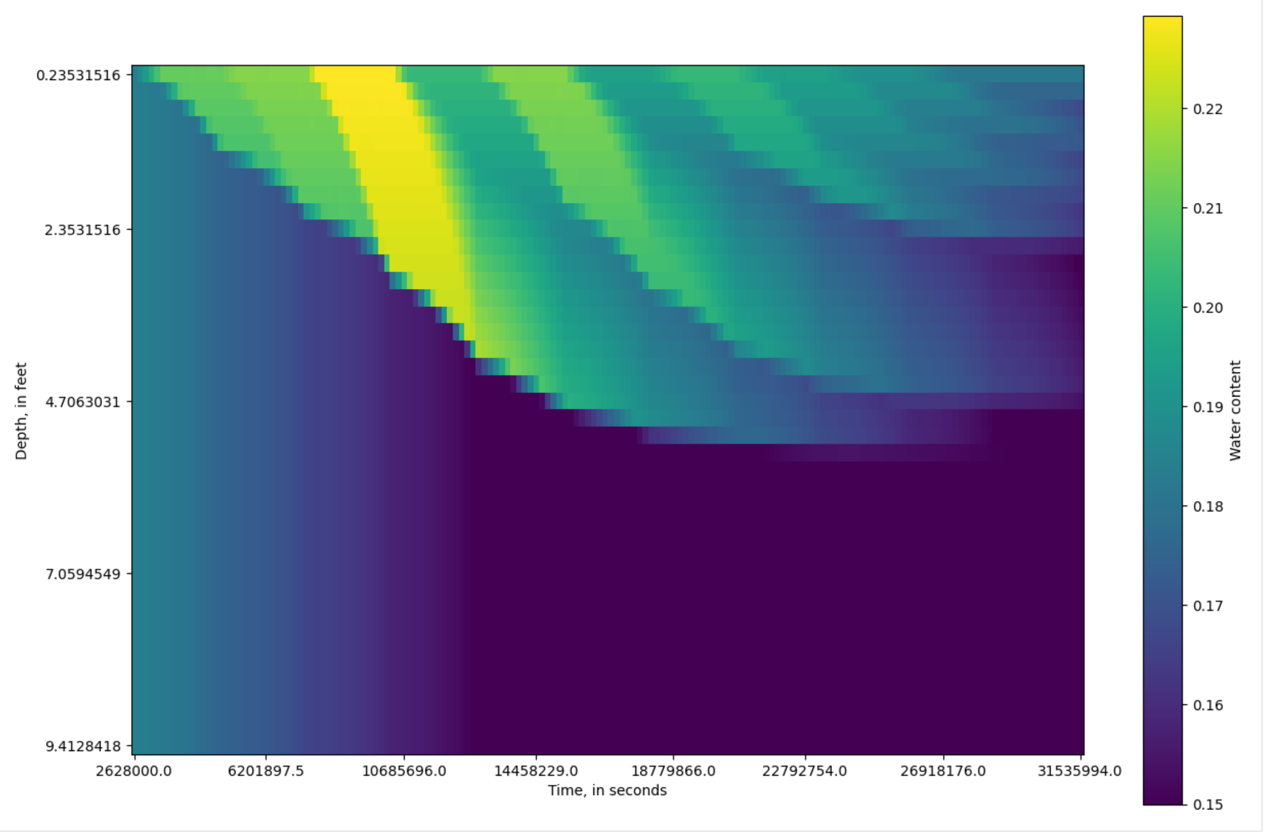
```
                layer = int(line.pop(0))
                time = float(line.pop(0))
                head = float(line.pop(0))
                uzthick = float(line.pop(0))
            depth = float(line.pop(0))
            watercontent = float(line.pop(0))
            data.append([layer, time, head, uzthick, depth, watercontent])
```

[23]:
```
if avail:
    df3 = pd.DataFrame(
        data,
        columns=["layer", "time", "head", "uzthick", "depth", "watercontent"],
    )
    df3.head(41)
```

[24]:
```
if avail:
    wc = df3.watercontent.values.reshape(len(df3.time.unique()), 40).T
    wc = pd.DataFrame(wc, columns=df3.time.unique(), index=df3.depth[0:40])
    wc.head()
```

[25]:
```
if avail:
    fig, ax = plt.subplots(figsize=(15, 10))
    plt.imshow(wc, interpolation="None")
    ax.set_aspect(3)
    r, c = wc.shape
    xcol_locs = np.linspace(0, c - 1, 8, dtype=int)
    ycol_locs = np.linspace(0, r - 1, 5, dtype=int)
    ax.set_xticks(xcol_locs)

    xlabels = wc.columns
    ax.set_xticklabels(xlabels[xcol_locs])
    ax.set_ylabel("Depth, in feet")
    ax.set_yticks(ycol_locs)
    ax.set_yticklabels(wc.index[ycol_locs])
    ax.set_xlabel("Time, in seconds")
    plt.colorbar(label="Water content")
```



Clean up the temporary directory.

[26]:
```python
try:
    # ignore PermissionError on Windows
    temp_dir.cleanup()
except:
    pass
```

6.8 MODPATH examples

6.8.1 Working with MODPATH 6

This notebook demonstrates forward and backward tracking with MODPATH. The notebook also shows how to create subsets of pathline and endpoint information, plot MODPATH results on ModelMap objects, and export endpoints and pathlines as shapefiles.

[1]:
```python
import glob
import os
import shutil
```

[2]:
```python
import sys
from tempfile import TemporaryDirectory

import matplotlib as mpl
```

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```
import matplotlib.pyplot as plt
import numpy as np
import pandas as pd

# run installed version of flopy or add local path
try:
    import flopy
except:
    fpth = os.path.abspath(os.path.join("..", ".."))
    sys.path.append(fpth)
    import flopy

print(sys.version)
print(f"numpy version: {np.__version__}")
print(f"matplotlib version: {mpl.__version__}")
print(f"pandas version: {pd.__version__}")
print(f"flopy version: {flopy.__version__}")
```

```
3.8.18 (default, Aug 28 2023, 08:27:22)
[GCC 11.4.0]
numpy version: 1.24.4
matplotlib version: 3.7.4
pandas version: 2.0.3
flopy version: 3.5.0
```

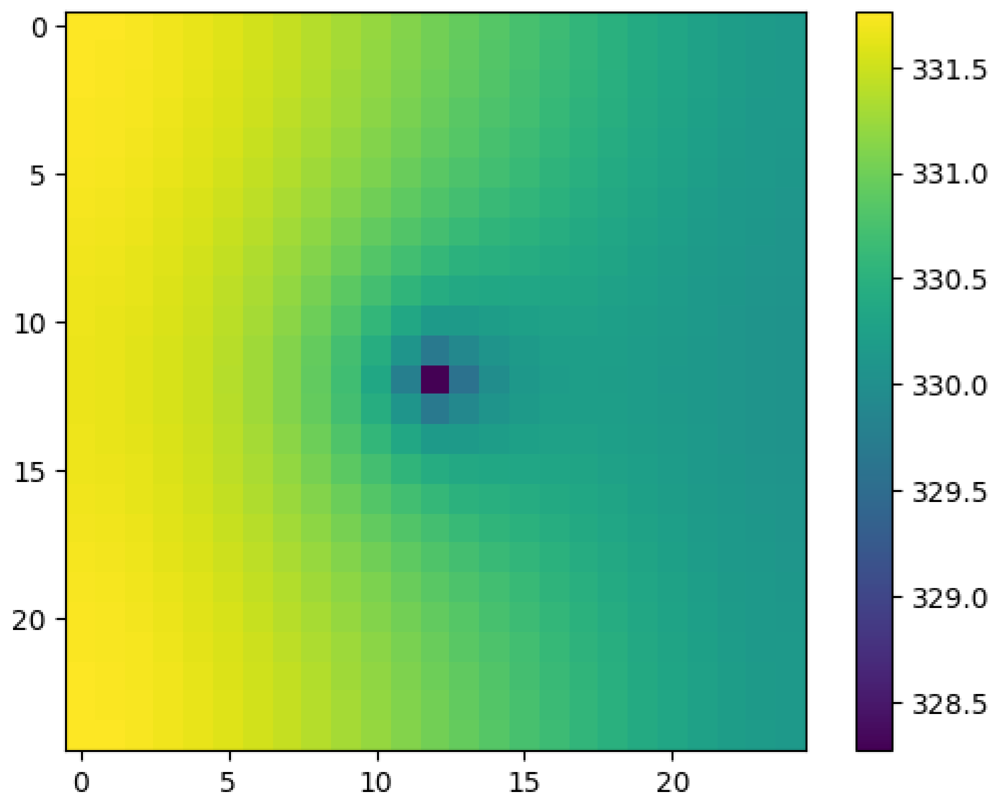
Load the MODFLOW model, then switch to a temporary working directory.

[3]:
```
from pathlib import Path

# temporary directory
temp_dir = TemporaryDirectory()
model_ws = temp_dir.name

model_path = Path.cwd().parent.parent / "examples" / "data" / "mp6"
mffiles = list(model_path.glob("EXAMPLE.*"))

m = flopy.modflow.Modflow.load("EXAMPLE.nam", model_ws=model_path)

hdsfile = flopy.utils.HeadFile(os.path.join(model_path, "EXAMPLE.HED"))
hdsfile.get_kstpkper()

hds = hdsfile.get_data(kstpkper=(0, 2))
```

Plot RIV bc and head results.

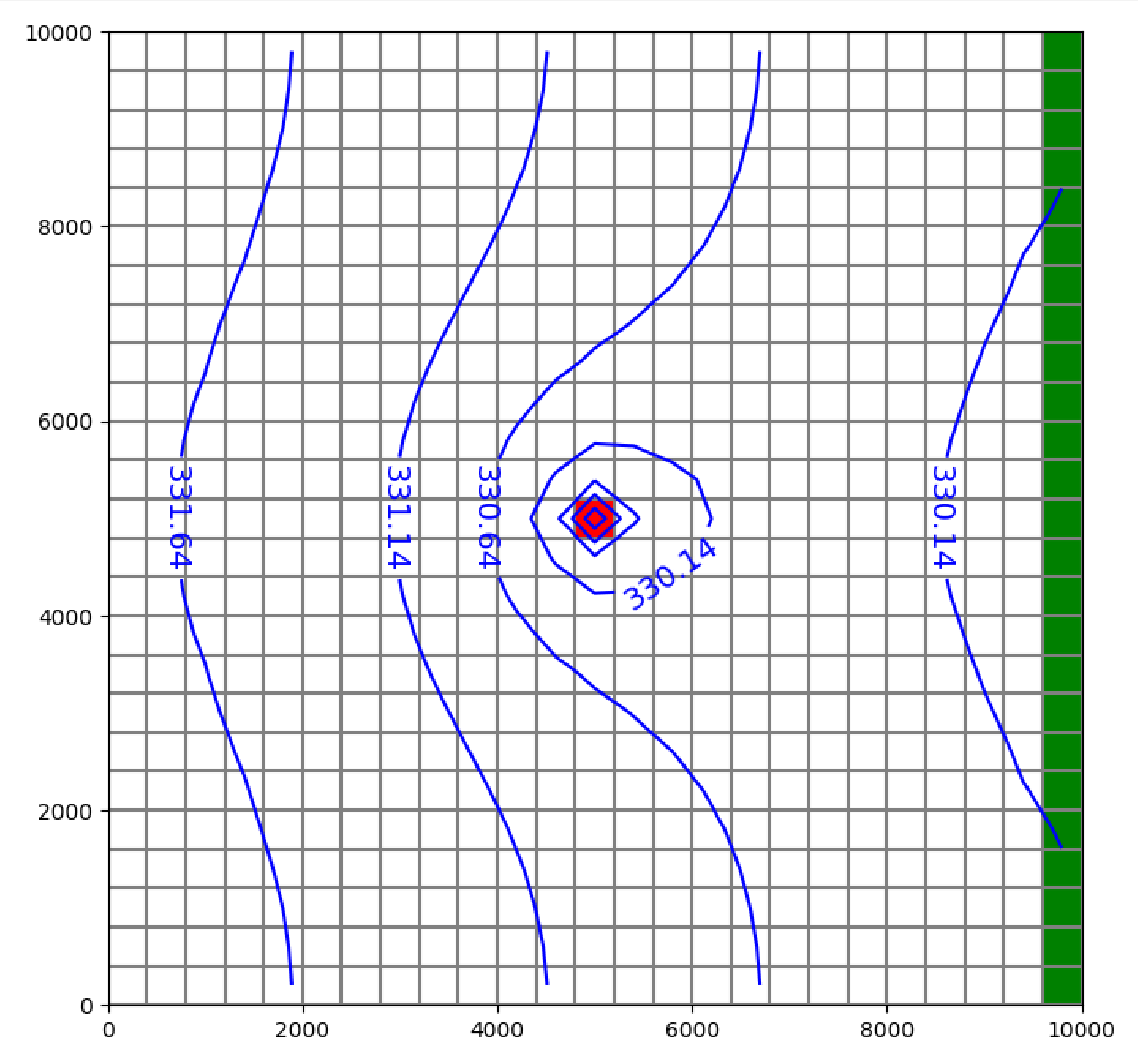
[4]:
```
plt.imshow(hds[4, :, :])
plt.colorbar()
```

[4]:
```
<matplotlib.colorbar.Colorbar at 0x7f4e720e9e20>
```



[5]:
```
fig = plt.figure(figsize=(8, 8))
ax = fig.add_subplot(1, 1, 1, aspect="equal")
mapview = flopy.plot.PlotMapView(model=m, layer=4)
quadmesh = mapview.plot_ibound()
linecollection = mapview.plot_grid()
riv = mapview.plot_bc("RIV", color="g", plotAll=True)
quadmesh = mapview.plot_bc("WEL", kper=1, plotAll=True)
contour_set = mapview.contour_array(
    hds, levels=np.arange(np.min(hds), np.max(hds), 0.5), colors="b"
)
plt.clabel(contour_set, inline=1, fontsize=14)
```

[5]:
```
<a list of 5 text.Text objects>
```



Now create forward particle tracking simulation where particles are released at the top of each cell in layer 1: * specifying the recharge package in `create_mpsim` releases a single particle on iface=6 of each top cell * start the particles at begining of per 3, step 1, as in example 3 in MODPATH6 manual

Note: in FloPy version 3.3.5 and previous, the `Modpath6` constructor `dis_file`, `head_file` and `budget_file` arguments expected filenames relative to the model workspace. In 3.3.6 and later, full paths must be provided — if they are not, discretization, head and budget data are read directly from the model, as before.

[6]:
```
from os.path import join

mp = flopy.modpath.Modpath6(
    modelname="ex6",
    exe_name="mp6",
    modflowmodel=m,
    model_ws=str(model_path),
)
```

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```
mpb = flopy.modpath.Modpath6Bas(
    mp, hdry=m.lpf.hdry, laytyp=m.lpf.laytyp, ibound=1, prsity=0.1
)

# start the particles at begining of per 3, step 1, as in example 3 in MODPATH6 manual
# (otherwise particles will all go to river)
sim = mp.create_mpsim(
    trackdir="forward",
    simtype="pathline",
    packages="RCH",
    start_time=(2, 0, 1.0),
)

shutil.copy(model_path / "EXAMPLE.DIS", join(model_ws, "EXAMPLE.DIS"))
shutil.copy(model_path / "EXAMPLE.HED", join(model_ws, "EXAMPLE.HED"))
shutil.copy(model_path / "EXAMPLE.BUD", join(model_ws, "EXAMPLE.BUD"))

mp.change_model_ws(model_ws)
mp.write_name_file()
mp.write_input()
success, buff = mp.run_model(silent=True, report=True)
if success:
    for line in buff:
        print(line)
else:
    raise ValueError("Failed to run.")
```

```
Processing basic data ...
Checking head file ...
Checking budget file and building index ...

Run particle tracking simulation ...
Processing Time Step      1 Period     3.  Time =  4.10000E+05
Particle tracking complete. Writing endpoint file ...
End of MODPATH simulation. Normal termination.
```

Read in the endpoint file and plot particles that terminated in the well.

[7]:
```
fpth = os.path.join(model_ws, "ex6.mpend")
epobj = flopy.utils.EndpointFile(fpth)
well_epd = epobj.get_destination_endpoint_data(dest_cells=[(4, 12, 12)])
# returns record array of same form as epobj.get_all_data()
```

[8]:
```
well_epd[0:2]
```

[8]:
```
rec.array([(50, 0, 2, 0., 29565.62, 1, 0, 2, 0, 6, 0, 0.5, 0.5, 1., 200., 9000., 339.
↪1231, 1, 4, 12, 12, 2, 0, 1.        , 0.9178849, 0.09755219, 5200.    , 5167.154,  9.
↪755219, b'rch'),
           (75, 0, 2, 0., 26106.59, 1, 0, 3, 0, 6, 0, 0.5, 0.5, 1., 200., 8600., 339.
↪1203, 1, 4, 12, 12, 4, 0, 0.7848778, 1.        , 0.1387314 , 5113.951, 5200.    , 13.
↪87314 , b'rch')],
          dtype=[('particleid', '<i4'), ('particlegroup', '<i4'), ('status', '<i4'), (
```

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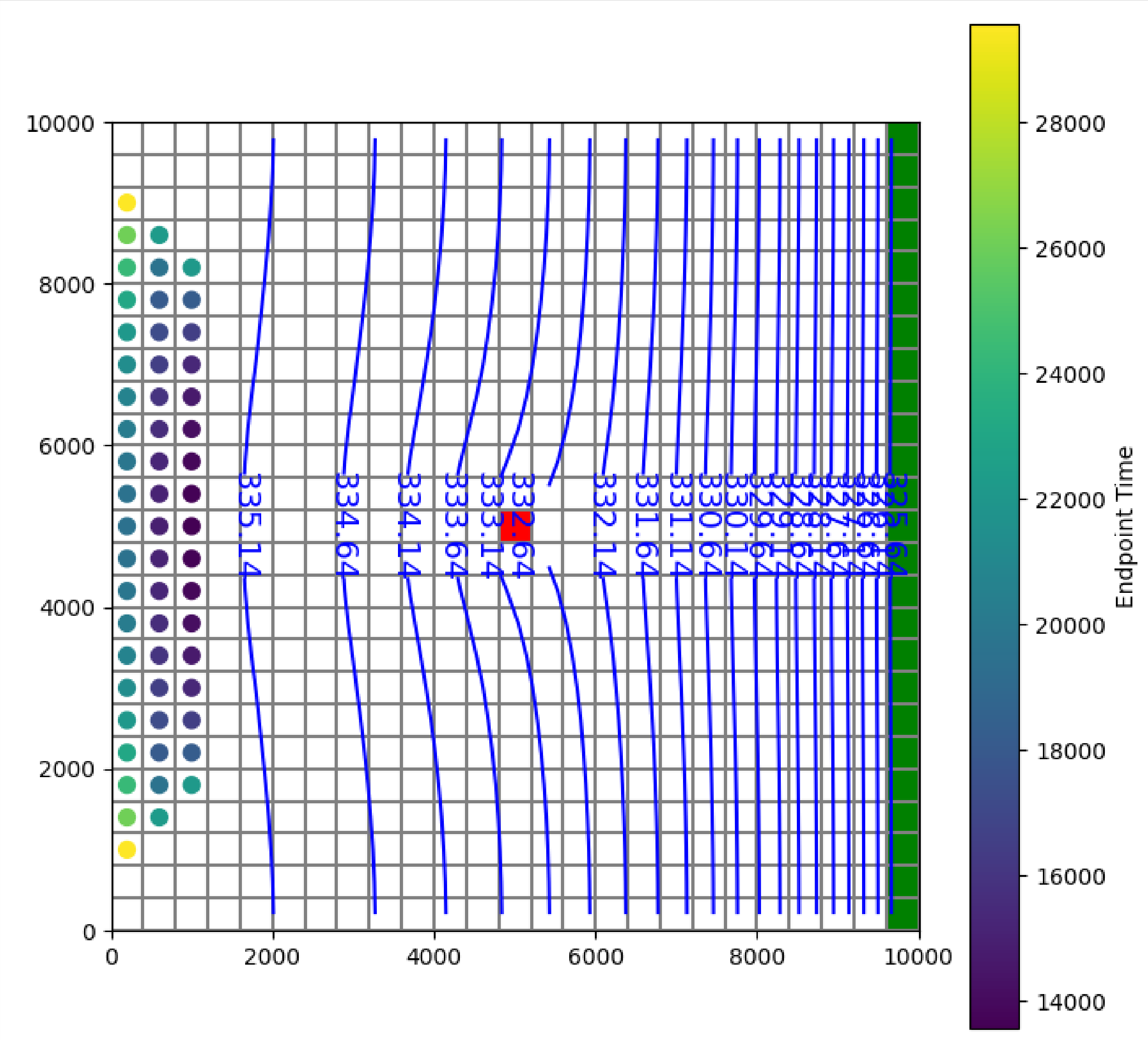
```
↪'time0', '<f4'), ('time', '<f4'), ('initialgrid', '<i4'), ('k0', '<i4'), ('i0', '<i4'),
↪ ('j0', '<i4'), ('cellface0', '<i4'), ('zone0', '<i4'), ('xloc0', '<f4'), ('yloc0', '
↪<f4'), ('zloc0', '<f4'), ('x0', '<f4'), ('y0', '<f4'), ('z0', '<f4'), ('finalgrid', '
↪<i4'), ('k', '<i4'), ('i', '<i4'), ('j', '<i4'), ('cellface', '<i4'), ('zone', '<i4'),␣
↪('xloc', '<f4'), ('yloc', '<f4'), ('zloc', '<f4'), ('x', '<f4'), ('y', '<f4'), ('z', '
↪<f4'), ('label', 'O')])
```

[9]:
```
fig = plt.figure(figsize=(8, 8))
ax = fig.add_subplot(1, 1, 1, aspect="equal")
mapview = flopy.plot.PlotMapView(model=m, layer=2)
quadmesh = mapview.plot_ibound()
linecollection = mapview.plot_grid()
riv = mapview.plot_bc("RIV", color="g", plotAll=True)
quadmesh = mapview.plot_bc("WEL", kper=1, plotAll=True)
contour_set = mapview.contour_array(
    hds, levels=np.arange(np.min(hds), np.max(hds), 0.5), colors="b"
)
plt.clabel(contour_set, inline=1, fontsize=14)
mapview.plot_endpoint(well_epd, direction="starting", colorbar=True)
```

[9]:
```
<matplotlib.collections.PathCollection at 0x7f4e8df0edf0>
```



Write starting locations to a shapefile.

[10]:
```
fpth = os.path.join(model_ws, "starting_locs.shp")
print(type(fpth))
epobj.write_shapefile(
    well_epd, direction="starting", shpname=fpth, mg=m.modelgrid
)
```

```
<class 'str'>
No CRS information for writing a .prj file.
Supply an valid coordinate system reference to the attached modelgrid object or .
↪export() method.
```

```
/opt/hostedtoolcache/Python/3.8.18/x64/lib/python3.8/site-packages/flopy/export/
↪shapefile_utils.py:492: UserWarning: Truncating shapefile fieldname particlegroup to␣
↪partiroup_
  warn(f"Truncating shapefile fieldname {s} to {name}")
```

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```
/opt/hostedtoolcache/Python/3.8.18/x64/lib/python3.8/site-packages/flopy/export/
↪shapefile_utils.py:492: UserWarning: Truncating shapefile fieldname initialgrid to␣
↪initigrid_
  warn(f"Truncating shapefile fieldname {s} to {name}")
```

Read in the pathline file and subset to pathlines that terminated in the well .

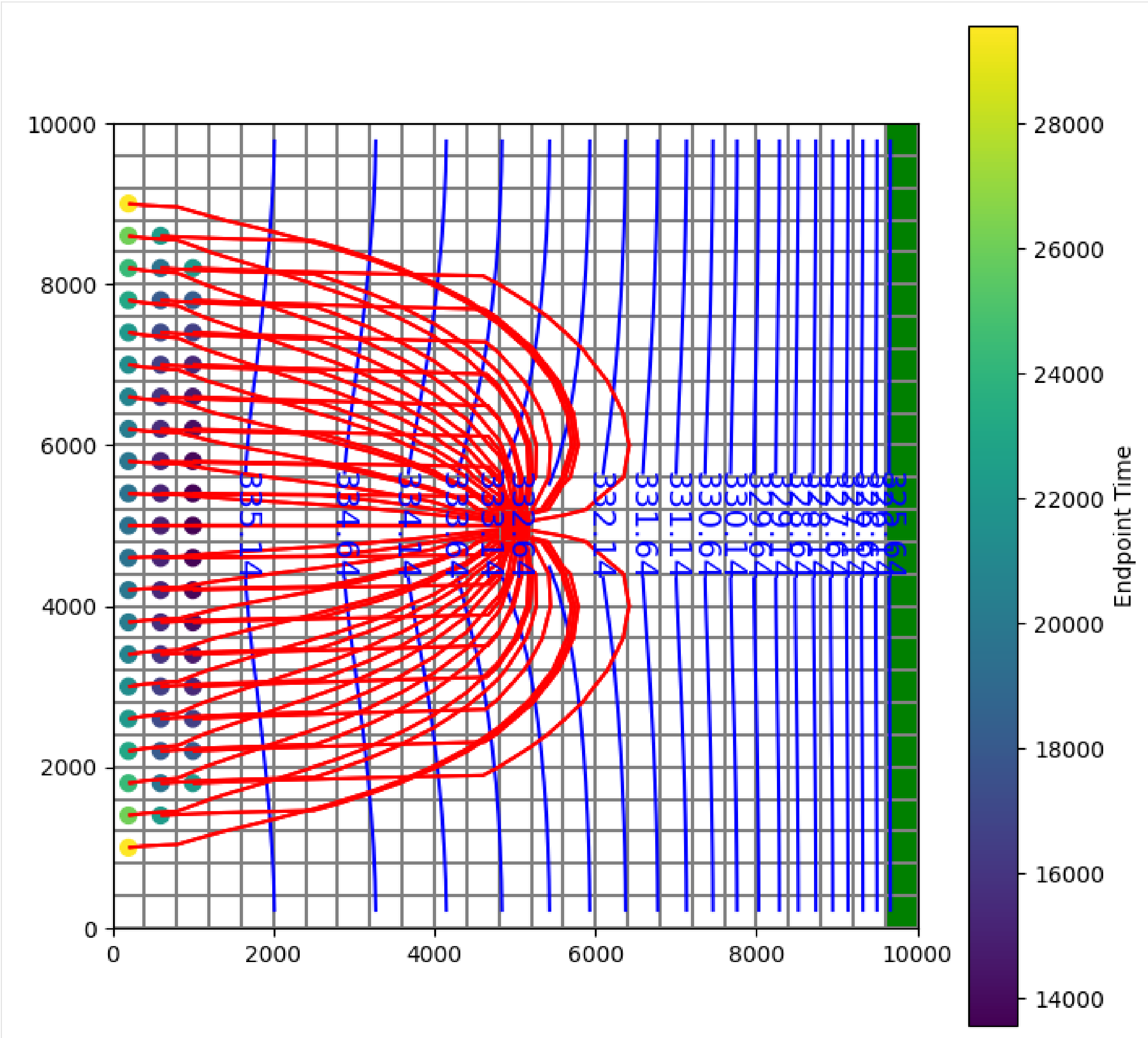
```
[11]: # make a selection of cells that terminate in the well cell = (4, 12, 12)
pthobj = flopy.utils.PathlineFile(os.path.join(model_ws, "ex6.mppth"))
well_pathlines = pthobj.get_destination_pathline_data(dest_cells=[(4, 12, 12)])
```

Plot the pathlines that terminate in the well and the starting locations of the particles.

```
[12]: fig = plt.figure(figsize=(8, 8))
ax = fig.add_subplot(1, 1, 1, aspect="equal")
mapview = flopy.plot.PlotMapView(model=m, layer=2)
quadmesh = mapview.plot_ibound()
linecollection = mapview.plot_grid()
riv = mapview.plot_bc("RIV", color="g", plotAll=True)
quadmesh = mapview.plot_bc("WEL", kper=1, plotAll=True)
contour_set = mapview.contour_array(
    hds, levels=np.arange(np.min(hds), np.max(hds), 0.5), colors="b"
)
plt.clabel(contour_set, inline=1, fontsize=14)

mapview.plot_endpoint(well_epd, direction="starting", colorbar=True)
# for now, each particle must be plotted individually
# (plot_pathline() will plot a single line for recarray with multiple particles)
# for pid in np.unique(well_pathlines.particleid):
#   modelmap.plot_pathline(pthobj.get_data(pid), layer='all', colors='red');
mapview.plot_pathline(well_pathlines, layer="all", colors="red")
```

```
[12]: <matplotlib.collections.LineCollection at 0x7f4e8dd81d00>
```



Write pathlines to a shapefile.

[13]:
```python
# one line feature per particle
pthobj.write_shapefile(
    well_pathlines,
    direction="starting",
    shpname=os.path.join(model_ws, "pathlines.shp"),
    mg=m.modelgrid,
    verbose=False,
)

# one line feature for each row in pathline file
# (can be used to color lines by time or layer in a GIS)
pthobj.write_shapefile(
    well_pathlines,
    one_per_particle=False,
```

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```
    shpname=os.path.join(model_ws, "pathlines_1per.shp"),
    mg=m.modelgrid,
    verbose=False,
)
```

```
(numpy.record, {'names': ['x', 'y', 'z', 'time', 'k', 'particleid'], 'formats': ['<f4', '
↪<f4', '<f4', '<f4', '<i4', '<i4'], 'offsets': [20, 24, 28, 16, 32, 0], 'itemsize': 64})
No CRS information for writing a .prj file.
Supply an valid coordinate system reference to the attached modelgrid object or .
↪export() method.
(numpy.record, {'names': ['x', 'y', 'z', 'time', 'k', 'particleid'], 'formats': ['<f4', '
↪<f4', '<f4', '<f4', '<i4', '<i4'], 'offsets': [20, 24, 28, 16, 32, 0], 'itemsize': 64})
No CRS information for writing a .prj file.
Supply an valid coordinate system reference to the attached modelgrid object or .
↪export() method.
```

Replace WEL package with MNW2, and create backward tracking simulation using particles released at MNW well.

[14]:
```
m2 = flopy.modflow.Modflow.load(
    "EXAMPLE.nam", model_ws=str(model_path), exe_name="mf2005"
)
m2.get_package_list()
```

[14]:
```
['DIS', 'BAS6', 'WEL', 'RIV', 'RCH', 'OC', 'PCG', 'LPF']
```

[15]:
```
m2.nrow_ncol_nlay_nper
```

[15]:
```
(25, 25, 5, 3)
```

[16]:
```
m2.wel.stress_period_data.data
```

[16]:
```
{0: 0,
 1: rec.array([(4, 12, 12, -150000., 0.)],
           dtype=[('k', '<i8'), ('i', '<i8'), ('j', '<i8'), ('flux', '<f4'), ('iface', '
↪<f4')]),
 2: rec.array([(4, 12, 12, -150000., 0.)],
           dtype=[('k', '<i8'), ('i', '<i8'), ('j', '<i8'), ('flux', '<f4'), ('iface', '
↪<f4')])}
```

[17]:
```
node_data = np.array(
    [
        (3, 12, 12, "well1", "skin", -1, 0, 0, 0, 1.0, 2.0, 5.0, 6.2),
        (4, 12, 12, "well1", "skin", -1, 0, 0, 0, 0.5, 2.0, 5.0, 6.2),
    ],
    dtype=[
        ("k", int),
        ("i", int),
        ("j", int),
        ("wellid", object),
        ("losstype", object),
        ("pumploc", int),
        ("qlimit", int),
        ("ppflag", int),
```

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```
        ("pumpcap", int),
        ("rw", float),
        ("rskin", float),
        ("kskin", float),
        ("zpump", float),
    ],
).view(np.recarray)

stress_period_data = {
    0: np.array(
        [(0, "well1", -150000.0)],
        dtype=[("per", int), ("wellid", object), ("qdes", float)],
    )
}
```

[18]:
```
m2.name = "Example_mnw"
m2.remove_package("WEL")
mnw2 = flopy.modflow.ModflowMnw2(
    model=m2,
    mnwmax=1,
    node_data=node_data,
    stress_period_data=stress_period_data,
    itmp=[1, -1, -1],
)
m2.get_package_list()
```

[18]:
```
['DIS', 'BAS6', 'RIV', 'RCH', 'OC', 'PCG', 'LPF', 'MNW2']
```

Write and run MODFLOW.

[19]:
```
m2.change_model_ws(model_ws)
m2.write_name_file()
m2.write_input()
success, buff = m2.run_model(silent=True, report=True)
if success:
    for line in buff:
        print(line)
else:
    raise ValueError("Failed to run.")
```

```

                                  MODFLOW-2005
    U.S. GEOLOGICAL SURVEY MODULAR FINITE-DIFFERENCE GROUND-WATER FLOW MODEL
                             Version 1.12.00 2/3/2017

 Using NAME file: Example_mnw.nam
 Run start date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:30:22

 Solving:  Stress period:     1    Time step:     1    Ground-Water Flow Eqn.
 Solving:  Stress period:     2    Time step:     1    Ground-Water Flow Eqn.
 Solving:  Stress period:     2    Time step:     2    Ground-Water Flow Eqn.
 Solving:  Stress period:     2    Time step:     3    Ground-Water Flow Eqn.
 Solving:  Stress period:     2    Time step:     4    Ground-Water Flow Eqn.
```

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```
Solving:  Stress period:     2    Time step:     5    Ground-Water Flow Eqn.
Solving:  Stress period:     2    Time step:     6    Ground-Water Flow Eqn.
Solving:  Stress period:     2    Time step:     7    Ground-Water Flow Eqn.
Solving:  Stress period:     2    Time step:     8    Ground-Water Flow Eqn.
Solving:  Stress period:     2    Time step:     9    Ground-Water Flow Eqn.
Solving:  Stress period:     2    Time step:    10    Ground-Water Flow Eqn.
Solving:  Stress period:     3    Time step:     1    Ground-Water Flow Eqn.
Run end date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:30:22
Elapsed run time:  0.049 Seconds

 Normal termination of simulation
```

Create a new Modpath6 object.

[20]:
```
mp = flopy.modpath.Modpath6(
    modelname="ex6mnw",
    exe_name="mp6",
    modflowmodel=m2,
    model_ws=model_ws,
)

mpb = flopy.modpath.Modpath6Bas(
    mp, hdry=m2.lpf.hdry, laytyp=m2.lpf.laytyp, ibound=1, prsity=0.1
)
sim = mp.create_mpsim(trackdir="backward", simtype="pathline", packages="MNW2")

mp.change_model_ws(model_ws)
mp.write_name_file()
mp.write_input()
success, buff = mp.run_model(silent=True, report=True)
if success:
    for line in buff:
        print(line)
else:
    raise ValueError("Failed to run.")
```

```
Processing basic data ...
Checking head file ...
Checking budget file and building index ...

Run particle tracking simulation ...
Processing Time Step     1 Period     1.  Time =  2.00000E+05
Particle tracking complete. Writing endpoint file ...
End of MODPATH simulation. Normal termination.
```

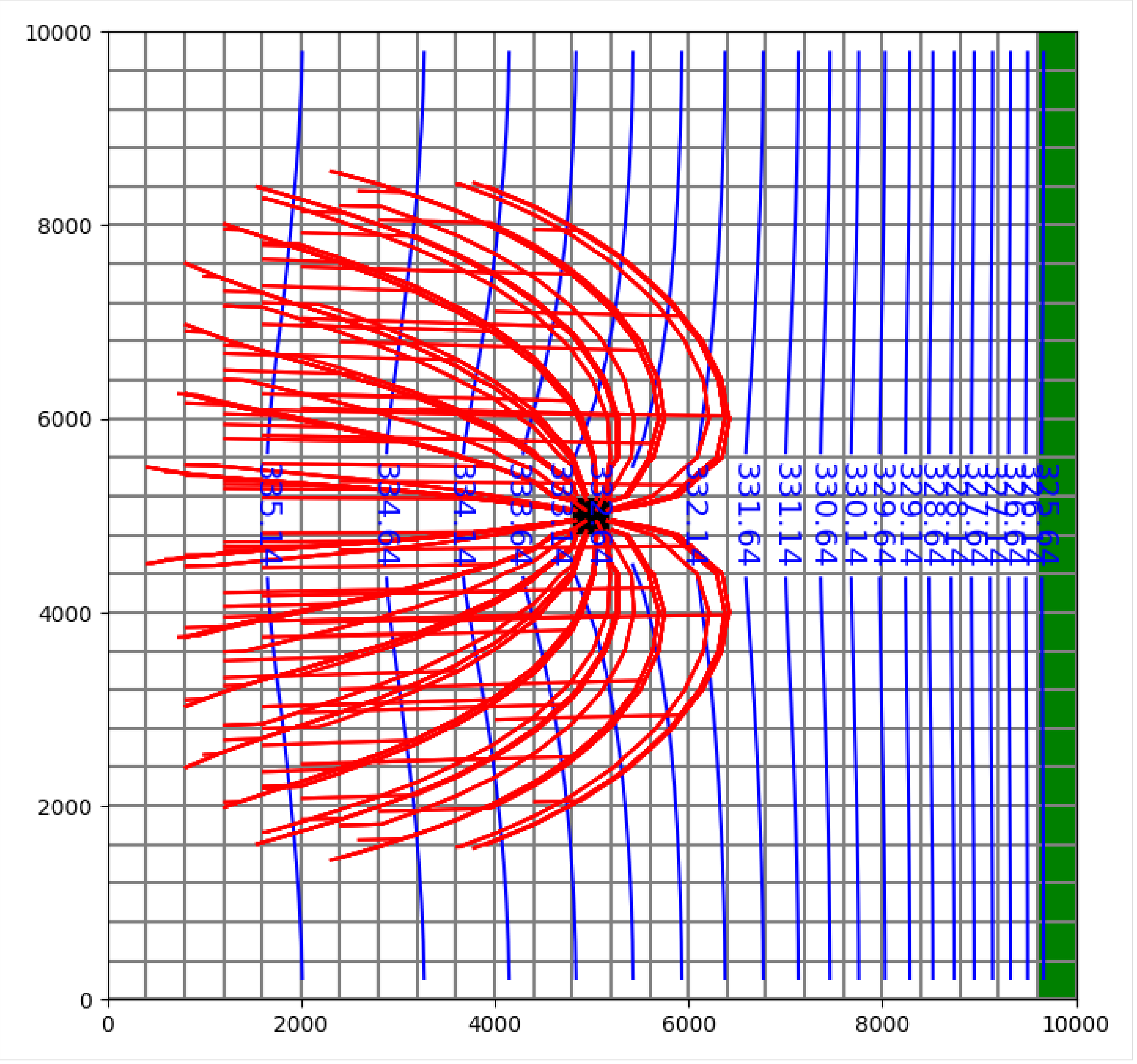
Read in results and plot.

[21]:
```
pthobj = flopy.utils.PathlineFile(os.path.join(model_ws, "ex6mnw.mppth"))
epdobj = flopy.utils.EndpointFile(os.path.join(model_ws, "ex6mnw.mpend"))
well_epd = epdobj.get_alldata()
well_pathlines = (
    pthobj.get_alldata()
)  # returns a list of recarrays; one per pathline
```

[22]:
```
fig = plt.figure(figsize=(8, 8))
ax = fig.add_subplot(1, 1, 1, aspect="equal")
mapview = flopy.plot.PlotMapView(model=m2, layer=2)
quadmesh = mapview.plot_ibound()
linecollection = mapview.plot_grid()
riv = mapview.plot_bc("RIV", color="g", plotAll=True)
quadmesh = mapview.plot_bc("MNW2", kper=1, plotAll=True)
contour_set = mapview.contour_array(
    hds, levels=np.arange(np.min(hds), np.max(hds), 0.5), colors="b"
)
plt.clabel(contour_set, inline=1, fontsize=14)

mapview.plot_pathline(
    well_pathlines, travel_time="<10000", layer="all", colors="red"
)
```

[22]:
```
<matplotlib.collections.LineCollection at 0x7f4e8da9dbb0>
```



[23]:
```
try:
    # ignore PermissionError on Windows
    temp_dir.cleanup()
except:
    pass
```

6.8.2 Creating a MODPATH 7 simulation

This notebook demonstrates how to create a simple forward and backward MODPATH 7 simulation using the `.create_mp7()` method. The notebooks also shows how to create subsets of endpoint output and plot MODPATH results on ModelMap objects.

[1]:
```
import os
```

[2]:
```
import sys
from tempfile import TemporaryDirectory

import matplotlib as mpl
import matplotlib.pyplot as plt
import numpy as np

# run installed version of flopy or add local path
try:
    import flopy
except:
    fpth = os.path.abspath(os.path.join("..", ".."))
    sys.path.append(fpth)
    import flopy

print(sys.version)
print(f"numpy version: {np.__version__}")
print(f"matplotlib version: {mpl.__version__}")
print(f"flopy version: {flopy.__version__}")

# temporary directory
temp_dir = TemporaryDirectory()
model_ws = temp_dir.name
```

```
3.8.18 (default, Aug 28 2023, 08:27:22)
[GCC 11.4.0]
numpy version: 1.24.4
matplotlib version: 3.7.4
flopy version: 3.5.0
```

[3]:
```
# define executable names
mpexe = "mp7"
mfexe = "mf6"
```

Flow model data

[4]:
```
nper, nstp, perlen, tsmult = 1, 1, 1.0, 1.0
nlay, nrow, ncol = 3, 21, 20
delr = delc = 500.0
top = 400.0
botm = [220.0, 200.0, 0.0]
laytyp = [1, 0, 0]
kh = [50.0, 0.01, 200.0]
kv = [10.0, 0.01, 20.0]
```

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```
wel_loc = (2, 10, 9)
wel_q = -150000.0
rch = 0.005
riv_h = 320.0
riv_z = 317.0
riv_c = 1.0e5
```

[5]:
```
def get_nodes(locs):
    nodes = []
    for k, i, j in locs:
        nodes.append(k * nrow * ncol + i * ncol + j)
    return nodes
```

MODPATH 7 using MODFLOW 6

Create and run MODFLOW 6

[6]:
```
ws = os.path.join(model_ws, "mp7_ex1_cs")
nm = "ex01_mf6"

# Create the Flopy simulation object
sim = flopy.mf6.MFSimulation(
    sim_name=nm, exe_name=mfexe, version="mf6", sim_ws=ws
)

# Create the Flopy temporal discretization object
pd = (perlen, nstp, tsmult)
tdis = flopy.mf6.modflow.mftdis.ModflowTdis(
    sim, pname="tdis", time_units="DAYS", nper=nper, perioddata=[pd]
)

# Create the Flopy groundwater flow (gwf) model object
model_nam_file = f"{nm}.nam"
gwf = flopy.mf6.ModflowGwf(
    sim, modelname=nm, model_nam_file=model_nam_file, save_flows=True
)

# Create the Flopy iterative model solver (ims) Package object
ims = flopy.mf6.modflow.mfims.ModflowIms(
    sim,
    pname="ims",
    complexity="SIMPLE",
    outer_hclose=1e-6,
    inner_hclose=1e-6,
    rcloserecord=1e-6,
)

# create gwf file
dis = flopy.mf6.modflow.mfgwfdis.ModflowGwfdis(
    gwf,
```

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```
    pname="dis",
    nlay=nlay,
    nrow=nrow,
    ncol=ncol,
    length_units="FEET",
    delr=delr,
    delc=delc,
    top=top,
    botm=botm,
)
# Create the initial conditions package
ic = flopy.mf6.modflow.mfgwfic.ModflowGwfic(gwf, pname="ic", strt=top)

# Create the node property flow package
npf = flopy.mf6.modflow.mfgwfnpf.ModflowGwfnpf(
    gwf, pname="npf", icelltype=laytyp, k=kh, k33=kv
)


# recharge
flopy.mf6.modflow.mfgwfrcha.ModflowGwfrcha(gwf, recharge=rch)
# wel
wd = [(wel_loc, wel_q)]
flopy.mf6.modflow.mfgwfwel.ModflowGwfwel(
    gwf, maxbound=1, stress_period_data={0: wd}
)
# river
rd = []
for i in range(nrow):
    rd.append([(0, i, ncol - 1), riv_h, riv_c, riv_z])
flopy.mf6.modflow.mfgwfriv.ModflowGwfriv(gwf, stress_period_data={0: rd})
# Create the output control package
headfile = f"{nm}.hds"
head_record = [headfile]
budgetfile = f"{nm}.cbb"
budget_record = [budgetfile]
saverecord = [("HEAD", "ALL"), ("BUDGET", "ALL")]
oc = flopy.mf6.modflow.mfgwfoc.ModflowGwfoc(
    gwf,
    pname="oc",
    saverecord=saverecord,
    head_filerecord=head_record,
    budget_filerecord=budget_record,
)

# Write the datasets
sim.write_simulation()
# Run the simulation
success, buff = sim.run_simulation(silent=True, report=True)
assert success, "mf6 model did not run"
for line in buff:
    print(line)
```

```
writing simulation...
  writing simulation name file...
  writing simulation tdis package...
  writing solution package ims...
  writing model ex01_mf6...
    writing model name file...
    writing package dis...
    writing package ic...
    writing package npf...
    writing package rcha_0...
    writing package wel_0...
    writing package riv_0...
INFORMATION: maxbound in ('gwf6', 'riv', 'dimensions') changed to 21 based on size of␣
↪stress_period_data
    writing package oc...
                                   MODFLOW 6
                U.S. GEOLOGICAL SURVEY MODULAR HYDROLOGIC MODEL
                            VERSION 6.4.2 06/28/2023

   MODFLOW 6 compiled Jul 05 2023 20:29:14 with Intel(R) Fortran Intel(R) 64
   Compiler Classic for applications running on Intel(R) 64, Version 2021.7.0
                             Build 20220726_000000

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and distribution information.


 Run start date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:30:28

 Writing simulation list file: mfsim.lst
 Using Simulation name file: mfsim.nam

    Solving:  Stress period:     1    Time step:     1

 Run end date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:30:28
 Elapsed run time:  0.027 Seconds


WARNING REPORT:

  1. NONLINEAR BLOCK VARIABLE 'OUTER_HCLOSE' IN FILE 'ex01_mf6.ims' WAS
     DEPRECATED IN VERSION 6.1.1. SETTING OUTER_DVCLOSE TO OUTER_HCLOSE VALUE.
  2. LINEAR BLOCK VARIABLE 'INNER_HCLOSE' IN FILE 'ex01_mf6.ims' WAS
```

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```
    DEPRECATED IN VERSION 6.1.1. SETTING INNER_DVCLOSE TO INNER_HCLOSE VALUE.
 Normal termination of simulation.
```

Get locations to extract data

[7]:
```
nodew = get_nodes([wel_loc])
cellids = gwf.riv.stress_period_data.get_data()[0]["cellid"]
nodesr = get_nodes(cellids)
```

Create and run MODPATH 7

Forward tracking

[8]:
```
# create modpath files
mpnamf = f"{nm}_mp_forward"

# create basic forward tracking modpath simulation
mp = flopy.modpath.Modpath7.create_mp7(
    modelname=mpnamf,
    trackdir="forward",
    flowmodel=gwf,
    model_ws=ws,
    rowcelldivisions=1,
    columncelldivisions=1,
    layercelldivisions=1,
    exe_name=mpexe,
)

# write modpath datasets
mp.write_input()

# run modpath
succes, buff = mp.run_model(silent=True, report=True)
assert success, "mp7 forward tracking failed to run"
for line in buff:
    print(line)
```

```

MODPATH Version 7.2.001
Program compiled Jul 05 2023 20:31:49 with IFORT compiler (ver. 20.21.7)


Run particle tracking simulation ...
Processing Time Step     1 Period     1.  Time =  1.00000E+00  Steady-state flow

Particle Summary:
         0 particles are pending release.
         0 particles remain active.
         0 particles terminated at boundary faces.
         0 particles terminated at weak sink cells.
         0 particles terminated at weak source cells.
```

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```
      1260 particles terminated at strong source/sink cells.
         0 particles terminated in cells with a specified zone number.
         0 particles were stranded in inactive or dry cells.
         0 particles were unreleased.
         0 particles have an unknown status.

Normal termination.
```

Backward tracking from well and river locations

[9]:
```
# create modpath files
mpnamb = f"{nm}_mp_backward"

# create basic forward tracking modpath simulation
mp = flopy.modpath.Modpath7.create_mp7(
    modelname=mpnamb,
    trackdir="backward",
    flowmodel=gwf,
    model_ws=ws,
    rowcelldivisions=5,
    columncelldivisions=5,
    layercelldivisions=5,
    nodes=nodew + nodesr,
    exe_name=mpexe,
)

# write modpath datasets
mp.write_input()

# run modpath
success, buff = mp.run_model(silent=True, report=True)
assert success, "mp7 backward tracking failed to run"
for line in buff:
    print(line)
```

```

MODPATH Version 7.2.001
Program compiled Jul 05 2023 20:31:49 with IFORT compiler (ver. 20.21.7)


Run particle tracking simulation ...
Processing Time Step     1 Period     1.  Time =  1.00000E+00  Steady-state flow

Particle Summary:
         0 particles are pending release.
         0 particles remain active.
         0 particles terminated at boundary faces.
         0 particles terminated at weak sink cells.
         0 particles terminated at weak source cells.
      2750 particles terminated at strong source/sink cells.
         0 particles terminated in cells with a specified zone number.
         0 particles were stranded in inactive or dry cells.
         0 particles were unreleased.
```

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```
        0 particles have an unknown status.

Normal termination.
```

Load and Plot MODPATH 7 output

Forward Tracking

Load forward tracking pathline data

[10]:
```
fpth = os.path.join(ws, f"{mpnamf}.mppth")
p = flopy.utils.PathlineFile(fpth)
pw = p.get_destination_pathline_data(dest_cells=nodew)
pr = p.get_destination_pathline_data(dest_cells=nodesr)
```

Load forward tracking endpoint data

[11]:
```
fpth = os.path.join(ws, f"{mpnamf}.mpend")
e = flopy.utils.EndpointFile(fpth)
```

Get forward particles that terminate in the well

[12]:
```
well_epd = e.get_destination_endpoint_data(dest_cells=nodew)
```

Get particles that terminate in the river boundaries

[13]:
```
riv_epd = e.get_destination_endpoint_data(dest_cells=nodesr)
```

Well and river forward tracking pathlines

[14]:
```
colors = ["green", "orange", "red"]
```

[15]:
```
f, axes = plt.subplots(
    ncols=3, nrows=2, sharey=True, sharex=True, figsize=(15, 10)
)
axes = axes.flatten()

idax = 0
for k in range(nlay):
    ax = axes[idax]
    ax.set_aspect("equal")
    ax.set_title(f"Well pathlines - Layer {k + 1}")
    mm = flopy.plot.PlotMapView(model=gwf, ax=ax)
    mm.plot_grid(lw=0.5)
    mm.plot_pathline(pw, layer=k, colors=colors[k], lw=0.75)
    idax += 1

for k in range(nlay):
    ax = axes[idax]
    ax.set_aspect("equal")
    ax.set_title(f"River pathlines - Layer {k + 1}")
```

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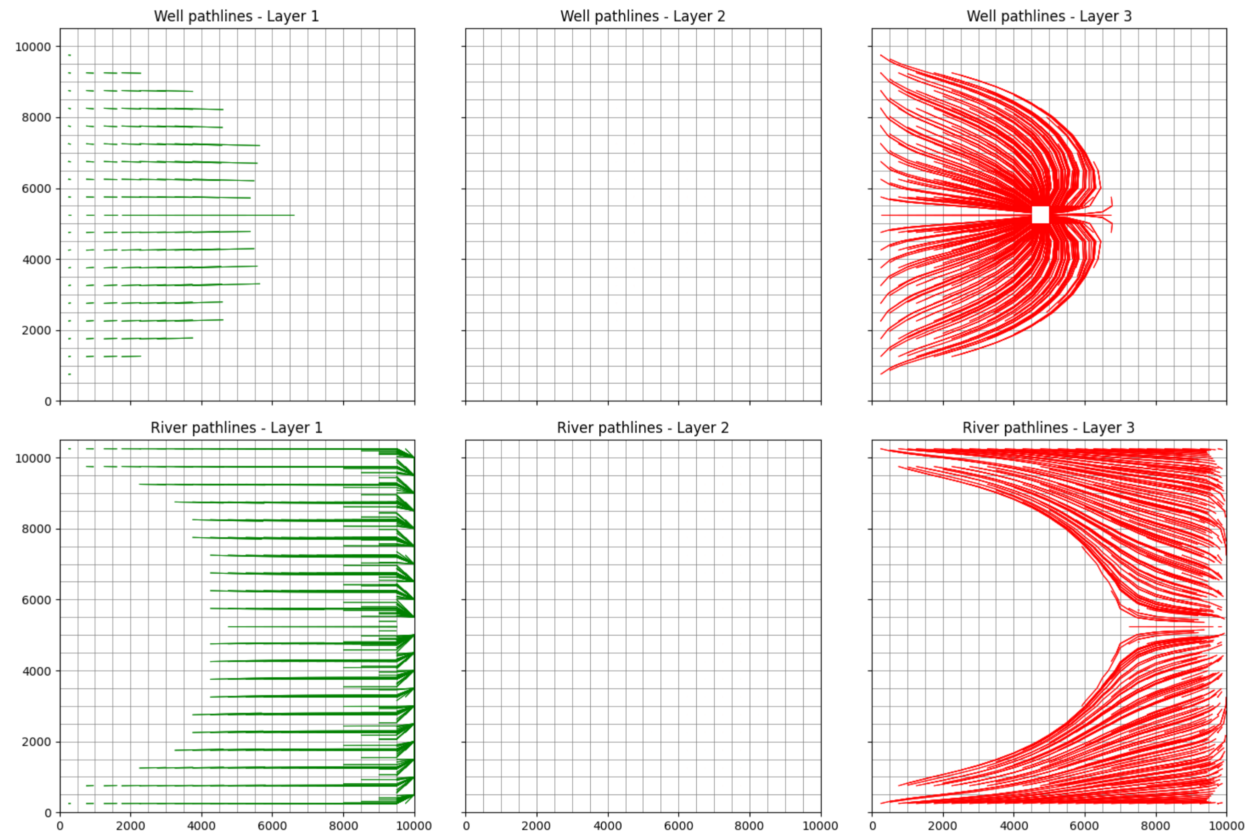
```
    mm = flopy.plot.PlotMapView(model=gwf, ax=ax)
    mm.plot_grid(lw=0.5)
    mm.plot_pathline(pr, layer=k, colors=colors[k], lw=0.75)
    idax += 1

plt.tight_layout()
```



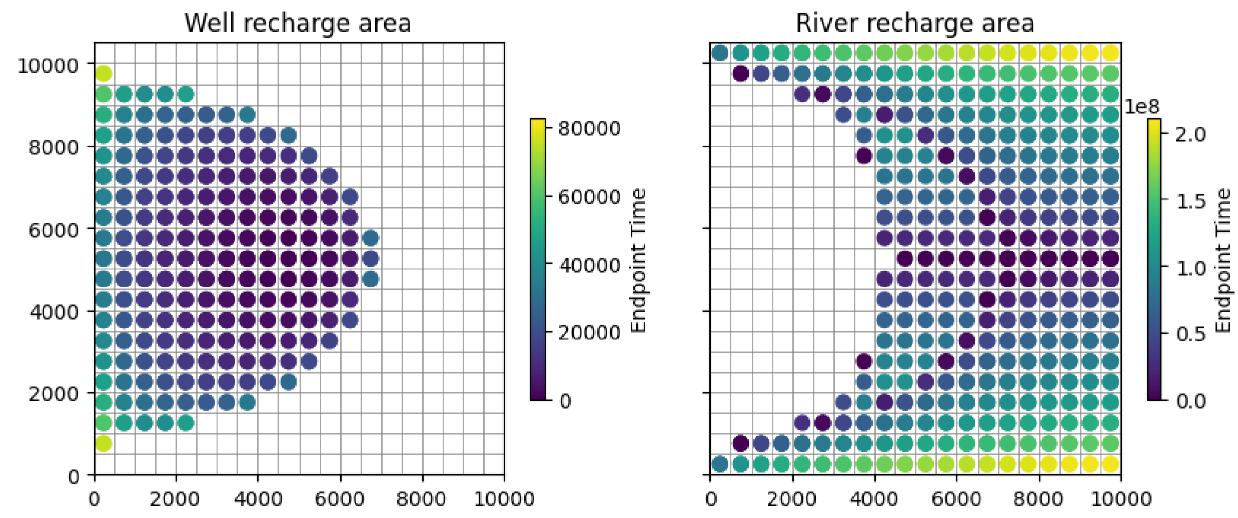
Forward tracking endpoints captured by the well and river

[16]:
```
f, axes = plt.subplots(ncols=2, nrows=1, sharey=True, figsize=(10, 5))
axes = axes.flatten()

ax = axes[0]
ax.set_aspect("equal")
ax.set_title("Well recharge area")
mm = flopy.plot.PlotMapView(model=gwf, ax=ax)
mm.plot_grid(lw=0.5)
mm.plot_endpoint(well_epd, direction="starting", colorbar=True, shrink=0.5)

ax = axes[1]
ax.set_aspect("equal")
ax.set_title("River recharge area")
mm = flopy.plot.PlotMapView(model=gwf, ax=ax)
mm.plot_grid(lw=0.5)
mm.plot_endpoint(riv_epd, direction="starting", colorbar=True, shrink=0.5)
```

[16]:
```
<matplotlib.collections.PathCollection at 0x7fc1619038b0>
```



Backward tracking

Load backward tracking pathlines

[17]:
```
fpth = os.path.join(ws, f"{mpnamb}.mppth")
p = flopy.utils.PathlineFile(fpth)
pwb = p.get_destination_pathline_data(dest_cells=nodew)
prb = p.get_destination_pathline_data(dest_cells=nodesr)
```

Load backward tracking endpoints

[18]:
```
fpth = os.path.join(ws, f"{mpnamb}.mpend")
e = flopy.utils.EndpointFile(fpth)
ewb = e.get_destination_endpoint_data(dest_cells=nodew, source=True)
erb = e.get_destination_endpoint_data(dest_cells=nodesr, source=True)
```

Well backward tracking pathlines

[19]:
```
f, axes = plt.subplots(ncols=2, nrows=1, figsize=(10, 5))

ax = axes[0]
ax.set_aspect("equal")
ax.set_title("Well recharge area")
mm = flopy.plot.PlotMapView(model=gwf, ax=ax)
mm.plot_grid(lw=0.5)
mm.plot_pathline(
    pwb,
    layer="all",
    colors="blue",
    lw=0.5,
    linestyle=":",
    label="captured by wells",
)
```

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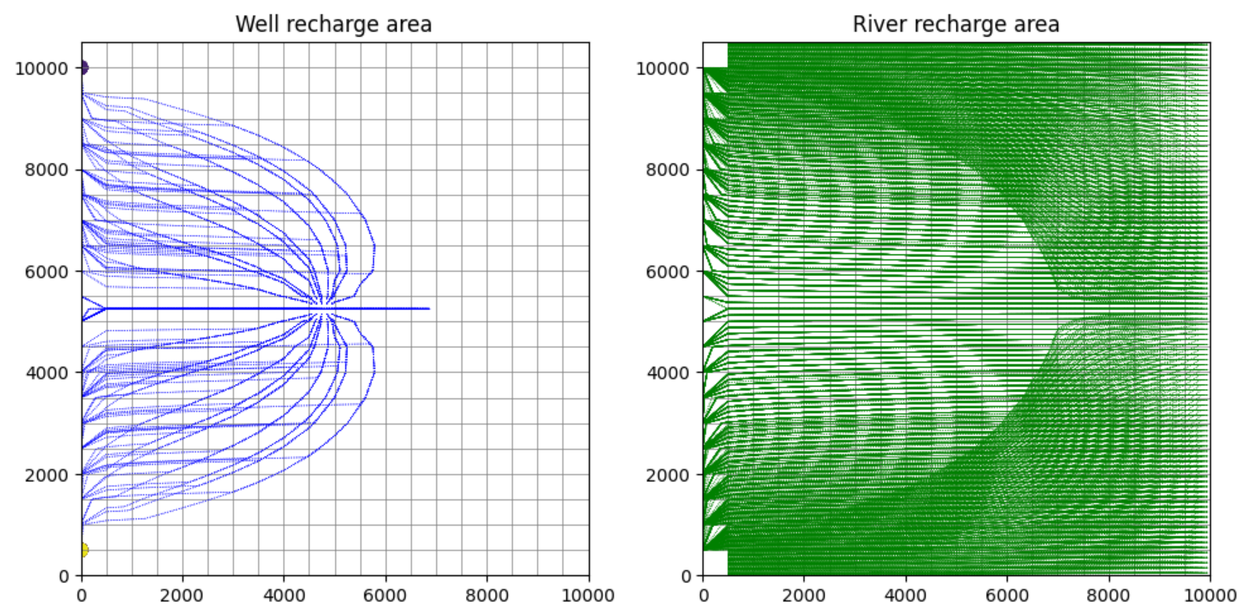
```
mm.plot_endpoint(ewb, direction="ending")  # , colorbar=True, shrink=0.5);

ax = axes[1]
ax.set_aspect("equal")
ax.set_title("River recharge area")
mm = flopy.plot.PlotMapView(model=gwf, ax=ax)
mm.plot_grid(lw=0.5)
mm.plot_pathline(
    prb,
    layer="all",
    colors="green",
    lw=0.5,
    linestyle=":",
    label="captured by rivers",
)

plt.tight_layout()
```



6.8.3 Using MODPATH 7 with structured grids

This notebook demonstrates how to create and run example 1a from the MODPATH 7 documentation for MODFLOW-2005 and MODFLOW 6. The notebooks also shows how to create subsets of endpoint output and plot MODPATH results on PlotMapView objects.

[1]:
```
import os
```

[2]:
```
import sys
from tempfile import TemporaryDirectory

import matplotlib as mpl
import matplotlib.pyplot as plt
```

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```
import numpy as np
from numpy.lib.recfunctions import repack_fields

# run installed version of flopy or add local path
try:
    import flopy
except:
    fpth = os.path.abspath(os.path.join("..", ".."))
    sys.path.append(fpth)
    import flopy

    print(sys.version)
print(f"numpy version: {np.__version__}")
print(f"matplotlib version: {mpl.__version__}")
print(f"flopy version: {flopy.__version__}")

# temporary directory
temp_dir = TemporaryDirectory()
workspace = temp_dir.name
```

```
numpy version: 1.24.4
matplotlib version: 3.7.4
flopy version: 3.5.0
```

Flow model data

[3]:
```
nper, nstp, perlen, tsmult = 1, 1, 1.0, 1.0
nlay, nrow, ncol = 3, 21, 20
delr = delc = 500.0
top = 400.0
botm = [220.0, 200.0, 0.0]
laytyp = [1, 0, 0]
kh = [50.0, 0.01, 200.0]
kv = [10.0, 0.01, 20.0]
wel_loc = (2, 10, 9)
wel_q = -150000.0
rch = 0.005
riv_h = 320.0
riv_z = 317.0
riv_c = 1.0e5
```

MODPATH 7 data

[4]:
```
# MODPATH zones
zone3 = np.ones((nrow, ncol), dtype=np.int32)
zone3[wel_loc[1:]] = 2
zones = [1, 1, zone3]

# create particles
# particle group 1
plocs = []
pids = []
for idx in range(nrow):
    plocs.append((0, idx, 2))
    pids.append(idx)
part0 = flopy.modpath.ParticleData(
    plocs, drape=0, structured=True, particleids=pids
)
pg0 = flopy.modpath.ParticleGroup(
    particlegroupname="PG1", particledata=part0, filename="ex01a.pg1.sloc"
)

# particle group 2
v = [(2, 0, 0), (0, 20, 0)]
part1 = flopy.modpath.ParticleData(
    v, drape=1, structured=True, particleids=[1000, 1001]
)
pg1 = flopy.modpath.ParticleGroup(
    particlegroupname="PG2", particledata=part1, filename="ex01a.pg2.sloc"
)

locsa = [[0, 0, 0, 0, nrow - 1, ncol - 1], [1, 0, 0, 1, nrow - 1, ncol - 1]]
locsb = [[2, 0, 0, 2, nrow - 1, ncol - 1]]
sd = flopy.modpath.CellDataType(
    drape=0, columncelldivisions=1, rowcelldivisions=1, layercelldivisions=1
)
p = flopy.modpath.LRCParticleData(
    subdivisiondata=[sd, sd], lrcregions=[locsa, locsb]
)
pg2 = flopy.modpath.ParticleGroupLRCTemplate(
    particlegroupname="PG3", particledata=p, filename="ex01a.pg3.sloc"
)

particlegroups = [pg2]

# default iface for MODFLOW-2005 and MODFLOW 6
defaultiface = {"RECHARGE": 6, "ET": 6}
defaultiface6 = {"RCH": 6, "EVT": 6}
```

MODPATH 7 using MODFLOW-2005

Create and run MODFLOW-2005

[5]:
```python
ws = os.path.join(workspace, "mp7_ex1_mf2005_dis")
nm = "ex01_mf2005"
exe_name = "mf2005"
iu_cbc = 130
m = flopy.modflow.Modflow(nm, model_ws=ws, exe_name=exe_name)
flopy.modflow.ModflowDis(
    m,
    nlay=nlay,
    nrow=nrow,
    ncol=ncol,
    nper=nper,
    itmuni=4,
    lenuni=2,
    perlen=perlen,
    nstp=nstp,
    tsmult=tsmult,
    steady=True,
    delr=delr,
    delc=delc,
    top=top,
    botm=botm,
)
flopy.modflow.ModflowLpf(
    m, ipakcb=iu_cbc, laytyp=laytyp, hk=kh, vka=kv, constantcv=True
)
flopy.modflow.ModflowBas(m, ibound=1, strt=top)
# recharge
flopy.modflow.ModflowRch(m, ipakcb=iu_cbc, rech=rch)
# wel
wd = [i for i in wel_loc] + [wel_q]
flopy.modflow.ModflowWel(m, ipakcb=iu_cbc, stress_period_data={0: wd})
# river
rd = []
for i in range(nrow):
    rd.append([0, i, ncol - 1, riv_h, riv_c, riv_z])
flopy.modflow.ModflowRiv(m, ipakcb=iu_cbc, stress_period_data={0: rd})
# output control
flopy.modflow.ModflowOc(
    m, stress_period_data={(0, 0): ["save head", "save budget", "print head"]}
)
flopy.modflow.ModflowPcg(m, hclose=1e-6, rclose=1e-6)

m.write_input()
success, buff = m.run_model(silent=True, report=True)
assert success, "mf2005 model did not run"
for line in buff:
    print(line)
```

```
                                  MODFLOW-2005
    U.S. GEOLOGICAL SURVEY MODULAR FINITE-DIFFERENCE GROUND-WATER FLOW MODEL
                             Version 1.12.00 2/3/2017

 Using NAME file: ex01_mf2005.nam
 Run start date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:30:48

 Solving:  Stress period:     1    Time step:     1    Ground-Water Flow Eqn.
 Run end date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:30:48
 Elapsed run time:  0.010 Seconds

  Normal termination of simulation
```

Create and run MODPATH 7

[6]:
```python
# create modpath files
exe_name = "mp7"
mp = flopy.modpath.Modpath7(
    modelname=f"{nm}_mp", flowmodel=m, exe_name=exe_name, model_ws=ws
)
mpbas = flopy.modpath.Modpath7Bas(mp, porosity=0.1, defaultiface=defaultiface)
mpsim = flopy.modpath.Modpath7Sim(
    mp,
    simulationtype="combined",
    trackingdirection="forward",
    weaksinkoption="pass_through",
    weaksourceoption="pass_through",
    budgetoutputoption="summary",
    budgetcellnumbers=[1049, 1259],
    traceparticledata=[1, 1000],
    referencetime=[0, 0, 0.0],
    stoptimeoption="extend",
    timepointdata=[500, 1000.0],
    zonedataoption="on",
    zones=zones,
    particlegroups=particlegroups,
)

# write modpath datasets
mp.write_input()

# run modpath
success, buff = mp.run_model(silent=True, report=True)
assert success, "mp7 failed to run"
for line in buff:
    print(line)
```

```
MODPATH Version 7.2.001
Program compiled Jul 05 2023 20:31:49 with IFORT compiler (ver. 20.21.7)
```

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```
Run particle tracking simulation ...
Processing Time Step     1 Period     1.  Time =  1.00000E+00  Steady-state flow

Particle Summary:
         0 particles are pending release.
         0 particles remain active.
         0 particles terminated at boundary faces.
         0 particles terminated at weak sink cells.
         0 particles terminated at weak source cells.
      1260 particles terminated at strong source/sink cells.
         0 particles terminated in cells with a specified zone number.
         0 particles were stranded in inactive or dry cells.
         0 particles were unreleased.
         0 particles have an unknown status.

Normal termination.
```

Load MODPATH 7 output

Get locations to extract pathline data

[7]:
```
nodew = m.dis.get_node([wel_loc])
riv_locs = repack_fields(m.riv.stress_period_data[0][["k", "i", "j"]])
nodesr = m.dis.get_node(riv_locs.tolist())
```

Pathline data

[8]:
```
fpth = os.path.join(ws, f"{nm}_mp.mppth")
p = flopy.utils.PathlineFile(fpth)
pw0 = p.get_destination_pathline_data(nodew, to_recarray=True)
pr0 = p.get_destination_pathline_data(nodesr, to_recarray=True)
```

Endpoint data

Get particles that terminate in the well

[9]:
```
fpth = os.path.join(ws, f"{nm}_mp.mpend")
e = flopy.utils.EndpointFile(fpth)
well_epd = e.get_destination_endpoint_data(dest_cells=nodew)
well_epd.shape
```

[9]:
```
(564,)
```

Get particles that terminate in the river boundaries

[10]:
```
riv_epd = e.get_destination_endpoint_data(dest_cells=nodesr)
riv_epd.shape
```

[10]:
```
(696,)
```

Merge the particles that end in the well and the river boundaries.

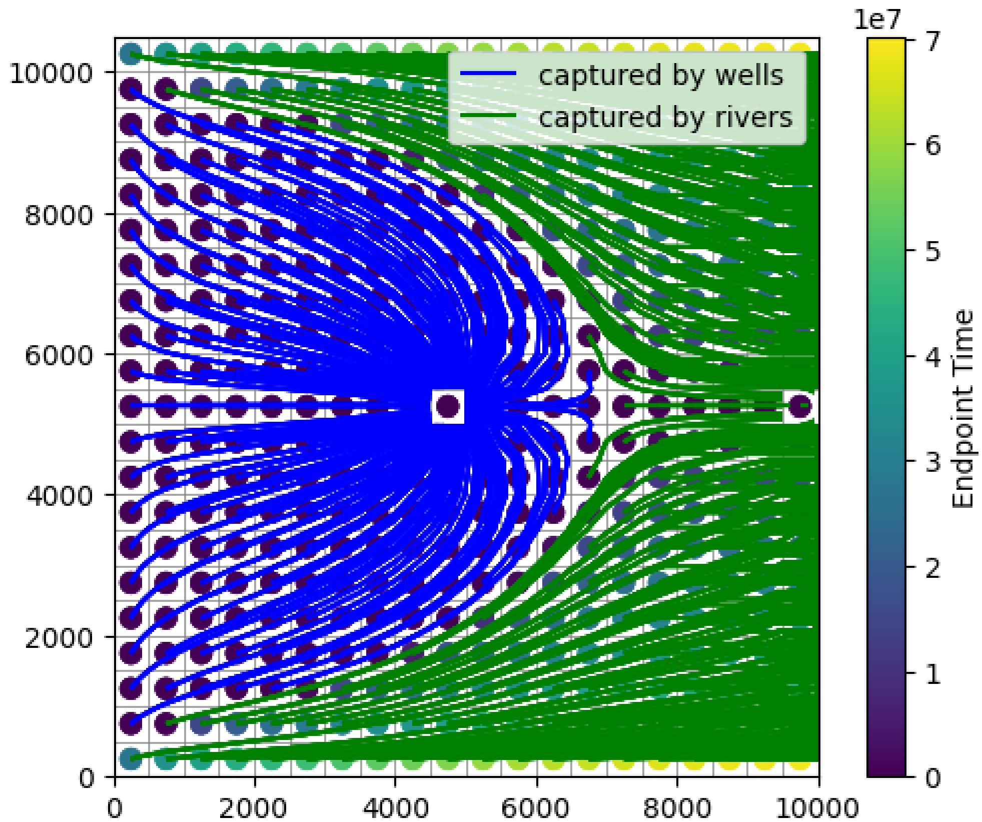
[11]:
```
epd0 = np.concatenate((well_epd, riv_epd))
epd0.shape
```

[11]:
```
(1260,)
```

Plot MODPATH 7 output

[12]:
```
mm = flopy.plot.PlotMapView(model=m)
mm.plot_grid(lw=0.5)
mm.plot_pathline(pw0, layer="all", colors="blue", label="captured by wells")
mm.plot_pathline(pr0, layer="all", colors="green", label="captured by rivers")
mm.plot_endpoint(epd0, direction="starting", colorbar=True)
mm.ax.legend()
```

[12]:
```
<matplotlib.legend.Legend at 0x7f8f71f7dd90>
```



MODPATH 7 using MODFLOW 6

Create and run MODFLOW 6

[13]:
```
ws = os.path.join(workspace, "mp7_ex1_mf6_dis")
nm = "ex01_mf6"
exe_name = "mf6"

# Create the Flopy simulation object
sim = flopy.mf6.MFSimulation(
    sim_name=nm, exe_name="mf6", version="mf6", sim_ws=ws
)

# Create the Flopy temporal discretization object
pd = (perlen, nstp, tsmult)
tdis = flopy.mf6.modflow.mftdis.ModflowTdis(
    sim, pname="tdis", time_units="DAYS", nper=nper, perioddata=[pd]
)

# Create the Flopy groundwater flow (gwf) model object
model_nam_file = f"{nm}.nam"
gwf = flopy.mf6.ModflowGwf(
    sim, modelname=nm, model_nam_file=model_nam_file, save_flows=True
)

# Create the Flopy iterative model solver (ims) Package object
ims = flopy.mf6.modflow.mfims.ModflowIms(
    sim,
    pname="ims",
    complexity="SIMPLE",
    outer_dvclose=1e-6,
    inner_dvclose=1e-6,
    rcloserecord=1e-6,
)

# create gwf file
dis = flopy.mf6.modflow.mfgwfdis.ModflowGwfdis(
    gwf,
    pname="dis",
    nlay=nlay,
    nrow=nrow,
    ncol=ncol,
    length_units="FEET",
    delr=delr,
    delc=delc,
    top=top,
    botm=botm,
)
# Create the initial conditions package
ic = flopy.mf6.modflow.mfgwfic.ModflowGwfic(gwf, pname="ic", strt=top)

# Create the node property flow package
```

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```
npf = flopy.mf6.modflow.mfgwfnpf.ModflowGwfnpf(
    gwf, pname="npf", icelltype=laytyp, k=kh, k33=kv
)


# recharge
flopy.mf6.modflow.mfgwfrcha.ModflowGwfrcha(gwf, recharge=rch)
# wel
wd = [(wel_loc, wel_q)]
flopy.mf6.modflow.mfgwfwel.ModflowGwfwel(
    gwf, maxbound=1, stress_period_data={0: wd}
)
# river
rd = []
for i in range(nrow):
    rd.append([(0, i, ncol - 1), riv_h, riv_c, riv_z])
flopy.mf6.modflow.mfgwfriv.ModflowGwfriv(gwf, stress_period_data={0: rd})
# Create the output control package
headfile = f"{nm}.hds"
head_record = [headfile]
budgetfile = f"{nm}.cbb"
budget_record = [budgetfile]
saverecord = [("HEAD", "ALL"), ("BUDGET", "ALL")]
oc = flopy.mf6.modflow.mfgwfoc.ModflowGwfoc(
    gwf,
    pname="oc",
    saverecord=saverecord,
    head_filerecord=head_record,
    budget_filerecord=budget_record,
)

# Write the datasets
sim.write_simulation()
# Run the simulation
success, buff = sim.run_simulation(silent=True, report=True)
assert success, "mf6 model did not run"
for line in buff:
    print(line)
```

```
writing simulation...
  writing simulation name file...
  writing simulation tdis package...
  writing solution package ims...
  writing model ex01_mf6...
    writing model name file...
    writing package dis...
    writing package ic...
    writing package npf...
    writing package rcha_0...
    writing package wel_0...
    writing package riv_0...
INFORMATION: maxbound in ('gwf6', 'riv', 'dimensions') changed to 21 based on size of
```

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```
↪stress_period_data
    writing package oc...
                                   MODFLOW 6
                U.S. GEOLOGICAL SURVEY MODULAR HYDROLOGIC MODEL
                            VERSION 6.4.2 06/28/2023

   MODFLOW 6 compiled Jul 05 2023 20:29:14 with Intel(R) Fortran Intel(R) 64
   Compiler Classic for applications running on Intel(R) 64, Version 2021.7.0
                             Build 20220726_000000

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and distribution information.


 Run start date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:30:58

 Writing simulation list file: mfsim.lst
 Using Simulation name file: mfsim.nam

    Solving:  Stress period:     1    Time step:     1

 Run end date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:30:58
 Elapsed run time:  0.028 Seconds

 Normal termination of simulation.
```

Create and run MODPATH 7

[14]:

```python
# create modpath files
exe_name = "mp7"
mp = flopy.modpath.Modpath7(
    modelname=f"{nm}_mp", flowmodel=gwf, exe_name=exe_name, model_ws=ws
)
mpbas = flopy.modpath.Modpath7Bas(mp, porosity=0.1, defaultiface=defaultiface6)
mpsim = flopy.modpath.Modpath7Sim(
    mp,
    simulationtype="combined",
    trackingdirection="forward",
    weaksinkoption="pass_through",
    weaksourceoption="pass_through",
```

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```
    budgetoutputoption="summary",
    budgetcellnumbers=[1049, 1259],
    traceparticledata=[1, 1000],
    referencetime=[0, 0, 0.0],
    stoptimeoption="extend",
    timepointdata=[500, 1000.0],
    zonedataoption="on",
    zones=zones,
    particlegroups=particlegroups,
)

# write modpath datasets
mp.write_input()

# run modpath
success, buff = mp.run_model(silent=True, report=True)
assert success, "mp7 failed to run"
for line in buff:
    print(line)
```

```
MODPATH Version 7.2.001
Program compiled Jul 05 2023 20:31:49 with IFORT compiler (ver. 20.21.7)


Run particle tracking simulation ...
Processing Time Step     1 Period     1.  Time =  1.00000E+00  Steady-state flow

Particle Summary:
         0 particles are pending release.
         0 particles remain active.
         0 particles terminated at boundary faces.
         0 particles terminated at weak sink cells.
         0 particles terminated at weak source cells.
      1260 particles terminated at strong source/sink cells.
         0 particles terminated in cells with a specified zone number.
         0 particles were stranded in inactive or dry cells.
         0 particles were unreleased.
         0 particles have an unknown status.

Normal termination.
```

Load MODPATH 7 output

Pathline data

[15]:
```
fpth = os.path.join(ws, f"{nm}_mp.mppth")
p = flopy.utils.PathlineFile(fpth)
pw1 = p.get_destination_pathline_data(nodew, to_recarray=True)
pr1 = p.get_destination_pathline_data(nodesr, to_recarray=True)
```

Endpoint data

Get particles that terminate in the well

[16]:
```
fpth = os.path.join(ws, f"{nm}_mp.mpend")
e = flopy.utils.EndpointFile(fpth)
well_epd = e.get_destination_endpoint_data(dest_cells=nodew)
```

Get particles that terminate in the river boundaries

[17]:
```
riv_epd = e.get_destination_endpoint_data(dest_cells=nodesr)
```

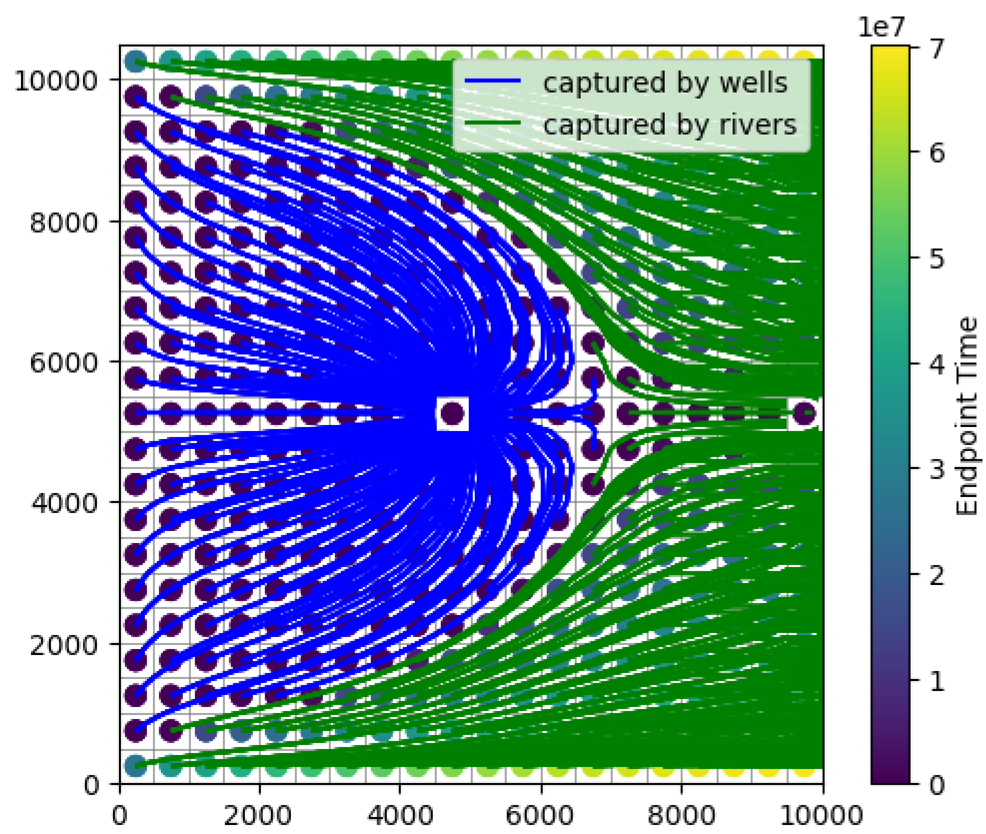
Merge the particles that end in the well and the river boundaries.

[18]:
```
epd1 = np.concatenate((well_epd, riv_epd))
```

Plot MODPATH 7 output

[19]:
```
mm = flopy.plot.PlotMapView(model=gwf)
mm.plot_grid(lw=0.5)
mm.plot_pathline(pw1, layer="all", colors="blue", label="captured by wells")
mm.plot_pathline(pr1, layer="all", colors="green", label="captured by rivers")
mm.plot_endpoint(epd1, direction="starting", colorbar=True)
mm.ax.legend()
```

[19]:
```
<matplotlib.legend.Legend at 0x7f8f714b7dc0>
```



Compare MODPATH results

Compare MODPATH results for MODFLOW-2005 and MODFLOW 6. Also show pathline points every 5th point.

[20]:
```
f, axes = plt.subplots(ncols=3, nrows=1, sharey=True, figsize=(15, 10))
axes = axes.flatten()
ax = axes[0]
ax.set_aspect("equal")
mm = flopy.plot.PlotMapView(model=m, ax=ax)
mm.plot_grid(lw=0.5)
mm.plot_pathline(
    pw0,
    layer="all",
    colors="blue",
    lw=1,
    marker="o",
    markercolor="black",
    markersize=3,
    markerevery=5,
)
mm.plot_pathline(
    pr0,
    layer="all",
    colors="green",
    lw=1,
    marker="o",
    markercolor="black",
    markersize=3,
    markerevery=5,
)
ax.set_title("MODFLOW-2005")

ax = axes[1]
ax.set_aspect("equal")
mm = flopy.plot.PlotMapView(model=gwf, ax=ax)
mm.plot_grid(lw=0.5)
mm.plot_pathline(
    pw1,
    layer="all",
    colors="blue",
    lw=1,
    marker="o",
    markercolor="black",
    markersize=3,
    markerevery=5,
)
mm.plot_pathline(
    pr1,
    layer="all",
    colors="green",
    lw=1,
    marker="o",
    markercolor="black",
```

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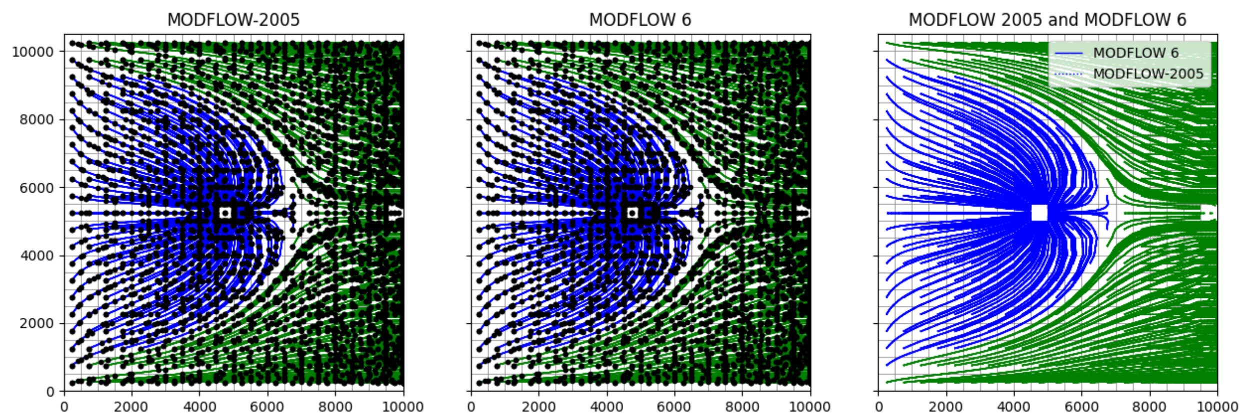
```
    markersize=3,
    markerevery=5,
)
ax.set_title("MODFLOW 6")


ax = axes[2]
ax.set_aspect("equal")
mm = flopy.plot.PlotMapView(model=m, ax=ax)
mm.plot_grid(lw=0.5)
mm.plot_pathline(pw1, layer="all", colors="blue", lw=1, label="MODFLOW 6")
mm.plot_pathline(
    pw0, layer="all", colors="blue", lw=1, linestyle=":", label="MODFLOW-2005"
)
mm.plot_pathline(pr1, layer="all", colors="green", lw=1, label="_none")
mm.plot_pathline(
    pr0, layer="all", colors="green", lw=1, linestyle=":", label="_none"
)
ax.legend()
ax.set_title("MODFLOW 2005 and MODFLOW 6")
```

[20]:

```
Text(0.5, 1.0, 'MODFLOW 2005 and MODFLOW 6')
```



6.8.4 Using MODPATH 7 with structured grids (transient example)

This notebook reproduces example 3a from the MODPATH 7 documentation, demonstrating a transient MODFLOW 6 simulation based on the same flow system as the basic structured and unstructured examples. Particles are released at 10 20-day intervals for the first 200 days of the simulation. 2 discharge wells are added 100,000 days into the simulation and pump at a constant rate for the remainder. There are three stress periods:

Stress period	Type	Time steps	Length (days)
1	steady-state	1	100000
2	transient	10	36500
3	steady-state	1	100000

Setting up the simulation

First import FloPy and set up a temporary workspace.

[1]:
```
import os
```

[2]:
```
import sys
from os.path import join
from pathlib import Path
from tempfile import TemporaryDirectory

import matplotlib as mpl
import matplotlib.pyplot as plt
import numpy as np

proj_root = Path.cwd().parent.parent

# run installed version of flopy or add local path
try:
    import flopy
except:
    sys.path.append(proj_root)
    import flopy

print(sys.version)
print(f"numpy version: {np.__version__}")
print(f"matplotlib version: {mpl.__version__}")
print(f"flopy version: {flopy.__version__}")

temp_dir = TemporaryDirectory()
sim_name = "mp7_ex03a_mf6"
workspace = Path(temp_dir.name) / sim_name
```

```
3.8.18 (default, Aug 28 2023, 08:27:22)
[GCC 11.4.0]
numpy version: 1.24.4
matplotlib version: 3.7.4
flopy version: 3.5.0
```

Define flow model data.

[3]:
```
nlay, nrow, ncol = 3, 21, 20
delr = delc = 500.0
top = 400.0
botm = [220.0, 200.0, 0.0]
laytyp = [1, 0, 0]
kh = [50.0, 0.01, 200.0]
kv = [10.0, 0.01, 20.0]
rch = 0.005
riv_h = 320.0
riv_z = 317.0
riv_c = 1.0e5
```

Define well data. Although this notebook will refer to layer/row/column indices starting at 1, indices in FloPy (and more generally in Python) are zero-based. A negative discharge indicates pumping, while a positive value indicates injection.

[4]:
```python
wells = [
    # layer, row, col, discharge
    (0, 10, 9, -75000),
    (2, 12, 4, -100000),
]
```

Define the drain location.

[5]:
```python
drain = (0, 14, (9, 20))
```

Configure locations for particle tracking to terminate. We have three explicitly defined termination zones:

- 2: the well in layer 1, at row 11, column 10
- 3: the well in layer 3, at row 13, column 5
- 4: the drain in layer 1, running through row 15 from column 10-20

MODFLOW 6 reserves zone number 1 to indicate that particles may move freely within the zone.

The river running through column 20 is also a termination zone, but it doesn't need to be defined separately since we are using the RIV package.

[6]:
```python
zone_maps = []


# zone 1 is the default (non-terminating regions)
def fill_zone_1():
    return np.ones((nrow, ncol), dtype=np.int32)


# zone map for layer 1
za = fill_zone_1()
za[wells[0][1:3]] = 2
za[drain[1], drain[2][0] : drain[2][1]] = 4
zone_maps.append(za)

# constant layer 2 (zone 1)
zone_maps.append(1)

# zone map for layer 3
za = fill_zone_1()
za[wells[1][1:3]] = 3
zone_maps.append(za)
```

Define particles to track. We release particles from the top of a 2x2 square of cells in the upper left of the model grid's top layer.

[7]:
```python
rel_minl = rel_maxl = 1
rel_minr = 2
rel_maxr = 3
rel_minc = 2
rel_maxc = 3
sd = flopy.modpath.CellDataType(
```

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```
    drape=0
)  # particles added at top of cell (no drape)
pd = flopy.modpath.LRCParticleData(
    subdivisiondata=[sd],
    lrcregions=[
        [[rel_minl, rel_minr, rel_minc, rel_maxl, rel_maxr, rel_maxc]]
    ],
)
pg = flopy.modpath.ParticleGroupLRCTemplate(
    particlegroupname="PG1", particledata=pd, filename=f"{sim_name}.pg1.sloc"
)
pgs = [pg]
defaultiface = {"RECHARGE": 6, "ET": 6}
```

Create the MODFLOW 6 simulation.

[8]:
```
# simulation
sim = flopy.mf6.MFSimulation(
    sim_name=sim_name, exe_name="mf6", version="mf6", sim_ws=workspace
)

# temporal discretization
nper = 3
pd = [
    # perlen, nstp, tsmult
    (100000, 1, 1),
    (36500, 10, 1),
    (100000, 1, 1),
]
tdis = flopy.mf6.modflow.mftdis.ModflowTdis(
    sim, pname="tdis", time_units="DAYS", nper=nper, perioddata=pd
)

# groundwater flow (gwf) model
model_nam_file = f"{sim_name}.nam"
gwf = flopy.mf6.ModflowGwf(
    sim, modelname=sim_name, model_nam_file=model_nam_file, save_flows=True
)

# iterative model solver (ims) package
ims = flopy.mf6.modflow.mfims.ModflowIms(
    sim,
    pname="ims",
    complexity="SIMPLE",
    outer_dvclose=1e-6,
    inner_dvclose=1e-6,
    rcloserecord=1e-6,
)

# grid discretization
dis = flopy.mf6.modflow.mfgwfdis.ModflowGwfdis(
    gwf,
```

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```
    pname="dis",
    nlay=nlay,
    nrow=nrow,
    ncol=ncol,
    length_units="FEET",
    delr=delr,
    delc=delc,
    top=top,
    botm=botm,
)

# initial conditions
ic = flopy.mf6.modflow.mfgwfic.ModflowGwfic(gwf, pname="ic", strt=top)

# node property flow
npf = flopy.mf6.modflow.mfgwfnpf.ModflowGwfnpf(
    gwf, pname="npf", icelltype=laytyp, k=kh, k33=kv
)

# recharge
rch = flopy.mf6.modflow.mfgwfrcha.ModflowGwfrcha(gwf, recharge=rch)


# wells
def no_flow(w):
    return w[0], w[1], w[2], 0


wel = flopy.mf6.modflow.mfgwfwel.ModflowGwfwel(
    gwf,
    maxbound=1,
    stress_period_data={0: [no_flow(w) for w in wells], 1: wells, 2: wells},
)

# river
rd = [[(0, i, ncol - 1), riv_h, riv_c, riv_z] for i in range(nrow)]
flopy.mf6.modflow.mfgwfriv.ModflowGwfriv(
    gwf, stress_period_data={0: rd, 1: rd, 2: rd}
)

# drain (set auxiliary IFACE var to 6 for top of cell)
dd = [
    [drain[0], drain[1], i + drain[2][0], 322.5, 100000.0, 6]
    for i in range(drain[2][1] - drain[2][0])
]
drn = flopy.mf6.modflow.mfgwfdrn.ModflowGwfdrn(
    gwf, auxiliary=["IFACE"], stress_period_data={0: dd}
)

# output control
headfile = f"{sim_name}.hds"
head_record = [headfile]
```

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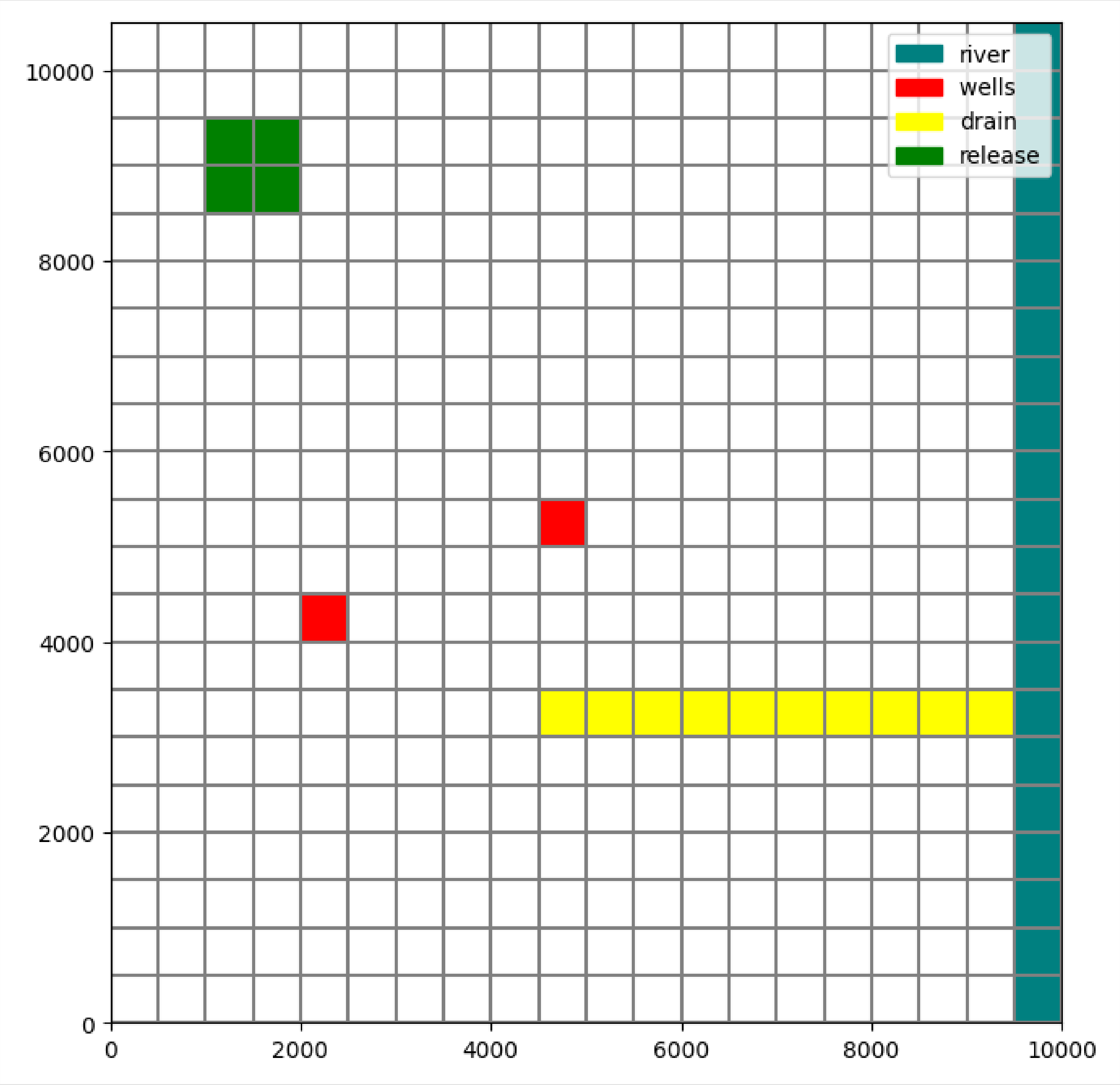
```
budgetfile = f"{sim_name}.cbb"
budget_record = [budgetfile]
saverecord = [("HEAD", "ALL"), ("BUDGET", "ALL")]
oc = flopy.mf6.modflow.mfgwfoc.ModflowGwfoc(
    gwf,
    pname="oc",
    saverecord=saverecord,
    head_filerecord=head_record,
    budget_filerecord=budget_record,
)
```

Take a look at the model grid before running the simulation.

[9]:
```
def add_release(ax):
    ax.add_patch(
        mpl.patches.Rectangle(
            (2 * delc, (nrow - 2) * delr),
            1000,
            -1000,
            facecolor="green",
        )
    )


def add_legend(ax):
    ax.legend(
        handles=[
            mpl.patches.Patch(color="teal", label="river"),
            mpl.patches.Patch(color="red", label="wells "),
            mpl.patches.Patch(color="yellow", label="drain"),
            mpl.patches.Patch(color="green", label="release"),
        ]
    )


fig = plt.figure(figsize=(8, 8))
ax = fig.add_subplot(1, 1, 1, aspect="equal")
mv = flopy.plot.PlotMapView(model=gwf)
mv.plot_grid()
mv.plot_bc("DRN")
mv.plot_bc("RIV")
mv.plot_bc("WEL", plotAll=True)  # include both wells (1st and 3rd layer)
add_release(ax)
add_legend(ax)
plt.show()
```



Running the simulation

Run the MODFLOW 6 flow simulation.

[10]:
```
sim.write_simulation()
success, buff = sim.run_simulation(silent=True, report=True)
assert success, "Failed to run simulation."
for line in buff:
    print(line)
```

```
writing simulation...
  writing simulation name file...
  writing simulation tdis package...
```

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```
  writing solution package ims...
  writing model mp7_ex03a_mf6...
    writing model name file...
    writing package dis...
    writing package ic...
    writing package npf...
    writing package rcha_0...
    writing package wel_0...
INFORMATION: maxbound in ('gwf6', 'wel', 'dimensions') changed to 2 based on size of␣
↪stress_period_data
    writing package riv_0...
INFORMATION: maxbound in ('gwf6', 'riv', 'dimensions') changed to 21 based on size of␣
↪stress_period_data
    writing package drn_0...
INFORMATION: maxbound in ('gwf6', 'drn', 'dimensions') changed to 11 based on size of␣
↪stress_period_data
    writing package oc...
                                   MODFLOW 6
                U.S. GEOLOGICAL SURVEY MODULAR HYDROLOGIC MODEL
                            VERSION 6.4.2 06/28/2023

   MODFLOW 6 compiled Jul 05 2023 20:29:14 with Intel(R) Fortran Intel(R) 64
   Compiler Classic for applications running on Intel(R) 64, Version 2021.7.0
                             Build 20220726_000000

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and distribution information.


 Run start date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:31:18

 Writing simulation list file: mfsim.lst
 Using Simulation name file: mfsim.nam

    Solving:  Stress period:     1    Time step:     1
    Solving:  Stress period:     2    Time step:     1
    Solving:  Stress period:     2    Time step:     2
    Solving:  Stress period:     2    Time step:     3
    Solving:  Stress period:     2    Time step:     4
    Solving:  Stress period:     2    Time step:     5
    Solving:  Stress period:     2    Time step:     6
    Solving:  Stress period:     2    Time step:     7
```

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```
    Solving:  Stress period:     2    Time step:     8
    Solving:  Stress period:     2    Time step:     9
    Solving:  Stress period:     2    Time step:    10
    Solving:  Stress period:     3    Time step:     1

 Run end date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:31:18
 Elapsed run time:  0.080 Seconds

 Normal termination of simulation.
```

Create and run MODPATH 7 particle tracking model in `combined` mode, which includes both pathline and timeseries.

[11]:
```
# create modpath files
mp = flopy.modpath.Modpath7(
    modelname=f"{sim_name}_mp",
    flowmodel=gwf,
    exe_name="mp7",
    model_ws=workspace,
)
mpbas = flopy.modpath.Modpath7Bas(mp, porosity=0.1, defaultiface=defaultiface)
mpsim = flopy.modpath.Modpath7Sim(
    mp,
    simulationtype="combined",
    trackingdirection="forward",
    weaksinkoption="pass_through",
    weaksourceoption="pass_through",
    budgetoutputoption="summary",
    referencetime=[0, 0, 0.9],
    timepointdata=[10, 20.0],  # release every 20 days, for 200 days
    zonedataoption="on",
    zones=zone_maps,
    particlegroups=pgs,
)

mp.write_input()
success, buff = mp.run_model(silent=True, report=True)
assert success
for line in buff:
    print(line)
```

```

MODPATH Version 7.2.001
Program compiled Jul 05 2023 20:31:49 with IFORT compiler (ver. 20.21.7)


Run particle tracking simulation ...
Processing Time Step     1 Period     1.  Time =  1.00000E+05  Steady-state flow
Processing Time Step     1 Period     2.  Time =  1.03650E+05  Steady-state flow
Processing Time Step     2 Period     2.  Time =  1.07300E+05  Steady-state flow
Processing Time Step     3 Period     2.  Time =  1.10950E+05  Steady-state flow
Processing Time Step     4 Period     2.  Time =  1.14600E+05  Steady-state flow
Processing Time Step     5 Period     2.  Time =  1.18250E+05  Steady-state flow
Processing Time Step     6 Period     2.  Time =  1.21900E+05  Steady-state flow
```

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```
Processing Time Step     7 Period     2.  Time =  1.25550E+05  Steady-state flow
Processing Time Step     8 Period     2.  Time =  1.29200E+05  Steady-state flow
Processing Time Step     9 Period     2.  Time =  1.32850E+05  Steady-state flow
Processing Time Step    10 Period     2.  Time =  1.36500E+05  Steady-state flow
Processing Time Step     1 Period     3.  Time =  2.36500E+05  Steady-state flow

Particle Summary:
         0 particles are pending release.
         0 particles remain active.
         5 particles terminated at boundary faces.
         0 particles terminated at weak sink cells.
         0 particles terminated at weak source cells.
       103 particles terminated at strong source/sink cells.
         0 particles terminated in cells with a specified zone number.
         0 particles were stranded in inactive or dry cells.
         0 particles were unreleased.
         0 particles have an unknown status.

Normal termination.
```

Inspecting results

First we need the particle termination locations.

[12]:
```
wel_locs = [w[0:3] for w in wells]
riv_locs = [(0, i, 19) for i in range(20)]
drn_locs = [(drain[0], drain[1], d) for d in range(drain[2][0], drain[2][1])]
wel_nids = gwf.modelgrid.get_node(wel_locs)
riv_nids = gwf.modelgrid.get_node(riv_locs)
drn_nids = gwf.modelgrid.get_node(drn_locs)
```

Next, load pathline data from the MODPATH 7 pathline output file, filtering by termination location.

[13]:
```
fpth = workspace / f"{sim_name}_mp.mppth"
p = flopy.utils.PathlineFile(fpth)

pl1 = p.get_destination_pathline_data(wel_nids, to_recarray=True)
pl2 = p.get_destination_pathline_data(riv_nids + drn_nids, to_recarray=True)
```

Load endpoint data from the MODPATH 7 endpoint output file.

[14]:
```
fpth = workspace / f"{sim_name}_mp.mpend"
e = flopy.utils.EndpointFile(fpth)

ep1 = e.get_destination_endpoint_data(dest_cells=wel_nids)
ep2 = e.get_destination_endpoint_data(dest_cells=riv_nids + drn_nids)
```

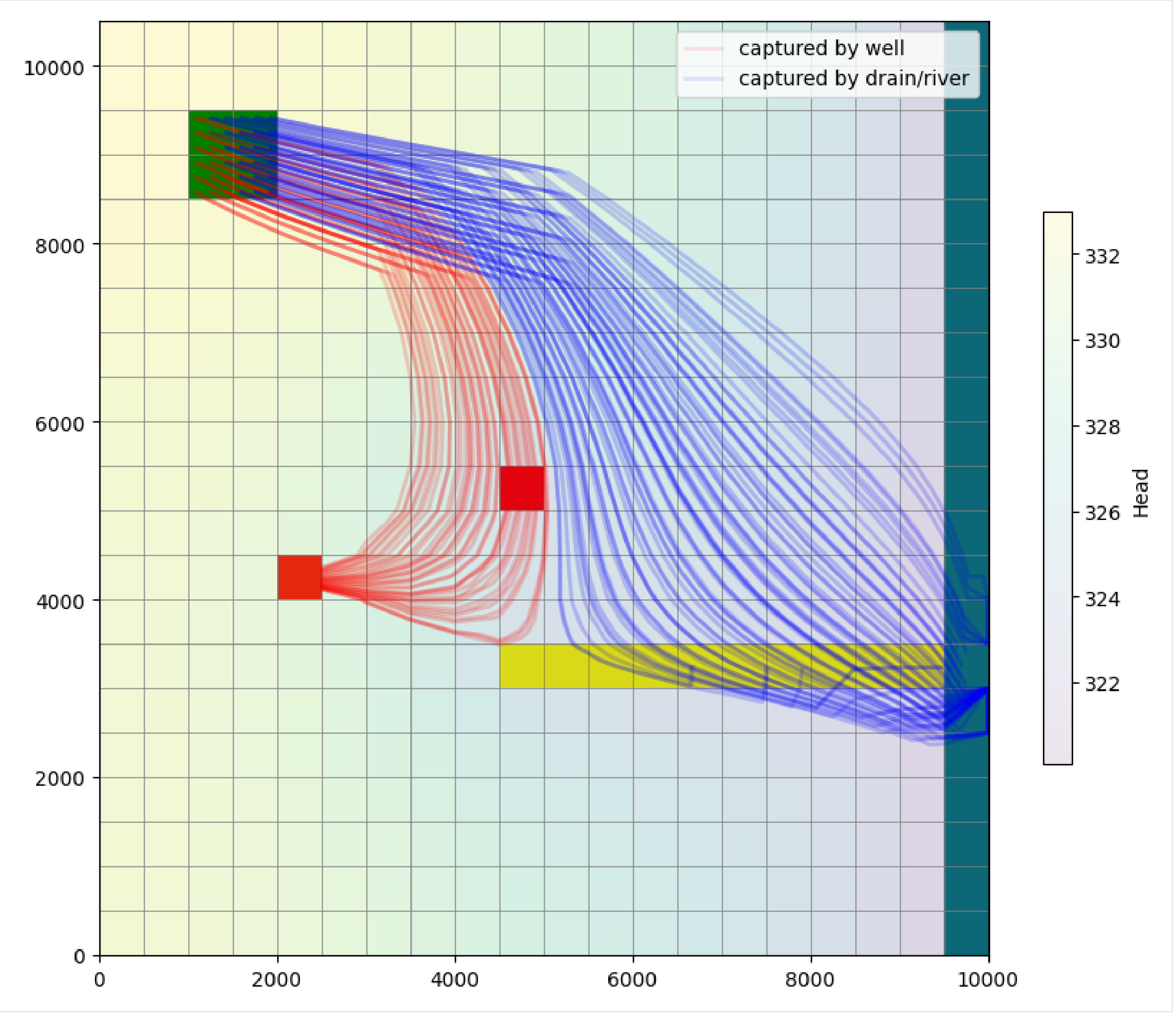
Extract head data from the GWF model’s output files.

[15]:
```
hf = flopy.utils.HeadFile(workspace / f"{sim_name}.hds")
head = hf.get_data()
```

Plot heads over a map view of the model, then add particle starting points and pathlines. The apparent number of particle starting locations is less than the total number of particles because a separate particle begins at each location every 20 days during the release period at the beginning of the simulation.

[16]:
```python
fig = plt.figure(figsize=(10, 10))
ax = fig.add_subplot(1, 1, 1, aspect="equal")

mv = flopy.plot.PlotMapView(model=gwf)
mv.plot_grid(lw=0.5)
mv.plot_bc("DRN")
mv.plot_bc("RIV")
mv.plot_bc("WEL", plotAll=True)
hd = mv.plot_array(head, alpha=0.1)
cb = plt.colorbar(hd, shrink=0.5)
cb.set_label("Head")
mv.plot_pathline(
    pl1, layer="all", alpha=0.1, colors=["red"], lw=2, label="captured by well"
)
mv.plot_pathline(
    pl2,
    layer="all",
    alpha=0.1,
    colors=["blue"],
    lw=2,
    label="captured by drain/river",
)
add_release(ax)
mv.ax.legend()
plt.show()
```



Clean up the temporary directory.

[17]:
```
try:
    # ignore PermissionError on Windows
    temp_dir.cleanup()
except:
    pass
```

6.8.5 Using MODPATH 7 with a DISV unstructured model

This is a replication of the MODPATH Problem 2 example that is described on page 12 of the modpath_7_examples.pdf file. The results shown here should be the same as the results in the MODPATH example, however, the vertex and node numbering used here may be different from the numbering used in MODPATH, so head values may not be compared directly without some additional mapping.

Part I. Setup Notebook

[1]:
```python
import os
```

[2]:
```python
import sys
from pathlib import Path
from tempfile import TemporaryDirectory

import matplotlib as mpl
import matplotlib.pyplot as plt
import numpy as np

proj_root = Path.cwd().parent.parent

# run installed version of flopy or add local path
try:
    import flopy
except:
    sys.path.append(proj_root)
    import flopy

print(sys.version)
print(f"numpy version: {np.__version__}")
print(f"matplotlib version: {mpl.__version__}")
print(f"flopy version: {flopy.__version__}")

# temporary directory
temp_dir = TemporaryDirectory()
workspace = Path(temp_dir.name)
```

```
3.8.18 (default, Aug 28 2023, 08:27:22)
[GCC 11.4.0]
numpy version: 1.24.4
matplotlib version: 3.7.4
flopy version: 3.5.0
```

Part II. Gridgen Creation of Model Grid

Create the base model grid.

```
[3]: Lx = 10000.0
Ly = 10500.0
nlay = 3
nrow = 21
ncol = 20
delr = Lx / ncol
delc = Ly / nrow
top = 400
botm = [220, 200, 0]
```

```
[4]: ms = flopy.modflow.Modflow()
dis5 = flopy.modflow.ModflowDis(
    ms,
    nlay=nlay,
    nrow=nrow,
    ncol=ncol,
    delr=delr,
    delc=delc,
    top=top,
    botm=botm,
)
```

Create the Gridgen object.

```
[5]: from flopy.utils.gridgen import Gridgen

model_name = "mp7p2_u"
model_ws = workspace / "mp7_ex2" / "mf6"
gridgen_ws = model_ws / "gridgen"
g = Gridgen(ms.modelgrid, model_ws=gridgen_ws)
```

Refine the grid.

```
[6]: rf0shp = gridgen_ws / "rf0"
xmin = 7 * delr
xmax = 12 * delr
ymin = 8 * delc
ymax = 13 * delc
rfpoly = [
    [
        list(
            reversed(
                [
                    (xmin, ymin),
                    (xmax, ymin),
                    (xmax, ymax),
                    (xmin, ymax),
                    (xmin, ymin),
                ]
```

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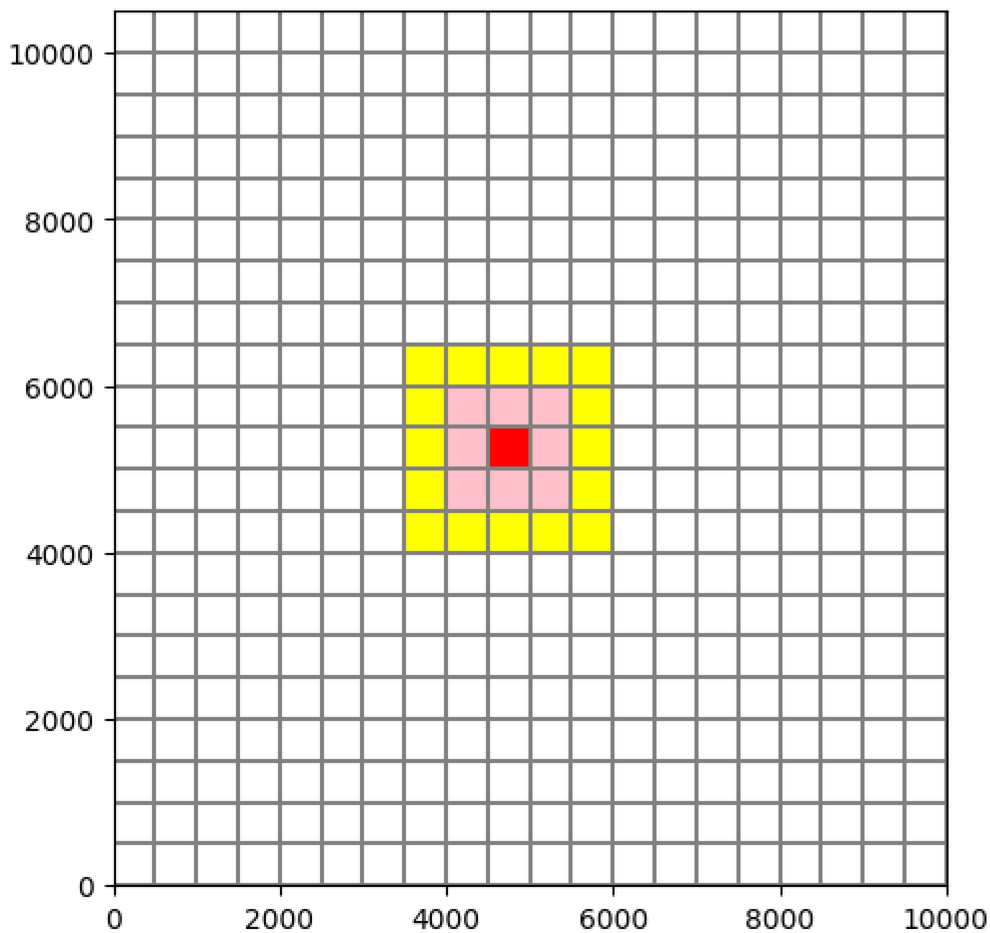
```
            )
        )
    ]
]
g.add_refinement_features(rfpoly, "polygon", 1, range(nlay))

rf1shp = gridgen_ws / "rf1"
xmin = 8 * delr
xmax = 11 * delr
ymin = 9 * delc
ymax = 12 * delc
rfpoly = [
    [
        list(
            reversed(
                [
                    (xmin, ymin),
                    (xmax, ymin),
                    (xmax, ymax),
                    (xmin, ymax),
                    (xmin, ymin),
                ]
            )
        )
    ]
]
g.add_refinement_features(rfpoly, "polygon", 2, range(nlay))

rf2shp = gridgen_ws / "rf2"
xmin = 9 * delr
xmax = 10 * delr
ymin = 10 * delc
ymax = 11 * delc
rfpoly = [
    [
        list(
            reversed(
                [
                    (xmin, ymin),
                    (xmax, ymin),
                    (xmax, ymax),
                    (xmin, ymax),
                    (xmin, ymin),
                ]
            )
        )
    ]
]
g.add_refinement_features(rfpoly, "polygon", 3, range(nlay))
```

Show the model grid with refinement levels superimposed.

[7]:
```
fig = plt.figure(figsize=(5, 5), constrained_layout=True)
ax = fig.add_subplot(1, 1, 1)
mm = flopy.plot.PlotMapView(model=ms)
mm.plot_grid()
flopy.plot.plot_shapefile(rf0shp, ax=ax, facecolor="yellow", edgecolor="none")
flopy.plot.plot_shapefile(rf1shp, ax=ax, facecolor="pink", edgecolor="none")
flopy.plot.plot_shapefile(rf2shp, ax=ax, facecolor="red", edgecolor="none")
```

[7]:
```
<matplotlib.collections.PatchCollection at 0x7f9746d8fb50>
```



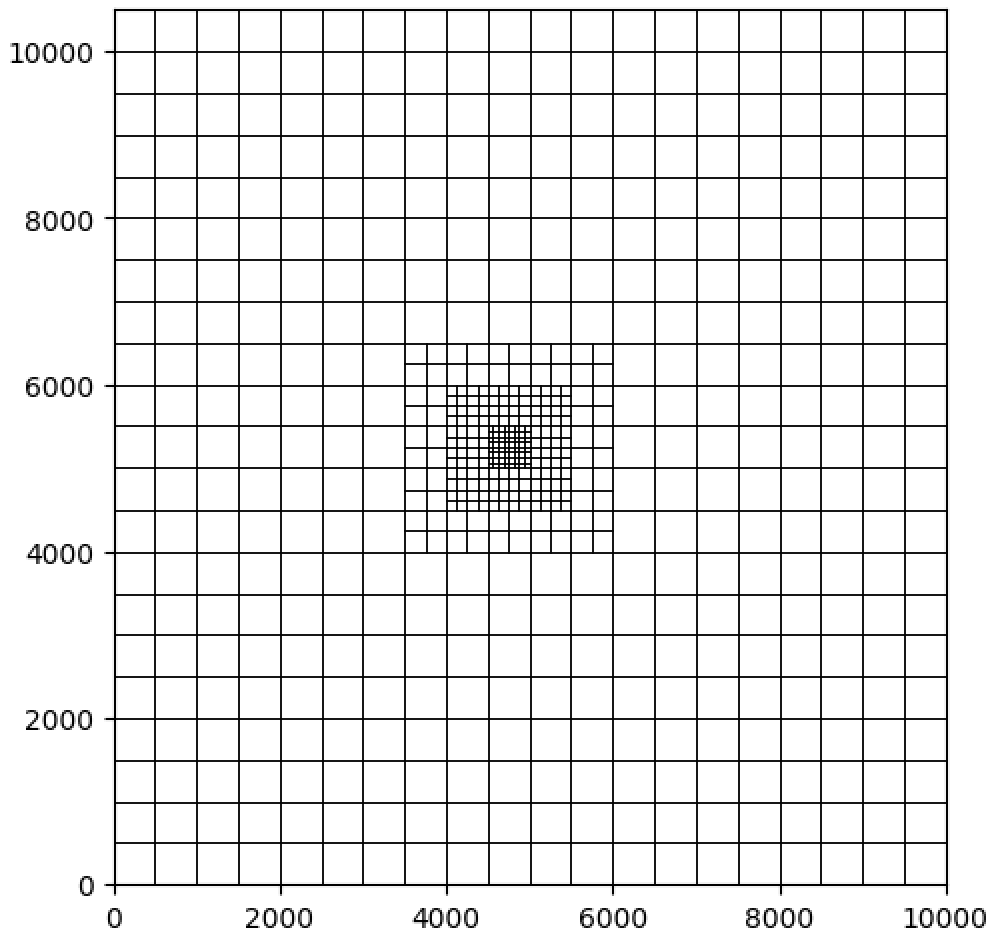
Build the refined grid.

[8]:
```
g.build(verbose=False)
```

Show the refined grid.

[9]:
```
fig = plt.figure(figsize=(5, 5), constrained_layout=True)
ax = fig.add_subplot(1, 1, 1, aspect="equal")
g.plot(ax, linewidth=0.5)
```

[9]:
```
<matplotlib.collections.PatchCollection at 0x7f974a6e2df0>
```



Extract the refined grid's properties.

[10]:
```
gridprops = g.get_gridprops_disv()
ncpl = gridprops["ncpl"]
top = gridprops["top"]
botm = gridprops["botm"]
nvert = gridprops["nvert"]
vertices = gridprops["vertices"]
cell2d = gridprops["cell2d"]
```

Part III. Create the Flopy Model

[11]:
```
# create simulation
sim = flopy.mf6.MFSimulation(
    sim_name=model_name, version="mf6", exe_name="mf6", sim_ws=model_ws
)

# create tdis package
tdis_rc = [(1000.0, 1, 1.0)]
tdis = flopy.mf6.ModflowTdis(
```

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```
    sim, pname="tdis", time_units="DAYS", perioddata=tdis_rc
)

# create gwf model
gwf = flopy.mf6.ModflowGwf(
    sim, modelname=model_name, model_nam_file=f"{model_name}.nam"
)
gwf.name_file.save_flows = True

# create iterative model solution and register the gwf model with it
ims = flopy.mf6.ModflowIms(
    sim,
    pname="ims",
    print_option="SUMMARY",
    complexity="SIMPLE",
    outer_dvclose=1.0e-5,
    outer_maximum=100,
    under_relaxation="NONE",
    inner_maximum=100,
    inner_dvclose=1.0e-6,
    rcloserecord=0.1,
    linear_acceleration="BICGSTAB",
    scaling_method="NONE",
    reordering_method="NONE",
    relaxation_factor=0.99,
)
sim.register_ims_package(ims, [gwf.name])

# disv
disv = flopy.mf6.ModflowGwfdisv(
    gwf,
    nlay=nlay,
    ncpl=ncpl,
    top=top,
    botm=botm,
    nvert=nvert,
    vertices=vertices,
    cell2d=cell2d,
)

# initial conditions
ic = flopy.mf6.ModflowGwfic(gwf, pname="ic", strt=320.0)

# node property flow
npf = flopy.mf6.ModflowGwfnpf(
    gwf,
    xt3doptions=[("xt3d")],
    icelltype=[1, 0, 0],
    k=[50.0, 0.01, 200.0],
    k33=[10.0, 0.01, 20.0],
)
```

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```
# wel
wellpoints = [(4750.0, 5250.0)]
welcells = g.intersect(wellpoints, "point", 0)
# welspd = flopy.mf6.ModflowGwfwel.stress_period_data.empty(gwf, maxbound=1, aux_vars=[
↪'iface'])
welspd = [[(2, icpl), -150000, 0] for icpl in welcells["nodenumber"]]
wel = flopy.mf6.ModflowGwfwel(
    gwf, print_input=True, auxiliary=[("iface",)], stress_period_data=welspd
)

# rch
aux = [np.ones(ncpl, dtype=int) * 6]
rch = flopy.mf6.ModflowGwfrcha(
    gwf, recharge=0.005, auxiliary=[("iface",)], aux={0: [6]}
)
# riv
riverline = [[(Lx - 1.0, Ly), (Lx - 1.0, 0.0)]]
rivcells = g.intersect(riverline, "line", 0)
rivspd = [[(0, icpl), 320.0, 100000.0, 318] for icpl in rivcells["nodenumber"]]
riv = flopy.mf6.ModflowGwfriv(gwf, stress_period_data=rivspd)

# output control
oc = flopy.mf6.ModflowGwfoc(
    gwf,
    pname="oc",
    budget_filerecord=f"{model_name}.cbb",
    head_filerecord=f"{model_name}.hds",
    headprintrecord=[("COLUMNS", 10, "WIDTH", 15, "DIGITS", 6, "GENERAL")],
    saverecord=[("HEAD", "ALL"), ("BUDGET", "ALL")],
    printrecord=[("HEAD", "ALL"), ("BUDGET", "ALL")],
)
```

```
WARNING: Unable to resolve dimension of ('gwf6', 'disv', 'cell2d', 'cell2d', 'icvert')␣
↪based on shape "ncvert".
```

Now write the simulation input files.

[12]:
```
sim.write_simulation()
```

```
writing simulation...
  writing simulation name file...
  writing simulation tdis package...
  writing solution package ims...
  writing model mp7p2_u...
    writing model name file...
    writing package disv...
    writing package ic...
    writing package npf...
    writing package wel_0...
INFORMATION: maxbound in ('gwf6', 'wel', 'dimensions') changed to 1 based on size of␣
↪stress_period_data
    writing package rcha_0...
    writing package riv_0...
```

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```
INFORMATION: maxbound in ('gwf6', 'riv', 'dimensions') changed to 21 based on size of␣
↪stress_period_data
    writing package oc...
```

Part IV. Run the MODFLOW 6 Model

[13]:
```
success, buff = sim.run_simulation(silent=True, report=True)
assert success, "mf6 failed to run"
for line in buff:
    print(line)
```

```
                                   MODFLOW 6
                U.S. GEOLOGICAL SURVEY MODULAR HYDROLOGIC MODEL
                            VERSION 6.4.2 06/28/2023

   MODFLOW 6 compiled Jul 05 2023 20:29:14 with Intel(R) Fortran Intel(R) 64
   Compiler Classic for applications running on Intel(R) 64, Version 2021.7.0
                             Build 20220726_000000

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 Run start date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:31:23

 Writing simulation list file: mfsim.lst
 Using Simulation name file: mfsim.nam

    Solving:  Stress period:     1    Time step:     1

 Run end date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:31:23
 Elapsed run time:  0.101 Seconds

 Normal termination of simulation.
```
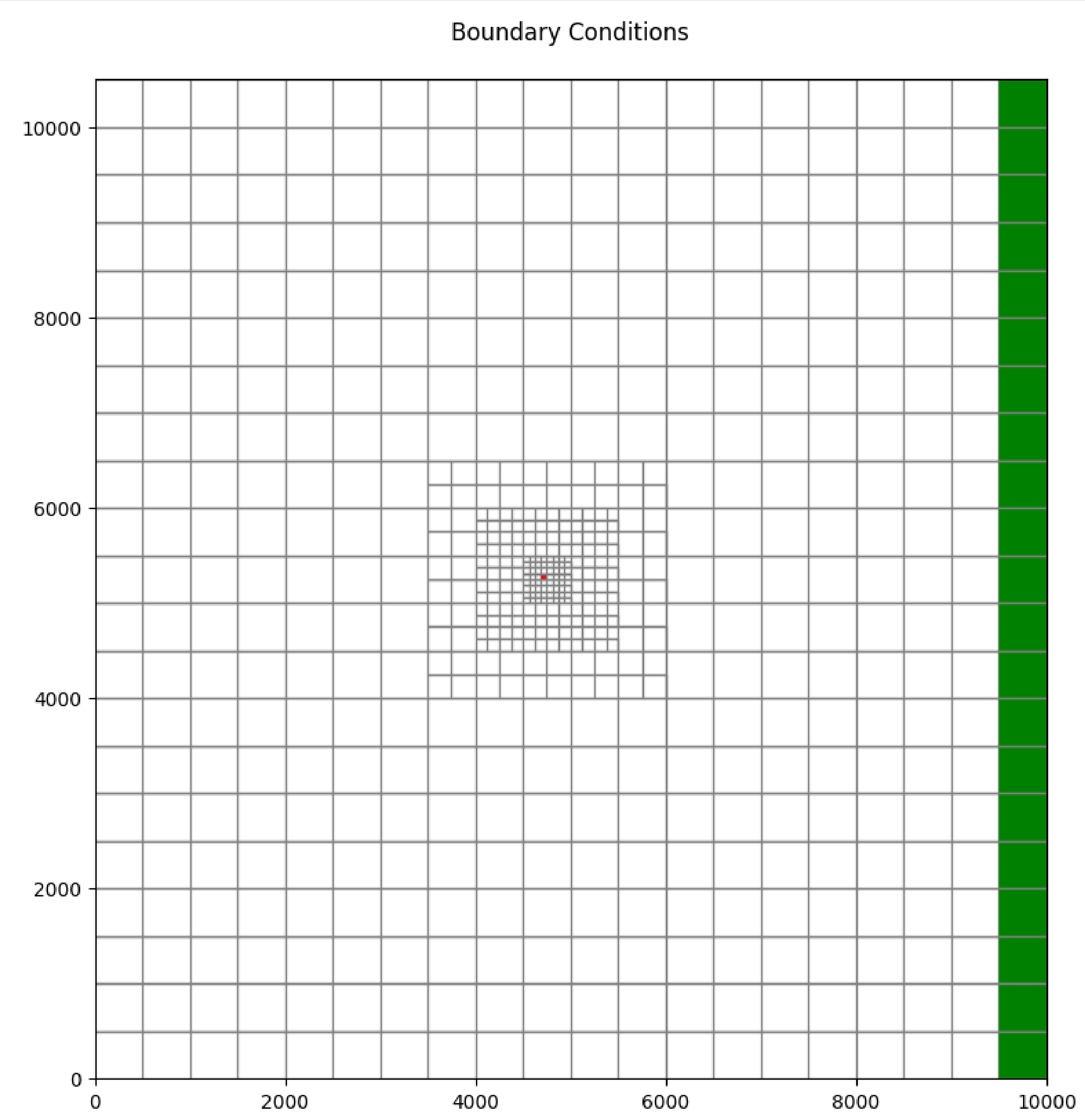

Part V. Import and Plot the Results

Plot the boundary conditions on the grid.

[14]:
```
fname = os.path.join(model_ws, f"{model_name}.disv.grb")
grd = flopy.mf6.utils.MfGrdFile(fname, verbose=False)
mg = grd.modelgrid
ibd = np.zeros((ncpl), dtype=int)
ibd[welcells["nodenumber"]] = 1
ibd[rivcells["nodenumber"]] = 2
ibd = np.ma.masked_equal(ibd, 0)
fig = plt.figure(figsize=(8, 8), constrained_layout=True)
ax = fig.add_subplot(1, 1, 1, aspect="equal")
pmv = flopy.plot.PlotMapView(modelgrid=mg, ax=ax)
ax.set_xlim(0, Lx)
ax.set_ylim(0, Ly)
cmap = mpl.colors.ListedColormap(
    [
        "r",
        "g",
    ]
)
pc = pmv.plot_array(ibd, cmap=cmap, edgecolor="gray")
t = ax.set_title("Boundary Conditions\n")
```



[15]:
```
fname = os.path.join(model_ws, f"{model_name}.hds")
hdobj = flopy.utils.HeadFile(fname)
head = hdobj.get_data()
head.shape
```

[15]:
```
(3, 1, 651)
```

[16]:
```
ilay = 2
cint = 0.25
fig = plt.figure(figsize=(8, 8), constrained_layout=True)
ax = fig.add_subplot(1, 1, 1, aspect="equal")
```

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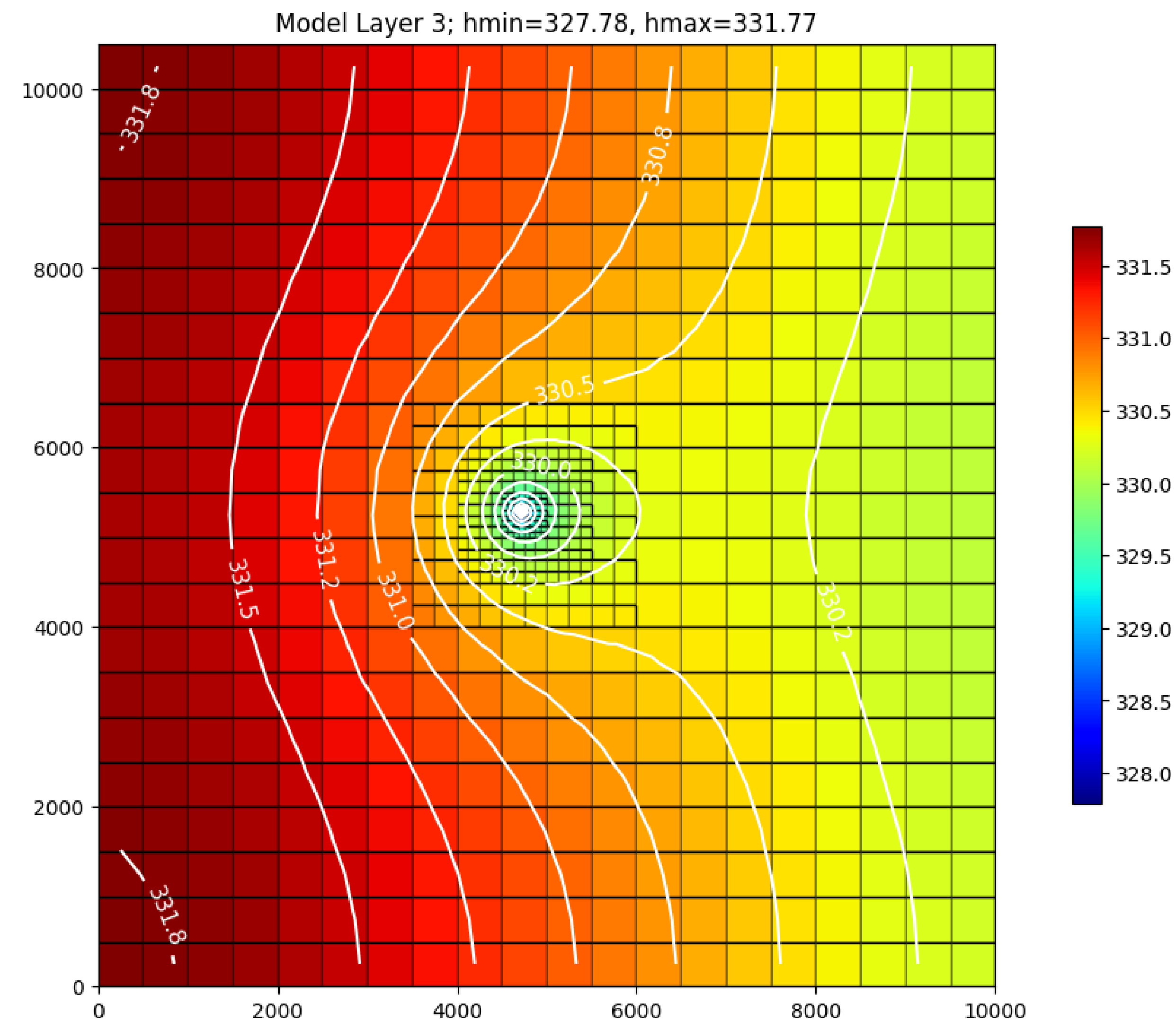
```
mm = flopy.plot.PlotMapView(modelgrid=mg, ax=ax, layer=ilay)
ax.set_xlim(0, Lx)
ax.set_ylim(0, Ly)
pc = mm.plot_array(head[:, 0, :], cmap="jet", edgecolor="black")
hmin = head[ilay, 0, :].min()
hmax = head[ilay, 0, :].max()
levels = np.arange(np.floor(hmin), np.ceil(hmax) + cint, cint)
cs = mm.contour_array(head[:, 0, :], colors="white", levels=levels)
plt.clabel(cs, fmt="%.1f", colors="white", fontsize=11)
cb = plt.colorbar(pc, shrink=0.5)
t = ax.set_title(f"Model Layer {ilay + 1}; hmin={hmin:6.2f}, hmax={hmax:6.2f}")
```



Inspect model cells and vertices.

[17]:
```
# zoom area
xmin, xmax = 2000, 4500
ymin, ymax = 5400, 7500
```

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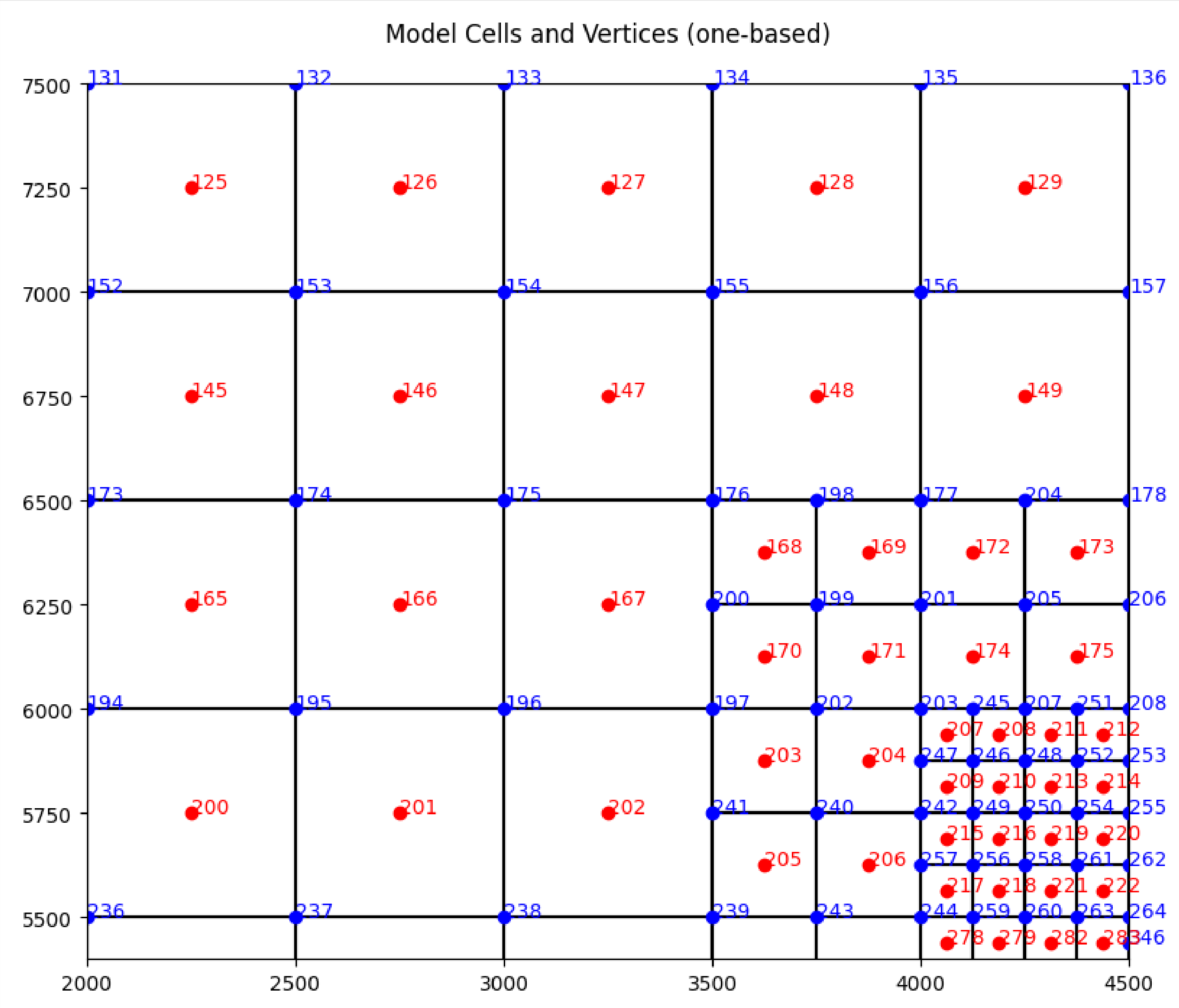
```
mg.get_cell_vertices
fig = plt.figure(figsize=(8, 8), constrained_layout=True)
ax = fig.add_subplot(1, 1, 1, aspect="equal")
mm = flopy.plot.PlotMapView(modelgrid=mg, ax=ax)
v = mm.plot_grid(edgecolor="black")
t = ax.set_title("Model Cells and Vertices (one-based)\n")
ax.set_xlim(xmin, xmax)
ax.set_ylim(ymin, ymax)

verts = mg.verts
ax.plot(verts[:, 0], verts[:, 1], "bo")
for i in range(ncpl):
    x, y = verts[i, 0], verts[i, 1]
    if xmin <= x <= xmax and ymin <= y <= ymax:
        ax.annotate(str(i + 1), verts[i, :], color="b")

xc, yc = mg.get_xcellcenters_for_layer(0), mg.get_ycellcenters_for_layer(0)
for i in range(ncpl):
    x, y = xc[i], yc[i]
    ax.plot(x, y, "ro")
    if xmin <= x <= xmax and ymin <= y <= ymax:
        ax.annotate(str(i + 1), (x, y), color="r")
```



Part VI. Create the Flopy MODPATH7 Models

Define names for the MODPATH 7 simulations.

```
[18]: mp_namea = f"{model_name}a_mp"
      mp_nameb = f"{model_name}b_mp"
```

Create particles for the pathline and timeseries analysis.

```
[19]: pcoord = np.array(
          [
              [0.000, 0.125, 0.500],
              [0.000, 0.375, 0.500],
              [0.000, 0.625, 0.500],
              [0.000, 0.875, 0.500],
              [1.000, 0.125, 0.500],
              [1.000, 0.375, 0.500],
```

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```
        [1.000, 0.625, 0.500],
        [1.000, 0.875, 0.500],
        [0.125, 0.000, 0.500],
        [0.375, 0.000, 0.500],
        [0.625, 0.000, 0.500],
        [0.875, 0.000, 0.500],
        [0.125, 1.000, 0.500],
        [0.375, 1.000, 0.500],
        [0.625, 1.000, 0.500],
        [0.875, 1.000, 0.500],
    ]
)
nodew = gwf.disv.ncpl.array * 2 + welcells["nodenumber"][0]
plocs = [nodew for i in range(pcoord.shape[0])]

# create particle data
pa = flopy.modpath.ParticleData(
    plocs,
    structured=False,
    localx=pcoord[:, 0],
    localy=pcoord[:, 1],
    localz=pcoord[:, 2],
    drape=0,
)

# create backward particle group
fpth = f"{mp_namea}.sloc"
pga = flopy.modpath.ParticleGroup(
    particlegroupname="BACKWARD1", particledata=pa, filename=fpth
)
```

Create particles for endpoint analysis.

[20]:
```
facedata = flopy.modpath.FaceDataType(
    drape=0,
    verticaldivisions1=10,
    horizontaldivisions1=10,
    verticaldivisions2=10,
    horizontaldivisions2=10,
    verticaldivisions3=10,
    horizontaldivisions3=10,
    verticaldivisions4=10,
    horizontaldivisions4=10,
    rowdivisions5=0,
    columndivisions5=0,
    rowdivisions6=4,
    columndivisions6=4,
)
pb = flopy.modpath.NodeParticleData(subdivisiondata=facedata, nodes=nodew)
# create forward particle group
fpth = f"{mp_nameb}.sloc"
pgb = flopy.modpath.ParticleGroupNodeTemplate(
```

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```
    particlegroupname="BACKWARD2", particledata=pb, filename=fpth
)
```

Create and run the pathline and timeseries analysis model.

[21]:
```
# create modpath files
mp = flopy.modpath.Modpath7(
    modelname=mp_namea, flowmodel=gwf, exe_name="mp7", model_ws=model_ws
)
flopy.modpath.Modpath7Bas(mp, porosity=0.1)
flopy.modpath.Modpath7Sim(
    mp,
    simulationtype="combined",
    trackingdirection="backward",
    weaksinkoption="pass_through",
    weaksourceoption="pass_through",
    referencetime=0.0,
    stoptimeoption="extend",
    timepointdata=[500, 1000.0],
    particlegroups=pga,
)

# write modpath datasets
mp.write_input()

# run modpath
success, buff = mp.run_model(silent=True, report=True)
assert success, "mp7 failed to run"
for line in buff:
    print(line)
```

```
MODPATH Version 7.2.001
Program compiled Jul 05 2023 20:31:49 with IFORT compiler (ver. 20.21.7)


Run particle tracking simulation ...
Processing Time Step     1 Period     1.  Time =  1.00000E+03  Steady-state flow

Particle Summary:
         0 particles are pending release.
         0 particles remain active.
        16 particles terminated at boundary faces.
         0 particles terminated at weak sink cells.
         0 particles terminated at weak source cells.
         0 particles terminated at strong source/sink cells.
         0 particles terminated in cells with a specified zone number.
         0 particles were stranded in inactive or dry cells.
         0 particles were unreleased.
         0 particles have an unknown status.

Normal termination.
```

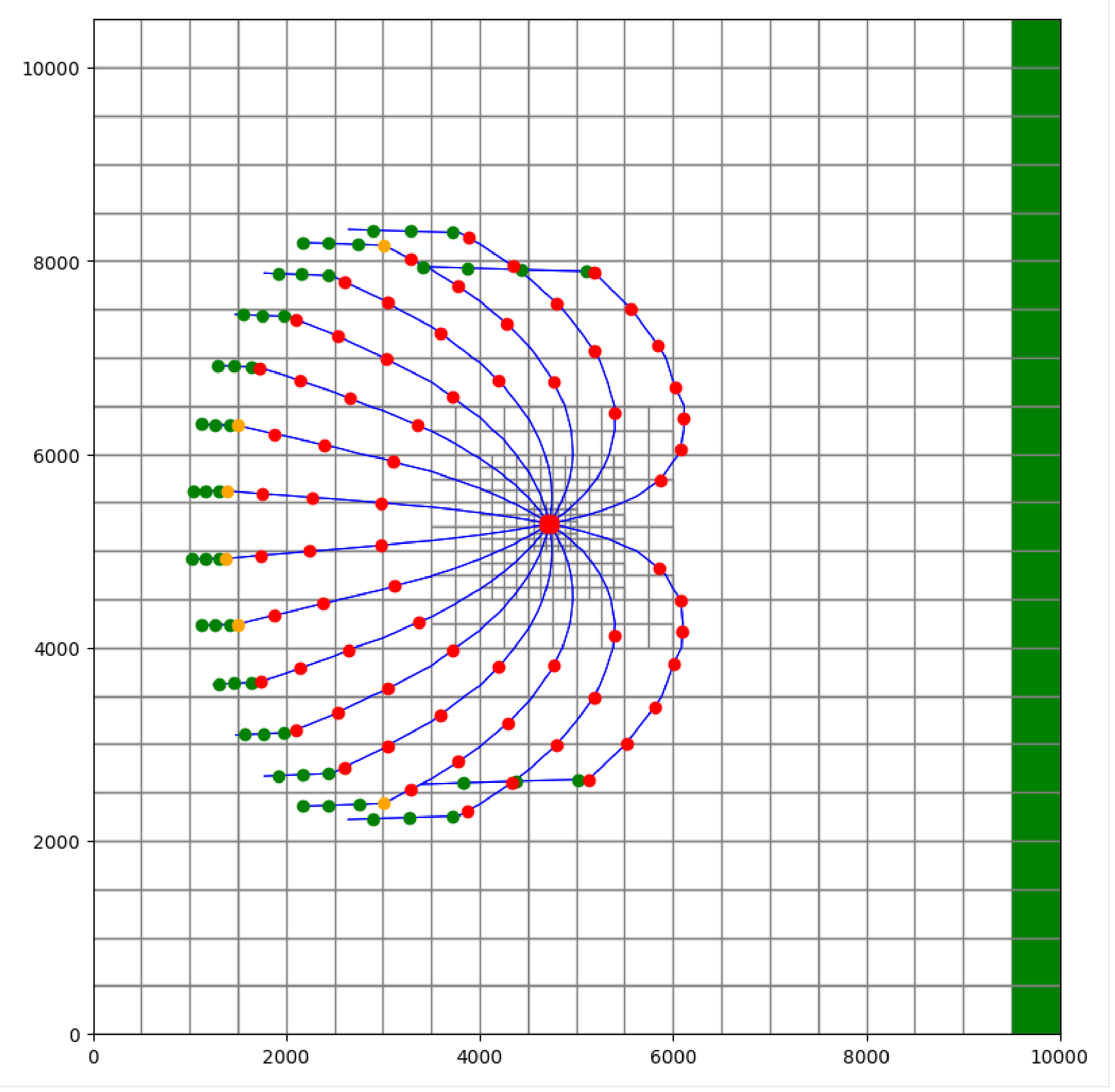
Load the pathline and timeseries data.

[22]:
```
fpth = model_ws / f"{mp_namea}.mppth"
p = flopy.utils.PathlineFile(fpth)
p0 = p.get_alldata()
```

[23]:
```
fpth = model_ws / f"{mp_namea}.timeseries"
ts = flopy.utils.TimeseriesFile(fpth)
ts0 = ts.get_alldata()
```

Plot the pathline and timeseries data.

[24]:
```
fig = plt.figure(figsize=(8, 8), constrained_layout=True)
ax = fig.add_subplot(1, 1, 1, aspect="equal")
mm = flopy.plot.PlotMapView(modelgrid=mg, ax=ax)
ax.set_xlim(0, Lx)
ax.set_ylim(0, Ly)
cmap = mpl.colors.ListedColormap(
    [
        "r",
        "g",
    ]
)
v = mm.plot_array(ibd, cmap=cmap, edgecolor="gray")
mm.plot_pathline(p0, layer="all", colors="blue", lw=0.75)
colors = ["green", "orange", "red"]
for k in range(nlay):
    mm.plot_timeseries(ts0, layer=k, marker="o", lw=0, color=colors[k])
```



Create and run the endpoint analysis model.

[25]:
```
# create modpath files
mp = flopy.modpath.Modpath7(
    modelname=mp_nameb, flowmodel=gwf, exe_name="mp7", model_ws=model_ws
)
flopy.modpath.Modpath7Bas(mp, porosity=0.1)
flopy.modpath.Modpath7Sim(
    mp,
    simulationtype="endpoint",
    trackingdirection="backward",
    weaksinkoption="pass_through",
    weaksourceoption="pass_through",
```

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```
    referencetime=0.0,
    stoptimeoption="extend",
    particlegroups=pgb,
)

# write modpath datasets
mp.write_input()

# run modpath
success, buff = mp.run_model(silent=True, report=True)
assert success, "mp7 failed to run"
for line in buff:
    print(line)
```

```
MODPATH Version 7.2.001
Program compiled Jul 05 2023 20:31:49 with IFORT compiler (ver. 20.21.7)


Run particle tracking simulation ...
Processing Time Step     1 Period     1.  Time =  1.00000E+03  Steady-state flow

Particle Summary:
         0 particles are pending release.
         0 particles remain active.
       416 particles terminated at boundary faces.
         0 particles terminated at weak sink cells.
         0 particles terminated at weak source cells.
         0 particles terminated at strong source/sink cells.
         0 particles terminated in cells with a specified zone number.
         0 particles were stranded in inactive or dry cells.
         0 particles were unreleased.
         0 particles have an unknown status.

Normal termination.
```

Load the endpoint data.

[26]:
```
fpth = model_ws / f"{mp_nameb}.mpend"
e = flopy.utils.EndpointFile(fpth)
e0 = e.get_alldata()
```

Plot the endpoint data.

[27]:
```
fig = plt.figure(figsize=(8, 8), constrained_layout=True)
ax = fig.add_subplot(1, 1, 1, aspect="equal")
mm = flopy.plot.PlotMapView(modelgrid=mg, ax=ax)
ax.set_xlim(0, Lx)
ax.set_ylim(0, Ly)
cmap = mpl.colors.ListedColormap(
    [
        "r",
        "g",
```

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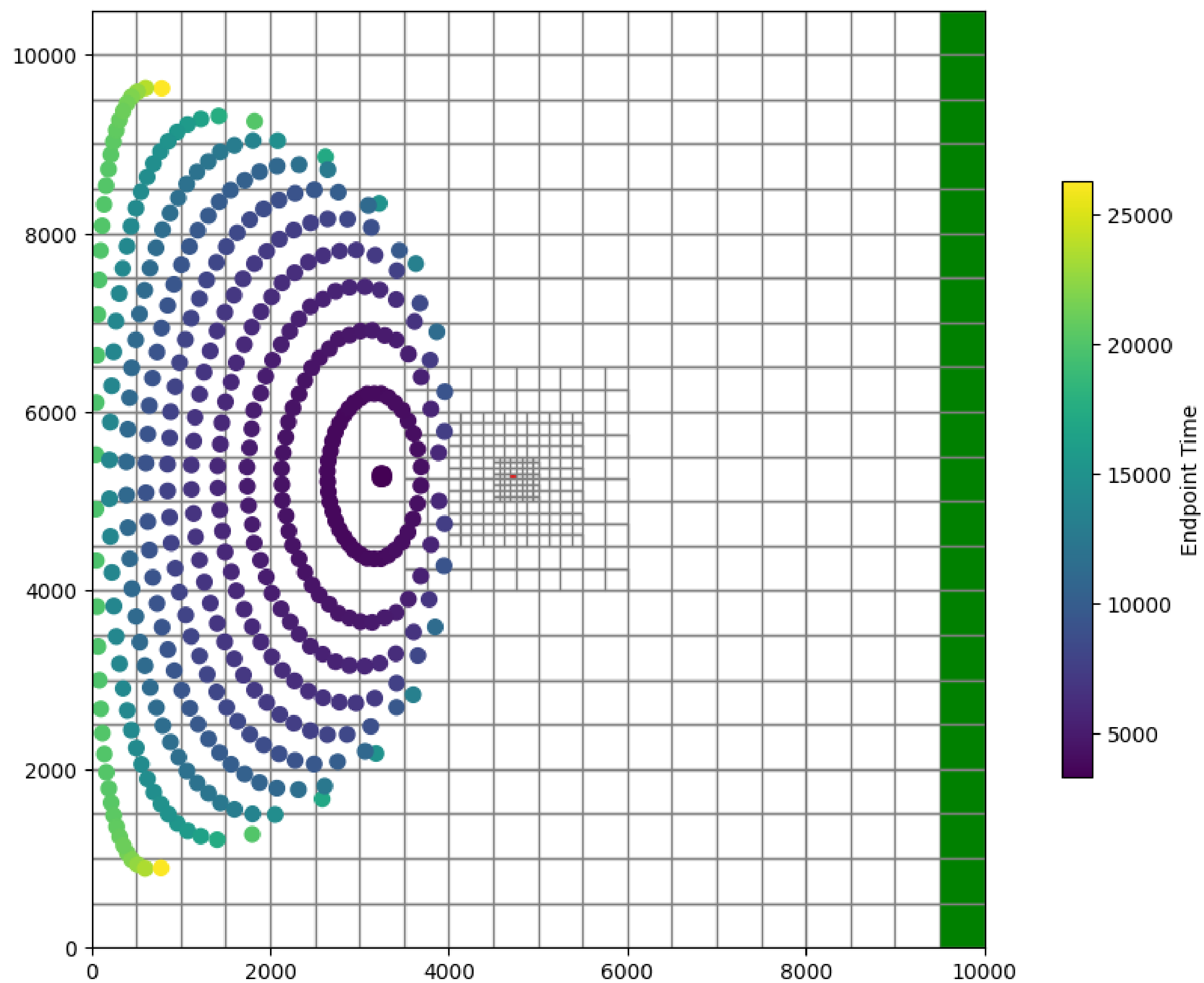
```
    ]
)
v = mm.plot_array(ibd, cmap=cmap, edgecolor="gray")
mm.plot_endpoint(e0, direction="ending", colorbar=True, shrink=0.5)
```

[27]: <matplotlib.collections.PathCollection at 0x7f97534facd0>



Clean up the temporary workspace.

[28]:
```
try:
    # ignore PermissionError on Windows
    temp_dir.cleanup()
except:
    pass
```

6.8.6 Using MODPATH 7: DISV quadpatch example

This notebook demonstrates example 4 from the MODPATH 7 documentation, a steady-state MODFLOW 6 simulation using a quadpatch DISV grid with an irregular domain and a large number of inactive cells. Particles are tracked backwards from terminating locations, including a pair of wells in a locally-refined region of the grid and constant-head cells along the grid's right side, to release locations along the left border of the grid's active region. Injection wells along the left-hand border are used to generate boundary flows.

First import FloPy and set up a temporary workspace.

[1]:
```
import sys
from pathlib import Path
from tempfile import TemporaryDirectory

import matplotlib as mpl
import matplotlib.pyplot as plt
import numpy as np

proj_root = Path.cwd().parent.parent

# run installed version of flopy or add local path
try:
    import flopy
except:
    sys.path.append(proj_root)
    import flopy


temp_dir = TemporaryDirectory()
workspace = Path(temp_dir.name)
sim_name = "ex04_mf6"

print("Python version:", sys.version)
print("NumPy version:", np.__version__)
print("Matplotlib version:", mpl.__version__)
print("FloPy version:", flopy.__version__)
```

```
Python version: 3.8.18 (default, Aug 28 2023, 08:27:22)
[GCC 11.4.0]
NumPy version: 1.24.4
Matplotlib version: 3.7.4
FloPy version: 3.5.0
```

Grid creation/refinement

In this example we use GRIDGEN to create a quadpatch grid with a refined region in the upper left quadrant.

The grid has 3 nested refinement levels, all nearly but not perfectly rectangular (a 500x500 area is carved out of each corner of each). Outer levels of refinement have a width of 500. To produce this pattern we use 5 rectangular polygons for each level.

First, create the coarse-grained grid discretization.

[2]:
```
nlay, nrow, ncol = 1, 21, 26  # coarsest-grained grid is 21x26
delr = delc = 500.0
top = 100.0
botm = np.zeros((nlay, nrow, ncol), dtype=np.float32)
ms = flopy.modflow.Modflow()
dis = flopy.modflow.ModflowDis(
    ms,
    nlay=nlay,
    nrow=nrow,
    ncol=ncol,
    delr=delr,
    delc=delc,
    top=top,
    botm=botm,
)
```

Next, refine the grid. Create a `Gridgen` object from the base grid, then add refinement features (3 groups of polygons).

[3]:
```
from flopy.utils.gridgen import Gridgen

# create Gridgen workspace
gridgen_ws = workspace / "gridgen"
gridgen_ws.mkdir()

# create Gridgen object
g = Gridgen(ms.modelgrid, model_ws=gridgen_ws)

# add polygon for each refinement level
outer_polygon = [
    [
        (2500, 6000),
        (2500, 9500),
        (3000, 9500),
        (3000, 10000),
        (6000, 10000),
        (6000, 9500),
        (6500, 9500),
        (6500, 6000),
        (6000, 6000),
        (6000, 5500),
        (3000, 5500),
        (3000, 6000),
        (2500, 6000),
    ]
]
g.add_refinement_features([outer_polygon], "polygon", 1, range(nlay))
refshp0 = gridgen_ws / "rf0"

middle_polygon = [
    [
        (3000, 6500),
        (3000, 9000),
        (3500, 9000),
```

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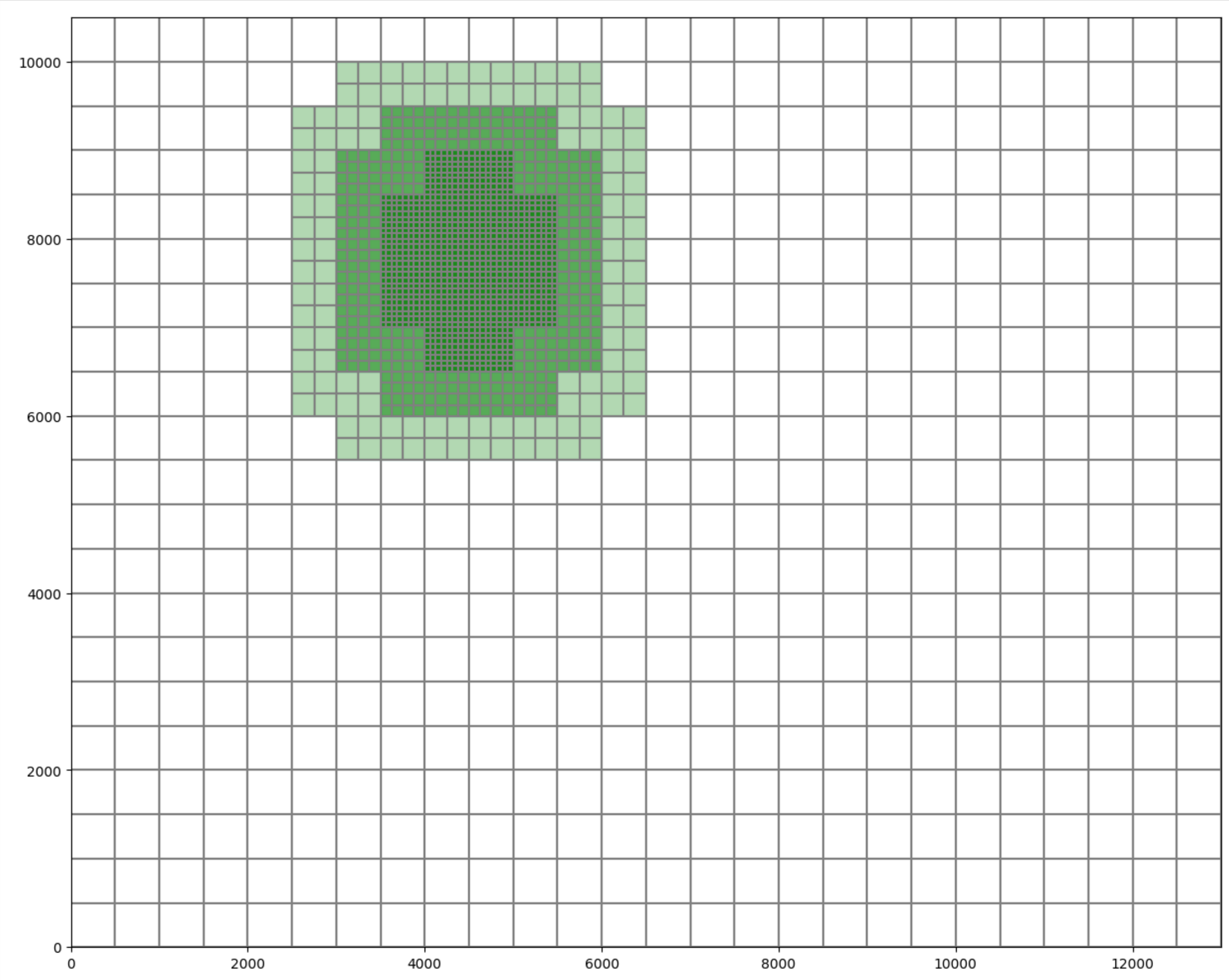
```
        (3500, 9500),
        (5500, 9500),
        (5500, 9000),
        (6000, 9000),
        (6000, 6500),
        (5500, 6500),
        (5500, 6000),
        (3500, 6000),
        (3500, 6500),
        (3000, 6500),
    ]
]
g.add_refinement_features([middle_polygon], "polygon", 2, range(nlay))
refshp1 = gridgen_ws / "rf1"

inner_polygon = [
    [
        (3500, 7000),
        (3500, 8500),
        (4000, 8500),
        (4000, 9000),
        (5000, 9000),
        (5000, 8500),
        (5500, 8500),
        (5500, 7000),
        (5000, 7000),
        (5000, 6500),
        (4000, 6500),
        (4000, 7000),
        (3500, 7000),
    ]
]
g.add_refinement_features([inner_polygon], "polygon", 3, range(nlay))
refshp2 = gridgen_ws / "rf2"
```

Create and plot the refined grid with refinement levels superimposed.

[4]:
```
g.build(verbose=False)
grid = flopy.discretization.VertexGrid(**g.get_gridprops_vertexgrid())

fig = plt.figure(figsize=(15, 15))
ax = fig.add_subplot(1, 1, 1, aspect="equal")
mm = flopy.plot.PlotMapView(model=ms)
grid.plot(ax=ax)
flopy.plot.plot_shapefile(refshp0, ax=ax, facecolor="green", alpha=0.3)
flopy.plot.plot_shapefile(refshp1, ax=ax, facecolor="green", alpha=0.5)
flopy.plot.plot_shapefile(str(refshp2), ax=ax, facecolor="green", alpha=0.7)
```

[4]:
```
<matplotlib.collections.PatchCollection at 0x7f560d3bb250>
```



Groundwater flow model

Next, create a GWF model. The particle-tracking model will consume its output.

[5]:
```
# simulation
sim = flopy.mf6.MFSimulation(
    sim_name=sim_name, sim_ws=workspace, exe_name="mf6", version="mf6"
)

# temporal discretization
tdis = flopy.mf6.ModflowTdis(
    sim, time_units="days", nper=1, perioddata=[(10000, 1, 1.0)]
)

# iterative model solver
ims = flopy.mf6.ModflowIms(
    sim,
    pname="ims",
    complexity="SIMPLE",
    outer_dvclose=1e-4,
```

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```python
    outer_maximum=100,
    inner_dvclose=1e-5,
    under_relaxation_theta=0,
    under_relaxation_kappa=0,
    under_relaxation_gamma=0,
    under_relaxation_momentum=0,
    linear_acceleration="BICGSTAB",
    relaxation_factor=0.99,
    number_orthogonalizations=2,
)

# groundwater flow model
gwf = flopy.mf6.ModflowGwf(
    sim, modelname=sim_name, model_nam_file=f"{sim_name}.nam", save_flows=True
)

# grid discretization
# fmt: off
idomain = [
    0,0,0,0,0,0,0,0,0,0,1,1,1,1,1,1,1,1,0,0,0,0,0,0,0,
    0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,1,1,1,1,1,1,
    1,1,1,1,1,1,1,1,1,1,1,1,1,1,0,0,0,0,0,0,0,0,0,0,0,
    0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,1,1,0,
    0,0,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,
    1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,
    1,1,1,1,1,1,1,1,1,1,1,1,1,1,0,0,0,0,0,0,0,0,0,0,0,
    0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,1,1,
    1,0,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,
    1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,
    1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,
    1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,
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    1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,
    1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,
    1,1,1,1,1,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,
    0,0,1,0,0,0,0,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,
    1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,
    1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,
    1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,
    1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,
    1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,
    1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,
    1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,
    1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,
    1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,
    1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,
    1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,0,0,
    0,0,0,0,0,0,0,0,1,0,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,
    1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,
    1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,
    1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,
    1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,
```

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```
    1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,
    1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,
    1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,
    1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,
    1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,
    1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,
    1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,
    1,1,1,1,1,1,1,1,1,1,1,1,1,0,0,0,0,0,0,0,1,1,1,1,1,
    1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,
    1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,
    1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,
    1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,
    1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,
    1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,
    1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,
    1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,
    1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,
    1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,
    1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,
    1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,
    1,1,1,0,0,0,0,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,
    1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,
    1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,
    1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,
    1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,
    1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,
    1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,
    1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,
    1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,0,0,0,1,
    1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,
    1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,
    1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,
    1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,0,0,1,1,1,1,
    1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,
    1,1,1,1,1,1,1,1,1,1,1,1,1,0,0,1,1,1,1,1,1,1,1,1,1,
    1,1,1,1,1,1,1,1,1,1,1,1,1,1,0,1,1,1,1,1,1,1,1,1,1,
    1,1,1,1,1,1,1,1,1,1,1,1,1,1,0,1,1,1,1,1,1,1,1,1,1,
    1,1,1,1,1,1,1,1,1,1,1,1,1,1,0,0,1,1,1,1,1,1,1,1,1,
    1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,0,0,1,1,1,1,1,1,1,1,
    1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,0,0,0,1,1,1,1,1,1,1,
    1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,0,0,0,0,1,1,1,1,1,
    1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,0,0,0,0,0,0,0,0,1,
    1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,0,0,0,0,0,0,0,0,0,
    0,0,0,1,1,1,1,1,1,1,1,1,1,1,1,1,1,0,0,0,0,0,0,0,0,
    0,0,0,0,0,1,1,1,1,1,1,1,1,1,1,1,1,0,0,0,0,0,0,0,0,
    0,0,0,0,0,0,0,0,0,1,1,1,1,1,1,1,0,0,0,0,0,0,0,0
]
# fmt: on
disv_props = g.get_gridprops_disv()
disv = flopy.mf6.ModflowGwfdisv(
    gwf, length_units="feet", idomain=idomain, **disv_props
)
```

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```
# initial conditions
ic = flopy.mf6.ModflowGwfic(gwf, strt=150.0)

# wells are tuples (layer, node number, q, iface)
wells = [
    # negative q: discharge
    (0, 861, -30000.0, 0),
    (0, 891, -30000.0, 0),
    # positive q: injection
    (0, 1959, 10000.0, 1),
    (0, 1932, 10000.0, 3),
    (0, 1931, 10000.0, 3),
    (0, 1930, 5000.0, 1),
    (0, 1930, 5000.0, 3),
    (0, 1903, 5000.0, 1),
    (0, 1903, 5000.0, 3),
    (0, 1876, 10000.0, 3),
    (0, 1875, 10000.0, 3),
    (0, 1874, 5000.0, 1),
    (0, 1874, 5000.0, 3),
    (0, 1847, 10000.0, 3),
    (0, 1846, 5000.0, 3),
    (0, 1845, 5000.0, 1),
    (0, 1845, 5000.0, 3),
    (0, 1818, 5000.0, 1),
    (0, 1818, 5000.0, 3),
    (0, 1792, 10000.0, 1),
    (0, 1766, 10000.0, 1),
    (0, 1740, 5000.0, 1),
    (0, 1740, 5000.0, 4),
    (0, 1715, 5000.0, 1),
    (0, 1715, 5000.0, 4),
    (0, 1690, 10000.0, 1),
    (0, 1646, 5000.0, 1),
    (0, 1646, 5000.0, 4),
    (0, 1549, 5000.0, 1),
    (0, 1549, 5000.0, 4),
    (0, 1332, 5000.0, 4),
    (0, 1332, 5000.0, 1),
    (0, 1021, 2500.0, 1),
    (0, 1021, 2500.0, 4),
    (0, 1020, 5000.0, 1),
    (0, 708, 2500.0, 1),
    (0, 708, 2500.0, 4),
    (0, 711, 625.0, 1),
    (0, 711, 625.0, 4),
    (0, 710, 625.0, 1),
    (0, 710, 625.0, 4),
    (0, 409, 1250.0, 1),
    (0, 407, 625.0, 1),
    (0, 407, 625.0, 4),
```

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```
    (0, 402, 625.0, 1),
    (0, 402, 625.0, 4),
    (0, 413, 1250.0, 1),
    (0, 411, 1250.0, 1),
    (0, 203, 1250.0, 1),
    (0, 202, 1250.0, 1),
    (0, 202, 1250.0, 4),
    (0, 199, 2500.0, 1),
    (0, 197, 1250.0, 1),
    (0, 197, 1250.0, 4),
    (0, 96, 2500.0, 1),
    (0, 97, 1250.0, 1),
    (0, 97, 1250.0, 4),
    (0, 103, 1250.0, 1),
    (0, 103, 1250.0, 4),
    (0, 102, 1250.0, 1),
    (0, 102, 1250.0, 4),
    (0, 43, 2500.0, 1),
    (0, 43, 2500.0, 4),
    (0, 44, 2500.0, 1),
    (0, 44, 2500.0, 4),
    (0, 45, 5000.0, 4),
    (0, 10, 10000.0, 1),
]
flopy.mf6.modflow.mfgwfwel.ModflowGwfwel(
    gwf,
    maxbound=68,
    auxiliary="IFACE",
    save_flows=True,
    stress_period_data={0: wells},
)

# node property flow
npf = flopy.mf6.ModflowGwfnpf(
    gwf,
    xt3doptions=True,
    save_flows=True,
    save_specific_discharge=True,
    icelltype=[0],
    k=[50],
)

# constant head boundary (period, node number, head)
chd_bound = [
    (0, 1327, 150.0),
    (0, 1545, 150.0),
    (0, 1643, 150.0),
    (0, 1687, 150.0),
    (0, 1713, 150.0),
]
chd = flopy.mf6.ModflowGwfchd(
    gwf, pname="chd", save_flows=True, stress_period_data=chd_bound
```

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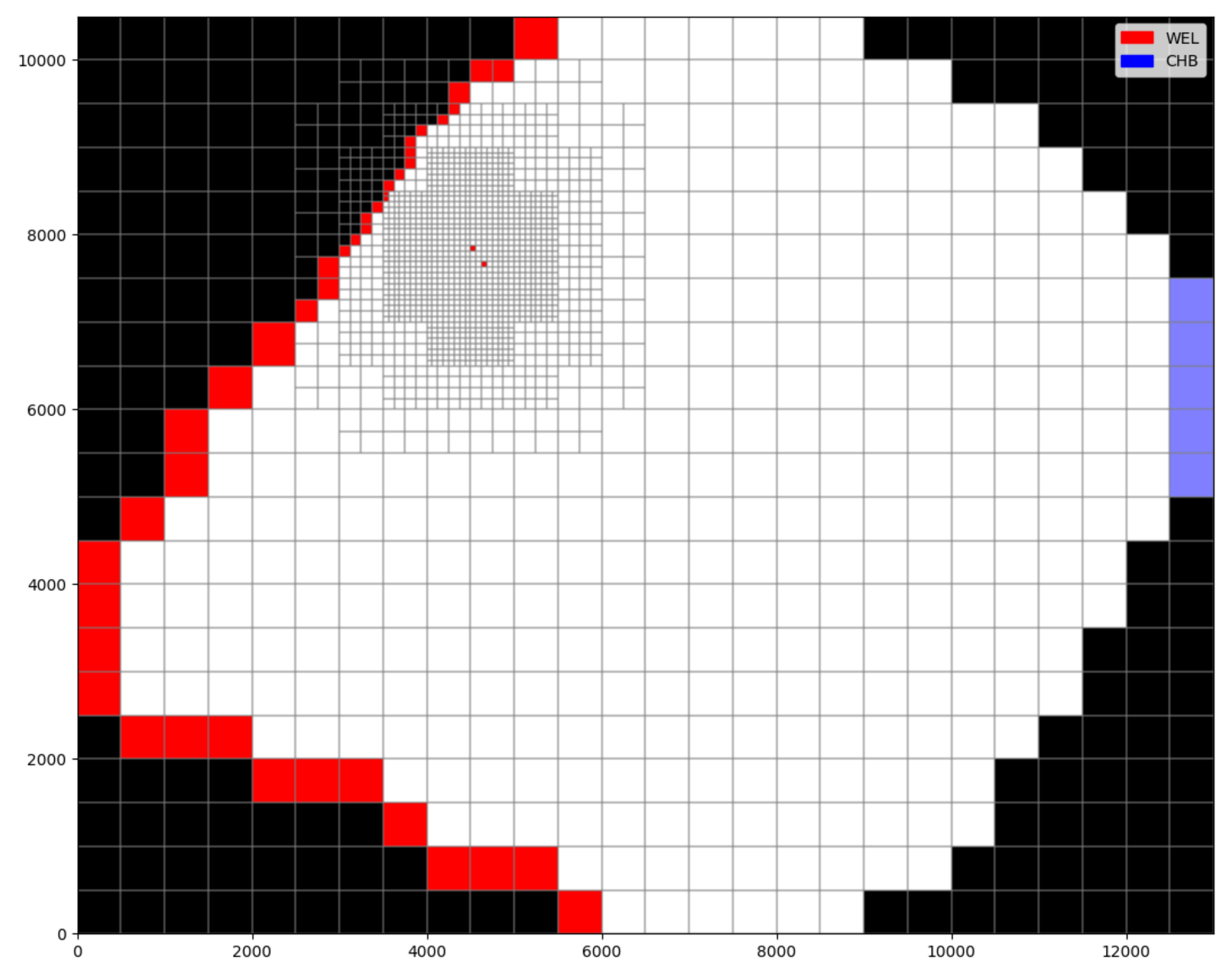
```
)

# output control
budget_file = f"{sim_name}.bud"
head_file = f"{sim_name}.hds"
oc = flopy.mf6.ModflowGwfoc(
    gwf,
    pname="oc",
    budget_filerecord=[budget_file],
    head_filerecord=[head_file],
    saverecord=[("HEAD", "ALL"), ("BUDGET", "ALL")],
)
```

```
WARNING: Unable to resolve dimension of ('gwf6', 'disv', 'cell2d', 'cell2d', 'icvert')␣
↪based on shape "ncvert".
```

Before running the simulation, view the model's boundary conditions.

[6]:
```
fig = plt.figure(figsize=(13, 13))
ax = fig.add_subplot(1, 1, 1, aspect="equal")
mv = flopy.plot.PlotMapView(model=gwf, ax=ax)
mv.plot_grid(alpha=0.3)
mv.plot_ibound()
mv.plot_bc("WEL")
ax.add_patch(
    mpl.patches.Rectangle(
        ((ncol - 1) * delc, (nrow - 6) * delr),
        1000,
        -2500,
        linewidth=5,
        facecolor="blue",
        alpha=0.5,
    )
)
ax.legend(
    handles=[
        mpl.patches.Patch(color="red", label="WEL"),
        mpl.patches.Patch(color="blue", label="CHB"),
    ]
)

plt.show()
```



Run the simulation.

[7]:
```
sim.set_sim_path(workspace)
sim.write_simulation()
success, buff = sim.run_simulation(silent=True, report=True)
assert success, f"Failed to run MF6 simulation."
for line in buff:
    print(line)
```

```
writing simulation...
  writing simulation name file...
  writing simulation tdis package...
  writing solution package ims...
  writing model ex04_mf6...
    writing model name file...
    writing package disv...
    writing package ic...
    writing package wel_0...
    writing package npf...
    writing package chd...
INFORMATION: maxbound in ('gwf6', 'chd', 'dimensions') changed to 5 based on size of␣
```

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```
↪stress_period_data
    writing package oc...
                                   MODFLOW 6
                U.S. GEOLOGICAL SURVEY MODULAR HYDROLOGIC MODEL
                            VERSION 6.4.2 06/28/2023

   MODFLOW 6 compiled Jul 05 2023 20:29:14 with Intel(R) Fortran Intel(R) 64
   Compiler Classic for applications running on Intel(R) 64, Version 2021.7.0
                             Build 20220726_000000

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 Run start date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:31:32

 Writing simulation list file: mfsim.lst
 Using Simulation name file: mfsim.nam

    Solving:  Stress period:     1    Time step:     1

 Run end date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:31:32
 Elapsed run time:  0.049 Seconds

 Normal termination of simulation.
```

Particle tracking

This example is a reverse-tracking model, with termination and release zones inverted: we "release" particles from the constant head boundary on the grid's right edge and from the two pumping wells, and track the particles backwards to release locations at the wells along the left boundary of the active domain.

[8]:
```
particles = [
    # node number, localx, localy, localz
    (1327, 0.000, 0.125, 0.500),
    (1327, 0.000, 0.375, 0.500),
    (1327, 0.000, 0.625, 0.500),
    (1327, 0.000, 0.875, 0.500),
    (1545, 0.000, 0.125, 0.500),
    (1545, 0.000, 0.375, 0.500),
    (1545, 0.000, 0.625, 0.500),
```

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```
    (1545, 0.000, 0.875, 0.500),
    (1643, 0.000, 0.125, 0.500),
    (1643, 0.000, 0.375, 0.500),
    (1643, 0.000, 0.625, 0.500),
    (1643, 0.000, 0.875, 0.500),
    (1687, 0.000, 0.125, 0.500),
    (1687, 0.000, 0.375, 0.500),
    (1687, 0.000, 0.625, 0.500),
    (1687, 0.000, 0.875, 0.500),
    (1713, 0.000, 0.125, 0.500),
    (1713, 0.000, 0.375, 0.500),
    (1713, 0.000, 0.625, 0.500),
    (1713, 0.000, 0.875, 0.500),
    (861, 0.000, 0.125, 0.500),
    (861, 0.000, 0.375, 0.500),
    (861, 0.000, 0.625, 0.500),
    (861, 0.000, 0.875, 0.500),
    (861, 1.000, 0.125, 0.500),
    (861, 1.000, 0.375, 0.500),
    (861, 1.000, 0.625, 0.500),
    (861, 1.000, 0.875, 0.500),
    (861, 0.125, 0.000, 0.500),
    (861, 0.375, 0.000, 0.500),
    (861, 0.625, 0.000, 0.500),
    (861, 0.875, 0.000, 0.500),
    (861, 0.125, 1.000, 0.500),
    (861, 0.375, 1.000, 0.500),
    (861, 0.625, 1.000, 0.500),
    (861, 0.875, 1.000, 0.500),
    (891, 0.000, 0.125, 0.500),
    (891, 0.000, 0.375, 0.500),
    (891, 0.000, 0.625, 0.500),
    (891, 0.000, 0.875, 0.500),
    (891, 1.000, 0.125, 0.500),
    (891, 1.000, 0.375, 0.500),
    (891, 1.000, 0.625, 0.500),
    (891, 1.000, 0.875, 0.500),
    (891, 0.125, 0.000, 0.500),
    (891, 0.375, 0.000, 0.500),
    (891, 0.625, 0.000, 0.500),
    (891, 0.875, 0.000, 0.500),
    (891, 0.125, 1.000, 0.500),
    (891, 0.375, 1.000, 0.500),
    (891, 0.625, 1.000, 0.500),
    (891, 0.875, 1.000, 0.500),
]

pd = flopy.modpath.ParticleData(
    partlocs=[p[0] for p in particles],
    localx=[p[1] for p in particles],
    localy=[p[2] for p in particles],
    localz=[p[3] for p in particles],
```

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```
    timeoffset=0,
    drape=0,
)
pg = flopy.modpath.ParticleGroup(
    particlegroupname="G1", particledata=pd, filename=f"{sim_name}.sloc"
)
```

Create and run the backwards particle tracking model in `pathline` mode.

[9]:
```
mp = flopy.modpath.Modpath7(
    modelname=f"{sim_name}_mp",
    flowmodel=gwf,
    exe_name="mp7",
    model_ws=workspace,
)
mpbas = flopy.modpath.Modpath7Bas(
    mp,
    porosity=0.1,
)
mpsim = flopy.modpath.Modpath7Sim(
    mp,
    simulationtype="pathline",
    trackingdirection="backward",
    budgetoutputoption="summary",
    particlegroups=[pg],
)

mp.write_input()
success, buff = mp.run_model(silent=True, report=True)
assert success, "Failed to run particle-tracking model."
for line in buff:
    print(line)
```

```
MODPATH Version 7.2.001
Program compiled Jul 05 2023 20:31:49 with IFORT compiler (ver. 20.21.7)


Run particle tracking simulation ...
Processing Time Step     1 Period     1.  Time =  1.00000E+04  Steady-state flow

Particle Summary:
         0 particles are pending release.
         0 particles remain active.
        51 particles terminated at boundary faces.
         0 particles terminated at weak sink cells.
         1 particles terminated at weak source cells.
         0 particles terminated at strong source/sink cells.
         0 particles terminated in cells with a specified zone number.
         0 particles were stranded in inactive or dry cells.
         0 particles were unreleased.
         0 particles have an unknown status.
```

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```
Normal termination.
```

Load pathline data from the model's pathline output file.

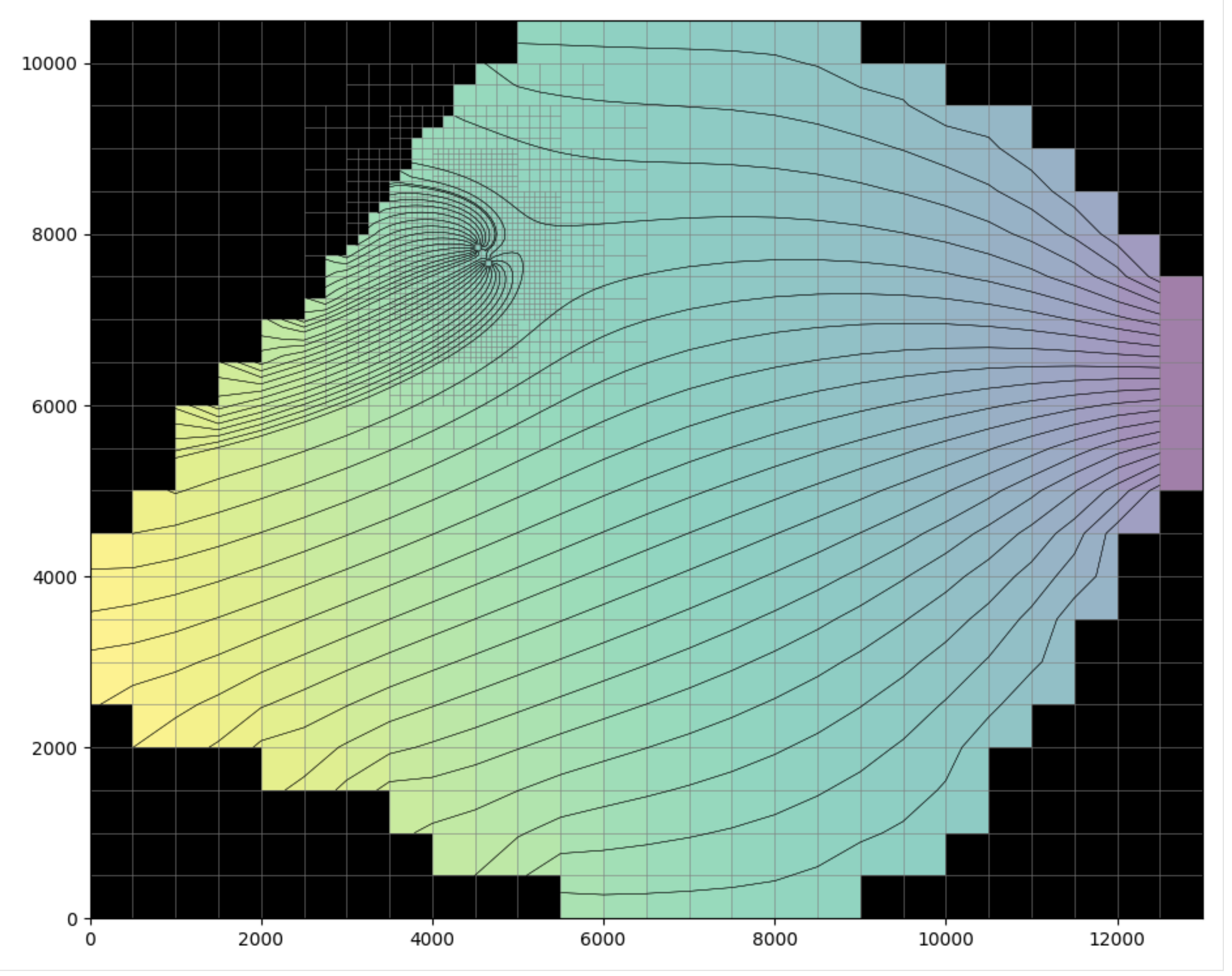
[10]:
```
fpth = workspace / f"{sim_name}_mp.mppth"
p = flopy.utils.PathlineFile(fpth)
pl = p.get_destination_pathline_data(
    range(gwf.modelgrid.nnodes), to_recarray=True
)
```

Load head data.

[11]:
```
hf = flopy.utils.HeadFile(workspace / f"{sim_name}.hds")
hd = hf.get_data()
```

Plot heads and particle paths over the grid.

[12]:
```
fig = plt.figure(figsize=(11, 11))
ax = fig.add_subplot(1, 1, 1, aspect="equal")
mm = flopy.plot.PlotMapView(model=gwf)
mm.plot_grid(lw=0.5, alpha=0.5)
mm.plot_ibound()
mm.plot_array(hd, alpha=0.5)
mm.plot_pathline(pl, layer="all", lw=0.3, colors=["black"])
plt.show()
```



Clean up the temporary workspace.

[13]:
```
try:
    # ignore PermissionError on Windows
    temp_dir.cleanup()
except:
    pass
```

6.8.7 FloPy VTK/PyVista particle tracking pathline visualization demo

This notebook arranges and runs a steady state MODFLOW 6 groundwater flow model, then a MODPATH 7 particle tracking model, using the Freyberg grid. Particle tracks are exported to VTK files, then loaded and visualized with PyVista, first in a static plot and then an animated GIF.

First, import FloPy and show the version.

[1]:
```
import sys

import flopy
```

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```
print(sys.version)
print(f"flopy version: {flopy.__version__}")
```

```
3.8.18 (default, Aug 28 2023, 08:27:22)
[GCC 11.4.0]
flopy version: 3.5.0
```

Load the Freyberg MF6 groundwater flow model.

[2]:
```
from pathlib import Path

from flopy.mf6 import MFSimulation

mdl_name = "freyberg"
sim_name = f"mf6-{mdl_name}-vtk-pathlines"
sim_path = Path.cwd().parent / "../examples/data" / f"mf6-{mdl_name}"

sim = MFSimulation.load(sim_name=sim_name, sim_ws=sim_path)
```

```
loading simulation...
  loading simulation name file...
  loading tdis package...
  loading model gwf6...
    loading package dis...
    loading package ic...
WARNING: Block "options" is not a valid block name for file type ic.
    loading package oc...
    loading package npf...
    loading package sto...
    loading package chd...
    loading package riv...
    loading package wel...
    loading package rch...
  loading solution package freyberg...
```

Create a temporary directory and change the simulation's workspace.

[3]:
```
from tempfile import TemporaryDirectory

temp_path = TemporaryDirectory()
workspace = Path(temp_path.name)
sim.set_sim_path(workspace)
```

Write the input files to the temporary workspace.

[4]:
```
sim.write_simulation()
```

```
writing simulation...
  writing simulation name file...
  writing simulation tdis package...
  writing solution package freyberg...
  writing model freyberg...
    writing model name file...
    writing package dis...
```

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```
    writing package ic...
    writing package oc...
    writing package npf...
    writing package sto...
    writing package chd-1...
    writing package riv-1...
    writing package wel-1...
    writing package rch-1...
```

Run the groundwater flow simulation.

[5]:
```
success, buff = sim.run_simulation(silent=True, report=True)
assert success, "MODFLOW 6 simulation failed"
for line in buff:
    print(line)
```

```
                                   MODFLOW 6
                U.S. GEOLOGICAL SURVEY MODULAR HYDROLOGIC MODEL
                            VERSION 6.4.2 06/28/2023

   MODFLOW 6 compiled Jul 05 2023 20:29:14 with Intel(R) Fortran Intel(R) 64
   Compiler Classic for applications running on Intel(R) 64, Version 2021.7.0
                             Build 20220726_000000

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and distribution information.


 Run start date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:39:50

 Writing simulation list file: mfsim.lst
 Using Simulation name file: mfsim.nam

    Solving:  Stress period:     1    Time step:     1

 Run end date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:39:50
 Elapsed run time:  0.047 Seconds

 Normal termination of simulation.
```

Define particle release locations. In this example we will release 16 particles, with each particle released at the center of a unique grid cell. Cells containing particle release points are clustered into four 2x2 square regions.

[6]:
```python
pgs = []
gwf = sim.get_model(mdl_name)

for i in range(1, 5):
    nrow = gwf.modelgrid.nrow
    ncol = gwf.modelgrid.ncol
    m = i * 2 if i < 3 else (nrow - i * 4)
    n = i * 2 if i < 3 else (ncol - i * 4)
    celldata = flopy.modpath.CellDataType(
        drape=0,
        columncelldivisions=1,
        rowcelldivisions=1,
        layercelldivisions=1,
    )
    lrcpd = flopy.modpath.LRCParticleData(
        subdivisiondata=[celldata],
        lrcregions=[[[0, m, n, 0, m + 1, n + 1]]],
    )
    pg = flopy.modpath.ParticleGroupLRCTemplate(
        particlegroupname=f"PG{i}",
        particledata=lrcpd,
        filename=f"{sim_name}.pg{i}.sloc",
    )
    pgs.append(pg)
```

Retrieve well locations (to define termination zones).

[7]:
```python
import numpy as np

wel_locs = [
    (rec[0][1], rec[0][2]) for rec in (gwf.wel.stress_period_data.data[0])
]
print(wel_locs)
```

```
[(8, 15), (10, 12), (19, 13), (25, 9), (28, 5), (33, 11)]
```

Define particle termination zones.

[8]:
```python
zone_maps = []


# zone 1 is the default (non-terminating regions)
def fill_zone_1():
    return np.ones((nrow, ncol), dtype=np.int32)


za = fill_zone_1()
for wl in wel_locs:
    za[wl] = 2  # wells
za[:, 14] = 3  # river is in column 14
zone_maps.append(za)
```

Create a MODPATH 7 simulation forward tracking model in `combined` (pathline & timeseries) mode.

[9]:
```python
mp = flopy.modpath.Modpath7(
    modelname=f"{sim_name}_mp",
    flowmodel=gwf,
    exe_name="mp7",
    model_ws=workspace,
)
mpbas = flopy.modpath.Modpath7Bas(mp, porosity=0.1)
mpsim = flopy.modpath.Modpath7Sim(
    mp,
    simulationtype="combined",
    trackingdirection="forward",
    budgetoutputoption="summary",
    referencetime=[0, 0, 0.0],
    timepointdata=[1, [0]],
    zonedataoption="on",
    zones=zone_maps,
    particlegroups=pgs,
)
```

Write and run the particle tracking model.

[10]:
```python
mp.write_input()
success, buff = mp.run_model(silent=True, report=True)
assert success, "MODPATH 7 simulation failed"
for line in buff:
    print(line)
```

```
MODPATH Version 7.2.001
Program compiled Jul 05 2023 20:31:49 with IFORT compiler (ver. 20.21.7)


Run particle tracking simulation ...
Processing Time Step     1 Period     1.  Time =  1.00000E+01  Steady-state flow

Particle Summary:
         0 particles are pending release.
         0 particles remain active.
         0 particles terminated at boundary faces.
        16 particles terminated at weak sink cells.
         0 particles terminated at weak source cells.
         0 particles terminated at strong source/sink cells.
         0 particles terminated in cells with a specified zone number.
         0 particles were stranded in inactive or dry cells.
         0 particles were unreleased.
         0 particles have an unknown status.

Normal termination.
```

Open the pathline output file and read pathline data.

[11]:
```python
from flopy.utils import PathlineFile

pf = PathlineFile(workspace / mpsim.pathlinefilename)
```

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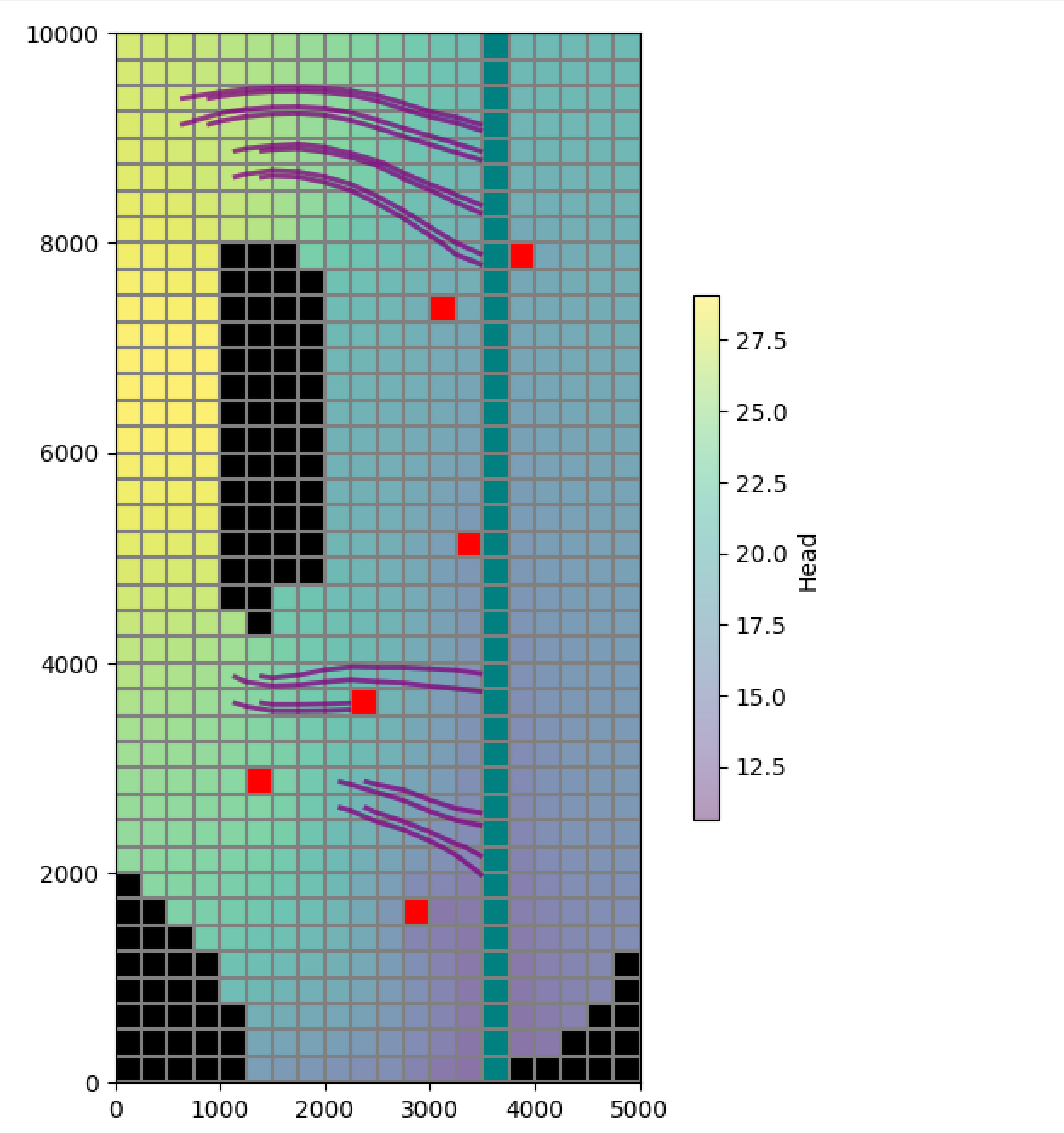
```
pl = pf.get_alldata()
```

Plot the grid, heads, boundary conditions, and pathlines.

[12]:
```
import matplotlib.pyplot as plt

hf = flopy.utils.HeadFile(workspace / f"{mdl_name}.hds")
hds = hf.get_data()

fig = plt.figure(figsize=(8, 8))
ax = fig.add_subplot(1, 1, 1, aspect="equal")
mv = flopy.plot.PlotMapView(model=gwf)
mv.plot_grid()
mv.plot_ibound()
hd = mv.plot_array(hds, alpha=0.4)
cb = plt.colorbar(hd, shrink=0.5)
cb.set_label("Head")
mv.plot_bc("RIV")
mv.plot_bc("WEL", plotAll=True)
mv.plot_pathline(pl, layer="all", alpha=0.5, colors=["purple"], lw=2)
plt.show()
```



Create a `Vtk` object and add the flow model outputs and pathlines.

[13]:
```
from flopy.export.vtk import Vtk

vtk = Vtk(model=gwf, binary=False, vertical_exageration=50, smooth=False)
vtk.add_model(gwf)
vtk.add_pathline_points(pl)
```

Convert the VTK object to PyVista meshes.

[14]:
```
grid, pathlines = vtk.to_pyvista()
```

Rotate the meshes to match the orientation of the map view plot above.

[15]:
```
import pyvista as pv

axes = pv.Axes(show_actor=True, actor_scale=2.0, line_width=5)

grid.rotate_z(160, point=axes.origin, inplace=True)
pathlines.rotate_z(160, point=axes.origin, inplace=True)
```

[15]:
```
UnstructuredGrid (0x7ff47fe8a160)
  N Cells:    223
  N Points:   207
  X Bounds:   -6.410e+03, -2.297e+03
  Y Bounds:   -8.596e+03, -6.525e+02
  Z Bounds:   3.392e+02, 1.160e+03
  N Arrays:   2
```

Check some grid properties to make sure the export succeeded.

[16]:
```
assert grid.n_cells == gwf.modelgrid.nnodes
print("Model grid has", grid.n_cells, "cells")
print("Model grid has", grid.n_arrays, "arrays")
```

```
Model grid has 800 cells
Model grid has 9 arrays
```

Select particle release locations and build a dictionary of particle tracks (pathlines). This will be used below for particle labelling, as well as for animation.

Note: while below we construct pathlines manually from data read from the exported VTK files, pathlines may also be read directly from the MODPATH 7 pathline output file (provided the simulation was run in `pathline` or `combined` mode, as this one was).

[17]:
```
tracks = {}
particle_ids = set()
release_locs = list()

for i, t in enumerate(pathlines["time"]):
    pid = str(round(float(pathlines["particleid"][i])))
    loc = pathlines.points[i]

    if pid not in tracks:
        tracks[pid] = []
        particle_ids.add(pid)
        release_locs.append(loc)

    # store the particle location in the corresponding track
    tracks[pid].append((loc, t))

release_locs = np.array(release_locs)
tracks = {k: np.array(v, dtype=object) for k, v in tracks.items()}
max_track_len = max([len(v) for v in tracks.values()])
print("The maximum number of locations per particle track is", max_track_len)
```

```
The maximum number of locations per particle track is 18
```

View the grid and pathlines with PyVista, with particle tracks/locations colored by time. Also add particle ID labels to a few particles' release locations.

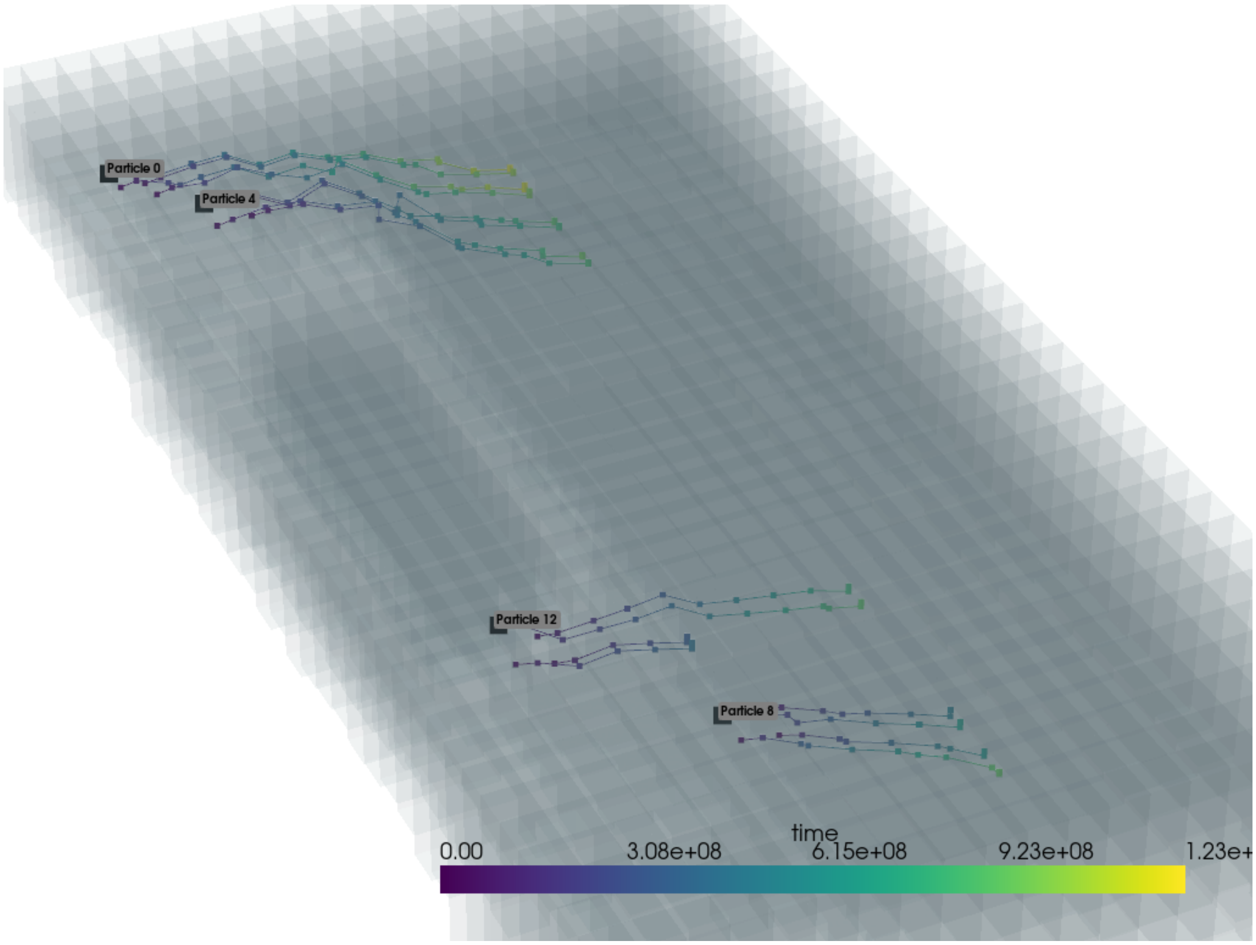
[18]:
```
pv.set_plot_theme("document")
pv.set_jupyter_backend("static")

# create the plot and add the grid and pathline meshes
p = pv.Plotter()
p.add_mesh(grid, opacity=0.05)
p.add_mesh(pathlines, scalars="time")

# add a particle ID label to each 4th particle's starting point
label_coords = []
start_labels = []
for pid, track in tracks.items():
    if int(pid) % 4 == 0:
        label_coords.append(track[0][0])
        start_labels.append(f"Particle {pid}")

p.add_point_labels(
    label_coords,
    start_labels,
    font_size=10,
    point_size=15,
    point_color="black",
)

# zoom in and show the plot
p.camera.zoom(2.4)
p.show()
```



Create an animated GIF of the particles traveling along their pathlines, with particles colored by time.

[19]:
```
# create plotter
p = pv.Plotter(notebook=False, off_screen=True)

# open GIF file
gif_path = workspace / f"{sim_name}_tracks.gif"
p.open_gif(str(gif_path))

# create mesh from release locations
spls = pv.PolyData(release_locs)
spls.point_data["time"] = np.zeros(len(spls.points))

# add the underlying grid mesh and particle data, then zoom in
p.add_mesh(grid, opacity=0.05)
p.add_mesh(spls, clim=[0, 1.23e09])
p.camera.zoom(2.4)

# cycle through time steps and update particle location
for i in range(1, max_track_len):
    pts = []
    times = []
```

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```
    segments = []

    for pid in particle_ids:
        track = tracks[pid]
        npts = len(track)
        # use last locn if particle has already terminated
        loc, t = track[i] if i < npts else track[npts - 1]
        pts.append(loc)
        times.append(t)
        if i < npts:
            segments.append(track[i - 1][0])
            segments.append(loc)

    p.update_coordinates(np.vstack(pts), render=False)
    p.update_scalars(np.array(times), mesh=spls, render=False)
    p.add_lines(np.array(segments), width=1, color="black")
    p.write_frame()  # write frame to file

# close the plotter and the GIF file
p.close()
```

Show the GIF.

[20]:
```
from IPython.core.display import Image

display(Image(data=open(gif_path, "rb").read(), format="gif"))
```

```
<IPython.core.display.Image object>
```

Clean up the temporary workspace.

[21]:
```
try:
    # ignore PermissionError on Windows
    temp_path.cleanup()
except:
    pass
```

6.9 MT3D and SEAWAT examples

6.9.1 MT3D-USGS Example

Demonstrates functionality of the flopy MT3D-USGS module using the ‘Crank-Nicolson’ example distributed with MT3D-USGS.

Problem description:

- Grid dimensions: 1 Layer, 3 Rows, 650 Columns
- Stress periods: 3
- Units are in seconds and meters
- Flow package: UPW
- Stress packages: SFR, GHB
- Solvers: NWT, GCG

[1]:
```
import math
import os
import string
```

[2]:
```
import sys
from io import BytesIO, StringIO
from tempfile import TemporaryDirectory

import matplotlib as mpl
import matplotlib.pyplot as plt
import numpy as np

# run installed version of flopy or add local path
try:
    import flopy
except:
    fpth = os.path.abspath(os.path.join("..", ".."))
    sys.path.append(fpth)
    import flopy

print(sys.version)
print(f"numpy version: {np.__version__}")
print(f"matplotlib version: {mpl.__version__}")
print(f"flopy version: {flopy.__version__}")
```

```
3.8.18 (default, Aug 28 2023, 08:27:22)
[GCC 11.4.0]
numpy version: 1.24.4
matplotlib version: 3.7.4
flopy version: 3.5.0
```

[3]:
```
temp_dir = TemporaryDirectory()
modelpth = temp_dir.name
modelname = "CrnkNic"
mfexe = "mfnwt"
mtexe = "mt3dusgs"

# Make sure modelpth directory exists
if not os.path.isdir(modelpth):
    os.makedirs(modelpth, exist_ok=True)

# Instantiate MODFLOW object in flopy
```

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```
mf = flopy.modflow.Modflow(
    modelname=modelname, exe_name=mfexe, model_ws=modelpth, version="mfnwt"
)
```

Set up model discretization

```
[4]: Lx = 650.0
Ly = 15
nrow = 3
ncol = 650
nlay = 1

delr = Lx / ncol
delc = Ly / nrow

xmax = ncol * delr
ymax = nrow * delc

X, Y = np.meshgrid(
    np.linspace(delr / 2, xmax - delr / 2, ncol),
    np.linspace(ymax - delc / 2, 0 + delc / 2, nrow),
)
```

Instantiate output control (oc) package for MODFLOW-NWT

```
[5]: # Output Control: Create a flopy output control object
oc = flopy.modflow.ModflowOc(mf)
```

Instantiate solver package for MODFLOW-NWT

```
[6]: # Newton-Raphson Solver: Create a flopy nwt package object

headtol = 1.0e-4
fluxtol = 5
maxiterout = 5000
thickfact = 1e-06
linmeth = 2
iprnwt = 1
ibotav = 1

nwt = flopy.modflow.ModflowNwt(
    mf,
    headtol=headtol,
    fluxtol=fluxtol,
    maxiterout=maxiterout,
    thickfact=thickfact,
    linmeth=linmeth,
    iprnwt=iprnwt,
    ibotav=ibotav,
    options="SIMPLE",
)
```

Instantiate discretization (DIS) package for MODFLOW-NWT

[7]:
```
# The equations for calculating the ground elevation in the 1 Layer CrnkNic model.
# Although Y isn't used, keeping it here for symetry


def topElev(X, Y):
    return 100.0 - (np.ceil(X) - 1) * 0.03


grndElev = topElev(X, Y)
bedRockElev = grndElev - 3.0

Steady = [False, False, False]
nstp = [1, 1, 1]
tsmult = [1.0, 1.0, 1.0]

# Stress periods extend from (12AM-8:29:59AM); (8:30AM-11:30:59AM); (11:31AM-23:59:59PM)
perlen = [30600, 10800, 45000]

# Create the discretization object
# itmuni = 1 (seconds); lenuni = 2 (meters)
dis = flopy.modflow.ModflowDis(
    mf,
    nlay,
    nrow,
    ncol,
    nper=3,
    delr=delr,
    delc=delc,
    top=grndElev,
    botm=bedRockElev,
    laycbd=0,
    itmuni=1,
    lenuni=2,
    steady=Steady,
    nstp=nstp,
    tsmult=tsmult,
    perlen=perlen,
)
```

Instantiate upstream weighting (UPW) flow package for MODFLOW-NWT

[8]:
```
# UPW parameters
# UPW must be instantiated after DIS.  Otherwise, during the mf.write_input() procedures,
# flopy will crash.


laytyp = 1
layavg = 2
chani = 1.0
layvka = 1
iphdry = 0
hk = 0.1
hani = 1
```

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```
vka = 1.0
ss = 0.000001
sy = 0.20
hdry = -888

upw = flopy.modflow.ModflowUpw(
    mf,
    laytyp=laytyp,
    layavg=layavg,
    chani=chani,
    layvka=layvka,
    ipakcb=53,
    hdry=hdry,
    iphdry=iphdry,
    hk=hk,
    hani=hani,
    vka=vka,
    ss=ss,
    sy=sy,
)
```

Instantiate basic (BAS or BA6) package for MODFLOW-NWT

[9]:
```
# Create a flopy basic package object
def calc_strtElev(X, Y):
    return 99.5 - (np.ceil(X) - 1) * 0.0001


ibound = np.ones((nlay, nrow, ncol))
ibound[:, 0, :] *= -1
ibound[:, 2, :] *= -1

strtElev = calc_strtElev(X, Y)

bas = flopy.modflow.ModflowBas(mf, ibound=ibound, hnoflo=hdry, strt=strtElev)
```

Instantiate streamflow routing (SFR2) package for MODFLOW-NWT

[10]:
```
# Streamflow Routing Package: Try and set up with minimal options in use
# 9 11 IFACE # Data Set 1: ISTCB1  ISTCB2

nstrm = ncol
nss = 6
const = 1.0
dleak = 0.0001
istcb1 = -10
istcb2 = 11
isfropt = 1

segment_data = None
channel_geometry_data = None
channel_flow_data = None
```

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```
dataset_5 = None
reachinput = True


# The next couple of lines set up the reach_data for the 30x100 hypothetical model.
# Will need to adjust the row based on which grid discretization we're doing.
# Ensure that the stream goes down one of the middle rows of the model.

strmBed_Elev = 98.75 - (np.ceil(X[1, :]) - 1) * 0.0001

s1 = "k,i,j,iseg,ireach,rchlen,strtop,slope,strthick,strhc1\n"
iseg = 0
irch = 0

for y in range(ncol):
    if y <= 37:
        if iseg == 0:
            irch = 1
        else:
            irch += 1
        iseg = 1
        strhc1 = 1.0e-10
    elif y <= 104:
        if iseg == 1:
            irch = 1
        else:
            irch += 1
        iseg = 2
        strhc1 = 1.0e-10
    elif y <= 280:
        if iseg == 2:
            irch = 1
        else:
            irch += 1
        iseg = 3
        strhc1 = 2.946219199e-6
    elif y <= 432:
        if iseg == 3:
            irch = 1
        else:
            irch += 1
        iseg = 4
        strhc1 = 1.375079882e-6
    elif y <= 618:
        if iseg == 4:
            irch = 1
        else:
            irch += 1
        iseg = 5
        strhc1 = 1.764700062e-6
    else:
        if iseg == 5:
```

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```
            irch = 1
        else:
            irch += 1
        iseg = 6
        strhc1 = 1e-10

    # remember that lay, row, col need to be zero-based and are adjusted accordingly by␣
↪flopy
    #    layer +  row      +      col     +       iseg      +      irch      +     ␣
↪rchlen      +            strtop          +        slope        +      strthick    +    ␣
↪strmbed K
    s1 += f"0,{1}"
    s1 += f",{y}"
    s1 += f",{iseg}"
    s1 += f",{irch}"
    s1 += f",{delr}"
    s1 += f",{strmBed_Elev[y]}"
    s1 += f",{0.0001}"
    s1 += f",{0.50}"
    s1 += f",{strhc1}\n"


fpth = os.path.join(modelpth, "s1.csv")
f = open(fpth, "w")
f.write(s1)
f.close()

dtype = [
    ("k", "<i4"),
    ("i", "<i4"),
    ("j", "<i4"),
    ("iseg", "<i4"),
    ("ireach", "<f8"),
    ("rchlen", "<f8"),
    ("strtop", "<f8"),
    ("slope", "<f8"),
    ("strthick", "<f8"),
    ("strhc1", "<f8"),
]

f = open(fpth, "rb")

reach_data = np.genfromtxt(f, delimiter=",", names=True, dtype=dtype)
f.close()

s2 = "nseg,icalc,outseg,iupseg,nstrpts,   flow,runoff,etsw,pptsw,        roughch,        ␣
↪roughbk,cdpth,fdpth,awdth,bwdth,width1,width2\n \
      1,     1,      2,      0,       0, 0.0125,   0.0, 0.0,   0.0, 0.082078856000, 0.
↪082078856000,  0.0,  0.0,  0.0,  0.0,    1.5,    1.5\n \
      2,     1,      3,      0,       0,    0.0,   0.0, 0.0,   0.0, 0.143806300000, 0.
↪143806300000,  0.0,  0.0,  0.0,  0.0,    1.5,    1.5\n \
      3,     1,      4,      0,       0,    0.0,   0.0, 0.0,   0.0, 0.104569661821, 0.
```

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```
↪104569661821,  0.0,  0.0,  0.0,  0.0,   1.5,   1.5\n \
      4,    1,     5,     0,      0,    0.0,   0.0, 0.0,  0.0, 0.126990045841, 0.
↪126990045841,  0.0,  0.0,  0.0,  0.0,   1.5,   1.5\n \
      5,    1,     6,     0,      0,    0.0,   0.0, 0.0,  0.0, 0.183322283828, 0.
↪183322283828,  0.0,  0.0,  0.0,  0.0,   1.5,   1.5\n \
      6,    1,     0,     0,      0,    0.0,   0.0, 0.0,  0.0, 0.183322283828, 0.
↪183322283828,  0.0,  0.0,  0.0,  0.0,   1.5,   1.5"

fpth = os.path.join(modelpth, "s2.csv")
f = open(fpth, "w")
f.write(s2)
f.close()

f = open(fpth, "rb")

segment_data = np.genfromtxt(f, delimiter=",", names=True)
f.close()

# Be sure to convert segment_data to a dictionary keyed on stress period.
segment_data = np.atleast_1d(segment_data)
segment_data = {0: segment_data, 1: segment_data, 2: segment_data}

# There are 3 stress periods
dataset_5 = {0: [nss, 0, 0], 1: [nss, 0, 0], 2: [nss, 0, 0]}

sfr = flopy.modflow.ModflowSfr2(
    mf,
    nstrm=nstrm,
    nss=nss,
    const=const,
    dleak=dleak,
    isfropt=isfropt,
    istcb2=0,
    reachinput=True,
    reach_data=reach_data,
    dataset_5=dataset_5,
    segment_data=segment_data,
    channel_geometry_data=channel_geometry_data,
)
```

Instantiate gage package for use with MODFLOW-NWT package

```
[11]: gages = [
    [1, 38, 61, 1],
    [2, 67, 62, 1],
    [3, 176, 63, 1],
    [4, 152, 64, 1],
    [5, 186, 65, 1],
    [6, 31, 66, 1],
]
files = [
    "CrnkNic.gage",
```

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```
    "CrnkNic.gag1",
    "CrnkNic.gag2",
    "CrnkNic.gag3",
    "CrnkNic.gag4",
    "CrnkNic.gag5",
    "CrnkNic.gag6",
]
gage = flopy.modflow.ModflowGage(
    mf, numgage=6, gage_data=gages, filenames=files
)
```

Instantiate linkage with mass transport routing (LMT) package for MODFLOW-NWT (generates linker file)

[12]:
```
lmt = flopy.modflow.ModflowLmt(
    mf,
    output_file_name="CrnkNic.ftl",
    output_file_header="extended",
    output_file_format="formatted",
    package_flows=["sfr"],
)
```

Write the MODFLOW input files

[13]:
```
mf.write_input()

# run the model
success, buff = mf.run_model(silent=True, report=True)
if success:
    for line in buff:
        print(line)
else:
    raise ValueError("Failed to run.")
```

```

                                  MODFLOW-NWT-SWR1
    U.S. GEOLOGICAL SURVEY MODULAR FINITE-DIFFERENCE GROUNDWATER-FLOW MODEL
                             WITH NEWTON FORMULATION
                             Version 1.3.0 07/01/2022
                    BASED ON MODFLOW-2005 Version 1.12.0 02/03/2017

                    SWR1 Version 1.05.0 03/10/2022

 Using NAME file: CrnkNic.nam
 Run start date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:31:35

 Solving:  Stress period:     1    Time step:     1    Groundwater-Flow Eqn.
 Solving:  Stress period:     2    Time step:     1    Groundwater-Flow Eqn.
 Solving:  Stress period:     3    Time step:     1    Groundwater-Flow Eqn.
 Run end date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:31:35
 Elapsed run time:  0.061 Seconds

  Normal termination of simulation
```

Now draft up MT3D-USGS input files.

[14]:
```
# Instantiate MT3D-USGS object in flopy
mt = flopy.mt3d.Mt3dms(
    modflowmodel=mf,
    modelname=modelname,
    model_ws=modelpth,
    version="mt3d-usgs",
    namefile_ext="mtnam",
    exe_name=mtexe,
    ftlfilename="CrnkNic.ftl",
    ftlfree=True,
)
```

Instantiate basic transport (BTN) package for MT3D-USGS

[15]:
```
btn = flopy.mt3d.Mt3dBtn(
    mt,
    sconc=3.7,
    ncomp=1,
    prsity=0.2,
    cinact=-1.0,
    thkmin=0.001,
    nprs=-1,
    nprobs=10,
    chkmas=True,
    nprmas=10,
    dt0=180,
    mxstrn=2500,
)
```

Instantiate advection (ADV) package for MT3D-USGS

[16]:
```
adv = flopy.mt3d.Mt3dAdv(mt, mixelm=0, percel=1.00, mxpart=5000, nadvfd=1)
```

Instatiate generalized conjugate gradient solver (GCG) package for MT3D-USGS

[17]:
```
rct = flopy.mt3d.Mt3dRct(mt, isothm=0, ireact=100, igetsc=0, rc1=0.01)
```

[18]:
```
gcg = flopy.mt3d.Mt3dGcg(
    mt, mxiter=10, iter1=50, isolve=3, ncrs=0, accl=1, cclose=1e-6, iprgcg=1
)
```

Instantiate source-sink mixing (SSM) package for MT3D-USGS

[19]:
```
# For SSM, need to set the constant head boundary conditions to the ambient concentration
# for all 1,300 constant head boundary cells.

itype = flopy.mt3d.Mt3dSsm.itype_dict()
ssm_data = {}
ssm_data[0] = [(0, 0, 0, 3.7, itype["CHD"])]
ssm_data[0].append((0, 2, 0, 3.7, itype["CHD"]))
for i in [0, 2]:
    for j in range(1, ncol):
        ssm_data[0].append((0, i, j, 3.7, itype["CHD"]))
```

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```
ssm = flopy.mt3d.Mt3dSsm(mt, stress_period_data=ssm_data)
```

Instantiate streamflow transport (SFT) package for MT3D-USGS

[20]:
```
dispsf = []
for y in range(ncol):
    if y <= 37:
        dispsf.append(0.12)
    elif y <= 104:
        dispsf.append(0.15)
    elif y <= 280:
        dispsf.append(0.24)
    elif y <= 432:
        dispsf.append(0.31)
    elif y <= 618:
        dispsf.append(0.40)
    else:
        dispsf.append(0.40)

# Enter a list of the observation points
# Each observation is taken as the last reach within the first 5 segments

seg_len = np.unique(reach_data["iseg"], return_counts=True)
obs_sf = np.cumsum(seg_len[1])
obs_sf = obs_sf.tolist()

# The last reach is not an observation point, therefore drop
obs_sf.pop(-1)

# In the first and last stress periods, concentration at the headwater is 3.7
sf_stress_period_data = {0: [0, 0, 3.7], 1: [0, 0, 11.4], 2: [0, 0, 3.7]}

gage_output = [None, None, "CrnkNic.sftobs"]

sft = flopy.mt3d.Mt3dSft(
    mt,
    nsfinit=650,
    mxsfbc=650,
    icbcsf=81,
    ioutobs=82,
    isfsolv=1,
    cclosesf=1.0e-6,
    mxitersf=10,
    crntsf=1.0,
    iprtxmd=0,
    coldsf=3.7,
    dispsf=dispsf,
    nobssf=5,
    obs_sf=obs_sf,
    sf_stress_period_data=sf_stress_period_data,
    filenames=gage_output,
```

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```
)

sft.dispsf[0].format.fortran = "(10E15.6)"
```

Write the MT3D-USGS input files and run the model.

[21]:
```
mt.write_input()
mt.run_model(silent=True, report=True)
```

[21]:
```
(False,
 ['',
  ' MT3D-USGS - Modular 3D Multi-Species Transport Model [Ver 1.1.0]   ',
  ' and based on MT3DMS. MT3D-USGS developed in cooperation by ',
  ' S.S. Papadopulos & Associates and the U.S. Geological Survey',
  '',
  ' Using NAME File: CrnkNic.mtnam',
  '',
  ' STRESS PERIOD NO.    1',
  '',
  ' TIME STEP NO.    1',
  ' FROM TIME =   0.0000     TO    30600.    ',
  '',
  ' Transport Step:    1   Step Size:   180.0     Total Elapsed Time:   180.00    ',
  ' Outer Iter.  1  Inner Iter.  1:  Max. DC =  0.4865      [K,I,J]    1    2  289',
  ' Outer Iter.  1  Inner Iter.  2:  Max. DC =  0.5960E-07  [K,I,J]    1    1   36',
  ' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
  ' Transport Step:    2   Step Size:   180.0     Total Elapsed Time:   360.00    ',
  ' Outer Iter.  1  Inner Iter.  1:  Max. DC =  0.9385      [K,I,J]    1    2  394',
  ' Outer Iter.  1  Inner Iter.  2:  Max. DC =  0.1788E-06  [K,I,J]    1    2  294',
  ' Outer Iter.  2  Inner Iter.  1:  Max. DC =  0.3934E-05  [K,I,J]    1    2  294',
  ' Outer Iter.  2  Inner Iter.  2:  Max. DC =   0.000      [K,I,J]    1    1    1',
  ' Outer Iter.  3  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
  ' Transport Step:    3   Step Size:   180.0     Total Elapsed Time:   540.00    ',
  ' Outer Iter.  1  Inner Iter.  1:  Max. DC =  0.7602      [K,I,J]    1    1    1',
  ' Outer Iter.  1  Inner Iter.  2:  Max. DC =  0.1788E-06  [K,I,J]    1    2    2',
  ' Outer Iter.  2  Inner Iter.  1:  Max. DC =  0.8884E-06  [K,I,J]    1    1  642',
  ' Transport Step:    4   Step Size:   180.0     Total Elapsed Time:   720.00    ',
  ' Outer Iter.  1  Inner Iter.  1:  Max. DC =  0.3366E-03  [K,I,J]    1    2    1',
  ' Outer Iter.  1  Inner Iter.  2:  Max. DC =  0.4657E-09  [K,I,J]    1    2    1',
  ' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
  ' Transport Step:    5   Step Size:   180.0     Total Elapsed Time:   900.00    ',
  ' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
  ' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
  ' Transport Step:    6   Step Size:   180.0     Total Elapsed Time:   1080.0    ',
  ' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
  ' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
  ' Transport Step:    7   Step Size:   180.0     Total Elapsed Time:   1260.0    ',
  ' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
  ' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
  ' Transport Step:    8   Step Size:   180.0     Total Elapsed Time:   1440.0    ',
  ' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
  ' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
  ' Transport Step:    9   Step Size:   180.0     Total Elapsed Time:   1620.0    ',
```

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```
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   10   Step Size:   180.0     Total Elapsed Time:   1800.0    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   11   Step Size:   180.0     Total Elapsed Time:   1980.0    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   12   Step Size:   180.0     Total Elapsed Time:   2160.0    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   13   Step Size:   180.0     Total Elapsed Time:   2340.0    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   14   Step Size:   180.0     Total Elapsed Time:   2520.0    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   15   Step Size:   180.0     Total Elapsed Time:   2700.0    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   16   Step Size:   180.0     Total Elapsed Time:   2880.0    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   17   Step Size:   180.0     Total Elapsed Time:   3060.0    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   18   Step Size:   180.0     Total Elapsed Time:   3240.0    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   19   Step Size:   180.0     Total Elapsed Time:   3420.0    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   20   Step Size:   180.0     Total Elapsed Time:   3600.0    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   21   Step Size:   180.0     Total Elapsed Time:   3780.0    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   22   Step Size:   180.0     Total Elapsed Time:   3960.0    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   23   Step Size:   180.0     Total Elapsed Time:   4140.0    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   24   Step Size:   180.0     Total Elapsed Time:   4320.0    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   25   Step Size:   180.0     Total Elapsed Time:   4500.0    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   26   Step Size:   180.0     Total Elapsed Time:   4680.0    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
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```
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   27   Step Size:   180.0     Total Elapsed Time:   4860.0    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   28   Step Size:   180.0     Total Elapsed Time:   5040.0    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   29   Step Size:   180.0     Total Elapsed Time:   5220.0    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   30   Step Size:   180.0     Total Elapsed Time:   5400.0    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   31   Step Size:   180.0     Total Elapsed Time:   5580.0    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   32   Step Size:   180.0     Total Elapsed Time:   5760.0    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   33   Step Size:   180.0     Total Elapsed Time:   5940.0    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   34   Step Size:   180.0     Total Elapsed Time:   6120.0    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   35   Step Size:   180.0     Total Elapsed Time:   6300.0    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   36   Step Size:   180.0     Total Elapsed Time:   6480.0    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   37   Step Size:   180.0     Total Elapsed Time:   6660.0    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   38   Step Size:   180.0     Total Elapsed Time:   6840.0    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   39   Step Size:   180.0     Total Elapsed Time:   7020.0    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   40   Step Size:   180.0     Total Elapsed Time:   7200.0    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   41   Step Size:   180.0     Total Elapsed Time:   7380.0    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   42   Step Size:   180.0     Total Elapsed Time:   7560.0    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   43   Step Size:   180.0     Total Elapsed Time:   7740.0    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
```

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```
' Transport Step:   44   Step Size:   180.0     Total Elapsed Time:   7920.0    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   45   Step Size:   180.0     Total Elapsed Time:   8100.0    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   46   Step Size:   180.0     Total Elapsed Time:   8280.0    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   47   Step Size:   180.0     Total Elapsed Time:   8460.0    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   48   Step Size:   180.0     Total Elapsed Time:   8640.0    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   49   Step Size:   180.0     Total Elapsed Time:   8820.0    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   50   Step Size:   180.0     Total Elapsed Time:   9000.0    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   51   Step Size:   180.0     Total Elapsed Time:   9180.0    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   52   Step Size:   180.0     Total Elapsed Time:   9360.0    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   53   Step Size:   180.0     Total Elapsed Time:   9540.0    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   54   Step Size:   180.0     Total Elapsed Time:   9720.0    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   55   Step Size:   180.0     Total Elapsed Time:   9900.0    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   56   Step Size:   180.0     Total Elapsed Time:   10080.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   57   Step Size:   180.0     Total Elapsed Time:   10260.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   58   Step Size:   180.0     Total Elapsed Time:   10440.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   59   Step Size:   180.0     Total Elapsed Time:   10620.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   60   Step Size:   180.0     Total Elapsed Time:   10800.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   61   Step Size:   180.0     Total Elapsed Time:   10980.    ',
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' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   62   Step Size:   180.0     Total Elapsed Time:   11160.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   63   Step Size:   180.0     Total Elapsed Time:   11340.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   64   Step Size:   180.0     Total Elapsed Time:   11520.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   65   Step Size:   180.0     Total Elapsed Time:   11700.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   66   Step Size:   180.0     Total Elapsed Time:   11880.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   67   Step Size:   180.0     Total Elapsed Time:   12060.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   68   Step Size:   180.0     Total Elapsed Time:   12240.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   69   Step Size:   180.0     Total Elapsed Time:   12420.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   70   Step Size:   180.0     Total Elapsed Time:   12600.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   71   Step Size:   180.0     Total Elapsed Time:   12780.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   72   Step Size:   180.0     Total Elapsed Time:   12960.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   73   Step Size:   180.0     Total Elapsed Time:   13140.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   74   Step Size:   180.0     Total Elapsed Time:   13320.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   75   Step Size:   180.0     Total Elapsed Time:   13500.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   76   Step Size:   180.0     Total Elapsed Time:   13680.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   77   Step Size:   180.0     Total Elapsed Time:   13860.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   78   Step Size:   180.0     Total Elapsed Time:   14040.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
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' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   79   Step Size:   180.0     Total Elapsed Time:   14220.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   80   Step Size:   180.0     Total Elapsed Time:   14400.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   81   Step Size:   180.0     Total Elapsed Time:   14580.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   82   Step Size:   180.0     Total Elapsed Time:   14760.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   83   Step Size:   180.0     Total Elapsed Time:   14940.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   84   Step Size:   180.0     Total Elapsed Time:   15120.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   85   Step Size:   180.0     Total Elapsed Time:   15300.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   86   Step Size:   180.0     Total Elapsed Time:   15480.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   87   Step Size:   180.0     Total Elapsed Time:   15660.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   88   Step Size:   180.0     Total Elapsed Time:   15840.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   89   Step Size:   180.0     Total Elapsed Time:   16020.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   90   Step Size:   180.0     Total Elapsed Time:   16200.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   91   Step Size:   180.0     Total Elapsed Time:   16380.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   92   Step Size:   180.0     Total Elapsed Time:   16560.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   93   Step Size:   180.0     Total Elapsed Time:   16740.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   94   Step Size:   180.0     Total Elapsed Time:   16920.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   95   Step Size:   180.0     Total Elapsed Time:   17100.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
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' Transport Step:   96   Step Size:   180.0     Total Elapsed Time:   17280.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   97   Step Size:   180.0     Total Elapsed Time:   17460.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   98   Step Size:   180.0     Total Elapsed Time:   17640.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   99   Step Size:   180.0     Total Elapsed Time:   17820.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:  100   Step Size:   180.0     Total Elapsed Time:   18000.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:  101   Step Size:   180.0     Total Elapsed Time:   18180.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:  102   Step Size:   180.0     Total Elapsed Time:   18360.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:  103   Step Size:   180.0     Total Elapsed Time:   18540.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:  104   Step Size:   180.0     Total Elapsed Time:   18720.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:  105   Step Size:   180.0     Total Elapsed Time:   18900.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:  106   Step Size:   180.0     Total Elapsed Time:   19080.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:  107   Step Size:   180.0     Total Elapsed Time:   19260.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:  108   Step Size:   180.0     Total Elapsed Time:   19440.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:  109   Step Size:   180.0     Total Elapsed Time:   19620.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:  110   Step Size:   180.0     Total Elapsed Time:   19800.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:  111   Step Size:   180.0     Total Elapsed Time:   19980.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:  112   Step Size:   180.0     Total Elapsed Time:   20160.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:  113   Step Size:   180.0     Total Elapsed Time:   20340.    ',
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' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:  114   Step Size:   180.0     Total Elapsed Time:   20520.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:  115   Step Size:   180.0     Total Elapsed Time:   20700.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:  116   Step Size:   180.0     Total Elapsed Time:   20880.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:  117   Step Size:   180.0     Total Elapsed Time:   21060.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:  118   Step Size:   180.0     Total Elapsed Time:   21240.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:  119   Step Size:   180.0     Total Elapsed Time:   21420.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:  120   Step Size:   180.0     Total Elapsed Time:   21600.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:  121   Step Size:   180.0     Total Elapsed Time:   21780.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:  122   Step Size:   180.0     Total Elapsed Time:   21960.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:  123   Step Size:   180.0     Total Elapsed Time:   22140.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:  124   Step Size:   180.0     Total Elapsed Time:   22320.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:  125   Step Size:   180.0     Total Elapsed Time:   22500.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:  126   Step Size:   180.0     Total Elapsed Time:   22680.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:  127   Step Size:   180.0     Total Elapsed Time:   22860.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:  128   Step Size:   180.0     Total Elapsed Time:   23040.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:  129   Step Size:   180.0     Total Elapsed Time:   23220.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:  130   Step Size:   180.0     Total Elapsed Time:   23400.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
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' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:  131   Step Size:   180.0     Total Elapsed Time:   23580.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:  132   Step Size:   180.0     Total Elapsed Time:   23760.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:  133   Step Size:   180.0     Total Elapsed Time:   23940.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:  134   Step Size:   180.0     Total Elapsed Time:   24120.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:  135   Step Size:   180.0     Total Elapsed Time:   24300.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:  136   Step Size:   180.0     Total Elapsed Time:   24480.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:  137   Step Size:   180.0     Total Elapsed Time:   24660.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:  138   Step Size:   180.0     Total Elapsed Time:   24840.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:  139   Step Size:   180.0     Total Elapsed Time:   25020.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:  140   Step Size:   180.0     Total Elapsed Time:   25200.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:  141   Step Size:   180.0     Total Elapsed Time:   25380.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:  142   Step Size:   180.0     Total Elapsed Time:   25560.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:  143   Step Size:   180.0     Total Elapsed Time:   25740.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:  144   Step Size:   180.0     Total Elapsed Time:   25920.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:  145   Step Size:   180.0     Total Elapsed Time:   26100.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:  146   Step Size:   180.0     Total Elapsed Time:   26280.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:  147   Step Size:   180.0     Total Elapsed Time:   26460.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
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' Transport Step:  148   Step Size:   180.0     Total Elapsed Time:   26640.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:  149   Step Size:   180.0     Total Elapsed Time:   26820.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:  150   Step Size:   180.0     Total Elapsed Time:   27000.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:  151   Step Size:   180.0     Total Elapsed Time:   27180.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:  152   Step Size:   180.0     Total Elapsed Time:   27360.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:  153   Step Size:   180.0     Total Elapsed Time:   27540.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:  154   Step Size:   180.0     Total Elapsed Time:   27720.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:  155   Step Size:   180.0     Total Elapsed Time:   27900.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:  156   Step Size:   180.0     Total Elapsed Time:   28080.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:  157   Step Size:   180.0     Total Elapsed Time:   28260.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:  158   Step Size:   180.0     Total Elapsed Time:   28440.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:  159   Step Size:   180.0     Total Elapsed Time:   28620.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:  160   Step Size:   180.0     Total Elapsed Time:   28800.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:  161   Step Size:   180.0     Total Elapsed Time:   28980.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:  162   Step Size:   180.0     Total Elapsed Time:   29160.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:  163   Step Size:   180.0     Total Elapsed Time:   29340.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:  164   Step Size:   180.0     Total Elapsed Time:   29520.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:  165   Step Size:   180.0     Total Elapsed Time:   29700.    ',
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' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:  166   Step Size:   180.0     Total Elapsed Time:   29880.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:  167   Step Size:   180.0     Total Elapsed Time:   30060.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:  168   Step Size:   180.0     Total Elapsed Time:   30240.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:  169   Step Size:   180.0     Total Elapsed Time:   30420.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:  170   Step Size:   180.0     Total Elapsed Time:   30600.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
'',
' STRESS PERIOD NO.    2',
'',
' TIME STEP NO.    1',
' FROM TIME =   30600.     TO    41400.    ',
'',
' Transport Step:    1   Step Size:   180.0     Total Elapsed Time:   30780.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =  0.2062E-04  [K,I,J]    1    1    1',
' Outer Iter.  1  Inner Iter.  2:  Max. DC =  0.6548E-10  [K,I,J]    1    2    3',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:    2   Step Size:   180.0     Total Elapsed Time:   30960.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:    3   Step Size:   180.0     Total Elapsed Time:   31140.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:    4   Step Size:   180.0     Total Elapsed Time:   31320.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:    5   Step Size:   180.0     Total Elapsed Time:   31500.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:    6   Step Size:   180.0     Total Elapsed Time:   31680.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:    7   Step Size:   180.0     Total Elapsed Time:   31860.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:    8   Step Size:   180.0     Total Elapsed Time:   32040.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:    9   Step Size:   180.0     Total Elapsed Time:   32220.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   10   Step Size:   180.0     Total Elapsed Time:   32400.    ',
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 ' Outer Iter.  1  Inner Iter.   1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Outer Iter.  2  Inner Iter.   1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Transport Step:   11   Step Size:   180.0     Total Elapsed Time:   32580.    ',
 ' Outer Iter.  1  Inner Iter.   1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Outer Iter.  2  Inner Iter.   1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Transport Step:   12   Step Size:   180.0     Total Elapsed Time:   32760.    ',
 ' Outer Iter.  1  Inner Iter.   1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Outer Iter.  2  Inner Iter.   1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Transport Step:   13   Step Size:   180.0     Total Elapsed Time:   32940.    ',
 ' Outer Iter.  1  Inner Iter.   1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Outer Iter.  2  Inner Iter.   1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Transport Step:   14   Step Size:   180.0     Total Elapsed Time:   33120.    ',
 ' Outer Iter.  1  Inner Iter.   1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Outer Iter.  2  Inner Iter.   1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Transport Step:   15   Step Size:   180.0     Total Elapsed Time:   33300.    ',
 ' Outer Iter.  1  Inner Iter.   1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Outer Iter.  2  Inner Iter.   1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Transport Step:   16   Step Size:   180.0     Total Elapsed Time:   33480.    ',
 ' Outer Iter.  1  Inner Iter.   1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Outer Iter.  2  Inner Iter.   1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Transport Step:   17   Step Size:   180.0     Total Elapsed Time:   33660.    ',
 ' Outer Iter.  1  Inner Iter.   1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Outer Iter.  2  Inner Iter.   1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Transport Step:   18   Step Size:   180.0     Total Elapsed Time:   33840.    ',
 ' Outer Iter.  1  Inner Iter.   1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Outer Iter.  2  Inner Iter.   1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Transport Step:   19   Step Size:   180.0     Total Elapsed Time:   34020.    ',
 ' Outer Iter.  1  Inner Iter.   1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Outer Iter.  2  Inner Iter.   1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Transport Step:   20   Step Size:   180.0     Total Elapsed Time:   34200.    ',
 ' Outer Iter.  1  Inner Iter.   1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Outer Iter.  2  Inner Iter.   1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Transport Step:   21   Step Size:   180.0     Total Elapsed Time:   34380.    ',
 ' Outer Iter.  1  Inner Iter.   1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Outer Iter.  2  Inner Iter.   1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Transport Step:   22   Step Size:   180.0     Total Elapsed Time:   34560.    ',
 ' Outer Iter.  1  Inner Iter.   1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Outer Iter.  2  Inner Iter.   1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Transport Step:   23   Step Size:   180.0     Total Elapsed Time:   34740.    ',
 ' Outer Iter.  1  Inner Iter.   1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Outer Iter.  2  Inner Iter.   1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Transport Step:   24   Step Size:   180.0     Total Elapsed Time:   34920.    ',
 ' Outer Iter.  1  Inner Iter.   1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Outer Iter.  2  Inner Iter.   1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Transport Step:   25   Step Size:   180.0     Total Elapsed Time:   35100.    ',
 ' Outer Iter.  1  Inner Iter.   1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Outer Iter.  2  Inner Iter.   1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Transport Step:   26   Step Size:   180.0     Total Elapsed Time:   35280.    ',
 ' Outer Iter.  1  Inner Iter.   1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Outer Iter.  2  Inner Iter.   1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Transport Step:   27   Step Size:   180.0     Total Elapsed Time:   35460.    ',
 ' Outer Iter.  1  Inner Iter.   1:  Max. DC =   0.000      [K,I,J]    1    1    1',
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' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   28   Step Size:   180.0     Total Elapsed Time:   35640.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   29   Step Size:   180.0     Total Elapsed Time:   35820.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   30   Step Size:   180.0     Total Elapsed Time:   36000.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   31   Step Size:   180.0     Total Elapsed Time:   36180.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   32   Step Size:   180.0     Total Elapsed Time:   36360.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   33   Step Size:   180.0     Total Elapsed Time:   36540.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   34   Step Size:   180.0     Total Elapsed Time:   36720.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   35   Step Size:   180.0     Total Elapsed Time:   36900.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   36   Step Size:   180.0     Total Elapsed Time:   37080.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   37   Step Size:   180.0     Total Elapsed Time:   37260.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   38   Step Size:   180.0     Total Elapsed Time:   37440.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   39   Step Size:   180.0     Total Elapsed Time:   37620.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   40   Step Size:   180.0     Total Elapsed Time:   37800.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   41   Step Size:   180.0     Total Elapsed Time:   37980.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   42   Step Size:   180.0     Total Elapsed Time:   38160.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   43   Step Size:   180.0     Total Elapsed Time:   38340.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   44   Step Size:   180.0     Total Elapsed Time:   38520.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
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' Transport Step:   45   Step Size:   180.0     Total Elapsed Time:   38700.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   46   Step Size:   180.0     Total Elapsed Time:   38880.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   47   Step Size:   180.0     Total Elapsed Time:   39060.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   48   Step Size:   180.0     Total Elapsed Time:   39240.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   49   Step Size:   180.0     Total Elapsed Time:   39420.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   50   Step Size:   180.0     Total Elapsed Time:   39600.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   51   Step Size:   180.0     Total Elapsed Time:   39780.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   52   Step Size:   180.0     Total Elapsed Time:   39960.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   53   Step Size:   180.0     Total Elapsed Time:   40140.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   54   Step Size:   180.0     Total Elapsed Time:   40320.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   55   Step Size:   180.0     Total Elapsed Time:   40500.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   56   Step Size:   180.0     Total Elapsed Time:   40680.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   57   Step Size:   180.0     Total Elapsed Time:   40860.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   58   Step Size:   180.0     Total Elapsed Time:   41040.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   59   Step Size:   180.0     Total Elapsed Time:   41220.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   60   Step Size:   180.0     Total Elapsed Time:   41400.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
'',
' STRESS PERIOD NO.    3',
'',
' TIME STEP NO.    1',
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' FROM TIME =   41400.     TO    86400.    ',
'',
' Transport Step:    1   Step Size:   180.0     Total Elapsed Time:   41580.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:    2   Step Size:   180.0     Total Elapsed Time:   41760.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:    3   Step Size:   180.0     Total Elapsed Time:   41940.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:    4   Step Size:   180.0     Total Elapsed Time:   42120.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:    5   Step Size:   180.0     Total Elapsed Time:   42300.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:    6   Step Size:   180.0     Total Elapsed Time:   42480.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:    7   Step Size:   180.0     Total Elapsed Time:   42660.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:    8   Step Size:   180.0     Total Elapsed Time:   42840.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:    9   Step Size:   180.0     Total Elapsed Time:   43020.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   10   Step Size:   180.0     Total Elapsed Time:   43200.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   11   Step Size:   180.0     Total Elapsed Time:   43380.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   12   Step Size:   180.0     Total Elapsed Time:   43560.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   13   Step Size:   180.0     Total Elapsed Time:   43740.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   14   Step Size:   180.0     Total Elapsed Time:   43920.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   15   Step Size:   180.0     Total Elapsed Time:   44100.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   16   Step Size:   180.0     Total Elapsed Time:   44280.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   17   Step Size:   180.0     Total Elapsed Time:   44460.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
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 ' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Transport Step:   18   Step Size:   180.0     Total Elapsed Time:   44640.    ',
 ' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Transport Step:   19   Step Size:   180.0     Total Elapsed Time:   44820.    ',
 ' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Transport Step:   20   Step Size:   180.0     Total Elapsed Time:   45000.    ',
 ' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Transport Step:   21   Step Size:   180.0     Total Elapsed Time:   45180.    ',
 ' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Transport Step:   22   Step Size:   180.0     Total Elapsed Time:   45360.    ',
 ' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Transport Step:   23   Step Size:   180.0     Total Elapsed Time:   45540.    ',
 ' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Transport Step:   24   Step Size:   180.0     Total Elapsed Time:   45720.    ',
 ' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Transport Step:   25   Step Size:   180.0     Total Elapsed Time:   45900.    ',
 ' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Transport Step:   26   Step Size:   180.0     Total Elapsed Time:   46080.    ',
 ' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Transport Step:   27   Step Size:   180.0     Total Elapsed Time:   46260.    ',
 ' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Transport Step:   28   Step Size:   180.0     Total Elapsed Time:   46440.    ',
 ' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Transport Step:   29   Step Size:   180.0     Total Elapsed Time:   46620.    ',
 ' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Transport Step:   30   Step Size:   180.0     Total Elapsed Time:   46800.    ',
 ' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Transport Step:   31   Step Size:   180.0     Total Elapsed Time:   46980.    ',
 ' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Transport Step:   32   Step Size:   180.0     Total Elapsed Time:   47160.    ',
 ' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Transport Step:   33   Step Size:   180.0     Total Elapsed Time:   47340.    ',
 ' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Transport Step:   34   Step Size:   180.0     Total Elapsed Time:   47520.    ',
 ' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
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 ' Transport Step:   35   Step Size:   180.0     Total Elapsed Time:   47700.    ',
 ' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Transport Step:   36   Step Size:   180.0     Total Elapsed Time:   47880.    ',
 ' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Transport Step:   37   Step Size:   180.0     Total Elapsed Time:   48060.    ',
 ' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Transport Step:   38   Step Size:   180.0     Total Elapsed Time:   48240.    ',
 ' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Transport Step:   39   Step Size:   180.0     Total Elapsed Time:   48420.    ',
 ' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Transport Step:   40   Step Size:   180.0     Total Elapsed Time:   48600.    ',
 ' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Transport Step:   41   Step Size:   180.0     Total Elapsed Time:   48780.    ',
 ' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Transport Step:   42   Step Size:   180.0     Total Elapsed Time:   48960.    ',
 ' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Transport Step:   43   Step Size:   180.0     Total Elapsed Time:   49140.    ',
 ' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Transport Step:   44   Step Size:   180.0     Total Elapsed Time:   49320.    ',
 ' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Transport Step:   45   Step Size:   180.0     Total Elapsed Time:   49500.    ',
 ' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Transport Step:   46   Step Size:   180.0     Total Elapsed Time:   49680.    ',
 ' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Transport Step:   47   Step Size:   180.0     Total Elapsed Time:   49860.    ',
 ' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Transport Step:   48   Step Size:   180.0     Total Elapsed Time:   50040.    ',
 ' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Transport Step:   49   Step Size:   180.0     Total Elapsed Time:   50220.    ',
 ' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Transport Step:   50   Step Size:   180.0     Total Elapsed Time:   50400.    ',
 ' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Transport Step:   51   Step Size:   180.0     Total Elapsed Time:   50580.    ',
 ' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Transport Step:   52   Step Size:   180.0     Total Elapsed Time:   50760.    ',
```

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```
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   53   Step Size:   180.0     Total Elapsed Time:   50940.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   54   Step Size:   180.0     Total Elapsed Time:   51120.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   55   Step Size:   180.0     Total Elapsed Time:   51300.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   56   Step Size:   180.0     Total Elapsed Time:   51480.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   57   Step Size:   180.0     Total Elapsed Time:   51660.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   58   Step Size:   180.0     Total Elapsed Time:   51840.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   59   Step Size:   180.0     Total Elapsed Time:   52020.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   60   Step Size:   180.0     Total Elapsed Time:   52200.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   61   Step Size:   180.0     Total Elapsed Time:   52380.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   62   Step Size:   180.0     Total Elapsed Time:   52560.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   63   Step Size:   180.0     Total Elapsed Time:   52740.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   64   Step Size:   180.0     Total Elapsed Time:   52920.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   65   Step Size:   180.0     Total Elapsed Time:   53100.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   66   Step Size:   180.0     Total Elapsed Time:   53280.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   67   Step Size:   180.0     Total Elapsed Time:   53460.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   68   Step Size:   180.0     Total Elapsed Time:   53640.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   69   Step Size:   180.0     Total Elapsed Time:   53820.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
```

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```
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   70   Step Size:   180.0     Total Elapsed Time:   54000.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   71   Step Size:   180.0     Total Elapsed Time:   54180.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   72   Step Size:   180.0     Total Elapsed Time:   54360.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   73   Step Size:   180.0     Total Elapsed Time:   54540.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   74   Step Size:   180.0     Total Elapsed Time:   54720.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   75   Step Size:   180.0     Total Elapsed Time:   54900.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   76   Step Size:   180.0     Total Elapsed Time:   55080.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   77   Step Size:   180.0     Total Elapsed Time:   55260.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   78   Step Size:   180.0     Total Elapsed Time:   55440.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   79   Step Size:   180.0     Total Elapsed Time:   55620.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   80   Step Size:   180.0     Total Elapsed Time:   55800.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   81   Step Size:   180.0     Total Elapsed Time:   55980.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   82   Step Size:   180.0     Total Elapsed Time:   56160.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   83   Step Size:   180.0     Total Elapsed Time:   56340.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   84   Step Size:   180.0     Total Elapsed Time:   56520.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   85   Step Size:   180.0     Total Elapsed Time:   56700.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Transport Step:   86   Step Size:   180.0     Total Elapsed Time:   56880.    ',
' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
```

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```
 ' Transport Step:   87   Step Size:   180.0     Total Elapsed Time:   57060.    ',
 ' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Transport Step:   88   Step Size:   180.0     Total Elapsed Time:   57240.    ',
 ' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Transport Step:   89   Step Size:   180.0     Total Elapsed Time:   57420.    ',
 ' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Transport Step:   90   Step Size:   180.0     Total Elapsed Time:   57600.    ',
 ' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Transport Step:   91   Step Size:   180.0     Total Elapsed Time:   57780.    ',
 ' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Transport Step:   92   Step Size:   180.0     Total Elapsed Time:   57960.    ',
 ' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Transport Step:   93   Step Size:   180.0     Total Elapsed Time:   58140.    ',
 ' Outer Iter.  1  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ' Outer Iter.  2  Inner Iter.  1:  Max. DC =   0.000      [K,I,J]    1    1    1',
 ...])
```

Compare mt3d-usgs results to an analytical solution

[22]:
```
# Define a function to read SFT output file
def load_ts_from_SFT_output(fname, nd=1):
    f = open(fname)
    iline = 0
    lst = []
    for line in f:
        if line.strip().split()[0].replace(".", "", 1).isdigit():
            l = line.strip().split()
            t = float(l[0])
            loc = int(l[1])
            conc = float(l[2])
            if loc == nd:
                lst.append([t, conc])

    ts = np.array(lst)
    f.close()
    return ts


# Also define a function to read OTIS output file
def load_ts_from_otis(fname, iobs=1):
    f = open(fname)
    iline = 0
    lst = []
    for line in f:
```

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```
        l = line.strip().split()
        t = float(l[0])
        val = float(l[iobs])
        lst.append([t, val])

    ts = np.array(lst)
    f.close()
    return ts
```

Load output from SFT as well as from the OTIS solution

[23]:
```
# Model output
fname_SFTout = os.path.join(modelpth, "CrnkNic.sftcobs.out")

# Loading MT3D-USGS output
ts1_mt3d = load_ts_from_SFT_output(fname_SFTout, nd=38)
ts2_mt3d = load_ts_from_SFT_output(fname_SFTout, nd=105)
ts3_mt3d = load_ts_from_SFT_output(fname_SFTout, nd=281)
ts4_mt3d = load_ts_from_SFT_output(fname_SFTout, nd=433)
ts5_mt3d = load_ts_from_SFT_output(fname_SFTout, nd=619)

# OTIS results located here
fname_OTIS = "../../examples/data/mt3d_test/mfnwt_mt3dusgs/sft_crnkNic/OTIS_solution.out"

# Loading OTIS output
ts1_Otis = load_ts_from_otis(fname_OTIS, 1)
ts2_Otis = load_ts_from_otis(fname_OTIS, 2)
ts3_Otis = load_ts_from_otis(fname_OTIS, 3)
ts4_Otis = load_ts_from_otis(fname_OTIS, 4)
ts5_Otis = load_ts_from_otis(fname_OTIS, 5)
```

Set up some plotting functions

[24]:
```
def set_plot_params():
    import matplotlib as mpl
    from matplotlib.font_manager import FontProperties

    mpl.rcParams["font.sans-serif"] = "Arial"
    mpl.rcParams["font.serif"] = "Times"
    mpl.rcParams["font.cursive"] = "Zapf Chancery"
    mpl.rcParams["font.fantasy"] = "Comic Sans MS"
    mpl.rcParams["font.monospace"] = "Courier New"
    mpl.rcParams["pdf.compression"] = 0
    mpl.rcParams["pdf.fonttype"] = 42

    ticksize = 10
    mpl.rcParams["legend.fontsize"] = 7
    mpl.rcParams["axes.labelsize"] = 12
    mpl.rcParams["xtick.labelsize"] = ticksize
    mpl.rcParams["ytick.labelsize"] = ticksize
    return
```

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```
def set_sizexaxis(a, fmt, sz):
    success = 0
    x = a.get_xticks()
    #   print x
    xc = np.chararray(len(x), itemsize=16)
    for i in range(0, len(x)):
        text = fmt % (x[i])
        xc[i] = string.strip(string.ljust(text, 16))
    #   print xc
    a.set_xticklabels(xc, size=sz)
    success = 1
    return success


def set_sizeyaxis(a, fmt, sz):
    success = 0
    y = a.get_yticks()
    #   print y
    yc = np.chararray(len(y), itemsize=16)
    for i in range(0, len(y)):
        text = fmt % (y[i])
        yc[i] = string.strip(string.ljust(text, 16))
    #   print yc
    a.set_yticklabels(yc, size=sz)
    success = 1
    return success
```

Compare output:

[25]:
```
# set up figure
try:
    plt.close("all")
except:
    pass

set_plot_params()

fig = plt.figure(figsize=(6, 4), facecolor="w")
ax = fig.add_subplot(1, 1, 1)

ax.plot(ts1_Otis[:, 0], ts1_Otis[:, 1], "k-", linewidth=1.0)
ax.plot(ts2_Otis[:, 0], ts2_Otis[:, 1], "b-", linewidth=1.0)
ax.plot(ts3_Otis[:, 0], ts3_Otis[:, 1], "r-", linewidth=1.0)
ax.plot(ts4_Otis[:, 0], ts4_Otis[:, 1], "g-", linewidth=1.0)
ax.plot(ts5_Otis[:, 0], ts5_Otis[:, 1], "c-", linewidth=1.0)

ax.plot(
    (ts1_mt3d[:, 0]) / 3600,
    ts1_mt3d[:, 1],
    "kD",
    markersize=2.0,
```

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```
    mfc="none",
    mec="k",
)
ax.plot(
    (ts2_mt3d[:, 0]) / 3600,
    ts2_mt3d[:, 1],
    "b*",
    markersize=3.0,
    mfc="none",
    mec="b",
)
ax.plot((ts3_mt3d[:, 0]) / 3600, ts3_mt3d[:, 1], "r+", markersize=3.0)
ax.plot(
    (ts4_mt3d[:, 0]) / 3600,
    ts4_mt3d[:, 1],
    "g^",
    markersize=2.0,
    mfc="none",
    mec="g",
)
ax.plot(
    (ts5_mt3d[:, 0]) / 3600,
    ts5_mt3d[:, 1],
    "co",
    markersize=2.0,
    mfc="none",
    mec="c",
)

# customize plot
ax.set_xlabel("Time, hours")
ax.set_ylabel("Concentration, mg L-1")
ax.set_ylim([3.5, 13])
ticksize = 10

# legend
leg = ax.legend(
    (
        "Otis, Site 1",
        "Otis, Site 2",
        "Otis, Site 3",
        "Otis, Site 4",
        "Otis, Site 5",
        "MT3D-USGS, Site 1",
        "MT3D-USGS, Site 2",
        "MT3D-USGS, Site 3",
        "MT3D-USGS, Site 4",
        "MT3D-USGS, Site 5",
    ),
    loc="upper right",
    labelspacing=0.25,
    columnspacing=1,
```

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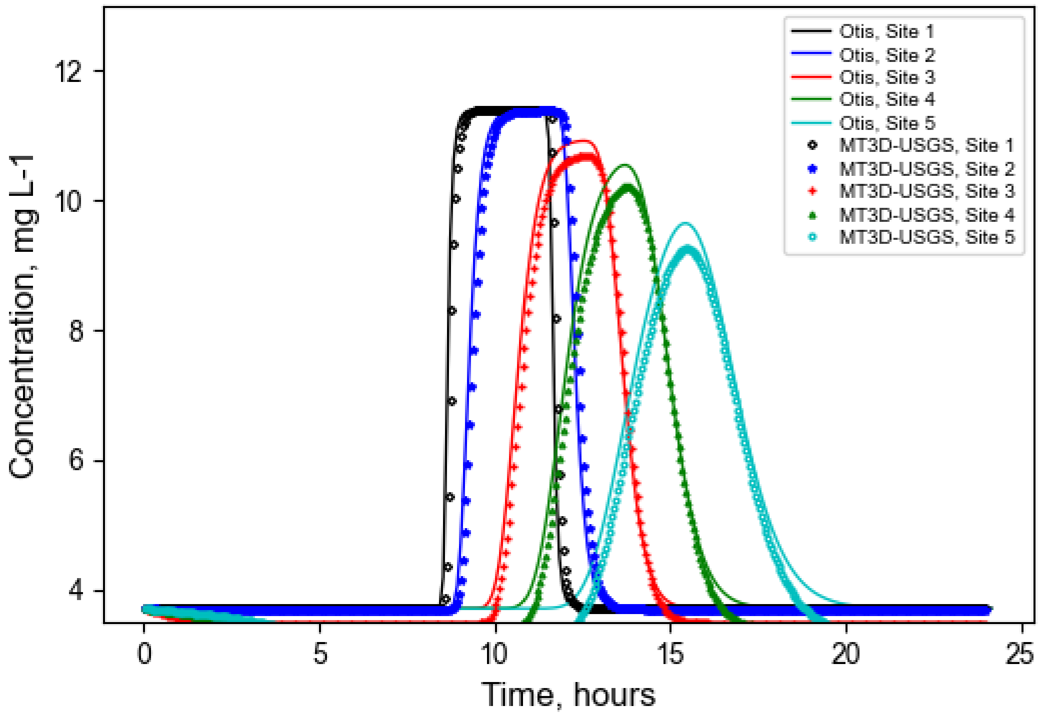
```
    handletextpad=0.5,
    handlelength=2.0,
    numpoints=1,
)
leg._drawFrame = False

plt.show()
```



[26]:
```
try:
    # ignore PermissionError on Windows
    temp_dir.cleanup()
except:
    pass
```

6.9.2 MT3DMS Example Problems

The purpose of this notebook is to recreate the example problems that are described in the 1999 MT3DMS report.

There are 10 example problems: 1. One-Dimensional Transport in a Uniform Flow Field 2. One-Dimensional Transport with Nonlinear or Nonequilibrium Sorption 3. Two-Dimensional Transport in a Uniform Flow Field 4. Two-Dimensional Transport in a Diagonal Flow Field 5. Two-Dimensional Transport in a Radial Flow Field 6. Concentration at an Injection/Extraction Well 7. Three-Dimensional Transport in a Uniform Flow Field 8. Two-Dimensional, Vertical Transport in a Heterogeneous Aquifer 9. Two-Dimensional Application Example 10. Three-Dimensional Field Case Study

[1]:
```
import os
```

[2]:
```python
import sys
from tempfile import TemporaryDirectory

import matplotlib as mpl
import matplotlib.pyplot as plt
import numpy as np

# run installed version of flopy or add local path
try:
    import flopy
except:
    fpth = os.path.abspath(os.path.join("..", ".."))
    sys.path.append(fpth)
    import flopy

from flopy.utils.util_array import read1d

mpl.rcParams["figure.figsize"] = (8, 8)

exe_name_mf = "mf2005"
exe_name_mt = "mt3dms"
datadir = os.path.join("..", "..", "examples", "data", "mt3d_test", "mt3dms")

# temporary directory
temp_dir = TemporaryDirectory()
workdir = temp_dir.name

print(sys.version)
print(f"numpy version: {np.__version__}")
print(f"matplotlib version: {mpl.__version__}")
print(f"flopy version: {flopy.__version__}")
```

```
3.8.18 (default, Aug 28 2023, 08:27:22)
[GCC 11.4.0]
numpy version: 1.24.4
matplotlib version: 3.7.4
flopy version: 3.5.0
```

Example 1. One-Dimensional Transport in a Uniform Flow Field

This example has 4 cases: * Case 1a: Advection only * Case 1b: Advection and dispersion * Case 1c: Advection, dispersion, and sorption * Case 1d: Advection, dispersion, sorption, and decay

[3]:
```python
def p01(dirname, al, retardation, lambda1, mixelm):
    model_ws = os.path.join(workdir, dirname)
    nlay = 1
    nrow = 1
    ncol = 101
    delr = 10
    delc = 1
    delv = 1
    Lx = (ncol - 1) * delr
```

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```
    v = 0.24
    prsity = 0.25
    q = v * prsity

    perlen = 2000.0
    hk = 1.0
    laytyp = 0
    rhob = 0.25
    kd = (retardation - 1.0) * prsity / rhob

    modelname_mf = f"{dirname}_mf"
    mf = flopy.modflow.Modflow(
        modelname=modelname_mf, model_ws=model_ws, exe_name=exe_name_mf
    )
    dis = flopy.modflow.ModflowDis(
        mf,
        nlay=nlay,
        nrow=nrow,
        ncol=ncol,
        delr=delr,
        delc=delc,
        top=0.0,
        botm=[0 - delv],
        perlen=perlen,
    )
    ibound = np.ones((nlay, nrow, ncol), dtype=int)
    ibound[0, 0, 0] = -1
    ibound[0, 0, -1] = -1
    strt = np.zeros((nlay, nrow, ncol), dtype=float)
    h1 = q * Lx
    strt[0, 0, 0] = h1
    bas = flopy.modflow.ModflowBas(mf, ibound=ibound, strt=strt)
    lpf = flopy.modflow.ModflowLpf(mf, hk=hk, laytyp=laytyp)
    pcg = flopy.modflow.ModflowPcg(mf)
    lmt = flopy.modflow.ModflowLmt(mf)
    mf.write_input()
    success, buff = mf.run_model(silent=True, report=True)
    if success:
        for line in buff:
            print(line)
    else:
        raise ValueError("Failed to run.")

    modelname_mt = f"{dirname}_mt"
    mt = flopy.mt3d.Mt3dms(
        modelname=modelname_mt,
        model_ws=model_ws,
        exe_name=exe_name_mt,
        modflowmodel=mf,
    )
    c0 = 1.0
    icbund = np.ones((nlay, nrow, ncol), dtype=int)
```

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```
    icbund[0, 0, 0] = -1
    sconc = np.zeros((nlay, nrow, ncol), dtype=float)
    sconc[0, 0, 0] = c0
    btn = flopy.mt3d.Mt3dBtn(mt, icbund=icbund, prsity=prsity, sconc=sconc)
    dceps = 1.0e-5
    nplane = 1
    npl = 0
    nph = 4
    npmin = 0
    npmax = 8
    nlsink = nplane
    npsink = nph
    adv = flopy.mt3d.Mt3dAdv(
        mt,
        mixelm=mixelm,
        dceps=dceps,
        nplane=nplane,
        npl=npl,
        nph=nph,
        npmin=npmin,
        npmax=npmax,
        nlsink=nlsink,
        npsink=npsink,
        percel=0.5,
    )
    dsp = flopy.mt3d.Mt3dDsp(mt, al=al)
    rct = flopy.mt3d.Mt3dRct(
        mt,
        isothm=1,
        ireact=1,
        igetsc=0,
        rhob=rhob,
        sp1=kd,
        rc1=lambda1,
        rc2=lambda1,
    )
    ssm = flopy.mt3d.Mt3dSsm(mt)
    gcg = flopy.mt3d.Mt3dGcg(mt)
    mt.write_input()
    fname = os.path.join(model_ws, "MT3D001.UCN")
    if os.path.isfile(fname):
        os.remove(fname)
    mt.run_model(silent=True)

    fname = os.path.join(model_ws, "MT3D001.UCN")
    ucnobj = flopy.utils.UcnFile(fname)
    times = ucnobj.get_times()
    conc = ucnobj.get_alldata()

    fname = os.path.join(model_ws, "MT3D001.OBS")
    if os.path.isfile(fname):
        cvt = mt.load_obs(fname)
```

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```
    else:
        cvt = None

    fname = os.path.join(model_ws, "MT3D001.MAS")
    mvt = mt.load_mas(fname)

    return mf, mt, conc, cvt, mvt
```

[4]:

```
mf, mt, conc, cvt, mvt = p01("case1a", 0, 1, 0, 1)
x = mf.modelgrid.xcellcenters.ravel()
y = conc[0, 0, 0, :]
plt.plot(x, y, label="Case 1a")

mf, mt, conc, cvt, mvt = p01("case1b", 10, 1, 0, 1)
y = conc[0, 0, 0, :]
plt.plot(x, y, label="Case 1b")

mf, mt, conc, cvt, mvt = p01("case1c", 10, 5, 0, 2)
y = conc[0, 0, 0, :]
plt.plot(x, y, label="Case 1c")

mf, mt, conc, cvt, mvt = p01("case1d", 10, 5, 0.002, 2)
y = conc[0, 0, 0, :]
plt.plot(x, y, label="Case 1d")

plt.xlim(0, 1000)
plt.ylim(0, 1.2)
plt.xlabel("DISTANCE, IN METERS")
plt.ylabel("NORMALIZED CONCENTRATION, UNITLESS")
plt.legend()
```

```
                                  MODFLOW-2005
    U.S. GEOLOGICAL SURVEY MODULAR FINITE-DIFFERENCE GROUND-WATER FLOW MODEL
                             Version 1.12.00 2/3/2017

 Using NAME file: case1a_mf.nam
 Run start date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:31:17

 Solving:  Stress period:     1    Time step:     1    Ground-Water Flow Eqn.
 Run end date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:31:17
 Elapsed run time:  0.002 Seconds

  Normal termination of simulation

                                  MODFLOW-2005
    U.S. GEOLOGICAL SURVEY MODULAR FINITE-DIFFERENCE GROUND-WATER FLOW MODEL
                             Version 1.12.00 2/3/2017

 Using NAME file: case1b_mf.nam
 Run start date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:31:17
```

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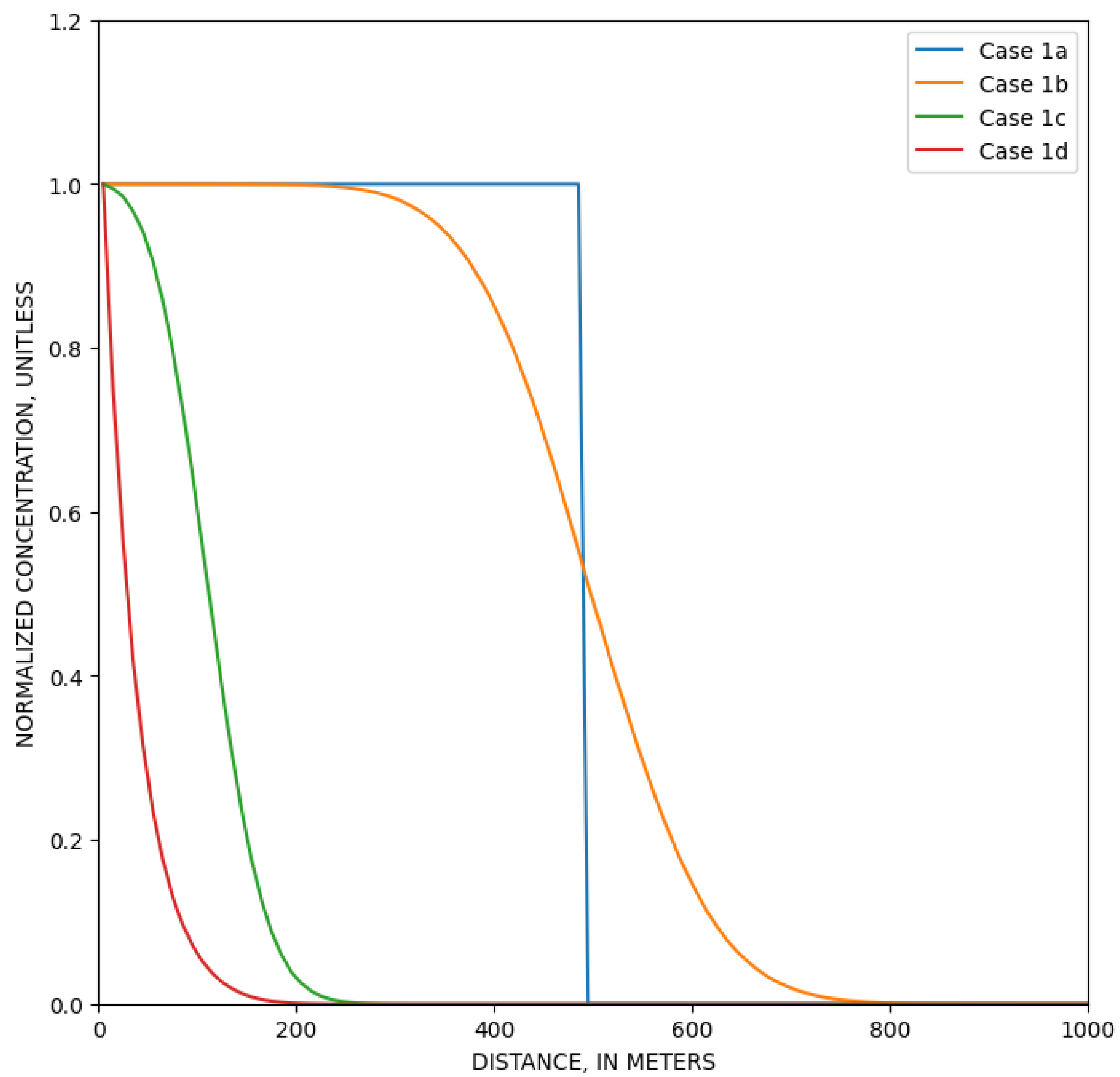
```
Solving:  Stress period:     1    Time step:     1    Ground-Water Flow Eqn.
Run end date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:31:17
Elapsed run time:  0.001 Seconds

 Normal termination of simulation

                                  MODFLOW-2005
   U.S. GEOLOGICAL SURVEY MODULAR FINITE-DIFFERENCE GROUND-WATER FLOW MODEL
                             Version 1.12.00 2/3/2017

Using NAME file: case1c_mf.nam
Run start date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:31:17

Solving:  Stress period:     1    Time step:     1    Ground-Water Flow Eqn.
Run end date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:31:17
Elapsed run time:  0.001 Seconds

 Normal termination of simulation

                                  MODFLOW-2005
   U.S. GEOLOGICAL SURVEY MODULAR FINITE-DIFFERENCE GROUND-WATER FLOW MODEL
                             Version 1.12.00 2/3/2017

Using NAME file: case1d_mf.nam
Run start date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:31:17

Solving:  Stress period:     1    Time step:     1    Ground-Water Flow Eqn.
Run end date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:31:17
Elapsed run time:  0.001 Seconds

 Normal termination of simulation
```

[4]:
```
<matplotlib.legend.Legend at 0x7f3003f0e100>
```



[5]:
```
mf, mt, conc, cvt, mvt = p01("case1e", 0, 1, 0, 1)
y = conc[0, 0, 0, :]
plt.plot(x, y, label="MOC")

mf, mt, conc, cvt, mvt = p01("case1f", 0, 1, 0, -1)
y = conc[0, 0, 0, :]
plt.plot(x, y, label="ULTIMATE")

mf, mt, conc, cvt, mvt = p01("case1g", 0, 1, 0, 0)
y = conc[0, 0, 0, :]
plt.plot(x, y, label="Upstream FD")

plt.xlim(0, 1000)
```

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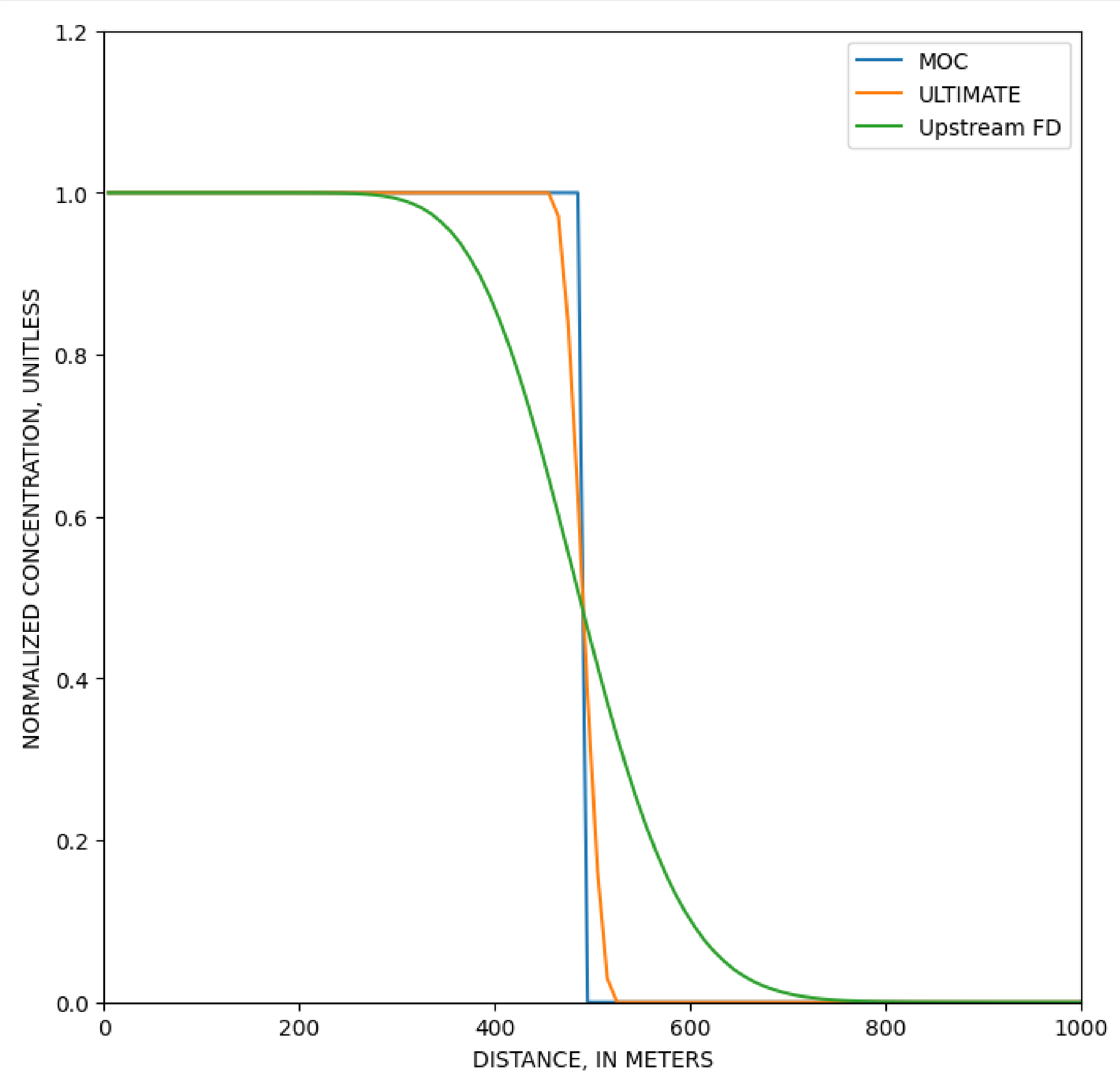
```
plt.ylim(0, 1.2)
plt.xlabel("DISTANCE, IN METERS")
plt.ylabel("NORMALIZED CONCENTRATION, UNITLESS")
plt.legend()
```

```
                                  MODFLOW-2005
    U.S. GEOLOGICAL SURVEY MODULAR FINITE-DIFFERENCE GROUND-WATER FLOW MODEL
                             Version 1.12.00 2/3/2017

 Using NAME file: case1e_mf.nam
 Run start date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:31:17

 Solving:  Stress period:     1    Time step:     1    Ground-Water Flow Eqn.
 Run end date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:31:17
 Elapsed run time:  0.001 Seconds

  Normal termination of simulation

                                  MODFLOW-2005
    U.S. GEOLOGICAL SURVEY MODULAR FINITE-DIFFERENCE GROUND-WATER FLOW MODEL
                             Version 1.12.00 2/3/2017

 Using NAME file: case1f_mf.nam
 Run start date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:31:17

 Solving:  Stress period:     1    Time step:     1    Ground-Water Flow Eqn.
 Run end date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:31:17
 Elapsed run time:  0.001 Seconds

  Normal termination of simulation

                                  MODFLOW-2005
    U.S. GEOLOGICAL SURVEY MODULAR FINITE-DIFFERENCE GROUND-WATER FLOW MODEL
                             Version 1.12.00 2/3/2017

 Using NAME file: case1g_mf.nam
 Run start date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:31:17

 Solving:  Stress period:     1    Time step:     1    Ground-Water Flow Eqn.
 Run end date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:31:17
 Elapsed run time:  0.001 Seconds

  Normal termination of simulation
```

[5]:
```
<matplotlib.legend.Legend at 0x7f3003f61850>
```



[6]:

```
mf, mt, conc, cvt, mvt = p01("case1e", 10, 1, 0, 1)
y = conc[0, 0, 0, :]
plt.plot(x, y, label="MOC")

mf, mt, conc, cvt, mvt = p01("case1f", 10, 1, 0, -1)
y = conc[0, 0, 0, :]
plt.plot(x, y, label="ULTIMATE")

mf, mt, conc, cvt, mvt = p01("case1g", 10, 1, 0, 0)
y = conc[0, 0, 0, :]
plt.plot(x, y, label="Upstream FD")

plt.xlim(0, 1000)
```

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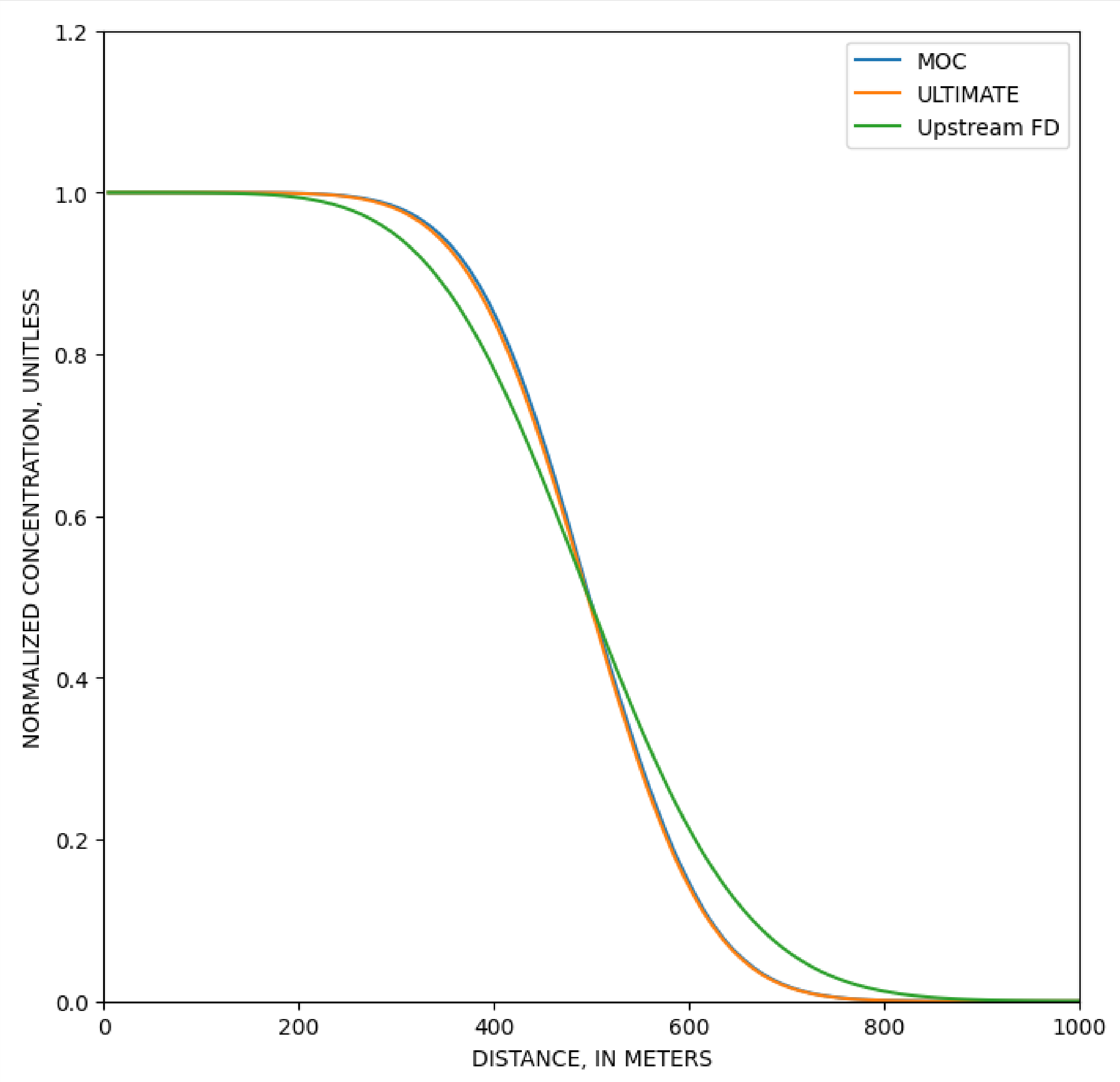
```
plt.ylim(0, 1.2)
plt.xlabel("DISTANCE, IN METERS")
plt.ylabel("NORMALIZED CONCENTRATION, UNITLESS")
plt.legend()
```

```
                                  MODFLOW-2005
    U.S. GEOLOGICAL SURVEY MODULAR FINITE-DIFFERENCE GROUND-WATER FLOW MODEL
                             Version 1.12.00 2/3/2017

 Using NAME file: case1e_mf.nam
 Run start date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:31:17

 Solving:  Stress period:     1    Time step:     1    Ground-Water Flow Eqn.
 Run end date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:31:17
 Elapsed run time:  0.001 Seconds

  Normal termination of simulation

                                  MODFLOW-2005
    U.S. GEOLOGICAL SURVEY MODULAR FINITE-DIFFERENCE GROUND-WATER FLOW MODEL
                             Version 1.12.00 2/3/2017

 Using NAME file: case1f_mf.nam
 Run start date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:31:17

 Solving:  Stress period:     1    Time step:     1    Ground-Water Flow Eqn.
 Run end date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:31:17
 Elapsed run time:  0.001 Seconds

  Normal termination of simulation

                                  MODFLOW-2005
    U.S. GEOLOGICAL SURVEY MODULAR FINITE-DIFFERENCE GROUND-WATER FLOW MODEL
                             Version 1.12.00 2/3/2017

 Using NAME file: case1g_mf.nam
 Run start date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:31:17

 Solving:  Stress period:     1    Time step:     1    Ground-Water Flow Eqn.
 Run end date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:31:17
 Elapsed run time:  0.001 Seconds

  Normal termination of simulation
```

```
[6]: <matplotlib.legend.Legend at 0x7f3024925b80>
```



Example 2. One-Dimensional Transport with Nonlinear or Nonequilibrium Sorption

[7]:
```
def p02(dirname, isothm, sp1, sp2, mixelm):
    model_ws = os.path.join(workdir, dirname)
    nlay = 1
    nrow = 1
    ncol = 101
    delr = 0.16
    delc = 1
    delv = 1
    Lx = (ncol - 1) * delr
    v = 0.1
```

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```
    prsity = 0.37
    q = v * prsity

    perlen_mf = 1.0
    perlen_mt = [160, 1320]
    hk = 1.0
    laytyp = 0
    rhob = 1.587

    modelname_mf = f"{dirname}_mf"
    mf = flopy.modflow.Modflow(
        modelname=modelname_mf, model_ws=model_ws, exe_name=exe_name_mf
    )
    dis = flopy.modflow.ModflowDis(
        mf,
        nlay=nlay,
        nrow=nrow,
        ncol=ncol,
        delr=delr,
        delc=delc,
        top=0.0,
        botm=[0 - delv],
        perlen=perlen_mf,
    )
    ibound = np.ones((nlay, nrow, ncol), dtype=int)
    ibound[0, 0, 0] = -1
    ibound[0, 0, -1] = -1
    strt = np.zeros((nlay, nrow, ncol), dtype=float)
    h1 = q * Lx
    strt[0, 0, 0] = h1
    bas = flopy.modflow.ModflowBas(mf, ibound=ibound, strt=strt)
    lpf = flopy.modflow.ModflowLpf(mf, hk=hk, laytyp=laytyp)
    pcg = flopy.modflow.ModflowPcg(mf)
    lmt = flopy.modflow.ModflowLmt(mf)
    mf.write_input()
    mf.run_model(silent=True)

    modelname_mt = f"{dirname}_mt"
    mt = flopy.mt3d.Mt3dms(
        modelname=modelname_mt,
        model_ws=model_ws,
        exe_name=exe_name_mt,
        modflowmodel=mf,
    )
    btn = flopy.mt3d.Mt3dBtn(
        mt,
        icbund=1,
        prsity=prsity,
        sconc=0,
        nper=2,
        perlen=perlen_mt,
        obs=[(0, 0, 50)],
```

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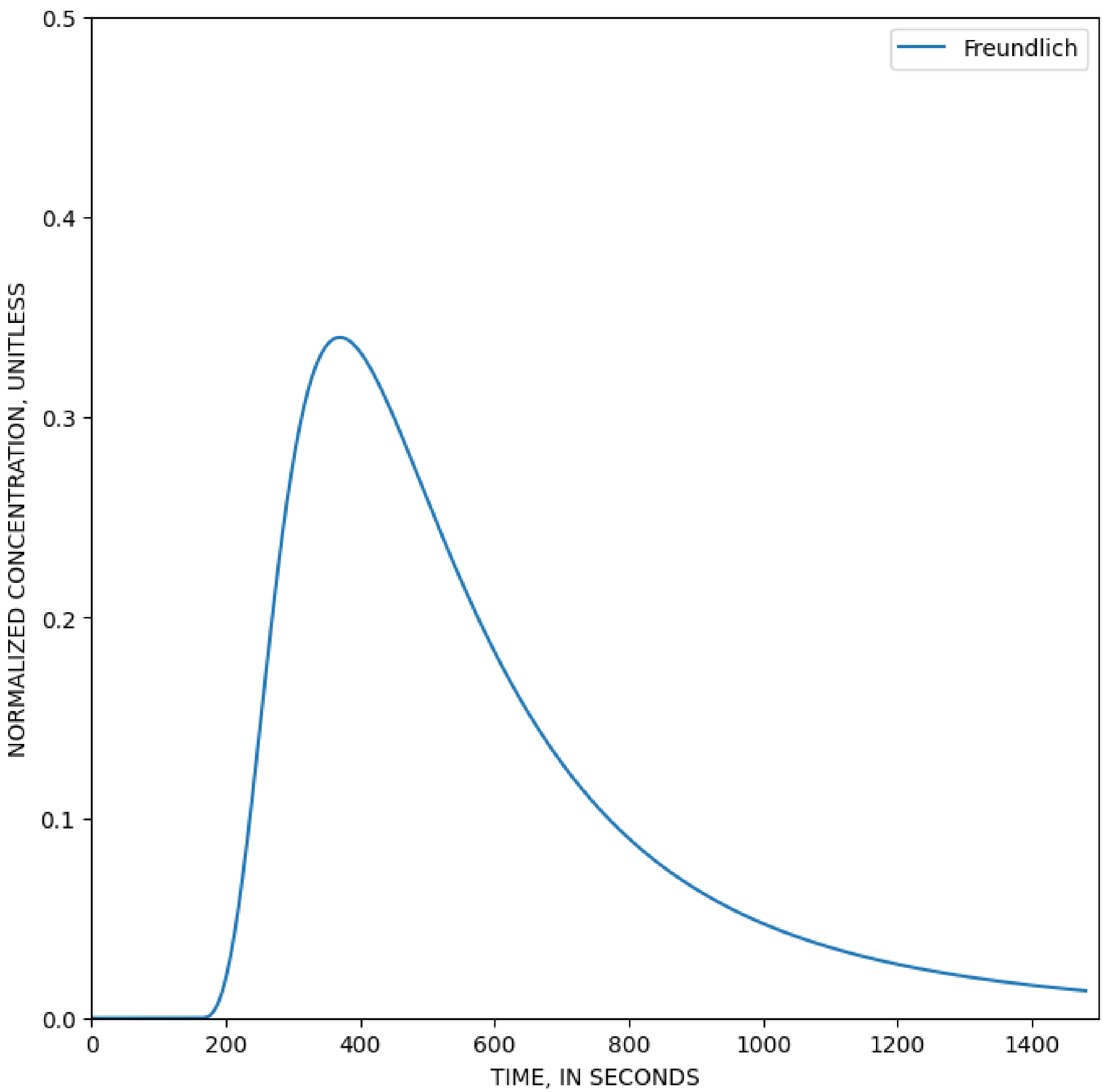
```
    )
    dceps = 1.0e-5
    nplane = 1
    npl = 0
    nph = 4
    npmin = 0
    npmax = 8
    nlsink = nplane
    npsink = nph
    adv = flopy.mt3d.Mt3dAdv(
        mt,
        mixelm=mixelm,
        dceps=dceps,
        nplane=nplane,
        npl=npl,
        nph=nph,
        npmin=npmin,
        npmax=npmax,
        nlsink=nlsink,
        npsink=npsink,
        percel=0.5,
    )
    al = 1.0
    dsp = flopy.mt3d.Mt3dDsp(mt, al=al)
    rct = flopy.mt3d.Mt3dRct(
        mt, isothm=isothm, ireact=0, igetsc=0, rhob=rhob, sp1=sp1, sp2=sp2
    )
    c0 = 0.05
    spd = {0: [0, 0, 0, c0, 1], 1: [0, 0, 0, 0.0, 1]}
    ssm = flopy.mt3d.Mt3dSsm(mt, stress_period_data=spd)
    gcg = flopy.mt3d.Mt3dGcg(mt)
    mt.write_input()
    fname = os.path.join(model_ws, "MT3D001.UCN")
    if os.path.isfile(fname):
        os.remove(fname)
    mt.run_model(silent=True)

    fname = os.path.join(model_ws, "MT3D001.UCN")
    ucnobj = flopy.utils.UcnFile(fname)
    times = ucnobj.get_times()
    conc = ucnobj.get_alldata()

    fname = os.path.join(model_ws, "MT3D001.OBS")
    if os.path.isfile(fname):
        cvt = mt.load_obs(fname)
    else:
        cvt = None

    fname = os.path.join(model_ws, "MT3D001.MAS")
    mvt = mt.load_mas(fname)

    return mf, mt, conc, cvt, mvt
```

[8]:
```
mf, mt, conc, cvt, mvt = p02("freundlich", 2, 0.3, 0.7, -1)
x = cvt["time"]
y = cvt["(1, 1, 51)"] / 0.05
plt.plot(x, y, label="Freundlich")
plt.xlim(0, 1500)
plt.ylim(0, 0.5)
plt.xlabel("TIME, IN SECONDS")
plt.ylabel("NORMALIZED CONCENTRATION, UNITLESS")
plt.legend()
```

[8]:
```
<matplotlib.legend.Legend at 0x7f3003ba3f40>
```



[9]:
```
mf, mt, conc, cvt, mvt = p02("langmuir", 3, 100.0, 0.003, -1)
x = cvt["time"]
```

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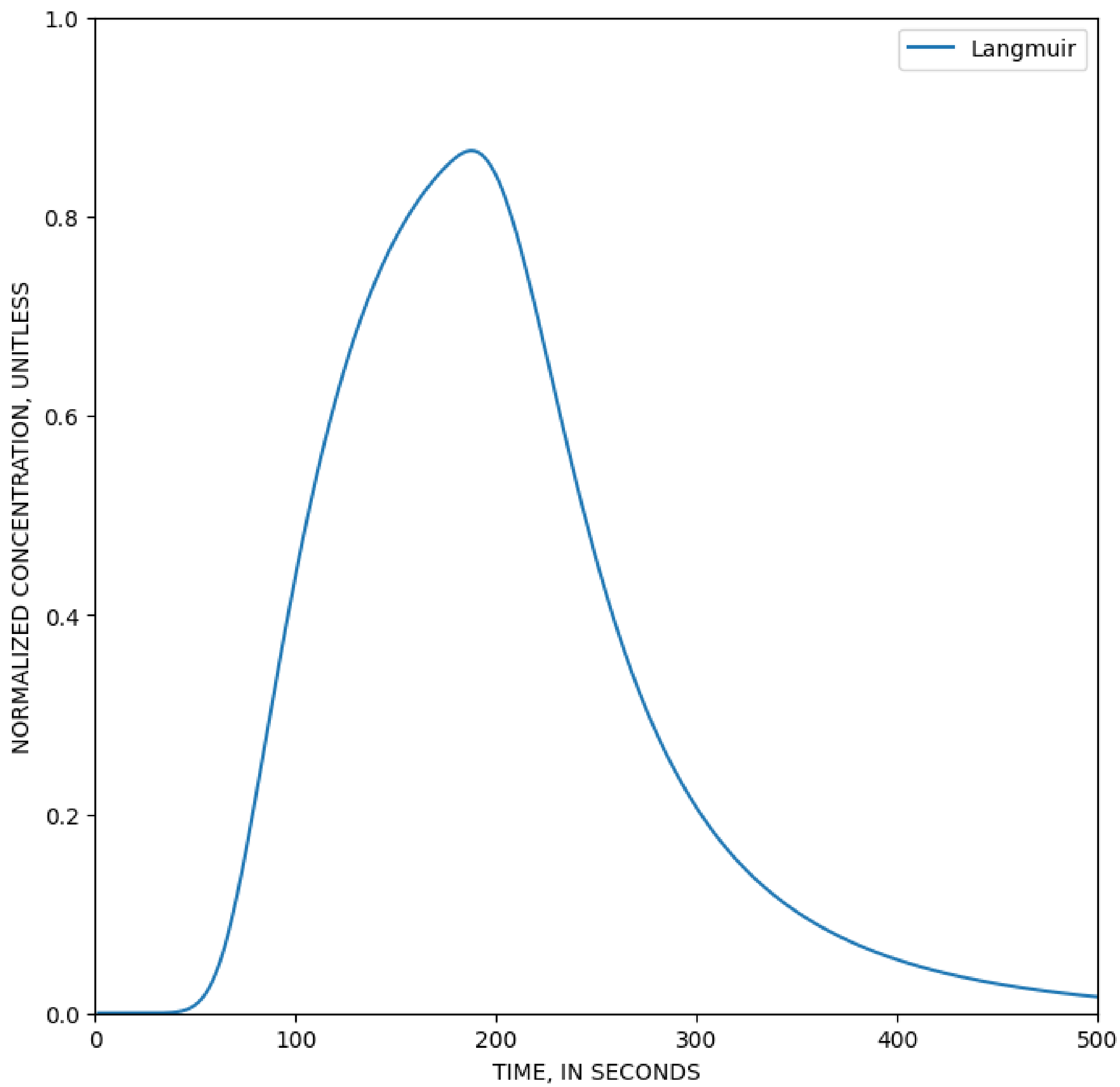
```
y = cvt["(1, 1, 51)"] / 0.05
plt.plot(x, y, label="Langmuir")
plt.xlim(0, 500)
plt.ylim(0, 1.0)
plt.xlabel("TIME, IN SECONDS")
plt.ylabel("NORMALIZED CONCENTRATION, UNITLESS")
plt.legend()
```

[9]: <matplotlib.legend.Legend at 0x7f30035c20d0>



[10]:
```
for beta in [0, 2.0e-3, 1.0e-2, 20.0]:
    lbl = f"beta={beta}"
    mf, mt, conc, cvt, mvt = p02("nonequilibrium", 4, 0.933, beta, -1)
    x = cvt["time"]
```

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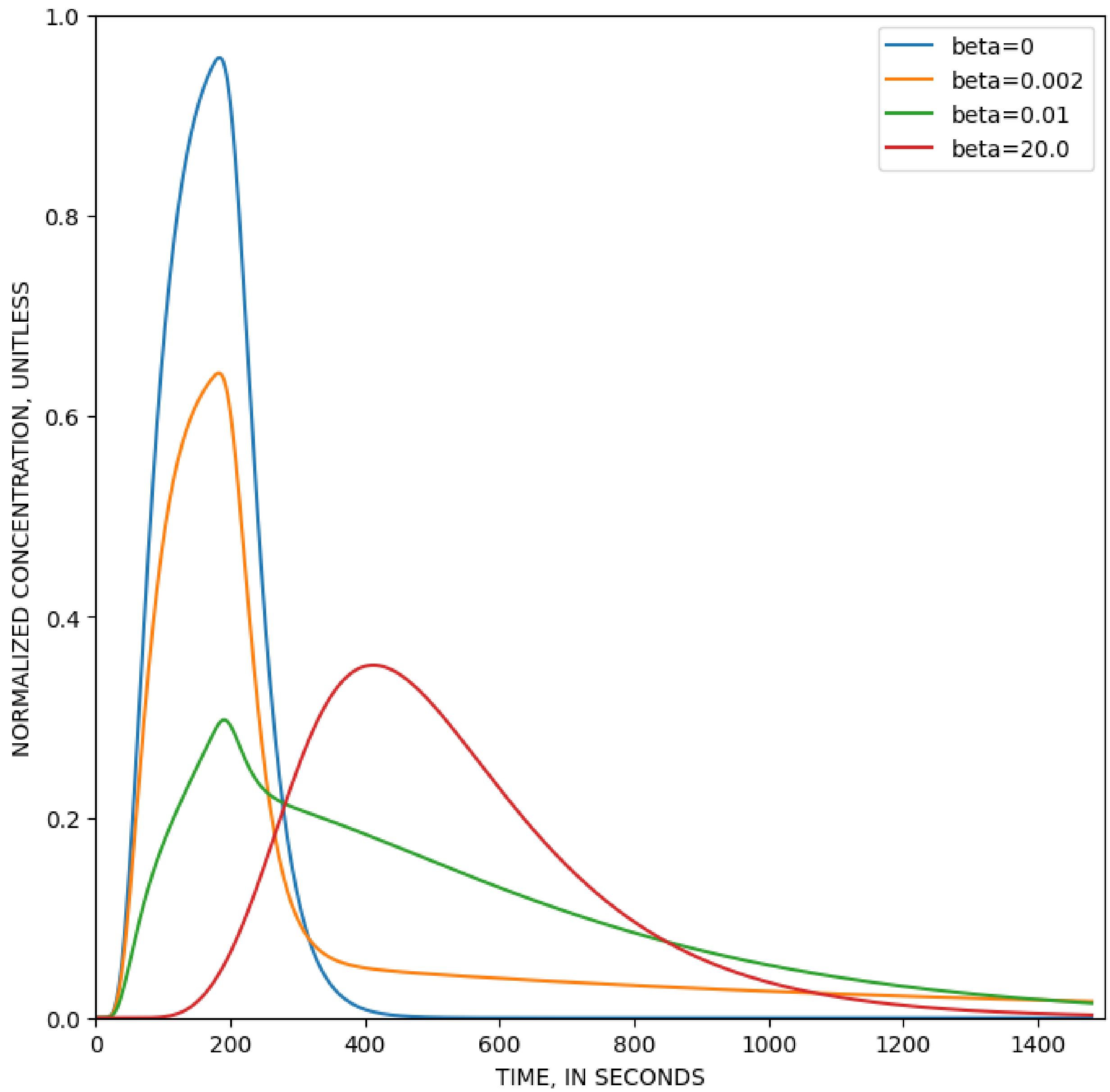
```
    y = cvt["(1, 1, 51)"] / 0.05
    plt.plot(x, y, label=lbl)
plt.xlim(0, 1500)
plt.ylim(0, 1.0)
plt.xlabel("TIME, IN SECONDS")
plt.ylabel("NORMALIZED CONCENTRATION, UNITLESS")
plt.legend()
```

[10]: <matplotlib.legend.Legend at 0x7f30039ed100>



Example 3. Two-Dimensional Transport in a Uniform Flow Field

[11]:
```
def p03(dirname, mixelm):
    model_ws = os.path.join(workdir, dirname)
    nlay = 1
    nrow = 31
    ncol = 46
    delr = 10
    delc = 10
    delv = 10
    Lx = (ncol - 1) * delr
    v = 1.0 / 3.0
    prsity = 0.3
    q = v * prsity
    al = 10.0
    trpt = 0.3
    q0 = 1.0
    c0 = 1000.0

    perlen_mf = 365.0
    perlen_mt = 365.0
    hk = 1.0
    laytyp = 0

    modelname_mf = f"{dirname}_mf"
    mf = flopy.modflow.Modflow(
        modelname=modelname_mf, model_ws=model_ws, exe_name=exe_name_mf
    )
    dis = flopy.modflow.ModflowDis(
        mf,
        nlay=nlay,
        nrow=nrow,
        ncol=ncol,
        delr=delr,
        delc=delc,
        top=0.0,
        botm=[0 - delv],
        perlen=perlen_mf,
    )
    ibound = np.ones((nlay, nrow, ncol), dtype=int)
    ibound[0, :, 0] = -1
    ibound[0, :, -1] = -1
    strt = np.zeros((nlay, nrow, ncol), dtype=float)
    h1 = q * Lx
    strt[0, :, 0] = h1
    bas = flopy.modflow.ModflowBas(mf, ibound=ibound, strt=strt)
    lpf = flopy.modflow.ModflowLpf(mf, hk=hk, laytyp=laytyp)
    wel = flopy.modflow.ModflowWel(mf, stress_period_data=[[0, 15, 15, q0]])
    pcg = flopy.modflow.ModflowPcg(mf)
    lmt = flopy.modflow.ModflowLmt(mf)
    mf.write_input()
    mf.run_model(silent=True)
```

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```
    modelname_mt = f"{dirname}_mt"
    mt = flopy.mt3d.Mt3dms(
        modelname=modelname_mt,
        model_ws=model_ws,
        exe_name=exe_name_mt,
        modflowmodel=mf,
    )
    btn = flopy.mt3d.Mt3dBtn(mt, icbund=1, prsity=prsity, sconc=0)
    dceps = 1.0e-5
    nplane = 1
    npl = 0
    nph = 16
    npmin = 2
    npmax = 32
    dchmoc = 1.0e-3
    nlsink = nplane
    npsink = nph
    adv = flopy.mt3d.Mt3dAdv(
        mt,
        mixelm=mixelm,
        dceps=dceps,
        nplane=nplane,
        npl=npl,
        nph=nph,
        npmin=npmin,
        npmax=npmax,
        nlsink=nlsink,
        npsink=npsink,
        percel=0.5,
    )
    dsp = flopy.mt3d.Mt3dDsp(mt, al=al, trpt=trpt)
    spd = {0: [0, 15, 15, c0, 2]}
    ssm = flopy.mt3d.Mt3dSsm(mt, stress_period_data=spd)
    gcg = flopy.mt3d.Mt3dGcg(mt)
    mt.write_input()
    fname = os.path.join(model_ws, "MT3D001.UCN")
    if os.path.isfile(fname):
        os.remove(fname)
    mt.run_model(silent=True)

    fname = os.path.join(model_ws, "MT3D001.UCN")
    ucnobj = flopy.utils.UcnFile(fname)
    times = ucnobj.get_times()
    conc = ucnobj.get_alldata()

    fname = os.path.join(model_ws, "MT3D001.OBS")
    if os.path.isfile(fname):
        cvt = mt.load_obs(fname)
    else:
        cvt = None

    fname = os.path.join(model_ws, "MT3D001.MAS")
```

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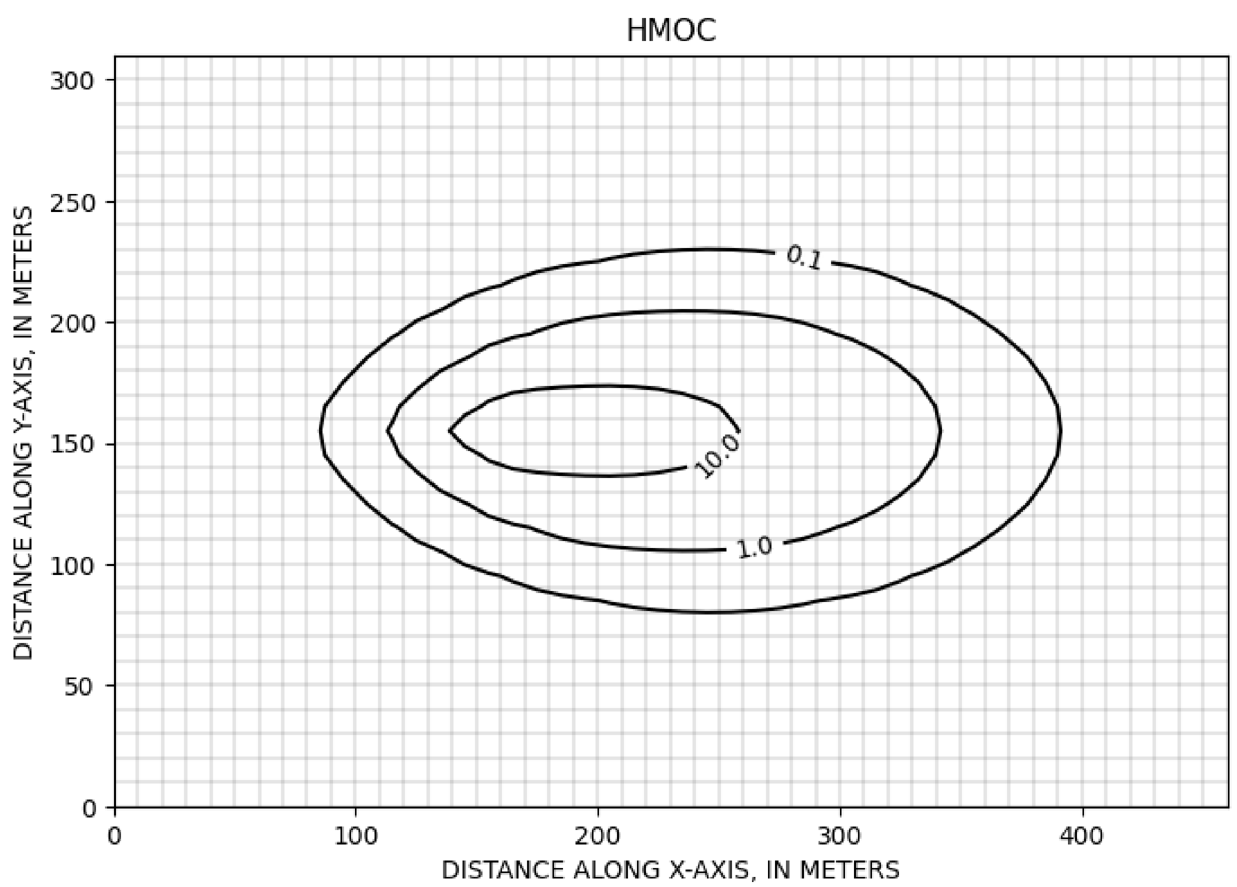
```
    mvt = mt.load_mas(fname)

    return mf, mt, conc, cvt, mvt
```

[12]:
```
ax = plt.subplot(1, 1, 1, aspect="equal")
mf, mt, conc, cvt, mvt = p03("p03", 3)
conc = conc[0, :, :, :]
pmv = flopy.plot.PlotMapView(model=mf)
pmv.plot_grid(color=".5", alpha=0.2)
cs = pmv.contour_array(conc, levels=[0.1, 1.0, 10.0, 50.0], colors="k")
plt.clabel(cs)
plt.xlabel("DISTANCE ALONG X-AXIS, IN METERS")
plt.ylabel("DISTANCE ALONG Y-AXIS, IN METERS")
plt.title("HMOC")
```

[12]:
```
Text(0.5, 1.0, 'HMOC')
```



[13]:
```
ax = plt.subplot(1, 1, 1, aspect="equal")
mf, mt, conc, cvt, mvt = p03("p03", -1)
conc = conc[0, :, :, :]
pmv = flopy.plot.PlotMapView(model=mf)
pmv.plot_grid(color=".5", alpha=0.2)
cs = pmv.contour_array(conc, levels=[0.1, 1.0, 10.0, 50.0], colors="k")
```

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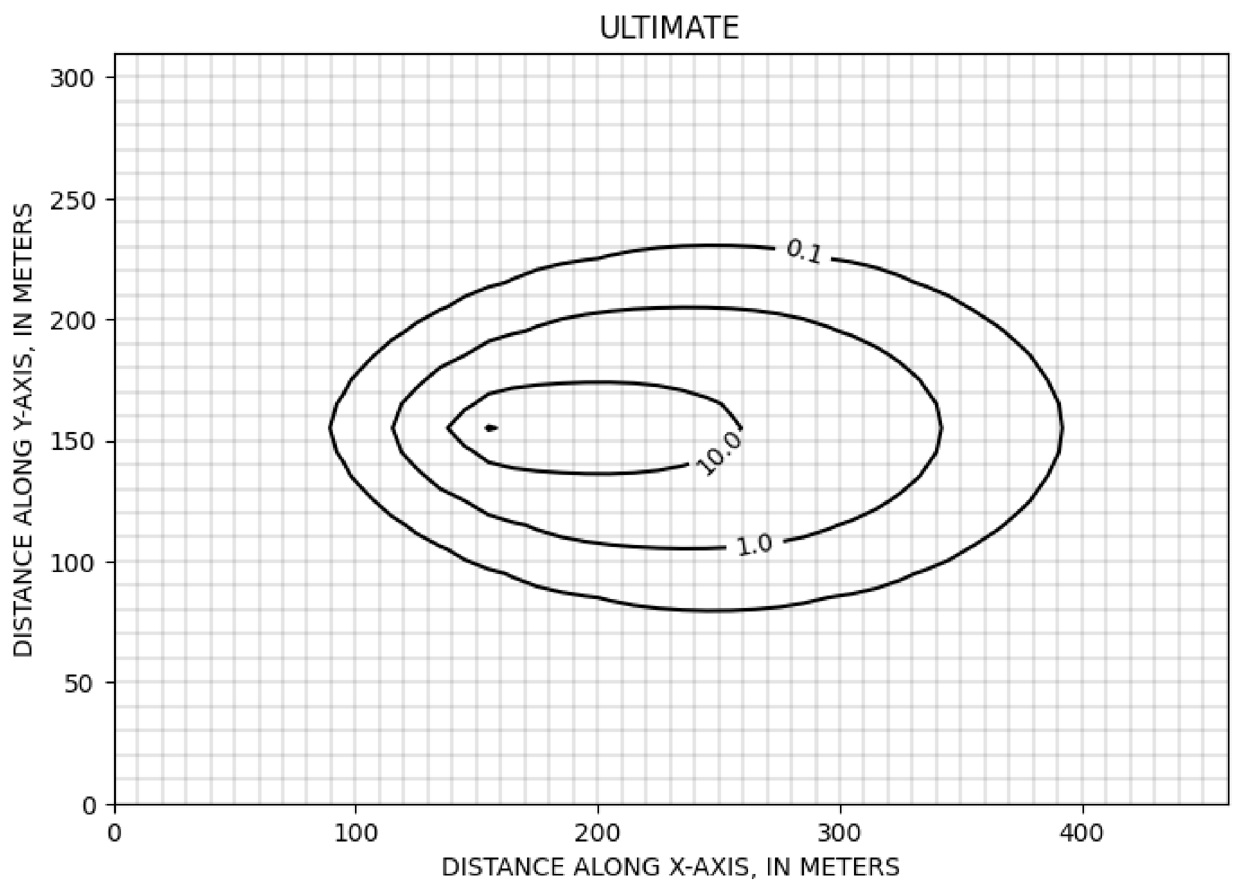
```
plt.clabel(cs)
plt.xlabel("DISTANCE ALONG X-AXIS, IN METERS")
plt.ylabel("DISTANCE ALONG Y-AXIS, IN METERS")
plt.title("ULTIMATE")
```

[13]:
```
Text(0.5, 1.0, 'ULTIMATE')
```



Example 4. Two-Dimensional Transport in a Diagonal Flow Field

[14]:
```
def p04(dirname, mixelm):
    model_ws = os.path.join(workdir, dirname)
    nlay = 1
    nrow = 100
    ncol = 100
    delr = 10
    delc = 10
    delv = 1
    Lx = (ncol - 1) * delr
    Ly = (nrow - 1) * delc
    Ls = np.sqrt(Lx**2 + Ly**2)
    v = 1.0
    prsity = 0.14
```

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```
    q = v * prsity
    al = 2.0
    trpt = 0.1
    q0 = 0.01
    c0 = 1000.0

    perlen_mf = 1000.0
    perlen_mt = 1000.0
    hk = 1.0
    laytyp = 0

    modelname_mf = f"{dirname}_mf"
    mf = flopy.modflow.Modflow(
        modelname=modelname_mf, model_ws=model_ws, exe_name=exe_name_mf
    )
    dis = flopy.modflow.ModflowDis(
        mf,
        nlay=nlay,
        nrow=nrow,
        ncol=ncol,
        delr=delr,
        delc=delc,
        top=0.0,
        botm=[0 - delv],
        perlen=perlen_mf,
    )
    ibound = np.ones((nlay, nrow, ncol), dtype=int) * -1
    ibound[:, 1 : nrow - 1, 1 : ncol - 1] = 1

    # set strt as a linear gradient at a 45 degree angle
    h1 = q * Ls
    x = mf.modelgrid.xcellcenters
    y = mf.modelgrid.ycellcenters
    a = -1
    b = -1
    c = 1
    d = abs(a * x + b * y + c) / np.sqrt(2)
    strt = h1 - d / Ls * h1

    bas = flopy.modflow.ModflowBas(mf, ibound=ibound, strt=strt)
    lpf = flopy.modflow.ModflowLpf(mf, hk=hk, laytyp=laytyp)
    wel = flopy.modflow.ModflowWel(mf, stress_period_data=[[0, 79, 20, q0]])
    pcg = flopy.modflow.ModflowPcg(mf)
    lmt = flopy.modflow.ModflowLmt(mf)
    mf.write_input()
    mf.run_model(silent=True)

    modelname_mt = f"{dirname}_mt"
    mt = flopy.mt3d.Mt3dms(
        modelname=modelname_mt,
        model_ws=model_ws,
        exe_name=exe_name_mt,
```

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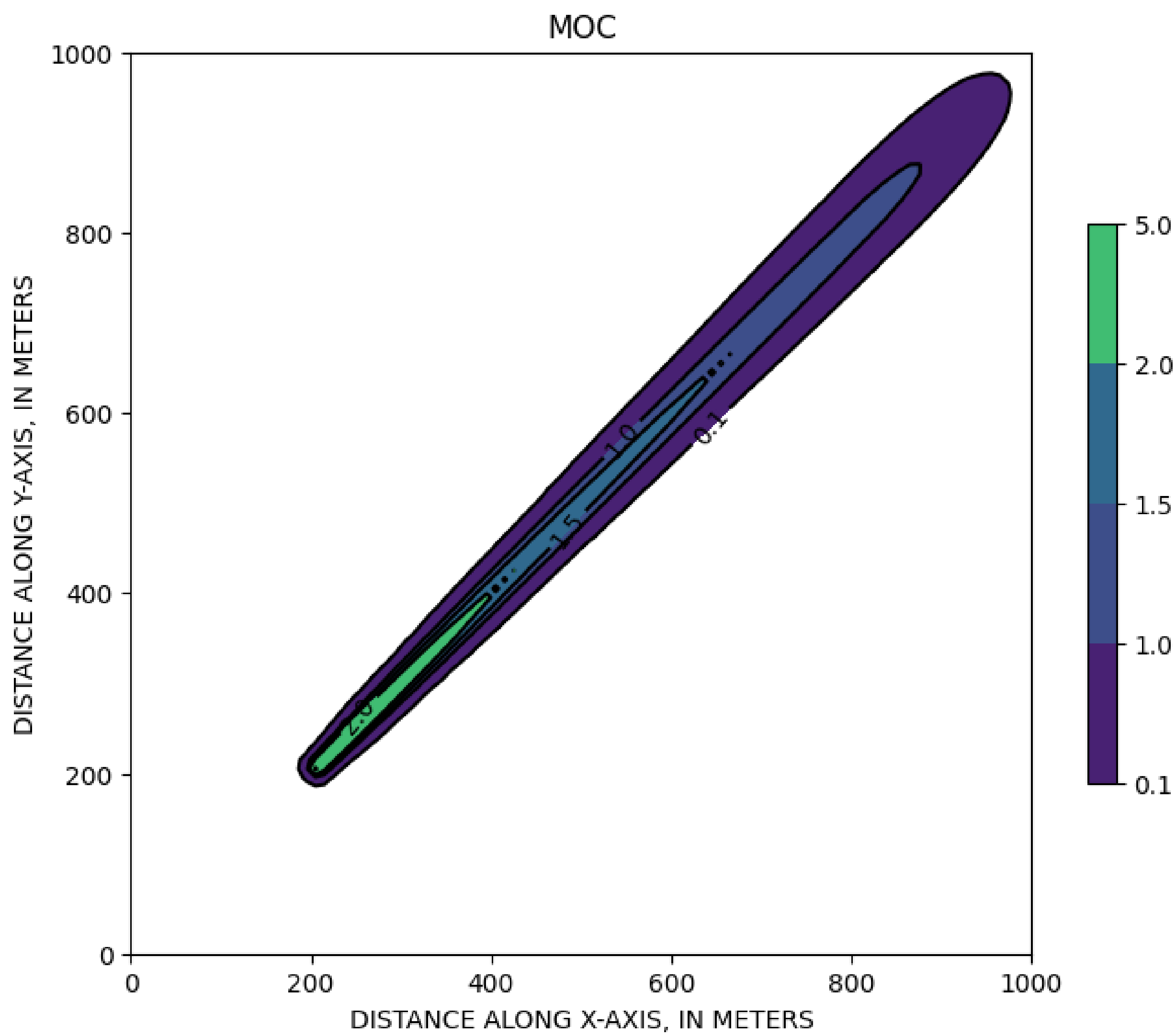
```
        modflowmodel=mf,
    )
    btn = flopy.mt3d.Mt3dBtn(mt, icbund=1, prsity=prsity, sconc=0)
    dceps = 1.0e-5
    nplane = 1
    npl = 0
    nph = 16
    npmin = 2
    npmax = 32
    dchmoc = 1.0e-3
    nlsink = nplane
    npsink = nph
    adv = flopy.mt3d.Mt3dAdv(
        mt,
        mixelm=mixelm,
        dceps=dceps,
        nplane=nplane,
        npl=npl,
        nph=nph,
        npmin=npmin,
        npmax=npmax,
        nlsink=nlsink,
        npsink=npsink,
        percel=0.5,
    )
    dsp = flopy.mt3d.Mt3dDsp(mt, al=al, trpt=trpt)
    spd = {0: [0, 79, 20, c0, 2]}
    ssm = flopy.mt3d.Mt3dSsm(mt, stress_period_data=spd)
    gcg = flopy.mt3d.Mt3dGcg(mt)
    mt.write_input()
    fname = os.path.join(model_ws, "MT3D001.UCN")
    if os.path.isfile(fname):
        os.remove(fname)
    mt.run_model(silent=True)

    fname = os.path.join(model_ws, "MT3D001.UCN")
    ucnobj = flopy.utils.UcnFile(fname)
    times = ucnobj.get_times()
    conc = ucnobj.get_alldata()

    fname = os.path.join(model_ws, "MT3D001.OBS")
    if os.path.isfile(fname):
        cvt = mt.load_obs(fname)
    else:
        cvt = None

    fname = os.path.join(model_ws, "MT3D001.MAS")
    mvt = mt.load_mas(fname)

    return mf, mt, conc, cvt, mvt
```

[15]:
```
ax = plt.subplot(1, 1, 1, aspect="equal")
mf, mt, conc, cvt, mvt = p04("p04", 1)
grid = mf.modelgrid
conc = conc[0, :, :, :]
levels = [0.1, 1.0, 1.5, 2.0, 5.0]
pmv = flopy.plot.PlotMapView(model=mf)
cf = plt.contourf(grid.xcellcenters, grid.ycellcenters, conc[0], levels=levels)
plt.colorbar(cf, shrink=0.5)
cs = pmv.contour_array(conc, levels=levels, colors="k")
plt.clabel(cs)
plt.xlabel("DISTANCE ALONG X-AXIS, IN METERS")
plt.ylabel("DISTANCE ALONG Y-AXIS, IN METERS")
plt.title("MOC")
```

[15]:
```
Text(0.5, 1.0, 'MOC')
```



[16]:
```
ax = plt.subplot(1, 1, 1, aspect="equal")
mf, mt, conc, cvt, mvt = p04("p04", 0)
```

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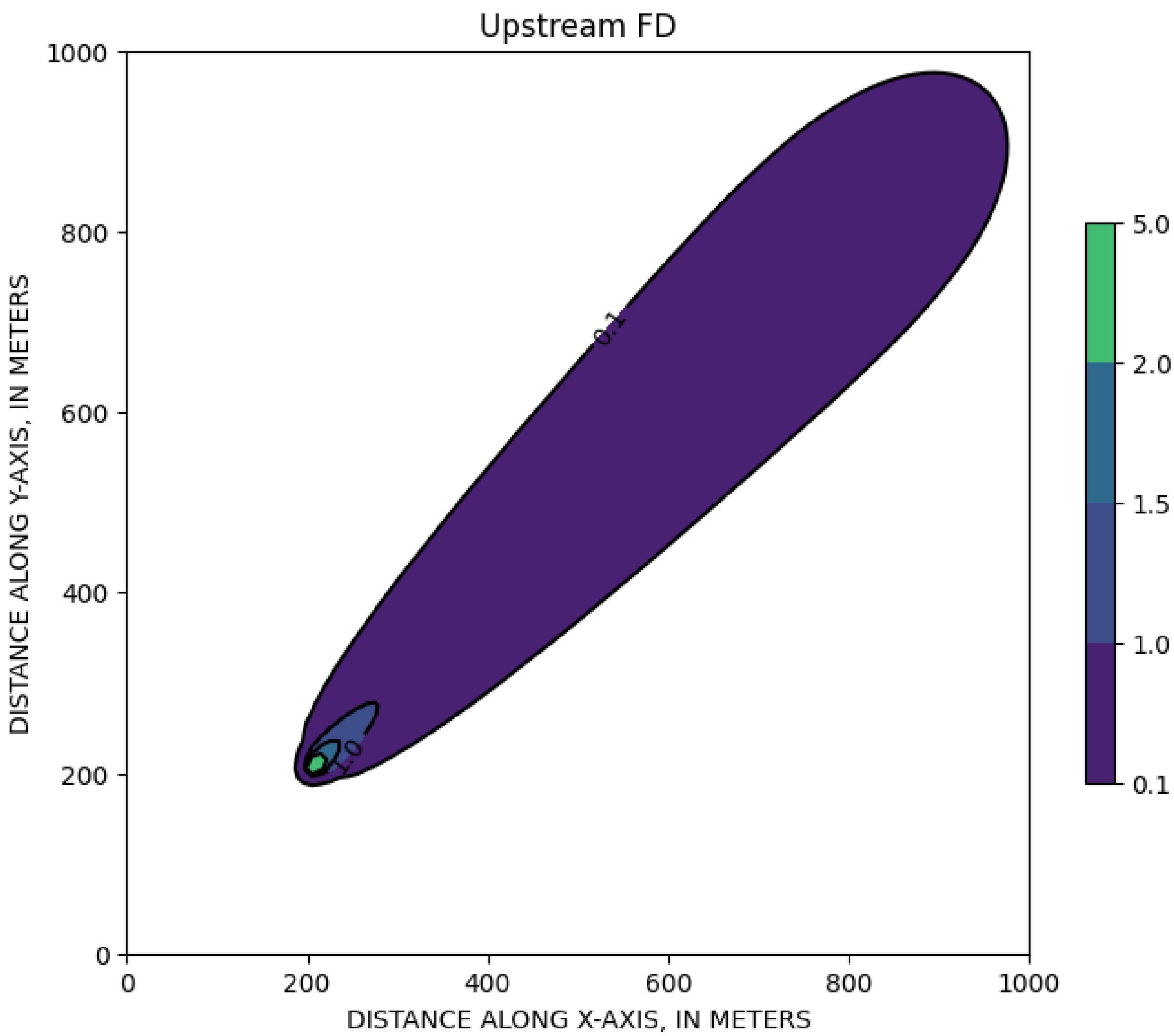
```
grid = mf.modelgrid
conc = conc[0, :, :, :]
levels = [0.1, 1.0, 1.5, 2.0, 5.0]
pmv = flopy.plot.PlotMapView(model=mf)
cf = plt.contourf(grid.xcellcenters, grid.ycellcenters, conc[0], levels=levels)
plt.colorbar(cf, shrink=0.5)
cs = pmv.contour_array(conc, levels=levels, colors="k")
plt.clabel(cs)
plt.xlabel("DISTANCE ALONG X-AXIS, IN METERS")
plt.ylabel("DISTANCE ALONG Y-AXIS, IN METERS")
plt.title("Upstream FD")
```

[16]:

```
Text(0.5, 1.0, 'Upstream FD')
```



[17]:

```
ax = plt.subplot(1, 1, 1, aspect="equal")
mf, mt, conc, cvt, mvt = p04("p04", -1)
grid = mf.modelgrid
```

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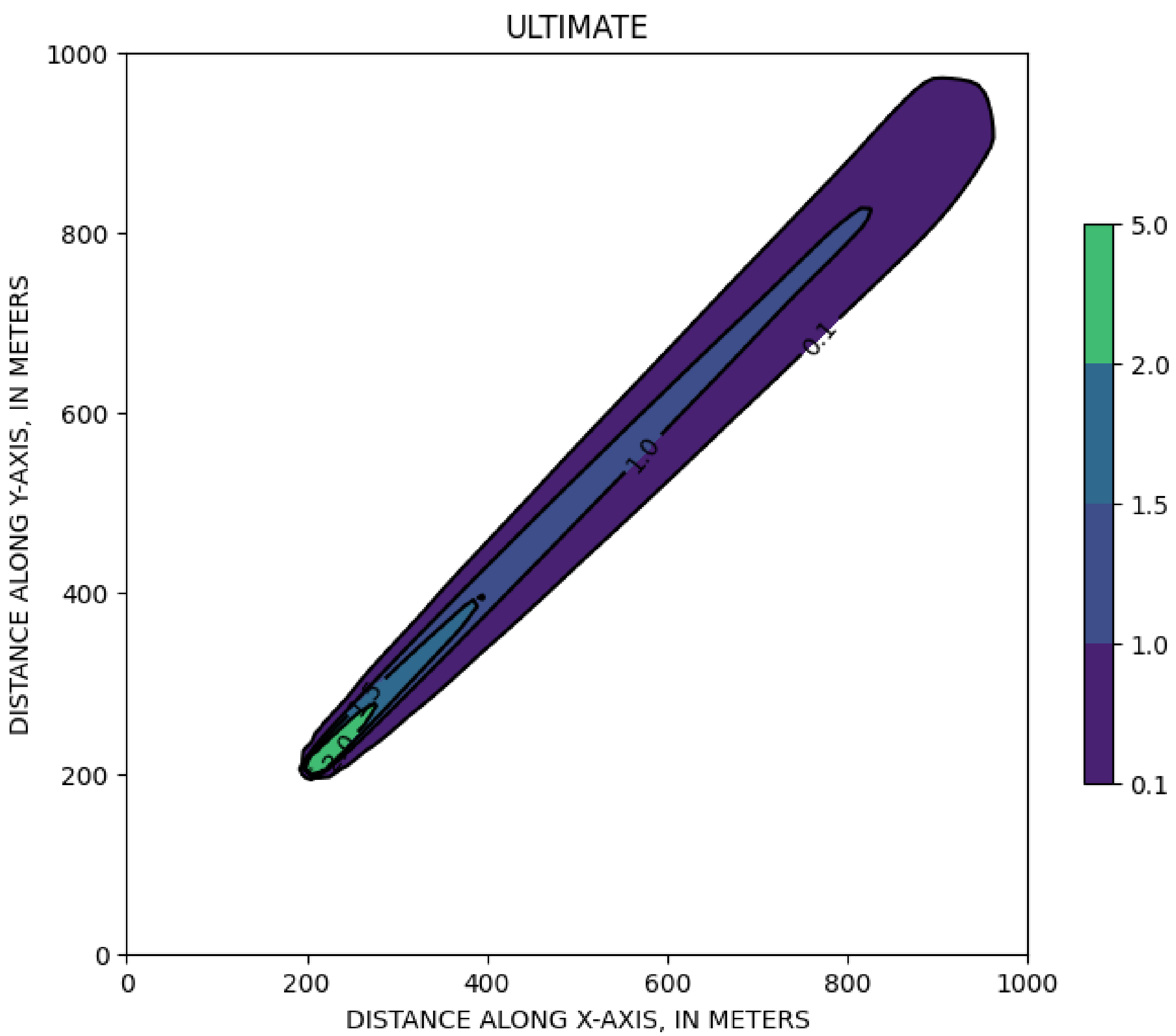
```
conc = conc[0, :, :, :]
levels = [0.1, 1.0, 1.5, 2.0, 5.0]
pmv = flopy.plot.PlotMapView(model=mf)
cf = plt.contourf(grid.xcellcenters, grid.ycellcenters, conc[0], levels=levels)
plt.colorbar(cf, shrink=0.5)
cs = pmv.contour_array(conc, levels=levels, colors="k")
plt.clabel(cs)
plt.xlabel("DISTANCE ALONG X-AXIS, IN METERS")
plt.ylabel("DISTANCE ALONG Y-AXIS, IN METERS")
plt.title("ULTIMATE")
```

[17]:
```
Text(0.5, 1.0, 'ULTIMATE')
```



Example 5. Two-Dimensional Transport in a Radial Flow Field

[18]:
```python
def p05(dirname, mixelm, dt0, ttsmult):
    model_ws = os.path.join(workdir, dirname)
    nlay = 1
    nrow = 31
    ncol = 31
    delr = 10
    delc = 10
    delv = 1
    prsity = 0.30
    al = 10.0
    trpt = 1.0
    q0 = 100.0
    c0 = 1.0

    perlen_mf = 27.0
    perlen_mt = 27.0
    hk = 1.0
    laytyp = 0

    modelname_mf = f"{dirname}_mf"
    mf = flopy.modflow.Modflow(
        modelname=modelname_mf, model_ws=model_ws, exe_name=exe_name_mf
    )
    dis = flopy.modflow.ModflowDis(
        mf,
        nlay=nlay,
        nrow=nrow,
        ncol=ncol,
        delr=delr,
        delc=delc,
        top=0.0,
        botm=[0 - delv],
        perlen=perlen_mf,
    )
    ibound = np.ones((nlay, nrow, ncol), dtype=int) * -1
    ibound[:, 1 : nrow - 1, 1 : ncol - 1] = 1
    strt = 0.0

    bas = flopy.modflow.ModflowBas(mf, ibound=ibound, strt=strt)
    lpf = flopy.modflow.ModflowLpf(mf, hk=hk, laytyp=laytyp)
    wel = flopy.modflow.ModflowWel(mf, stress_period_data=[[0, 15, 15, q0]])
    sip = flopy.modflow.ModflowSip(mf)
    lmt = flopy.modflow.ModflowLmt(mf)
    mf.write_input()
    mf.run_model(silent=True)

    modelname_mt = f"{dirname}_mt"
    mt = flopy.mt3d.Mt3dms(
        modelname=modelname_mt,
        model_ws=model_ws,
        exe_name=exe_name_mt,
```

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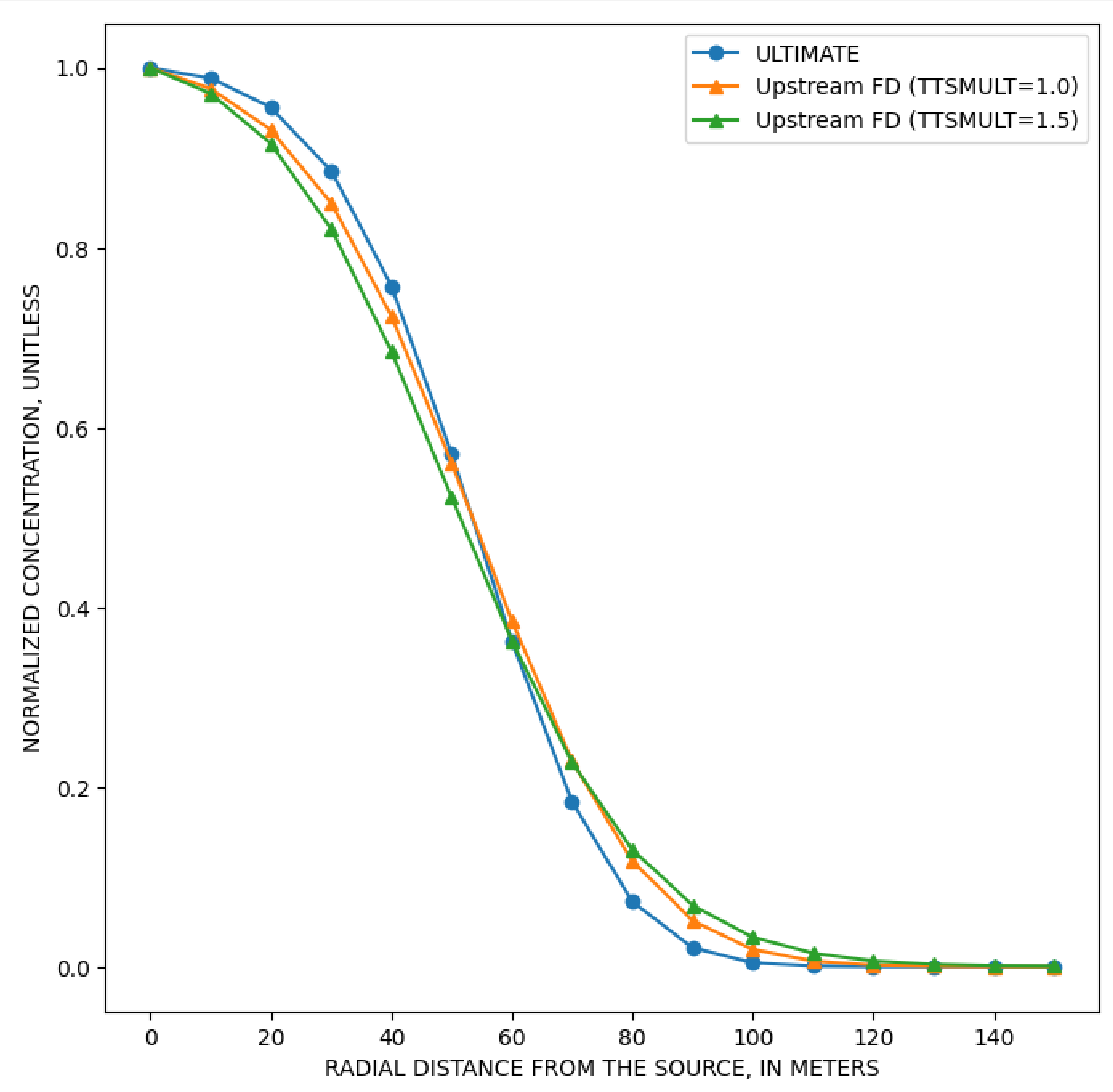
```
        modflowmodel=mf,
    )
    btn = flopy.mt3d.Mt3dBtn(
        mt, icbund=1, prsity=prsity, sconc=0, dt0=dt0, ttsmult=ttsmult
    )
    dceps = 1.0e-5
    nplane = 1
    npl = 0
    nph = 16
    npmin = 2
    npmax = 32
    dchmoc = 1.0e-3
    nlsink = nplane
    npsink = nph
    adv = flopy.mt3d.Mt3dAdv(
        mt,
        mixelm=mixelm,
        dceps=dceps,
        nplane=nplane,
        npl=npl,
        nph=nph,
        npmin=npmin,
        npmax=npmax,
        nlsink=nlsink,
        npsink=npsink,
        percel=0.5,
    )
    dsp = flopy.mt3d.Mt3dDsp(mt, al=al, trpt=trpt)
    spd = {0: [0, 15, 15, c0, -1]}
    ssm = flopy.mt3d.Mt3dSsm(mt, stress_period_data=spd)
    gcg = flopy.mt3d.Mt3dGcg(mt)
    mt.write_input()
    fname = os.path.join(model_ws, "MT3D001.UCN")
    if os.path.isfile(fname):
        os.remove(fname)
    mt.run_model(silent=True)

    fname = os.path.join(model_ws, "MT3D001.UCN")
    ucnobj = flopy.utils.UcnFile(fname)
    times = ucnobj.get_times()
    conc = ucnobj.get_alldata()

    fname = os.path.join(model_ws, "MT3D001.OBS")
    if os.path.isfile(fname):
        cvt = mt.load_obs(fname)
    else:
        cvt = None

    fname = os.path.join(model_ws, "MT3D001.MAS")
    mvt = mt.load_mas(fname)

    return mf, mt, conc, cvt, mvt
```

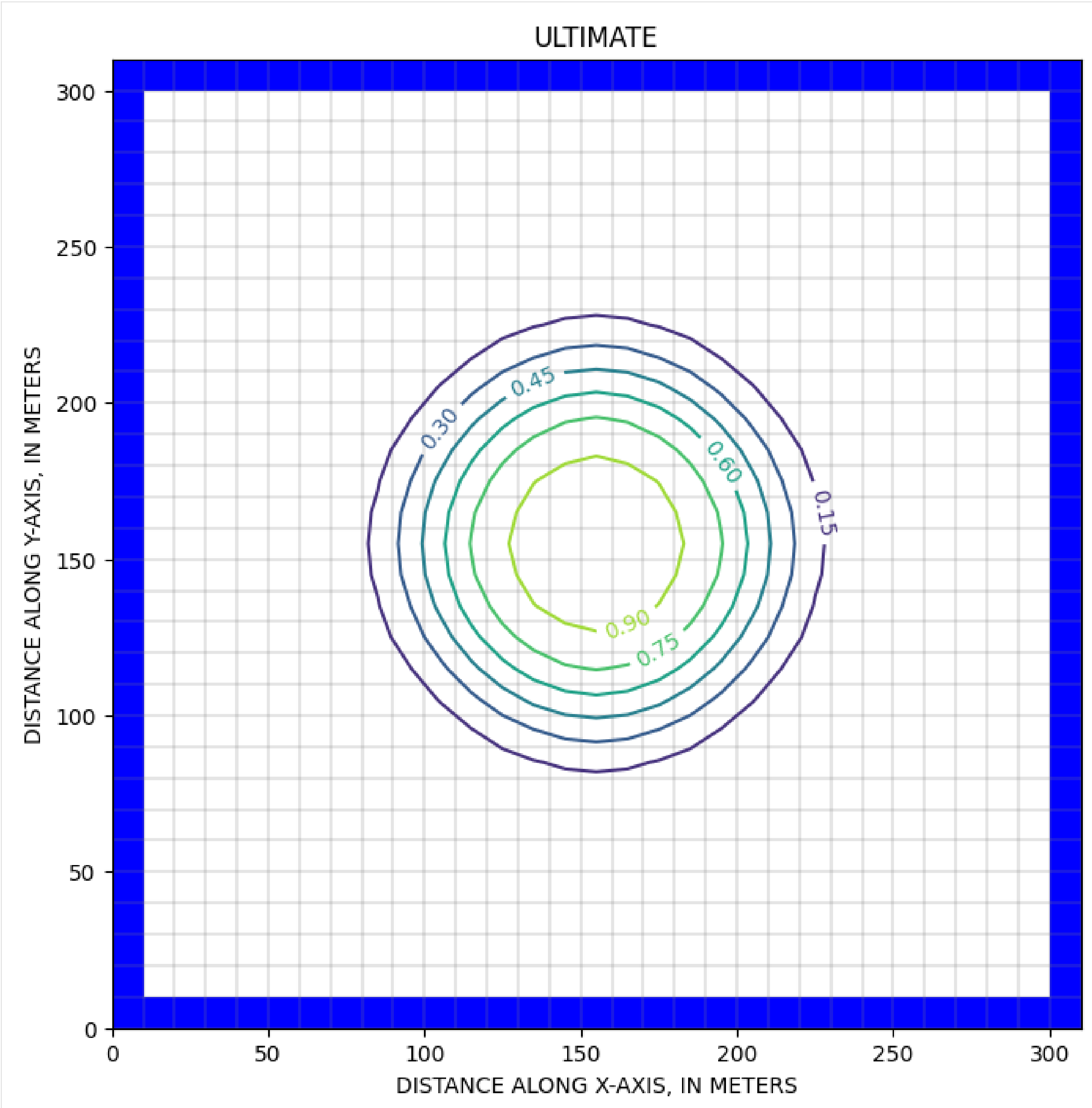
[19]:
```
mf, mt, conc, cvt, mvt = p05("p05", -1, 0.3, 1.0)
grid = mf.modelgrid
conc = conc[0, 0, :, :]
x = grid.xcellcenters[15, 15:] - grid.xcellcenters[15, 15]
y = conc[15, 15:]
plt.plot(x, y, label="ULTIMATE", marker="o")

mf, mt, conc, cvt, mvt = p05("p05", 0, 0.3, 1.0)
conc = conc[0, 0, :, :]
x = grid.xcellcenters[15, 15:] - grid.xcellcenters[15, 15]
y = conc[15, 15:]
plt.plot(x, y, label="Upstream FD (TTSMULT=1.0)", marker="^")

mf, mt, conc, cvt, mvt = p05("p05", 0, 0.3, 1.5)
conc = conc[0, 0, :, :]
x = grid.xcellcenters[15, 15:] - grid.xcellcenters[15, 15]
y = conc[15, 15:]
plt.plot(x, y, label="Upstream FD (TTSMULT=1.5)", marker="^")

plt.xlabel("RADIAL DISTANCE FROM THE SOURCE, IN METERS")
plt.ylabel("NORMALIZED CONCENTRATION, UNITLESS")
plt.legend()
```

[19]:
```
<matplotlib.legend.Legend at 0x7f3003269610>
```



[20]:
```python
ax = plt.subplot(1, 1, 1, aspect="equal")
mf, mt, conc, cvt, mvt = p05("p05", -1, 0.3, 1.0)
pmv = flopy.plot.PlotMapView(model=mf)
pmv.plot_grid(color=".5", alpha=0.2)
pmv.plot_ibound()
cs = pmv.contour_array(conc[0])
plt.clabel(cs)
plt.xlabel("DISTANCE ALONG X-AXIS, IN METERS")
plt.ylabel("DISTANCE ALONG Y-AXIS, IN METERS")
plt.title("ULTIMATE")
```

[20]:
```
Text(0.5, 1.0, 'ULTIMATE')
```



Example 6. Concentration at an Injection/Extraction Well

[21]:
```
def p06(dirname, mixelm, dt0):
    model_ws = os.path.join(workdir, dirname)
    nlay = 1
    nrow = 31
    ncol = 31
    delr = 900
    delc = 900
    delv = 20
```

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```
    prsity = 0.30
    al = 100.0
    trpt = 1.0
    q0 = 86400.0
    c0 = 100.0

    perlen_mf = [912.5, 2737.5]
    perlen_mt = perlen_mf
    hk = 0.005 * 86400
    laytyp = 0

    modelname_mf = f"{dirname}_mf"
    mf = flopy.modflow.Modflow(
        modelname=modelname_mf, model_ws=model_ws, exe_name=exe_name_mf
    )
    dis = flopy.modflow.ModflowDis(
        mf,
        nlay=nlay,
        nrow=nrow,
        ncol=ncol,
        delr=delr,
        delc=delc,
        top=0.0,
        botm=[0 - delv],
        nper=2,
        perlen=perlen_mf,
    )
    ibound = np.ones((nlay, nrow, ncol), dtype=int) * -1
    ibound[:, 1 : nrow - 1, 1 : ncol - 1] = 1
    strt = 0.0

    bas = flopy.modflow.ModflowBas(mf, ibound=ibound, strt=strt)
    lpf = flopy.modflow.ModflowLpf(mf, hk=hk, laytyp=laytyp)
    welspd = {0: [[0, 15, 15, q0]], 1: [[0, 15, 15, -q0]]}
    wel = flopy.modflow.ModflowWel(mf, stress_period_data=welspd)
    sip = flopy.modflow.ModflowSip(mf)
    lmt = flopy.modflow.ModflowLmt(mf)
    mf.write_input()
    mf.run_model(silent=True)

    modelname_mt = f"{dirname}_mt"
    mt = flopy.mt3d.Mt3dms(
        modelname=modelname_mt,
        model_ws=model_ws,
        exe_name=exe_name_mt,
        modflowmodel=mf,
    )
    btn = flopy.mt3d.Mt3dBtn(
        mt,
        icbund=1,
        prsity=prsity,
        sconc=0,
```

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```
        nper=2,
        perlen=perlen_mt,
        dt0=dt0,
        obs=[(0, 15, 15)],
    )
    dceps = 1.0e-5
    nplane = 1
    npl = 16
    nph = 16
    npmin = 4
    npmax = 32
    dchmoc = 1.0e-3
    nlsink = nplane
    npsink = nph
    adv = flopy.mt3d.Mt3dAdv(
        mt,
        mixelm=mixelm,
        dceps=dceps,
        nplane=nplane,
        npl=npl,
        nph=nph,
        npmin=npmin,
        npmax=npmax,
        nlsink=nlsink,
        npsink=npsink,
        percel=0.5,
    )
    dsp = flopy.mt3d.Mt3dDsp(mt, al=al, trpt=trpt)
    spd = {0: [0, 15, 15, c0, 2], 1: [0, 15, 15, 0.0, 2]}
    ssm = flopy.mt3d.Mt3dSsm(mt, stress_period_data=spd)
    gcg = flopy.mt3d.Mt3dGcg(mt)
    mt.write_input()
    fname = os.path.join(model_ws, "MT3D001.UCN")
    if os.path.isfile(fname):
        os.remove(fname)
    mt.run_model(silent=True)

    fname = os.path.join(model_ws, "MT3D001.UCN")
    ucnobj = flopy.utils.UcnFile(fname)
    times = ucnobj.get_times()
    conc = ucnobj.get_alldata()

    fname = os.path.join(model_ws, "MT3D001.OBS")
    if os.path.isfile(fname):
        cvt = mt.load_obs(fname)
    else:
        cvt = None

    fname = os.path.join(model_ws, "MT3D001.MAS")
    mvt = mt.load_mas(fname)

    return mf, mt, conc, cvt, mvt
```

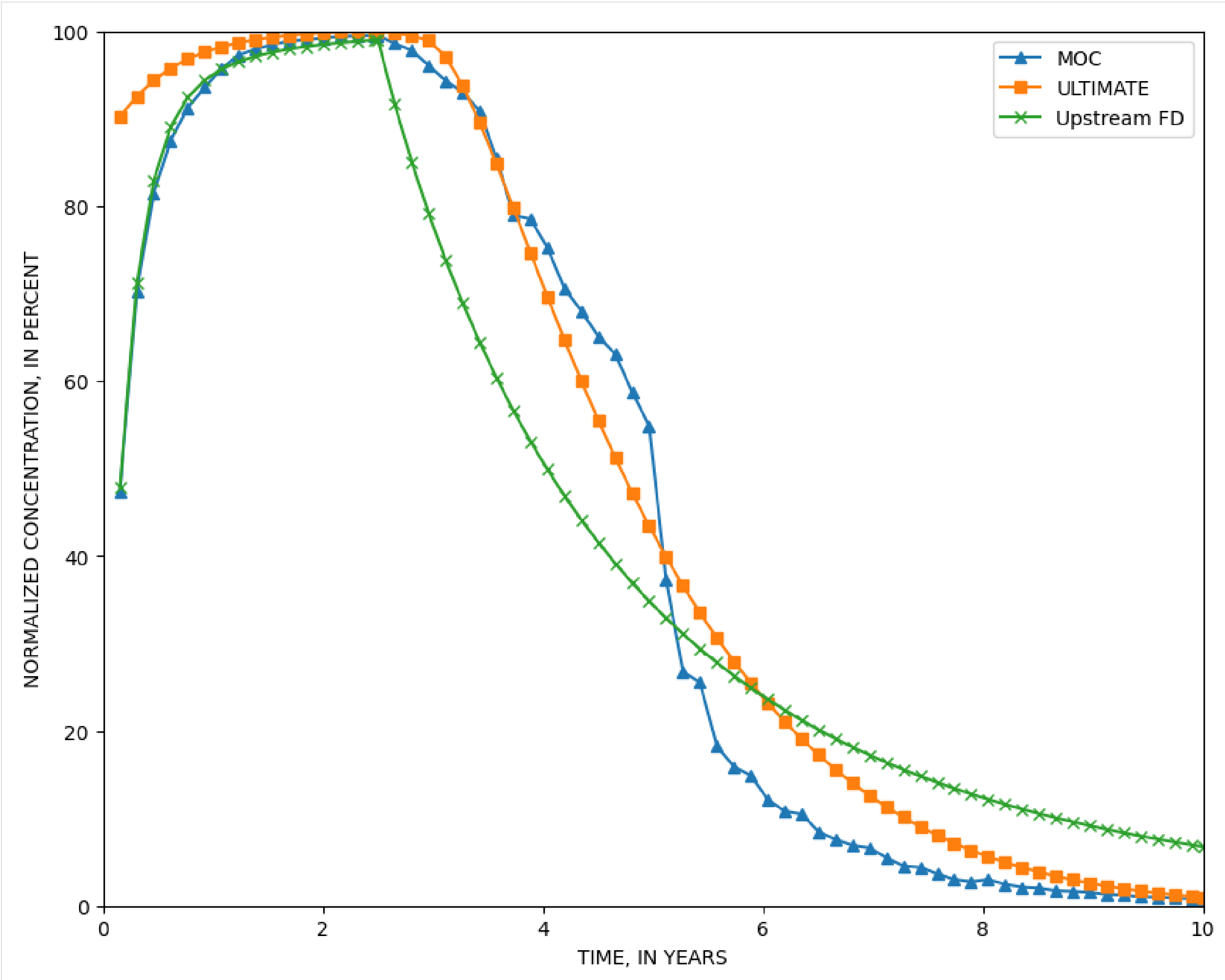
[22]:
```
fig = plt.figure(figsize=(10, 8))
ax = fig.add_subplot(1, 1, 1)
mf, mt, conc, cvt, mvt = p06("p06", 1, 56.25)
x = cvt["time"] / 365.0
y = cvt["(1, 16, 16)"]
ax.plot(x, y, label="MOC", marker="^")

mf, mt, conc, cvt, mvt = p06("p06", -1, 56.25)
x = cvt["time"] / 365.0
y = cvt["(1, 16, 16)"]
ax.plot(x, y, label="ULTIMATE", marker="s")

mf, mt, conc, cvt, mvt = p06("p06", 0, 56.25)
x = cvt["time"] / 365.0
y = cvt["(1, 16, 16)"]
ax.plot(x, y, label="Upstream FD", marker="x")

plt.xlim(0, 10)
plt.ylim(0, 100.0)
plt.xlabel("TIME, IN YEARS")
plt.ylabel("NORMALIZED CONCENTRATION, IN PERCENT")
plt.legend()
```

[22]:
```
<matplotlib.legend.Legend at 0x7f30030af910>
```



Example 7. Three-Dimensional Transport in a Uniform Flow Field

[23]:
```
def p07(dirname, mixelm):
    model_ws = os.path.join(workdir, dirname)
    nlay = 8
    nrow = 15
    ncol = 21
    delr = 10
    delc = 10
    delv = 10
    Lx = (ncol - 1) * delr
    v = 1.0 / 3.0
    prsity = 0.2
    q = v * prsity
    al = 10.0
    trpt = 0.3
    trpv = 0.3
    q0 = 0.5
    c0 = 100.0
```

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```
perlen_mf = 100.0
perlen_mt = 100.0
hk = 0.5
laytyp = 0

modelname_mf = f"{dirname}_mf"
mf = flopy.modflow.Modflow(
    modelname=modelname_mf, model_ws=model_ws, exe_name=exe_name_mf
)
dis = flopy.modflow.ModflowDis(
    mf,
    nlay=nlay,
    nrow=nrow,
    ncol=ncol,
    delr=delr,
    delc=delc,
    top=0.0,
    botm=[-delv * k for k in range(1, nlay + 1)],
    perlen=perlen_mf,
)
ibound = np.ones((nlay, nrow, ncol), dtype=int)
ibound[:, :, 0] = -1
ibound[:, :, -1] = -1
strt = np.zeros((nlay, nrow, ncol), dtype=float)
h1 = q * Lx
strt[:, :, 0] = h1
bas = flopy.modflow.ModflowBas(mf, ibound=ibound, strt=strt)
lpf = flopy.modflow.ModflowLpf(mf, hk=hk, laytyp=laytyp)
wel = flopy.modflow.ModflowWel(mf, stress_period_data=[[6, 7, 2, q0]])
pcg = flopy.modflow.ModflowPcg(mf)
lmt = flopy.modflow.ModflowLmt(mf)
mf.write_input()
mf.run_model(silent=True)

modelname_mt = f"{dirname}_mt"
mt = flopy.mt3d.Mt3dms(
    modelname=modelname_mt,
    model_ws=model_ws,
    exe_name=exe_name_mt,
    modflowmodel=mf,
)
btn = flopy.mt3d.Mt3dBtn(mt, icbund=1, prsity=prsity, sconc=0)
dceps = 1.0e-5
nplane = 1
npl = 0
nph = 16
npmin = 2
npmax = 32
dchmoc = 1.0e-3
nlsink = nplane
npsink = nph
```

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```
    adv = flopy.mt3d.Mt3dAdv(
        mt,
        mixelm=mixelm,
        dceps=dceps,
        nplane=nplane,
        npl=npl,
        nph=nph,
        npmin=npmin,
        npmax=npmax,
        nlsink=nlsink,
        npsink=npsink,
        percel=0.5,
    )
    dsp = flopy.mt3d.Mt3dDsp(mt, al=al, trpt=trpt, trpv=trpv)
    spd = {0: [6, 7, 2, c0, 2]}
    ssm = flopy.mt3d.Mt3dSsm(mt, stress_period_data=spd)
    gcg = flopy.mt3d.Mt3dGcg(mt)
    mt.write_input()
    fname = os.path.join(model_ws, "MT3D001.UCN")
    if os.path.isfile(fname):
        os.remove(fname)
    mt.run_model(silent=True)

    fname = os.path.join(model_ws, "MT3D001.UCN")
    ucnobj = flopy.utils.UcnFile(fname)
    times = ucnobj.get_times()
    conc = ucnobj.get_alldata()

    fname = os.path.join(model_ws, "MT3D001.OBS")
    if os.path.isfile(fname):
        cvt = mt.load_obs(fname)
    else:
        cvt = None

    fname = os.path.join(model_ws, "MT3D001.MAS")
    mvt = mt.load_mas(fname)

    return mf, mt, conc, cvt, mvt
```

[24]:
```
fig = plt.figure(figsize=(10, 20))
mf, mt, conc, cvt, mvt = p07("p07", -1)
conc = conc[0]

ax = fig.add_subplot(3, 1, 1, aspect="equal")
ilay = 4
pmv = flopy.plot.PlotMapView(ax=ax, model=mf, layer=ilay)
pmv.plot_grid(color=".5", alpha=0.2)
pmv.plot_ibound()
cs = pmv.contour_array(conc, levels=[0.01, 0.05, 0.15, 0.50], colors="k")
plt.clabel(cs)
plt.xlabel("DISTANCE ALONG X-AXIS, IN METERS")
plt.ylabel("DISTANCE ALONG Y-AXIS, IN METERS")
```

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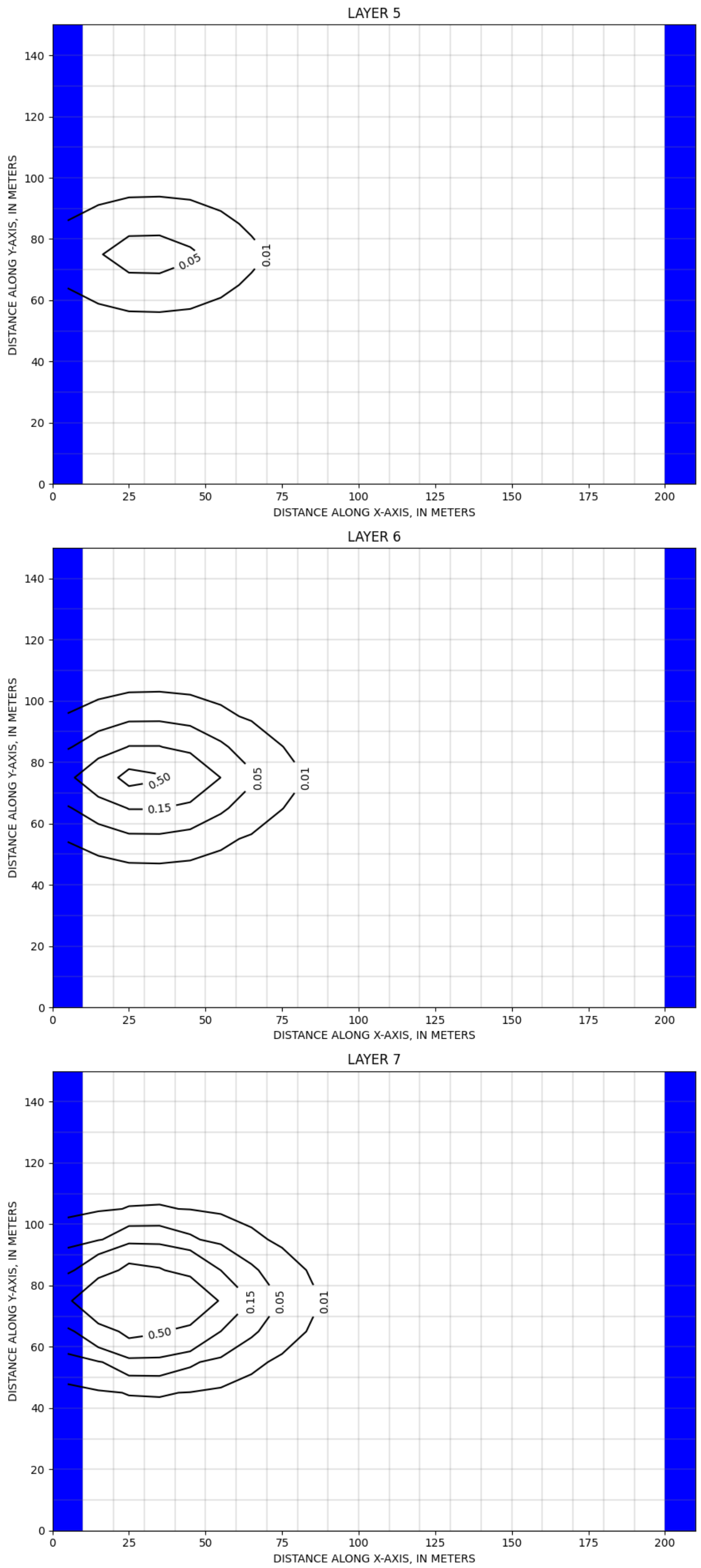
```
plt.title(f"LAYER {ilay + 1}")

ax = fig.add_subplot(3, 1, 2, aspect="equal")
ilay = 5
pmv = flopy.plot.PlotMapView(ax=ax, model=mf, layer=ilay)
pmv.plot_grid(color=".5", alpha=0.2)
pmv.plot_ibound()
cs = pmv.contour_array(conc, levels=[0.01, 0.05, 0.15, 0.50], colors="k")
plt.clabel(cs)
plt.xlabel("DISTANCE ALONG X-AXIS, IN METERS")
plt.ylabel("DISTANCE ALONG Y-AXIS, IN METERS")
plt.title(f"LAYER {ilay + 1}")

ax = fig.add_subplot(3, 1, 3, aspect="equal")
ilay = 6
pmv = flopy.plot.PlotMapView(ax=ax, model=mf, layer=ilay)
pmv.plot_grid(color=".5", alpha=0.2)
pmv.plot_ibound()
cs = pmv.contour_array(conc, levels=[0.01, 0.05, 0.15, 0.50], colors="k")
plt.clabel(cs)
plt.xlabel("DISTANCE ALONG X-AXIS, IN METERS")
plt.ylabel("DISTANCE ALONG Y-AXIS, IN METERS")
plt.title(f"LAYER {ilay + 1}")
plt.plot(grid.xcellcenters[7, 2], grid.ycellcenters[7, 2], "ko")

plt.tight_layout()
```


LAYER 5
DISTANCE ALONG Y-AXIS, IN METERS
DISTANCE ALONG X-AXIS, IN METERS
0.05
0.01
LAYER 6
DISTANCE ALONG Y-AXIS, IN METERS
DISTANCE ALONG X-AXIS, IN METERS
0.50
0.15
0.05
0.01
LAYER 7
DISTANCE ALONG Y-AXIS, IN METERS
DISTANCE ALONG X-AXIS, IN METERS
0.50
0.15
0.05
0.01
0
20
40
60
80
100
120
140
0
25
50
75
100
125
150
175
200

Example 8. Two-Dimensional, Vertical Transport in a Heterogeneous Aquifer

[25]:
```python
def p08(dirname, mixelm):
    model_ws = os.path.join(workdir, dirname)
    nlay = 27
    nrow = 1
    ncol = 50
    delr = 5
    delc = 1
    delv = 0.25
    prsity = 0.35
    al = 0.5
    trpt = 0.01
    trpv = 0.01
    dmcoef = 1.34e-5 / 100 / 100 * 86400
    rech = 0.1 / 365  # m/d

    perlen_mf = 1
    perlen_mt = [5 * 365, 15 * 365]

    k1 = 5e-4 / 100.0 * 86400  # m/d
    k2 = 1e-2 / 100.0 * 86400  # m/d
    hk = k1 * np.ones((nlay, nrow, ncol), dtype=float)
    hk[11:19, :, 0:24] = k2
    hk[11:19, :, 36:] = k2
    laytyp = 6 * [1] + 21 * [0]

    modelname_mf = f"{dirname}_mf"
    mf = flopy.modflow.Modflow(
        modelname=modelname_mf, model_ws=model_ws, exe_name=exe_name_mf
    )
    dis = flopy.modflow.ModflowDis(
        mf,
        nlay=nlay,
        nrow=nrow,
        ncol=ncol,
        delr=delr,
        delc=delc,
        top=6.75,
        botm=[6.75 - delv * k for k in range(1, nlay + 1)],
        perlen=perlen_mf,
    )
    f = open(os.path.join(datadir, "p08shead.dat"))
    strt = np.empty((nlay * ncol), dtype=float)
    strt = read1d(f, strt).reshape((nlay, nrow, ncol))
    f.close()
    ibound = np.ones((nlay, nrow, ncol), dtype=int)
    ibound[5:, :, -1] = -1
    ibound[strt < 0] = 0

    bas = flopy.modflow.ModflowBas(mf, ibound=ibound, strt=strt)
    lpf = flopy.modflow.ModflowLpf(mf, hk=hk, vka=hk, laytyp=laytyp)
    rch = flopy.modflow.ModflowRch(mf, rech=rech)
```
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```
    pcg = flopy.modflow.ModflowPcg(mf)
    lmt = flopy.modflow.ModflowLmt(mf)
    mf.write_input()
    mf.run_model(silent=True)

    modelname_mt = f"{dirname}_mt"
    mt = flopy.mt3d.Mt3dms(
        modelname=modelname_mt,
        model_ws=model_ws,
        exe_name=exe_name_mt,
        modflowmodel=mf,
    )
    btn = flopy.mt3d.Mt3dBtn(
        mt,
        icbund=1,
        prsity=prsity,
        sconc=0,
        nper=2,
        perlen=perlen_mt,
        timprs=[8 * 365, 12 * 365, 20 * 365],
    )
    percel = 1.0
    itrack = 3
    wd = 0.5
    dceps = 1.0e-5
    nplane = 0
    npl = 0
    nph = 10
    npmin = 2
    npmax = 20
    dchmoc = 1.0e-3
    nlsink = nplane
    npsink = nph
    adv = flopy.mt3d.Mt3dAdv(
        mt,
        mixelm=mixelm,
        dceps=dceps,
        nplane=nplane,
        npl=npl,
        nph=nph,
        npmin=npmin,
        npmax=npmax,
        nlsink=nlsink,
        npsink=npsink,
        percel=percel,
        itrack=itrack,
        wd=wd,
    )
    dsp = flopy.mt3d.Mt3dDsp(mt, al=al, trpt=trpt, trpv=trpv, dmcoef=dmcoef)
    crch1 = np.zeros((nrow, ncol), dtype=float)
    crch1[0, 9:18] = 1.0
    cnc0 = [(0, 0, j, 1, -1) for j in range(8, 16)]
```

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```
    cnc1 = [(0, 0, j, 0.0, -1) for j in range(8, 16)]
    ssmspd = {0: cnc0, 1: cnc1}
    ssm = flopy.mt3d.Mt3dSsm(mt, stress_period_data=ssmspd)
    gcg = flopy.mt3d.Mt3dGcg(mt)
    mt.write_input()
    fname = os.path.join(model_ws, "MT3D001.UCN")
    if os.path.isfile(fname):
        os.remove(fname)
    mt.run_model(silent=True)

    fname = os.path.join(model_ws, "MT3D001.UCN")
    ucnobj = flopy.utils.UcnFile(fname)
    times = ucnobj.get_times()
    conc = ucnobj.get_alldata()

    fname = os.path.join(model_ws, "MT3D001.OBS")
    if os.path.isfile(fname):
        cvt = mt.load_obs(fname)
    else:
        cvt = None

    fname = os.path.join(model_ws, "MT3D001.MAS")
    mvt = mt.load_mas(fname)

    return mf, mt, conc, cvt, mvt
```

[26]:
```
fig = plt.figure(figsize=(10, 15))
mf, mt, conc, cvt, mvt = p08("p08", 3)
hk = mf.lpf.hk.array

ax = fig.add_subplot(3, 1, 1)
mx = flopy.plot.PlotCrossSection(ax=ax, model=mf, line={"row": 0})
mx.plot_array(hk, masked_values=[hk[0, 0, 0]], alpha=0.2)
mx.plot_ibound()
mx.plot_grid(color="0.5", alpha=0.2)
cs = mx.contour_array(
    conc[1], levels=np.arange(0.05, 0.55, 0.05), masked_values=[1.0e30]
)
ax.set_title("TIME = 8 YEARS")

ax = fig.add_subplot(3, 1, 2)
mx = flopy.plot.PlotCrossSection(ax=ax, model=mf, line={"row": 0})
mx.plot_array(hk, masked_values=[hk[0, 0, 0]], alpha=0.2)
mx.plot_ibound()
mx.plot_grid(color="0.5", alpha=0.2)
cs = mx.contour_array(
    conc[2], levels=np.arange(0.05, 0.55, 0.05), masked_values=[1.0e30]
)
ax.set_title("TIME = 12 YEARS")

ax = fig.add_subplot(3, 1, 3)
mx = flopy.plot.PlotCrossSection(ax=ax, model=mf, line={"row": 0})
```

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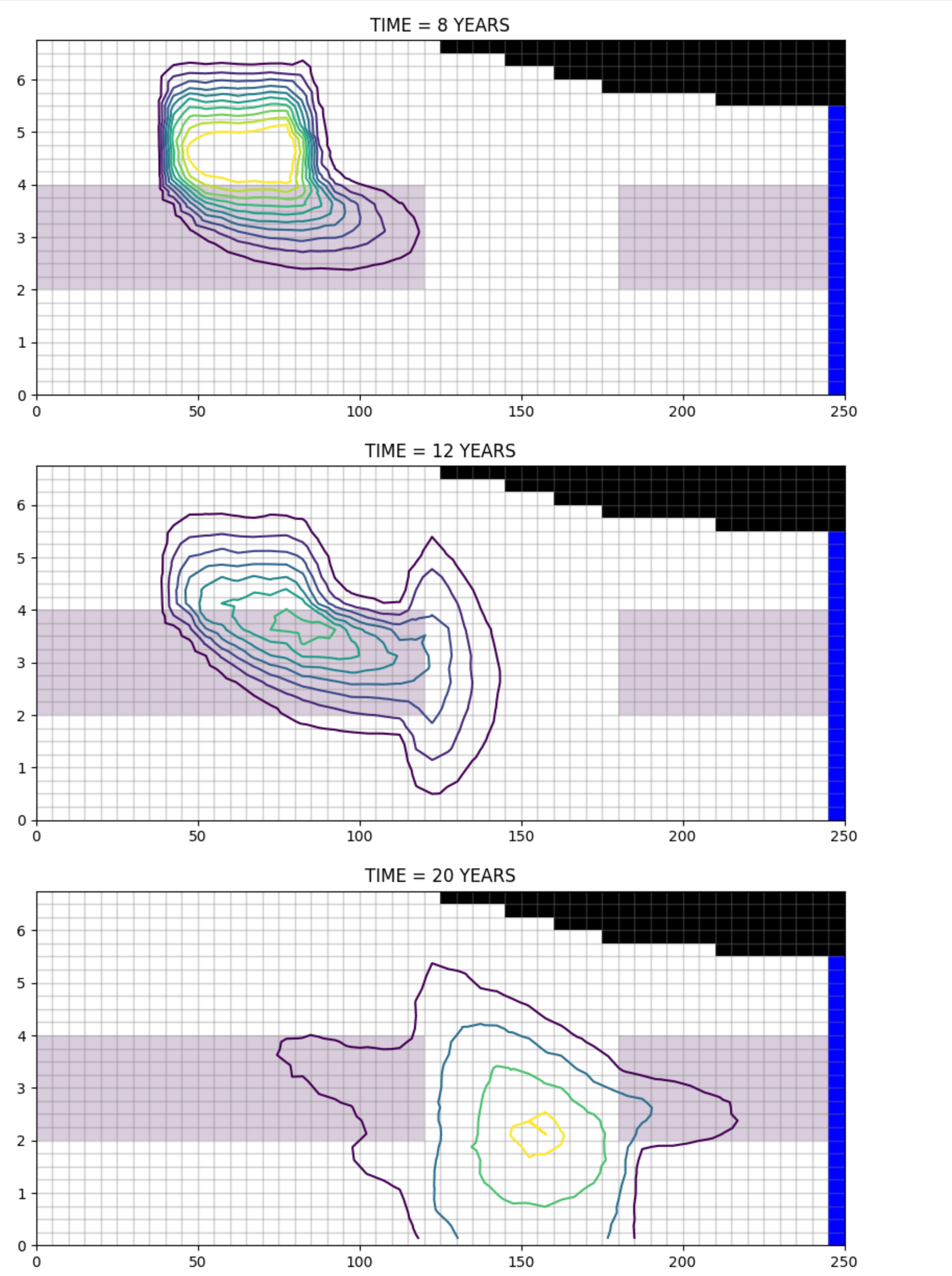
```
mx.plot_array(hk, masked_values=[hk[0, 0, 0]], alpha=0.2)
mx.plot_ibound()
mx.plot_grid(color="0.5", alpha=0.2)
cs = mx.contour_array(
    conc[3], levels=[0.05, 0.1, 0.15, 0.19], masked_values=[1.0e30]
)
ax.set_title("TIME = 20 YEARS")
```

```
found 'rch' in modflow model, resetting crch to 0.0
```

[26]:
```
Text(0.5, 1.0, 'TIME = 20 YEARS')
```


TIME = 8 YEARS
TIME = 12 YEARS
TIME = 20 YEARS
0
1
2
3
4
5
6
0
50
100
150
200
250

Example 9. Two-Dimensional Application Example

[27]:
```
def p09(dirname, mixelm, nadvfd):
    model_ws = os.path.join(workdir, dirname)
    nlay = 1
    nrow = 18
    ncol = 14
    delr = 100
    delc = 100
    delv = 10
    prsity = 0.3
    al = 20.0
    trpt = 0.2

    perlen_mf = 1.0
    perlen_mt = [365.0 * 86400, 365.0 * 86400]
    laytyp = 0
    k1 = 1.474e-4
    k2 = 1.474e-7
    hk = k1 * np.ones((nlay, nrow, ncol), dtype=float)
    hk[:, 5:8, 1:8] = k2

    modelname_mf = f"{dirname}_mf"
    mf = flopy.modflow.Modflow(
        modelname=modelname_mf, model_ws=model_ws, exe_name=exe_name_mf
    )
    dis = flopy.modflow.ModflowDis(
        mf,
        nlay=nlay,
        nrow=nrow,
        ncol=ncol,
        delr=delr,
        delc=delc,
        top=0.0,
        botm=[0 - delv],
        perlen=perlen_mf,
    )
    ibound = np.ones((nlay, nrow, ncol), dtype=int)
    ibound[0, 0, :] = -1
    ibound[0, -1, :] = -1
    strt = np.zeros((nlay, nrow, ncol), dtype=float)
    strt[0, 0, :] = 250.0
    xc = mf.modelgrid.xcellcenters
    for j in range(ncol):
        strt[0, -1, j] = 20.0 + (xc[0, j] - xc[0, 0]) * 2.5 / 100
    bas = flopy.modflow.ModflowBas(mf, ibound=ibound, strt=strt)
    lpf = flopy.modflow.ModflowLpf(mf, hk=hk, laytyp=laytyp)
    welspd = [[0, 3, 6, 0.001], [0, 10, 6, -0.0189]]
    wel = flopy.modflow.ModflowWel(mf, stress_period_data=welspd)
    pcg = flopy.modflow.ModflowPcg(mf)
    lmt = flopy.modflow.ModflowLmt(mf)
    mf.write_input()
    mf.run_model(silent=True)
```

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```
modelname_mt = f"{dirname}_mt"
mt = flopy.mt3d.Mt3dms(
    modelname=modelname_mt,
    model_ws=model_ws,
    exe_name=exe_name_mt,
    modflowmodel=mf,
)
btn = flopy.mt3d.Mt3dBtn(
    mt,
    icbund=1,
    prsity=prsity,
    sconc=0,
    nper=2,
    perlen=perlen_mt,
    obs=[[0, 10, 6]],
)
percel = 1.0
itrack = 2
dceps = 1.0e-5
nplane = 0
npl = 0
nph = 16
npmin = 0
npmax = 32
dchmoc = 1.0e-3
nlsink = nplane
npsink = nph
adv = flopy.mt3d.Mt3dAdv(
    mt,
    mixelm=mixelm,
    dceps=dceps,
    nplane=nplane,
    npl=npl,
    nph=nph,
    npmin=npmin,
    npmax=npmax,
    nlsink=nlsink,
    npsink=npsink,
    percel=percel,
    itrack=itrack,
    nadvfd=nadvfd,
)
dsp = flopy.mt3d.Mt3dDsp(mt, al=al, trpt=trpt)
spd = {
    0: [[0, 3, 6, 57.87, 2], [0, 10, 6, 0.0, 2]],
    1: [[0, 3, 6, 0.0, 2], [0, 10, 6, 0.0, 2]],
}
ssm = flopy.mt3d.Mt3dSsm(mt, stress_period_data=spd)
gcg = flopy.mt3d.Mt3dGcg(mt)
mt.write_input()
fname = os.path.join(model_ws, "MT3D001.UCN")
```

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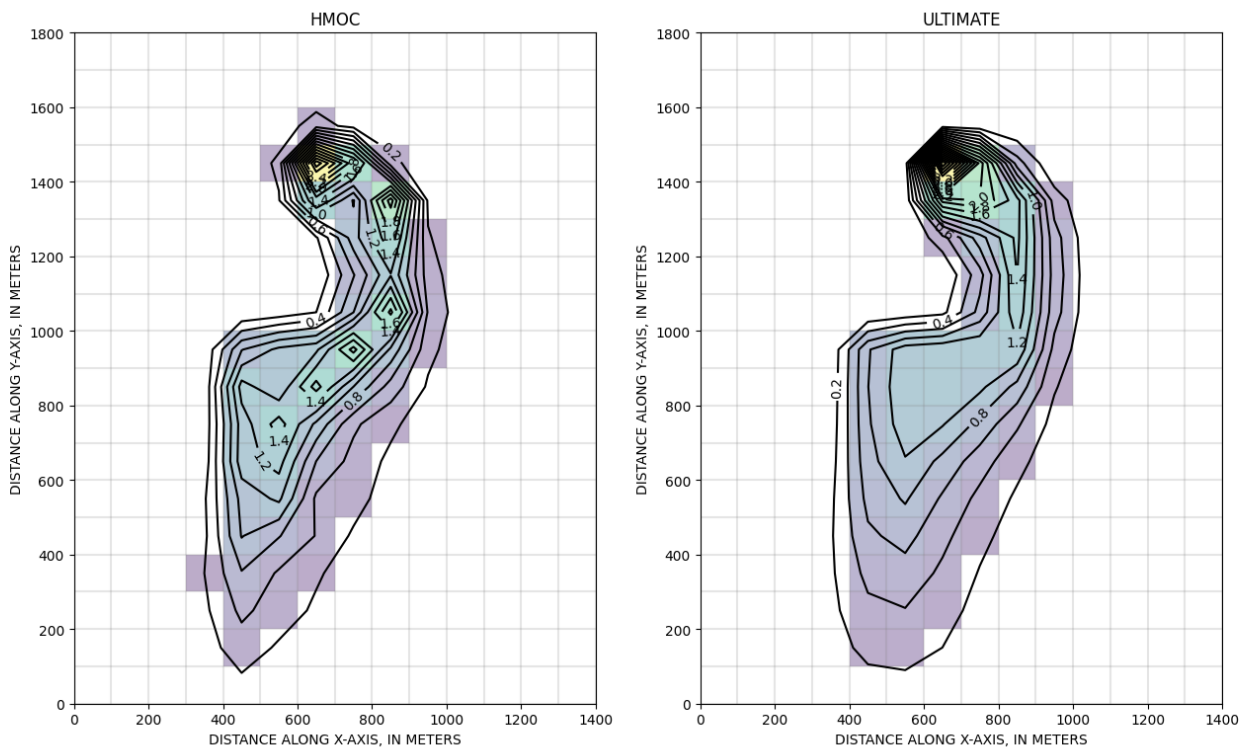
```
    if os.path.isfile(fname):
        os.remove(fname)
    mt.run_model(silent=True)

    fname = os.path.join(model_ws, "MT3D001.UCN")
    ucnobj = flopy.utils.UcnFile(fname)
    times = ucnobj.get_times()
    conc = ucnobj.get_alldata()

    fname = os.path.join(model_ws, "MT3D001.OBS")
    if os.path.isfile(fname):
        cvt = mt.load_obs(fname)
    else:
        cvt = None

    fname = os.path.join(model_ws, "MT3D001.MAS")
    mvt = mt.load_mas(fname)

    return mf, mt, conc, cvt, mvt
```

[28]:
```
fig = plt.figure(figsize=(15, 10))
levels = np.arange(0.2, 10, 0.2)

ax = fig.add_subplot(1, 2, 1, aspect="equal")
mf, mt, conc, cvt, mvt = p09("p09", 3, 1)
cvt["time"] / 365.0 / 86400.0
y = cvt["(1, 11, 7)"]
conc = conc[:, 0, :, :]
cflood = np.ma.masked_less_equal(conc, 0.2)
pmv = flopy.plot.PlotMapView(ax=ax, model=mf)
pmv.plot_grid(color=".5", alpha=0.2)
cs = pmv.plot_array(cflood[0], alpha=0.2, vmin=0, vmax=3)
cs = pmv.contour_array(conc[0], colors="k", levels=levels)
plt.clabel(cs)
plt.xlabel("DISTANCE ALONG X-AXIS, IN METERS")
plt.ylabel("DISTANCE ALONG Y-AXIS, IN METERS")
plt.title("HMOC")

ax = fig.add_subplot(1, 2, 2, aspect="equal")
mf, mt, conc, cvt, mvt = p09("p09", -1, 1)
cvt["time"] / 365.0 / 86400.0
y = cvt["(1, 11, 7)"]
conc = conc[:, 0, :, :]
cflood = np.ma.masked_less_equal(conc, 0.2)
pmv = flopy.plot.PlotMapView(ax=ax, model=mf)
pmv.plot_grid(color=".5", alpha=0.2)
cs = pmv.plot_array(cflood[0], alpha=0.2, vmin=0, vmax=3)
cs = pmv.contour_array(conc[0], colors="k", levels=levels)
plt.clabel(cs)
plt.xlabel("DISTANCE ALONG X-AXIS, IN METERS")
plt.ylabel("DISTANCE ALONG Y-AXIS, IN METERS")
plt.title("ULTIMATE")
```

[28]:
```
Text(0.5, 1.0, 'ULTIMATE')
```



[29]:
```
fig = plt.figure(figsize=(10, 8))
ax = fig.add_subplot(1, 1, 1)

mf, mt, conc, cvt, mvt = p09("p09", 3, 1)
x = cvt["time"] / 365.0 / 86400.0
y = cvt["(1, 11, 7)"]
plt.plot(x, y, label="HMOC", marker="d")

mf, mt, conc, cvt, mvt = p09("p09", -1, 1)
x = cvt["time"] / 365.0 / 86400.0
y = cvt["(1, 11, 7)"]
plt.plot(x, y, label="ULTIMATE", marker="^")

mf, mt, conc, cvt, mvt = p09("p09", 0, 1)
x = cvt["time"] / 365.0 / 86400.0
y = cvt["(1, 11, 7)"]
plt.plot(x, y, label="Upstream FD", marker="^")

mf, mt, conc, cvt, mvt = p09("p09", 0, 2)
x = cvt["time"] / 365.0 / 86400.0
y = cvt["(1, 11, 7)"]
plt.plot(x, y, label="Central FD", marker="^")

plt.xlim(0, 2)
plt.ylim(-0.2, 1.4)
plt.xlabel("TIME, IN YEARS")
```

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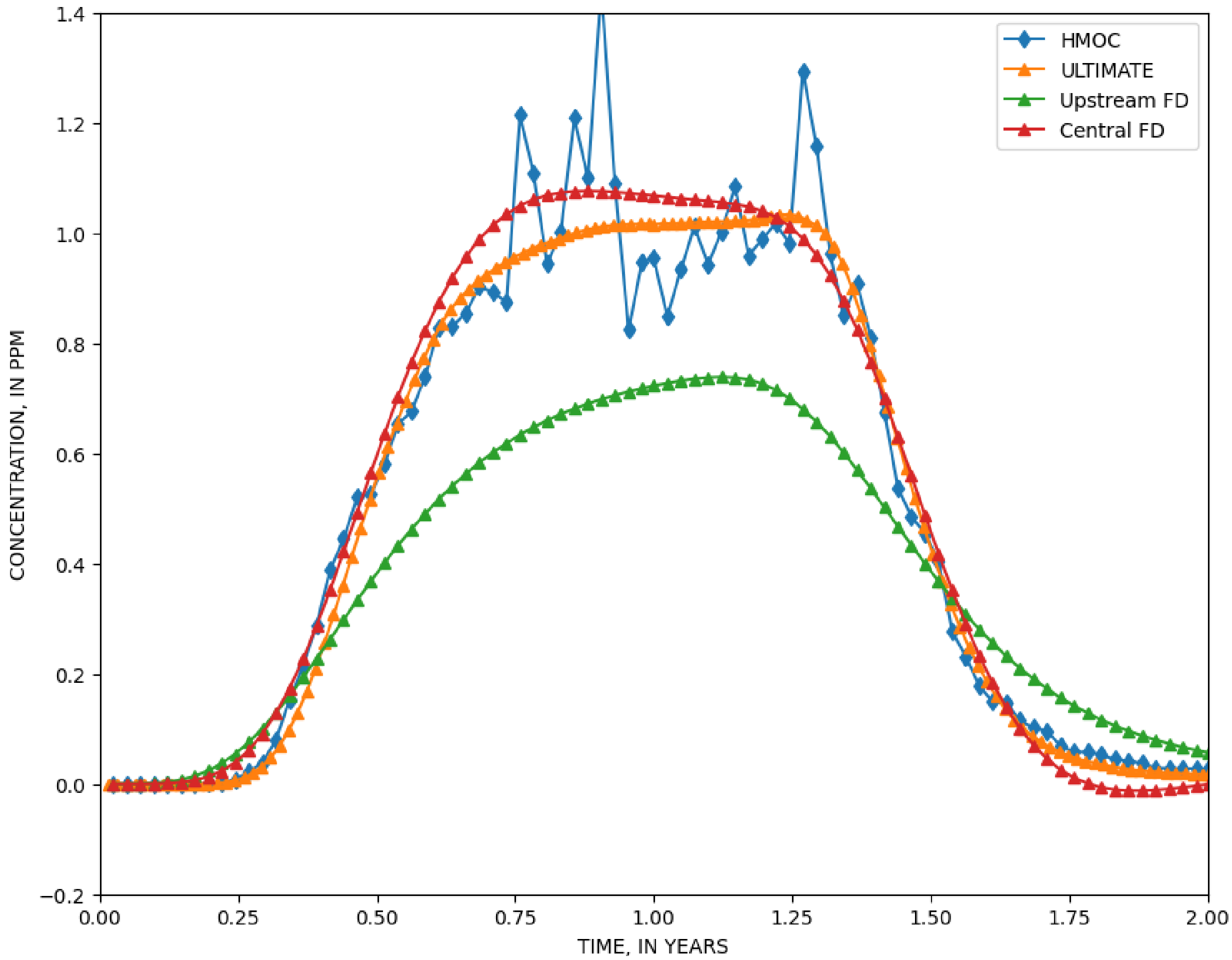
```
plt.ylabel("CONCENTRATION, IN PPM")
plt.legend()
```

[29]: <matplotlib.legend.Legend at 0x7f2fff15a880>



Example 10. Three-Dimensional Field Case Study

```
[30]: def p10(dirname, mixelm, perlen=1000, isothm=1, sp2=0.0, ttsmult=1.2):
    model_ws = os.path.join(workdir, dirname)
    nlay = 4
    nrow = 61
    ncol = 40
    delr = (
        [2000, 1600, 800, 400, 200, 100]
        + 28 * [50]
        + [100, 200, 400, 800, 1600, 2000]
    )
    delc = (
        [2000, 2000, 2000, 1600, 800, 400, 200, 100]
        + 45 * [50]
```

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```
    + [100, 200, 400, 800, 1600, 2000, 2000, 2000]
)
delv = 25.0
top = 780.0
botm = [top - delv * k for k in range(1, nlay + 1)]
prsity = 0.3
al = 10.0
trpt = 0.2
trpv = 0.2

perlen_mf = perlen
perlen_mt = perlen
hk = [60.0, 60.0, 520.0, 520.0]
vka = 0.1
laytyp = 0

modelname_mf = f"{dirname}_mf"
mf = flopy.modflow.Modflow(
    modelname=modelname_mf, model_ws=model_ws, exe_name=exe_name_mf
)
dis = flopy.modflow.ModflowDis(
    mf,
    nlay=nlay,
    nrow=nrow,
    ncol=ncol,
    delr=delr,
    delc=delc,
    top=top,
    botm=botm,
    perlen=perlen_mf,
)
ibound = np.ones((nlay, nrow, ncol), dtype=int)

# left side
ibound[:, :, 0] = -1
# right side
ibound[:, :, -1] = -1
# top
ibound[:, 0, :] = -1
# bottom
ibound[:, -1, :] = -1

f = open(os.path.join(datadir, "p10shead.dat"))
s0 = np.empty((nrow * ncol), dtype=float)
s0 = read1d(f, s0).reshape((nrow, ncol))
f.close()
strt = np.zeros((nlay, nrow, ncol), dtype=float)
for k in range(nlay):
    strt[k] = s0
bas = flopy.modflow.ModflowBas(mf, ibound=ibound, strt=strt)
lpf = flopy.modflow.ModflowLpf(mf, hk=hk, layvka=1, vka=vka, laytyp=laytyp)
welspd = [
```

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```
        [3 - 1, 11 - 1, 29 - 1, -19230.00],
        [3 - 1, 19 - 1, 26 - 1, -19230.00],
        [3 - 1, 26 - 1, 23 - 1, -19230.00],
        [3 - 1, 33 - 1, 20 - 1, -19230.00],
        [3 - 1, 40 - 1, 17 - 1, -19230.00],
        [3 - 1, 48 - 1, 14 - 1, -19230.00],
        [3 - 1, 48 - 1, 9 - 1, -15384.00],
        [3 - 1, 52 - 1, 17 - 1, -17307.00],
    ]
    wel = flopy.modflow.ModflowWel(mf, stress_period_data=welspd)
    rch = flopy.modflow.ModflowRch(mf, rech=1.14e-3)
    pcg = flopy.modflow.ModflowPcg(mf)
    lmt = flopy.modflow.ModflowLmt(mf)
    mf.write_input()
    fname = os.path.join(model_ws, "MT3D001.UCN")
    if os.path.isfile(fname):
        os.remove(fname)
    mf.run_model(silent=True)

    modelname_mt = f"{dirname}_mt"
    mt = flopy.mt3d.Mt3dms(
        modelname=modelname_mt,
        model_ws=model_ws,
        exe_name=exe_name_mt,
        modflowmodel=mf,
    )
    f = open(os.path.join(datadir, "p10cinit.dat"))
    c0 = np.empty((nrow * ncol), dtype=float)
    c0 = read1d(f, c0).reshape((nrow, ncol))
    f.close()
    sconc = np.zeros((nlay, nrow, ncol), dtype=float)
    sconc[1] = 0.2 * c0
    sconc[2] = c0
    obs = [
        [3 - 1, 11 - 1, 29 - 1],
        [3 - 1, 19 - 1, 26 - 1],
        [3 - 1, 26 - 1, 23 - 1],
        [3 - 1, 33 - 1, 20 - 1],
        [3 - 1, 40 - 1, 17 - 1],
        [3 - 1, 48 - 1, 14 - 1],
        [3 - 1, 48 - 1, 9 - 1],
        [3 - 1, 52 - 1, 17 - 1],
    ]
    btn = flopy.mt3d.Mt3dBtn(
        mt,
        icbund=1,
        prsity=prsity,
        sconc=sconc,
        timprs=[500, 750, 1000],
        dt0=2.25,
        ttsmult=ttsmult,
        obs=obs,
```

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```
    )
    dceps = 1.0e-5
    nplane = 0
    npl = 0
    nph = 16
    npmin = 2
    npmax = 32
    dchmoc = 0.01
    nlsink = nplane
    npsink = nph
    adv = flopy.mt3d.Mt3dAdv(
        mt,
        mixelm=mixelm,
        dceps=dceps,
        nplane=nplane,
        npl=npl,
        nph=nph,
        npmin=npmin,
        npmax=npmax,
        nlsink=nlsink,
        npsink=npsink,
        percel=1.0,
    )
    dsp = flopy.mt3d.Mt3dDsp(mt, al=al, trpt=trpt, trpv=trpv)
    ssm = flopy.mt3d.Mt3dSsm(mt, crch=0.0)
    rct = flopy.mt3d.Mt3dRct(
        mt, isothm=isothm, igetsc=0, rhob=1.7, sp1=0.176, sp2=sp2
    )
    mxiter = 1
    if isothm == 4:
        mxiter = 50
    gcg = flopy.mt3d.Mt3dGcg(mt, mxiter=mxiter, iter1=500)
    mt.write_input()
    fname = os.path.join(model_ws, "MT3D001.UCN")
    if os.path.isfile(fname):
        os.remove(fname)
    mt.run_model(silent=True)

    fname = os.path.join(model_ws, "MT3D001.UCN")
    ucnobj = flopy.utils.UcnFile(fname)
    times = ucnobj.get_times()
    conc = ucnobj.get_alldata()

    fname = os.path.join(model_ws, "MT3D001.OBS")
    if os.path.isfile(fname):
        cvt = mt.load_obs(fname)
    else:
        cvt = None

    fname = os.path.join(model_ws, "MT3D001.MAS")
    mvt = mt.load_mas(fname)
```

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```
    return mf, mt, conc, cvt, mvt
```

[31]:
```
mf, mt, conctvd, cvttvd, mvttvd = p10("p10", -1)
mf, mt, conchmoc, cvthmoc, mvthmoc = p10("p10", 3)
mf, mt, concupfd, cvtupfd, mvtupfd = p10("p10", 0, ttsmult=1.0)
grid = mf.modelgrid
```

[32]:
```
fig = plt.figure(figsize=(10, 15))
ax = fig.add_subplot(2, 2, 1, aspect="equal")
cinit = mt.btn.sconc[0].array[2]
pmv = flopy.plot.PlotMapView(model=mf)
pmv.plot_grid(color=".5", alpha=0.2)
cs = pmv.contour_array(cinit, levels=np.arange(20, 200, 20))
plt.xlim(5100, 5100 + 28 * 50)
plt.ylim(9100, 9100 + 45 * 50)
plt.xlabel("DISTANCE ALONG X-AXIS, IN METERS")
plt.ylabel("DISTANCE ALONG Y-AXIS, IN METERS")
plt.title(f"LAYER {3} INITIAL CONCENTRATION")
for k, i, j, q in mf.wel.stress_period_data[0]:
    plt.plot(grid.xcellcenters[i, j], grid.ycellcenters[i, j], "ks")

ax = fig.add_subplot(2, 2, 2, aspect="equal")
c = conctvd[0, 2]
chmoc = conchmoc[0, 2]
pmv = flopy.plot.PlotMapView(model=mf)
pmv.plot_grid(color=".5", alpha=0.2)
cs = pmv.contour_array(c, levels=np.arange(20, 200, 20))
cs = pmv.contour_array(chmoc, linestyles=":", levels=np.arange(20, 200, 20))
plt.xlim(5100, 5100 + 28 * 50)
plt.ylim(9100, 9100 + 45 * 50)
plt.xlabel("DISTANCE ALONG X-AXIS, IN METERS")
plt.ylabel("DISTANCE ALONG Y-AXIS, IN METERS")
plt.title(f"LAYER {3} TIME = 500 DAYS")
for k, i, j, q in mf.wel.stress_period_data[0]:
    plt.plot(grid.xcellcenters[i, j], grid.ycellcenters[i, j], "ks")

ax = fig.add_subplot(2, 2, 3, aspect="equal")
c = conctvd[1, 2]
chmoc = conchmoc[1, 2]
pmv = flopy.plot.PlotMapView(model=mf)
pmv.plot_grid(color=".5", alpha=0.2)
cs = pmv.contour_array(c, levels=np.arange(20, 200, 20))
cs = pmv.contour_array(chmoc, linestyles=":", levels=np.arange(20, 200, 20))
plt.xlim(5100, 5100 + 28 * 50)
plt.ylim(9100, 9100 + 45 * 50)
plt.xlabel("DISTANCE ALONG X-AXIS, IN METERS")
plt.ylabel("DISTANCE ALONG Y-AXIS, IN METERS")
plt.title(f"LAYER {3} TIME = 750 DAYS")
for k, i, j, q in mf.wel.stress_period_data[0]:
    plt.plot(grid.xcellcenters[i, j], grid.ycellcenters[i, j], "ks")
```

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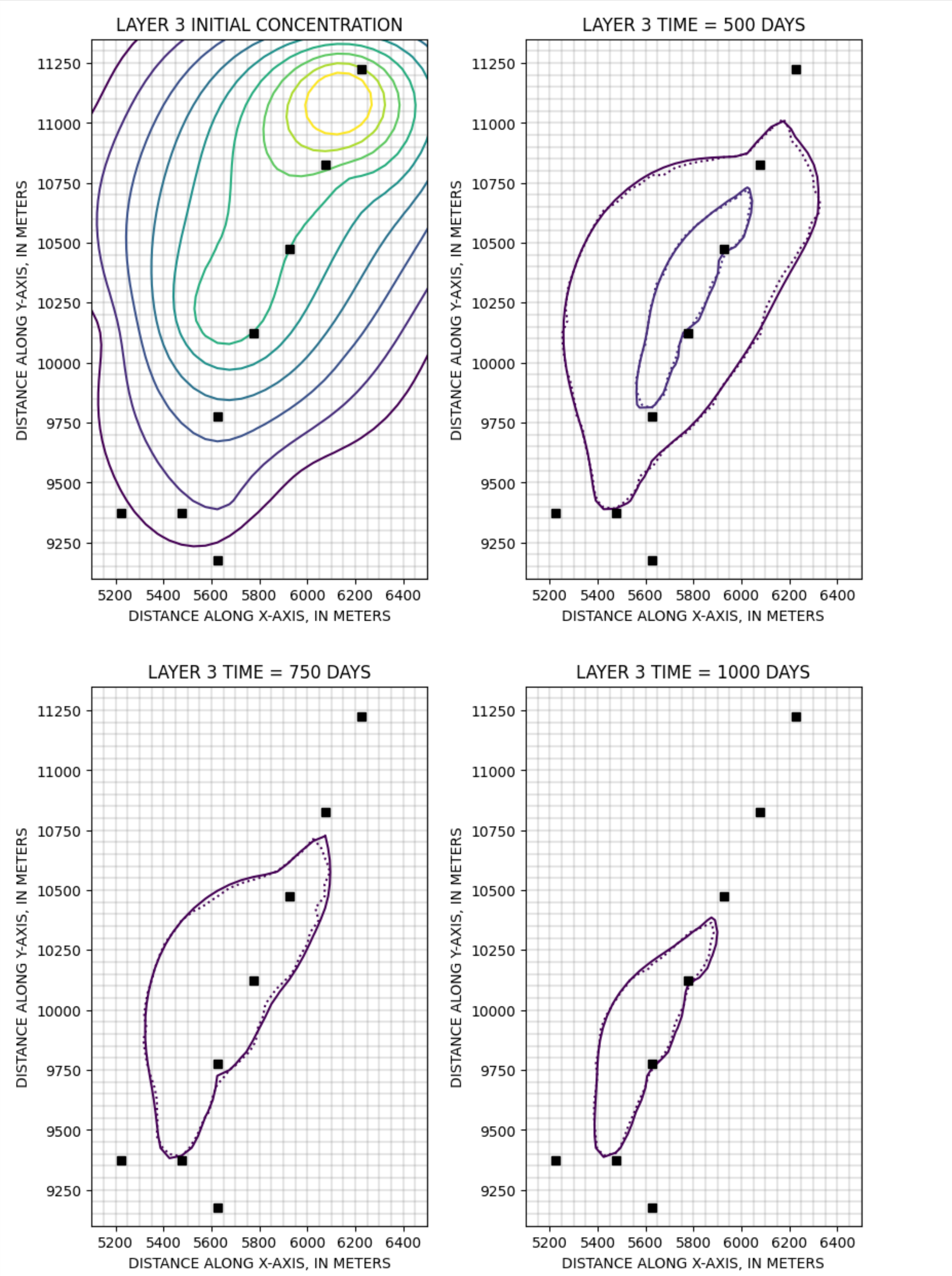
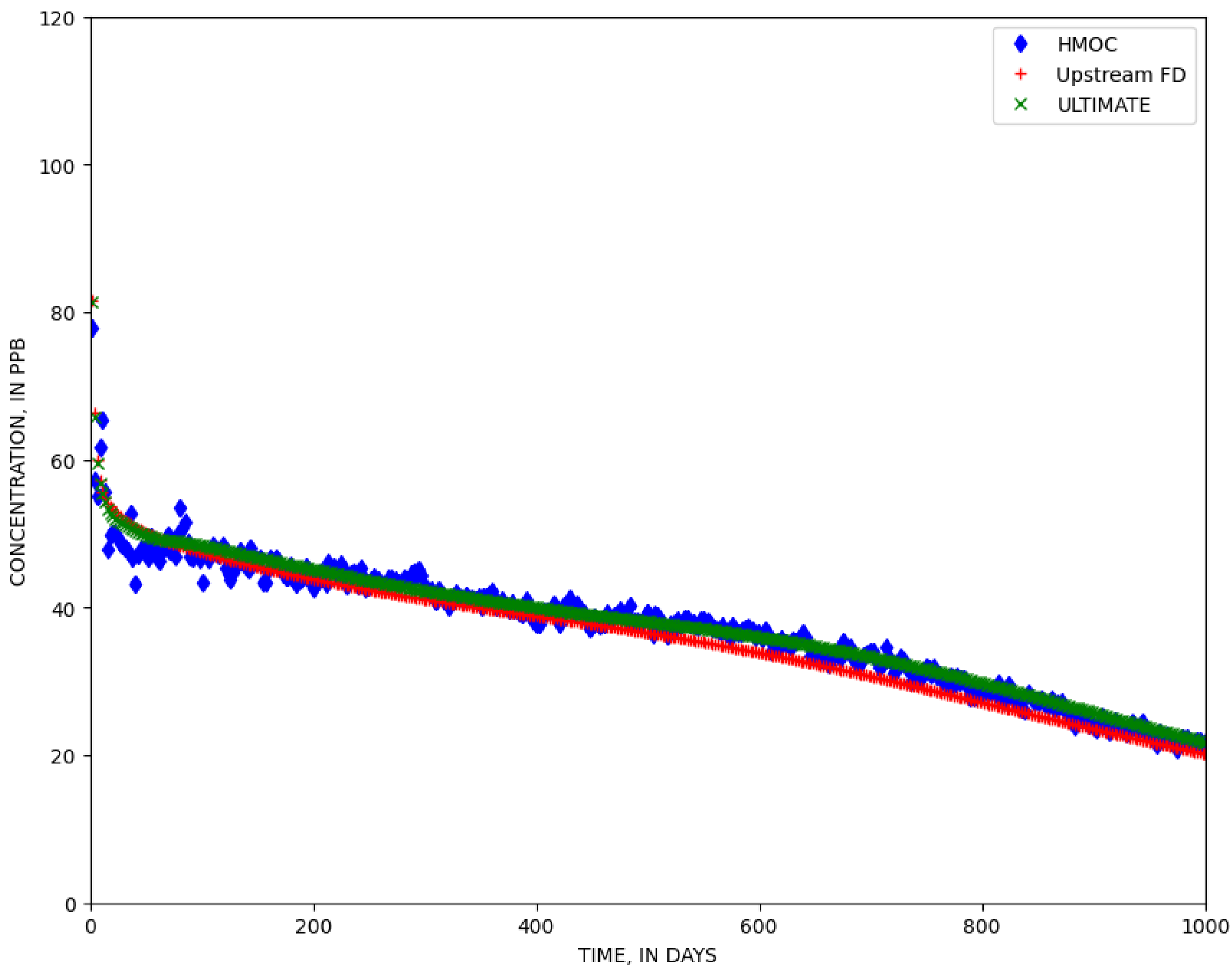
```
ax = fig.add_subplot(2, 2, 4, aspect="equal")
c = conctvd[2, 2]
chmoc = conchmoc[2, 2]
pmv = flopy.plot.PlotMapView(model=mf)
pmv.plot_grid(color=".5", alpha=0.2)
cs = pmv.contour_array(c, levels=np.arange(20, 200, 20))
cs = pmv.contour_array(chmoc, linestyles=":", levels=np.arange(20, 200, 20))
plt.xlim(5100, 5100 + 28 * 50)
plt.ylim(9100, 9100 + 45 * 50)
plt.xlabel("DISTANCE ALONG X-AXIS, IN METERS")
plt.ylabel("DISTANCE ALONG Y-AXIS, IN METERS")
plt.title(f"LAYER {3} TIME = 1000 DAYS")
for k, i, j, q in mf.wel.stress_period_data[0]:
    plt.plot(grid.xcellcenters[i, j], grid.ycellcenters[i, j], "ks")

# plt.tight_layout()
```


LAYER 3 INITIAL CONCENTRATION
LAYER 3 TIME = 500 DAYS
LAYER 3 TIME = 750 DAYS
LAYER 3 TIME = 1000 DAYS
DISTANCE ALONG Y-AXIS, IN METERS
DISTANCE ALONG X-AXIS, IN METERS
11250
11000
10750
10500
10250
10000
9750
9500
9250
5200
5400
5600
5800
6000
6200
6400

[33]:
```
fig = plt.figure(figsize=(10, 8))
ax = fig.add_subplot(1, 1, 1)
w4 = "(3, 33, 20)"
ax.plot(cvthmoc["time"], cvthmoc[w4], "bd", label="HMOC")
ax.plot(cvtupfd["time"], cvtupfd[w4], "r+", label="Upstream FD")
ax.plot(cvttvd["time"], cvttvd[w4], "gx", label="ULTIMATE")
plt.xlim(0, 1000)
plt.ylim(0, 120)
plt.legend()
plt.xlabel("TIME, IN DAYS")
plt.ylabel("CONCENTRATION, IN PPB")
```

[33]:
```
Text(0, 0.5, 'CONCENTRATION, IN PPB')
```



[34]:
```
mf, mt, conctvd, cvttvd, mvt0 = p10("p10", 0, perlen=2000, isothm=0)
mf, mt, conctvd, cvttvd, mvt1 = p10("p10", 0, perlen=2000, isothm=1)
mf, mt, conctvd, cvttvd, mvt2 = p10("p10", 0, perlen=2000, isothm=4, sp2=0.1)
mf, mt, conctvd, cvttvd, mvt3 = p10(
    "p10", 0, perlen=2000, isothm=4, sp2=1.5e-4
)
mf, mt, conctvd, cvttvd, mvt4 = p10(
```

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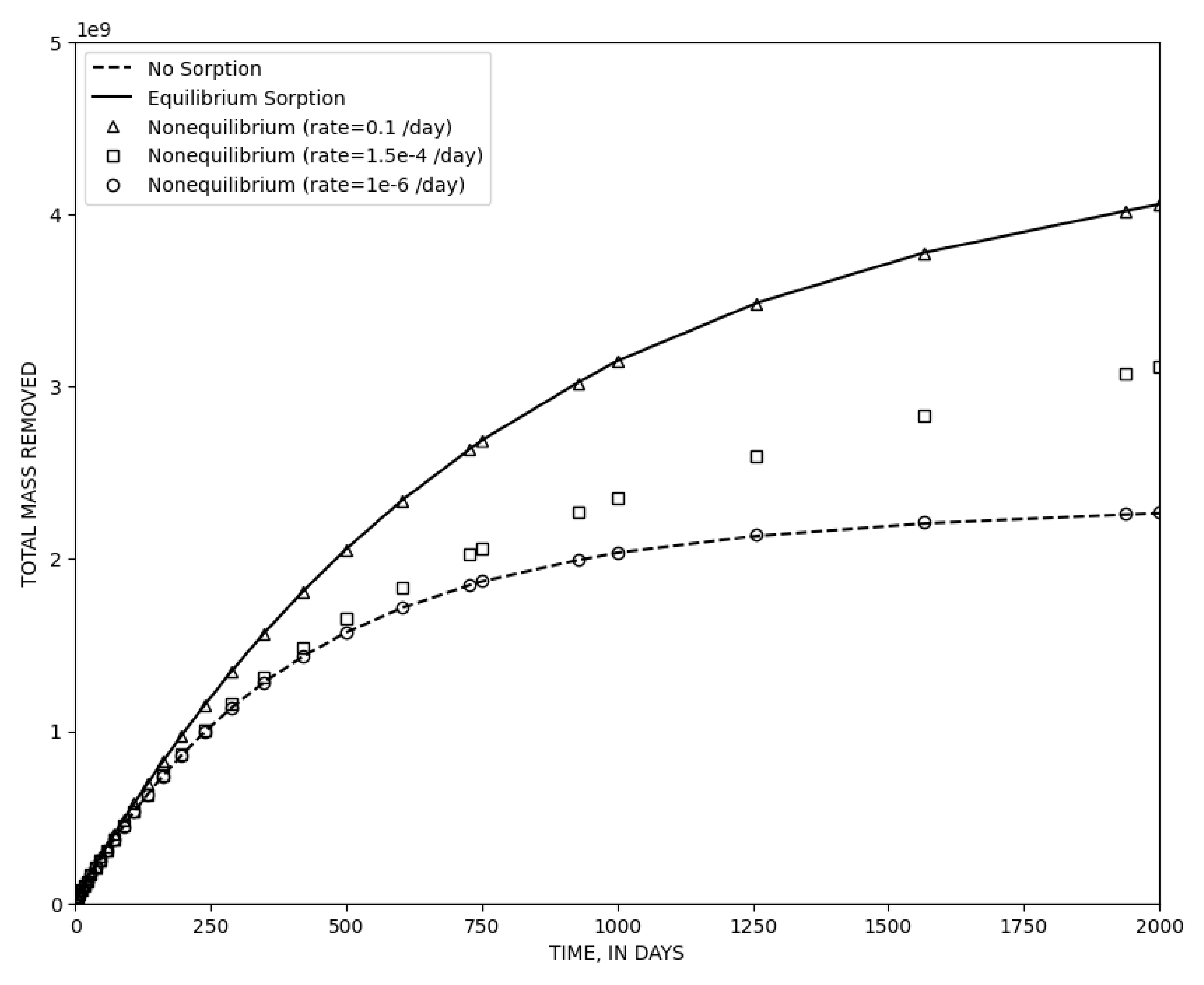
```
    "p10", 0, perlen=2000, isothm=4, sp2=1.0e-6
)
```

[35]:
```
fig = plt.figure(figsize=(10, 8))
ax = fig.add_subplot(1, 1, 1)
ax.plot(mvt0["time"], -mvt0["sinks"], "k--", label="No Sorption")
ax.plot(mvt1["time"], -mvt1["sinks"], "k-", label="Equilibrium Sorption")
ax.plot(
    mvt2["time"],
    -mvt2["sinks"],
    "k^",
    fillstyle="none",
    label="Nonequilibrium (rate=0.1 /day)",
)
ax.plot(
    mvt3["time"],
    -mvt3["sinks"],
    "ks",
    fillstyle="none",
    label="Nonequilibrium (rate=1.5e-4 /day)",
)
ax.plot(
    mvt4["time"],
    -mvt4["sinks"],
    "ko",
    fillstyle="none",
    label="Nonequilibrium (rate=1e-6 /day)",
)
plt.xlim(0, 2000)
plt.ylim(0, 5e9)
plt.legend(loc=2)
plt.xlabel("TIME, IN DAYS")
plt.ylabel("TOTAL MASS REMOVED")
```

[35]:
```
Text(0, 0.5, 'TOTAL MASS REMOVED')
```



[36]:
```
try:
    # ignore PermissionError on Windows
    temp_dir.cleanup()
except:
    pass
```

6.10 Examples from Bakker and others (2016)

6.10.1 Basic Flopy example

From: Bakker, Mark, Post, Vincent, Langevin, C. D., Hughes, J. D., White, J. T., Starn, J. J. and Fienen, M. N., 2016, Scripting MODFLOW Model Development Using Python and FloPy: Groundwater, v. 54, p. 733–739, https://doi.org/10.1111/gwat.12413.

Import the `modflow` and `utils` subpackages of FloPy and give them the aliases `fpm` and `fpu`, respectively

[1]:
```
import os
import sys
```

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```
import matplotlib as mpl
import numpy as np

# run installed version of flopy or add local path
try:
    import flopy
except:
    fpth = os.path.abspath(os.path.join("..", "..", ".."))
    sys.path.append(fpth)
    import flopy

import flopy.modflow as fpm
import flopy.utils as fpu

print(sys.version)
print(f"numpy version: {np.__version__}")
print(f"matplotlib version: {mpl.__version__}")
print(f"flopy version: {flopy.__version__}")
```

```
3.8.18 (default, Aug 28 2023, 08:27:22)
[GCC 11.4.0]
numpy version: 1.24.4
matplotlib version: 3.7.4
flopy version: 3.5.0
```

Create a MODFLOW model object. Here, the MODFLOW model object is stored in a Python variable called {model}, but this can be an arbitrary name. This object name is important as it will be used as a reference to the model in the remainder of the FloPy script. In addition, a {modelname} is specified when the MODFLOW model object is created. This {modelname} is used for all the files that are created by FloPy for this model.

[2]:
```
exe = "mf2005"
ws = os.path.join("temp")
model = fpm.Modflow(modelname="gwexample", exe_name=exe, model_ws=ws)
```

The discretization of the model is specified with the discretization file (DIS) of MODFLOW. The aquifer is divided into 201 cells of length 10 m and width 1 m. The first input of the discretization package is the name of the model object. All other input arguments are self explanatory.

[3]:
```
fpm.ModflowDis(
    model, nlay=1, nrow=1, ncol=201, delr=10, delc=1, top=50, botm=0
)
```

[3]:
```

    MODFLOW Discretization Package Class.

    Parameters
    ----------
    model : model object
        The model object (of type :class:`flopy.modflow.Modflow`) to which
        this package will be added.
```

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```
    nlay : int
        Number of model layers (the default is 1).
    nrow : int
        Number of model rows (the default is 2).
    ncol : int
        Number of model columns (the default is 2).
    nper : int
        Number of model stress periods (the default is 1).
    delr : float or array of floats (ncol), optional
        An array of spacings along a row (the default is 1.0).
    delc : float or array of floats (nrow), optional
        An array of spacings along a column (the default is 0.0).
    laycbd : int or array of ints (nlay), optional
        An array of flags indicating whether or not a layer has a Quasi-3D
        confining bed below it. 0 indicates no confining bed, and not zero
        indicates a confining bed. LAYCBD for the bottom layer must be 0. (the
        default is 0)
    top : float or array of floats (nrow, ncol), optional
        An array of the top elevation of layer 1. For the common situation in
        which the top layer represents a water-table aquifer, it may be
        reasonable to set Top equal to land-surface elevation (the default is
        1.0)
    botm : float or array of floats (nlay, nrow, ncol), optional
        An array of the bottom elevation for each model cell (the default is
        0.)
    perlen : float or array of floats (nper)
        An array of the stress period lengths.
    nstp : int or array of ints (nper)
        Number of time steps in each stress period (default is 1).
    tsmult : float or array of floats (nper)
        Time step multiplier (default is 1.0).
    steady : bool or array of bool (nper)
        true or False indicating whether or not stress period is steady state
        (default is True).
    itmuni : int
        Time units, default is days (4)
    lenuni : int
        Length units, default is meters (2)
    extension : string
        Filename extension (default is 'dis')
    unitnumber : int
        File unit number (default is None).
    filenames : str or list of str
        Filenames to use for the package. If filenames=None the package name
        will be created using the model name and package extension. If a
        single string is passed the package will be set to the string.
        Default is None.
    xul : float
        x coordinate of upper left corner of the grid, default is None, which
        means xul will be set to zero.
    yul : float
        y coordinate of upper-left corner of the grid, default is None, which
```

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```
        means yul will be calculated as the sum of the delc array.  This
        default, combined with the xul and rotation defaults will place the
        lower-left corner of the grid at (0, 0).
    rotation : float
        counter-clockwise rotation (in degrees) of the grid about the lower-
        left corner. default is 0.0
    crs : pyproj.CRS, int, str, optional if `prjfile` is specified
        Coordinate reference system (CRS) for the model grid
        (must be projected; geographic CRS are not supported).
        The value can be anything accepted by
        :meth:`pyproj.CRS.from_user_input() <pyproj.crs.CRS.from_user_input>`,
        such as an authority string (eg "EPSG:26916") or a WKT string.
    prjfile : str or pathlike, optional if `crs` is specified
        ESRI-style projection file with well-known text defining the CRS
        for the model grid (must be projected; geographic CRS are not supported).
    start_datetime : str
        starting datetime of the simulation. default is '1/1/1970'
    **kwargs : dict, optional
        Support deprecated keyword options.

        .. deprecated:: 3.5
           ``proj4_str`` will be removed for FloPy 3.6, use ``crs`` instead.

    Attributes
    ----------
    heading : str
        Text string written to top of package input file.

    Methods
    -------

    See Also
    --------

    Notes
    -----

    Examples
    --------

    >>> import flopy
    >>> m = flopy.modflow.Modflow()
    >>> dis = flopy.modflow.ModflowDis(m)

     _name = DIS
 _parent = MODFLOW 1 layer(s) 1 row(s) 201 column(s) 1 stress period(s) ('flopy.modflow.
↪mf.Modflow)
 _totim = None ('NoneType)
 acceptable_dtypes (list, items = 3)
 allowDuplicates = False ('bool)
 botm = <flopy.utils.util_array.Util3d object at 0x7fccece71bb0> ('flopy.utils.util_
↪array.Util3d)
```

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```
delc = <flopy.utils.util_array.Util2d object at 0x7fccece71b20> ('flopy.utils.util_
↪array.Util2d)
delr = <flopy.utils.util_array.Util2d object at 0x7fccece71ac0> ('flopy.utils.util_
↪array.Util2d)
file_name = gwexample.dis
fn_path = /home/runner/work/flopy/flopy/.docs/Notebooks/temp/gwexample.dis ('str)
itmuni = 4 ('int)
itmuni_dict = {0: 'undefined', 1: 'seconds', 2: 'minutes', 3: 'hours', 4: 'days', 5:
↪'years'} ('dict)
laycbd = <flopy.utils.util_array.Util2d object at 0x7fccece71af0> ('flopy.utils.util_
↪array.Util2d)
lenuni = 2 ('int)
ncol = 201 ('int)
nlay = 1 ('int)
nper = 1 ('int)
nrow = 1 ('int)
nstp = <flopy.utils.util_array.Util2d object at 0x7fccece71c40> ('flopy.utils.util_
↪array.Util2d)
perlen = <flopy.utils.util_array.Util2d object at 0x7fccece71be0> ('flopy.utils.util_
↪array.Util2d)
start_datetime = 1-1-1970 ('str)
steady = <flopy.utils.util_array.Util2d object at 0x7fccece71d60> ('flopy.utils.util_
↪array.Util2d)
top = <flopy.utils.util_array.Util2d object at 0x7fccece718b0> ('flopy.utils.util_array.
↪Util2d)
tr = <flopy.utils.reference.TemporalReference object at 0x7fcd1c4e2e80> ('flopy.utils.
↪reference.TemporalReference)
tsmult = <flopy.utils.util_array.Util2d object at 0x7fccece71ca0> ('flopy.utils.util_
↪array.Util2d)
unit_number = 11
```

Active cells and the like are defined with the Basic package (BAS), which is required for every MODFLOW model. It contains the {ibound} array, which is used to specify which cells are active (value is positive), inactive (value is 0), or fixed head (value is negative). The {numpy} package (aliased as {np}) can be used to quickly initialize the {ibound} array with values of 1, and then set the {ibound} value for the first and last columns to -1. The {numpy} package (and Python, in general) uses zero-based indexing and supports negative indexing so that row 1 and column 1, and row 1 and column 201, can be referenced as [0, 0], and [0, -1], respectively. Although this simulation is for steady flow, starting heads still need to be specified. They are used as the head for fixed-head cells (where {ibound} is negative), and as a starting point to compute the saturated thickness for cases of unconfined flow.

[4]:
```python
ibound = np.ones((1, 201))
ibound[0, 0] = ibound[0, -1] = -1
fpm.ModflowBas(model, ibound=ibound, strt=20)
```

[4]:
```

    MODFLOW Basic Package Class.

    Parameters
    ----------
    model : model object
```

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```
        The model object (of type :class:`flopy.modflow.mf.Modflow`) to which
        this package will be added.
    ibound : array of ints, optional
        The ibound array (the default is 1).
    strt : array of floats, optional
        An array of starting heads (the default is 1.0).
    ifrefm : bool, optional
        Indication if data should be read using free format (the default is
        True).
    ixsec : bool, optional
        Indication of whether model is cross sectional or not (the default is
        False).
    ichflg : bool, optional
        Flag indicating that flows between constant head cells should be
        calculated (the default is False).
    stoper : float
        percent discrepancy that is compared to the budget percent discrepancy
        continue when the solver convergence criteria are not met.  Execution
        will unless the budget percent discrepancy is greater than stoper
        (default is None). MODFLOW-2005 only
    hnoflo : float
        Head value assigned to inactive cells (default is -999.99).
    extension : str, optional
        File extension (default is 'bas').
    unitnumber : int, optional
        FORTRAN unit number for this package (default is None).
    filenames : str or list of str
        Filenames to use for the package. If filenames=None the package name
        will be created using the model name and package extension. If a single
        string is passed the package name will be set to the string.
        Default is None.

    Attributes
    ----------
    heading : str
        Text string written to top of package input file.
    options : list of str
        Can be either or a combination of XSECTION, CHTOCH or FREE.
    ifrefm : bool
        Indicates whether or not packages will be written as free format.

    Methods
    -------

    See Also
    --------

    Notes
    -----

    Examples
    --------
```

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```
    >>> import flopy
    >>> m = flopy.modflow.Modflow()
    >>> bas = flopy.modflow.ModflowBas(m)

     _name = BAS6
 _parent = MODFLOW 1 layer(s) 1 row(s) 201 column(s) 1 stress period(s) ('flopy.modflow.
↪mf.Modflow)
 acceptable_dtypes (list, items = 3)
 allowDuplicates = False ('bool)
 file_name = gwexample.bas
 fn_path = /home/runner/work/flopy/flopy/.docs/Notebooks/temp/gwexample.bas ('str)
 hnoflo = -999.99 ('float)
 ibound = <flopy.utils.util_array.Util3d object at 0x7fcd1c4e2eb0> ('flopy.utils.util_
↪array.Util3d)
 ichflg = False ('bool)
 ixsec = False ('bool)
 options =  ('str)
 stoper = None ('NoneType)
 strt = <flopy.utils.util_array.Util3d object at 0x7fcd1c4e2c70> ('flopy.utils.util_
↪array.Util3d)
 unit_number = 13
```

The hydraulic properties of the aquifer are specified with the Layer Properties Flow (LPF) package (alternatively, the Block Centered Flow (BCF) package may be used). Only the hydraulic conductivity of the aquifer and the layer type ({laytyp}) need to be specified. The latter is set to 1, which means that MODFLOW will calculate the saturated thickness differently depending on whether or not the head is above the top of the aquifer.

[5]:
```
fpm.ModflowLpf(model, hk=10, laytyp=1)
```

[5]:
```

    MODFLOW Layer Property Flow Package Class.

    Parameters
    ----------
    model : model object
        The model object (of type :class:`flopy.modflow.mf.Modflow`) to which
        this package will be added.
    ipakcb : int, optional
        Toggles whether cell-by-cell budget data should be saved. If None or zero,
        budget data will not be saved (default is None).
    hdry : float
        Is the head that is assigned to cells that are converted to dry during
        a simulation. Although this value plays no role in the model
        calculations, it is useful as an indicator when looking at the
        resulting heads that are output from the model. HDRY is thus similar
        to HNOFLO in the Basic Package, which is the value assigned to cells
        that are no-flow cells at the start of a model simulation.
        (default is -1.e30).
    laytyp : int or array of ints (nlay)
        Layer type, contains a flag for each layer that specifies the layer
```

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```
        type.
        0 confined
        >0 convertible
        <0 convertible unless the THICKSTRT option is in effect.
        (default is 0).
    layavg : int or array of ints (nlay)
        Layer average
        0 is harmonic mean
        1 is logarithmic mean
        2 is arithmetic mean of saturated thickness and logarithmic mean of
        of hydraulic conductivity
        (default is 0).
    chani : float or array of floats (nlay)
        contains a value for each layer that is a flag or the horizontal
        anisotropy. If CHANI is less than or equal to 0, then variable HANI
        defines horizontal anisotropy. If CHANI is greater than 0, then CHANI
        is the horizontal anisotropy for the entire layer, and HANI is not
        read. If any HANI parameters are used, CHANI for all layers must be
        less than or equal to 0. Use as many records as needed to enter a
        value of CHANI for each layer. The horizontal anisotropy is the ratio
        of the hydraulic conductivity along columns (the Y direction) to the
        hydraulic conductivity along rows (the X direction).
        (default is 1).
    layvka : int or array of ints (nlay)
        a flag for each layer that indicates whether variable VKA is vertical
        hydraulic conductivity or the ratio of horizontal to vertical
        hydraulic conductivity.
        0: VKA is vertical hydraulic conductivity
        not 0: VKA is the ratio of horizontal to vertical hydraulic conductivity
        (default is 0).
    laywet : int or array of ints (nlay)
        contains a flag for each layer that indicates if wetting is active.
        0 wetting is inactive
        not 0 wetting is active
        (default is 0).
    wetfct : float
        is a factor that is included in the calculation of the head that is
        initially established at a cell when it is converted from dry to wet.
        (default is 0.1).
    iwetit : int
        is the iteration interval for attempting to wet cells. Wetting is
        attempted every IWETIT iteration. If using the PCG solver
        (Hill, 1990), this applies to outer iterations, not inner iterations.
        If IWETIT  less than or equal to 0, it is changed to 1.
        (default is 1).
    ihdwet : int
        is a flag that determines which equation is used to define the
        initial head at cells that become wet.
        (default is 0)
    hk : float or array of floats (nlay, nrow, ncol)
        is the hydraulic conductivity along rows. HK is multiplied by
        horizontal anisotropy (see CHANI and HANI) to obtain hydraulic
```

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```
        conductivity along columns.
        (default is 1.0).
    hani : float or array of floats (nlay, nrow, ncol)
        is the ratio of hydraulic conductivity along columns to hydraulic
        conductivity along rows, where HK of item 10 specifies the hydraulic
        conductivity along rows. Thus, the hydraulic conductivity along
        columns is the product of the values in HK and HANI.
        (default is 1.0).
    vka : float or array of floats (nlay, nrow, ncol)
        is either vertical hydraulic conductivity or the ratio of horizontal
        to vertical hydraulic conductivity depending on the value of LAYVKA.
        (default is 1.0).
    ss : float or array of floats (nlay, nrow, ncol)
        is specific storage unless the STORAGECOEFFICIENT option is used.
        When STORAGECOEFFICIENT is used, Ss is confined storage coefficient.
        (default is 1.e-5).
    sy : float or array of floats (nlay, nrow, ncol)
        is specific yield.
        (default is 0.15).
    vkcb : float or array of floats (nlay, nrow, ncol)
        is the vertical hydraulic conductivity of a Quasi-three-dimensional
        confining bed below a layer. (default is 0.0).  Note that if an array
        is passed for vkcb it must be of size (nlay, nrow, ncol) even though
        the information for the bottom layer is not needed.
    wetdry : float or array of floats (nlay, nrow, ncol)
        is a combination of the wetting threshold and a flag to indicate
        which neighboring cells can cause a cell to become wet.
        (default is -0.01).
    storagecoefficient : boolean
        indicates that variable Ss and SS parameters are read as storage
        coefficient rather than specific storage.
        (default is False).
    constantcv : boolean
         indicates that vertical conductance for an unconfined cell is
         computed from the cell thickness rather than the saturated thickness.
         The CONSTANTCV option automatically invokes the NOCVCORRECTION
         option. (default is False).
    thickstrt : boolean
        indicates that layers having a negative LAYTYP are confined, and their
        cell thickness for conductance calculations will be computed as
        STRT-BOT rather than TOP-BOT. (default is False).
    nocvcorrection : boolean
        indicates that vertical conductance is not corrected when the vertical
        flow correction is applied. (default is False).
    novfc : boolean
         turns off the vertical flow correction under dewatered conditions.
         This option turns off the vertical flow calculation described on p.
         5-8 of USGS Techniques and Methods Report 6-A16 and the vertical
         conductance correction described on p. 5-18 of that report.
         (default is False).
    extension : string
        Filename extension (default is 'lpf')
```

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```
    unitnumber : int
        File unit number (default is None).
    filenames : str or list of str
        Filenames to use for the package and the output files. If
        filenames=None the package name will be created using the model name
        and package extension and the cbc output name will be created using
        the model name and .cbc extension (for example, modflowtest.cbc),
        if ipakcb is a number greater than zero. If a single string is passed
        the package will be set to the string and cbc output name will be
        created using the model name and .cbc extension, if ipakcb is a
        number greater than zero. To define the names for all package files
        (input and output) the length of the list of strings should be 2.
        Default is None.
    add_package : bool
        Flag to add the initialised package object to the parent model object.
        Default is True.

    Attributes
    ----------

    Methods
    -------

    See Also
    --------

    Notes
    -----

    Examples
    --------

    >>> import flopy
    >>> m = flopy.modflow.Modflow()
    >>> lpf = flopy.modflow.ModflowLpf(m)

     _name = LPF
_parent = MODFLOW 1 layer(s) 1 row(s) 201 column(s) 1 stress period(s) ('flopy.modflow.
↪mf.Modflow)
acceptable_dtypes (list, items = 3)
allowDuplicates = False ('bool)
chani = <flopy.utils.util_array.Util2d object at 0x7fccece71a30> ('flopy.utils.util_
↪array.Util2d)
file_name = gwexample.lpf
fn_path = /home/runner/work/flopy/flopy/.docs/Notebooks/temp/gwexample.lpf ('str)
hani = <flopy.utils.util_array.Util3d object at 0x7fccece71550> ('flopy.utils.util_
↪array.Util3d)
hdry = -1e+30 ('float)
hk = <flopy.utils.util_array.Util3d object at 0x7fccece71610> ('flopy.utils.util_array.
↪Util3d)
ihdwet = 0 ('int)
ikcflag = 0 ('int)
```

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```
ipakcb = 0 ('int)
iwetit = 1 ('int)
layavg = <flopy.utils.util_array.Util2d object at 0x7fccece71eb0> ('flopy.utils.util_
↪array.Util2d)
laytyp = <flopy.utils.util_array.Util2d object at 0x7fccece717c0> ('flopy.utils.util_
↪array.Util2d)
layvka = <flopy.utils.util_array.Util2d object at 0x7fccece71760> ('flopy.utils.util_
↪array.Util2d)
laywet = <flopy.utils.util_array.Util2d object at 0x7fccece71400> ('flopy.utils.util_
↪array.Util2d)
nplpf = 0 ('int)
options =   ('str)
ss = <flopy.utils.util_array.Util3d object at 0x7fcd1c4f16d0> ('flopy.utils.util_array.
↪Util3d)
sy = <flopy.utils.util_array.Util3d object at 0x7fcd1c4f1850> ('flopy.utils.util_array.
↪Util3d)
unit_number = 15
vka = <flopy.utils.util_array.Util3d object at 0x7fccece71ee0> ('flopy.utils.util_array.
↪Util3d)
vkcb = <flopy.utils.util_array.Util3d object at 0x7fcd1c4f1730> ('flopy.utils.util_
↪array.Util3d)
wetdry = <flopy.utils.util_array.Util3d object at 0x7fcd1e57fac0> ('flopy.utils.util_
↪array.Util3d)
wetfct = 0.1 ('float)
```

Aquifer recharge is simulated with the Recharge package (RCH) and the extraction of water at the two ditches is simulated with the Well package (WEL). The latter requires specification of the layer, row, column, and injection rate of the well for each stress period. The layers, rows, columns, and the stress period are numbered (consistent with Python's zero-based numbering convention) starting at 0. The required data are stored in a Python dictionary ({lrcQ} in the code below), which is used in FloPy to store data that can vary by stress period. The {lrcQ} dictionary specifies that two wells (one in cell 1, 1, 51 and one in cell 1, 1, 151), each with a rate of -1 m^3/m/d, will be active for the first stress period. Because this is a steady-state model, there is only one stress period and therefore only one entry in the dictionary.

[6]:
```
fpm.ModflowRch(model, rech=0.001)
lrcQ = {0: [[0, 0, 50, -1], [0, 0, 150, -1]]}
fpm.ModflowWel(model, stress_period_data=lrcQ)
```

[6]:
```

    MODFLOW Well Package Class.

    Parameters
    ----------
    model : model object
        The model object (of type :class:`flopy.modflow.mf.Modflow`) to which
        this package will be added.
    ipakcb : int, optional
        Toggles whether cell-by-cell budget data should be saved. If None or zero,
        budget data will not be saved (default is None).
    stress_period_data : list, recarray, dataframe or dictionary of boundaries.
        Each well is defined through definition of
```

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```
        layer (int), row (int), column (int), flux (float).
        The simplest form is a dictionary with a lists of boundaries for each
        stress period, where each list of boundaries itself is a list of
        boundaries. Indices of the dictionary are the numbers of the stress
        period. This gives the form of:

            stress_period_data =
            {0: [
                [lay, row, col, flux],
                [lay, row, col, flux],
                [lay, row, col, flux]
                ],
            1:  [
                [lay, row, col, flux],
                [lay, row, col, flux],
                [lay, row, col, flux]
                ], ...
            kper:
                [
                [lay, row, col, flux],
                [lay, row, col, flux],
                [lay, row, col, flux]
                ]
            }

        Note that if the number of lists is smaller than the number of stress
        periods, then the last list of wells will apply until the end of the
        simulation. Full details of all options to specify stress_period_data
        can be found in the flopy3 boundaries Notebook in the basic
        subdirectory of the examples directory
    dtype : custom datatype of stress_period_data.
        If None the default well datatype will be applied (default is None).
    extension : string
        Filename extension (default is 'wel')
    options : list of strings
        Package options (default is None).
    unitnumber : int
        File unit number (default is None).
    filenames : str or list of str
        Filenames to use for the package and the output files. If
        filenames=None the package name will be created using the model name
        and package extension and the cbc output name will be created using
        the model name and .cbc extension (for example, modflowtest.cbc),
        if ipakcb is a number greater than zero. If a single string is passed
        the package will be set to the string and cbc output names will be
        created using the model name and .cbc extension, if ipakcb is a
        number greater than zero. To define the names for all package files
        (input and output) the length of the list of strings should be 2.
        Default is None.
    add_package : bool
        Flag to add the initialised package object to the parent model object.
        Default is True.
```

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```
    Attributes
    ----------
    mxactw : int
        Maximum number of wells for a stress period.  This is calculated
        automatically by FloPy based on the information in
        stress_period_data.

    Methods
    -------

    See Also
    --------

    Notes
    -----
    Parameters are not supported in FloPy.

    Examples
    --------

    >>> import flopy
    >>> m = flopy.modflow.Modflow()
    >>> lrcq = {0:[[2, 3, 4, -100.]], 1:[[2, 3, 4, -100.]]}
    >>> wel = flopy.modflow.ModflowWel(m, stress_period_data=lrcq)

     _name = WEL
 _parent = MODFLOW 1 layer(s) 1 row(s) 201 column(s) 1 stress period(s) ('flopy.modflow.
↪mf.Modflow)
 acceptable_dtypes (list, items = 3)
 allowDuplicates = False ('bool)
 dtype = [('k', '<i8'), ('i', '<i8'), ('j', '<i8'), ('flux', '<f4')] ('numpy.dtype[void])
 file_name = gwexample.wel
 fn_path = /home/runner/work/flopy/flopy/.docs/Notebooks/temp/gwexample.wel ('str)
 ipakcb = 0 ('int)
 iunitramp = None ('NoneType)
 np = 0 ('int)
 options (list, items = 0)
 phiramp = None ('NoneType)
 specify = False ('bool)
 stress_period_data = <flopy.utils.util_list.MfList object at 0x7fcd1c4e7160> ('flopy.
↪utils.util_list.MfList)
 unit_number = 20
```

The Preconditioned Conjugate-Gradient (PCG) solver, using the default settings, is specified to solve the model.

[7]:
```
fpm.ModflowPcg(model)
```

[7]:
```

    MODFLOW Pcg Package Class.

    Parameters
```

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```
    ----------
    model : model object
        The model object (of type :class:`flopy.modflow.mf.Modflow`) to which
        this package will be added.
    mxiter : int
        maximum number of outer iterations. (default is 50)
    iter1 : int
        maximum number of inner iterations. (default is 30)
    npcond : int
        flag used to select the matrix conditioning method. (default is 1).
        specify npcond = 1 for Modified Incomplete Cholesky.
        specify npcond = 2 for Polynomial.
    hclose : float
        is the head change criterion for convergence. (default is 1e-5).
    rclose : float
        is the residual criterion for convergence. (default is 1e-5)
    relax : float
        is the relaxation parameter used with npcond = 1. (default is 1.0)
    nbpol : int
        is only used when npcond = 2 to indicate whether the estimate of the
        upper bound on the maximum eigenvalue is 2.0, or whether the estimate
        will be calculated. nbpol = 2 is used to specify the value is 2.0;
        for any other value of nbpol, the estimate is calculated. Convergence
        is generally insensitive to this parameter. (default is 0).
    iprpcg : int
        solver print out interval. (default is 0).
    mutpcg : int
        If mutpcg = 0, tables of maximum head change and residual will be
        printed each iteration.
        If mutpcg = 1, only the total number of iterations will be printed.
        If mutpcg = 2, no information will be printed.
        If mutpcg = 3, information will only be printed if convergence fails.
        (default is 3).
    damp : float
        is the steady-state damping factor. (default is 1.)
    dampt : float
        is the transient damping factor. (default is 1.)
    ihcofadd : int
        is a flag that determines what happens to an active cell that is
        surrounded by dry cells.  (default is 0). If ihcofadd=0, cell
        converts to dry regardless of HCOF value. This is the default, which
        is the way PCG2 worked prior to the addition of this option. If
        ihcofadd<>0, cell converts to dry only if HCOF has no head-dependent
        stresses or storage terms.
    extension : list string
        Filename extension (default is 'pcg')
    unitnumber : int
        File unit number (default is None).
    filenames : str or list of str
        Filenames to use for the package. If filenames=None the package name
        will be created using the model name and package extension. If a
        single string is passed the package will be set to the string.
```

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```
        Default is None.

    Attributes
    ----------

    Methods
    -------

    See Also
    --------

    Notes
    -----

    Examples
    --------

    >>> import flopy
    >>> m = flopy.modflow.Modflow()
    >>> pcg = flopy.modflow.ModflowPcg(m)

     _name = PCG
 _parent = MODFLOW 1 layer(s) 1 row(s) 201 column(s) 1 stress period(s) ('flopy.modflow.
↪mf.Modflow)
 acceptable_dtypes (list, items = 3)
 allowDuplicates = False ('bool)
 damp = 1.0 ('float)
 dampt = 1.0 ('float)
 file_name = gwexample.pcg
 fn_path = /home/runner/work/flopy/flopy/.docs/Notebooks/temp/gwexample.pcg ('str)
 hclose = 1e-05 ('float)
 ihcofadd = 0 ('int)
 iprpcg = 0 ('int)
 iter1 = 30 ('int)
 mutpcg = 3 ('int)
 mxiter = 50 ('int)
 nbpol = 0 ('int)
 npcond = 1 ('int)
 rclose = 1e-05 ('float)
 relax = 1.0 ('float)
 unit_number = 27
```

The frequency and type of output that MODFLOW writes to an output file is specified with the Output Control (OC) package. In this case, the budget is printed and heads are saved (the default), so no arguments are needed.

[8]:
```
fpm.ModflowOc(model)
```

[8]:
```

    MODFLOW Output Control Package Class.

    Parameters
    ----------
```

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```
    model : model object
        The model object (of type :class:`flopy.modflow.mf.Modflow`) to which
        this package will be added.
    ihedfm : int
        is a code for the format in which heads will be printed.
        (default is 0).
    iddnfm : int
        is a code for the format in which drawdown will be printed.
        (default is 0).
    chedfm : string
        is a character value that specifies the format for saving heads.
        The format must contain 20 characters or less and must be a valid
        Fortran format that is enclosed in parentheses. The format must be
        enclosed in apostrophes if it contains one or more blanks or commas.
        The optional word LABEL after the format is used to indicate that
        each layer of output should be preceded with a line that defines the
        output (simulation time, the layer being output, and so forth). If
        there is no record specifying CHEDFM, then heads are written to a
        binary (unformatted) file. Binary files are usually more compact than
        text files, but they are not generally transportable among different
        computer operating systems or different Fortran compilers.
        (default is None)
    cddnfm : string
        is a character value that specifies the format for saving drawdown.
        The format must contain 20 characters or less and must be a valid
        Fortran format that is enclosed in parentheses. The format must be
        enclosed in apostrophes if it contains one or more blanks or commas.
        The optional word LABEL after the format is used to indicate that
        each layer of output should be preceded with a line that defines the
        output (simulation time, the layer being output, and so forth). If
        there is no record specifying CDDNFM, then drawdowns are written to a
        binary (unformatted) file. Binary files are usually more compact than
        text files, but they are not generally transportable among different
        computer operating systems or different Fortran compilers.
        (default is None)
    cboufm : string
        is a character value that specifies the format for saving ibound.
        The format must contain 20 characters or less and must be a valid
        Fortran format that is enclosed in parentheses. The format must be
        enclosed in apostrophes if it contains one or more blanks or commas.
        The optional word LABEL after the format is used to indicate that
        each layer of output should be preceded with a line that defines the
        output (simulation time, the layer being output, and so forth). If
        there is no record specifying CBOUFM, then ibounds are written to a
        binary (unformatted) file. Binary files are usually more compact than
        text files, but they are not generally transportable among different
        computer operating systems or different Fortran compilers.
        (default is None)
    stress_period_data : dictionary of lists
        Dictionary key is a tuple with the zero-based period and step
        (IPEROC, ITSOC) for each print/save option list. If stress_period_data
        is None, then heads are saved for the last time step of each stress
```

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```
        period. (default is None)

        The list can have any valid MODFLOW OC print/save option:
            PRINT HEAD
            PRINT DRAWDOWN
            PRINT BUDGET
            SAVE HEAD
            SAVE DRAWDOWN
            SAVE BUDGET
            SAVE IBOUND

            The lists can also include (1) DDREFERENCE in the list to reset
            drawdown reference to the period and step and (2) a list of layers
            for PRINT HEAD, SAVE HEAD, PRINT DRAWDOWN, SAVE DRAWDOWN, and
            SAVE IBOUND.

        stress_period_data = {(0,1):['save head']}) would save the head for
        the second timestep in the first stress period.

    compact : boolean
        Save results in compact budget form. (default is True).
    extension : list of strings
        (default is ['oc', 'hds', 'ddn', 'cbc', 'ibo']).
    unitnumber : list of ints
        (default is [14, 51, 52, 53, 0]).
    filenames : str or list of str
        Filenames to use for the package and the head, drawdown, budget (not
        used), and ibound output files. If filenames=None the package name
        will be created using the model name and package extension and the
        output file names will be created using the model name and extensions.
        If a single string is passed the package will be set to the string and
        output names will be created using the model name and head, drawdown,
        budget, and ibound extensions. To define the names for all package
        files (input and output) the length of the list of strings should be 5.
        Default is None.

    Attributes
    ----------

    Methods
    -------

    See Also
    --------

    Notes
    -----
    The "words" method for specifying output control is the only option
    available.  Also, the "compact" budget should normally be used as it
    produces files that are typically much smaller.  The compact budget form is
    also a requirement for using the MODPATH particle tracking program.
```

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```
    Examples
    --------

    >>> import flopy
    >>> m = flopy.modflow.Modflow()
    >>> spd = {(0, 0): ['print head'],
    ...   (0, 1): [],
    ...   (0, 249): ['print head'],
    ...   (0, 250): [],
    ...   (0, 499): ['print head', 'save ibound'],
    ...   (0, 500): [],
    ...   (0, 749): ['print head', 'ddreference'],
    ...   (0, 750): [],
    ...   (0, 999): ['print head']}
    >>> oc = flopy.modflow.ModflowOc(m, stress_period_data=spd, cboufm='(20i5)')

     _name = OC
 _parent = MODFLOW 1 layer(s) 1 row(s) 201 column(s) 1 stress period(s) ('flopy.modflow.
↪mf.Modflow)
 acceptable_dtypes (list, items = 3)
 allowDuplicates = False ('bool)
 cboufm = None ('NoneType)
 cddnfm = None ('NoneType)
 chedfm = None ('NoneType)
 compact = True ('bool)
 file_name = gwexample.oc
 fn_path = /home/runner/work/flopy/flopy/.docs/Notebooks/temp/gwexample.oc ('str)
 ibouun = 0 ('int)
 iddnfm = 0 ('int)
 ihedfm = 0 ('int)
 iubud = 0 ('int)
 iuddn = 0 ('int)
 iuhead = 51 ('int)
 iuibnd = 0 ('int)
 label = LABEL ('str)
 savebud = False ('bool)
 saveddn = False ('bool)
 savehead = True ('bool)
 saveibnd = False ('bool)
 stress_period_data = {(0, 0): ['save head']} ('dict)
 unit_number = 14
```

Finally the MODFLOW input files are written (eight files for this model) and the model is run. This requires, of course, that MODFLOW is installed on your computer and FloPy can find the executable in your path.

[9]:
```python
model.write_input()
success, buff = model.run_model(silent=True, report=True)
if success:
    for line in buff:
        print(line)
else:
```

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```
    raise ValueError("Failed to run.")
```

```
                                  MODFLOW-2005
    U.S. GEOLOGICAL SURVEY MODULAR FINITE-DIFFERENCE GROUND-WATER FLOW MODEL
                             Version 1.12.00 2/3/2017

 Using NAME file: gwexample.nam
 Run start date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:29:17

 Solving:  Stress period:     1    Time step:     1    Ground-Water Flow Eqn.
 Run end date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:29:17
 Elapsed run time:  0.001 Seconds

  Normal termination of simulation
```

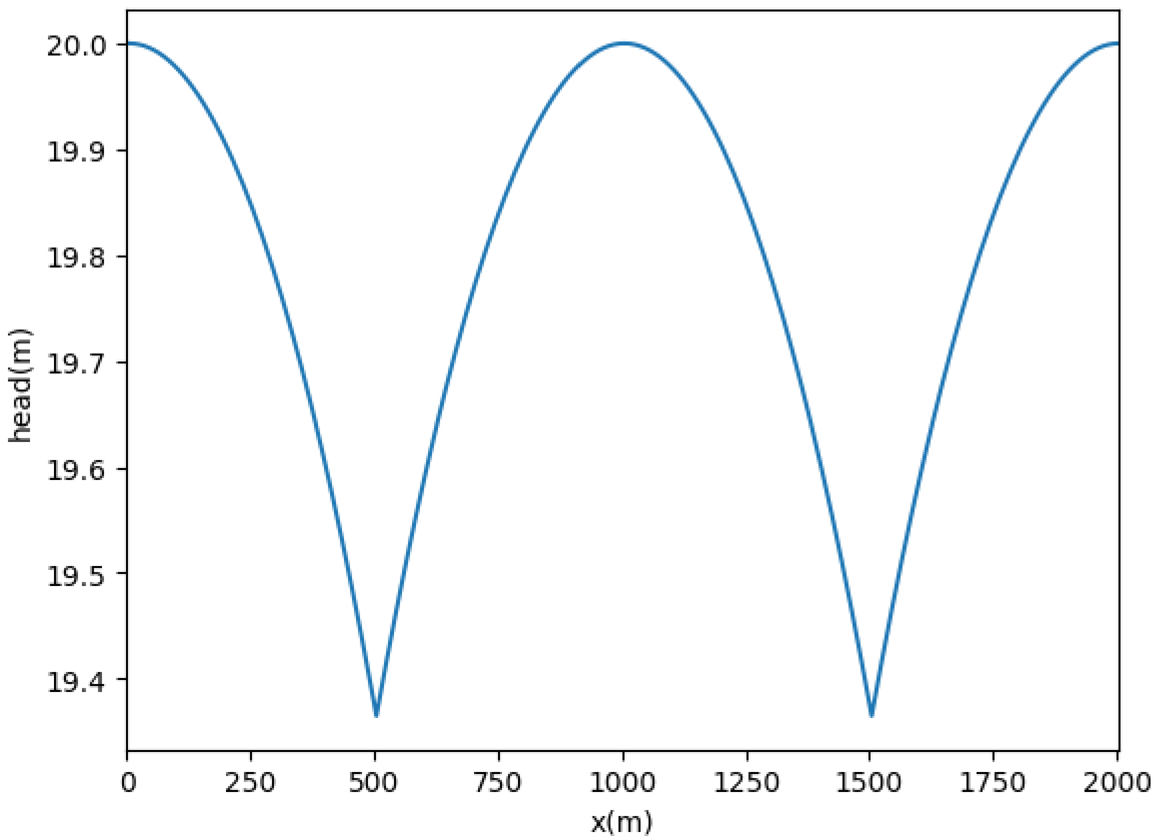
After MODFLOW has responded with the positive {Normal termination of simulation}, the calculated heads can be read from the binary output file. First a file object is created. As the modelname used for all MODFLOW files was specified as {gwexample} in step 1, the file with the heads is called {gwexample.hds}. FloPy includes functions to read data from the file object, including heads for specified layers or time steps, or head time series at individual cells. For this simple mode, all computed heads are read.

[10]:
```
fpth = os.path.join(ws, "gwexample.hds")
hfile = fpu.HeadFile(fpth)
h = hfile.get_data(totim=1.0)
```

The heads are now stored in the Python variable {h}. FloPy includes powerful plotting functions to plot the grid, boundary conditions, head, etc. This functionality is demonstrated later. For this simple one-dimensional example, a plot is created with the matplotlib package

[11]:
```
import matplotlib.pyplot as plt

ax = plt.subplot(111)
x = model.modelgrid.xcellcenters[0]
ax.plot(x, h[0, 0, :])
ax.set_xlim(0, x.max())
ax.set_xlabel("x(m)")
ax.set_ylabel("head(m)")
plt.show()
```



6.10.2 Capture fraction example

From: Bakker, Mark, Post, Vincent, Langevin, C. D., Hughes, J. D., White, J. T., Starn, J. J. and Fienen, M. N., 2016, Scripting MODFLOW Model Development Using Python and FloPy: Groundwater, v. 54, p. 733-739, https://doi.org/10.1111/gwat.12413.

[1]:
```
import os
import sys

import matplotlib as mpl
import matplotlib.pyplot as plt
import numpy as np
import scipy.ndimage

try:
    import flopy
except:
    fpth = os.path.abspath(os.path.join("..", "..", ".."))
    sys.path.append(fpth)
    import flopy

print(sys.version)
print(f"numpy version: {np.__version__}")
```

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```
print(f"matplotlib version: {mpl.__version__}")
print(f"flopy version: {flopy.__version__}")
```

```
3.8.18 (default, Aug 28 2023, 08:27:22)
[GCC 11.4.0]
numpy version: 1.24.4
matplotlib version: 3.7.4
flopy version: 3.5.0
```

[2]:
```
ws = os.path.join("temp")
if not os.path.exists(ws):
    os.makedirs(ws)
```

[3]:
```
fn = os.path.join(
    "..",
    "groundwater_paper",
    "uspb",
    "results",
    "USPB_capture_fraction_04_01.dat",
)
cf = np.loadtxt(fn)
print(cf.shape)
```

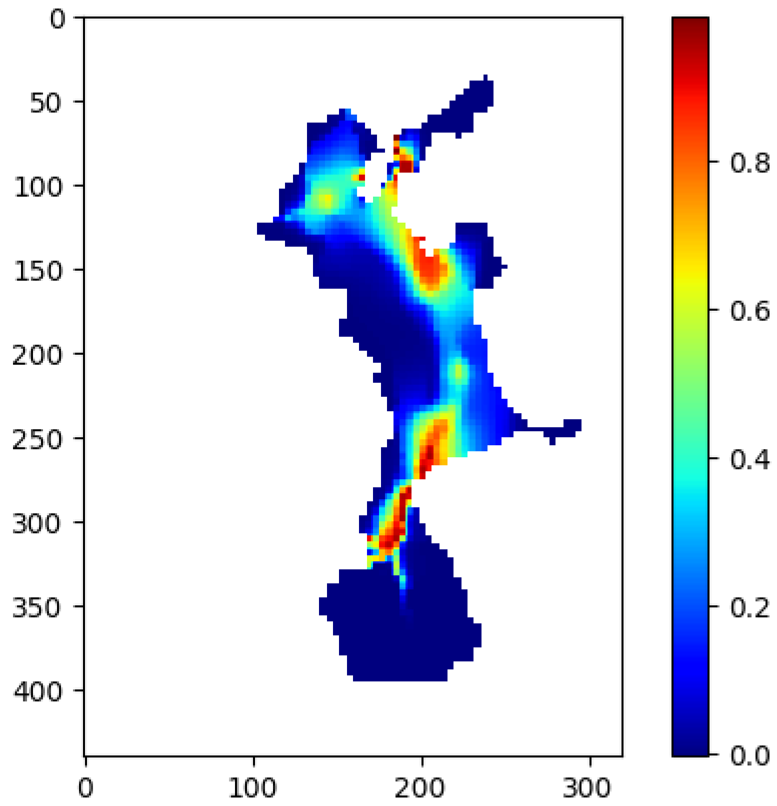
```
(110, 80)
```

[4]:
```
cf2 = scipy.ndimage.zoom(cf, 4, order=0)
print(cf2.shape)
```

```
(440, 320)
```

[5]:
```
c = plt.imshow(cf2, cmap="jet")
plt.colorbar(c)
```

[5]:
```
<matplotlib.colorbar.Colorbar at 0x7fac0cfc6850>
```



[6]:
```
wsl = os.path.join("..", "groundwater_paper", "uspb", "flopy")
ml = flopy.modflow.Modflow.load("DG.nam", model_ws=wsl, verbose=False)
```

[7]:
```
nlay, nrow, ncol = ml.nlay, ml.dis.nrow, ml.dis.ncol
xmax, ymax = ncol * 250.0, nrow * 250.0
```

[8]:
```
plt.rcParams.update({"font.size": 6})
fig = plt.figure(figsize=(3.25, 4.47))
ax1 = plt.gca()
ax1.set_aspect("equal")
mm1 = flopy.plot.PlotMapView(model=ml, layer=4)
plt.xlim(0, xmax)
plt.ylim(0, ymax)
mm1.plot_inactive(color_noflow="0.75")
c = plt.imshow(cf2, cmap="jet", extent=[0, ncol * 250.0, 0, nrow * 250.0])
cb = plt.colorbar(c, shrink=0.5)
cb.ax.set_ylabel("Layer 4 capture fraction")
mm1.plot_bc(ftype="STR", plotAll=True)
plt.plot(
    [-10000],
    [-10000],
    marker="s",
    ms=10,
    lw=0.0,
    mec="0.2",
```

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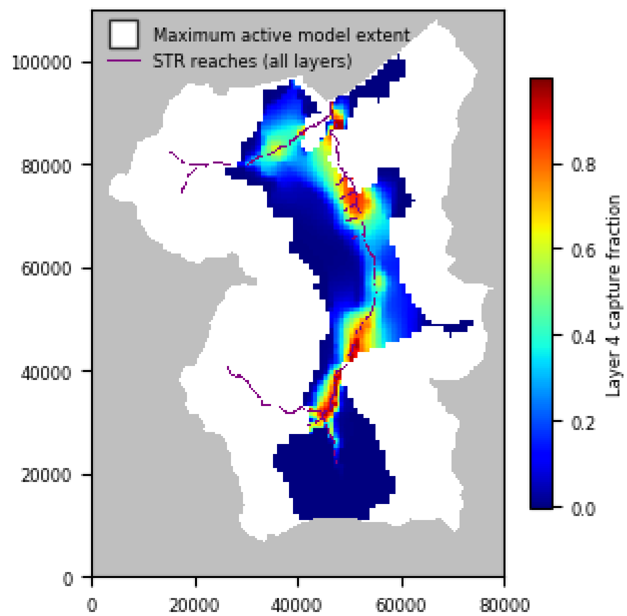
```
    mfc="white",
    label="Maximum active model extent",
)
plt.plot(
    [-10000, 0],
    [-10000, 0],
    color="purple",
    lw=0.75,
    label="STR reaches (all layers)",
)
leg = plt.legend(loc="upper left", numpoints=1, prop={"size": 6})
leg.draw_frame(False)
plt.xticks([0, 20000, 40000, 60000, 80000])
plt.tight_layout()
plt.savefig(os.path.join(ws, "capture_fraction_010y.png"), dpi=300)
```



Rerun the model after changing workspace and writing input files

[9]:
```
ml.change_model_ws(ws)
ml.exe_name = "mf2005dbl"
ml.write_input()
ml.run_model(silent=True)
```

[9]:
```
(True, [])
```

[10]:
```
hedObj = flopy.utils.HeadFile(os.path.join(ws, "DG.hds"), precision="double")
h = hedObj.get_data(kstpkper=(0, 0))
cbcObj = flopy.utils.CellBudgetFile(
    os.path.join(ws, "DG.cbc"), precision="double"
)

frf = cbcObj.get_data(kstpkper=(0, 0), text="FLOW RIGHT FACE")[0]
```

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```
fff = cbcObj.get_data(kstpkper=(0, 0), text="FLOW FRONT FACE")[0]
qx, qy, qz = flopy.utils.postprocessing.get_specific_discharge(
    (frf, fff, None), ml
)
```

[11]:
```
cnt = np.arange(1200, 1700, 100)
f, (ax1, ax2) = plt.subplots(
    1, 2, figsize=(6.75, 4.47), constrained_layout=True
)
ax1.set_xlim(0, xmax)
ax1.set_ylim(0, ymax)
ax2.set_xlim(0, xmax)
ax2.set_ylim(0, ymax)
ax1.set_aspect("equal")
ax2.set_aspect("equal")

mm1 = flopy.plot.PlotMapView(model=ml, ax=ax1, layer=3)
h1 = mm1.plot_array(h, masked_values=[-888, -999], vmin=1100, vmax=1700)
mm1.plot_inactive(color_noflow="0.75")
mm1.plot_bc(ftype="STR")
q1 = mm1.plot_vector(
    qx,
    qy,
    istep=5,
    jstep=5,
    normalize=True,
    color="0.4",
    scale=70,
    headwidth=3,
    headlength=3,
    headaxislength=3,
)
c1 = mm1.contour_array(
    h, masked_values=[-888, -999], colors="black", levels=cnt, linewidths=0.5
)
ax1.clabel(c1, fmt="%.0f", inline_spacing=0.5)

mm2 = flopy.plot.PlotMapView(model=ml, ax=ax2, layer=4)
h2 = mm2.plot_array(h, masked_values=[-888, -999], vmin=1100, vmax=1700)
mm2.plot_inactive(color_noflow="0.75")
mm2.plot_bc(ftype="STR")
q2 = mm2.plot_vector(
    qx,
    qy,
    istep=5,
    jstep=5,
    normalize=True,
    color="0.4",
    scale=70,
    headwidth=3,
    headlength=3,
    headaxislength=3,
```

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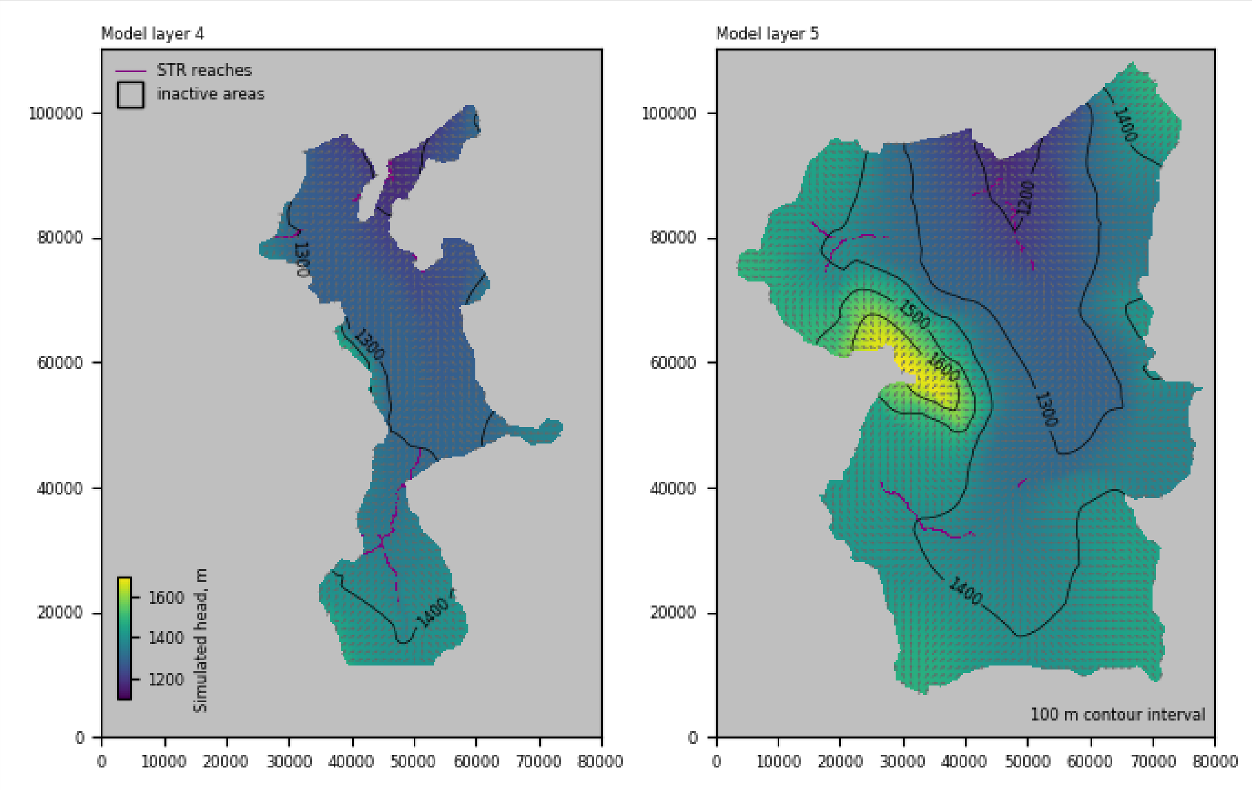
```
)
c2 = mm2.contour_array(
    h, masked_values=[-888, -999], colors="black", levels=cnt, linewidths=0.5
)
ax2.clabel(c2, fmt="%.0f", inline_spacing=0.5)

ax3 = f.add_axes([0.08, 0.125, 0.01, 0.15])
cb = plt.colorbar(h2, cax=ax3)
cb.ax.set_ylabel("Simulated head, m")

ax1.plot(
    [-10000, 0], [-10000, 0], color="purple", lw=0.75, label="STR reaches"
)
ax1.plot(
    [-10000],
    [-10000],
    marker="s",
    ms=10,
    lw=0.0,
    mec="black",
    mfc="None",
    label="inactive areas",
)
leg = ax1.legend(loc="upper left", numpoints=1, prop={"size": 6})
leg.draw_frame(False)

ax1.text(
    0.0, 1.01, "Model layer 4", ha="left", va="bottom", transform=ax1.transAxes
)
ax2.text(
    0.98,
    0.02,
    "100 m contour interval",
    ha="right",
    va="bottom",
    transform=ax2.transAxes,
)
ax2.text(
    0.0, 1.01, "Model layer 5", ha="left", va="bottom", transform=ax2.transAxes
)

plt.savefig(os.path.join(ws, "uspb_heads.png"), dpi=300)
```



[12]:
```
fn = os.path.join(
    "..",
    "groundwater_paper",
    "uspb",
    "results",
    "USPB_capture_fraction_04_10.dat",
)
cf = np.loadtxt(fn)
cf2 = scipy.ndimage.zoom(cf, 4, order=0)
```

[13]:
```
fig = plt.figure(figsize=(3.25, 4.47), constrained_layout=True)
ax1 = plt.gca()
ax1.set_aspect("equal")
mm1 = flopy.plot.PlotMapView(model=ml, layer=4)
plt.xlim(0, xmax)
plt.ylim(0, ymax)
mm1.plot_inactive(color_noflow="0.75")
c = plt.imshow(cf2, cmap="jet", extent=[0, ncol * 250.0, 0, nrow * 250.0])
cb = plt.colorbar(c, shrink=0.5)
cb.ax.set_ylabel("Layer 4 capture fraction")
mm1.plot_bc(ftype="STR", plotAll=True)
plt.plot(
    [-10000, 0],
    [-10000, 0],
    color="purple",
    lw=0.75,
    label="STR reaches (all layers)",
```

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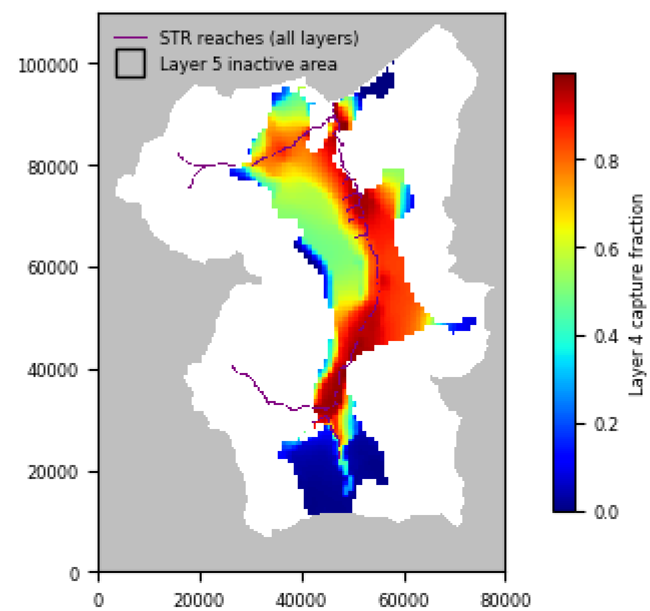
```
)
plt.plot(
    [-10000],
    [-10000],
    marker="s",
    ms=10,
    lw=0.0,
    mec="black",
    mfc="None",
    label="Layer 5 inactive area",
)
leg = plt.legend(loc="upper left", numpoints=1, prop={"size": 6})
leg.draw_frame(False)
plt.xticks([0, 20000, 40000, 60000, 80000])
plt.savefig(os.path.join(ws, "capture_fraction_100y.png"), dpi=300)
```



6.11 Examples from Hughes and others (2023)

6.11.1 Watershed geoprocessing example

From Hughes, Joseph D., Langevin, Christian D., Paulinski, Scott R., Larsen, Joshua D., and Brakenhoff, David, 2023, FloPy Workflows for Creating Structured and Unstructured MODFLOW Models: Groundwater, https://doi.org/10.1111/gwat.13327

[1]:
```
import os
import pathlib as pl
import sys
```

[2]:
```
import matplotlib as mpl
import matplotlib.gridspec as gridspec
import matplotlib.pyplot as plt
import numpy as np
from shapely.geometry import LineString
```

[3]:
```
import flopy
import flopy.plot.styles as styles
from flopy.discretization import StructuredGrid, VertexGrid
from flopy.utils.gridgen import Gridgen
from flopy.utils.triangle import Triangle
from flopy.utils.voronoi import VoronoiGrid
```

[4]:
```
print(sys.version)
print(f"numpy version: {np.__version__}")
print(f"matplotlib version: {mpl.__version__}")
print(f"flopy version: {flopy.__version__}")
```

```
3.8.18 (default, Aug 28 2023, 08:27:22)
[GCC 11.4.0]
numpy version: 1.24.4
matplotlib version: 3.7.4
flopy version: 3.5.0
```

[5]:
```
# import all plot style information from defaults.py
sys.path.append("../common")
from groundwater2023_utils import (
    densify_geometry,
    geometries,
    set_idomain,
    string2geom,
)
```

[6]:
```
# basic figure size
figwidth = 180  # 90 # mm
figwidth = figwidth / 10 / 2.54  # inches
figheight = figwidth
figsize = (figwidth, figheight)
```

[7]:
```
# figure settings
levels = np.arange(10, 110, 10)
contour_color = "black"
contour_style = "--"
contour_dict = {
    "levels": levels,
    "linewidths": 0.5,
    "colors": contour_color,
    "linestyles": contour_style,
}
clabel_dict = {
    "inline": True,
    "fmt": "%1.0f",
```

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```
    "fontsize": 6,
    "inline_spacing": 0.5,
}
font_dict = {
    "fontsize": 5,
    "color": "black",
}
grid_dict = {
    "lw": 0.25,
    "color": "0.5",
}
refinement_dict = {
    "color": "magenta",
    "ls": ":",
    "lw": 1.0,
}
river_dict = {
    "color": "blue",
    "linestyle": "-",
    "linewidth": 1,
}
intersection_cmap = "Pastel2"
temp_cmap = mpl.colormaps[intersection_cmap]
intersection_rgba = temp_cmap(0)
```

[8]:
```
# make a temporary working directory for gridgen output
temp_path = "./temp"
if not os.path.isdir(temp_path):
    os.mkdir(temp_path)
```

[9]:
```
# Load the fine topography that will be sampled
ascii_file = pl.Path("../../examples/data/geospatial/fine_topo.asc")
fine_topo = flopy.utils.Raster.load(ascii_file)
```

Define the problem size and extents

[10]:
```
Lx = 180000
Ly = 100000
extent = (0, Lx, 0, Ly)
vmin, vmax = 0.0, 100.0
```

Create boundary and river data that will be used to refine the unstructured grids

[11]:
```
boundary_polygon = string2geom(geometries["boundary"])
bp = np.array(boundary_polygon)

sgs = [string2geom(geometries[f"streamseg{i}"]) for i in range(1, 5)]

fig = plt.figure(figsize=figsize)
ax = fig.add_subplot()
ax.set_aspect("equal")
```

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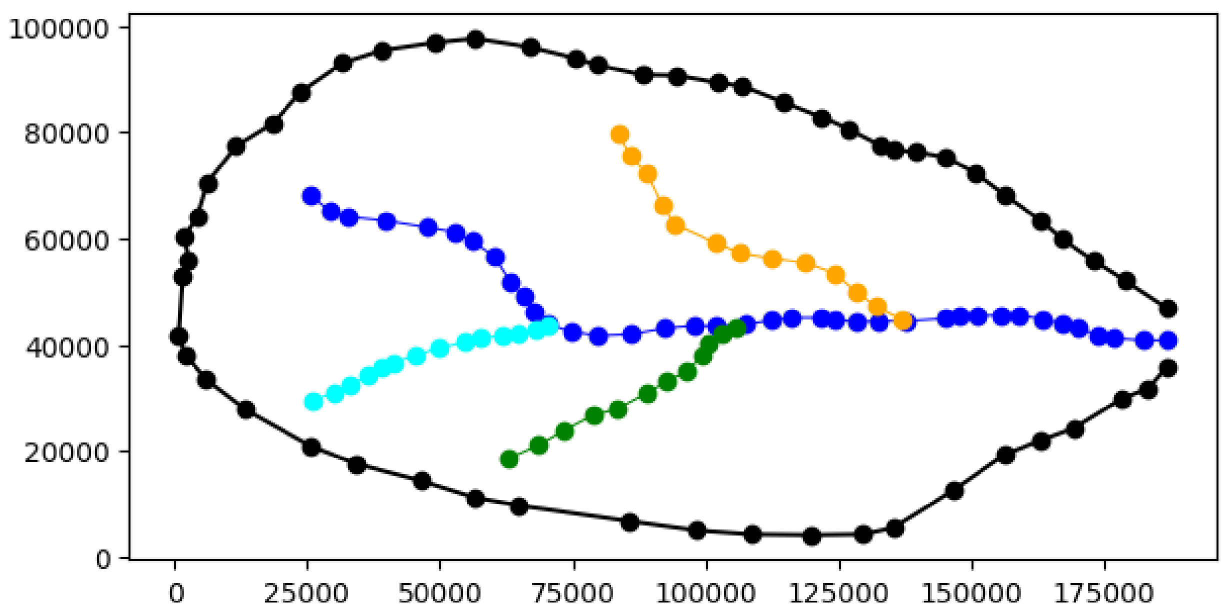
```
riv_colors = ("blue", "cyan", "green", "orange", "red")

ax.plot(bp[:, 0], bp[:, 1], "ko-")
for idx, sg in enumerate(sgs):
    sa = np.array(sg)
    ax.plot(sa[:, 0], sa[:, 1], color=riv_colors[idx], lw=0.75, marker="o")
```



Structured Grids

Structured grid with constant row and column spacing

[12]:
```
dx = dy = 1666.66666667
nlay = 1
nrow = int(Ly / dy) + 1
ncol = int(Lx / dx) + 1
delr = np.array(ncol * [dx])
delc = np.array(nrow * [dy])
top = np.ones((nrow, ncol)) * 1000.0
botm = np.ones((nlay, nrow, ncol)) * -100.0
struct_grid = StructuredGrid(
    nlay=nlay, delr=delr, delc=delc, xoff=0.0, yoff=0.0, top=top, botm=botm
)

set_idomain(struct_grid, boundary_polygon)
```

[13]:
```
top_sg = fine_topo.resample_to_grid(
    struct_grid,
    band=fine_topo.bands[0],
    method="linear",
```

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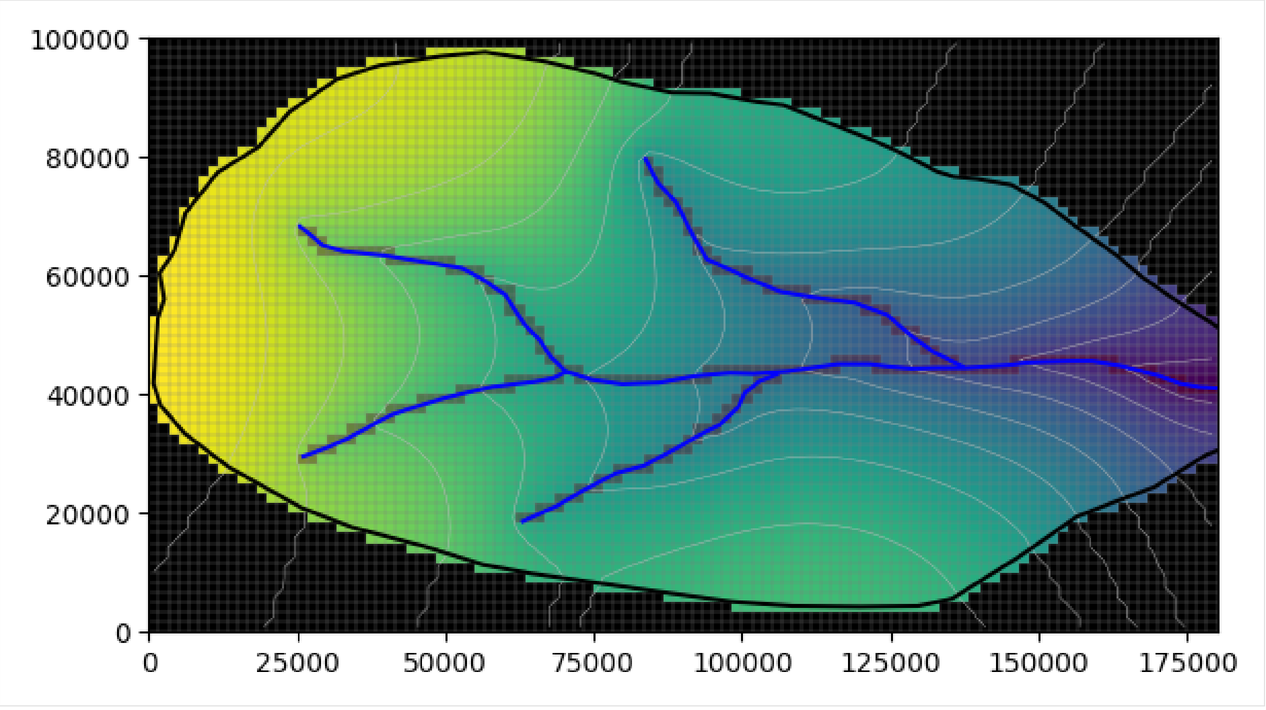
```
    extrapolate_edges=True,
)
```

[14]:
```
ixs = flopy.utils.GridIntersect(struct_grid, method="structured")
cellids = []
for sg in sgs:
    v = ixs.intersect(LineString(sg), sort_by_cellid=True)
    cellids += v["cellids"].tolist()
intersection_sg = np.zeros(struct_grid.shape[1:])
for loc in cellids:
    intersection_sg[loc] = 1
```

[15]:
```
fig = plt.figure(figsize=figsize)
ax = fig.add_subplot()
pmv = flopy.plot.PlotMapView(modelgrid=struct_grid)
ax.set_aspect("equal")
pmv.plot_array(top_sg)
pmv.plot_array(
    intersection_sg,
    masked_values=[
        0,
    ],
    alpha=0.2,
    cmap="Reds_r",
)
pmv.plot_grid(lw=0.25, color="0.5")
cg = pmv.contour_array(top_sg, levels=levels, linewidths=0.3, colors="0.75")
pmv.plot_inactive()

ax.plot(bp[:, 0], bp[:, 1], "k-")
for sg in sgs:
    sa = np.array(sg)
    ax.plot(sa[:, 0], sa[:, 1], "b-")
```



Structured grid with variable row and column spacing

[16]:
```
dx = dy = 5000

# create transition cells
multiplier = 1.175
transition = 20000.0
ncells = 7
smoothr = [
    transition * (multiplier - 1.0) / (multiplier ** float(ncells) - 1.0)
]
for i in range(ncells - 1):
    smoothr.append(smoothr[i] * multiplier)
smooth = smoothr.copy()
smooth.reverse()
```

[17]:
```
# build the structured grid with variable row and column spacing
dx = 9 * [5000] + smooth + 15 * [1666.66666667] + smoothr + 14 * [5000]
dy = 4 * [5000] + smooth + 12 * [1666.66666667] + smoothr + 4 * [5000]

nlay = 1
ncol = len(dx)
nrow = len(dy)

top = np.ones((nrow, ncol)) * 1000.0
botm = np.ones((nlay, nrow, ncol)) * -100.0

delr = np.array(dx)
```
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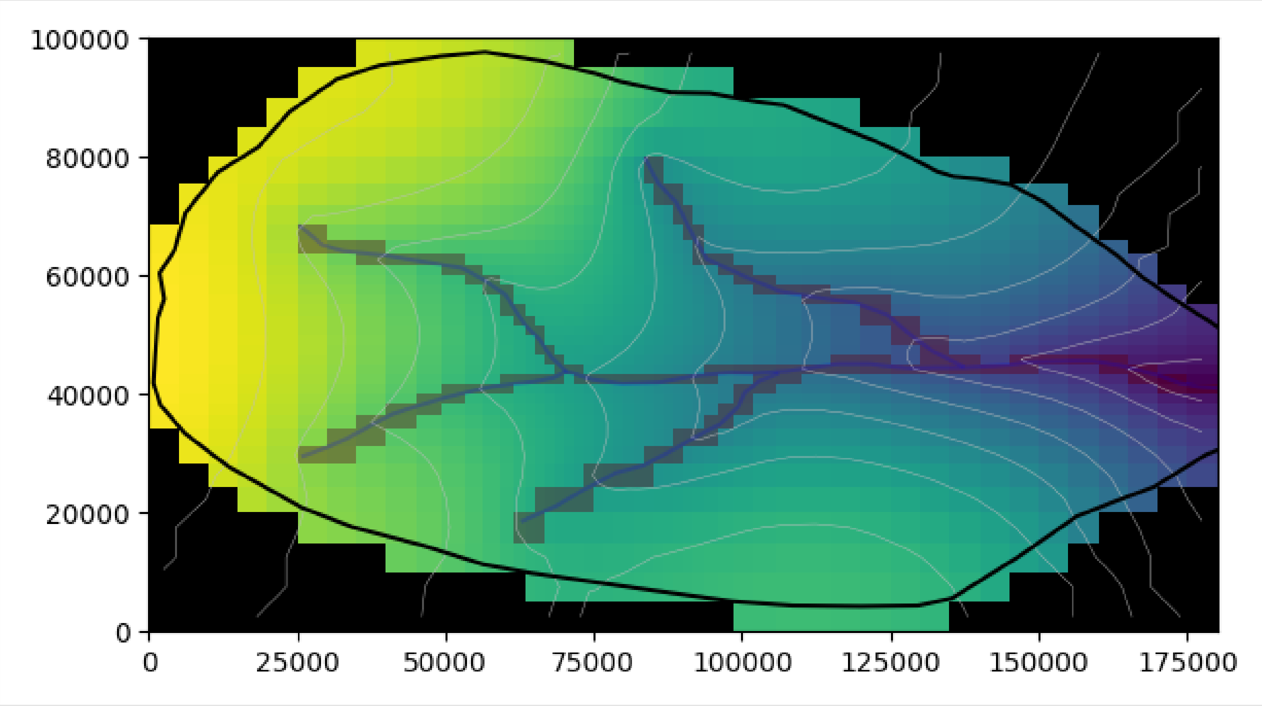
```
delc = np.array(dy)
struct_vrc_grid = StructuredGrid(
    nlay=nlay,
    delr=delr,
    delc=delc,
    xoff=0.0,
    yoff=0.0,
    top=top,
    botm=botm,
)
set_idomain(struct_vrc_grid, boundary_polygon)
```

[18]:
```
top_sg_vrc = fine_topo.resample_to_grid(
    struct_vrc_grid,
    band=fine_topo.bands[0],
    method="linear",
    extrapolate_edges=True,
)
```

[19]:
```
ixs = flopy.utils.GridIntersect(struct_vrc_grid, method="structured")
cellids = []
for sg in sgs:
    v = ixs.intersect(LineString(sg), sort_by_cellid=True)
    cellids += v["cellids"].tolist()
intersection_sg_vrc = np.zeros(struct_vrc_grid.shape[1:])
for loc in cellids:
    intersection_sg_vrc[loc] = 1
```

[20]:
```
fig = plt.figure(figsize=figsize)
ax = fig.add_subplot()
pmv = flopy.plot.PlotMapView(modelgrid=struct_vrc_grid)
ax.set_aspect("equal")
pmv.plot_array(top_sg_vrc)
pmv.plot_array(
    intersection_sg_vrc,
    masked_values=[
        0,
    ],
    alpha=0.2,
    cmap="Reds_r",
)
cg = pmv.contour_array(
    top_sg_vrc, levels=levels, linewidths=0.3, colors="0.75"
)
pmv.plot_inactive()

ax.plot(bp[:, 0], bp[:, 1], "k-")
for sg in sgs:
    sa = np.array(sg)
    ax.plot(sa[:, 0], sa[:, 1], "b-", alpha=0.2)
```



Local grid refinement grid

[21]:
```
from flopy.utils.lgrutil import Lgr

nlayp = 1
dx = 5000
nrowp = int(Ly / dx)
ncolp = int(Lx / dx)
delrp = dx
delcp = dx
# topp = 1000.0
# botmp = [-100.]
topp = np.ones((nrowp, ncolp)) * 1000.0
botmp = np.ones((nlayp, nrowp, ncolp)) * -100.0

idomainp = np.ones((nlayp, nrowp, ncolp), dtype=int)
idomainp[0, 8:12, 13:18] = 0

ncpp = 3
ncppl = [1]

lgr = Lgr(
    nlayp,
    nrowp,
    ncolp,
    delrp,
    delcp,
    topp,
```
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```
    botmp,
    idomainp,
    ncpp=ncpp,
    ncppl=ncppl,
    xllp=0.0,
    yllp=0.0,
)

delr = np.array(ncolp * [dx])
delc = np.array(nrowp * [dx])
struct_gridp = StructuredGrid(
    nlay=1, delr=delr, delc=delc, idomain=idomainp, top=topp, botm=botmp
)
set_idomain(struct_gridp, boundary_polygon)

delr_child, delc_child = lgr.get_delr_delc()
xoff, yoff = lgr.get_lower_left()
nrowc, ncolc = delc_child.shape[0], delr_child.shape[0]
topc = np.ones((nrowc, ncolc)) * 1000.0
botmc = np.ones((nlayp, nrowc, ncolc)) * -100.0
struct_gridc = StructuredGrid(
    delr=delr_child,
    delc=delc_child,
    xoff=xoff,
    yoff=yoff,
    idomain=idomainp,
    top=topc,
    botm=botmc,
)

extent_child = struct_gridc.extent

nested_grid = [struct_gridp, struct_gridc]
```

[22]:
```
top_ngp = fine_topo.resample_to_grid(
    struct_gridp,
    band=fine_topo.bands[0],
    method="linear",
    extrapolate_edges=True,
)
top_ngc = fine_topo.resample_to_grid(
    struct_gridc,
    band=fine_topo.bands[0],
    method="linear",
    extrapolate_edges=True,
)
top_nested_grid = [top_ngp, top_ngc]
```

[23]:
```
ixs = flopy.utils.GridIntersect(struct_gridp, method="structured")
cellids = []
for sg in sgs:
```

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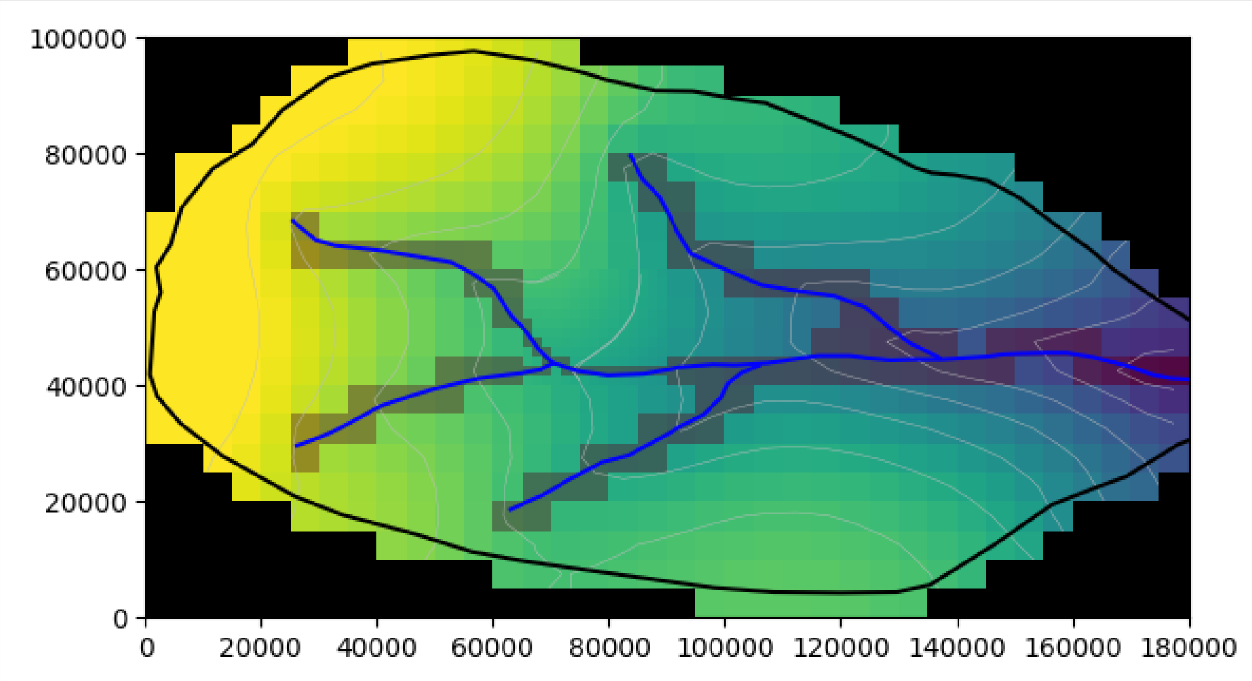
```
    v = ixs.intersect(LineString(sg), sort_by_cellid=True)
    cellids += v["cellids"].tolist()
intersection_ngp = np.zeros(struct_gridp.shape[1:])
for loc in cellids:
    intersection_ngp[loc] = 1
intersection_ngp[idomainp[0] == 0] = 0

ixs = flopy.utils.GridIntersect(struct_gridc, method="structured")
cellids = []
for sg in sgs:
    v = ixs.intersect(LineString(sg), sort_by_cellid=True)
    cellids += v["cellids"].tolist()
intersection_ngc = np.zeros(struct_gridc.shape[1:])
for loc in cellids:
    intersection_ngc[loc] = 1

intersection_nested_grid = [intersection_ngp, intersection_ngc]
```

[24]:
```
fig = plt.figure(figsize=figsize)
ax = fig.add_subplot()
pmv = flopy.plot.PlotMapView(modelgrid=struct_gridp, extent=extent)
pmv.plot_inactive()
pmv.plot_array(top_ngp, vmin=vmin, vmax=vmax)
pmv.plot_array(
    intersection_nested_grid[0],
    masked_values=[
        0,
    ],
    alpha=0.2,
    cmap="Reds_r",
)
cgp = pmv.contour_array(top_ngp, levels=levels, linewidths=0.3, colors="0.75")
pmv.plot_inactive(zorder=100)
ax.set_aspect("equal")

pmvc = flopy.plot.PlotMapView(modelgrid=struct_gridc, ax=ax, extent=extent)
# pmvc.plot_grid()
pmvc.plot_array(top_ngc, vmin=vmin, vmax=vmax)
pmvc.plot_array(
    intersection_nested_grid[1],
    masked_values=[
        0,
    ],
    alpha=0.2,
    cmap="Reds_r",
)
cgc = pmvc.contour_array(top_ngc, levels=levels, linewidths=0.3, colors="0.75")

ax.plot(bp[:, 0], bp[:, 1], "k-")
for sg in sgs:
    sa = np.array(sg)
    ax.plot(sa[:, 0], sa[:, 1], "b-")
```



Unstructured grids

```
[25]: # create a polygon of the common refinement area for the quadtree grid
lgr_poly = [
    [
        (extent_child[0], extent_child[2]),
        (extent_child[0], extent_child[3]),
        (extent_child[1], extent_child[3]),
        (extent_child[1], extent_child[2]),
        (extent_child[0], extent_child[2]),
    ]
]
```

Quadtree grid

```
[26]: sim = flopy.mf6.MFSimulation()
gwf = gwf = flopy.mf6.ModflowGwf(sim)
dx = dy = 5000.0
nr = int(Ly / dy)
nc = int(Lx / dx)
dis6 = flopy.mf6.ModflowGwfdis(
    gwf,
    nrow=nr,
    ncol=nc,
    delr=dy,
    delc=dx,
)
```

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```
g = Gridgen(gwf.modelgrid, model_ws=temp_path)
adpoly = [
    [[(1000, 1000), (3000, 1000), (3000, 2000), (1000, 2000), (1000, 1000)]]
]
adpoly = boundary_polygon + [boundary_polygon[0]]
adpoly = [[adpoly]]
g.add_refinement_features([lgr_poly], "polygon", 2, range(1))

refine_line = sgs
g.add_refinement_features(refine_line, "line", 2, range(1))
g.build(verbose=False)

gridprops_vg = g.get_gridprops_vertexgrid()
quadtree_grid = flopy.discretization.VertexGrid(**gridprops_vg)
set_idomain(quadtree_grid, boundary_polygon)
```

[27]:
```
top_qg = fine_topo.resample_to_grid(
    quadtree_grid,
    band=fine_topo.bands[0],
    method="linear",
    extrapolate_edges=True,
)
```

[28]:
```
ixs = flopy.utils.GridIntersect(quadtree_grid, method="vertex")
cellids = []
for sg in sgs:
    v = ixs.intersect(LineString(sg), sort_by_cellid=True)
    cellids += v["cellids"].tolist()
intersection_qg = np.zeros(quadtree_grid.shape[1:])
for loc in cellids:
    intersection_qg[loc] = 1
```

[29]:
```
fig = plt.figure(figsize=figsize)
ax = fig.add_subplot()
pmv = flopy.plot.PlotMapView(modelgrid=quadtree_grid)
pmv.plot_array(top_qg, ec="0.75")
pmv.plot_array(
    intersection_qg,
    masked_values=[
        0,
    ],
    alpha=0.2,
    cmap="Reds_r",
)
cg = pmv.contour_array(top_qg, levels=levels, linewidths=0.3, colors="white")
pmv.plot_inactive(zorder=100)
ax.set_aspect("equal")

ax.plot(bp[:, 0], bp[:, 1], "k-")
for sg in sgs:
    sa = np.array(sg)
```

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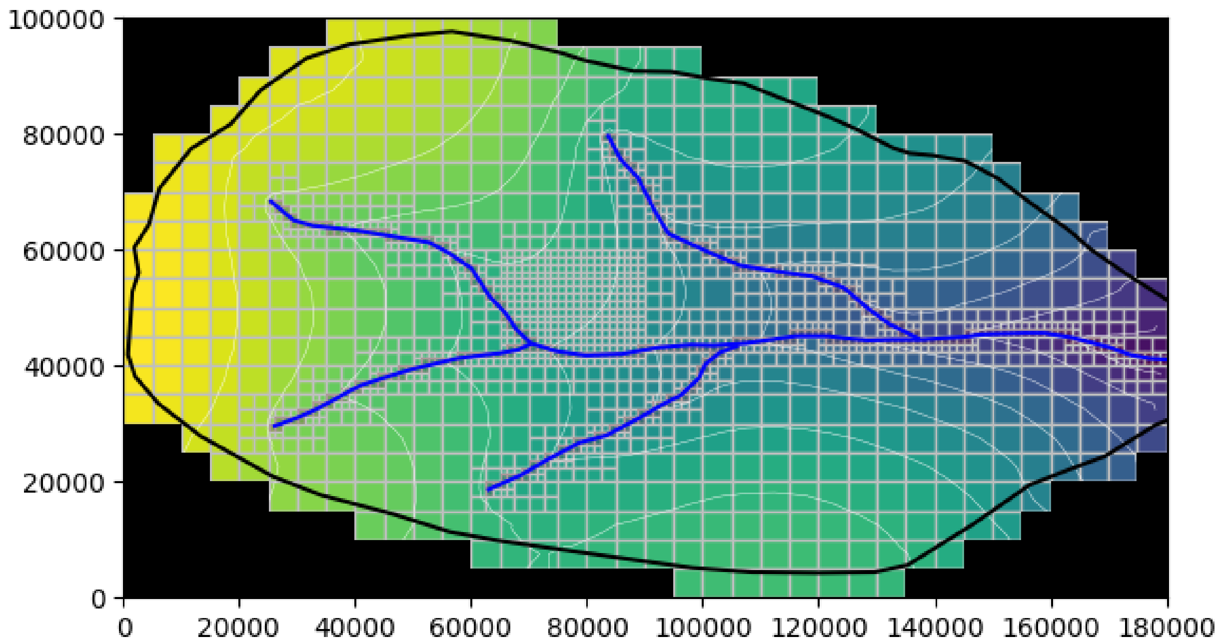
```
    ax.plot(sa[:, 0], sa[:, 1], "b-")
```



Triangular grid

[30]:
```
nodes = []
for sg in sgs:
    sg_densify = densify_geometry(sg, 2000)
    nodes.extend(sg_densify)
for x in struct_gridc.get_xvertices_for_layer(0)[0, :]:
    for y in struct_gridc.get_yvertices_for_layer(0)[:, 0]:
        nodes.append((x, y))
nodes = np.array(nodes)
```

[31]:
```
tri = Triangle(
    maximum_area=5000 * 5000, angle=30, nodes=nodes, model_ws=temp_path
)
poly = bp
tri.add_polygon(poly)
tri.build(verbose=False)


cell2d = tri.get_cell2d()
vertices = tri.get_vertices()

top = np.ones(tri.ncpl) * 1000.0
botm = np.ones((1, tri.ncpl)) * -100.0
idomain = np.ones((1, tri.ncpl), dtype=int)
```

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```
triangular_grid = VertexGrid(
    vertices=vertices,
    cell2d=cell2d,
    idomain=idomain,
    nlay=1,
    ncpl=tri.ncpl,
    top=top,
    botm=botm,
)
```

[32]:
```
top_tg = fine_topo.resample_to_grid(
    triangular_grid,
    band=fine_topo.bands[0],
    method="linear",
    extrapolate_edges=True,
)
```

[33]:
```
ixs = flopy.utils.GridIntersect(triangular_grid)  # , method="vertex")
cellids = []
for sg in sgs:
    v = ixs.intersect(
        LineString(sg),
        return_all_intersections=True,
        keepzerolengths=False,
        sort_by_cellid=True,
    )
    cellids += v["cellids"].tolist()
intersection_tg = np.zeros(triangular_grid.shape[1:])
for loc in cellids:
    intersection_tg[loc] = 1
```

[34]:
```
fig = plt.figure(figsize=figsize)
ax = fig.add_subplot()
ax.set_aspect("equal")

pmv = flopy.plot.PlotMapView(modelgrid=triangular_grid)

pmv.plot_array(top_tg, ec="0.75")
pmv.plot_array(
    intersection_tg,
    masked_values=[
        0,
    ],
    alpha=0.2,
    cmap="Reds_r",
)
cg = pmv.contour_array(top_tg, levels=levels, linewidths=0.3, colors="white")
ax.clabel(cg, cg.levels, inline=True, fmt="%1.0f", fontsize=10)

pmv.plot_inactive(zorder=100)
```

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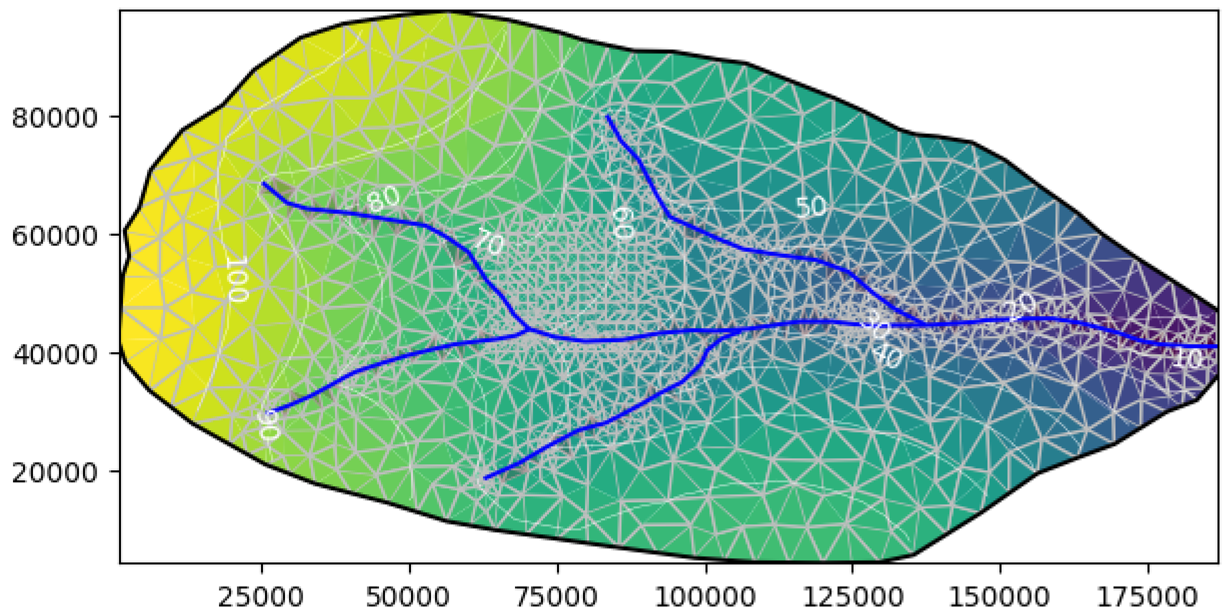
```
if True:
    ax.plot(bp[:, 0], bp[:, 1], "k-")
    for sg in sgs:
        sa = np.array(sg)
        ax.plot(sa[:, 0], sa[:, 1], "b-")
```



Voronoi Grid from the Triangle object

[35]:
```
# create vor object and VertexGrid from the triangle object tri
vor = VoronoiGrid(tri)
gridprops = vor.get_gridprops_vertexgrid()
idomain = np.ones((1, vor.ncpl), dtype=int)
voronoi_grid = VertexGrid(**gridprops, nlay=1, idomain=idomain)
```

[36]:
```
top_vg = fine_topo.resample_to_grid(
    voronoi_grid,
    band=fine_topo.bands[0],
    method="linear",
    extrapolate_edges=True,
)
```

[37]:
```
ixs = flopy.utils.GridIntersect(voronoi_grid, method="vertex")
cellids = []
for sg in sgs:
    v = ixs.intersect(
        LineString(sg),
        return_all_intersections=True,
        keepzerolengths=False,
        sort_by_cellid=True,
```

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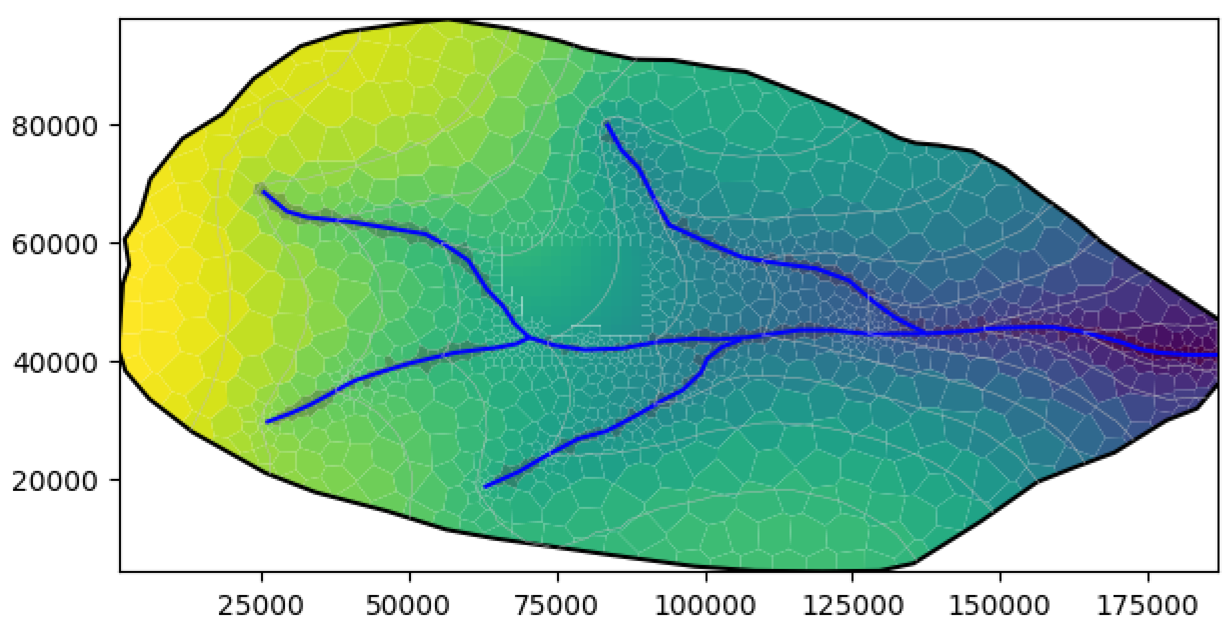
```
    )
    cellids += v["cellids"].tolist()
intersection_vg = np.zeros(voronoi_grid.shape[1:])
for loc in cellids:
    intersection_vg[loc] = 1
```

[38]:

```
fig = plt.figure(figsize=figsize)
ax = fig.add_subplot()
pmv = flopy.plot.PlotMapView(modelgrid=voronoi_grid)
ax.set_aspect("equal")
pmv.plot_array(top_vg)
pmv.plot_array(
    intersection_vg,
    masked_values=[
        0,
    ],
    alpha=0.2,
    cmap="Reds_r",
)
pmv.plot_inactive()
ax.plot(bp[:, 0], bp[:, 1], "k-")
for sg in sgs:
    sa = np.array(sg)
    ax.plot(sa[:, 0], sa[:, 1], "b-")

cg = pmv.contour_array(top_vg, levels=levels, linewidths=0.3, colors="0.75")
```



Plot all six grids

Create a polyline for Local Grid Refinement area

[39]:
```
lgr_poly_array = np.array(lgr_poly).squeeze()
```

Plot the grids

[40]:
```
# Make a plot of the six grids
figwidth = 17.15 / 2.54
figheight = 3.66 * (Ly / Lx) * 8.25 / 2.54
grids = [
    struct_grid,
    struct_vrc_grid,
    nested_grid,
    quadtree_grid,
    triangular_grid,
    voronoi_grid,
    None,
]
topo_grids = [top_sg, top_sg_vrc, top_nested_grid, top_qg, top_tg, top_vg]
extent = (0, 180000, 0, 100000)
cbar_axis = [0.0, 0.1, 0.25, 0.9]

with styles.USGSMap():
    fig = plt.figure(figsize=(figwidth, figheight), constrained_layout=True)
    gs = gridspec.GridSpec(ncols=16, nrows=17, figure=fig)
    axs = [fig.add_subplot(gs[:5, :8])]
    axs.append(fig.add_subplot(gs[:5, 8:]))
    axs.append(fig.add_subplot(gs[5:10, :8]))
    axs.append(fig.add_subplot(gs[5:10, 8:]))
    axs.append(fig.add_subplot(gs[10:15, :8]))
    axs.append(fig.add_subplot(gs[10:15, 8:]))
    axs.append(fig.add_subplot(gs[15:, :]))

    for idx, ax in enumerate(axs[:-1]):
        g = grids[idx]
        t = topo_grids[idx]
        if g is not None:
            if isinstance(g, list):
                g = g[0]
                t = t[0]

            pmv = flopy.plot.PlotMapView(modelgrid=g, ax=ax)

            v = pmv.plot_array(t)
            pmv.plot_grid(**grid_dict)
            cg = pmv.contour_array(t, **contour_dict)
            pmv.ax.clabel(cg, cg.levels, **clabel_dict)
            pmv.plot_inactive(color_noflow="gray", zorder=100)
```

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```
        if isinstance(grids[idx], list):
            gg = grids[idx]
            tt = topo_grids[idx]
            for g, t in zip(gg[1:], tt[1:]):
                pmvc = flopy.plot.PlotMapView(
                    modelgrid=g, ax=ax, extent=extent
                )
                pmvc.plot_array(top_ngc, vmin=vmin, vmax=vmax)
                pmvc.plot_grid(**grid_dict)
                cgc = pmvc.contour_array(top_ngc, **contour_dict)

        # plot lgr polyline
        ax.plot(
            lgr_poly_array[:, 0],
            lgr_poly_array[:, 1],
            zorder=101,
            **refinement_dict,
        )

        ax.set_aspect("equal")
        ax.set_axisbelow(False)

        ax.set_xlim(extent[0], extent[1])
        ax.set_xticks(np.arange(0, 200000, 50000))
        if idx in (4, 5):
            ax.set_xticklabels(np.arange(0, 200, 50))
            ax.set_xlabel("x position (km)")
        else:
            ax.set_xticklabels([])

        ax.set_ylim(extent[2], extent[3])
        ax.set_yticks(np.arange(0, 150000, 50000))
        if idx in (0, 2, 4):
            ax.set_yticklabels(np.arange(0, 150, 50))
            ax.set_ylabel("y position (km)")
        else:
            ax.set_yticklabels([])

        styles.heading(ax, idx=idx)
        if True:
            ax.plot(bp[:, 0], bp[:, 1], "k-", lw=2.0)
            for sg in sgs:
                sa = np.array(sg)
                ax.plot(sa[:, 0], sa[:, 1], **river_dict)

    # legend
    ax = axs[-1]
    xy0 = (-100, -100)
    ax.set_xlim(0, 1)
    ax.set_ylim(0, 1)
    ax.set_axis_off()
```

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```
    ax.axhline(
        xy0[0],
        color="black",
        lw=2,
        label="Basin boundary",
    )
    ax.axhline(
        xy0[0],
        **river_dict,
        label="River",
    )
    ax.axhline(
        xy0[0],
        color=contour_color,
        lw=0.5,
        ls="--",
        label="Elevation contour",
    )
    ax.axhline(
        xy0[0],
        label="Grid refinement area",
        **refinement_dict,
    )
    ax.axhline(
        xy0[0],
        marker="s",
        mec="0.5",
        mfc="white",
        markeredgewidth=0.25,
        lw=0,
        label="Grid cell",
    )
    ax.axhline(
        xy0[0],
        marker="s",
        mec="0.5",
        mfc="gray",
        markeredgewidth=0.25,
        lw=0,
        label="Inactive area",
    )
    styles.graph_legend(
        ax,
        ncol=3,
        loc="lower center",
        labelspacing=0.5,
        columnspacing=0.6,
        handletextpad=0.3,
    )

    # colorbar
    ax = fig.add_subplot(gs[15:, 14:])
```

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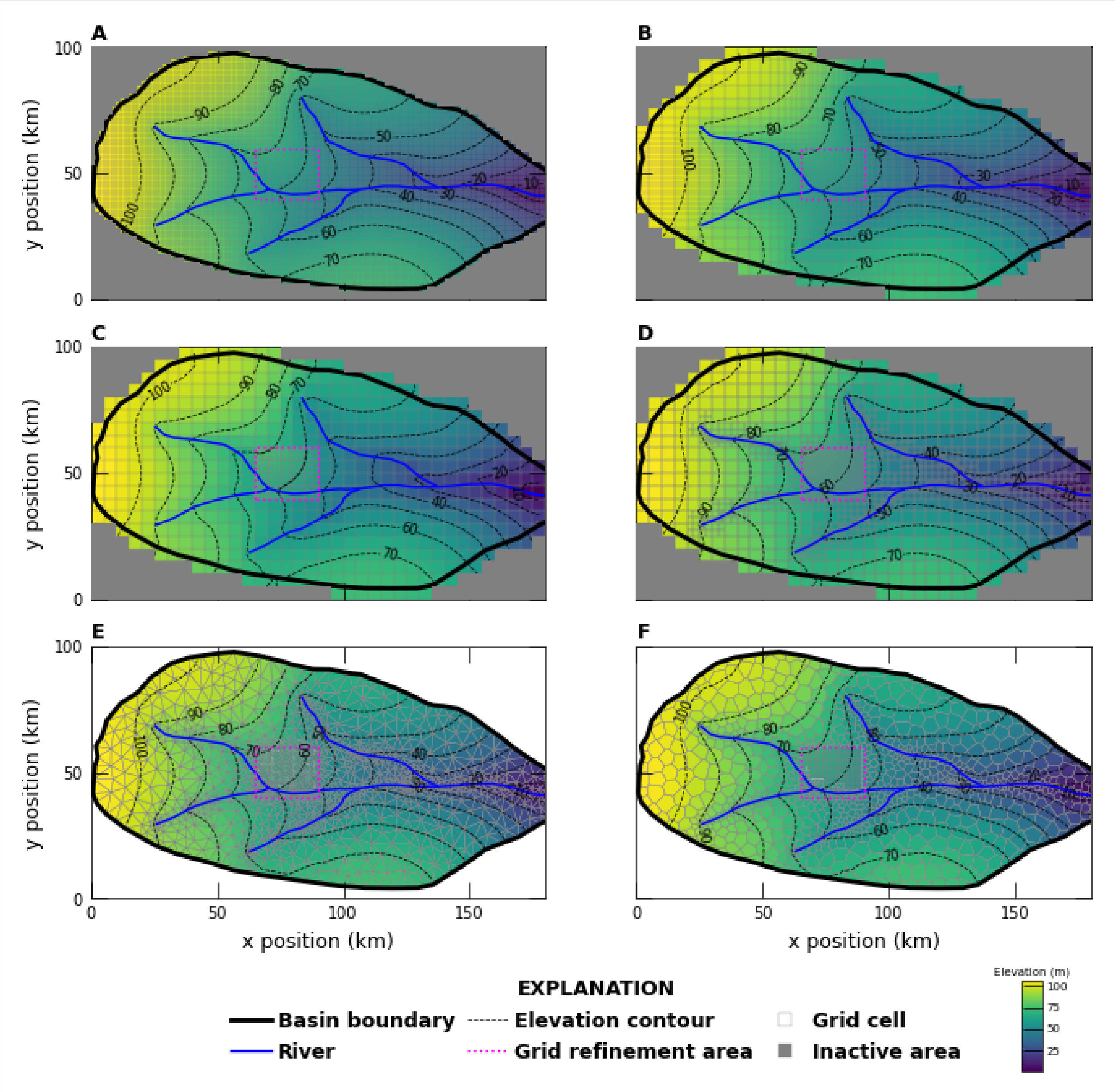
```
    ax.set_xlim(0, 1)
    ax.set_ylim(0, 1)
    ax.set_axis_off()
    cax = ax.inset_axes(
        cbar_axis,
    )
    #     cax.set_axisbelow(False)
    cbar = plt.colorbar(
        v,
        orientation="vertical",
        cax=cax,
        ticks=[25, 50, 75, 100],
    )
    cbar.ax.tick_params(
        labelsize=5,
        labelcolor="black",
        color="black",
        length=9,
        pad=2,
    )
    cbar.ax.set_title(
        "Elevation (m)", pad=2.5, loc="center", fontdict=font_dict
    )
```



Plot the river intersection for the six grids

[41]:
```
figwidth = 17.15 / 2.54
figheight = 3.66 * (Ly / Lx) * 8.25 / 2.54
grids = [
    struct_grid,
    struct_vrc_grid,
    nested_grid,
    quadtree_grid,
    triangular_grid,
    voronoi_grid,
```
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```
    None,
]
intersections = [
    intersection_sg,
    intersection_sg_vrc,
    intersection_nested_grid,
    intersection_qg,
    intersection_tg,
    intersection_vg,
    None,
]
extent = list(extent_child)
de = 10000.0
extent[0] -= 2.0 * de
extent[1] += 2.5 * de
extent[2] -= de
extent[3] += de


with styles.USGSMap():
    fig = plt.figure(figsize=(figwidth, figheight), constrained_layout=True)
    gs = gridspec.GridSpec(ncols=2, nrows=16, figure=fig)
    axs = [fig.add_subplot(gs[:5, 0])]
    axs.append(fig.add_subplot(gs[:5, 1]))
    axs.append(fig.add_subplot(gs[5:10, 0]))
    axs.append(fig.add_subplot(gs[5:10, 1]))
    axs.append(fig.add_subplot(gs[10:15, 0]))
    axs.append(fig.add_subplot(gs[10:15, 1]))
    axs.append(fig.add_subplot(gs[15:, :]))

    for idx, ax in enumerate(axs[:-1]):
        g = grids[idx]
        t = intersections[idx]
        if g is not None:
            if isinstance(g, list):
                g = g[0]
                t = t[0]

            pmv = flopy.plot.PlotMapView(modelgrid=g, ax=ax, extent=extent)

            v = pmv.plot_array(t, masked_values=(0,), cmap=intersection_cmap)
            pmv.plot_grid(**grid_dict)

            pmv.plot_inactive(color_noflow="gray", zorder=100)

            if isinstance(grids[idx], list):
                gg = grids[idx]
                tt = intersections[idx]
                for g, t in zip(gg[1:], tt[1:]):
                    pmvc = flopy.plot.PlotMapView(
                        modelgrid=g, ax=ax, extent=extent
                    )
```

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```
                pmvc.plot_array(
                    t, masked_values=(0,), cmap=intersection_cmap
                )
                pmvc.plot_grid(**grid_dict)

        # plot lgr polyline
        ax.plot(
            lgr_poly_array[:, 0],
            lgr_poly_array[:, 1],
            zorder=101,
            **refinement_dict,
        )

        ax.set_aspect("equal")
        ax.set_axisbelow(False)

        ax.set_xlim(extent[0], extent[1])
        ax.set_xticks(np.arange(50000, 120000, 10000))
        if idx in (4, 5):
            ax.set_xticklabels(np.arange(50, 120, 10))
            ax.set_xlabel("x position (km)")
        else:
            ax.set_xticklabels([])

        ax.set_ylim(extent[2], extent[3])
        ax.set_yticks(np.arange(35000, 70000, 10000))
        if idx in (0, 2, 4):
            ax.set_yticklabels(np.arange(35, 75, 10))
            ax.set_ylabel("y position (km)")
        else:
            ax.set_yticklabels([])

        styles.heading(ax, idx=idx)
        if True:
            ax.plot(bp[:, 0], bp[:, 1], "k-", lw=2.0)
            for sg in sgs:
                sa = np.array(sg)
                ax.plot(sa[:, 0], sa[:, 1], **river_dict)

# legend
ax = axs[-1]
xy0 = (-100, -100)
ax.set_xlim(0, 1)
ax.set_ylim(0, 1)
ax.set_axis_off()

ax.axhline(xy0[0], **river_dict, label="River")
ax.axhline(
    xy0[0],
    label="Grid refinement area",
    **refinement_dict,
)
```

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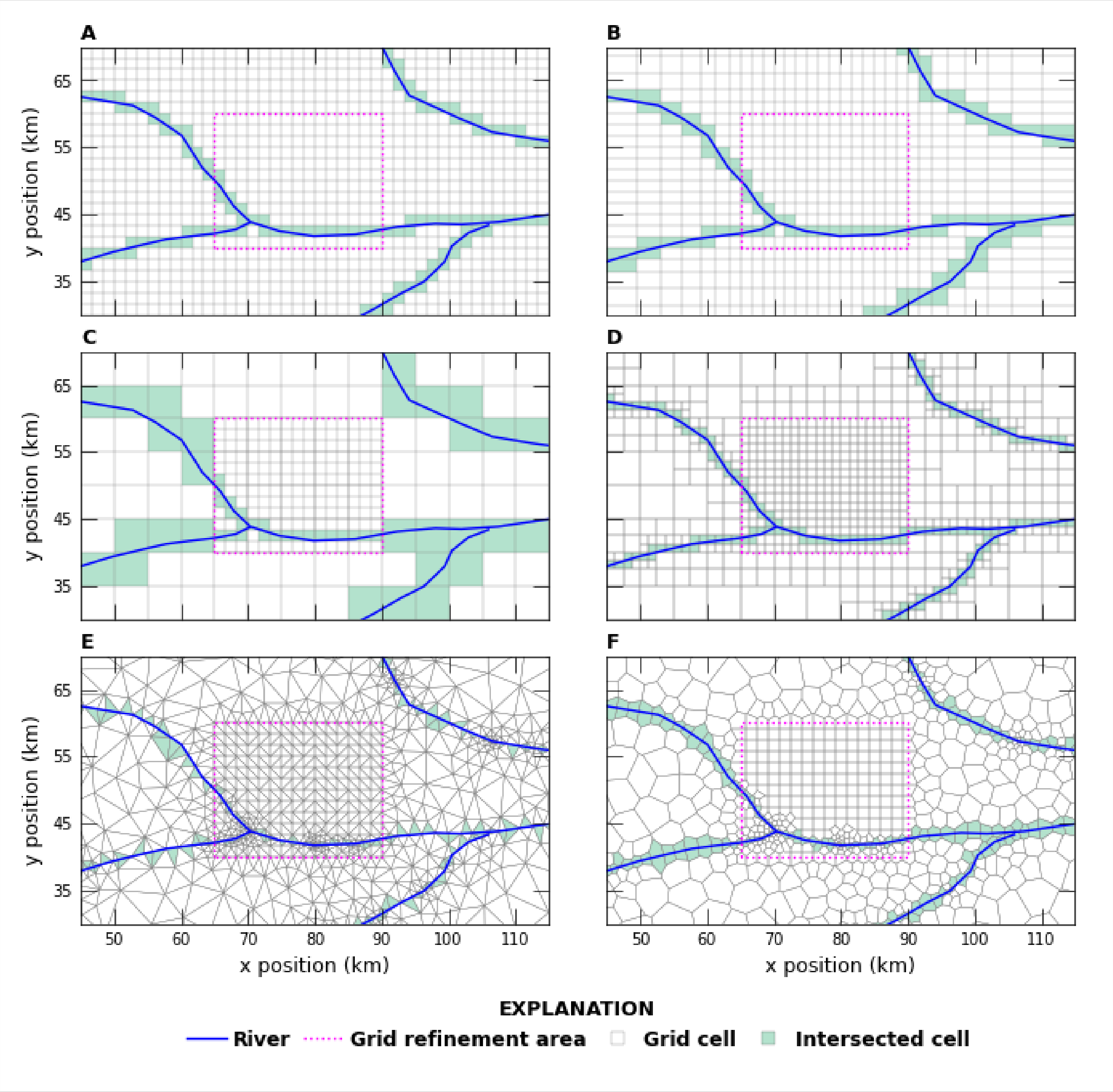
```
    ax.axhline(
        xy0[0],
        marker="s",
        mec="0.5",
        mfc="white",
        markeredgewidth=0.25,
        lw=0,
        label="Grid cell",
    )
    ax.axhline(
        xy0[0],
        marker="s",
        mfc=intersection_rgba,
        mec="0.5",
        markeredgewidth=0.25,
        lw=0,
        label="Intersected cell",
    )
    styles.graph_legend(
        ax,
        ncol=4,
        loc="lower center",
        labelspacing=0.5,
        columnspacing=0.6,
        handletextpad=0.3,
    )
```



6.12 Miscellaneous examples

6.12.1 Henry Saltwater Intrusion Problem

In this notebook, we will use Flopy to create, run, and post process the Henry saltwater intrusion problem using SEAWAT Version 4.

[1]:
```
import os
import sys
from tempfile import TemporaryDirectory
```

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```
import numpy as np

# run installed version of flopy or add local path
try:
    import flopy
except:
    fpth = os.path.abspath(os.path.join("..", ".."))
    sys.path.append(fpth)
    import flopy

print(sys.version)
print(f"numpy version: {np.__version__}")
print(f"flopy version: {flopy.__version__}")
```

```
3.8.18 (default, Aug 28 2023, 08:27:22)
[GCC 11.4.0]
numpy version: 1.24.4
flopy version: 3.5.0
```

[2]:
```
# temporary directory
temp_dir = TemporaryDirectory()
workspace = temp_dir.name
```

[3]:
```
# Input variables for the Henry Problem
Lx = 2.0
Lz = 1.0
nlay = 50
nrow = 1
ncol = 100
delr = Lx / ncol
delc = 1.0
delv = Lz / nlay
henry_top = 1.0
henry_botm = np.linspace(henry_top - delv, 0.0, nlay)
qinflow = 5.702  # m3/day
dmcoef = 0.57024  # m2/day  Could also try 1.62925 as another case of the Henry problem
hk = 864.0  # m/day
```

[4]:
```
# Create the basic MODFLOW model structure
modelname = "henry"
swt = flopy.seawat.Seawat(modelname, exe_name="swtv4", model_ws=workspace)
print(swt.namefile)

# save cell fluxes to unit 53
ipakcb = 53

# Add DIS package to the MODFLOW model
dis = flopy.modflow.ModflowDis(
    swt,
    nlay,
    nrow,
    ncol,
```

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```
    nper=1,
    delr=delr,
    delc=delc,
    laycbd=0,
    top=henry_top,
    botm=henry_botm,
    perlen=1.5,
    nstp=15,
)

# Variables for the BAS package
ibound = np.ones((nlay, nrow, ncol), dtype=np.int32)
ibound[:, :, -1] = -1
bas = flopy.modflow.ModflowBas(swt, ibound, 0)

# Add LPF package to the MODFLOW model
lpf = flopy.modflow.ModflowLpf(swt, hk=hk, vka=hk, ipakcb=ipakcb)

# Add PCG Package to the MODFLOW model
pcg = flopy.modflow.ModflowPcg(swt, hclose=1.0e-8)

# Add OC package to the MODFLOW model
oc = flopy.modflow.ModflowOc(
    swt,
    stress_period_data={(0, 0): ["save head", "save budget"]},
    compact=True,
)

# Create WEL and SSM data
itype = flopy.mt3d.Mt3dSsm.itype_dict()
wel_data = {}
ssm_data = {}
wel_sp1 = []
ssm_sp1 = []
for k in range(nlay):
    wel_sp1.append([k, 0, 0, qinflow / nlay])
    ssm_sp1.append([k, 0, 0, 0.0, itype["WEL"]])
    ssm_sp1.append([k, 0, ncol - 1, 35.0, itype["BAS6"]])
wel_data[0] = wel_sp1
ssm_data[0] = ssm_sp1
wel = flopy.modflow.ModflowWel(swt, stress_period_data=wel_data, ipakcb=ipakcb)
```

```
henry.nam
```

[5]:
```
# Create the basic MT3DMS model structure
# mt = flopy.mt3d.Mt3dms(modelname, 'nam_mt3dms', mf, model_ws=workspace)
btn = flopy.mt3d.Mt3dBtn(
    swt,
    nprs=-5,
    prsity=0.35,
    sconc=35.0,
    ifmtcn=0,
```

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```
    chkmas=False,
    nprobs=10,
    nprmas=10,
    dt0=0.001,
)
adv = flopy.mt3d.Mt3dAdv(swt, mixelm=0)
dsp = flopy.mt3d.Mt3dDsp(swt, al=0.0, trpt=1.0, trpv=1.0, dmcoef=dmcoef)
gcg = flopy.mt3d.Mt3dGcg(swt, iter1=500, mxiter=1, isolve=1, cclose=1e-7)
ssm = flopy.mt3d.Mt3dSsm(swt, stress_period_data=ssm_data)

# Create the SEAWAT model structure
# mswt = flopy.seawat.Seawat(modelname, 'nam_swt', mf, mt, model_ws=workspace, exe_name=
↪'swtv4')
vdf = flopy.seawat.SeawatVdf(
    swt,
    iwtable=0,
    densemin=0,
    densemax=0,
    denseref=1000.0,
    denseslp=0.7143,
    firstdt=1e-3,
)
```

[6]:
```
# Write the input files
swt.write_input()
```

[7]:
```
# Try to delete the output files, to prevent accidental use of older files
try:
    os.remove(os.path.join(workspace, "MT3D001.UCN"))
    os.remove(os.path.join(workspace, f"{modelname}.hds"))
    os.remove(os.path.join(workspace, f"{modelname}.cbc"))
except:
    pass
```

[8]:
```
v = swt.run_model(silent=True, report=True)
for idx in range(-3, 0):
    print(v[1][idx])
```

```
Elapsed run time: 10.688 Seconds

Normal termination of SEAWAT
```

[9]:
```
# Post-process the results
import numpy as np

import flopy.utils.binaryfile as bf

# Load data
ucnobj = bf.UcnFile(os.path.join(workspace, "MT3D001.UCN"), model=swt)
times = ucnobj.get_times()
concentration = ucnobj.get_data(totim=times[-1])
```

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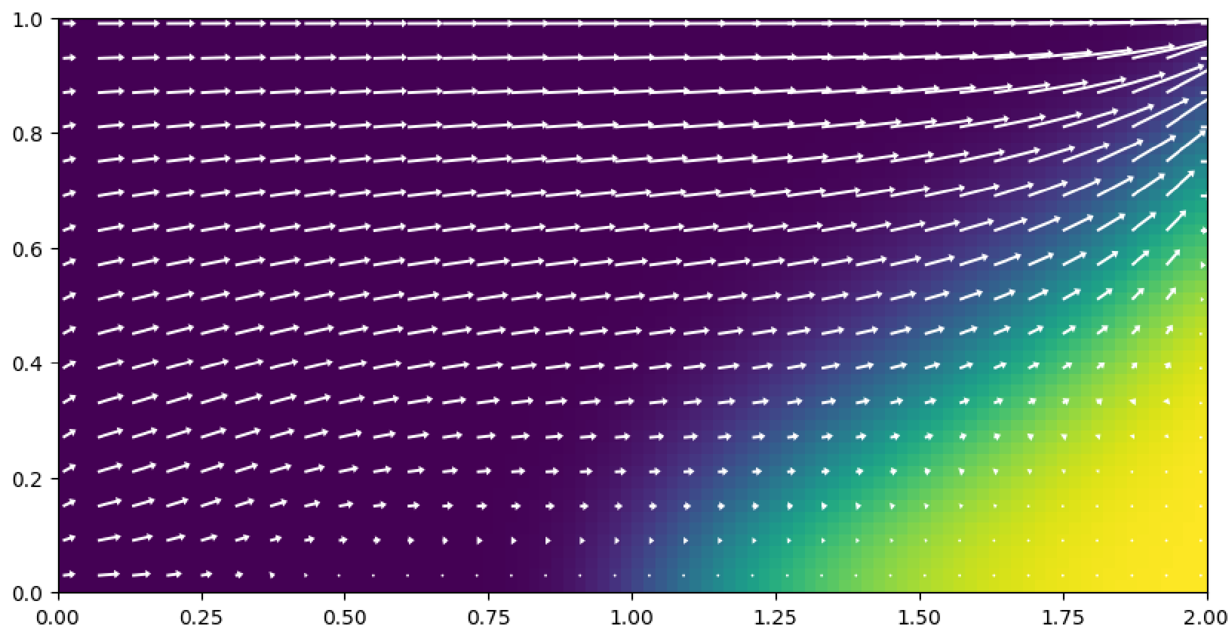
```
cbbobj = bf.CellBudgetFile(os.path.join(workspace, "henry.cbc"))
times = cbbobj.get_times()
qx = cbbobj.get_data(text="flow right face", totim=times[-1])[0]
qz = cbbobj.get_data(text="flow lower face", totim=times[-1])[0]

# Average flows to cell centers
qx_avg = np.empty(qx.shape, dtype=qx.dtype)
qx_avg[:, :, 1:] = 0.5 * (qx[:, :, 0 : ncol - 1] + qx[:, :, 1:ncol])
qx_avg[:, :, 0] = 0.5 * qx[:, :, 0]
qz_avg = np.empty(qz.shape, dtype=qz.dtype)
qz_avg[1:, :, :] = 0.5 * (qz[0 : nlay - 1, :, :] + qz[1:nlay, :, :])
qz_avg[0, :, :] = 0.5 * qz[0, :, :]
```

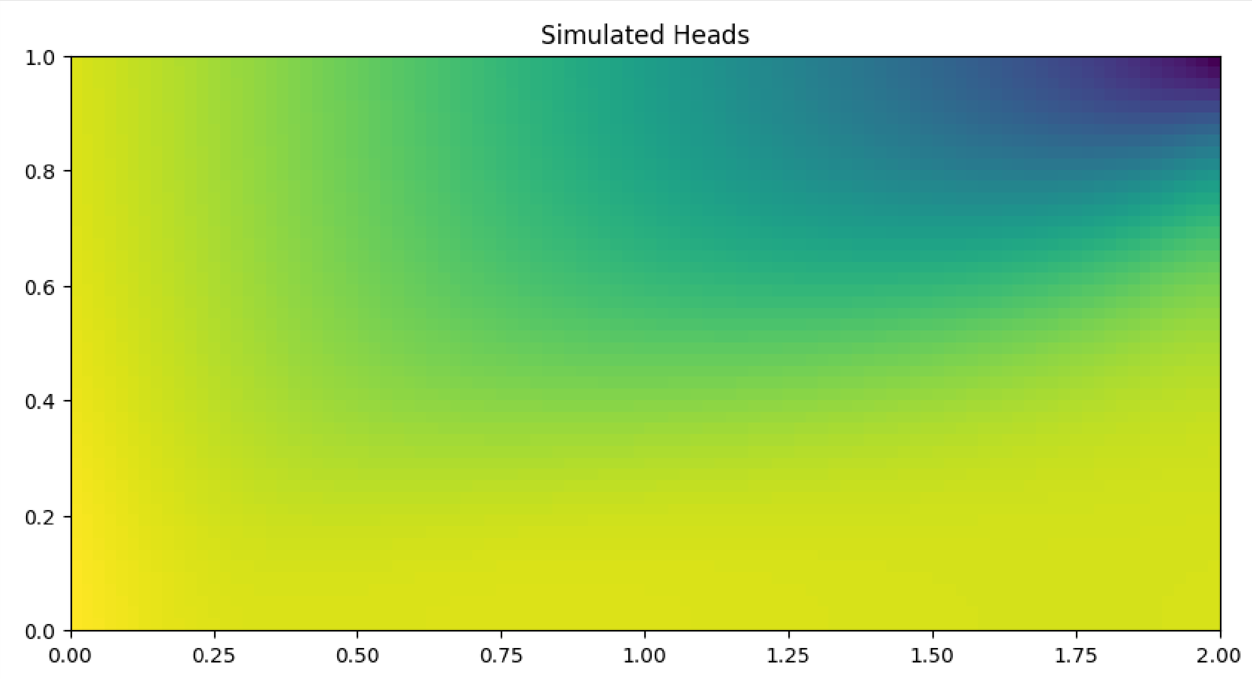
[10]:
```
# Make the plot
import matplotlib.pyplot as plt

fig = plt.figure(figsize=(10, 10))
ax = fig.add_subplot(1, 1, 1, aspect="equal")
ax.imshow(
    concentration[:, 0, :], interpolation="nearest", extent=(0, Lx, 0, Lz)
)
y, x, z = dis.get_node_coordinates()
X, Z = np.meshgrid(x, z[:, 0, 0])
iskip = 3
ax.quiver(
    X[::iskip, ::iskip],
    Z[::iskip, ::iskip],
    qx_avg[::iskip, 0, ::iskip],
    -qz_avg[::iskip, 0, ::iskip],
    color="w",
    scale=5,
    headwidth=3,
    headlength=2,
    headaxislength=2,
    width=0.0025,
)
plt.savefig(os.path.join(workspace, "henry.png"))
plt.show()
```



[11]:
```
# Extract the heads
fname = os.path.join(workspace, "henry.hds")
headobj = bf.HeadFile(fname)
times = headobj.get_times()
head = headobj.get_data(totim=times[-1])
```

[12]:
```
# Make a simple head plot
fig = plt.figure(figsize=(10, 10))
ax = fig.add_subplot(1, 1, 1, aspect="equal")
im = ax.imshow(head[:, 0, :], interpolation="nearest", extent=(0, Lx, 0, Lz))
ax.set_title("Simulated Heads")
```

[12]:
```
Text(0.5, 1.0, 'Simulated Heads')
```



Change the format of several arrays and rerun the model

[13]:
```
swt.btn.prsity.how = "constant"
swt.btn.prsity[0].how = "internal"
swt.btn.prsity[1].how = "external"
swt.btn.sconc[0].how = "external"
swt.btn.prsity[0].fmtin = "(100E15.6)"
swt.lpf.hk[0].fmtin = "(BINARY)"
```

[14]:
```
swt.write_input()
v = swt.run_model(silent=True, report=True)
for idx in range(-3, 0):
    print(v[1][idx])
```

```
Util2d:hk layer 1: resetting 'how' to external
 Elapsed run time:  7.818 Seconds

 Normal termination of SEAWAT
```

[15]:
```
try:
    # ignore PermissionError on Windows
    temp_dir.cleanup()
except:
    pass
```

6.12.2 ZoneBudget Example

This notebook demonstrates how to use the ZoneBudget class to extract budget information from the cell by cell budget file using an array of zones.

First set the path and import the required packages. The flopy path doesn't have to be set if you install flopy from a binary installer. If you want to run this notebook, you have to set the path to your own flopy path.

[1]:
```
import sys
from pathlib import Path
from tempfile import TemporaryDirectory

import matplotlib as mpl
import matplotlib.pyplot as plt
import numpy as np
import pandas as pd

proj_root = Path.cwd().parent.parent

# run installed version of flopy or add local path
try:
    import flopy
except:
    sys.path.append(proj_root)
    import flopy

print(sys.version)
print(f"numpy version: {np.__version__}")
print(f"matplotlib version: {mpl.__version__}")
print(f"pandas version: {pd.__version__}")
print(f"flopy version: {flopy.__version__}")
```

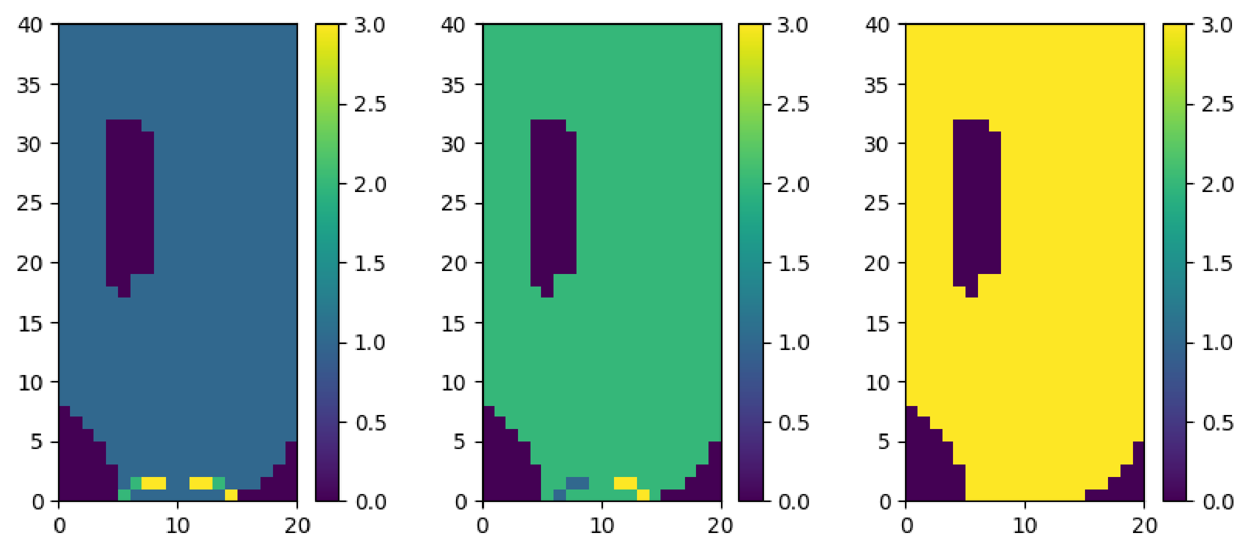
```
3.8.18 (default, Aug 28 2023, 08:27:22)
[GCC 11.4.0]
numpy version: 1.24.4
matplotlib version: 3.7.4
pandas version: 2.0.3
flopy version: 3.5.0
```

[2]:
```
# temporary workspace
temp_dir = TemporaryDirectory()
workspace = Path(temp_dir.name)

# Set path to example datafiles
loadpth = proj_root / "examples" / "data" / "zonbud_examples"
cbc_f = loadpth / "freyberg.gitcbc"
```

Read File Containing Zones

Using the ZoneBudget.read_zone_file() utility, we can import zonebudget-style array files.

[3]:
```
from flopy.utils import ZoneBudget

zone_file = loadpth / "zonef_mlt.zbr"
zon = ZoneBudget.read_zone_file(zone_file)
nlay, nrow, ncol = zon.shape

fig = plt.figure(figsize=(10, 4))

for lay in range(nlay):
    ax = fig.add_subplot(1, nlay, lay + 1)
    im = ax.pcolormesh(zon[lay, ::-1, :])
    cbar = plt.colorbar(im)
    plt.gca().set_aspect("equal")

plt.show()
```



Extract Budget Information from ZoneBudget Object

At the core of the ZoneBudget object is a numpy structured array. The class provides some wrapper functions to help us interogate the array and save it to disk.

[4]:
```
# Create a ZoneBudget object and get the budget record array
zb = flopy.utils.ZoneBudget(cbc_f, zon, kstpkper=(0, 1096))
zb.get_budget()
```

[4]:
```
array([(1097., 0, 1096, 'FROM_STORAGE',  0., 0.0000000e+00, 0.0000000e+00, 0.
↪0000000e+00),
       (1097., 0, 1096, 'FROM_CONSTANT_HEAD',  0., 0.0000000e+00, 2.3156659e+02, 8.
↪6217201e+01),
       (1097., 0, 1096, 'FROM_WELLS',  0., 0.0000000e+00, 0.0000000e+00, 0.0000000e+00),
```
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```
        (1097., 0, 1096, 'FROM_DRAINS',  0., 0.0000000e+00, 0.0000000e+00, 0.0000000e+00),
        (1097., 0, 1096, 'FROM_RECHARGE',  0., 5.1455815e+03, 1.4936376e+01, 2.
↪9872751e+01),
        (1097., 0, 1096, 'FROM_ZONE_0',  0., 0.0000000e+00, 0.0000000e+00, 0.0000000e+00),
        (1097., 0, 1096, 'FROM_ZONE_1',  0., 0.0000000e+00, 3.4751235e+03, 1.3860045e+02),
        (1097., 0, 1096, 'FROM_ZONE_2',  0., 3.2693188e+03, 0.0000000e+00, 1.7646553e+03),
        (1097., 0, 1096, 'FROM_ZONE_3',  0., 1.9218604e+02, 1.5280482e+03, 0.0000000e+00),
        (1097., 0, 1096, 'TOTAL_IN',  0., 8.6070859e+03, 5.2496748e+03, 2.0193457e+03),
        (1097., 0, 1096, 'TO_STORAGE',  0., 0.0000000e+00, 0.0000000e+00, 0.0000000e+00),
        (1097., 0, 1096, 'TO_CONSTANT_HEAD',  0., 2.3054836e+02, 2.1570151e+02, 2.
↪9911380e+02),
        (1097., 0, 1096, 'TO_WELLS',  0., 4.7627998e+03, 0.0000000e+00, 0.0000000e+00),
        (1097., 0, 1096, 'TO_DRAINS',  0., 0.0000000e+00, 0.0000000e+00, 0.0000000e+00),
        (1097., 0, 1096, 'TO_RECHARGE',  0., 0.0000000e+00, 0.0000000e+00, 0.0000000e+00),
        (1097., 0, 1096, 'TO_ZONE_0',  0., 0.0000000e+00, 0.0000000e+00, 0.0000000e+00),
        (1097., 0, 1096, 'TO_ZONE_1',  0., 0.0000000e+00, 3.2693188e+03, 1.9218604e+02),
        (1097., 0, 1096, 'TO_ZONE_2',  0., 3.4751235e+03, 0.0000000e+00, 1.5280482e+03),
        (1097., 0, 1096, 'TO_ZONE_3',  0., 1.3860045e+02, 1.7646553e+03, 0.0000000e+00),
        (1097., 0, 1096, 'TOTAL_OUT',  0., 8.6070723e+03, 5.2496758e+03, 2.0193480e+03),
        (1097., 0, 1096, 'IN-OUT',  0., 1.3671875e-02, 9.7656250e-04, 2.3193359e-03),
        (1097., 0, 1096, 'PERCENT_DISCREPANCY', nan, 1.5884454e-04, 1.8602341e-05, 1.
↪1485574e-04)],
      dtype=[('totim', '<f4'), ('time_step', '<i4'), ('stress_period', '<i4'), ('name', '
↪<U50'), ('ZONE_0', '<f4'), ('ZONE_1', '<f4'), ('ZONE_2', '<f4'), ('ZONE_3', '<f4')])
```

[5]:
```
# Get a list of the unique budget record names
zb.get_record_names()
```

[5]:
```
array(['FROM_CONSTANT_HEAD', 'FROM_DRAINS', 'FROM_RECHARGE',
       'FROM_STORAGE', 'FROM_WELLS', 'FROM_ZONE_0', 'FROM_ZONE_1',
       'FROM_ZONE_2', 'FROM_ZONE_3', 'IN-OUT', 'PERCENT_DISCREPANCY',
       'TOTAL_IN', 'TOTAL_OUT', 'TO_CONSTANT_HEAD', 'TO_DRAINS',
       'TO_RECHARGE', 'TO_STORAGE', 'TO_WELLS', 'TO_ZONE_0', 'TO_ZONE_1',
       'TO_ZONE_2', 'TO_ZONE_3'], dtype='<U50')
```

[6]:
```
# Look at a subset of fluxes
names = ["FROM_RECHARGE", "FROM_ZONE_1", "FROM_ZONE_3"]
zb.get_budget(names=names)
```

[6]:
```
array([(1097., 0, 1096, 'FROM_RECHARGE', 0., 5145.5815 ,   14.936376,   29.872751),
       (1097., 0, 1096, 'FROM_ZONE_1', 0.,    0.      , 3475.1235   , 138.60045 ),
       (1097., 0, 1096, 'FROM_ZONE_3', 0.,  192.18604, 1528.0482   ,    0.       )],
      dtype=[('totim', '<f4'), ('time_step', '<i4'), ('stress_period', '<i4'), ('name', '
↪<U50'), ('ZONE_0', '<f4'), ('ZONE_1', '<f4'), ('ZONE_2', '<f4'), ('ZONE_3', '<f4')])
```

[7]:
```
# Look at fluxes in from zone 2
names = ["FROM_RECHARGE", "FROM_ZONE_1", "FROM_ZONE_3"]
zones = ["ZONE_2"]
zb.get_budget(names=names, zones=zones)
```

[7]:
```
array([(1097., 0, 1096, 'FROM_RECHARGE',   14.936376),
       (1097., 0, 1096, 'FROM_ZONE_1', 3475.1235  ),
       (1097., 0, 1096, 'FROM_ZONE_3', 1528.0482  )],
```

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```
      dtype={'names': ['totim', 'time_step', 'stress_period', 'name', 'ZONE_2'], 'formats
↪': ['<f4', '<i4', '<i4', '<U50', '<f4'], 'offsets': [0, 4, 8, 12, 220], 'itemsize':␣
↪228})
```

[8]:
```
# Look at all of the mass-balance records
names = ["TOTAL_IN", "TOTAL_OUT", "IN-OUT", "PERCENT_DISCREPANCY"]
zb.get_budget(names=names)
```

[8]:
```
array([(1097., 0, 1096, 'TOTAL_IN',  0., 8.6070859e+03, 5.249675e+03, 2.0193457e+03),
       (1097., 0, 1096, 'TOTAL_OUT',  0., 8.6070723e+03, 5.249676e+03, 2.0193480e+03),
       (1097., 0, 1096, 'IN-OUT',  0., 1.3671875e-02, 9.765625e-04, 2.3193359e-03),
       (1097., 0, 1096, 'PERCENT_DISCREPANCY', nan, 1.5884454e-04, 1.860234e-05, 1.
↪1485574e-04)],
      dtype=[('totim', '<f4'), ('time_step', '<i4'), ('stress_period', '<i4'), ('name', '
↪<U50'), ('ZONE_0', '<f4'), ('ZONE_1', '<f4'), ('ZONE_2', '<f4'), ('ZONE_3', '<f4')])
```

Convert Units

The ZoneBudget class supports the use of mathematical operators and returns a new copy of the object.

[9]:
```
cmd = flopy.utils.ZoneBudget(cbc_f, zon, kstpkper=(0, 0))
cfd = cmd / 35.3147
inyr = (cfd / (250 * 250)) * 365 * 12

cmdbud = cmd.get_budget()
cfdbud = cfd.get_budget()
inyrbud = inyr.get_budget()

names = ["FROM_RECHARGE"]
rowidx = np.in1d(cmdbud["name"], names)
colidx = "ZONE_1"

print(f"{cmdbud[rowidx][colidx][0]:,.1f} cubic meters/day")
print(f"{cfdbud[rowidx][colidx][0]:,.1f} cubic feet/day")
print(f"{inyrbud[rowidx][colidx][0]:,.1f} inches/year")
```

```
6,222.7 cubic meters/day
176.2 cubic feet/day
12.3 inches/year
```

[10]:
```
cmd is cfd
```

[10]:
```
False
```

Alias Names

A dictionary of {zone: "alias"} pairs can be passed to replace the typical "ZONE_X" fieldnames of the ZoneBudget structured array with more descriptive names.

[11]:
```
aliases = {1: "SURF", 2: "CONF", 3: "UFA"}
zb = flopy.utils.ZoneBudget(cbc_f, zon, totim=[1097.0], aliases=aliases)
zb.get_budget()
```

[11]:
```
array([(1097., 0, 1096, 'FROM_STORAGE',  0., 0.0000000e+00, 0.0000000e+00, 0.
↪0000000e+00),
       (1097., 0, 1096, 'FROM_CONSTANT_HEAD',  0., 0.0000000e+00, 2.3156659e+02, 8.
↪6217201e+01),
       (1097., 0, 1096, 'FROM_WELLS',  0., 0.0000000e+00, 0.0000000e+00, 0.0000000e+00),
       (1097., 0, 1096, 'FROM_DRAINS',  0., 0.0000000e+00, 0.0000000e+00, 0.0000000e+00),
       (1097., 0, 1096, 'FROM_RECHARGE',  0., 5.1455815e+03, 1.4936376e+01, 2.
↪9872751e+01),
       (1097., 0, 1096, 'FROM_ZONE_0',  0., 0.0000000e+00, 0.0000000e+00, 0.0000000e+00),
       (1097., 0, 1096, 'FROM_SURF',  0., 0.0000000e+00, 3.4751235e+03, 1.3860045e+02),
       (1097., 0, 1096, 'FROM_CONF',  0., 3.2693188e+03, 0.0000000e+00, 1.7646553e+03),
       (1097., 0, 1096, 'FROM_UFA',  0., 1.9218604e+02, 1.5280482e+03, 0.0000000e+00),
       (1097., 0, 1096, 'TOTAL_IN',  0., 8.6070859e+03, 5.2496748e+03, 2.0193457e+03),
       (1097., 0, 1096, 'TO_STORAGE',  0., 0.0000000e+00, 0.0000000e+00, 0.0000000e+00),
       (1097., 0, 1096, 'TO_CONSTANT_HEAD',  0., 2.3054836e+02, 2.1570151e+02, 2.
↪9911380e+02),
       (1097., 0, 1096, 'TO_WELLS',  0., 4.7627998e+03, 0.0000000e+00, 0.0000000e+00),
       (1097., 0, 1096, 'TO_DRAINS',  0., 0.0000000e+00, 0.0000000e+00, 0.0000000e+00),
       (1097., 0, 1096, 'TO_RECHARGE',  0., 0.0000000e+00, 0.0000000e+00, 0.0000000e+00),
       (1097., 0, 1096, 'TO_ZONE_0',  0., 0.0000000e+00, 0.0000000e+00, 0.0000000e+00),
       (1097., 0, 1096, 'TO_SURF',  0., 0.0000000e+00, 3.2693188e+03, 1.9218604e+02),
       (1097., 0, 1096, 'TO_CONF',  0., 3.4751235e+03, 0.0000000e+00, 1.5280482e+03),
       (1097., 0, 1096, 'TO_UFA',  0., 1.3860045e+02, 1.7646553e+03, 0.0000000e+00),
       (1097., 0, 1096, 'TOTAL_OUT',  0., 8.6070723e+03, 5.2496758e+03, 2.0193480e+03),
       (1097., 0, 1096, 'IN-OUT',  0., 1.3671875e-02, 9.7656250e-04, 2.3193359e-03),
       (1097., 0, 1096, 'PERCENT_DISCREPANCY', nan, 1.5884454e-04, 1.8602341e-05, 1.
↪1485574e-04)],
      dtype=[('totim', '<f4'), ('time_step', '<i4'), ('stress_period', '<i4'), ('name', '
↪<U50'), ('ZONE_0', '<f4'), ('SURF', '<f4'), ('CONF', '<f4'), ('UFA', '<f4')])
```

Return the Budgets as a Pandas DataFrame

Set kstpkper and totim keyword args to None (or omit) to return all times. The get_dataframes() method will return a DataFrame multi-indexed on totim and name.

[12]:
```
aliases = {1: "SURF", 2: "CONF", 3: "UFA"}
times = list(range(1092, 1097 + 1))
zb = flopy.utils.ZoneBudget(cbc_f, zon, totim=times, aliases=aliases)
zb.get_dataframes()
```

[12]:
```
                            ZONE_0        SURF        CONF         UFA
totim  name
1092.0 FROM_STORAGE            0.0  393.480286  230.476242  228.273621
       FROM_CONSTANT_HEAD      0.0    0.000000   13.225761    5.042325
```

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```
       FROM_WELLS             0.0     0.000000     0.000000     0.000000
       FROM_DRAINS            0.0     0.000000     0.000000     0.000000
       FROM_RECHARGE          0.0  6018.483887    17.470200    34.940399
...                           ...          ...          ...          ...
1097.0 TO_CONF                0.0  3475.123535     0.000000  1528.048218
       TO_UFA                 0.0   138.600449  1764.655273     0.000000
       TOTAL_OUT              0.0  8607.072266  5249.675781  2019.348022
       IN-OUT                 0.0     0.013672     0.000977     0.002319
       PERCENT_DISCREPANCY    NaN     0.000159     0.000019     0.000115

[132 rows x 4 columns]
```

Slice the multi-index dataframe to retrieve a subset of the budget. NOTE: We can pass "names" directly to the get_dataframes() method to return a subset of reocrds. By omitting the "FROM_" or "TO_" prefix we get both.

[13]:
```
dateidx1 = 1095.0
dateidx2 = 1097.0
names = ["FROM_RECHARGE", "TO_WELLS", "CONSTANT_HEAD"]
zones = ["SURF", "CONF"]
df = zb.get_dataframes(names=names)
df.loc[(slice(dateidx1, dateidx2), slice(None)), :][zones]
```

[13]:
```
                                  SURF        CONF
totim  name
1095.0 FROM_CONSTANT_HEAD     0.000000   14.531923
       FROM_RECHARGE       5010.149414   14.543249
       TO_CONSTANT_HEAD     664.912598  493.175781
       TO_WELLS             794.582886    0.000000
1096.0 FROM_CONSTANT_HEAD     0.000000    6.501888
       FROM_RECHARGE       6115.663086   17.752289
       TO_CONSTANT_HEAD     690.230591  511.618652
       TO_WELLS            1373.782715    0.000000
1097.0 FROM_CONSTANT_HEAD     0.000000  231.566589
       FROM_RECHARGE       5145.581543   14.936376
       TO_CONSTANT_HEAD     230.548355  215.701508
       TO_WELLS            4762.799805    0.000000
```

Look at pumpage (TO_WELLS) as a percentage of recharge (FROM_RECHARGE)

[14]:
```
dateidx1 = 1095.0
dateidx2 = 1097.0
zones = ["SURF"]

# Pull out the individual records of interest
rech = df.loc[(slice(dateidx1, dateidx2), ["FROM_RECHARGE"]), :][zones]
pump = df.loc[(slice(dateidx1, dateidx2), ["TO_WELLS"]), :][zones]

# Remove the "record" field from the index so we can
# take the difference of the two DataFrames
rech = rech.reset_index()
rech = rech.set_index(["totim"])
rech = rech[zones]
```

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```
pump = pump.reset_index()
pump = pump.set_index(["totim"])
pump = pump[zones] * -1

# Compute pumping as a percentage of recharge
(pump / rech) * 100.0
```

[14]:

```
             SURF
totim
1095.0 -15.859466
1096.0 -22.463348
1097.0 -92.560966
```

Pass start_datetime and timeunit keyword arguments to return a dataframe with a datetime multi-index

[15]:

```
dateidx1 = pd.Timestamp("1972-12-29")
dateidx2 = pd.Timestamp("1972-12-30")
names = ["FROM_RECHARGE", "TO_WELLS", "CONSTANT_HEAD"]
zones = ["SURF", "CONF"]
df = zb.get_dataframes(start_datetime="1970-01-01", timeunit="D", names=names)
df.loc[(slice(dateidx1, dateidx2), slice(None)), :][zones]
```

[15]:

```
                                      SURF        CONF
datetime   name
1972-12-29 FROM_CONSTANT_HEAD     0.000000   16.905813
           FROM_RECHARGE       4203.679199   12.202263
           TO_CONSTANT_HEAD     655.814514  487.094849
           TO_WELLS            1930.483154    0.000000
1972-12-30 FROM_CONSTANT_HEAD     0.000000   18.877954
           FROM_RECHARGE       4047.502441   11.748919
           TO_CONSTANT_HEAD     650.441589  482.853638
           TO_WELLS            1279.166382    0.000000
```

Pass index_key to indicate which fields to use in the multi-index (default is "totim"; valid keys are "totim" and "kstpkper")

[16]:

```
df = zb.get_dataframes(index_key="kstpkper")
df.head()
```

[16]:

```
                                            ZONE_0         SURF        CONF  \
time_step stress_period name
0         1091          FROM_STORAGE           0.0   393.480286  230.476242
                        FROM_CONSTANT_HEAD     0.0     0.000000   13.225761
                        FROM_WELLS             0.0     0.000000    0.000000
                        FROM_DRAINS            0.0     0.000000    0.000000
                        FROM_RECHARGE          0.0  6018.483887   17.470200


                                                   UFA
time_step stress_period name
0         1091          FROM_STORAGE        228.273621
                        FROM_CONSTANT_HEAD    5.042325
                        FROM_WELLS            0.000000
                        FROM_DRAINS           0.000000
```

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```
                    FROM_RECHARGE         34.940399
```

Write Budget Output to CSV

We can write the resulting recarray to a csv file with the .to_csv() method of the ZoneBudget object.

[17]:
```
zb = flopy.utils.ZoneBudget(cbc_f, zon, kstpkper=[(0, 0), (0, 1096)])
f_out = workspace / "Example_output.csv"
zb.to_csv(f_out)

# Read the file in to see the contents
try:
    import pandas as pd

    print(pd.read_csv(f_out).to_string(index=False))
except:
    with open(f_out) as f:
        for line in f.readlines():
            print("\t".join(line.split(",")))
```

```
 totim  time_step  stress_period               name  ZONE_0      ZONE_1      ZONE_2  ␣
↪ ZONE_3
   1.0          0              0       FROM_STORAGE     0.0    0.000000    0.000000  ␣
↪0.000000
   1.0          0              0  FROM_CONSTANT_HEAD     0.0    0.000000    0.000000  ␣
↪0.000000
   1.0          0              0         FROM_WELLS     0.0    0.000000    0.000000  ␣
↪0.000000
   1.0          0              0        FROM_DRAINS     0.0    0.000000    0.000000  ␣
↪0.000000
   1.0          0              0      FROM_RECHARGE     0.0 6222.673300   18.062912  ␣
↪36.125824
   1.0          0              0        FROM_ZONE_0     0.0    0.000000    0.000000  ␣
↪0.000000
   1.0          0              0        FROM_ZONE_1     0.0    0.000000 4275.257300  ␣
↪491.945070
   1.0          0              0        FROM_ZONE_2     0.0 2744.821800    0.000000␣
↪2115.654000
   1.0          0              0        FROM_ZONE_3     0.0  451.545720 1215.952300  ␣
↪0.000000
   1.0          0              0           TOTAL_IN     0.0 9419.041000 5509.272500␣
↪2643.725000
   1.0          0              0         TO_STORAGE     0.0    0.000000    0.000000  ␣
↪0.000000
   1.0          0              0    TO_CONSTANT_HEAD     0.0  821.283200  648.806100  ␣
↪976.233600
   1.0          0              0           TO_WELLS     0.0    0.000000    0.000000  ␣
↪0.000000
   1.0          0              0          TO_DRAINS     0.0 3832.150000    0.000000  ␣
↪0.000000
```

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```
    1.0          0           0          TO_RECHARGE     0.0    0.000000    0.000000   ␣
↪0.000000
    1.0          0           0            TO_ZONE_0     0.0    0.000000    0.000000   ␣
↪0.000000
    1.0          0           0            TO_ZONE_1     0.0    0.000000 2744.821800 ␣
↪451.545720
    1.0          0           0            TO_ZONE_2     0.0 4275.257300    0.000000␣
↪1215.952300
    1.0          0           0            TO_ZONE_3     0.0  491.945070 2115.654000   ␣
↪0.000000
    1.0          0           0            TOTAL_OUT     0.0 9420.636000 5509.282000␣
↪2643.731400
    1.0          0           0               IN-OUT     0.0    1.594727    0.009766   ␣
↪0.006348
    1.0          0           0 PERCENT_DISCREPANCY      NaN    0.016929    0.000177   ␣
↪0.000240
 1097.0          0        1096         FROM_STORAGE     0.0    0.000000    0.000000   ␣
↪0.000000
 1097.0          0        1096   FROM_CONSTANT_HEAD     0.0    0.000000  231.566590  ␣
↪86.217200
 1097.0          0        1096           FROM_WELLS     0.0    0.000000    0.000000   ␣
↪0.000000
 1097.0          0        1096          FROM_DRAINS     0.0    0.000000    0.000000   ␣
↪0.000000
 1097.0          0        1096        FROM_RECHARGE     0.0 5145.581500   14.936376  ␣
↪29.872751
 1097.0          0        1096          FROM_ZONE_0     0.0    0.000000    0.000000   ␣
↪0.000000
 1097.0          0        1096          FROM_ZONE_1     0.0    0.000000 3475.123500 ␣
↪138.600450
 1097.0          0        1096          FROM_ZONE_2     0.0 3269.318800    0.000000␣
↪1764.655300
 1097.0          0        1096          FROM_ZONE_3     0.0  192.186040 1528.048200   ␣
↪0.000000
 1097.0          0        1096             TOTAL_IN     0.0 8607.086000 5249.675000␣
↪2019.345700
 1097.0          0        1096           TO_STORAGE     0.0    0.000000    0.000000   ␣
↪0.000000
 1097.0          0        1096     TO_CONSTANT_HEAD     0.0  230.548360  215.701500 ␣
↪299.113800
 1097.0          0        1096             TO_WELLS     0.0 4762.800000    0.000000   ␣
↪0.000000
 1097.0          0        1096            TO_DRAINS     0.0    0.000000    0.000000   ␣
↪0.000000
 1097.0          0        1096          TO_RECHARGE     0.0    0.000000    0.000000   ␣
↪0.000000
 1097.0          0        1096            TO_ZONE_0     0.0    0.000000    0.000000   ␣
↪0.000000
 1097.0          0        1096            TO_ZONE_1     0.0    0.000000 3269.318800 ␣
↪192.186040
 1097.0          0        1096            TO_ZONE_2     0.0 3475.123500    0.000000␣
↪1528.048200
```

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```
1097.0          0         1096          TO_ZONE_3     0.0  138.600450 1764.655300  ␣
↪0.000000
1097.0          0         1096          TOTAL_OUT     0.0 8607.072000 5249.676000␣
↪2019.348000
1097.0          0         1096             IN-OUT     0.0    0.013672    0.000977  ␣
↪0.002319
1097.0          0         1096 PERCENT_DISCREPANCY    NaN    0.000159    0.000019  ␣
↪0.000115
```

Net Budget

Using the "net" keyword argument, we can request a net budget for each zone/record name or for a subset of zones and record names. Note that we can identify the record names we want without the added "_IN" or "_OUT" string suffix.

[18]:
```
zon = np.ones((nlay, nrow, ncol), int)
zon[1, :, :] = 2
zon[2, :, :] = 3

aliases = {1: "SURF", 2: "CONF", 3: "UFA"}
times = list(range(1092, 1097 + 1))
zb = flopy.utils.ZoneBudget(cbc_f, zon, totim=times, aliases=aliases)
zb.get_budget(names=["STORAGE", "WELLS"], zones=["SURF", "UFA"], net=True)
```

[18]:
```
array([(1092., 0, 1091, 'STORAGE',  -386.15085, -425.65155),
       (1092., 0, 1091, 'WELLS', -2829.812  ,    0.     ),
       (1093., 0, 1092, 'STORAGE',   -12.50354, -151.3594 ),
       (1093., 0, 1092, 'WELLS', -1930.4832 ,    0.     ),
       (1094., 0, 1093, 'STORAGE',  -198.92935, -270.8744 ),
       (1094., 0, 1093, 'WELLS', -1279.1664 ,    0.     ),
       (1095., 0, 1094, 'STORAGE',  -718.4885 , -604.8537 ),
       (1095., 0, 1094, 'WELLS',  -794.5829 ,    0.     ),
       (1096., 0, 1095, 'STORAGE',  -855.1075 , -622.88477),
       (1096., 0, 1095, 'WELLS', -1373.7827 ,    0.     ),
       (1097., 0, 1096, 'STORAGE',     0.     ,    0.     ),
       (1097., 0, 1096, 'WELLS', -4762.8    ,    0.     )],
      dtype={'names': ['totim', 'time_step', 'stress_period', 'name', 'SURF', 'UFA'],
↪'formats': ['<f4', '<i4', '<i4', '<U50', '<f4', '<f4'], 'offsets': [0, 4, 8, 12, 212,␣
↪220], 'itemsize': 224})
```

[19]:
```
df = zb.get_dataframes(
    names=["STORAGE", "WELLS"], zones=["SURF", "UFA"], net=True
)
df.head(6)
```

[19]:
```
                      SURF         UFA
totim  name
1092.0 STORAGE  -386.150848 -425.651550
       WELLS   -2829.812012    0.000000
1093.0 STORAGE   -12.503540 -151.359406
       WELLS   -1930.483154    0.000000
```

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```
1094.0 STORAGE  -198.929352 -270.874390
       WELLS   -1279.166382    0.000000
```

Plot Budget Components

The following is a function that can be used to better visualize the budget components using matplotlib.

[20]:
```
def tick_label_formatter_comma_sep(x, pos):
    return f"{x:,.0f}"


def volumetric_budget_bar_plot(values_in, values_out, labels, **kwargs):
    if "ax" in kwargs:
        ax = kwargs.pop("ax")
    else:
        ax = plt.gca()

    x_pos = np.arange(len(values_in))
    rects_in = ax.bar(x_pos, values_in, align="center", alpha=0.5)

    x_pos = np.arange(len(values_out))
    rects_out = ax.bar(x_pos, values_out, align="center", alpha=0.5)

    plt.xticks(list(x_pos), labels)
    ax.set_xticklabels(ax.xaxis.get_majorticklabels(), rotation=90)
    ax.get_yaxis().set_major_formatter(
        mpl.ticker.FuncFormatter(tick_label_formatter_comma_sep)
    )

    ymin, ymax = ax.get_ylim()
    if ymax != 0:
        if abs(ymin) / ymax < 0.33:
            ymin = -(ymax * 0.5)
        else:
            ymin *= 1.35
    else:
        ymin *= 1.35
    plt.ylim([ymin, ymax * 1.25])

    for i, rect in enumerate(rects_in):
        label = f"{values_in[i]:,.0f}"
        height = values_in[i]
        x = rect.get_x() + rect.get_width() / 2
        y = height + (0.02 * ymax)
        vertical_alignment = "bottom"
        horizontal_alignment = "center"
        ax.text(
            x,
            y,
            label,
```

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```
            ha=horizontal_alignment,
            va=vertical_alignment,
            rotation=90,
        )

    for i, rect in enumerate(rects_out):
        label = f"{values_out[i]:,.0f}"
        height = values_out[i]
        x = rect.get_x() + rect.get_width() / 2
        y = height + (0.02 * ymin)
        vertical_alignment = "top"
        horizontal_alignment = "center"
        ax.text(
            x,
            y,
            label,
            ha=horizontal_alignment,
            va=vertical_alignment,
            rotation=90,
        )

    # horizontal line indicating zero
    ax.plot(
        [
            rects_in[0].get_x() - rects_in[0].get_width() / 2,
            rects_in[-1].get_x() + rects_in[-1].get_width(),
        ],
        [0, 0],
        "k",
    )

    return rects_in, rects_out
```

[21]:
```
fig = plt.figure(figsize=(16, 5))

times = [2.0, 500.0, 1000.0, 1095.0]

for idx, t in enumerate(times):
    ax = fig.add_subplot(1, len(times), idx + 1)

    zb = flopy.utils.ZoneBudget(
        cbc_f, zon, kstpkper=None, totim=t, aliases=aliases
    )

    recname = "STORAGE"
    values_in = zb.get_dataframes(names=f"FROM_{recname}").T.squeeze()
    values_out = zb.get_dataframes(names=f"TO_{recname}").T.squeeze() * -1
    labels = values_in.index.tolist()

    rects_in, rects_out = volumetric_budget_bar_plot(
        values_in, values_out, labels, ax=ax
    )
```

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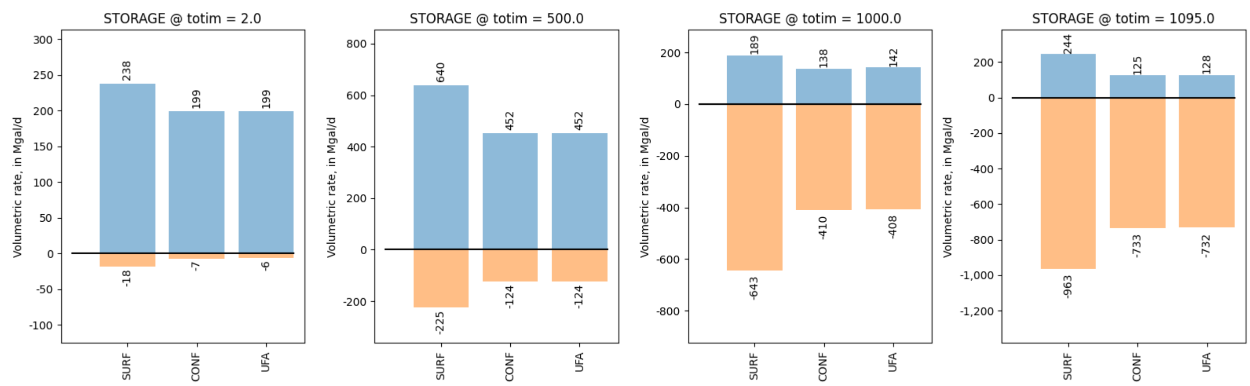
```
    plt.ylabel("Volumetric rate, in Mgal/d")
    plt.title(f"{recname} @ totim = {t}")

plt.tight_layout()
plt.show()
```



Zonebudget for Modflow 6 (ZoneBudget6)

This section shows how to build and run a Zonebudget when working with a MODFLOW 6 model.

First let's load a model

[22]:
```
mf6_exe = "mf6"
zb6_exe = "zbud6"

sim_ws = proj_root / "examples" / "data" / "mf6-freyberg"
cpth = workspace / "zbud6"
cpth.mkdir()

sim = flopy.mf6.MFSimulation.load(sim_ws=sim_ws, exe_name=mf6_exe)
sim.simulation_data.mfpath.set_sim_path(cpth)
sim.write_simulation()
success, buff = sim.run_simulation(silent=True, report=True)
assert success, "Failed to run"
for line in buff:
    print(line)
```

```
loading simulation...
  loading simulation name file...
  loading tdis package...
  loading model gwf6...
    loading package dis...
    loading package ic...
WARNING: Block "options" is not a valid block name for file type ic.
    loading package oc...
    loading package npf...
    loading package sto...
    loading package chd...
```

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```
    loading package riv...
    loading package wel...
    loading package rch...
  loading solution package freyberg...
WARNING: MFFileMgt's set_sim_path has been deprecated.  Please use MFSimulation's set_
↪sim_path in the future.
writing simulation...
  writing simulation name file...
  writing simulation tdis package...
  writing solution package freyberg...
  writing model freyberg...
    writing model name file...
    writing package dis...
    writing package ic...
    writing package oc...
    writing package npf...
    writing package sto...
    writing package chd-1...
    writing package riv-1...
    writing package wel-1...
    writing package rch-1...
                                   MODFLOW 6
                U.S. GEOLOGICAL SURVEY MODULAR HYDROLOGIC MODEL
                            VERSION 6.4.2 06/28/2023

   MODFLOW 6 compiled Jul 05 2023 20:29:14 with Intel(R) Fortran Intel(R) 64
   Compiler Classic for applications running on Intel(R) 64, Version 2021.7.0
                             Build 20220726_000000

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and distribution information.


 Run start date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:36:59

 Writing simulation list file: mfsim.lst
 Using Simulation name file: mfsim.nam

    Solving:  Stress period:     1    Time step:     1

 Run end date and time (yyyy/mm/dd hh:mm:ss): 2023/11/26  0:36:59
 Elapsed run time:  0.049 Seconds
```

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```
Normal termination of simulation.
```

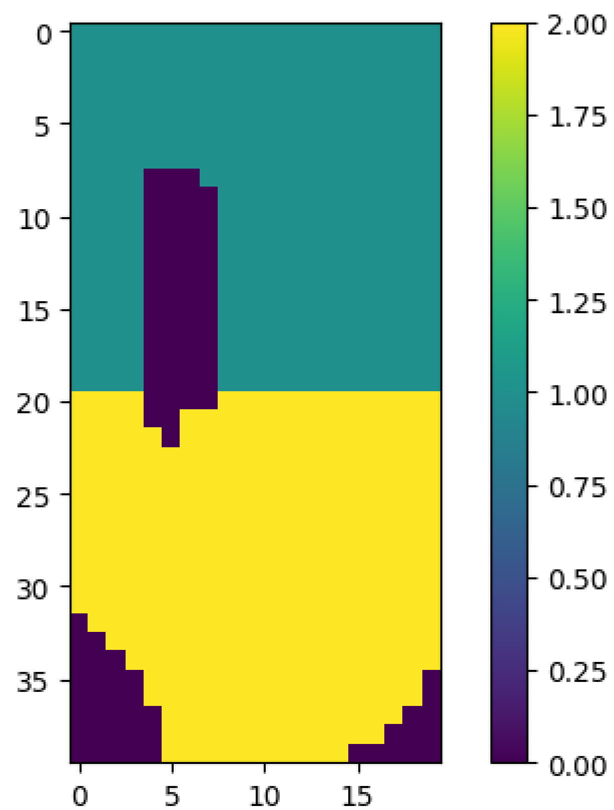
Use the the `.output` model attribute to create a zonebudget model

The .output attribute allows the user to access model output and create zonebudget models easily. The user only needs to pass in a zone array to create a zonebudget model!

[23]:
```
# let's get our idomain array from the model, split it into two zones, and use it as a␣
↪zone array
ml = sim.get_model("freyberg")
zones = ml.modelgrid.idomain
zones[0, 20:] = np.where(zones[0, 20:] != 0, 2, 0)

plt.imshow(zones[0])
plt.colorbar()
```

[23]:
```
<matplotlib.colorbar.Colorbar at 0x7f4e27591220>
```



[24]:
```
# now let's build a zonebudget model and run it!
zonbud = ml.output.zonebudget(zones)
zonbud.change_model_ws(cpth)
zonbud.write_input()
success, buff = zonbud.run_model(exe_name=zb6_exe, silent=True)
```

Getting the zonebudget output

We can then get the output as a recarray using the .get_budget() method or as a pandas dataframe using the .get_dataframes() method.

[25]:
```
zonbud.get_budget()
```

[25]:
```
rec.array([(10., 0, 0, 'STO_SS_IN', 0.        , 0.        ),
           (10., 0, 0, 'STO_SY_IN', 0.        , 0.        ),
           (10., 0, 0, 'DATA_SPDIS_IN', 0.        , 0.        ),
           (10., 0, 0, 'WEL_IN', 0.        , 0.        ),
           (10., 0, 0, 'RIV_IN', 0.00419403, 0.        ),
           (10., 0, 0, 'RCHA_IN', 0.0353    , 0.0342    ),
           (10., 0, 0, 'CHD_IN', 0.        , 0.00017814),
           (10., 0, 0, 'STO_SS_OUT', 0.        , 0.        ),
           (10., 0, 0, 'STO_SY_OUT', 0.        , 0.        ),
           (10., 0, 0, 'DATA_SPDIS_OUT', 0.        , 0.        ),
           (10., 0, 0, 'WEL_OUT', 0.0162    , 0.00585   ),
           (10., 0, 0, 'RIV_OUT', 0.02102198, 0.02637233),
           (10., 0, 0, 'RCHA_OUT', 0.        , 0.        ),
           (10., 0, 0, 'CHD_OUT', 0.        , 0.00442785),
           (10., 0, 0, 'FROM_ZONE_0', 0.        , 0.        ),
           (10., 0, 0, 'FROM_ZONE_1', 0.        , 0.00405829),
           (10., 0, 0, 'FROM_ZONE_2', 0.00178624, 0.        ),
           (10., 0, 0, 'TO_ZONE_0', 0.        , 0.        ),
           (10., 0, 0, 'TO_ZONE_1', 0.        , 0.00178624),
           (10., 0, 0, 'TO_ZONE_2', 0.00405829, 0.        )],
          dtype=[('totim', '<f8'), ('time_step', '<i8'), ('stress_period', '<i8'), ('name
↪', 'O'), ('ZONE_1', '<f8'), ('ZONE_2', '<f8')])
```

[26]:
```
# get the net flux using net=True flag
zonbud.get_dataframes(net=True)
```

[26]:
```
                    ZONE_1    ZONE_2
totim name
10.0  STO_SS      0.000000  0.000000
      STO_SY      0.000000  0.000000
      DATA_SPDIS  0.000000  0.000000
      WEL        -0.016200 -0.005850
      RIV        -0.016828 -0.026372
      RCHA        0.035300  0.034200
      CHD         0.000000 -0.004250
      ZONE_0      0.000000  0.000000
      ZONE_1      0.000000  0.002272
      ZONE_2     -0.002272  0.000000
```

[27]:
```
# we can also pivot the data into a spreadsheet like format
zonbud.get_dataframes(net=True, pivot=True)
```

[27]:
```
   totim  kper  kstp  zone      CHD  DATA_SPDIS    RCHA       RIV  STO_SS  \
0   10.0     0     0     1  0.00000         0.0  0.0353 -0.016828     0.0
1   10.0     0     0     2 -0.00425         0.0  0.0342 -0.026372     0.0

   STO_SY      WEL  ZONE_0    ZONE_1    ZONE_2
```

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```
0     0.0 -0.01620     0.0  0.000000 -0.002272
1     0.0 -0.00585     0.0  0.002272  0.000000
```

[28]:
```
# or get a volumetric budget by supplying modeltime
mt = ml.modeltime

# budget recarray must be pivoted to get volumetric budget!
zonbud.get_volumetric_budget(
    mt, recarray=zonbud.get_budget(net=True, pivot=True)
)
```

[28]:
```
   totim  kper  kstp  zone       CHD  DATA_SPDIS   RCHA       RIV  STO_SS  \
0   10.0     0     0     1  0.000000         0.0  0.353 -0.168280     0.0
1   10.0     0     0     2 -0.042497         0.0  0.342 -0.263723     0.0

   STO_SY     WEL  ZONE_0    ZONE_1    ZONE_2
0     0.0 -0.1620     0.0  0.000000 -0.022721
1     0.0 -0.0585     0.0  0.022721  0.000000
```

[29]:
```
try:
    # ignore PermissionError on Windows
    temp_dir.cleanup()
except:
    pass
```

CHAPTER

SEVEN

COMMAND LINE UTILITIES

The FloPy package installs several command-line utilities that can be used to help with installing MODFLOW 6 and other binaries, and regenerate FloPy class definitions for compatibility with MODFLOW 6.

7.1 Generating FloPy classes

- *Generating FloPy classes*
  - *Testing class generation*

MODFLOW 6 input continues to evolve as new models, packages, and options are developed, updated, and supported. All MODFLOW 6 input is described by DFN (definition) files, which are simple text files that describe the blocks and keywords in each input file. These definition files are used to build the input and output guide for MODFLOW 6. These definition files are also used to automatically generate FloPy classes for creating, reading and writing MODFLOW 6 models, packages, and options. FloPy and MODFLOW 6 are kept in sync by these DFN (definition) files, and therefore, it may be necessary for a user to update FloPy using a custom set of definition files, or a set of definition files from a previous release.

The FloPy classes for MODFLOW 6 are largely generated by a utility which converts DFN files in a modflow6 repository on GitHub or on the local machine into Python source files in your local FloPy install. For instance (output much abbreviated):

```
$ python -m flopy.mf6.utils.generate_classes



************************************************************************
Updating the flopy MODFLOW 6 classes
  Updating the MODFLOW 6 classes using MODFLOW-USGS/modflow6/master
  Downloading MODFLOW 6 repository from https://github.com/MODFLOW-USGS/modflow6/archive/
↪master.zip
Downloading https://github.com/MODFLOW-USGS/modflow6/archive/master.zip
   file size: 15,821,180 bytes

total download time: 0.88 seconds
Uncompressing: C:\Users\***\AppData\Local\Temp\***\master.zip
Deleting zipfile C:\Users\***\AppData\Local\Temp\***\master.zip
Done downloading and extracting master.zip to C:\Users\***\AppData\Local\Temp\***
```

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```
  Backup existing definition files in: C:\Users\***\flopy\flopy\mf6\data\dfn
  Replacing existing definition files with new ones.
  removing...common.dfn
  removing...exg-gwfgwf.dfn
  ...
  copying..common.dfn
  copying..exg-gwfgwf.dfn
  ...
  Deleting existing mf6 classes.
  removing...mfgnc.py
  removing...mfgwf.py
  ...
  Create mf6 classes using the downloaded definition files.
LIST OF FILES IN C:\Users\***\flopy\flopy\mf6\modflow
        1 - mfgnc.py
        2 - mfgwf.py
        ...
```

Similar functionality is available within Python, e.g.:

```
>>> from flopy.mf6.utils import generate_classes
>>> generate_classes()
```

The generate_classes() function has several optional parameters.

```
$ python -m flopy.mf6.utils.generate_classes -h
usage: generate_classes.py [-h] [--owner OWNER] [--repo REPO] [--ref REF]
                           [--dfnpath DFNPATH] [--no-backup]

Generate the MODFLOW 6 flopy classes using definition files from the MODFLOW 6
GitHub repository or a set of definition files in a folder provided by the
user.

options:
  -h, --help         show this help message and exit
  --owner OWNER      GitHub repository owner; default is 'MODFLOW-USGS'.
  --repo REPO        Name of GitHub repository; default is 'modflow6'.
  --ref REF          Branch name, tag, or commit hash to use to update the
                     definition; default is 'master'.
  --dfnpath DFNPATH  Path to a definition file folder that will be used to
                     generate the MODFLOW 6 classes.
  --no-backup        Set to disable backup. Default behavior is to keep a
                     backup of the definition files in dfn_backup with a date
                     and timestamp from when the definition files were
                     replaced.
```

For example, use the develop branch instead:

```
$ python -m flopy.mf6.utils.generate_classes --ref develop
```

use a fork of modflow6:

```
$ python -m flopy.mf6.utils.generate_classes --owner your-username --ref your-branch
```

maybe your fork has a different name:

```
$ python -m flopy.mf6.utils.generate_classes --owner your-username --repo your-modflow6 -
↪-ref your-branch
```

local copy of the repo:

```
$ python -m flopy.mf6.utils.generate_classes --dfnpath ../your/dfn/path
```

Branch names, commit hashes, or tags may be provided to ref.

By default, a backup is made of FloPy's package classes before rewriting them. To disable backups, use --no-backup from command-line, or backup=False with the Python function.

7.1.1 Testing class generation

Tests for the generate_classes() utility are located in test_generate_classes.py. The tests depend on virtualenv and will be skipped if run in parallel without the --dist loadfile option for pytest-xdist.

7.2 Install MODFLOW and related programs

- *Command-line interface*
  - *Using the get-modflow command*
  - Using get_modflow.py as a script
- *FloPy module*
- *Where to install?*
- *Selecting a distribution*

FloPy includes a get-modflow utility to install USGS MODFLOW and related programs for Windows, Mac or Linux. If FloPy is installed, the utility is available in the Python environment as a get-modflow command. The script flopy/utils/get_modflow.py has no dependencies and can be invoked independently.

The utility uses the GitHub releases API to download versioned archives containing executables compiled with Intel Fortran. The utility is able to match the binary archive to the operating system and extract the console programs to a user-defined directory. A prompt can also be used to help the user choose where to install programs.

7.2.1 Command-line interface

Using the get-modflow command

When FloPy is installed, a get-modflow (or get-modflow.exe for Windows) program is installed, which is usually installed to the PATH (depending on the Python setup). From a console:

```
$ get-modflow --help
usage: get-modflow [-h]
...
```

Using get_modflow.py as a script

The script requires Python 3.6 or later and does not have any dependencies, not even FloPy. It can be downloaded separately and used the same as the console program, except with a different invocation. For example:

```
$ wget https://raw.githubusercontent.com/modflowpy/flopy/develop/flopy/utils/get_modflow.
↪py
$ python3 get_modflow.py --help
usage: get_modflow.py [-h]
...
```

7.2.2 FloPy module

The same functionality of the command-line interface is available from the FloPy module, as demonstrated below:

```python
from pathlib import Path
import flopy

bindir = Path("/tmp/bin")
bindir.mkdir(exist_ok=True)
flopy.utils.get_modflow(bindir)
list(bindir.iterdir())

# Or use an auto-select option
flopy.utils.get_modflow(":flopy")
```

7.2.3 Where to install?

A required bindir parameter must be supplied to the utility, which specifies where to install the programs. This can be any existing directory, usually which is on the users' PATH environment variable.

To assist the user, special values can be specified starting with the colon character. Use a single : to interactively select an option of paths.

Other auto-select options are only available if the current user can write files (some may require sudo for Linux or macOS):

- :prev - if this utility was run by FloPy more than once, the first option will be the previously used bindir path selection
- :flopy - special option that will create and install programs for FloPy
- :python - use Python's bin (or Scripts) directory
- :home - use $HOME/.local/bin
- :system - use /usr/local/bin
- :windowsapps - use %LOCALAPPDATA%\Microsoft\WindowsApps

7.2.4 Selecting a distribution

By default the distribution from the MODFLOW-USGS/executables repository is installed. This includes the MODFLOW 6 binary mf6 and over 20 other related programs. The utility can also install from the main MODFLOW 6 repo or the nightly build distributions, which contain only:

- mf6
- mf5to6
- zbud6
- libmf6.dylib

To select a distribution, specify a repository name with the --repo command line option or the repo function argument. Valid names are:

- executables (default)
- modflow6
- modflow6-nightly-build

The repository owner can also be configured with the --owner option. This can be useful for installing from unreleased MODFLOW 6 feature branches still in development - the only compatibility requirement is that release assets be named identically to those on the official repositories.

CHAPTER

EIGHT

FREQUENTLY ASKED QUESTIONS

8.1 Executable does not exist

One common error is missing executables. FloPy can drive MODFLOW and a number of related progams. In order for you to run a model you have created or loaded using FloPy, the desired executable must be available in your path. Executable paths must either be provided explicitly, or if an executable name is provided, the binary must be on the system path.

You can test if the executable is available using the *which* function. For example, to test if the *mf2005* executable is available in your path, use:

```
flopy.which("mf2005")  # equivalent to shutil.which("mf2005")
```

If the executable is found, its path is returned, otherwise the function returns an empty string. If you receive the latter, you should:

1. Check the that you have spelled the executable correctly.
2. If you have spelled the executable correctly then you need to move the executable into your working directory or into a directory in your path.
3. **If you have spelled the executable correctly but don't have the executable. Your options are:**
    - Download a precompiled version of the executable. Precompiled versions of MODFLOW-based codes are available from the U.S. Geological Survey for the Windows operating system.
    - Compile the source code (available from the U.S. Geological Survey) for the Windows, OS X, Linux, and UNIX operating systems and place the compiled executable in the working directory or a directory contained in your path (for example, */Users/jdhughes/.local/bin/* as indicated above).

You can get a list of the directories in your system path using:

```
os.getenv("PATH")
```

There is a *get-modflow* command line utility that can be used to download MODFLOW executables. See the get-modflow documentation for more information.

CHAPTER

NINE

FLOPY MODEL CHECKS

- *FloPy Model Checks*
- List of available FloPy model checks
- *Visualizations*
- *Additional model checks and visualizations*

9.1 Available model checks

Package	Check	Implemented	Typ
NAM	unit number conflicts	Supported	Erro
NAM	compatible solver package	Supported	Erro
NAM	minimum packages needed to run the model	Not supported	Erro
all BC packages	overlapping boundary conditions	Not supported	Erro
all BC packages	NaN values in stress_period_data	Supported	Erro
all BC packages	valid indices for stress_period_data	Supported	Erro
LPF/UPW	hk or vka <=0	Supported	Erro
LPF/UPW	hani < 0	Supported	Erro
LPF/UPW	vkcb (quasi-3D kv values) <=0	Supported	Erro
LPF/UPW	unusually high or low values in hk and vka arrays	Supported	Warn
LPF/UPW	unusually high or low values in vkcb (quasi-3D kv values)	Supported	Warn
LPF/UPW	storage values <=0 (transient only)	Supported	Erro
LPF/UPW	unusual values of storage (transient only)	Supported	Erro
RIV/SFR/STR	check for surface water BCs in confined layers	Not supported	Warn
BAS	isolated cells	Supported	Warn
BAS	NaN values	Supported	Erro
DIS	cell thicknesses <= 0	Supported	Erro
DIS	cell thicknesses < thin_cell_threshold (default 1.0)	Supported	Warn
DIS	NaN values in top and bottom arrays	Supported	Erro
DIS	discretization that violates the 1.5 rule	Not supported	Warn
DIS	large changes in elevation	Not supported	Warn
DISU	large changes in elevation	Not supported	Warn
DISU	cell thicknesses <= 0	Not supported	Erro
DISU	cell thicknesses < thin_cell_threshold (default 1.0)	Not supported	Warn
DISU	NaN values in top and bottom arrays	Not supported	Erro
DISU	discretization that violates the 1.5 rule	Not supported	Warn
DISU	large changes in elevation	Not supported	Warn
MNW2	ITMP >= 0 for first stress period	Supported	Erro

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Table 1 – continued from previous page

Package	Check	Implemented	Typ
MNW2	ITMP > MNWMAX	Supported	Erro
MNWI	MNWI present without MNW2 package	Supported	Warn
RCH	unusually high or low R/T ratios	Supported	Warn
RCH	NRCHOP not specified as 3	Supported	Warn
SFR	continuity in segment and reach numbering	Supported	Erro
SFR	segment number decreases in downstream direction	Supported	Warn
SFR	circular routing	Supported	Erro
SFR	multiple non-zero conductances in a model cell	Supported	Warn
SFR	elevation increases in the downstream direction	Supported	Erro
SFR	streambed elevations above model top	Supported	Warn
SFR	streambed elevations below cell bottom	Supported	Erro
SFR	negative stream depth when icalc=0	Not supported	Erro
SFR	slopes above or below specified threshold	Supported	Warn
SFR	unusual values for manning's roughness and unit constant	Not supported	Warn
SFR	gaps in segment and reach routing	Not supported	Warn
SFR	outlets in interior of model domain	Not supported	Warn
WEL	PHIRAMP is < 1 and should be close to recommended value of 0.001	Not supported	Warn
MPSIM	invalid stop times	Supported	

9.2 Visualizations

Package	Check	Implemented	Type
All	Shapefile with detected errors	Not supported	Information
All	Shapefile with detected warnings	Not supported	Information
SFR/STR	Segment Connectivity	Not supported	Information
SFR/STR	Identification of diversions	Not supported	Information
SFR/STR	Identification of outlet tributaries	Not supported	Information

9.3 Additional model checks and visualizations

Please submit additional proposed model checks as issues on the FloPy development branch on github.

CHAPTER

TEN

OPTIONAL DEPENDENCIES

Additional dependencies to use optional FloPy helper methods are listed below. These may be installed with pip install flopy[optional].

Method	Python Package
.plot_shapefile()	**Pyshp** >= 2.0.0
.to_shapefile()	**Pyshp** >= 2.0.0
.export(*.shp)	**Pyshp** >= 2.0.0
.export(*.nc)	**netcdf4** >= 1.1, and **python-dateutil** >= 2.4.0
.export(*.tif)	**rasterio**
.export_array(*.asc) in flopy.export.utils	**scipy.ndimage**
.resample_to_grid() in flopy.utils.rasters	**scipy.interpolate**
.interpolate() in flopy.mf6.utils.reference StructuredSpatialReference class	**scipy.interpolate**
.get_authority_crs() in flopy.utils.crs	**pyproj** >= 2.2.0
.generate_classes() in flopy.mf6.utils	modflow-devtools
GridIntersect() in flopy.utils.gridintersect	**shapely**
GridIntersect().plot_polygon() in flopy.utils.gridintersect	**shapely** and **descartes**
Raster() in flopy.utils.Raster	**rasterio**, **rasterstats**, **affine**, and **scipy**
Raster().sample_polygon() in flopy.utils.Raster	**shapely**
Raster().crop() in flopy.utils.Raster	**shapely**
.array_at_verts() in flopy.discretization.structuredgrid StructuredGrid class	**scipy.interpolate**
get_sciencebase_xml_metadata() in flopy.export.metadata acdd class	**defusedxml**
flopy.utils.geospatial_utils GeoSpatialUtil class	**geojson**
flopy.utils.geospatial_utils GeoSpatialCollection class	**geojson**
flopy.export.vtk Vtk class	**vtk**, optionally **pyvista**

CHAPTER

ELEVEN

CHANGELOG

11.1 Version 3.5.0

11.1.1 New features

- feat(simulation+model options): Dynamically generate simulation options from simulation namefile dfn (#1842). Committed by spaulins-usgs on 2023-07-10.
- feat(binaryfile): Add reverse() method to HeadFile, CellBudgetFile (#1829). Committed by w-bonelli on 2023-07-29.
- feat(get-modflow): Allow specifying repo owner (#1910). Committed by w-bonelli on 2023-08-08.
- feat(generate_classes): Create a command-line interface (#1912). Committed by Mike Taves on 2023-08-16.
- feat(gridutil): Add function to help create DISV grid (#1952). Committed by langevin-usgs on 2023-09-18.
- feat(pandas list): Fix for handling special case where boundname set but not used (#1982). Committed by scottrp on 2023-10-06.
- feat(MfSimulationList): Add functionality to parse the mfsim.lst file (#2005). Committed by jdhughes-usgs on 2023-11-14.
- feat(modflow): Support dataframe for pkg data (#2010). Committed by wpbonelli on 2023-11-22.
- feat(mfsimlist): Add functionality to parse memory_print_options (#2009). Committed by jdhughes-usgs on 2023-11-22.

11.1.2 Bug fixes

- fix(exchange and gnc package cellids): #1866 (#1871). Committed by spaulins-usgs on 2023-07-11.
- fix(modelgrid): Retain crs data from classic nam files (#1904). Committed by Mike Taves on 2023-08-10.
- fix(generate_classes): Use branch arg if provided (#1938). Committed by w-bonelli on 2023-08-31.
- fix(remove_model): Remove_model method fix and tests (#1945). Committed by scottrp on 2023-09-14.

- fix(model_splitter.py): Standardizing naming of iuzno, rno, lakeno, & wellno to ifno (#1963). Committed by Eric Morway on 2023-09-25.
- fix(pandas list): Deal with cellids with inconsistent types (#1980). Committed by scottrp on 2023-10-06.
- fix(model_splitter): Check keys in mftransient array (#1998). Committed by jdhughes-usgs on 2023-11-13.
- fix(benchmarks): Fix benchmark post-processing (#2004). Committed by wpbonelli on 2023-11-14.
- fix(MfSimulationList): Add missing seek to get_runtime method (#2006). Committed by mjr-deltares on 2023-11-15.
- fix(get_disu_kwargs): Incorrect indexing of delr and delc (#2011). Committed by langevin-usgs on 2023-11-21.
- fix(PlotCrossSection): Boundary conditions not plotting for DISU (#2012). Committed by langevin-usgs on 2023-11-21.
- fix(release.yml): Don't regenerate pkgs from mf6 main on release (#2014). Committed by wpbonelli on 2023-11-24.
- fix(release.yml): Fix update changelog step (#2015). Committed by wpbonelli on 2023-11-25.

11.1.3 Refactoring

- refactor(_set_neighbors): Check for closed iverts and remove closing ivert (#1876). Committed by Joshua Larsen on 2023-07-14.
- refactor(crs): Provide support without pyproj, other deprecations (#1850). Committed by Mike Taves on 2023-07-19.
- refactor(Notebooks): Apply pyformat and black QA tools (#1879). Committed by Mike Taves on 2023-07-24.
- refactor: Require pandas>=2.0.0 as core dependency (#1887). Committed by w-bonelli on 2023-08-01.
- refactor(expired deprecation): Raise AttributeError with Grid.thick and Grid.saturated_thick (#1884). Committed by Mike Taves on 2023-08-01.
- refactor(pathline/endpoint plots): Support recarray or dataframe (#1888). Committed by w-bonelli on 2023-08-01.
- refactor(expired deprecation): Remove warning for third parameter of Grid.intersect (#1883). Committed by Mike Taves on 2023-08-01.
- refactor(dependencies): Constrain sphinx >=4 (#1898). Committed by w-bonelli on 2023-08-02.
- refactor(dependencies): Constrain sphinx-rtd-theme >=1 (#1900). Committed by w-bonelli on 2023-08-03.
- refactor(mf6): Remove deprecated features (#1894). Committed by w-bonelli on 2023-08-03.
- refactor(plotutil): Remove deprecated utilities (#1891). Committed by w-bonelli on 2023-08-03.

- refactor(shapefile_utils): Remove deprecated SpatialReference usages (#1892). Committed by w-bonelli on 2023-08-03.
- refactor(vtk): Remove deprecated export_* functions (#1890). Committed by w-bonelli on 2023-08-03.
- refactor(generate_classes): Deprecate branch for ref, introduce repo, test commit hashes (#1907). Committed by w-bonelli on 2023-08-09.
- refactor(expired deprecation): Remaining references to SpatialReference (#1914). Committed by Mike Taves on 2023-08-11.
- refactor(Mf6Splitter): Control record and additional splitting checks (#1919). Committed by Joshua Larsen on 2023-08-21.
- refactor(triangle): Raise if output files not found (#1954). Committed by wpbonelli on 2023-09-22.
- refactor(recarray_utils): Deprecate functions, use numpy builtins (#1960). Committed by wpbonelli on 2023-09-27.
- refactor(contour_array): Add layer param, update docstrings, expand tests (#1975). Committed by wpbonelli on 2023-10-18.
- refactor(model_splitter.py): (#1994). Committed by Joshua Larsen on 2023-11-01.
- refactor(modflow): Remove deprecated features (#1893). Committed by wpbonelli on 2023-11-03.
- refactor: Support python3.12, simplify tests and dependencies (#1999). Committed by wpbonelli on 2023-11-13.
- refactor(msfsr2): Write sfr_botm_conflicts.chk to model workspace (#2002). Committed by wpbonelli on 2023-11-14.
- refactor(shapefile_utils): Warn if fieldname truncated per 10 char limit (#2003). Committed by wpbonelli on 2023-11-14.
- refactor(pakbase): Standardize ipakcb docstrings/defaults (#2001). Committed by wpbonelli on 2023-11-22.
- refactor(.gitattributes): Exclude examples/data from linguist (#2017). Committed by wpbonelli on 2023-11-25.

11.2 Version 3.4.3

11.2.1 Bug fixes

- fix(export_contours/f): Support matplotlib 3.8+ (#1951). Committed by wpbonelli on 2023-09-19.
- fix(usg bcf): ksat util3d call -> util2d call (#1959). Committed by @cnicol-gwlogic on 2023-09-22.
- fix(resolve_exe): Support extensionless abs/rel paths on windows (#1957). Committed by wpbonelli on 2023-09-24.
- fix(mbase): Warn if duplicate pkgs or units (#1964). Committed by wpbonelli on 2023-09-26.

- fix(get_structured_faceflows): Cover edge cases, expand tests (#1968). Committed by wpbonelli on 2023-09-29.
- fix(CellBudgetFile): Detect compact fmt by negative nlay (#1966). Committed by wpbonelli on 2023-09-30.

11.3 Version 3.4.2

11.3.1 Bug fixes

- fix(binaryfile/gridutil): Avoid numpy deprecation warnings (#1868). Committed by w-bonelli on 2023-07-12.
- fix(binary): Fix binary header information (#1877). Committed by jdhughes-usgs on 2023-07-16.
- fix(time series): Fix for multiple time series attached to single package (#1867) (#1873). Committed by spaulins-usgs on 2023-07-20.
- fix(check): Check now works properly with confined conditions (#1880) (#1882). Committed by spaulins-usgs on 2023-07-27.
- fix(mtlistfile): Fix reading MT3D budget (#1899). Committed by Ralf Junghanns on 2023-08-03.
- fix(check): Updated flopy's check to work with cellid -1 values (#1885). Committed by spaulins-usgs on 2023-08-06.
- fix(BaseModel): Don't suppress error if exe not found (#1901). Committed by w-bonelli on 2023-08-07.
- fix(keyword data): Optional keywords (#1920). Committed by spaulins-usgs on 2023-08-16.
- fix(GridIntersect): Combine list of geometries using unary_union (#1923). Committed by Mike Taves on 2023-08-21.
- fix(gridintersect): Add multilinestring tests (#1924). Committed by Davíd Brakenhoff on 2023-08-21.
- fix(binary file): Was writing binary file information twice to external files (#1925) (#1928). Committed by scottrp on 2023-08-25.
- fix(ParticleData): Fix docstring, structured default is False (#1935). Committed by w-bonelli on 2023-08-25.

11.3.2 Refactoring

- refactor(_set_neighbors): Check for closed iverts and remove closing ivert (#1876). Committed by Joshua Larsen on 2023-07-14.
- refactor(dependencies): Constrain sphinx >=4 (#1898). Committed by w-bonelli on 2023-08-02.
- refactor(dependencies): Constrain sphinx-rtd-theme >=1 (#1900). Committed by w-bonelli on 2023-08-03.

11.4 Version 3.4.1

11.4.1 Bug fixes

- fix(get-modflow): Accommodate mf6 release asset name change (#1855). Committed by w-bonelli on 2023-06-29.

11.5 Version 3.4.0

11.5.1 New features

- feat(Simulation): Support pathlike (#1712). Committed by aleaf on 2023-02-13.
- feat(solvers): Support for multiple solver types (#1706) (#1709). Committed by spaulins-usgs on 2023-02-15.
- feat(pathlike): Support pathlike in user-facing APIs (#1730). Committed by w-bonelli on 2023-03-03.
- feat(export): Include particle track polylines in VTK exports (#1750). Committed by w-bonelli on 2023-04-19.
- feat(crs): Pyproj crs (#1737). Committed by aleaf on 2023-04-26.
- feat(vtk): Add to_pyvista() method (#1771). Committed by w-bonelli on 2023-04-30.
- feat(run_simulation): Add support for running parallel simulations with flopy (#1807). Committed by jdhughes-usgs on 2023-06-05.
- feat(model_splitter.py): Integrate model_splitter.py into FloPy (#1799). Committed by Joshua Larsen on 2023-06-05.
- feat(model_splitter): Add optional pymetis dependency (#1812). Committed by jdhughes-usgs on 2023-06-06.
- feat(model_splitter): Add support for models that do not use IDOMAIN (#1834). Committed by jdhughes-usgs on 2023-06-21.
- feat(generate_classes): Add optional owner param (#1833). Committed by w-bonelli on 2023-06-21.

11.5.2 Bug fixes

- fix(MFPackage kwargs check): Now verifying that only valid kwargs are passed to MFPackage (#1667). Committed by spaulins-usgs on 2022-12-22.
- fix(factor): Fixed factor bug where converting data from internal to external can cause the factor to be applied to the data (#1673). Committed by scottrp on 2023-01-09.
- fix(package dictionary): Removed package_key_dict since it is redundant and can cause errors (#1690). Committed by spaulins-usgs on 2023-01-26.
- fix(intersect): Multiple (#1696). Committed by w-bonelli on 2023-01-31.
- fix(datautil): Fix SFR connection file parsing (#1694). Committed by Wes Kitlasten on 2023-02-03.

- fix(CellBudgetFile): Strip auxname for imeth 5 (#1716). Committed by Mike Taves on 2023-02-13.
- fix(mfdatastorage): Use appropriate fill_value for data type (#1689). Committed by Mike Taves on 2023-02-13.
- fix(test_sfr): Update test to be more robust with Matplotlib versions (#1717). Committed by Mike Taves on 2023-02-14.
- fix(flopy performance): FloPy performance modifications + best practices documented (#1674). Committed by spaulins-usgs on 2023-02-15.
- fix(exe path): FloPy now correctly resolves relative paths to mf6 executable (#1633) (#1727). Committed by spaulins-usgs on 2023-03-02.
- fix(ParticleData): Support partlocs as ndarray or list of lists (#1752). Committed by w-bonelli on 2023-03-23.
- fix(mp6sim): Use keyword args for pandas DataFrame.drop (#1757). Committed by w-bonelli on 2023-04-06.
- fix(MFFileMgmt): Remove string_to_file_path (#1759). Committed by w-bonelli on 2023-04-06.
- fix(contours): Use nan for mpl contour masks on structured grids (#1766). Committed by w-bonelli on 2023-04-14.
- fix(MFFileMgmt): Avoid IndexError in strip_model_relative_path (#1748). Committed by w-bonelli on 2023-04-27.
- fix(mtdsp): Add support for keyword 'nocross' in MT3D dsp package (#1778). Committed by Eric Morway on 2023-05-09.
- fix(shapefile_utils): Tolerate missing arrays in model_attributes_to_shapefile (#1785). Committed by w-bonelli on 2023-05-17.
- fix(Modpath6Sim): Move import_optional_dependency("pandas") to method (#1783). Committed by Mike Taves on 2023-05-17.
- fix(float32, empty stress period): #1779 and #1793 (#1806). Committed by spaulins-usgs on 2023-06-02.
- fix(load_node_mapping): Add sim parameter to populate Mf6Splitter._model_dict (#1828). Committed by Joshua Larsen on 2023-06-13.
- fix(keystring): Flopy now does not rely on keystring name being a substring of the keystring record name (#1616) (#1830). Committed by spaulins-usgs on 2023-06-15.
- fix(get-modflow): Manage internal "bin" dir structures (#1837). Committed by Mike Taves on 2023-06-23.
- fix(GridIntersect): Fix indexing error for empty intersection comparison (#1838). Committed by Joshua Larsen on 2023-06-23.
- fix(mf6): Fix external binary files for vertex grids (#1839). Committed by jdhughes-usgs on 2023-06-26.
- fix(binary): Revert a few changes in PR #1839 (#1846). Committed by jdhughes-usgs on 2023-06-28.

11.5.3 Perf

- perf(Gridintersect): Optimize intersection methods for shapely 2.0 (#1666). Committed by Davíd Brakenhoff on 2022-12-23.

11.5.4 Refactoring

- refactor(tests): Use modflow-devtools fixtures and utilities (#1665). Committed by w-bonelli on 2022-12-20.
- refactor(utils): Move utils from modflow-devtools (#1621). Committed by w-bonelli on 2022-12-20.
- refactor: Drop Python 3.7, add Python 3.11 (#1662). Committed by Mike Taves on 2022-12-21.
- refactor(dependencies): Use devtools & relocated utils, drop pymake (#1670). Committed by w-bonelli on 2022-12-24.
- refactor: Move project metadata to pyproject.toml (#1678). Committed by Mike Taves on 2023-01-18.
- refactor(Modpath7): Update path construction for modpath nam file (#1679). Committed by Joshua Larsen on 2023-01-20.
- refactor(styles): Add graph_legend fontsize parameters (#1702). Committed by Joshua Larsen on 2023-02-07.
- refactor: Run pyupgrade and adjust a few f-strings (#1710). Committed by Mike Taves on 2023-02-14.
- refactor(MfGrdFile): Update docstrings in MfGrdFile (#1685). Committed by Joshua Larsen on 2023-02-16.
- refactor(notebooks, mfhob.py): Clean paths in jupyter notebooks (#1711). Committed by Joshua Larsen on 2023-02-16.
- refactor(grid.py): Add size property for model splitting support (#1720). Committed by Joshua Larsen on 2023-02-19.
- refactor(flopy_io, notebooks): Update path cleaning mechanism (#1728). Committed by w-bonelli on 2023-02-24.
- refactor(PlotMapView): Support color kwarg in plot_endpoint() (#1745). Committed by w-bonelli on 2023-03-21.
- refactor(Grid): Refactor thick and saturated_thick: (#1768). Committed by Joshua Larsen on 2023-04-15.
- refactor(neighbors): Overhaul of neighbors calculation (#1787). Committed by Joshua Larsen on 2023-05-19.
- refactor(triangle-gridgen): Refactor resolving triangle and gridgen exe (#1819). Committed by jdhughes-usgs on 2023-06-08.
- refactor(get-modflow): Use Path.replace instead of Path.rename (#1822). Committed by w-bonelli on 2023-06-08.
- refactor(Mf6Splitter): Feature updates and bugfixes (#1821). Committed by Joshua Larsen on 2023-06-10.

11.6 Version 3.3.6

11.6.1 New features

- feat(time step length): Added feature that returns time step lengths from listing file (#1435) (#1437). Committed by scottrp on 2022-06-30.
- feat: Get modflow utility (#1465). Committed by Mike Taves on 2022-07-27.
- feat(Gridintersect): New grid intersection options (#1468). Committed by Davíd Brakenhoff on 2022-07-27.
- feat: Unstructured grid from specification file (#1524). Committed by w-bonelli on 2022-09-08.
- feat(aux variable checking): Check now performs aux variable checking (#1399) (#1536). Committed by spaulins-usgs on 2022-09-12.
- feat(get/set data record): Updated get_data/set_data functionality and new get_record/set_record methods (#1568). Committed by spaulins-usgs on 2022-10-06.
- feat(get_modflow): Support modflow6 repo releases (#1573). Committed by w-bonelli on 2022-10-11.
- feat(contours): Use standard matplotlib contours for StructuredGrid map view plots (#1615). Committed by w-bonelli on 2022-11-10.

11.6.2 Bug fixes

- fix(geometry): Is_clockwise() now works as expected for a disv problem (#1374). Committed by Eric Morway on 2022-03-16.
- fix(packaging): Include pyproject.toml to sdist, check package for PyPI (#1373). Committed by Mike Taves on 2022-03-21.
- fix(url): Use modern DOI and USGS prefixes; upgrade other HTTP->HTTPS (#1381). Committed by Mike Taves on 2022-03-23.
- fix(packaging): Add docs/*.md to MANIFEST.in for sdist (#1391). Committed by Mike Taves on 2022-04-01.
- fix(_plot_transient2d_helper): Fix filename construction for saving plots (#1388). Committed by Joshua Larsen on 2022-04-01.
- fix(simulation packages): *** Breaks interface *** (#1394). Committed by spaulins-usgs on 2022-04-19.
- fix(plot_pathline): Split recarray into particle list when it contains multiple particle ids (#1400). Committed by Joshua Larsen on 2022-04-30.
- fix(lgrutil): Child delr/delc not correct if parent has variable row/col spacings (#1403). Committed by langevin-usgs on 2022-05-03.
- fix(ModflowUzf1): Fix for loading negative iuzfopt (#1408). Committed by Joshua Larsen on 2022-05-06.
- fix(features_to_shapefile): Fix missing bracket around linestring for shapefile (#1410). Committed by Joshua Larsen on 2022-05-06.
- fix(mp7): Ensure shape in variables 'zones' and 'retardation' is 3d (#1415). Committed by Ruben Caljé on 2022-05-11.

- fix(ModflowUzf1): Update load for iuzfopt = -1 (#1416). Committed by Joshua Larsen on 2022-05-17.
- fix(recursion): Infinite recursion fix for **getattr**. Spelling error fix in notebook. (#1414). Committed by scottrp on 2022-05-19.
- fix(get_structured_faceflows): Fix index issue in lower right cell (#1417). Committed by jdhughes-usgs on 2022-05-19.
- fix(package paths): Fixed auto-generated package paths to make them unique (#1401) (#1425). Committed by spaulins-usgs on 2022-05-31.
- fix(get-modflow/ci): Use GITHUB_TOKEN to side-step ratelimit (#1473). Committed by Mike Taves on 2022-07-29.
- fix(get-modflow/ci): Handle 404 error to retry request from GitHub (#1480). Committed by Mike Taves on 2022-08-04.
- fix(intersect): Update to raise error only when interface is called improperly (#1489). Committed by Joshua Larsen on 2022-08-11.
- fix(GridIntersect): Fix DeprecationWarnings for Shapely2.0 (#1504). Committed by Davíd Brakenhoff on 2022-08-19.
- fix: CI, tests & modpathfile (#1495). Committed by w-bonelli on 2022-08-22.
- fix(HeadUFile): Fix #1503 (#1510). Committed by w-bonelli on 2022-08-26.
- fix(setuptools): Only include flopy and flopy.* packages (not autotest) (#1529). Committed by Mike Taves on 2022-09-01.
- fix(mfpackage): Modify maxbound evaluation (#1530). Committed by jdhughes-usgs on 2022-09-02.
- fix(PlotCrossSection): Update number of points check (#1533). Committed by Joshua Larsen on 2022-09-08.
- fix(parsenamefile): Only do lowercase comparison when parent dir exists (#1554). Committed by Mike Taves on 2022-09-22.
- fix(obs): Modify observations to load single time step files (#1559). Committed by jdhughes-usgs on 2022-09-29.
- fix(PlotMapView notebook): Remove exact contour count assertion (#1564). Committed by w-bonelli on 2022-10-03.
- fix(test markers): Add missing markers for exes required (#1577). Committed by w-bonelli on 2022-10-07.
- fix(csvfile): Default csvfile to retain all characters in column names (#1587). Committed by langevin-usgs on 2022-10-14.
- fix(csvfile): Correction to read_csv args, close file handle (#1590). Committed by Mike Taves on 2022-10-16.
- fix(data shape): Fixed incorrect data shape for sfacrecord (#1584). Fixed a case where time array series data did not load correctly from a file when the data shape could not be determined (#1594). (#1598). Committed by spaulins-usgs on 2022-10-21.
- fix(write_shapefile): Fix transform call for exporting (#1608). Committed by Joshua Larsen on 2022-10-27.

- fix(multiple): Miscellanous fixes/enhancements (#1614). Committed by w-bonelli on 2022-11-03.
- fix: Not reading comma separated data correctly (#1634). Committed by Michael Ou on 2022-11-23.
- fix(get-modflow): Fix code.json handling (#1641). Committed by w-bonelli on 2022-12-08.
- fix(quotes+exe_path+nam_file): Fixes for quoted strings, exe path, and nam file (#1645). Committed by spaulins-usgs on 2022-12-08.

11.6.3 Refactoring

- refactor(vtk): Iverts compatibility updates for vtk (#1378). Committed by Joshua Larsen on 2022-03-19.
- refactor(Raster): Added "mode" resampling to resample_to_grid (#1390). Committed by Joshua Larsen on 2022-04-01.
- refactor(utils): Updates to zonbudget and get_specific_discharge (#1457). Committed by Joshua Larsen on 2022-07-20.
- refactor(line_intersect_grid, PlotCrossSection): Fix cell artifact and collinear issues (#1505). Committed by Joshua Larsen on 2022-08-19.
- refactor(get-modflow): Add option to have flopy bindir on PATH (#1511). Committed by Mike Taves on 2022-08-29.
- refactor(shapefile_utils): Remove appdirs dependency (#1523). Committed by Mike Taves on 2022-08-30.
- refactor(export_contours): (#1528). Committed by w-bonelli on 2022-09-01.
- refactor(CrossSectionPlot, GeoSpatialUtil): (#1521). Committed by w-bonelli on 2022-09-02.
- refactor(get_lni): Simplify get_lni signature & behavior (#1520). Committed by w-bonelli on 2022-09-02.
- refactor(make-release): Use CITATION.cff for author metadata (#1547). Committed by Mike Taves on 2022-09-19.
- refactor(exe_name): Remove unnecessary ".exe" suffix (#1563). Committed by Mike Taves on 2022-09-30.
- refactor(contour_array): Added routine to mask errant triangles (#1562). Committed by Joshua Larsen on 2022-10-02.
- refactor(GeoSpatialCollection, Gridgen): Added support for lists of shapely objects (#1565). Committed by Joshua Larsen on 2022-10-05.
- refactor(rasters.py, map.py): Speed improvement updates for resample_to_grid() (#1571). Committed by Joshua Larsen on 2022-10-07.
- refactor(shapefile_utils): Pathlib compatibility, other improvements (#1583). Committed by Mike Taves on 2022-10-13.
- refactor(tests): Simplify test utilities per convention that tests are run from autotest folder (#1586). Committed by w-bonelli on 2022-10-14.
- refactor(gridintersect): Faster **init** and better shapely 2.0 compat (#1593). Committed by Mike Taves on 2022-10-19.

- refactor(get_lrc, get_node): Use numpy methods, add examples (#1591). Committed by Mike Taves on 2022-10-19.
- refactor(vtk): Updates for errant interpolation in point_scalar routines (#1601). Committed by Joshua Larsen on 2022-10-21.
- refactor(docs/examples): Correction to authors, use Path.cwd() (#1602). Committed by Mike Taves on 2022-10-26.
- refactor(vtk): Use pathlib, corrections to docstrings (#1603). Committed by Mike Taves on 2022-10-26.
- refactor(docs): Add ORCID icon and link to authors (#1606). Committed by Mike Taves on 2022-10-27.
- refactor(plotting): Added default masked values (#1610). Committed by Joshua Larsen on 2022-10-31.

11.7 Version 3.3.5

11.7.1 New features

- feat(mvt): Add simulation-level support for mover transport (#1357). Committed by langevin-usgs on 2022-02-18.
- feat(gwtgwt-mvt): Add support for gwt-gwt with mover transport (#1356). Committed by langevin-usgs on 2022-02-18.
- feat(inspect cells): New feature that returns model data associated with specified model cells (#1140) (#1325). Committed by spaulins-usgs on 2022-01-11.
- feat(multiple package instances): Flopy support for multiple instances of the same package stored in dfn files (#1239) (#1321). Committed by spaulins-usgs on 2022-01-07.
- feat(Gridintersect): Add shapetype kwarg (#1301). Committed by Davíd Brakenhoff on 2021-12-03.
- feat(get_ts): Added support to get_ts for headufile (#1260). Committed by Ross Kushnereit on 2021-10-09.
- feat(CellBudget): Add support for full3d keyword (#1254). Committed by jdhughes-usgs on 2021-10-05.
- feat(mf6): Allow multi-package for stress package concentrations (spc) (#1242). Committed by langevin-usgs on 2021-09-16.
- feat(lak6): Support none lake bedleak values (#1189). Committed by jdhughes-usgs on 2021-08-16.

11.7.2 Bug fixes

- fix(exchange obs): Fixed building of obs package for exchange packages (through mfsimulation) (#1363). Committed by spaulins-usgs on 2022-02-28.
- fix(tab files): Fixed searching for tab file packages (#1337) (#1344). Committed by scottrp on 2022-02-16.
- fix(ModflowUtllaktab): Utl-lak-tab.dfn is redundant to utl-laktab.dfn (#1339). Committed by Mike Taves on 2022-01-27.
- fix(cellid): Fixes some issues with flopy properly identifying cell ids (#1335) (#1336). Committed by spaulins-usgs on 2022-01-25.
- fix(postprocessing): Get_structured_faceflows fix to support 3d models (#1333). Committed by langevin-usgs on 2022-01-21.
- fix(Raster): Resample_to_grid failure no data masking failure with int dtype (#1328). Committed by Joshua Larsen on 2022-01-21.
- fix(voronoi): Clean up voronoi examples and add error check (#1323). Committed by langevin-usgs on 2022-01-03.
- fix(filenames): Fixed how spaces in filenames are handled (#1236) (#1318). Committed by spaulins-usgs on 2021-12-16.
- fix(paths): Path code made more robust so that non-standard model folder structures are supported (#1311) (#1316). Committed by scottrp on 2021-12-09.
- fix(UnstructuredGrid): Load vertices for unstructured grids (#1312). Committed by Chris Nicol on 2021-12-09.
- fix(array): Getting array data (#1028) (#1290). Committed by spaulins-usgs on 2021-12-03.
- fix(plot_pathline): Sort projected pathline points by travel time instead of cell order (#1304). Committed by Joshua Larsen on 2021-12-03.
- fix(autotests): Added pytest.ini to declare test naming convention (#1307). Committed by Joshua Larsen on 2021-12-03.
- fix(geospatial_utils.py): Added pyshp and shapely imports check to geospatial_utils.py (#1305). Committed by Joshua Larsen on 2021-12-03.
- fix(path): Fix subdirectory path issues (#1298). Committed by Brioch Hemmings on 2021-11-18.
- fix(): fix(mfusg/str) (#1296). Committed by Chris Nicol on 2021-11-11.
- fix(io): Read comma separated list (#1285). Committed by Michael Ou on 2021-11-02.
- fixes(1247): Make flopy buildable with pyinstaller (#1248). Committed by Tim Mitchell on 2021-10-20.
- fix(keystring records): Fixed problem with keystring records containing multiple keywords (#1266). Committed by spaulins-usgs on 2021-10-15.
- fix(ModflowFhb): Update datasets 4, 5, 6, 7, 8 loading routine for multiline records (#1264). Committed by Joshua Larsen on 2021-10-15.
- fix(MFFileMgmt.string_to_file_path): Updated to support unc paths (#1256). Committed by Joshua Larsen on 2021-10-06.

- fix(_mg_resync): Added checks to reset the modelgrid resync (#1258). Committed by Joshua Larsen on 2021-10-06.
- fix(MFPackage): Fix mfsim.nam relative paths (#1252). Committed by Joshua Larsen on 2021-10-01.
- fix(voronoi): Voronoigrid class upgraded to better support irregular domains (#1253). Committed by langevin-usgs on 2021-10-01.
- fix(writing tas): Fixed writing non-constant tas (#1244) (#1245). Committed by spaulins-usgs on 2021-09-22.
- fix(numpy elementwise comparison): Fixed numpy futurewarning. no elementwise compare is needed if user passes in a numpy recarray, this is only necessary for dictionaries. (#1235). Committed by spaulins-usgs on 2021-09-13.
- fix(): fix(shapefile_utils) unstructured shapefile export (#1220) (#1222). Committed by Chris Nicol on 2021-09-03.
- fix(rename and comments): Package rename code and comment propagation (#1226). Committed by spaulins-usgs on 2021-09-03.
- fix(numpy): Handle deprecation warnings from numpy 1.21 (#1211). Committed by Mike Taves on 2021-08-23.
- fix(Grid.saturated_thick): Update saturated_thick to filter confining bed layers (#1197). Committed by Joshua Larsen on 2021-08-18.
- fix(): fix(pakbase) unstructured storage check (#1187) (#1194). Committed by Chris Nicol on 2021-08-17.
- fix(MF6Output): Fix add new obs package issue (#1193). Committed by Joshua Larsen on 2021-08-17.
- fix(): fix(plot/plot_bc) plot_bc fails with unstructured models (#1185). Committed by Chris Nicol on 2021-08-16.
- fix(): fix(modflow/mfriv) unstructured mfusg RIV package load check fix (#1184). Committed by Chris Nicol on 2021-08-16.
- fix(pakbase): Specify dtype=bool for 0-d active array used for usg (#1188). Committed by Mike Taves on 2021-08-16.
- fix(raster): Rework raster threads to work on osx (#1180). Committed by jdhughes-usgs on 2021-08-10.
- fix(): fix(loading mflist from file) (#1179). Committed by J Dub on 2021-08-09.
- fix(grid, plotting): Bugfixes for all grid instances and plotting code (#1174). Committed by Joshua Larsen on 2021-08-09.

11.8 Version 3.3.4

11.8.1 New features

- feat(mf6-lake): Add helper function to create lake connections (#1163). Committed by jdhughes-usgs on 2021-08-04.
- feat(data storage): Data automatically stored internally when simulation or model relative path changed (#1126) (#1157). Committed by spaulins-usgs on 2021-07-29.

- feat(get_reduced_pumping): Update to read external pumping reduction files (#1162). Committed by Joshua Larsen on 2021-07-29.
- feat(raster): Add option to extrapolate using nearest method (#1159). Committed by jdhughes-usgs on 2021-07-26.
- Feat(ZoneBudget6): Added zonebudget6 class to zonbud.py (#1149). Committed by Joshua Larsen on 2021-07-12.
- feat(grid): Add thickness method for all grid types (#1138). Committed by jdhughes-usgs on 2021-06-25.
- feat(flopy for mf6 docs): Documentation added and improved for flopy (#1121). Committed by spaulins-usgs on 2021-06-01.
- Feat(.output): Added output property method to mf6 packages and models (#1100). Committed by Joshua Larsen on 2021-04-23.

11.8.2 Bug fixes

- fix(flopy_io): Limit fixed point format string to fixed column widths (#1172). Committed by jdhughes-usgs on 2021-08-06.
- fix(modpath7): Address #993 and #1053 (#1170). Committed by jdhughes-usgs on 2021-08-05.
- fix(lakpak_utils): Fix telev and belev for horizontal connections (#1168). Committed by jdhughes-usgs on 2021-08-05.
- fix(mfsfr2.check): Make reach_connection_gaps.chk.csv a normal csv file (#1151). Committed by Mike Taves on 2021-07-27.
- fix(modflow/mfrch,mfevt): Mfusg rch,evt load and write fixes (#1148). Committed by Chris Nicol on 2021-07-13.
- fix(Raster): Update default dtypes to include unsigned integers (#1147). Committed by Joshua Larsen on 2021-07-12.
- fix(utils/check): File check for mfusg unstructured models (#1145). Committed by Chris Nicol on 2021-07-09.
- fix(list parsing): Fixed errors caused by parsing certain lists with keywords in the middle (#1135). Committed by spaulins-usgs on 2021-06-25.
- fix(plotutil.py, grid.py): Fix .plot() method using mflay parameter (#1134). Committed by Joshua Larsen on 2021-06-16.
- fix(map.py): Fix slow plotting routines (#1118). Committed by Joshua Larsen on 2021-06-11.
- fix(plot_pathline): Update modpath intersection routines (#1112). Committed by Joshua Larsen on 2021-06-11.
- fix(gridgen): Mfusg helper function not indexing correctly (#1124). Committed by langevin-usgs on 2021-05-28.
- fix(numpy): Aliases of builtin types is deprecated (#1105). Committed by Mike Taves on 2021-05-07.
- fix(mfsfr2.py): Dataset 6b and 6c write routine, remove blank lines (#1101). Committed by Joshua Larsen on 2021-04-26.

- fix(performance): Implemented performance improvements including improvements suggested by @briochh (#1092) (#1097). Committed by spaulins-usgs on 2021-04-12.
- fix(package write): Allow user to define and write empty stress period blocks to package files (#1091) (#1093). Committed by scottrp on 2021-04-08.
- fix(imports): Fix shapely and geojson imports (#1083). Committed by jdhughes-usgs on 2021-03-20.
- fix(shapely): Handle deprecation warnings from shapely 1.8 (#1069). Committed by Mike Taves on 2021-03-19.
- fix(mp7particledata): Update dtype comparison for unstructured partlocs (#1071). Committed by rodrperezi on 2021-03-19.
- fix(get_file_entry): None text removed from empty stress period data with aux variable (#1080) (#1081). Committed by scottrp on 2021-03-19.
- fix(data check): Minimum number of data columns check fixed (#1062) (#1067). Committed by spaulins-usgs on 2021-03-17.
- fix(plotutil): Number of plottable layers should be from util3d.shape[0] (#1077). Committed by Mike Taves on 2021-03-15.
- fix(data check): Minimum number of data columns check fixed (#1062) (#1065). Committed by spaulins-usgs on 2021-02-19.

11.9 Version 3.3.3

11.9.1 New features

- feat(voronoi): Add voronoigrid class (#1034). Committed by langevin-usgs on 2021-01-05.
- feat(unstructured): Improve unstructured grid support for modflow 6 and modflow-usg (#1021). Committed by langevin-usgs on 2020-11-27.

11.9.2 Bug fixes

- fix(createpackages): Avoid creating invalid escape characters (#1055). Committed by Mike Taves on 2021-02-17.
- fix(DeprecationWarning): Use collections.abc module instead of collections (#1057). Committed by Mike Taves on 2021-02-15.
- fix(DeprecationWarning): Related to numpy (#1058). Committed by Mike Taves on 2021-02-15.
- fix(numpy): Aliases of builtin types is deprecated as of numpy 1.20 (#1052). Committed by Mike Taves on 2021-02-11.
- fix(): fix(get_active) include the cbd layers when checking layer thickness before BAS is loaded (#1051). Committed by Michael Ou on 2021-02-08.
- fix(dis): Fix for dis.get_lrc() and dis.get_node() (#1049). Committed by langevin-usgs on 2021-02-04.
- fix(): fix(modflow/mflpf) mfusg unstructured lpf ikcflag addition (#1044). Committed by Chris Nicol on 2021-02-01.

- fix(print MFArray): Fixed printing of layered arrays - issue #1043 (#1045). Committed by spaulins-usgs on 2021-01-29.
- fix(GridIntersect): Fix vertices for offset grids (#1037). Committed by Davíd Brakenhoff on 2021-01-13.
- fix(PlotMapView.plot_array()): Fix value masking code for masked_values parameter (#1026). Committed by Joshua Larsen on 2020-12-03.
- fix(sfr ic option): Made ic optional and updated description (#1020). Committed by spaulins-usgs on 2020-11-27.

11.10 Version 3.3.2

11.10.1 New features

- feat(mf6): Update t503 autotest to use mf6examples zip file (#1007). Committed by jdhughes-usgs on 2020-10-21.
- feat(mf6): Add modflow 6 gwt dfn and classes (#1006). Committed by jdhughes-usgs on 2020-10-21.
- feat(geospatial_util): Geospatial consolidation utilities (#1002). Committed by Joshua Larsen on 2020-10-19.
- feat(cvfdutil): Capability to create disv nested grids (#997). Committed by langevin-usgs on 2020-10-02.
- feat(cellid not as tuple): List data input now accepts cellids as separate integers (#976). Committed by spaulins-usgs on 2020-08-27.
- feat(set_all_data_external) : New check_data option (#966). Committed by spaulins-usgs on 2020-08-17.

11.10.2 Bug fixes

- fix(gridintersect): Use linestrings and structured grid (#996). Committed by Tom van Steijn on 2020-09-25.
- fix(): fix(extraneous blocks and zero length data in a list) (#990). Committed by spaulins-usgs on 2020-09-03.
- fix(internal): Flopy fixed to correctly reads in internal keyword when no multiplier supplied. also, header line added to package files. (#962). Committed by spaulins-usgs on 2020-08-13.
- fix(mfsfr2.py: Find_path): wrap find_path() so that the routing dictionary (graph) can still be copied, but won't be copied with every call of find_path() as it recursively finds the routing connections along a path in the sfr network. this was severely impacting performance for large sfr networks. (#955). Committed by aleaf on 2020-08-11.
- fix(#958): Fix gridintersect._vtx_grid_to_shape_generator rtree for cells with more than 3 vertices (#959). Committed by mkennard-aquaveo on 2020-08-07.
- fix(GridIntersect): Fix crash intersecting 3d points that are outside... (#957). Committed by mkennard-aquaveo on 2020-08-05.

- fix(mvr): Added documentation explaining the difference between the two flopy mvr classes (#950). Committed by spaulins-usgs on 2020-07-31.
- fix(check): Get_active() error for confining bed layers (#937). Committed by Michael Ou on 2020-07-29.
- fix(rcha and evta): Irch and ievt arrays now zero based. fix for issue #941. also changed createpackages.py to always produce python scripts with unix-style line endings. (#949). Committed by spaulins-usgs on 2020-07-29.
- fix(lgrutil): Corrected bug in child to parent vertical exchanges (#948). Committed by langevin-usgs on 2020-07-27.
- fix(time series slowness): Speeds up performance when a large number of time series are used by a single stress package (#943). Committed by spaulins-usgs on 2020-07-17.
- fix: Restore python 3.5 compatibility (modulenotfounderror -> importerror) (#933). Committed by Mike Taves on 2020-07-09.
- fix(read binary file): Fix for reading binary files with array data (#931). Committed by spaulins-usgs on 2020-06-30.
- fix(idomain): Data checks now treat all positive idomain values as active (#929). Committed by spaulins-usgs on 2020-06-29.
- fix(Modpath7Sim): Fix timepointinterval calculation for timepointoption 3 (#927). Committed by jdhughes-usgs on 2020-06-26.

11.11 Version 3.3.1

11.11.1 New features

- feat(ModflowAg): Add the modflowag package for nwt (pull request #922). Committed by Joshua Larsen on 2020-06-25.
- feat(GridIntersect): #902 (#903). Committed by Davíd Brakenhoff on 2020-06-10.
- feat(mbase): Suppress duplicate package warning if verbose is false (#908). Committed by Hughes, J.D on 2020-06-09.
- feat(ModflowSms): Add support for simple, moderate, complex (#906). Committed by langevin-usgs on 2020-06-09.
- feat(str): Add irdflg and iptflg control to str (#905). Committed by Hughes, J.D on 2020-06-09.
- feat(Mf6ListBudget): Add support for mf6 budgets with multiple packages with same name (#900). Committed by langevin-usgs on 2020-06-02.
- feat(mfchd.py): Prevent write chk-file always (#869). Committed by Ralf Junghanns on 2020-05-08.
- feat(set all data external): Set all data external for simulation (#846). Committed by spaulins-usgs on 2020-04-08.
- feat(vtk): Improve export at vertices (#844). Committed by Etienne Bresciani on 2020-04-06.

- feat(netcdf): Use modern features from pyproj>=2.2.0 (#840). Committed by Mike Taves on 2020-03-31.
- feat(vtk): Export vectors to vtk. Committed by Etienne Bresciani on 2020-03-31.
- feat(vtk): Export in .vti and .vtr when possible. Committed by Etienne Bresciani on 2020-03-28.
- feat(vectors): Vector plots when stresses applied along boundaries (#817). Committed by langevin-usgs on 2020-03-05.
- feat(plot_bc): Updated plot_bc for maw, uzf, sfr, and multiple bc packages (#808). Committed by Joshua Larsen on 2020-02-11.
- feat(disl grids): Support for 1d vertex grids. fix for writing gridlines to shapefile (#799). Committed by spaulins-usgs on 2020-02-04.
- feat(zb netcdf): Zonebudget netcdf export support added (#781). Committed by Joshua Larsen on 2020-01-17.
- feat(mf6 checker): Input data check for mf6 (#779). Committed by spaulins-usgs on 2020-01-16.

11.11.2 Bug fixes

- fix(#280, #835): Set_all_data_external now includes constants, cellids in list data are checked (#920). Committed by spaulins-usgs on 2020-06-23.
- fix(mfsfr2.check): Negative segments for lakes no longer included in segment numbering order check (#915). Committed by aleaf on 2020-06-23.
- fix(GridIntersect): Fixes #916 and #917 (#918). Committed by Davíd Brakenhoff on 2020-06-22.
- fix(ZoneBudget): Fix faulty logic in ZoneBudget (#911). Committed by Jason Bellino on 2020-06-22.
- fix(SwtListBudget): Totim was not being read correctly for seawat list file (#910). Committed by langevin-usgs on 2020-06-10.
- fix(Seawat.modelgrid): Pass lenuni from dis file into modelgrid instance (#901). Committed by Joshua Larsen on 2020-06-02.
- fix(mfsimulation): Repair change for case insensitive model names (#897). Committed by langevin-usgs on 2020-06-01.
- fix(_plot_util3d_helper, export_array): (#895). Committed by Joshua Larsen on 2020-06-01.
- fix(): fix building in clean env (#894). Committed by Ritchie Vink on 2020-05-28.
- fix(setup.py): Read package name, version, etc. from version.py (#893). Committed by Hughes, J.D on 2020-05-26.
- fix(MFSimulation): Remove case sensitivity from register_ims_package() (#890). Committed by Joshua Larsen on 2020-05-25.
- fix(modelgrid): Fix offset for xul and yul in read_usgs_model_reference_file and attribs_from_namfile_header (#889). Committed by Joshua Larsen on 2020-05-19.
- fix(#886): Mfarray aux variable now always returned as an numpy.ndarray. fixed problem with pylistutil not fully supporting numpy.ndarray type. (#887). Committed by spaulins-usgs on 2020-05-19.

- fix(CellBudgetFile): Update for auto precision with imeth = 5 or 6 (#876). Committed by Joshua Larsen on 2020-05-14.
- fix(#870): Update ims name file record after removing ims package (#880). Committed by Joshua Larsen on 2020-05-14.
- fix: #868, #874, #879 (#881). Committed by spaulins-usgs on 2020-05-14.
- fix(#867): Fixed minimum record entry count for lists to never include keywords in the count (#875). Committed by spaulins-usgs on 2020-05-11.
- fix(SfrFile): Update sfrfile for streambed elevation when present (#866). Committed by Joshua Larsen on 2020-05-04.
- fix(#831,#858): Data length check and case-insensitive lookup (#864). Committed by spaulins-usgs on 2020-05-01.
- fix(#856): Specifying period data with value none now only removes data from that period. also, fixed an unrelated problem by updating the multi-package list. (#857). Committed by spaulins-usgs on 2020-04-22.
- fix(plot_array): Update plot_array method to mask using np.ma.masked_values (#851). Committed by Joshua Larsen on 2020-04-15.
- fix(ModflowDis): Zero based get_node() and get_lrc()... (#847). Committed by Joshua Larsen on 2020-04-10.
- fix(binaryfile_utils, CellbudgetFile): Update for imeth == 6 (#823). Committed by Joshua Larsen on 2020-04-10.
- fix(utils.gridintersect): Bug in gridintersect for vertex grids (#845). Committed by Davíd Brakenhoff on 2020-04-06.
- fix(mflmt.py): Clean up docstring for package_flows argument in lmt. Committed by emorway-usgs on 2020-03-31.
- fix(str): Add consistent fixed and free format approach (#838). Committed by Hughes, J.D on 2020-03-31.
- fix(vtk): Issues related to nan and type cast. Committed by Etienne Bresciani on 2020-03-31.
- fix(pyproj): Pyproj.proj's errcheck keyword option not reliable (#837). Committed by Mike Taves on 2020-03-29.
- fix: (#830): handling 'none' cellids in sfr package (#834). Committed by spaulins-usgs on 2020-03-25.
- fix(): Fix quasi3d plotting (#819). Committed by Ruben Caljé on 2020-03-02.
- fix(ModflowSfr2.export): Update modflowsfr2.export() to use grid instead of spatialreference (#820). Committed by Joshua Larsen on 2020-02-28.
- fix(flopy3_MT3DMS_examples.ipynb): Wrong indices were indexed (#815). Committed by Eric Morway on 2020-02-20.
- fix(build_exes.py): Fix bugs for windows (#810) (#813). Committed by Etienne Bresciani on 2020-02-18.
- fix(mflist): Default value not working (#812). Committed by langevin-usgs on 2020-02-13.
- fix(flopy3_MT3DMS_examples.ipynb): Match constant heads to original problem (#809). Committed by Eric Morway on 2020-02-11.

- fix(vtk): Change in export_cbc output file name (#795). Committed by rodrperezi on 2020-01-30.
- fix(mf6): Update create packages to support additional models (#790). Committed by Hughes, J.D on 2020-01-24.
- fix(remove_package): Fixed remove_package to rebuild namefile recarray correctly after removing package - issue #776 (#784). Committed by spaulins-usgs on 2020-01-17.
- fix(gridgen): X, y center was not correct for rotated grids (#783). Committed by langevin-usgs on 2020-01-16.
- fix(mtssm.py): Handle 1st stress period with incrch equal to -1 (#780). Committed by Eric Morway on 2020-01-16.
- fix(vtk): Change in export_model when packages_names is none (#770). Committed by rodrperezi on 2019-12-30.
- fix(): fix(repeating blocks) (#771). Committed by spaulins-usgs on 2019-12-30.
- fix(replace package): When a second package of the same type is added to a model, the model now checks to see if the package type supports multiple packages. if it does not it automatically removes the first package before adding the second (#767). (#768). Committed by spaulins-usgs on 2019-12-18.
- fix(Mflist): Allow none as a list entry (#765). Committed by langevin-usgs on 2019-12-16.

11.12 Version 3.3.0

- Dropped support for python 2.7
- Switched from pangeo binder binder to mybinder.org binder
- Added support for MODFLOW 6 Skeletal Compaction and Subsidence (CSUB) package

11.12.1 Bug fixes

- Fix issue in MNW2 when the input file had spaced between lines in Dataset 2. #736
- Fix issue in MNW2 when the input file uses wellids with inconsistent cases in Dataset 2 and 4. Internally the MNW2 will convert all wellids to lower case strings. #736
- Fix issue with VertexGrid plotting errors, squeeze proper dimension for head output, in PlotMapView and PlotCrossSection
- Fix issue in PlotUtilities._plot_array_helper mask MODFLOW-6 no flow and dry cells before plotting
- Removed assumption that transient SSM data appears in the first stress period #754 #756. Fix includes a new autotest (t068_test_ssm.py) that adds transient concentration data after the first stress period.
- Fix issues with add_record method for MfList #758

11.13 Version 3.2.13

- ModflowFlwob: Variable irefsp is now a zero-based integer (#596)
- ModflowFlwob: Added a load method and increased precision of toffset when writing to file (#598)
- New feature GridIntersect (#610): The GridIntersect object allows the user to intersect shapes (Points, LineStrings and Polygons) with a MODFLOW grid. These intersections return a numpy.recarray containing the intersection information, i.e. cell IDs, lengths or areas, and a shapely representation of the intersection results. Grids can be structured or vertex grids. Two intersections methods are implemented: "structured" and "strtree": the former accelerates intersections with structured grids. The latter is more flexible and also works for vertex grids. The GridIntersect class is available through flopy.utils.gridintersect. The functionality requires the Shapely module. See the *example notebook* for an overview of this new feature.
- New feature Raster (#634): The Raster object allows the user to load raster files (Geotiff, arc ascii, .img) and sample points, sample polygons, create cross sections, crop, and resample raster data to a Grid. Cropping has been implemented using a modified version of the ray casting algorithm for speed purposes. Resampling a raster can be performed with structured, vertex, and unstructured Grids. Rasters will return a numpy array of resampled data in the same shape as the Grid. The Raster class is available by calling flopy.utils.Raster. The functionality requires rasterio, affine, and scipy. See the (*example notebook*) for an overview of this feature.
- Modify NAM and MFList output files to remove excessive whitespace (#622, #722)
- Deprecate crs class from flopy.utils.reference in favor of CRS class from flopy.export.shapefile_utils (#608)
- New feature in PlotCrossSection (#660). Added a geographic_coords parameter flag to PlotCrossSection which allows the user to plot cross sections with geographic coordinates on the x-axis. The default behavior is to plot distance along cross sectional line on the x-axis. See the (*example notebook*) for an overview of this feature.
- New feature with binaryfile readers, including HeadFile and CellBudgetFile (#669): with statement is supported to open files for reading in a context manager, which automatically close when done or if an exception is raised.
- Improved the flopy list reader for MODFLOW stress packages (for mf2005, mfnwt, etc.), which may use SFAC to scale certain columns depending on the package. The list reading now supports reading from external files, in addition to open/close. The (binary) option is also supported for both open/close and external. This new list reader is used for reading standard stress package lists and also lists used to create parameters. The new list reader should be consistent with MODFLOW behavior.
- SfrFile detects additional columns (#708)
- Add a default_float_format property to mfsfr2, which is string formatted by NumPy versions > 1.14.0, or {:.8g} for older NumPy versions (#710)
- Support for pyshp 1.2.1 dropped, pyshp 2.1.0 support maintained
- Improved VTK export capabilities. Added export for VTK at array level, package level, and model level. Added binary head file export and cell by cell file export.

Added the ability to export point scalars in addition to cell scalars, and added smooth surface generation. VTK export now supports writing transient data as well as exporting to binary .vtu files.

- Support for copying model and package instances with copy.deepcopy()
- Added link to Binder on *README* and notebooks_examples markdown documents. Binder provides an environment that runs and interactively serves the FloPy Jupyter notebooks.

11.13.1 Bug fixes

- When using the default iuzfbnd=None in the __init__ routine of mtuzt.py, instantiation of IUZBND was generating a 3D array instead of a 2D array. Now generates a 2D array
- ModflowSfr2 __init__ was being slowed considerably by the ModflowSfr2.all_segments property method. Modified the ModflowSfr2.graph property method that describes routing connections between segments to handle cases where segments aren't listed in stress period 0.
- Ensure disordered fields in reach_data (Dataset 2) can be supported in ModflowSfr2 and written to MODFLOW SFR input files.
- When loading a MF model with UZF active, item 8 ("[IUZROW] [IUZCOL] IFTUNIT [IUZOPT]") wasn't processed correctly when a user comment appeared at the end of the line
- MODFLOW-6 DISU JA arrays are now treated as zero-based cell IDs. JA, IHC, CL12 are outputted as jagged arrays.
- Models with multiple MODFLOW-6 WEL packages now load and save correctly.
- Exporting individual array and list data to a shapefile was producing an invalid attribute error. Attribute reference has been fixed.
- Fix UnboundLocalError and typo with flopy.export.shapefile_utils.CRS class (#608)
- Fix Python 2.7 issue with flopy.export.utils.export_contourf (#625)
- When loading a MT3D-USGS model, keyword options (if used) were ignored (#649)
- When loading a modflow model, spatial reference information was not being passed to the SpatialReference class (#659)
- Fix specifysurfk option in UZF, ModflowUZF1 read and write surfk variable
- Fix minor errors in flopy gridgen wrapper
- Close opened files after loading, to reduce ResourceWarning messages (#673)
- Fix bugs related to flake8's F821 "undefined name 'name'", which includes issues related to Mt3dPhc, ModflowSfr2, ModflowDe4, ListBudget, and ModflowSms (#686)
- Fix bugs related to flake8's F811 "redefinition of unused 'name'" (#688)
- Fix bugs related to flake8's W605 "invalid escape sequence '\s'" (or similar) (#700)
- Fix EpsgReference class behavior with JSON user files (#702)
- Fix ModflowSfr2 read write logic for all combinations of isfropt and icalc
- IRCH array of the Recharge Package is now a zero-based variable, which means an IRCH value of 0 corresponds to the top model layer (#715)

- MODFLOW lists were not always read correctly if they used the SFAC or binary options or were used to define parameters (#683)
- Changed VDF Package density limiter defaults to zero (#646)

11.14 Version 3.2.12

- Added a check method for OC package (#558)
- Change default map projection from EPSG:4326 to None (#535)
- Refactor warning message visibility and categories (#554, #575)
- Support for MODFLOW 6 external binary files added. Flopy can read/write binary files containing list and array data (#470, #553).
- Added silent option for MODFLOW 6 write_simulation (#552)
- Refactored MODFLOW-6 data classes. File writing operations moved from mfdata*.py to new classes created in mffileaccess.py. Data storage classes moved from mfdata.py to mfdatastorage.py. MFArray, MFList, and MFScalar interface classes simplified with most of the data processing code moved to mfdatastorage.py and mffileaccess.py.
- Added MODFLOW 6 quickstart example to front page.
- Added lgrutil test as autotest/t063_test_lgrutil.py and implemented a get_replicated_parent_array() method to the Lgr class so that the user can pass in a parent array and get back an array that is the size of the child model.
- Refactored much of the flopy code style to conform with Python conventions and those checked by Codacy. Added an automated Codacy check as part of the pull request and commit checks.

11.14.1 Bug fixes

- Fixed bug in Mt3dms.load to show correct error message when loading non-existent NAM file (#545)
- Removed errant SFT parameter contained in Mt3dUzt.**init** routine (#572)
- Fixed DISV shapefile export bug that applied layer 1 parameter values to all model layers during export (#508)
- Updated ModflowSfr2.load to store channel_geometry and channel_flow_data (6d, 6e) by nseg instead of itmp position (#546)
- Fixed bug in ModflowMnw2.make_node_data to be able to set multiple wells with different numbers of nodes (#556)
- Fixed bug reading MODFLOW 6 comma separated files (#509)
- Fixed bug constructing a grid class with MODFLOW-USG (#513)
- Optimized performance of grid class by minimizing redundant operations through use of data result caching (#520)
- Fixed bug passing multiple auxiliary variables for MODFLOW 6 array data (#533)
- Fixed bug in Mt3dUzt.**init**; the variable ioutobs doesn't exist in the UZT package and was removed.

- Fixed MODFLOW-LGR bug in which ascii files were not able to be created for some output. Added better testing of the MODFLOW-LGR capabilities to t035_test.py.
- Fixed multiple issues in mfdis that resulted in incorrect row column determination when using the method get_rc_from_node_coordinates (#560). Added better testing of this to t007_test.py.
- Fixed the export_array_contours function as contours would not export in some cases (#577). Added tests of export_array_contours and export_array to t007_test.py as these methods were not tested at all.

11.15 Version 3.2.11

- Added support for the drain return package.
- Added support for pyshp version 2.x, which contains a different call signature for the writer than earlier versions.
- Added a new flopy3_MT3DMS_examples notebook, which uses Flopy to reproduce the example problems described in the MT3DMS documentation report by Zheng and Wang (1999).
- Pylint is now used on Travis for the Python 3.5 distribution to check for coding errors.
- Added testing with Python 3.7 on Travis, dropped testing Python 3.4.
- Added a new htop argument to the vtk writer, which allows cell tops to be defined by the simulated head.
- Generalized exporting and plotting to also work with MODFLOW 6. Added a new grid class and deprecated SpatialReference class. Added new plotting interfaces, PlotMapView and PlotCrossSection. Began deprecation of ModelMap and ModelCrossSection classes.
- Spatial reference system cache moved to epsgref.json in the user's data directory.
- Attempts to read empty files from flopy.utils raise a IOError exception.
- Changed interface for creating and accessing MODFLOW 6 observation, time series, and time array series packages. These packages can now be created and accessed directly from the package that references them. These changes are not backward compatible, and will require existing scripts to be modified. See the flopy3_mf6_obs_ts_tas.ipynb notebook for instructions.
- Changed the MODFLOW 6 fname argument to be filename. This change is not backward compatible, and will require existing scripts to be modified if the fname argument was used in the package constructor.
- Added modflow-nwt options support for ModflowWel, ModflowSfr2, and ModflowUzf1 via the OptionBlock class.

11.15.1 Bug fixes

- Removed variable MXUZCON from mtuzt.py that was present during the development of MT3D-USGS, but was not included in the release version of MT3D-USGS.
- Now account for UZT -> UZT2 changes with the release of MT3D-USGS 1.0.1. Use of UZT is no longer supported.
- Fixed bug in mfuzf1.py when reading and writing surfk when specifysurfk = True.
- Fixed bug in ModflowStr.load(), utility would fail to load when comments were present.
- Fixed bug in MNW2 in which nodes were not sorted correctly.
- Ensure that external 1-D free arrays are written on one line.
- Typos corrected for various functions, keyword arguments, property names, input file options, and documentation.
- Fixed bug in Mt3dUzt.__init__ that originated when copying code from mtsft.py to get started on mtuzt.py class. The variable ioutobs doesn't exist in the UZT package and should never have appeared in the package to begin with.

11.16 Version 3.2.10

- Added parameter_load variable to mbase that is set to true if parameter data are applied in the model (only used in models that support parameters). If this is set to True free_format_input is set to True (if currently False) when the write_input() method is called. This change preserves the precision of parameter data (which is free format data).
- MODFLOW 6 model and simulation packages can not be retrieved as a MFSimulation attribute
- Added support for multicomponent load in mfsft.py
- Added functionality to read esri-style epsg codes from spatialreference.org.
- Added functionality to MODFLOW 6 that will automatically replace the existing package with the one being added if it has the same name as the existing package.
- Added separate MODFLOW 6 model classes for each model type. Model classes contain name file options.
- Added standard run_model() method arguments to mf6 run_simulation() method.
- some performance improvements to checking
- SpatialReference.export_array() now writes 3-D numpy arrays to multiband GeoTiffs
- Add load support to for MNW1; ModflowMnw1 now uses a stress_period_data Mflist to store MNW information, similar to other BC packages.
- Added a Triangle class that is a light wrapper for the Triangle program for generating triangular meshes. Added a notebook called flopy3_triangle.ipynb that demonstrates how to use it and build a MODFLOW 6 model with a triangular mesh. The current version of this Triangle class should be considered beta functionality as it is likely to change.
- Added support for MODPATH 7 (beta).

- Added support for MODPATH 3 and 5 pathline and endpoint output files.
- Added support for MODPATH timeseries output files (flopy.utils.TimeseriesFile()).
- Added support for plotting MODPATH timeseries output data (plot_timeseries()) with ModelMap.

11.16.1 Bug fixes

- Fixed issue in HOB when the same layer is specified in the MLAY data (dataset 4). If the layer exists the previous fraction value is added to the current value.
- Fixed bug in segment renumbering
- Changed default value for ioutobs **kwargs in mtsft.py from None to 0 to prevent failure.
- Fixed bug when passing extra components info from load to constructor in mtsft.py and mtrct.py.
- Fixed bug in mt3ddsp load - if multidiffusion is not found, should only read one 3d array.
- Fixed bug in zonbud utility that wasn't accumulating flow from constant heads.
- Fixed minor bug that precluded the passing of mass-balance record names (TOTAL_IN, IN-OUT, etc.).
- Fixed bug when writing shapefile projection (.prj) files using relative paths.
- Fixed bugs in sfr.load() - weight and flwtol should be cast as floats, not integers.
- Fixed bug when SpatialReference supplied with geographic CRS.
- Fixed bug in mfsfr.py when writing kinematic data (irtflg >0).
- Fixed issue from change in MODFLOW 6 inspect.getargspec() method (for getting method arguments).
- Fixed MODFLOW 6 BINARY keyword for reading binary data from a file using OPEN/CLOSE (needs parentheses around it).
- Fixed bug in mtlkt.py when initiating, loading, and/or writing lkt input file related to multi-species problems.

11.17 Version 3.2.9

- Modified MODFLOW 5 OC stress_period_data=None default behaviour. If MODFLOW 5 OC stress_period_data is not provided then binary head output is saved for the last time step of each stress period.
- added multiple component support to mt3dusgs SFT module
- Optimized loading and saving of MODFLOW 6 files
- MODFLOW 6 identifiers are now zero based
- Added remove_package method in MFSimulation and MFModel that removes MODFLOW 6 packages from the existing simulation/model

- Changed some of the input argument names for MODFLOW 6 classes. Note that this will break some existing user scripts. For example, the stress period information was passed to the boundary package classes using the periodrecarray argument. The argument is now called stress_period_data in order to be consistent with other Flopy functionality.
- Flopy code for MODFLOW 6 generalized to support different model types
- Flopy code for some MODFLOW 6 arguments now have default values in order to be consistent with other Flopy functionality
- Added ModflowSfr2.export_transient_variable method to export shapefiles of segment data variables, with stress period data as attributes
- Added support for UZF package gages

11.17.1 Bug fixes

- Fixed issue with default settings for MODFLOW 5 SUB package dp dataset.
- Fixed issue if an external BC list file has only one entry
- Some patching for recarray issues with latest numpy release (there are more of these lurking...)
- Fixed setting model relative path for MODFLOW 6 simulations
- Python 2.7 compatibility issues fixed for MODFLOW 6 simulations
- IMS file name conflicts now automatically resolved
- Fixed issue with passing in numpy ndarrays arrays as layered data
- Doc string formatting for MODFLOW 6 packages fixed to make doc strings easier to read
- UZF package: fixed issues with handling of finf, pet, extdp and extwc arrays.
- SFR package: fixed issue with reading stress period data where not all segments are listed for periods > 0.
- SpatialReference.write_gridSpec was not converting the model origin coordinates to model length units.
- shorted integer field lengths written to shapefiles to 18 characters; some readers may misinterpret longer field lengths as float dtypes.

11.18 Version 3.2.8

- Added has_package(name) method to see if a package exists. This feature goes nicely with get_package(name) method.
- Added set_model_units() method to change model units for all files created by a model. This method can be useful when creating MODFLOW-LGR models from scratch.
- Added SFR2 package functionality
  - export_inlets method to write shapefile showing locations where external flows are entering the stream network.

11.18.1 Bug fixes

- Installation: Added dfn files required by MODFLOW 6 functionality to MANIFEST.in so that they are included in the distribution.
- SFR2 package: Fixed issue reading transient data when ISFOPT is 4 or 5 for the first stress period.

11.19 Version 3.2.7

- Added beta support for MODFLOW 6 See *here* for more information.
- Added support for retrieving time series from binary cell-by-cell files. Cell-by-cell time series are accessed in the same way they are accessed for heads and concentrations but a text string is required.
- Added support for FORTRAN free format array data using n*value where n is the number of times value is repeated.
- Added support for comma separators in 1D data in LPF and UPF files
- Added support for comma separators on non array data lines in DIS, BCF, LPF, UPW, HFB, and RCH Packages.
- Added .reset_budgetunit() method to OC package to facilitate saving cell-by-cell binary output to a single file for all packages that can save cell-by-cell output.
- Added a .get_residual() method to the CellBudgetFile class.
- Added support for binary stress period files (OPEN/CLOSE filename (BINARY)) in wel stress packages on load and instantiation. Will extend to other list-based MODFLOW stress packages.
- Added a new flopy.utils.HeadUFile Class (located in binaryfile.py) for reading unstructured head files from MODFLOW-USG. The .get_data() method for this class returns a list of one-dimensional head arrays for each layer.
- Added metadata.acdd class to fetch model metadata from ScienceBase.gov and manage CF/ACDD-complaint metadata for NetCDF export
- Added sparse export option for boundary condition stress period data, where only cells for that B.C. are exported (for example, package.stress_period_data.export('stuff.shp', sparse=True))
- Added additional SFR2 package functionality:
  - .export_linkages() and .export_outlets() methods to export routing linkages and outlets
  - sparse shapefile export, where only cells with SFR reaches are included
  - .plot_path() method to plot streambed elevation profile along sequence of segments
  - .assign_layers() method
  - additional error checks and bug fixes
- Added SpatialReference / GIS export functionality:
  - GeoTiff export option to SpatialReference.export_array

  - SpatialReference.export_array_contours: contours an array and then exports contours to shapefile
  - inverse option added to SpatialReference.transform
  - automatic reading of spatial reference info from .nam or usgs.model.reference files
- Modified node numbers in SFR package and ModflowDis.get_node() from one- to zero-based.
- Modified HYDMOD package klay variable from one- to zero-based.
- Added .get_layer() method to DIS package.
- Added .get_saturated_thickness() and .get_gradients() methods

11.19.1 Bug fixes

- OC package: Fixed bug when printing and saving data for select stress periods and timesteps. In previous versions, OC data was repeated until respecified.
- SUB package: Fixed bug if data set 15 is passed to preserved unit numbers (i.e., use unit numbers passed on load).
- SUB and SUB-WT packages: Fixed bugs .load() to pop original unit number.
- BTN package: Fixed bug in obs.
- LPF package: Fixed bug regarding when HANI is read and written.
- UZF package: added support for MODFLOW NWT options block; fixed issue with loading files with thti/thtr options
- SFR package: fixed bug with segment renumbering, issues with reading transient text file output,
- Fixed issues with dynamic setting of SpatialReference parameters
- NWT package: forgive missing value for MXITERXMD
- MNW2 package: fix bug where ztop and zbotm were written incorrectly in get_allnode_data(). This was not affecting writing of these variables, only their values in this summary array.
- PCGN package: fixed bug writing package.
- Fixed issue in Util2d when non-integer cnstnt passed.

11.20 Version 3.2.6

- Added functionality to read binary grd file for unstructured grids.
- Additions to SpatialReference class:
  - xll, yll input option
  - transform method to convert model coordinates to real-world coordinates
  - epsg and length_multiplier arguments
- Export:

  - Added writing of prj files to shapefile export; prj information can be passed through spatial reference class, or given as an EPSG code or existing prj file path
  - Added NetCDF export to MNW2
- Added MODFLOW support for:
  - FHB Package - no support for flow or head auxiliary variables (datasets 2, 3, 6, and 8)
  - HOB Package
- New utilities:
  - flopy.utils.get_transmissivities() Computes transmissivity in each model layer at specified locations and open intervals. A saturated thickness is determined for each row, column or x, y location supplied, based on the well open interval (sctop, scbot), if supplied, otherwise the layer tops and bottoms and the water table are used.
- Added MODFLOW-LGR support - no support for model name files in different directories than the directory with the lgr control file.
- Additions to MODPATH:
  - shapefile export of MODPATH Pathline and Endpoint data
  - Modpath.create_mpsim() supports MNW2
  - creation of MODPATH StartingLocations files
  - Easy subsetting of endpoint and pathline results to destination cells of interest
- New ZoneBudget class provides ZONEBUDGET functionality:
  - reads a CellBudgetFile and accumulates flows by zone
  - pass kstpkper or totim keyword arguments to retrieve a subset of available times in the CellBudgetFile
  - includes a method to write the budget recarrays to a .csv file
  - ZoneBudget objects support numerical operators to facilitate conversion of units
  - utilities are included which read/write ZONEBUDGET-style zone files to and from numpy arrays
  - pass a dictionary of {zone: "alias"} to rename fields to more descriptive names (e.g. {1: 'New York', 2: 'Delmarva'}
- Added new precision='auto' option to flopy.utils.binaryfile for HeadFile and UcnFile readers. This will automatically try and determine the float precision for head files created by single and double precision versions of MODFLOW. 'auto' is now the default. Not implemented yet for cell by cell flow file.
- Modified MT3D-related packages to also support MT3D-USGS
  - BTN will support the use of keywords (e.g., 'MODFLOWStyleArrays', etc.) on the first line
  - DSP will support the use of keyword NOCROSS
  - Keyword FREE now added to MT3D name file when the flow-transport link (FTL) file is formatted. Previously defaulted to unformatted only.

- Added 3 new packages:
  - SFT: Streamflow Transport, companion transport package for use with the SFR2 package in MODFLOW
  - LKT: Lake Transport, companion transport package for use with the LAK3 package in MODFLOW
  - UZT: Unsaturated-zone Transport, companion transport package for use with the UZF1 package in MODFLOW
- Modified LMT
  - load() functionality will now support optional PACKAGE_FLOWS line (last line of LMT input)
  - write_file() will will now insert PACKAGE_FLOWS line based on user input

11.20.1 Bug fixes

- Fixed bug in parsenamefile when file path in namefile is surrounded with quotes.
- Fixed bug in check routine when THICKSTRT is specified as an option in the LPF and UPW packages.
- Fixed bug in BinaryHeader.set_values method that prevented setting of entries based on passed kwargs.
- Fixed bugs in reading and writing SEAWAT Viscosity package.
- The DENSE and VISC arrays are now Transient3d objects, so they may change by stress period.
- MNW2: fixed bug with k, i, j node input option and issues with loading at model level
- Fixed bug in ModflowDis.get_cell_volumes().

11.21 Version 3.2.5

- Added support for LAK and GAGE packages - full load and write functionality supported.
- Added support for MNW2 package. Load and write of .mnw2 package files supported. Support for .mnwi, or the results files (.qsu, .byn) not yet implemented.
- Improved support for changing the output format of arrays and variables written to MODFLOW input files.
- Restructured SEAWAT support so that packages can be added directly to the SEAWAT model, in addition to the approach of adding a modflow model and a mt3d model. Can now load a SEAWAT model.
- Added load support for MT3DMS Reactions package
- Added multi-species support for MT3DMS Reactions package
- Added static method to Mt3dms().load_mas that reads an MT3D mass file and returns a recarray

- Added static method to Mt3dms().load_obs that reads an MT3D mass file and returns a recarray
- Added method to flopy.modpath.Modpath to create modpath simulation file from modflow model instance boundary conditions. Also added examples of creating modpath files and post-processing modpath pathline and endpoint files to the flopy3_MapExample notebook.

11.21.1 Bug fixes

- Fixed issue with VK parameters for LPF and UPW packages.
- Fixed issue with MT3D ADV load in cases where empty fields were present in the first line of the file.
- Fixed cross-section array plotting issues.
- BTN observation locations must now be entered in zero-based indices (a 1 is now added to the index values written to btn file)
- Uploaded supporting files for SFR example notebook; fixed issue with segment_data submitted as array (instead of dict) and as 0d array(s).
- Fixed CHD Package so that it now supports options, and therefore, auxiliary variables can be specified.
- Fixed loading BTN save times when numbers are touching.

11.22 Version 3.2.4

- Added basic model checking functionality (.check()).
- Added support for reading SWR Process observation, stage, budget, flow, reach-aquifer exchanges, and structure flows.
- flopy.utils.HydmodObs returns a numpy recarray. Previously numpy arrays were returned except when the slurp() method was used. The slurp method has been deprecated but the same functionality is available using the get_data() method. The recarray returned from the get_data() method includes the totim value and one or all of the observations (HYDLBL).
- Added support for MODFLOW-USG DISU package for unstructured grids.
- Added class (Gridgen) for creating layered quadtree grids using GRIDGEN (flopy.utils.gridgen). See the flopy3_gridgen notebook for an example of how to use the Gridgen class.
- Added user-specified control on use of OPEN/CLOSE array options (see flopy3_external_file_handling notebook).
- Added user-specified control for array output formats (see flopy3_array_outputformat_options IPython notebook).
- Added shapefile as optional output format to .export() method and deprecated .to_shapefile() method.

11.22.1 Bug fixes

- Fixed issue with right justified format statement for array control record for MT3DMS.
- Fixed bug writing PHIRAMP for MODFLOW-NWT well files.
- Fixed bugs in NETCDF export methods.
- Fixed bugs in LMT and BTN classes.

11.23 Version 3.2.3

- Added template creation support for several packages for used with PEST (and UCODE).
- Added support for the SEAWAT viscosity (VSC) package.
- Added support for the MODFLOW Stream (STR), Streamflow-Routing (SFR2), Subsidence (SUB), and Subsidence and Aquifer-System Compaction Package for Water-Table Aquifers (SWT) Packages.
- Mt3d model was redesigned based on recent changes to the Modflow model. Mt3d packages rewritten to support multi-species. Primary packages can be loaded (btn, adv, dsp, ssm, gcg). Array utilities modified to read some MT3D RARRAY formats.
- Fixed array loading functionality for case when the CNSTNT value is zero. If CNSTNT is zero and is used as an array multiplier, it is changed to 1 (as done in MODFLOW).
- Added support for the MODFLOW HYDMOD (HYD) Package and reading binary files created by the HYDMOD Package (HydmodObs Class) in the flopy.utils submodule.
- flopy.utils.CellBudgetFile returns a numpy recarray for list based budget data. Previously a dictionary with the node number and q were returned. The recarray will return the node number, q, and the aux variables for list based budget data.
- Added travis-ci automated testing.

11.24 Version 3.2.2

- FloPy now supports some simple plotting capabilities for two- and three-dimensional model input data array classes and transient two-dimensional stress period input data using the .plot() methods associated with the data array classes (util_2d, util_3d, and transient_2d). The model results reader classes (HeadFile, UcnFile, and CellBudgetFile) have also been extended to include a .plot() method that can be used to create simple plots of model output data. See the notebook flopy3_PlotArrayExample.
- Added .to_shapefile() method to two- and three-dimensional model input data array classes (util_2d and util_3d), transient two-dimensional stress period input data classes (transient_2d), and model output data classes (HeadFile, UcnFile, and CellBudgetFile) that allows model data to be exported as polygon shapefiles with separate attribute columns for each model layer.
- Added support for ASCII model results files.
- Added support for reading MODPATH version 6 pathline and endpoint output files and plotting MODPATH results using mapping capabilities in flopy.plot submodule.

- Added load() method for MODFLOW GMG solver.

11.24.1 Bug fixes

- Multiplier in array control record was not being applied to arrays
- vani parameter was not supported

11.25 Version 3.2.1

- FloPy can now be used with **Python 3.x**
- Revised setters for package class variables stored using the util_2d or util_3d classes.
- Added option to load a subset of MODFLOW packages in a MODFLOW model name file using load_only= keyword.

11.26 Version 3.1

- FloPy now supports some simple mapping and cross-section capabilities through the flopy.plot submodule. See the notebook flopy3_MapExample.
- Full support for all Output Control (OC) options including DDREFERENCE, SAVE IBOUND, and layer lists. All Output Control Input is specified using words. Output Control Input using numeric codes is still available in the ModflowOc88 class. The ModflowOc88 class is currently deprecated and no longer actively maintained.
- Added support for standard MULT package FUNCTION and EXPRESSION functionality are supported. MODFLOW parameters are not supported in write() methods.

11.27 Version 3.0

FloPy is significantly different from earlier versions of FloPy (previously hosted on googlecode). The main changes are:

- FloPy is fully zero-based. This means that layers, rows and columns start counting at *zero*. The reason for this is consistency. Arrays are zero-based by default in Python, so it was confusing to have a mix.
- Input for packages that take *layer*, *row*, *column*, *data* input (like the wel or ghb package) has changed and is much more flexible now. See the notebook flopy3boundaries
- Input for the MT3DMS Source/Sink Mixing (SSM) Package has been modified to be consistent with the new MODFLOW boundary package input and is more flexible than previous versions of FloPy. See the notebook flopy3ssm
- Support for use of EXTERNAL and OPEN/CLOSE array specifiers has been improved.
- *load()* methods have been developed for all of the standard MODFLOW packages and a few less used packages (*e.g.* SWI2).

- `MODFLOW parameter support has been added to the load() methods. MULT, PVAL, and ZONE packages are now supported and parameter data are converted to arrays in the load() methods. MODFLOW parameters are not supported in write() methods.`

CHAPTER TWELVE

API REFERENCE

12.1 MODFLOW 6

FloPy for MODFLOW 6 allows for the construction of multi-model simulations. In order to construct a MODFLOW 6 simulation using FloPy, first construct a simulation (MFSimulation) object. Then construct the MODFLOW 6 models (Modflowgwf and Modflowgwt) and the packages, like TDIS, that are associated with the simulation. Finally, construct the packages that are associated with each of your models.

12.1.1 MODFLOW 6 Base Classes

FloPy for MODFLOW 6 is object oriented code that uses inheritance. The FloPy classes used to define different types models and packages share common code that is defined in these base classes.

Contents:

flopy.mf6.mfbase module

Base classes for Modflow 6

class ExtFileAction(*value*, *names=None*, ***, *module=None*, *qualname=None*, *type=None*, *start=1*, *boundary=None*)

Bases: Enum

Defines what to do with external files when the simulation or model's path change.

copy_all = 1

copy_none = 2

copy_relative_paths = 3

exception FlopyException(*error*, *location=''*)

Bases: Exception

General FloPy exception

exception MFDataException(*model=None*, *package=None*, *path=None*, *current_process=None*, *data_element=None*, *method_caught_in=None*, *org_type=None*, *org_value=None*, *org_traceback=None*, *message=None*, *debug=None*, *mfdata_except=None*)

Bases: Exception

Exception with MODFLOW data. Exception includes detailed error information.

class MFFileMgmt(*path: str | PathLike*, *mfsim=None*)

Bases: object

Class containing MODFLOW path data

Parameters

path (*str or PathLike*) – Path on disk to the simulation

model_relative_path

Dictionary of relative paths to each model folder

Type

dict

add_ext_file(*file_path*, *model_name*)

Add an external file to the path list. For internal FloPy use, not intended for end user.

copy_files(*copy_relative_only=True*)

Copy files external to updated path.

Parameters

copy_relative_only (*bool*) – Only copy files with relative paths.

get_model_path(*key*, *last_loaded_path=False*)

Returns the model working path for the model *key*.

Parameters

- **key** (*str*) – Model name whose path flopy will retrieve
- **last_loaded_path** (*bool*) – Get the last path loaded by FloPy which may not be the most recent path.

Returns

model path

Return type

str

get_sim_path(*last_loaded_path=False*)

Get the simulation path.

get_updated_path(*external_file_path*, *model_name*, *ext_file_action*)

For internal FloPy use, not intended for end user.

resolve_path(*path*, *model_name*, *last_loaded_path=False*, *move_abs_paths=False*)

Resolve a simulation or model path. For internal FloPy use, not intended for end user.

set_last_accessed_model_path()

Set the last accessed model path to the current model path. For internal FloPy use, not intended for end user.

set_last_accessed_path()

Set the last accessed simulation path to the current simulation path. For internal FloPy use, not intended for end user.

set_sim_path(*path: str | PathLike*, *internal_use=False*)

Set the file path to the simulation files. Internal use only, call MFSimulation's set_sim_path method instead.

Parameters
path (*str or PathLike*) – Path to simulation folder

Return type
None

Examples

self.simulation_data.mfdata.set_sim_path('path/to/workspace')

strip_model_relative_path(*model_name*, *path*) → str

Strip out the model relative path part of *path*. For internal FloPy use, not intended for end user.

static **unique_file_name**(*file_name*, *lookup*)

Generate a unique file name. For internal FloPy use, not intended for end user.

class **MFFilePath**(*file_path*, *model_name*)

Bases: object

Class that stores a single file path along with the associated model name.

isabs()

exception **MFInvalidTransientBlockHeaderException**

Bases: Exception

Exception occurs when parsing a transient block header

class **PackageContainer**(*simulation_data*, *name*)

Bases: object

Base class for any class containing packages.

Parameters

- **simulation_data** (*SimulationData*) – The simulation's SimulationData object
- **name** (*str*) – Name of the package container object

package_type_dict

Dictionary of packages by package type

Type
dictionary

package_name_dict

Dictionary of packages by package name

Type
dictionary

static get_module_val(*module*, *item*, *attrb*)

Static method that returns a python class module value. For internal FloPy use only, not intended for end users.

get_package(*name=None*)

Finds a package by package name, package key, package type, or partial package name. returns either a single package, a list of packages, or None.

Parameters
name (*str*) – Name of the package, 'RIV', 'LPF', etc.

Returns
pp

Return type
Package object

static model_factory(*model_type*)

Static method that returns the appropriate model type object based on the model_type string. For internal FloPy use only, not intended for end users.

Parameters
model_type (*str*) – Type of model that package is a part of

Returns
model

Return type
MFModel subclass

models_by_type = {'gwf': <class 'flopy.mf6.modflow.mfgwf.ModflowGwf'>, 'gwt': <class 'flopy.mf6.modflow.mfgwt.ModflowGwt'>}

modflow_models = [<class 'flopy.mf6.modflow.mfgwf.ModflowGwf'>, <class 'flopy.mf6.modflow.mfgwt.ModflowGwt'>]

```
modflow_packages = [<class 'flopy.mf6.modflow.mfnam.ModflowNam'>, <class
'flopy.mf6.modflow.mftdis.ModflowTdis'>, <class
'flopy.mf6.modflow.mfems.ModflowEms'>, <class 'flopy.mf6.modflow.mfgnc.ModflowGnc'>,
<class 'flopy.mf6.modflow.mfgnc.GncPackages'>, <class
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'flopy.mf6.modflow.mfgwfbuy.ModflowGwfbuy'>, <class
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'flopy.mf6.modflow.mfgwfghb.ModflowGwfghb'>, <class
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'flopy.mf6.modflow.mfgwfmvr.GwfmvrPackages'>, <class
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'flopy.mf6.modflow.mfgwfrcha.ModflowGwfrcha'>, <class
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'flopy.mf6.modflow.mfgwfsfr.ModflowGwfsfr'>, <class
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'flopy.mf6.modflow.mfgwfvsc.ModflowGwfvsc'>, <class
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'flopy.mf6.modflow.mfgwtapi.ModflowGwtapi'>, <class
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'flopy.mf6.modflow.mfgwtgwt.ModflowGwtgwt'>, <class
'flopy.mf6.modflow.mfgwtic.ModflowGwtic'>, <class
'flopy.mf6.modflow.mfgwtist.ModflowGwtist'>, <class
'flopy.mf6.modflow.mfgwtlkt.ModflowGwtlkt'>, <class
'flopy.mf6.modflow.mfgwtmst.ModflowGwtmst'>, <class
'flopy.mf6.modflow.mfgwtmvt.ModflowGwtmvt'>, <class
'flopy.mf6.modflow.mfgwtmvt.GwtmvtPackages'>, <class
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'flopy.mf6.modflow.mfgwtsrc.ModflowGwtsrc'>, <class
'flopy.mf6.modflow.mfgwtssm.ModflowGwtssm'>, <class
'flopy.mf6.modflow.mfgwtuzt.ModflowGwtuzt'>, <class
'flopy.mf6.modflow.mfims.ModflowIms'>, <class 'flopy.mf6.modflow.mfmvr.ModflowMvr'>,
<class 'flopy.mf6.modflow.mfmvr.MvrPackages'>, <class
```

property package_dict

Returns a copy of the package name dictionary.

static package_factory(*package_type: str*, *model_type: str*)

Static method that returns the appropriate package type object based on the package_type and model_type strings. For internal FloPy use only, not intended for end users.

Parameters

- **package_type** (*str*) - Type of package to create
- **model_type** (*str*) - Type of model that package is a part of

Returns
package

Return type
MFPackage subclass

property package_key_dict

static package_list()

Static method that returns the list of available packages. For internal FloPy use only, not intended for end users.

Returns a list of MFPackage subclasses

property package_names

Returns a list of package names.

```
packages_by_abbr = {'ems': <class 'flopy.mf6.modflow.mfems.ModflowEms'>, 'gnc':
<class 'flopy.mf6.modflow.mfgnc.ModflowGnc'>, 'gncpackages': <class
'flopy.mf6.modflow.mfgnc.GncPackages'>, 'gwfapi': <class
'flopy.mf6.modflow.mfgwfapi.ModflowGwfapi'>, 'gwfbuy': <class
'flopy.mf6.modflow.mfgwfbuy.ModflowGwfbuy'>, 'gwfchd': <class
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'flopy.mf6.modflow.mfgwfdisu.ModflowGwfdisu'>, 'gwfdisv': <class
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'flopy.mf6.modflow.mfgwfgwf.ModflowGwfgwf'>, 'gwfgwt': <class
'flopy.mf6.modflow.mfgwfgwt.ModflowGwfgwt'>, 'gwfhfb': <class
'flopy.mf6.modflow.mfgwfhfb.ModflowGwfhfb'>, 'gwfic': <class
'flopy.mf6.modflow.mfgwfic.ModflowGwfic'>, 'gwflak': <class
'flopy.mf6.modflow.mfgwflak.ModflowGwflak'>, 'gwfmaw': <class
'flopy.mf6.modflow.mfgwfmaw.ModflowGwfmaw'>, 'gwfmvr': <class
'flopy.mf6.modflow.mfgwfmvr.ModflowGwfmvr'>, 'gwfmvrpackages': <class
'flopy.mf6.modflow.mfgwfmvr.GwfmvrPackages'>, 'gwfnam': <class
'flopy.mf6.modflow.mfgwfnam.ModflowGwfnam'>, 'gwfnpf': <class
'flopy.mf6.modflow.mfgwfnpf.ModflowGwfnpf'>, 'gwfoc': <class
'flopy.mf6.modflow.mfgwfoc.ModflowGwfoc'>, 'gwfrch': <class
'flopy.mf6.modflow.mfgwfrch.ModflowGwfrch'>, 'gwfrcha': <class
'flopy.mf6.modflow.mfgwfrcha.ModflowGwfrcha'>, 'gwfriv': <class
'flopy.mf6.modflow.mfgwfriv.ModflowGwfriv'>, 'gwfsfr': <class
'flopy.mf6.modflow.mfgwfsfr.ModflowGwfsfr'>, 'gwfsto': <class
'flopy.mf6.modflow.mfgwfsto.ModflowGwfsto'>, 'gwfuzf': <class
'flopy.mf6.modflow.mfgwfuzf.ModflowGwfuzf'>, 'gwfvsc': <class
'flopy.mf6.modflow.mfgwfvsc.ModflowGwfvsc'>, 'gwfwel': <class
'flopy.mf6.modflow.mfgwfwel.ModflowGwfwel'>, 'gwtadv': <class
'flopy.mf6.modflow.mfgwtadv.ModflowGwtadv'>, 'gwtapi': <class
'flopy.mf6.modflow.mfgwtapi.ModflowGwtapi'>, 'gwtcnc': <class
'flopy.mf6.modflow.mfgwtcnc.ModflowGwtcnc'>, 'gwtdis': <class
'flopy.mf6.modflow.mfgwtdis.ModflowGwtdis'>, 'gwtdisu': <class
'flopy.mf6.modflow.mfgwtdisu.ModflowGwtdisu'>, 'gwtdisv': <class
'flopy.mf6.modflow.mfgwtdisv.ModflowGwtdisv'>, 'gwtdsp': <class
'flopy.mf6.modflow.mfgwtdsp.ModflowGwtdsp'>, 'gwtfmi': <class
'flopy.mf6.modflow.mfgwtfmi.ModflowGwtfmi'>, 'gwtgwt': <class
'flopy.mf6.modflow.mfgwtgwt.ModflowGwtgwt'>, 'gwtic': <class
'flopy.mf6.modflow.mfgwtic.ModflowGwtic'>, 'gwtist': <class
'flopy.mf6.modflow.mfgwtist.ModflowGwtist'>, 'gwtlkt': <class
'flopy.mf6.modflow.mfgwtlkt.ModflowGwtlkt'>, 'gwtmst': <class
'flopy.mf6.modflow.mfgwtmst.ModflowGwtmst'>, 'gwtmvt': <class
'flopy.mf6.modflow.mfgwtmvt.ModflowGwtmvt'>, 'gwtmvtpackages': <class
'flopy.mf6.modflow.mfgwtmvt.GwtmvtPackages'>, 'gwtmwt': <class
'flopy.mf6.modflow.mfgwtmwt.ModflowGwtmwt'>, 'gwtnam': <class
'flopy.mf6.modflow.mfgwtnam.ModflowGwtnam'>, 'gwtoc': <class
'flopy.mf6.modflow.mfgwtoc.ModflowGwtoc'>, 'gwtsft': <class
'flopy.mf6.modflow.mfgwtsft.ModflowGwtsft'>, 'gwtsrc': <class
'flopy.mf6.modflow.mfgwtsrc.ModflowGwtsrc'>, 'gwtssm': <class
'flopy.mf6.modflow.mfgwtssm.ModflowGwtssm'>, 'gwtuzt': <class
'flopy.mf6.modflow.mfgwtuzt.ModflowGwtuzt'>, 'ims': <class
'flopy.mf6.modflow.mfims.ModflowIms'>, 'mvr': <class
'flopy.mf6.modflow.mfmvr.ModflowMvr'>, 'mvrpackages': <class
'flopy.mf6.modflow.mfmvr.MvrPackages'>, 'mvt': <class
```

register_package(*package*)

Base method for registering a package. Should be overridden.

class **PackageContainerType**(*value*, *names=None*, ***, *module=None*, *qualname=None*, *type=None*, *start=1*, *boundary=None*)

Bases: Enum

Determines whether a package container is a simulation, model, or package.

model = 2

package = 3

simulation = 1

exception **ReadAsArraysException**

Bases: Exception

Exception occurs when loading ReadAsArrays package as non-ReadAsArrays package.

exception **StructException**(*error*, *location*)

Bases: Exception

Exception with the package file structure

class **VerbosityLevel**(*value*, *names=None*, ***, *module=None*, *qualname=None*, *type=None*, *start=1*, *boundary=None*)

Bases: Enum

Determines how much information FloPy writes to the console

normal = 2

quiet = 1

verbose = 3

flopy.mf6.mfmodel module

class **MFModel**(*simulation*, *model_type='gwf6'*, *modelname='model'*, *model_nam_file=None*, *version='mf6'*, *exe_name='mf6'*, *add_to_simulation=True*, *structure=None*, *model_rel_path='.'*, *verbose=False*, ***kwargs*)

Bases: *PackageContainer*, *ModelInterface*

MODFLOW-6 model base class. Represents a single model in a simulation.

Parameters

- **simulation_data** (MFSimulationData) – Simulation data object of the simulation this model will belong to
- **structure** (*MFModelStructure*) – Structure of this type of model
- **modelname** (*str*) – Name of the model
- **model_nam_file** (*str*) – Relative path to the model name file from model working folder
- **version** (*str*) – Version of modflow

- **exe_name** (*str*) – Model executable name
- **model_ws** (*str*) – Model working folder path
- **disfile** (*str*) – Relative path to dis file from model working folder
- **grid_type** (*str*) – Type of grid the model will use (structured, unstructured, vertices)
- **verbose** (*bool*) – Verbose setting for model operations (default False)

name

Name of the model

Type
str

exe_name

Model executable name

Type
str

packages

Dictionary of model packages

Type
dict of *MFPackage*

check(*f=None*, *verbose=True*, *level=1*)

Check model data for common errors.

Parameters

- **f** (*str or file handle*) – String defining file name or file handle for summary file of check method output. If a string is passed a file handle is created. If f is None, check method does not write results to a summary file. (default is None)
- **verbose** (*bool*) – Boolean flag used to determine if check method results are written to the screen
- **level** (*int*) – Check method analysis level. If level=0, summary checks are performed. If level=1, full checks are performed.

Returns
success

Return type
bool

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow.load('model.nam')
>>> m.check()
```

property exename

MODFLOW executable name

export(*f*, ***kwargs*)

Method to export a model to a shapefile or netcdf file

Parameters

- **f** (*str*) – File name (".nc" for netcdf or ".shp" for shapefile) or dictionary of ....
- ****kwargs** (*keyword arguments*) –

  modelgrid: flopy.discretization.Grid
  User supplied modelgrid object which will supercede the built in modelgrid object

  if fmt is set to 'vtk', parameters of Vtk initializer

get_grid_type()

Return the type of grid used by model 'model_name' in simulation containing simulation data 'simulation_data'.

Returns
grid type

Return type
DiscretizationType

get_ims_package()

Get the IMS package associated with this model.

Returns
IMS package

Return type
ModflowIms

get_steadystate_list()

Returns a list of stress periods that are steady state.

Returns
steady state list

Return type
list

property hdry

Dry cell value

property hnoflo

No-flow cell value

inspect_cells(*cell_list*, *stress_period=None*, *output_file_path=None*, *inspect_budget=True*, *inspect_dependent_var=True*)

Inspect model cells. Returns model data associated with cells.

Parameters

- **cell_list** (*list of tuples*) – List of model cells. Each model cell is a tuple of integers. ex: [(1,1,1), (2,4,3)]
- **stress_period** (*int*) – For transient data qnly return data from this stress period. If not specified or None, all stress period data will be returned.

- **output_file_path** (*str*) – Path to output file that will contain the inspection results
- **inspect_budget** (*bool*) – Inspect budget file
- **inspect_dependent_var** (*bool*) – Inspect head file

Returns
output – Dictionary containing inspection results

Return type
dict

Examples

```
>>> import flopy
>>> sim = flopy.mf6.MFSimulationBase.load("name", "mf6", "mf6", ".")
>>> model = sim.get_model()
>>> inspect_list = [(2, 3, 2), (0, 4, 2), (0, 2, 4)]
>>> out_file = os.path.join("temp", "inspect_AdvGW_tidal.csv")
>>> model.inspect_cells(inspect_list, output_file_path=out_file)
```

is_valid()

Checks the validity of the model and all of its packages

Returns
valid

Return type
bool

property laycbd

Quasi-3D confining bed. Not supported in MODFLOW-6.

Returns
None

Return type
None

property laytyp

Layering type

static load_base(*cls_child*, *simulation*, *structure*, *modelname='NewModel'*, *model_nam_file='modflowtest.nam'*, *mtype='gwf'*, *version='mf6'*, *exe_name: str | PathLike = 'mf6'*, *strict=True*, *model_rel_path='.'*, *load_only=None*)

Class method that loads an existing model.

Parameters

- **simulation** (*MFSimulation*) – simulation object that this model is a part of
- **simulation_data** (*MFSimulationData*) – simulation data object
- **structure** (*MFModelStructure*) – structure of this type of model
- **model_name** (*str*) – name of the model

- **model_nam_file** (*str*) - relative path to the model name file from model working folder
- **version** (*str*) - version of modflow
- **exe_name** (*str or PathLike*) - model executable name or path
- **strict** (*bool*) - strict mode when loading files
- **model_rel_path** (*str*) - relative path of model folder to simulation folder
- **load_only** (*list*) - list of package abbreviations or package names corresponding to packages that flopy will load. default is None, which loads all packages. the discretization packages will load regardless of this setting. subpackages, like time series and observations, will also load regardless of this setting. example list: ['ic', 'maw', 'npf', 'oc', 'my_well_package_1']

Returns
model

Return type
MFModel

Examples

load_package(*ftype*, *fname*, *pname*, *strict*, *ref_path*, *dict_package_name=None*, *parent_package=None*)

Loads a package from a file. This method is used internally by FloPy and is not intended for the end user.

Parameters

- **ftype** (*str*) - the file type
- **fname** (*str*) - the name of the file containing the package input
- **pname** (*str*) - the user-defined name for the package
- **strict** (*bool*) - strict mode when loading the file
- **ref_path** (*str*) - path to the file. uses local path if set to None
- **dict_package_name** (*str*) - package name for dictionary lookup
- **parent_package** (MFPackage) - parent package

Examples

match_array_cells(*cell_list*, *data_shape*, *array_data*, *key*, *data_output*)

property model_ws

Model file path.

property modeldiscrit

Basic model spatial discretization information. This is used internally prior to model spatial discretization information being fully loaded.

Returns
model grid - FloPy object containing basic spatial discretization information for the model.

Return type
Grid subclass

property modelgrid

Model spatial discretization information.

Returns
model grid - FloPy object containing spatial discretization information for the model.

Return type
Grid subclass

property modeltime

Model time discretization information.

Returns
modeltime - FloPy object containing time discretization information for the simulation.

Return type
ModelTime

property namefile

Model namefile object.

property nper

Number of stress periods.

Returns
nper - Number of stress periods in the simulation.

Return type
int

property output

property packagelist

List of model packages.

plot(*SelPackList=None*, ***kwargs*)

Plot 2-D, 3-D, transient 2-D, and stress period list (MfList) model input data from a model instance

Parameters

- **model** - Flopy model instance
- **SelPackList** - (list) list of package names to plot, if none all packages will be plotted
- ****kwargs** - dict filename_base : str

  Base file name that will be used to automatically generate file names for output image files. Plots will be exported as image files if file_name_base is not None. (default is None)

file_extension
[str] Valid matplotlib.pyplot file extension for savefig(). Only used if filename_base is not None. (default is 'png')

mflay
[int] MODFLOW zero-based layer number to return. If None, then all all layers will be included. (default is None)

kper
[int] MODFLOW zero-based stress period number to return. (default is zero)

key
[str] MfList dictionary key. (default is None)

Returns

list
Empty list is returned if filename_base is not None. Otherwise a list of matplotlib.pyplot.axis are returned.

Return type
axes

register_package(*package*, *add_to_package_list=True*, *set_package_name=True*, *set_package_filename=True*)

Registers a package with the model. This method is used internally by FloPy and is not intended for use by the end user.

Parameters

- **package** (MFPackage) – Package to register
- **add_to_package_list** (*bool*) – Add package to lookup list
- **set_package_name** (*bool*) – Produce a package name for this package
- **set_package_filename** (*bool*) – Produce a filename for this package

Returns
path, package structure

Return type
tuple, MFPackageStructure

remove_package(*package_name*)

Removes package and all child packages from the model. *package_name* can be the package's name, type, or package object to be removed from the model.

Parameters
package_name (*str*) – Package name, package type, or package object to be removed from the model.

rename_all_packages(*name*)

Renames all package files in the model.

Parameters
name (*str*) – Prefix of package names. Packages files will be named <name>.<package ext>.

set_all_data_external(*check_data=True*, *external_data_folder=None*)

Sets the model's list and array data to be stored externally.

Parameters

- **check_data** (*bool*) – Determines if data error checking is enabled during this process.
- **external_data_folder** – Folder, relative to the simulation path or model relative path (see use_model_relative_path parameter), where external data will be stored

set_all_data_internal(*check_data=True*)

Sets the model's list and array data to be stored externally.

Parameters

check_data (*bool*) – Determines if data error checking is enabled during this process.

set_model_relative_path(*model_ws*)

Sets the file path to the model folder relative to the simulation folder and updates all model file paths, placing them in the model folder.

Parameters

model_ws (*str*) – Model working folder relative to simulation working folder

property solver_tols

Returns the solver inner hclose and rclose values.

Returns

inner_hclose, rclose

Return type

float, float

update_package_filename(*package*, *new_name*)

Updates the filename for a package. For internal flopy use only.

Parameters

- **package** (MFPackage) – Package object
- **new_name** (*str*) – New package name

property verbose

Verbose setting for model operations (True/False)

property version

Version of MODFLOW

write(*ext_file_action=ExtFileAction.copy_relative_paths*)

Writes out model's package files.

Parameters

ext_file_action (ExtFileAction) – Defines what to do with external files when the simulation path has changed. defaults to copy_relative_paths which copies only files with relative paths, leaving files defined by absolute paths fixed.

flopy.mf6.mfpackage module

class MFBlock(*simulation_data*, *dimensions*, *structure*, *path*, *model_or_sim*, *container_package*)

Bases: object

Represents a block in a MF6 input file. This class is used internally by FloPy and use by users of the FloPy library is not recommended.

Parameters

- **simulation_data** (MFSimulationData) – Data specific to this simulation
- **dimensions** (*MFDimensions*) – Describes model dimensions including model grid and simulation time
- **structure** (*MFVariableStructure*) – Structure describing block
- **path** (*tuple*) – Unique path to block

block_headers

Block header text (BEGIN/END), header variables, comments in the header

Type
MFBlockHeader

structure

Structure describing block

Type
MFBlockStructure

path

Unique path to block

Type
tuple

datasets

Dictionary of dataset objects with keys that are the name of the dataset

Type
OrderDict

datasets_keyword

Dictionary of dataset objects with keys that are key words to identify start of dataset

Type
dict

enabled

If block is being used in the simulation

Type
bool

add_dataset(*dataset_struct*, *data*, *var_path*)

Add data to this block.

data_factory(*sim_data*, *model_or_sim*, *structure*, *enable*, *path*, *dimensions*, *data=None*, *package=None*)

Creates the appropriate data child object derived from MFData.

header_exists(*key*, *data_path=None*)

is_allowed()

Determine if block is valid based on the values of dependant MODFLOW variables.

is_empty()

Returns true if this block is empty.

is_valid()

Returns true of the block is valid.

load(*block_header*, *fd*, *strict=True*)

Loads block from file object. file object must be advanced to beginning of block before calling.

Parameters

- **block_header** (MFBlockHeader) – Block header for block block being loaded.
- **fd** (*file*) – File descriptor of file being loaded
- **strict** (*bool*) – Enforce strict MODFLOW 6 file format.

set_all_data_external(*base_name*, *check_data=True*, *external_data_folder=None*)

Sets the block's list and array data to be stored externally, base_name is external file name's prefix, check_data determines if data error checking is enabled during this process.

Parameters

- **base_name** (*str*) – Base file name of external files where data will be written to.
- **check_data** (*bool*) – Whether to do data error checking.
- **external_data_folder** – Folder where external data will be stored

set_all_data_internal(*check_data=True*)

Sets the block's list and array data to be stored internally, check_data determines if data error checking is enabled during this process.

Parameters
check_data (*bool*) – Whether to do data error checking.

set_model_relative_path(*model_ws*)

Sets *model_ws* as the model path relative to the simulation's path.

Parameters
model_ws (*str*) – Model path relative to the simulation's path.

write(*fd*, *ext_file_action=ExtFileAction.copy_relative_paths*)

Writes block to a file object.

Parameters
fd (*file object*) – File object to write to.

class **MFBlockHeader**(*name*, *variable_strings*, *comment*, *simulation_data=None*, *path=None*, *block=None*)

Bases: object

Represents the header of a block in a MF6 input file. This class is used internally by FloPy and its direct use by a user of this library is not recommend.

Parameters

- **name** (*str*) – Block name
- **variable_strings** (*list*) – List of strings that appear after the block name
- **comment** (*MFComment*) – Comment text in the block header

name

Block name

Type
str

variable_strings

List of strings that appear after the block name

Type
list

comment

Comment text in the block header

Type
MFComment

data_items

List of MFVariable of the variables contained in this block

Type
list

add_data_item(*new_data*, *data*)

Adds data to the block.

build_header_variables(*simulation_data*, *block_header_structure*, *block_path*, *data*, *dimensions*)

Builds data objects to hold header variables.

connect_to_dict(*simulation_data*, *path*, *comment=None*)

Add comment to the simulation dictionary

get_comment()

Get block header comment

get_transient_key(*data_path=None*)

Get transient key associated with this block header.

is_same_header(*block_header*)

Checks if *block_header* is the same header as this header.

write_footer(*fd*)

Writes block footer to file object *fd*.

Parameters

fd (*file object*) – File object to write block footer to.

write_header(*fd*)

Writes block header to file object *fd*.

Parameters

fd (*file object*) – File object to write block header to.

class MFChildPackages(*model_or_sim*, *parent*, *pkg_type*, *filerecord*, *package=None*, *package_class=None*)

Bases: object

Behind the scenes code for creating an interface to access child packages from a parent package. This class is automatically constructed by the FloPy library and is for internal library use only.

init_package(*package*, *fname*, *remove_packages=True*)

class MFPackage(*parent*, *package_type*, *filename=None*, *pname=None*, *loading_package=False*, ***kwargs*)

Bases: *PackageContainer*, *PackageInterface*

Provides an interface for the user to specify data to build a package.

Parameters

- **parent** (MFModel, MFSimulation, *or* MFPackage) – The parent model, simulation, or package containing this package
- **package_type** (*str*) – String defining the package type
- **filename** (*str or PathLike*) – Name or path of file where this package is stored
- **quoted_filename** (*str*) – Filename with quotes around it when there is a space in the name
- **pname** (*str*) – Package name
- **loading_package** (*bool*) – Whether or not to add this package to the parent container's package list during initialization

blocks

Dictionary of blocks contained in this package by block name

Type

dict

path

Data dictionary path to this package

Type

tuple

structure

Describes the blocks and data contain in this package

Type

PackageStructure

dimensions

Resolves data dimensions for data within this package

Type
PackageDimension

build_child_package(*pkg_type*, *data*, *parameter_name*, *filerecord*)

Builds a child package. This method is only intended for FloPy internal use.

build_child_packages_container(*pkg_type*, *filerecord*)

Builds a container object for any child packages. This method is only intended for FloPy internal use.

build_mfdata(*var_name*, *data=None*)

Returns the appropriate data type object (mfdatalist, mfdataarray, or mfdatascalar) given that object the appropriate structure (looked up based on var_name) and any data supplied. This method is for internal FloPy library use only.

Parameters

- **var_name** (*str*) – Variable name
- **data** (*many supported types*) – Data contained in this object

Returns
data object

Return type
MFData subclass

check(*f=None*, *verbose=True*, *level=1*, *checktype=None*)

Data check, returns True on success.

create_package_dimensions()

Creates a package dimensions object. For internal FloPy library use.

Returns
package dimensions

Return type
PackageDimensions

property data_list

List of data in this package.

export(*f*, ***kwargs*)

Method to export a package to netcdf or shapefile based on the extension of the file name (.shp for shapefile, .nc for netcdf)

Parameters

- **f** (*str*) – Filename
- **kwargs** (*keyword arguments*) –

  modelgrid
  [flopy.discretization.Grid instance] User supplied modelgrid which can be used for exporting in lieu of the modelgrid associated with the model object

Return type
None or Netcdf object

property filename

Package's file name.

get_file_path()

Returns the package file's path.

Returns
file path

Return type
str

inspect_cells(*cell_list*, *stress_period=None*)

Inspect model cells. Returns package data associated with cells.

Parameters

- **cell_list** (*list of tuples*) – List of model cells. Each model cell is a tuple of integers. ex: [(1,1,1), (2,4,3)]
- **stress_period** (*int*) – For transient data, only return data from this stress period. If not specified or None, all stress period data will be returned.

Returns
output – Array containing inspection results

Return type
array

is_valid()

Returns whether or not this package is valid.

Returns
is valid

Return type
bool

load(*strict=True*)

Loads the package from file.

Parameters
strict (*bool*) – Enforce strict checking of data.

Returns
success

Return type
bool

property name

Name of package

property output

Method to get output associated with a specific package

Return type
MF6Output object

property package_type
String describing type of package

property parent
Parent package

plot(***kwargs*)
Plot 2-D, 3-D, transient 2-D, and stress period list (MfList) package input data

Parameters
****kwargs** (*dict*) –

filename_base
[str] Base file name that will be used to automatically generate file names for output image files. Plots will be exported as image files if file_name_base is not None. (default is None)

file_extension
[str] Valid matplotlib.pyplot file extension for savefig(). Only used if filename_base is not None. (default is 'png')

mflay
[int] MODFLOW zero-based layer number to return. If None, then all all layers will be included. (default is None)

kper
[int] MODFLOW zero-based stress period number to return. (default is zero)

key
[str] MfList dictionary key. (default is None)

Returns
axes – Empty list is returned if filename_base is not None. Otherwise a list of matplotlib.pyplot.axis are returned.

Return type
list

property plottable
If package is plottable

property quoted_filename
Package's file name with quotes if there is a space.

remove()
Removes this package from the simulation/model it is currently a part of.

set_all_data_external(*check_data=True*, *external_data_folder=None*)
Sets the package's list and array data to be stored externally.

Parameters

- **check_data** (*bool*) – Determine if data error checking is enabled
- **external_data_folder** – Folder where external data will be stored

set_all_data_internal(*check_data=True*)
Sets the package's list and array data to be stored internally.

Parameters
check_data (*bool*) – Determine if data error checking is enabled

set_model_relative_path(*model_ws*)

Sets the model path relative to the simulation's path.

Parameters

model_ws (*str*) – Model path relative to the simulation's path.

write(*ext_file_action=ExtFileAction.copy_relative_paths*)

Writes the package to a file.

Parameters

ext_file_action (ExtFileAction) – How to handle pathing of external data files.

flopy.mf6.mfsimbase module

class MFSimulationBase(*sim_name='sim'*, *version='mf6'*, *exe_name: str | PathLike = 'mf6'*, *sim_ws: str | PathLike = '.'*, *verbosity_level=1*, *continue_=None*, *nocheck=None*, *memory_print_option=None*, *write_headers=True*, *lazy_io=False*, *use_pandas=True*)

Bases: *PackageContainer*

Entry point into any MODFLOW simulation.

MFSimulation is used to load, build, and/or save a MODFLOW 6 simulation. A MFSimulation object must be created before creating any of the MODFLOW 6 model objects.

Parameters

- **sim_name** (*str*) – Name of the simulation.
- **version** (*str*) – Version of MODFLOW 6 executable
- **exe_name** (*str*) – Path to MODFLOW 6 executable
- **sim_ws** (*str*) – Path to MODFLOW 6 simulation working folder. This is the folder containing the simulation name file.
- **verbosity_level** (*int*) – Verbosity level of standard output from 0 to 2. When 0 is specified no standard output is written. When 1 is specified standard error/warning messages with some informational messages are written. When 2 is specified full error/warning/informational messages are written (this is ideal for debugging).
- **continue** (*bool*) – Sets the continue option in the simulation name file. The continue option is a keyword flag to indicate that the simulation should continue even if one or more solutions do not converge.
- **nocheck** (*bool*) – Sets the nocheck option in the simulation name file. The nocheck option is a keyword flag to indicate that the model input check routines should not be called prior to each time step. Checks are performed by default.
- **memory_print_option** (*str*) – Sets memory_print_option in the simulation name file. Memory_print_option is a flag that controls printing of detailed memory manager usage to the end of the simulation list file. NONE means do not print detailed information.

SUMMARY means print only the total memory for each simulation component. ALL means print information for each variable stored in the memory manager. NONE is default if memory_print_option is not specified.

- **write_headers** (*bool*) - When true flopy writes a header to each package file indicating that it was created by flopy.
- **lazy_io** (*bool*) - When true flopy only reads external data when the data is requested and only writes external data if the data has changed. This option automatically overrides the verify_data and auto_set_sizes, turning both off.
- **use_pandas** (*bool*) - Load/save data using pandas dataframes (for supported data)

Examples

```
>>> s = MFSimulationBase.load('my simulation', 'simulation.nam')
```

sim_name

Name of the simulation

Type
str

name_file

Simulation name file package

Type
MFPackage

check(*f: str | PathLike | None = None*, *verbose=True*, *level=1*)

Check model data for common errors.

Parameters

- **f** (*str or PathLike, optional*) - String defining file name or file handle for summary file of check method output. If str or pathlike, a file handle is created. If None, the method does not write results to a summary file. (default is None)
- **verbose** (*bool*) - Boolean flag used to determine if check method results are written to the screen
- **level** (*int*) - Check method analysis level. If level=0, summary checks are performed. If level=1, full checks are performed.

Returns
check list - Python list containing simulation check results

Return type
list

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow.load('model.nam')
>>> m.check()
```

delete_output_files()

Deletes simulation output files.

property exchange_files

Return list of exchange files associated with this simulation.

Returns
: **list**

Return type
: list of exchange names

get_exchange_file(*filename*)

Get a specified exchange file.

Parameters
: **filename** (*str*) – Name of exchange file to get

Returns
: **exchange package**

Return type
: *MFPackage*

get_file(*filename*)

Get a specified file.

Parameters
: **filename** (*str*) – Name of mover file to get

Returns
: **mover package**

Return type
: *MFPackage*

get_model(*model_name=None*)

Returns the models in the simulation with a given model name, name file name, or model type.

Parameters
: **model_name** (*str*) – Name of the model to get. Passing in None or an empty list will get the first model.

Returns
: **model**

Return type
: *MFModel*

get_solution_package(*key*)

Get the solution package with the specified *key*.

Parameters
: **key** (*str*) – solution package file name

Returns
solution_package

Return type
MFPackage

is_valid()

Checks the validity of the solution and all of its models and packages. Returns true if the solution is valid, false if it is not.

Returns
valid – Whether this is a valid simulation

Return type
bool

static load(*cls_child*, *sim_name='modflowsim'*, *version='mf6'*, *exe_name: str | PathLike = 'mf6'*, *sim_ws: str | PathLike = '.'*, *strict=True*, *verbosity_level=1*, *load_only=None*, *verify_data=False*, *write_headers=True*, *lazy_io=False*, *use_pandas=True*)

Load an existing model. Do not call this method directly. Should only be called by child class.

Parameters

- **cls_child** – cls object of child class calling load
- **sim_name** (*str*) – Name of the simulation.
- **version** (*str*) – MODFLOW version
- **exe_name** (*str or PathLike*) – Path to MODFLOW executable (relative to the simulation workspace or absolute)
- **sim_ws** (*str or PathLike*) – Path to simulation workspace
- **strict** (*bool*) – Strict enforcement of file formatting
- **verbosity_level** (*int*) –

  Verbosity level of standard output
  0: No standard output 1: Standard error/warning messages with some informational

  messages

  2: Verbose mode with full error/warning/informational
  messages. This is ideal for debugging.

- **load_only** (*list*) – List of package abbreviations or package names corresponding to packages that flopy will load. default is None, which loads all packages. the discretization packages will load regardless of this setting. subpackages, like time series and observations, will also load regardless of this setting. example list: ['ic', 'maw', 'npf', 'oc', 'ims', 'gwf6-gwf6']
- **verify_data** (*bool*) – Verify data when it is loaded. this can slow down loading
- **write_headers** (*bool*) – When true flopy writes a header to each package file indicating that it was created by flopy

- **lazy_io** (*bool*) – When true flopy only reads external data when the data is requested and only writes external data if the data has changed. This option automatically overrides the verify_data and auto_set_sizes, turning both off.
- **use_pandas** (*bool*) – Load/save data using pandas dataframes (for supported data)

Returns
sim

Return type
MFSimulation object

Examples

```
>>> s = flopy.mf6.mfsimulation.load('my simulation')
```

load_package(*ftype*, *fname: str | PathLike*, *pname*, *strict*, *ref_path: str | PathLike*, *dict_package_name=None*, *parent_package=None*)

Load a package from a file.

Parameters

- **ftype** (*str*) – the file type
- **fname** (*str or PathLike*) – the path of the file containing the package input
- **pname** (*str*) – the user-defined name for the package
- **strict** (*bool*) – strict mode when loading the file
- **ref_path** (*str*) – path to the file. uses local path if set to None
- **dict_package_name** (*str*) – package name for dictionary lookup
- **parent_package** (MFPackage) – parent package

property model_dict

Return a dictionary of models associated with this simulation.

Returns
model dict – dictionary of models

Return type
dict

property model_names

Return a list of model names associated with this simulation.

Returns
list

Return type
list of model names

plot(*model_list: str | List[str] | None = None*, *SelPackList=None*, ***kwargs*)

Plot simulation or models.

Method to plot a whole simulation or a series of models that are part of a simulation.

Parameters

- **model_list** (*list*, *optional*) – List of model names to plot, if none all models will be plotted
- **SelPackList** (*list*, *optional*) – List of package names to plot, if none all packages will be plotted
- **kwargs** –

  filename_base
  [str] Base file name that will be used to automatically generate file names for output image files. Plots will be exported as image files if file_name_base is not None. (default is None)

  file_extension
  [str] Valid matplotlib.pyplot file extension for savefig(). Only used if filename_base is not None. (default is 'png')

  mflay
  [int] MODFLOW zero-based layer number to return. If None, then all layers will be included. (default is None)

  kper
  [int] MODFLOW zero-based stress period number to return. (default is zero)

  key
  [str] MFList dictionary key. (default is None)

Returns
axes – matplotlib.pyplot.axes objects

Return type
(list)

register_exchange_file(*package*)

Register an exchange package file with the simulation. This is a call-back method made from the package and should not be called directly.

Parameters
package (MFPackage) – Exchange package object to register

register_ims_package(*solution_file: MFPackage*, *model_list: str | List[str]*)

register_model(*model*, *model_type*, *model_name*, *model_namefile*)

Add a model to the simulation. This is a call-back method made from the package and should not be called directly.

Parameters

- **model** (MFModel) – Model object to add to simulation
- **sln_group** (*str*) – Solution group of model

Returns
model_structure_object

Return type
MFModelStructure

register_package(*package*, *add_to_package_list=True*, *set_package_name=True*, *set_package_filename=True*)

Register a package file with the simulation. This is a call-back method made from the package and should not be called directly.

Parameters

- **package** (MFPackage) – Package to register
- **add_to_package_list** (*bool*) – Add package to lookup list
- **set_package_name** (*bool*) – Produce a package name for this package
- **set_package_filename** (*bool*) – Produce a filename for this package

Returns
(path

Return type
tuple, package structure : MFPackageStructure)

register_solution_package(*solution_file: MFPackage*, *model_list: str | List[str]*)

Register a solution package with the simulation.

Parameters

solution_file
[MFPackage] solution package to register

model_list
[list of strings] list of models using the solution package to be registered

remove_exchange_file(*package*)

Removes the exchange file "package". This is for internal flopy library use only.

Parameters
package (MFPackage) – Exchange package to be removed

remove_model(*model_name*)

Remove model with name *model_name* from the simulation

Parameters
model_name (*str*) – Model name to remove from simulation

remove_package(*package_name*)

Removes package from the simulation. *package_name* can be the package's name, type, or package object to be removed from the model.

Parameters
package_name (*str*) – Name of package to be removed

rename_all_packages(*name*)

Rename all packages with name as prefix.

Parameters

name (*str*) – Prefix of package names

rename_model_namefile(*model*, *new_namefile*)

Rename a model's namefile. For internal flopy library use only.

Parameters

- **model** (MFModel) – Model object whose namefile to rename
- **new_namefile** (*str*) – Name of the new namefile

run_simulation(*silent=None*, *pause=False*, *report=False*, *processors=None*, *normal_msg='normal termination'*, *use_async=False*, *cargs=None*)

Run the simulation.

Parameters

- **silent** (*bool*) – Run in silent mode
- **pause** (*bool*) – Pause at end of run
- **report** (*bool*) – Save stdout lines to a list (buff)
- **processors** (*int*) – Number of processors. Parallel simulations are only supported for MODFLOW 6 simulations. (default is None)
- **normal_msg** (*str or list*) – Normal termination message used to determine if the run terminated normally. More than one message can be provided using a list. (default is 'normal termination')
- **use_async** (*bool*) – Asynchronously read model stdout and report with timestamps. good for models that take long time to run. not good for models that run really fast
- **cargs** (*str or list of strings*) – Additional command line arguments to pass to the executable. default is None

Returns

- **success** (*bool*)
- **buff** (*list of lines of stdout*)

set_all_data_external(*check_data=True*, *external_data_folder=None*)

Sets the simulation's list and array data to be stored externally.

Parameters

- **check_data** (*bool*) – Determines if data error checking is enabled during this process. Data error checking can be slow on large datasets.
- **external_data_folder** (*str or PathLike*) – Path relative to the simulation path or model relative path (see use_model_relative_path parameter), where external data will be stored

set_all_data_internal(*check_data=True*)

set_sim_path(*path: str | PathLike*)

Return a list of output data keys.

Parameters

path (*str*) – Relative or absolute path to simulation root folder.

property sim_package_list

List of all "simulation level" packages

property sim_path: Path

update_package_filename(*package*, *new_name*)

Updates internal arrays to be consistent with a new file name. This is for internal flopy library use only.

Parameters

- **package** (MFPackage) – Package with new name
- **new_name** (*str*) – Package's new name

write_simulation(*ext_file_action=ExtFileAction.copy_relative_paths*, *silent=False*)

Write the simulation to files.

Parameters

ext_file_action

[ExtFileAction] Defines what to do with external files when the simulation path has changed. Defaults to copy_relative_paths which copies only files with relative paths, leaving files defined by absolute paths fixed.

silent

[bool] Writes out the simulation in silent mode (verbosity_level = 0)

class MFSimulationData(*path: str | PathLike*, *mfsim*)

Bases: object

Class containing MODFLOW simulation data and file formatting data. Use MFSimulationData to set simulation-wide settings which include data formatting and file location settings.

Parameters

path (*str*) – path on disk to the simulation

indent_string

String used to define how much indent to use (file formatting)

Type

str

internal_formatting

List defining string to use for internal formatting

Type

list

external_formatting

List defining string to use for external formatting

Type

list

open_close_formatting

List defining string to use for open/close

Type
list

max_columns_of_data

Maximum columns of data before line wraps. For structured grids this is set to ncol by default. For all other grids the default is 20.

Type
int

wrap_multidim_arrays

Whether to wrap line for multi-dimensional arrays at the end of a row/column/layer

Type
bool

_float_precision

Number of decimal points to write for a floating point number

Type
int

_float_characters

Number of characters a floating point number takes up

Type
int

write_headers

When true flopy writes a header to each package file indicating that it was created by flopy

Type
bool

sci_note_upper_thres

Numbers greater than this threshold are written in scientific notation

Type
float

sci_note_lower_thres

Numbers less than this threshold are written in scientific notation

Type
float

mfpath

File path location information for the simulation

Type
MFFileMgmt

model_dimensions

Dictionary containing discretization information for each model

Type
dict

mfdata
Custom dictionary containing all model data for the simulation

Type
SimulationDict

property float_characters
Gets max characters used in floating point numbers.

property float_precision
Gets precision of floating point numbers.

property lazy_io

property max_columns_of_data

set_sci_note_lower_thres(*value*)
Sets threshold number where any number smaller than threshold is represented in scientific notation.

Parameters
value (*float*) – threshold value

set_sci_note_upper_thres(*value*)
Sets threshold number where any number larger than threshold is represented in scientific notation.

Parameters
value (*float*) – threshold value

class SimulationDict(*path=None*)
Bases: dict

Class containing custom dictionary for MODFLOW simulations. Dictionary contains model data. Dictionary keys are "paths" to the data that include the model and package containing the data.

Behaves as an dict with some additional features described below.

Parameters
path (MFFileMgmt) – Object containing path information for the simulation

find_in_path(*key_path*, *key_leaf*)
Attempt to find key_leaf in a partial key path key_path.

Parameters

- **key_path** (*str*) – partial path to the data
- **key_leaf** (*str*) – name of the data

Returns

- **Data** (*MFData,*)
- **index** (*int*)

input_keys()

Return a list of input data keys.

Returns
input keys

Return type
list

keys()

Return a list of all keys.

Returns
all keys

Return type
list

observation_keys()

Return a list of observation keys.

Returns
observation keys

Return type
list

output_keys(*print_keys=True*)

Return a list of output data keys supported by the dictionary.

Parameters
print_keys (*bool*) – print keys to console

Returns
output keys

Return type
list

12.1.2 MODFLOW 6 Simulation

MODFLOW 6 allows you to create simulations that can contain multiple models and packages. The FloPy for MODFLOW 6 simulation classes define functionality that applies to the entire MODFLOW 6 simulation. When using FloPy for MODFLOW 6 the first object you will most likely create is a simulation (MFSimulation) object.

Contents:

flopy.mf6.modflow.mfsimulation module

class MFSimulation(*sim_name='sim'*, *version='mf6'*, *exe_name: str | PathLike = 'mf6'*, *sim_ws: str | PathLike = '.'*, *verbosity_level=1*, *write_headers=True*, *use_pandas=True*, *lazy_io=False*, *continue_=None*, *nocheck=None*, *memory_print_option=None*, *maxerrors=None*, *print_input=None*)

Bases: *MFSimulationBase*

MFSimulation is used to load, build, and/or save a MODFLOW 6 simulation. A MFSimulation object must be created before creating any of the MODFLOW 6 model objects.

Parameters

- **sim_name** (*str*) - Name of the simulation
- **continue** (*boolean*) -
  - continue (boolean) keyword flag to indicate that the simulation should continue even if one or more solutions do not converge.
- **nocheck** (*boolean*) -
  - nocheck (boolean) keyword flag to indicate that the model input check routines should not be called prior to each time step. Checks are performed by default.
- **memory_print_option** (*string*) -
  - memory_print_option (string) is a flag that controls printing of detailed memory manager usage to the end of the simulation list file. NONE means do not print detailed information. SUMMARY means print only the total memory for each simulation component. ALL means print information for each variable stored in the memory manager. NONE is default if MEMORY_PRINT_OPTION is not specified.
- **maxerrors** (*integer*) -
  - maxerrors (integer) maximum number of errors that will be stored and printed.
- **print_input** (*boolean*) -
  - print_input (boolean) keyword to activate printing of simulation input summaries to the simulation list file (mfsim.lst). With this keyword, input summaries will be written for those packages that support newer input data model routines. Not all packages are supported yet by the newer input data model routines.
- **tdis6** (*string*) -
  - tdis6 (string) is the name of the Temporal Discretization (TDIS) Input File.
- **models** (*[mtype, mfname, mname]*) -
  - mtype (string) is the type of model to add to simulation.
  - mfname (string) is the file name of the model name file.
  - mname (string) is the user-assigned name of the model. The model name cannot exceed 16 characters and must not have blanks within the name. The model name is case insensitive; any lowercase letters are converted and stored as upper case letters.
- **exchanges** (*[exgtype, exgfile, exgmnamea, exgmnameb]*) -
  - exgtype (string) is the exchange type.
  - exgfile (string) is the input file for the exchange.
  - exgmnamea (string) is the name of the first model that is part of this exchange.

  - exgmnameb (string) is the name of the second model that is part of this exchange.

- **mxiter** (*integer*) –
  - mxiter (integer) is the maximum number of outer iterations for this solution group. The default value is 1. If there is only one solution in the solution group, then MXITER must be 1.

- **solutiongroup** (*[slntype, slnfname, slnmnames]*) –
  - slntype (string) is the type of solution. The Integrated Model Solution (IMS6) is the only supported option in this version.
  - slnfname (string) name of file containing solution input.
  - slnmnames (string) is the array of model names to add to this solution. The number of model names is determined by the number of model names the user provides on this line.

load : (sim_name : str, version : string,

exe_name : str or PathLike, sim_ws : str or PathLike, strict : bool, verbosity_level : int, load_only : list, verify_data : bool, write_headers : bool, lazy_io : bool, use_pandas : bool,) : MFSimulation a class method that loads a simulation from files

classmethod load(*sim_name='modflowsim'*, *version='mf6'*, *exe_name: str | PathLike = 'mf6'*, *sim_ws: str | PathLike = '.'*, *strict=True*, *verbosity_level=1*, *load_only=None*, *verify_data=False*, *write_headers=True*, *lazy_io=False*, *use_pandas=True*)

Load an existing model. Do not call this method directly. Should only be called by child class.

Parameters

- **cls_child** – cls object of child class calling load
- **sim_name** (*str*) – Name of the simulation.
- **version** (*str*) – MODFLOW version
- **exe_name** (*str or PathLike*) – Path to MODFLOW executable (relative to the simulation workspace or absolute)
- **sim_ws** (*str or PathLike*) – Path to simulation workspace
- **strict** (*bool*) – Strict enforcement of file formatting
- **verbosity_level** (*int*) –

  Verbosity level of standard output

  0: No standard output 1: Standard error/warning messages with some informational

  messages

  2: Verbose mode with full error/warning/informational

  messages. This is ideal for debugging.

- **load_only** (*list*) – List of package abbreviations or package names corresponding to packages that flopy will load. default is None, which loads all packages. the discretization packages will load regardless of this setting. subpackages, like time series and observations, will also load regardless of this setting. example list: ['ic', 'maw', 'npf', 'oc', 'ims', 'gwf6-gwf6']

- **verify_data** (*bool*) - Verify data when it is loaded. this can slow down loading
- **write_headers** (*bool*) - When true flopy writes a header to each package file indicating that it was created by flopy
- **lazy_io** (*bool*) - When true flopy only reads external data when the data is requested and only writes external data if the data has changed. This option automatically overrides the verify_data and auto_set_sizes, turning both off.
- **use_pandas** (*bool*) - Load/save data using pandas dataframes (for supported data)

Returns
    sim

Return type
    MFSimulation object

Examples

```
>>> s = flopy.mf6.mfsimulation.load('my simulation')
```

12.1.3 MODFLOW 6 Simulation Packages

MODFLOW 6 simulation packages are the packages that are not necessarily tied to a specific model and can apply to the entire simulation or a group of models in the simulation.

Contents:

flopy.mf6.modflow.mfgnc module

class GncPackages(*model_or_sim*, *parent*, *pkg_type*, *filerecord*, *package=None*, *package_class=None*)

Bases: *MFChildPackages*

GncPackages is a container class for the ModflowGnc class.

initialize()

Initializes a new ModflowGnc package removing any sibling child packages attached to the same parent package. See ModflowGnc init documentation for definition of parameters.

append_package()

Adds a new ModflowGwfgnc package to the container. See ModflowGwfgnc init documentation for definition of parameters.

append_package(*print_input=None*, *print_flows=None*, *explicit=None*, *numgnc=None*, *numalphaj=None*, *gncdata=None*, *filename=None*, *pname=None*)

initialize(*print_input=None*, *print_flows=None*, *explicit=None*, *numgnc=None*, *numalphaj=None*, *gncdata=None*, *filename=None*, *pname=None*)

package_abbr = 'gncpackages'

class **ModflowGnc**(*simulation*, *loading_package=False*, *print_input=None*, *print_flows=None*, *explicit=None*, *numgnc=None*, *numalphaj=None*, *gncdata=None*, *filename=None*, *pname=None*, ***kwargs*)

Bases: *MFPackage*

ModflowGnc defines a gnc package.

Parameters

- **simulation** (MFSimulation) - Simulation that this package is a part of. Package is automatically added to simulation when it is initialized.
- **loading_package** (*bool*) - Do not set this parameter. It is intended for debugging and internal processing purposes only.
- **print_input** (*boolean*) -
  - print_input (boolean) keyword to indicate that the list of GNC information will be written to the listing file immediately after it is read.
- **print_flows** (*boolean*) -
  - print_flows (boolean) keyword to indicate that the list of GNC flow rates will be printed to the listing file for every stress period time step in which "BUDGET PRINT" is specified in Output Control. If there is no Output Control option and "PRINT_FLOWS" is specified, then flow rates are printed for the last time step of each stress period.
- **explicit** (*boolean*) -
  - explicit (boolean) keyword to indicate that the ghost node correction is applied in an explicit manner on the right-hand side of the matrix. The explicit approach will likely require additional outer iterations. If the keyword is not specified, then the correction will be applied in an implicit manner on the left-hand side. The implicit approach will likely converge better, but may require additional memory. If the EXPLICIT keyword is not specified, then the BICGSTAB linear acceleration option should be specified within the LINEAR block of the Sparse Matrix Solver.
- **numgnc** (*integer*) -
  - numgnc (integer) is the number of GNC entries.
- **numalphaj** (*integer*) -
  - numalphaj (integer) is the number of contributing factors.
- **gncdata** (*[cellidn, cellidm, cellidsj, alphasj]*) -

- cellidn ((integer, ...)) is the cellid of the cell, n, in which the ghost node is located. For a structured grid that uses the DIS input file, CELLIDN is the layer, row, and column numbers of the cell. For a grid that uses the DISV input file, CELLIDN is the layer number and CELL2D number for the two cells. If the model uses the unstructured discretization (DISU) input file, then CELLIDN is the node number for the cell. This argument is an index variable, which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.
- cellidm ((integer, ...)) is the cellid of the connecting cell, m, to which flow occurs from the ghost node. For a structured grid that uses the DIS input file, CELLIDM is the layer, row, and column numbers of the cell. For a grid that uses the DISV input file, CELLIDM is the layer number and CELL2D number for the two cells. If the model uses the unstructured discretization (DISU) input file, then CELLIDM is the node number for the cell. This argument is an index variable, which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.
- cellidsj ((integer, ...)) is the array of CELLIDS for the contributing j cells, which contribute to the interpolated head value at the ghost node. This item contains one CELLID for each of the contributing cells of the ghost node. Note that if the number of actual contributing cells needed by the user is less than NUMALPHAJ for any ghost node, then a dummy CELLID of zero(s) should be inserted with an associated contributing factor of zero. For a structured grid that uses the DIS input file, CELLID is the layer, row, and column numbers of the cell. For a grid that uses the DISV input file, CELLID is the layer number and cell2d number for the two cells. If the model uses the unstructured discretization (DISU) input file, then CELLID is the node number for the cell. This argument is an index variable, which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.
- alphasj (double) is the contributing factors for each contributing node in CELLIDSJ. Note that if the number of actual contributing cells is less than NUMALPHAJ for any ghost node, then dummy CELLIDS should be inserted with an associated contributing factor of zero. The sum of ALPHASJ should be less than one. This is because one minus the sum of ALPHASJ is equal to the alpha term (alpha n in equation 4-61 of the GWF Model report) that is multiplied by the head in cell n.

- **filename** (*String*) - File name for this package.
- **pname** (*String*) - Package name for this package.
- **parent_file** (MFPackage) - Parent package file that references this

package. Only needed for utility packages (mfutl*). For example, mfutllaktab package must have a mfgwflak package parent_file.

dfn = [['header'], ['block options', 'name print_input', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name print_flows', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name explicit', 'type keyword', 'tagged true', 'reader urword', 'optional true'], ['block dimensions', 'name numgnc', 'type integer', 'reader urword', 'optional false'], ['block dimensions', 'name numalphaj', 'type integer', 'reader urword', 'optional false'], ['block gncdata', 'name gncdata', 'type recarray cellidn cellidm cellidsj alphasj', 'shape (maxbound)', 'reader urword'], ['block gncdata', 'name cellidn', 'type integer', 'shape', 'tagged false', 'in_record true', 'reader urword', 'numeric_index true'], ['block gncdata', 'name cellidm', 'type integer', 'shape', 'tagged false', 'in_record true', 'reader urword', 'numeric_index true'], ['block gncdata', 'name cellidsj', 'type integer', 'shape (numalphaj)', 'tagged false', 'in_record true', 'reader urword', 'numeric_index true'], ['block gncdata', 'name alphasj', 'type double precision', 'shape (numalphaj)', 'tagged false', 'in_record true', 'reader urword']]

dfn_file_name = 'gwf-gnc.dfn'

gncdata = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

package_abbr = 'gnc'

flopy.mf6.modflow.mfims module

class ModflowIms(*simulation, loading_package=False, print_option=None, complexity=None, csv_output_filerecord=None, csv_outer_output_filerecord=None, csv_inner_output_filerecord=None, no_ptcrecord=None, ats_outer_maximum_fraction=None, outer_hclose=None, outer_dvclose=None, outer_rclosebnd=None, outer_maximum=None, under_relaxation=None, under_relaxation_gamma=None, under_relaxation_theta=None, under_relaxation_kappa=None, under_relaxation_momentum=None, backtracking_number=None, backtracking_tolerance=None, backtracking_reduction_factor=None, backtracking_residual_limit=None, inner_maximum=None, inner_hclose=None, inner_dvclose=None, rcloserecord=None, linear_acceleration=None, relaxation_factor=None, preconditioner_levels=None, preconditioner_drop_tolerance=None, number_orthogonalizations=None, scaling_method=None, reordering_method=None, filename=None, pname=None, **kwargs*)

Bases: *MFPackage*

ModflowIms defines a ims package.

Parameters

- **simulation** (MFSimulation) – Simulation that this package is a part of. Package is automatically added to simulation when it is initialized.
- **loading_package** (*bool*) – Do not set this parameter. It is intended for debugging and internal processing purposes only.
- **print_option** (*string*) –

  - print_option (string) is a flag that controls printing of convergence information from the solver. NONE means print nothing. SUMMARY means print only the total number of iterations and nonlinear residual reduction summaries. ALL means print linear matrix solver convergence information to the solution listing file and model specific linear matrix solver convergence information to each model listing file in addition to SUMMARY information. NONE is default if PRINT_OPTION is not specified.

- **complexity** (*string*) -

  - complexity (string) is an optional keyword that defines default non- linear and linear solver parameters. SIMPLE - indicates that default solver input values will be defined that work well for nearly linear models. This would be used for models that do not include nonlinear stress packages and models that are either confined or consist of a single unconfined layer that is thick enough to contain the water table within a single layer. MODERATE - indicates that default solver input values will be defined that work well for moderately nonlinear models. This would be used for models that include nonlinear stress packages and models that consist of one or more unconfined layers. The MODERATE option should be used when the SIMPLE option does not result in successful convergence. COMPLEX - indicates that default solver input values will be defined that work well for highly nonlinear models. This would be used for models that include nonlinear stress packages and models that consist of one or more unconfined layers representing complex geology and surface- water/groundwater interaction. The COMPLEX option should be used when the MODERATE option does not result in successful convergence. Non- linear and linear solver parameters assigned using a specified complexity can be modified in the NONLINEAR and LINEAR blocks. If the COMPLEXITY option is not specified, NONLINEAR and LINEAR variables will be assigned the simple complexity values.

- **csv_output_filerecord** (*[csvfile]*) -

  - csvfile (string) name of the ascii comma separated values output file to write solver convergence information. If PRINT_OPTION is NONE or SUMMARY, comma separated values output includes maximum head change convergence information at the end of each outer iteration for each time step. If PRINT_OPTION is ALL, comma separated values output includes maximum head change and maximum residual convergence information for the solution and each model (if the solution includes more than one model) and linear acceleration information for each inner iteration.

- **csv_outer_output_filerecord** (*[outer_csvfile]*) -

  - outer_csvfile (string) name of the ascii comma separated values output file to write maximum dependent-variable (for example, head) change convergence information at the end of each outer iteration for each time step.

- **csv_inner_output_filerecord** (*[inner_csvfile]*) -

- inner_csvfile (string) name of the ascii comma separated values output file to write solver convergence information. Comma separated values output includes maximum dependent-variable (for example, head) change and maximum residual convergence information for the solution and each model (if the solution includes more than one model) and linear acceleration information for each inner iteration.

- **no_ptcrecord** (*[no_ptc_option]*) -
  - no_ptc_option (string) is an optional keyword that is used to define options for disabling pseudo-transient continuation (PTC). FIRST is an optional keyword to disable PTC for the first stress period, if steady-state and one or more model is using the Newton-Raphson formulation. ALL is an optional keyword to disable PTC for all steady-state stress periods for models using the Newton-Raphson formulation. If NO_PTC_OPTION is not specified, the NO_PTC ALL option is used.
- **ats_outer_maximum_fraction** (*double*) -
  - ats_outer_maximum_fraction (double) real value defining the fraction of the maximum allowable outer iterations used with the Adaptive Time Step (ATS) capability if it is active. If this value is set to zero by the user, then this solution will have no effect on ATS behavior. This value must be greater than or equal to zero and less than or equal to 0.5 or the program will terminate with an error. If it is not specified by the user, then it is assigned a default value of one third. When the number of outer iterations for this solution is less than the product of this value and the maximum allowable outer iterations, then ATS will increase the time step length by a factor of DTADJ in the ATS input file. When the number of outer iterations for this solution is greater than the maximum allowable outer iterations minus the product of this value and the maximum allowable outer iterations, then the ATS (if active) will decrease the time step length by a factor of 1 / DTADJ.
- **outer_hclose** (*double*) -
  - outer_hclose (double) real value defining the head change criterion for convergence of the outer (nonlinear) iterations, in units of length. When the maximum absolute value of the head change at all nodes during an iteration is less than or equal to OUTER_HCLOSE, iteration stops. Commonly, OUTER_HCLOSE equals 0.01. The OUTER_HCLOSE option has been deprecated in favor of the more general OUTER_DVCLOSE (for dependent variable), however either one can be specified in order to maintain backward compatibility.
- **outer_dvclose** (*double*) -
  - outer_dvclose (double) real value defining the dependent-variable (for example, head) change criterion for convergence of the outer (nonlinear) iterations, in units of the dependent-variable (for example, length for head). When the maximum absolute value of the dependent-variable change at all nodes during an iteration is less than or equal to

OUTER_DVCLOSE, iteration stops. Commonly, OUTER_DVCLOSE equals 0.01. The keyword, OUTER_HCLOSE can be still be specified instead of OUTER_DVCLOSE for backward compatibility with previous versions of MODFLOW 6 but eventually OUTER_HCLOSE will be deprecated and specification of OUTER_HCLOSE will cause MODFLOW 6 to terminate with an error.

- **outer_rclosebnd** (*double*) -
  - outer_rclosebnd (double) real value defining the residual tolerance for convergence of model packages that solve a separate equation not solved by the IMS linear solver. This value represents the maximum allowable residual between successive outer iterations at any single model package element. An example of a model package that would use OUTER_RCLOSEBND to evaluate convergence is the SFR package which solves a continuity equation for each reach. The OUTER_RCLOSEBND option is deprecated and has no effect on simulation results as of version 6.1.1. The keyword, OUTER_RCLOSEBND can be still be specified for backward compatibility with previous versions of MODFLOW 6 but eventually specificiation of OUTER_RCLOSEBND will cause MODFLOW 6 to terminate with an error.
- **outer_maximum** (*integer*) -
  - outer_maximum (integer) integer value defining the maximum number of outer (nonlinear) iterations - that is, calls to the solution routine. For a linear problem OUTER_MAXIMUM should be 1.
- **under_relaxation** (*string*) -
  - under_relaxation (string) is an optional keyword that defines the nonlinear under-relaxation schemes used. Under-relaxation is also known as dampening, and is used to reduce the size of the calculated dependent variable before proceeding to the next outer iteration. Under-relaxation can be an effective tool for highly nonlinear models when there are large and often counteracting changes in the calculated dependent variable between successive outer iterations. By default under-relaxation is not used. NONE - under-relaxation is not used (default). SIMPLE - Simple under-relaxation scheme with a fixed relaxation factor (UNDER_RELAXATION_GAMMA) is used. COOLEY - Cooley under-relaxation scheme is used. DBD - delta-bar-delta under- relaxation is used. Note that the under-relaxation schemes are often used in conjunction with problems that use the Newton-Raphson formulation, however, experience has indicated that they also work well for non-Newton problems, such as those with the wet/dry options of MODFLOW 6.
- **under_relaxation_gamma** (*double*) -
  - under_relaxation_gamma (double) real value defining either the relaxation factor for the SIMPLE scheme or the history or memory term factor of the Cooley and delta-bar-delta algorithms. For the SIMPLE scheme, a value of one indicates that there is no under-relaxation and the full head change is applied. This value can be gradually reduced from one

as a way to improve convergence; for well behaved problems, using a value less than one can increase the number of outer iterations required for convergence and needlessly increase run times. UNDER_RELAXATION_GAMMA must be greater than zero for the SIMPLE scheme or the program will terminate with an error. For the Cooley and delta-bar-delta schemes, UNDER_RELAXATION_GAMMA is a memory term that can range between zero and one. When UNDER_RELAXATION_GAMMA is zero, only the most recent history (previous iteration value) is maintained. As UNDER_RELAXATION_GAMMA is increased, past history of iteration changes has greater influence on the memory term. The memory term is maintained as an exponential average of past changes. Retaining some past history can overcome granular behavior in the calculated function surface and therefore helps to overcome cyclic patterns of non-convergence. The value usually ranges from 0.1 to 0.3; a value of 0.2 works well for most problems. UNDER_RELAXATION_GAMMA only needs to be specified if UNDER_RELAXATION is not NONE.

- **under_relaxation_theta** (*double*) -
  - under_relaxation_theta (double) real value defining the reduction factor for the learning rate (under-relaxation term) of the delta- bar-delta algorithm. The value of UNDER_RELAXATION_THETA is between zero and one. If the change in the dependent-variable (for example, head) is of opposite sign to that of the previous iteration, the under-relaxation term is reduced by a factor of UNDER_RELAXATION_THETA. The value usually ranges from 0.3 to 0.9; a value of 0.7 works well for most problems. UNDER_RELAXATION_THETA only needs to be specified if UNDER_RELAXATION is DBD.
- **under_relaxation_kappa** (*double*) -
  - under_relaxation_kappa (double) real value defining the increment for the learning rate (under-relaxation term) of the delta-bar-delta algorithm. The value of UNDER_RELAXATION_kappa is between zero and one. If the change in the dependent-variable (for example, head) is of the same sign to that of the previous iteration, the under- relaxation term is increased by an increment of UNDER_RELAXATION_KAPPA. The value usually ranges from 0.03 to 0.3; a value of 0.1 works well for most problems. UNDER_RELAXATION_KAPPA only needs to be specified if UNDER_RELAXATION is DBD.
- **under_relaxation_momentum** (*double*) -
  - under_relaxation_momentum (double) real value defining the fraction of past history changes that is added as a momentum term to the step change for a nonlinear iteration. The value of UNDER_RELAXATION_MOMENTUM is between zero and one. A large momentum term should only be used when small learning rates are expected. Small amounts of the momentum term help convergence. The value usually ranges from 0.0001 to 0.1; a value of 0.001 works well for most problems. UNDER_RELAXATION_MOMENTUM only needs to be specified if UNDER_RELAXATION is DBD.

- **backtracking_number** (*integer*) -
  - backtracking_number (integer) integer value defining the maximum number of backtracking iterations allowed for residual reduction computations. If BACKTRACKING_NUMBER = 0 then the backtracking iterations are omitted. The value usually ranges from 2 to 20; a value of 10 works well for most problems.
- **backtracking_tolerance** (*double*) -
  - backtracking_tolerance (double) real value defining the tolerance for residual change that is allowed for residual reduction computations. BACKTRACKING_TOLERANCE should not be less than one to avoid getting stuck in local minima. A large value serves to check for extreme residual increases, while a low value serves to control step size more severely. The value usually ranges from 1.0 to 10:math:*^6*; a value of 10:math:*^4* works well for most problems but lower values like 1.1 may be required for harder problems. BACKTRACKING_TOLERANCE only needs to be specified if BACKTRACKING_NUMBER is greater than zero.
- **backtracking_reduction_factor** (*double*) -
  - backtracking_reduction_factor (double) real value defining the reduction in step size used for residual reduction computations. The value of BACKTRACKING_REDUCTION_FACTOR is between zero and one. The value usually ranges from 0.1 to 0.3; a value of 0.2 works well for most problems. BACKTRACKING_REDUCTION_FACTOR only needs to be specified if BACKTRACKING_NUMBER is greater than zero.
- **backtracking_residual_limit** (*double*) -
  - backtracking_residual_limit (double) real value defining the limit to which the residual is reduced with backtracking. If the residual is smaller than BACKTRACKING_RESIDUAL_LIMIT, then further backtracking is not performed. A value of 100 is suitable for large problems and residual reduction to smaller values may only slow down computations. BACKTRACKING_RESIDUAL_LIMIT only needs to be specified if BACKTRACKING_NUMBER is greater than zero.
- **inner_maximum** (*integer*) -
  - inner_maximum (integer) integer value defining the maximum number of inner (linear) iterations. The number typically depends on the characteristics of the matrix solution scheme being used. For nonlinear problems, INNER_MAXIMUM usually ranges from 60 to 600; a value of 100 will be sufficient for most linear problems.
- **inner_hclose** (*double*) -
  - inner_hclose (double) real value defining the head change criterion for convergence of the inner (linear) iterations, in units of length. When the maximum absolute value of the head change at all nodes during an iteration is less than or equal to INNER_HCLOSE, the matrix solver assumes convergence. Commonly, INNER_HCLOSE is set equal to or an order of magnitude

less than the OUTER_HCLOSE value specified for the NONLINEAR block. The INNER_HCLOSE keyword has been deprecated in favor of the more general INNER_DVCLOSE (for dependent variable), however either one can be specified in order to maintain backward compatibility.

- **inner_dvclose** (*double*) -
  - inner_dvclose (double) real value defining the dependent-variable (for example, head) change criterion for convergence of the inner (linear) iterations, in units of the dependent-variable (for example, length for head). When the maximum absolute value of the dependent- variable change at all nodes during an iteration is less than or equal to INNER_DVCLOSE, the matrix solver assumes convergence. Commonly, INNER_DVCLOSE is set equal to or an order of magnitude less than the OUTER_DVCLOSE value specified for the NONLINEAR block. The keyword, INNER_HCLOSE can be still be specified instead of INNER_DVCLOSE for backward compatibility with previous versions of MODFLOW 6 but eventually INNER_HCLOSE will be deprecated and specification of INNER_HCLOSE will cause MODFLOW 6 to terminate with an error.
- **rcloserecord** (*[inner_rclose, rclose_option]*) -
  - inner_rclose (double) real value that defines the flow residual tolerance for convergence of the IMS linear solver and specific flow residual criteria used. This value represents the maximum allowable residual at any single node. Value is in units of length cubed per time, and must be consistent with MODFLOW 6 length and time units. Usually a value of 1.0×10^{-1} is sufficient for the flow-residual criteria when meters and seconds are the defined MODFLOW 6 length and time.
  - rclose_option (string) an optional keyword that defines the specific flow residual criterion used. STRICT-an optional keyword that is used to specify that INNER_RCLOSE represents a infinity-Norm (absolute convergence criteria) and that the dependent-variable (for example, head) and flow convergence criteria must be met on the first inner iteration (this criteria is equivalent to the criteria used by the MODFLOW-2005 PCG package (Hill, 1990)). L2NORM_RCLOSE-an optional keyword that is used to specify that INNER_RCLOSE represents a L-2 Norm closure criteria instead of a infinity-Norm (absolute convergence criteria). When L2NORM_RCLOSE is specified, a reasonable initial INNER_RCLOSE value is 0.1 times the number of active cells when meters and seconds are the defined MODFLOW 6 length and time. RELATIVE_RCLOSE-an optional keyword that is used to specify that INNER_RCLOSE represents a relative L-2 Norm reduction closure criteria instead of a infinity-Norm (absolute convergence criteria). When RELATIVE_RCLOSE is specified, a reasonable initial INNER_RCLOSE value is 1.0×10^{-4} and convergence is achieved for a given inner (linear) iteration when Δh $\leq$ INNER_DVCLOSE and the current L-2 Norm is $\leq$ the product of the RELATIVE_RCLOSE and the initial L-2 Norm for the current inner (linear) iteration. If RCLOSE_OPTION is not

specified, an absolute residual (infinity-norm) criterion is used.

- **linear_acceleration** (*string*) -
  - linear_acceleration (string) a keyword that defines the linear acceleration method used by the default IMS linear solvers. CG - preconditioned conjugate gradient method. BICGSTAB - preconditioned bi-conjugate gradient stabilized method.
- **relaxation_factor** (*double*) -
  - relaxation_factor (double) optional real value that defines the relaxation factor used by the incomplete LU factorization preconditioners (MILU(0) and MILUT). RELAXATION_FACTOR is unitless and should be greater than or equal to 0.0 and less than or equal to 1.0. RELAXATION_FACTOR values of about 1.0 are commonly used, and experience suggests that convergence can be optimized in some cases with relax values of 0.97. A RELAXATION_FACTOR value of 0.0 will result in either ILU(0) or ILUT preconditioning (depending on the value specified for PRECONDITIONER_LEVELS and/or PRECONDITIONER_DROP_TOLERANCE). By default, RELAXATION_FACTOR is zero.
- **preconditioner_levels** (*integer*) -
  - preconditioner_levels (integer) optional integer value defining the level of fill for ILU decomposition used in the ILUT and MILUT preconditioners. Higher levels of fill provide more robustness but also require more memory. For optimal performance, it is suggested that a large level of fill be applied (7 or 8) with use of a drop tolerance. Specification of a PRECONDITIONER_LEVELS value greater than zero results in use of the ILUT preconditioner. By default, PRECONDITIONER_LEVELS is zero and the zero-fill incomplete LU factorization preconditioners (ILU(0) and MILU(0)) are used.
- **preconditioner_drop_tolerance** (*double*) -
  - preconditioner_drop_tolerance (double) optional real value that defines the drop tolerance used to drop preconditioner terms based on the magnitude of matrix entries in the ILUT and MILUT preconditioners. A value of 10^{-4} works well for most problems. By default, PRECONDITIONER_DROP_TOLERANCE is zero and the zero-fill incomplete LU factorization preconditioners (ILU(0) and MILU(0)) are used.
- **number_orthogonalizations** (*integer*) -
  - number_orthogonalizations (integer) optional integer value defining the interval used to explicitly recalculate the residual of the flow equation using the solver coefficient matrix, the latest dependent- variable (for example, head) estimates, and the right hand side. For problems that benefit from explicit recalculation of the residual, a number between 4 and 10 is appropriate. By default, NUMBER_ORTHOGONALIZATIONS is zero.
- **scaling_method** (*string*) -

  - scaling_method (string) an optional keyword that defines the matrix scaling approach used. By default, matrix scaling is not applied. NONE - no matrix scaling applied. DIAGONAL - symmetric matrix scaling using the POLCG preconditioner scaling method in Hill (1992). L2NORM - symmetric matrix scaling using the L2 norm.

- **reordering_method** (*string*) -
  - reordering_method (string) an optional keyword that defines the matrix reordering approach used. By default, matrix reordering is not applied. NONE - original ordering. RCM - reverse Cuthill McKee ordering. MD - minimum degree ordering.
- **filename** (*String*) - File name for this package.
- **pname** (*String*) - Package name for this package.
- **parent_file** (MFPackage) - Parent package file that references this package. Only needed for utility packages (mfutl*). For example, mfutllaktab package must have a mfgwflak package parent_file.

csv_inner_output_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

csv_outer_output_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

csv_output_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

dfn = [['header', ['solution_package', '*']], ['block options', 'name print_option', 'type string', 'reader urword', 'optional true'], ['block options', 'name complexity', 'type string', 'reader urword', 'optional true'], ['block options', 'name csv_output_filerecord', 'type record csv_output fileout csvfile', 'shape', 'reader urword', 'tagged true', 'optional true', 'deprecated 6.1.1'], ['block options', 'name csv_output', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false', 'deprecated 6.1.1'], ['block options', 'name csvfile', 'type string', 'preserve_case true', 'shape', 'in_record true', 'reader urword', 'tagged false', 'optional false', 'deprecated 6.1.1'], ['block options', 'name csv_outer_output_filerecord', 'type record csv_outer_output fileout outer_csvfile', 'shape', 'reader urword', 'tagged true', 'optional true'], ['block options', 'name csv_outer_output', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name fileout', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name outer_csvfile', 'type string', 'preserve_case true', 'shape', 'in_record true', 'reader urword', 'tagged false', 'optional false'], ['block options', 'name csv_inner_output_filerecord', 'type record csv_inner_output fileout inner_csvfile', 'shape', 'reader urword', 'tagged true', 'optional true'], ['block options', 'name csv_inner_output', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name inner_csvfile', 'type string', 'preserve_case true', 'shape', 'in_record true', 'reader urword', 'tagged false', 'optional false'], ['block options', 'name no_ptcrecord', 'type record no_ptc no_ptc_option', 'reader urword', 'optional true'], ['block options', 'name no_ptc', 'type keyword', 'in_record true', 'reader urword', 'optional false', 'tagged true'], ['block options', 'name no_ptc_option', 'type string', 'in_record true', 'reader urword', 'optional true', 'tagged false'], ['block options', 'name ats_outer_maximum_fraction', 'type double precision', 'reader urword', 'optional true'], ['block nonlinear', 'name outer_hclose', 'type double precision', 'reader urword', 'optional true', 'deprecated 6.1.1'], ['block nonlinear', 'name outer_dvclose', 'type double precision', 'reader urword', 'optional false'], ['block nonlinear', 'name outer_rclosebnd', 'type double precision', 'reader urword', 'optional true', 'deprecated 6.1.1'], ['block nonlinear', 'name outer_maximum', 'type integer', 'reader urword', 'optional false'], ['block nonlinear', 'name under_relaxation', 'type string', 'reader urword', 'optional true'], ['block nonlinear', 'name under_relaxation_gamma', 'type double precision', 'reader urword', 'optional true'], ['block nonlinear', 'name under_relaxation_theta', 'type double precision', 'reader urword', 'optional true'], ['block nonlinear', 'name under_relaxation_kappa', 'type double precision', 'reader urword', 'optional true'], ['block nonlinear', 'name under_relaxation_momentum', 'type double precision', 'reader urword', 'optional true'], ['block nonlinear', 'name backtracking_number', 'type integer', 'reader urword', 'optional true'], ['block nonlinear', 'name backtracking_tolerance', 'type double precision', 'reader urword', 'optional true'], ['block nonlinear', 'name backtracking_reduction_factor', 'type double precision', 'reader urword', 'optional true'], ['block nonlinear', 'name backtracking_residual_limit', 'type double precision', 'reader urword', 'optional true'], ['block linear', 'name inner_maximum', 'type integer', 'reader urword', 'optional false'], ['block linear', 'name inner_hclose', 'type double precision', 'reader urword', 'optional true', 'deprecated 6.1.1'], ['block linear', 'name inner_dvclose', 'type double precision', 'reader urword', 'optional false'], ['block linear', 'name rcloserecord', 'type record inner_rclose rclose_option', 'reader urword', 'optional false'], ['block linear', 'name inner_rclose', 'type double precision', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block linear', 'name rclose_option', 'type string', 'tagged false', 'in_record true', 'reader urword', 'optional true'], ['block linear', 'name linear_acceleration', 'type string', 'reader urword', 'optional false'], ['block linear', 'name relaxation_factor', 'type double precision', 'reader urword', 'optional true'], ['block linear', 'name preconditioner_levels', 'type integer', 'reader urword', 'optional true'], ['block linear', 'name preconditioner_drop_tolerance', 'type double precision', 'reader urword', 'optional

dfn_file_name = 'sln-ims.dfn'

no_ptcrecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

package_abbr = 'ims'

rcloserecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

flopy.mf6.modflow.mfmvr module

class ModflowMvr(*parent_model_or_package*, *loading_package=False*, *print_input=None*, *print_flows=None*, *modelnames=None*, *budget_filerecord=None*, *budgetcsv_filerecord=None*, *maxmvr=None*, *maxpackages=None*, *packages=None*, *perioddata=None*, *filename=None*, *pname=None*, ***kwargs*)

Bases: *MFPackage*

ModflowMvr defines a mvr package. This package can only be used to move water between two different models. To move water between two packages in the same model use the "model level" mover package (ex. ModflowGwfmvr).

Parameters

- **parent_model_or_package** (*MFModel/MFPackage*) – Parent_model_or_package that this package is a part of. Package is automatically added to parent_model_or_package when it is initialized.
- **loading_package** (*bool*) – Do not set this parameter. It is intended for debugging and internal processing purposes only.
- **print_input** (*boolean*) –
  - print_input (boolean) keyword to indicate that the list of MVR information will be written to the listing file immediately after it is read.
- **print_flows** (*boolean*) –
  - print_flows (boolean) keyword to indicate that the list of MVR flow rates will be printed to the listing file for every stress period time step in which "BUDGET PRINT" is specified in Output Control. If there is no Output Control option and "PRINT_FLOWS" is specified, then flow rates are printed for the last time step of each stress period.
- **modelnames** (*boolean*) –
  - modelnames (boolean) keyword to indicate that all package names will be preceded by the model name for the package. Model names are required when the Mover Package is used with a GWF-GWF Exchange. The MODELNAME keyword should not be used for a Mover Package that is for a single GWF Model.
- **budget_filerecord** (*[budgetfile]*) –
  - budgetfile (string) name of the output file to write budget information.
- **budgetcsv_filerecord** (*[budgetcsvfile]*) –

  - budgetcsvfile (string) name of the comma-separated value (CSV) output file to write budget summary information. A budget summary record will be written to this file for each time step of the simulation.

- **maxmvr** (*integer*) -
  - maxmvr (integer) integer value specifying the maximum number of water mover entries that will specified for any stress period.
- **maxpackages** (*integer*) -
  - maxpackages (integer) integer value specifying the number of unique packages that are included in this water mover input file.
- **packages** (*[mname, pname]*) -
  - mname (string) name of model containing the package. Model names are assigned by the user in the simulation name file.
  - pname (string) is the name of a package that may be included in a subsequent stress period block. The package name is assigned in the name file for the GWF Model. Package names are optionally provided in the name file. If they are not provided by the user, then packages are assigned a default value, which is the package acronym followed by a hyphen and the package number. For example, the first Drain Package is named DRN-1. The second Drain Package is named DRN-2, and so forth.
- **perioddata** (*[mname1, pname1, id1, mname2, pname2, id2, mvrtype, value]*) -
  - mname1 (string) name of model containing the package, PNAME1.
  - pname1 (string) is the package name for the provider. The package PNAME1 must be designated to provide water through the MVR Package by specifying the keyword "MOVER" in its OPTIONS block.
  - id1 (integer) is the identifier for the provider. For the standard boundary packages, the provider identifier is the number of the boundary as it is listed in the package input file. (Note that the order of these boundaries may change by stress period, which must be accounted for in the Mover Package.) So the first well has an identifier of one. The second is two, and so forth. For the advanced packages, the identifier is the reach number (SFR Package), well number (MAW Package), or UZF cell number. For the Lake Package, ID1 is the lake outlet number. Thus, outflows from a single lake can be routed to different streams, for example. This argument is an index variable, which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.
  - mname2 (string) name of model containing the package, PNAME2.
  - pname2 (string) is the package name for the receiver. The package PNAME2 must be designated to receive water from the

MVR Package by specifying the keyword "MOVER" in its OPTIONS block.

- id2 (integer) is the identifier for the receiver. The receiver identifier is the reach number (SFR Package), Lake number (LAK Package), well number (MAW Package), or UZF cell number. This argument is an index variable, which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.
- mvrtype (string) is the character string signifying the method for determining how much water will be moved. Supported values are "FACTOR" "EXCESS" "THRESHOLD" and "UPTO". These four options determine how the receiver flow rate, Q_R, is calculated. These options mirror the options defined for the cprior variable in the SFR package, with the term "FACTOR" being functionally equivalent to the "FRACTION" option for cprior.
- value (double) is the value to be used in the equation for calculating the amount of water to move. For the "FACTOR" option, VALUE is the α factor. For the remaining options, VALUE is the specified flow rate, Q_S.

- **filename** (*String*) - File name for this package.
- **pname** (*String*) - Package name for this package.
- **parent_file** (MFPackage) - Parent package file that references this package. Only needed for utility packages (mfutl*). For example, mfutllaktab package must have a mfgwflak package parent_file.

budget_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

budgetcsv_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

dfn = [['header'], ['block options', 'name print_input', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name print_flows', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name modelnames', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name budget_filerecord', 'type record budget fileout budgetfile', 'shape', 'reader urword', 'tagged true', 'optional true'], ['block options', 'name budget', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name fileout', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name budgetfile', 'type string', 'preserve_case true', 'shape', 'in_record true', 'reader urword', 'tagged false', 'optional false'], ['block options', 'name budgetcsv_filerecord', 'type record budgetcsv fileout budgetcsvfile', 'shape', 'reader urword', 'tagged true', 'optional true'], ['block options', 'name budgetcsv', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name budgetcsvfile', 'type string', 'preserve_case true', 'shape', 'in_record true', 'reader urword', 'tagged false', 'optional false'], ['block dimensions', 'name maxmvr', 'type integer', 'reader urword', 'optional false'], ['block dimensions', 'name maxpackages', 'type integer', 'reader urword', 'optional false'], ['block packages', 'name packages', 'type recarray mname pname', 'reader urword', 'shape (npackages)', 'optional false'], ['block packages', 'name mname', 'type string', 'reader urword', 'shape', 'tagged false', 'in_record true', 'optional true'], ['block packages', 'name pname', 'type string', 'reader urword', 'shape', 'tagged false', 'in_record true', 'optional false'], ['block period', 'name iper', 'type integer', 'block_variable True', 'in_record true', 'tagged false', 'shape', 'valid', 'reader urword', 'optional false'], ['block period', 'name perioddata', 'type recarray mname1 pname1 id1 mname2 pname2 id2 mvrtype value', 'shape (maxbound)', 'reader urword'], ['block period', 'name mname1', 'type string', 'reader urword', 'shape', 'tagged false', 'in_record true', 'optional true'], ['block period', 'name pname1', 'type string', 'shape', 'tagged false', 'in_record true', 'reader urword'], ['block period', 'name id1', 'type integer', 'shape', 'tagged false', 'in_record true', 'reader urword', 'numeric_index true'], ['block period', 'name mname2', 'type string', 'reader urword', 'shape', 'tagged false', 'in_record true', 'optional true'], ['block period', 'name pname2', 'type string', 'shape', 'tagged false', 'in_record true', 'reader urword'], ['block period', 'name id2', 'type integer', 'shape', 'tagged false', 'in_record true', 'reader urword', 'numeric_index true'], ['block period', 'name mvrtype', 'type string', 'shape', 'tagged false', 'in_record true', 'reader urword'], ['block period', 'name value', 'type double precision', 'shape', 'tagged false', 'in_record true', 'reader urword']]

dfn_file_name = 'gwf-mvr.dfn'

package_abbr = 'mvr'

packages = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

perioddata = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

class **MvrPackages**(*model_or_sim*, *parent*, *pkg_type*, *filerecord*, *package=None*, *package_class=None*)

Bases: *MFChildPackages*

MvrPackages is a container class for the ModflowMvr class.

initialize()

Initializes a new ModflowMvr package removing any sibling child packages attached to the same parent package. See ModflowMvr init documentation for definition of parameters.

append_package()

Adds a new ModflowGwfmvr package to the container. See ModflowGwfmvr init documentation for definition of parameters.

append_package(*print_input=None*, *print_flows=None*, *modelnames=None*, *budget_filerecord=None*, *budgetcsv_filerecord=None*, *maxmvr=None*, *maxpackages=None*, *packages=None*, *perioddata=None*, *filename=None*, *pname=None*)

initialize(*print_input=None*, *print_flows=None*, *modelnames=None*, *budget_filerecord=None*, *budgetcsv_filerecord=None*, *maxmvr=None*, *maxpackages=None*, *packages=None*, *perioddata=None*, *filename=None*, *pname=None*)

package_abbr = 'mvrpackages'

flopy.mf6.modflow.mfnam module

class **ModflowNam**(*simulation*, *loading_package=False*, *continue_=None*, *nocheck=None*, *memory_print_option=None*, *maxerrors=None*, *print_input=None*, *tdis6=None*, *models=None*, *exchanges=None*, *mxiter=None*, *solutiongroup=None*, *filename=None*, *pname=None*, ***kwargs*)

Bases: *MFPackage*

ModflowNam defines a nam package.

Parameters

- **simulation** (MFSimulation) – Simulation that this package is a part of. Package is automatically added to simulation when it is initialized.
- **loading_package** (*bool*) – Do not set this parameter. It is intended for debugging and internal processing purposes only.
- **continue** (*boolean*) –
  - continue (boolean) keyword flag to indicate that the simulation should continue even if one or more solutions do not converge.
- **nocheck** (*boolean*) –
  - nocheck (boolean) keyword flag to indicate that the model input check routines should not be called prior to each time step. Checks are performed by default.
- **memory_print_option** (*string*) –
  - memory_print_option (string) is a flag that controls printing of detailed memory manager usage to the end of the simulation list file. NONE means do not print detailed information. SUMMARY means print only the total memory for each simulation component. ALL means print information for each variable stored in the memory manager. NONE is default if MEMORY_PRINT_OPTION is not specified.

- **maxerrors** (*integer*) -
  - maxerrors (integer) maximum number of errors that will be stored and printed.
- **print_input** (*boolean*) -
  - print_input (boolean) keyword to activate printing of simulation input summaries to the simulation list file (mfsim.lst). With this keyword, input summaries will be written for those packages that support newer input data model routines. Not all packages are supported yet by the newer input data model routines.
- **tdis6** (*string*) -
  - tdis6 (string) is the name of the Temporal Discretization (TDIS) Input File.
- **models** (*[mtype, mfname, mname]*) -
  - mtype (string) is the type of model to add to simulation.
  - mfname (string) is the file name of the model name file.
  - mname (string) is the user-assigned name of the model. The model name cannot exceed 16 characters and must not have blanks within the name. The model name is case insensitive; any lowercase letters are converted and stored as upper case letters.
- **exchanges** (*[exgtype, exgfile, exgmnamea, exgmnameb]*) -
  - exgtype (string) is the exchange type.
  - exgfile (string) is the input file for the exchange.
  - exgmnamea (string) is the name of the first model that is part of this exchange.
  - exgmnameb (string) is the name of the second model that is part of this exchange.
- **mxiter** (*integer*) -
  - mxiter (integer) is the maximum number of outer iterations for this solution group. The default value is 1. If there is only one solution in the solution group, then MXITER must be 1.
- **solutiongroup** (*[slntype, slnfname, slnmnames]*) -
  - slntype (string) is the type of solution. The Integrated Model Solution (IMS6) is the only supported option in this version.
  - slnfname (string) name of file containing solution input.
  - slnmnames (string) is the array of model names to add to this solution. The number of model names is determined by the number of model names the user provides on this line.
- **filename** (*String*) - File name for this package.
- **pname** (*String*) - Package name for this package.

- **parent_file** (MFPackage) - Parent package file that references this package. Only needed for utility packages (mfutl*). For example, mfutllaktab package must have a mfgwflak package parent_file.

dfn = [['header'], ['block options', 'name continue', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name nocheck', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name memory_print_option', 'type string', 'reader urword', 'optional true', 'mf6internal prmem'], ['block options', 'name maxerrors', 'type integer', 'reader urword', 'optional true'], ['block options', 'name print_input', 'type keyword', 'reader urword', 'optional true'], ['block timing', 'name tdis6', 'preserve_case true', 'type string', 'reader urword', 'optional'], ['block models', 'name models', 'type recarray mtype mfname mname', 'reader urword', 'optional'], ['block models', 'name mtype', 'in_record true', 'type string', 'tagged false', 'reader urword'], ['block models', 'name mfname', 'in_record true', 'type string', 'preserve_case true', 'tagged false', 'reader urword'], ['block models', 'name mname', 'in_record true', 'type string', 'tagged false', 'reader urword'], ['block exchanges', 'name exchanges', 'type recarray exgtype exgfile exgmnamea exgmnameb', 'reader urword', 'optional'], ['block exchanges', 'name exgtype', 'in_record true', 'type string', 'tagged false', 'reader urword'], ['block exchanges', 'name exgfile', 'in_record true', 'type string', 'preserve_case true', 'tagged false', 'reader urword'], ['block exchanges', 'name exgmnamea', 'in_record true', 'type string', 'tagged false', 'reader urword'], ['block exchanges', 'name exgmnameb', 'in_record true', 'type string', 'tagged false', 'reader urword'], ['block solutiongroup', 'name group_num', 'type integer', 'block_variable True', 'in_record true', 'tagged false', 'shape', 'reader urword'], ['block solutiongroup', 'name mxiter', 'type integer', 'reader urword', 'optional true'], ['block solutiongroup', 'name solutiongroup', 'type recarray slntype slnfname slnmnames', 'reader urword'], ['block solutiongroup', 'name slntype', 'type string', 'valid ims6', 'in_record true', 'tagged false', 'reader urword'], ['block solutiongroup', 'name slnfname', 'type string', 'preserve_case true', 'in_record true', 'tagged false', 'reader urword'], ['block solutiongroup', 'name slnmnames', 'type string', 'in_record true', 'shape (:)', 'tagged false', 'reader urword']]

dfn_file_name = 'sim-nam.dfn'

exchanges = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

models = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

package_abbr = 'nam'

solutiongroup = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

flopy.mf6.modflow.mftdis module

class ModflowTdis(*simulation*, *loading_package=False*, *time_units=None*, *start_date_time=None*, *ats_perioddata=None*, *nper=1*, *perioddata=((1.0, 1, 1.0),)*, *filename=None*, *pname=None*, ***kwargs*)

Bases: *MFPackage*

ModflowTdis defines a tdis package.

Parameters

- **simulation** (MFSimulation) - Simulation that this package is a part of. Package is automatically added to simulation when it is initialized.
- **loading_package** (*bool*) - Do not set this parameter. It is intended for debugging and internal processing purposes only.
- **time_units** (*string*) -
  - time_units (string) is the time units of the simulation. This is a text string that is used as a label within model output files. Values for time_units may be "unknown", "seconds", "minutes", "hours", "days", or "years". The default time unit is "unknown".
- **start_date_time** (*string*) -
  - start_date_time (string) is the starting date and time of the simulation. This is a text string that is used as a label within the simulation list file. The value has no effect on the simulation. The recommended format for the starting date and time is described at https://www.w3.org/TR/NOTE-datetime.
- **ats_perioddata** (*{varname:data} or perioddata data*) -
  - Contains data for the ats package. Data can be stored in a dictionary containing data for the ats package with variable names as keys and package data as values. Data just for the ats_perioddata variable is also acceptable. See ats package documentation for more information.
- **nper** (*integer*) -
  - nper (integer) is the number of stress periods for the simulation.
- **perioddata** (*[perlen, nstp, tsmult]*) -
  - perlen (double) is the length of a stress period.
  - nstp (integer) is the number of time steps in a stress period.
  - tsmult (double) is the multiplier for the length of successive time steps. The length of a time step is calculated by multiplying the length of the previous time step by TSMULT. The length of the first time step, Δt_1, is related to PERLEN, NSTP, and TSMULT by the relation $\Delta t_1 = perlen \frac{tsmult-1}{tsmult^{nstp}-1}$.
- **filename** (*String*) - File name for this package.
- **pname** (*String*) - Package name for this package.
- **parent_file** (MFPackage) - Parent package file that references this package. Only needed for utility packages (mfutl*). For example, mfutllaktab package must have a mfgwflak package parent_file.

ats_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

dfn = [['header'], ['block options', 'name time_units', 'type string', 'reader urword', 'optional true'], ['block options', 'name start_date_time', 'type string', 'reader urword', 'optional true'], ['block options', 'name ats_filerecord', 'type record ats6 filein ats6_filename', 'shape', 'reader urword', 'tagged true', 'optional true', 'construct_package ats', 'construct_data perioddata', 'parameter_name ats_perioddata'], ['block options', 'name ats6', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name filein', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name ats6_filename', 'type string', 'preserve_case true', 'in_record true', 'reader urword', 'optional false', 'tagged false'], ['block dimensions', 'name nper', 'type integer', 'reader urword', 'optional false', 'default_value 1'], ['block perioddata', 'name perioddata', 'type recarray perlen nstp tsmult', 'reader urword', 'optional false', 'default_value ((1.0, 1, 1.0),)'], ['block perioddata', 'name perlen', 'type double precision', 'in_record true', 'tagged false', 'reader urword', 'optional false'], ['block perioddata', 'name nstp', 'type integer', 'in_record true', 'tagged false', 'reader urword', 'optional false'], ['block perioddata', 'name tsmult', 'type double precision', 'in_record true', 'tagged false', 'reader urword', 'optional false']]

dfn_file_name = 'sim-tdis.dfn'

package_abbr = 'tdis'

perioddata = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

12.1.4 MODFLOW 6 Models

MODFLOW 6 supports both groundwater flow (mfgwf.ModflowGwf) and groundwater transport (mfgwt.ModflowGwt) models. FloPy for MODFLOW 6 model objects can be constructed after a FloPy simulation (MFSimulation) object has been constructed.

Contents:

flopy.mf6.modflow.mfgwf module

class ModflowGwf(*simulation*, *modelname='model'*, *model_nam_file=None*, *version='mf6'*, *exe_name='mf6'*, *model_rel_path='.'*, *list=None*, *print_input=None*, *print_flows=None*, *save_flows=None*, *newtonoptions=None*, ***kwargs*)

Bases: *MFModel*

Modflowgwf defines a gwf model

Parameters

- **modelname** (*string*) – name of the model
- **model_nam_file** (*string*) – relative path to the model name file from model working folder
- **version** (*string*) – version of modflow
- **exe_name** (*string*) – model executable name
- **model_ws** (*string*) – model working folder path
- **sim** (MFSimulation) – Simulation that this model is a part of. Model is automatically added to simulation when it is initialized.

- **list** (*string*) -
  - list (string) is name of the listing file to create for this GWF model. If not specified, then the name of the list file will be the basename of the GWF model name file and the '.lst' extension. For example, if the GWF name file is called "my.model.nam" then the list file will be called "my.model.lst".
- **print_input** (*boolean*) -
  - print_input (boolean) keyword to indicate that the list of all model stress package information will be written to the listing file immediately after it is read.
- **print_flows** (*boolean*) -
  - print_flows (boolean) keyword to indicate that the list of all model package flow rates will be printed to the listing file for every stress period time step in which "BUDGET PRINT" is specified in Output Control. If there is no Output Control option and "PRINT_FLOWS" is specified, then flow rates are printed for the last time step of each stress period.
- **save_flows** (*boolean*) -
  - save_flows (boolean) keyword to indicate that all model package flow terms will be written to the file specified with "BUDGET FILEOUT" in Output Control.
- **newtonoptions** (*[under_relaxation]*) -
  - under_relaxation (string) keyword that indicates whether the groundwater head in a cell will be under-relaxed when water levels fall below the bottom of the model below any given cell. By default, Newton-Raphson UNDER_RELAXATION is not applied.
- **packages** (*[ftype, fname, pname]*) -
  - ftype (string) is the file type, which must be one of the following character values shown in table in mf6io.pdf. Ftype may be entered in any combination of uppercase and lowercase.
  - fname (string) is the name of the file containing the package input. The path to the file should be included if the file is not located in the folder where the program was run.
  - pname (string) is the user-defined name for the package. PNAME is restricted to 16 characters. No spaces are allowed in PNAME. PNAME character values are read and stored by the program for stress packages only. These names may be useful for labeling purposes when multiple stress packages of the same type are located within a single GWF Model. If PNAME is specified for a stress package, then PNAME will be used in the flow budget table in the listing file; it will also be used for the text entry in the cell-by-cell budget file. PNAME is case insensitive and is stored in all upper case letters.

load : (simulation : MFSimulationData, model_name : string,

namfile : string, version : string, exe_name : string, model_ws : string, strict : boolean) : MFSimulation a class method that loads a model from files

classmethod load(*simulation, structure, modelname='NewModel', model_nam_file='modflowtest.nam', version='mf6', exe_name='mf6', strict=True, model_rel_path='.', load_only=None*)

model_type = 'gwf'

flopy.mf6.modflow.mfgwt module

class ModflowGwt(*simulation, modelname='model', model_nam_file=None, version='mf6', exe_name='mf6', model_rel_path='.', list=None, print_input=None, print_flows=None, save_flows=None, **kwargs*)

Bases: *MFModel*

Modflowgwt defines a gwt model

Parameters

- **modelname** (*string*) – name of the model
- **model_nam_file** (*string*) – relative path to the model name file from model working folder
- **version** (*string*) – version of modflow
- **exe_name** (*string*) – model executable name
- **model_ws** (*string*) – model working folder path
- **sim** (MFSimulation) – Simulation that this model is a part of. Model is automatically added to simulation when it is initialized.
- **list** (*string*) –
  - list (string) is name of the listing file to create for this GWT model. If not specified, then the name of the list file will be the basename of the GWT model name file and the '.lst' extension. For example, if the GWT name file is called "my.model.nam" then the list file will be called "my.model.lst".
- **print_input** (*boolean*) –
  - print_input (boolean) keyword to indicate that the list of all model stress package information will be written to the listing file immediately after it is read.
- **print_flows** (*boolean*) –
  - print_flows (boolean) keyword to indicate that the list of all model package flow rates will be printed to the listing file for every stress period time step in which "BUDGET PRINT" is specified in Output Control. If there is no Output Control option and "PRINT_FLOWS" is specified, then flow rates are printed for the last time step of each stress period.
- **save_flows** (*boolean*) –
  - save_flows (boolean) keyword to indicate that all model package flow terms will be written to the file specified with "BUDGET FILEOUT" in Output Control.
- **packages** (*[ftype, fname, pname]*) –

- ftype (string) is the file type, which must be one of the following character values shown in table in mf6io.pdf. Ftype may be entered in any combination of uppercase and lowercase.
- fname (string) is the name of the file containing the package input. The path to the file should be included if the file is not located in the folder where the program was run.
- pname (string) is the user-defined name for the package. PNAME is restricted to 16 characters. No spaces are allowed in PNAME. PNAME character values are read and stored by the program for stress packages only. These names may be useful for labeling purposes when multiple stress packages of the same type are located within a single GWT Model. If PNAME is specified for a stress package, then PNAME will be used in the flow budget table in the listing file; it will also be used for the text entry in the cell-by-cell budget file. PNAME is case insensitive and is stored in all upper case letters.

load : (simulation : MFSimulationData, model_name : string,
namfile : string, version : string, exe_name : string, model_ws : string, strict : boolean) : MFSimulation a class method that loads a model from files

classmethod load(*simulation*, *structure*, *modelname='NewModel'*, *model_nam_file='modflowtest.nam'*, *version='mf6'*, *exe_name='mf6'*, *strict=True*, *model_rel_path='.'*, *load_only=None*)

model_type = 'gwt'

12.1.5 MODFLOW 6 Groundwater Flow Model Packages

MODFLOW 6 groundwater flow models support a number of required and optional packages. Once a MODFLOW 6 groundwater flow model object (mfgwf.ModflowGwf) has been constructed various packages associated with the groundwater flow model can be constructed.

Contents:

flopy.mf6.modflow.mfgwfapi module

class ModflowGwfapi(*model*, *loading_package=False*, *boundnames=None*, *print_input=None*, *print_flows=None*, *save_flows=None*, *observations=None*, *mover=None*, *maxbound=None*, *filename=None*, *pname=None*, ***kwargs*)

Bases: *MFPackage*

ModflowGwfapi defines a api package within a gwf6 model.

Parameters

- **model** (MFModel) – Model that this package is a part of. Package is automatically added to model when it is initialized.
- **loading_package** (*bool*) – Do not set this parameter. It is intended for debugging and internal processing purposes only.
- **boundnames** (*boolean*) –

  - boundnames (boolean) keyword to indicate that boundary names may be provided with the list of api boundary cells.
- **print_input** (*boolean*) -
  - print_input (boolean) keyword to indicate that the list of api boundary information will be written to the listing file immediately after it is read.
- **print_flows** (*boolean*) -
  - print_flows (boolean) keyword to indicate that the list of api boundary flow rates will be printed to the listing file for every stress period time step in which "BUDGET PRINT" is specified in Output Control. If there is no Output Control option and "PRINT_FLOWS" is specified, then flow rates are printed for the last time step of each stress period.
- **save_flows** (*boolean*) -
  - save_flows (boolean) keyword to indicate that api boundary flow terms will be written to the file specified with "BUDGET FILEOUT" in Output Control.
- **observations** (*{varname:data} or continuous data*) -
  - Contains data for the obs package. Data can be stored in a dictionary containing data for the obs package with variable names as keys and package data as values. Data just for the observations variable is also acceptable. See obs package documentation for more information.
- **mover** (*boolean*) -
  - mover (boolean) keyword to indicate that this instance of the api boundary Package can be used with the Water Mover (MVR) Package. When the MOVER option is specified, additional memory is allocated within the package to store the available, provided, and received water.
- **maxbound** (*integer*) -
  - maxbound (integer) integer value specifying the maximum number of api boundary cells that will be specified for use during any stress period.
- **filename** (*String*) - File name for this package.
- **pname** (*String*) - Package name for this package.
- **parent_file** (MFPackage) - Parent package file that references this package. Only needed for utility packages (mfutl*). For example, mfutllaktab package must have a mfgwflak package parent_file.

dfn = [['header'], ['block options', 'name boundnames', 'type keyword', 'shape', 'reader urword', 'optional true'], ['block options', 'name print_input', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name print_flows', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name save_flows', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name obs_filerecord', 'type record obs6 filein obs6_filename', 'shape', 'reader urword', 'tagged true', 'optional true', 'construct_package obs', 'construct_data continuous', 'parameter_name observations'], ['block options', 'name obs6', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name filein', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name obs6_filename', 'type string', 'preserve_case true', 'in_record true', 'tagged false', 'reader urword', 'optional false'], ['block options', 'name mover', 'type keyword', 'tagged true', 'reader urword', 'optional true'], ['block dimensions', 'name maxbound', 'type integer', 'reader urword', 'optional false']]

dfn_file_name = 'gwf-api.dfn'

obs_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

package_abbr = 'gwfapi'

flopy.mf6.modflow.mfgwfbuy module

class ModflowGwfbuy(*model*, *loading_package=False*, *hhformulation_rhs=None*, *denseref=1000.0*, *density_filerecord=None*, *dev_efh_formulation=None*, *nrhospecies=None*, *packagedata=None*, *filename=None*, *pname=None*, ***kwargs*)

Bases: *MFPackage*

ModflowGwfbuy defines a buy package within a gwf6 model.

Parameters

- **model** (MFModel) – Model that this package is a part of. Package is automatically added to model when it is initialized.
- **loading_package** (*bool*) – Do not set this parameter. It is intended for debugging and internal processing purposes only.
- **hhformulation_rhs** (*boolean*) –
  - hhformulation_rhs (boolean) use the variable-density hydraulic head formulation and add off-diagonal terms to the right-hand. This option will prevent the BUY Package from adding asymmetric terms to the flow matrix.
- **denseref** (*double*) –
  - denseref (double) fluid reference density used in the equation of state. This value is set to 1000. if not specified as an option.
- **density_filerecord** (*[densityfile]*) –
  - densityfile (string) name of the binary output file to write density information. The density file has the same format as the head file. Density values will be written to the density

file whenever heads are written to the binary head file. The settings for controlling head output are contained in the Output Control option.

- **dev_efh_formulation** (*boolean*) -
  - dev_efh_formulation (boolean) use the variable-density equivalent freshwater head formulation instead of the hydraulic head head formulation. This dev option has only been implemented for confined aquifer conditions and should generally not be used.
- **nrhospecies** (*integer*) -
  - nrhospecies (integer) number of species used in density equation of state. This value must be one or greater if the BUY package is activated.
- **packagedata** (*[irhospec, drhodc, crhoref, modelname, auxspeciesname]*) -
  - irhospec (integer) integer value that defines the species number associated with the specified PACKAGEDATA data on the line. IRHOSPECIES must be greater than zero and less than or equal to NRHOSPECIES. Information must be specified for each of the NRHOSPECIES species or the program will terminate with an error. The program will also terminate with an error if information for a species is specified more than once. This argument is an index variable, which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.
  - drhodc (double) real value that defines the slope of the density- concentration line for this species used in the density equation of state.
  - crhoref (double) real value that defines the reference concentration value used for this species in the density equation of state.
  - modelname (string) name of GWT model used to simulate a species that will be used in the density equation of state. This name will have no effect if the simulation does not include a GWT model that corresponds to this GWF model.
  - auxspeciesname (string) name of an auxiliary variable in a GWF stress package that will be used for this species to calculate a density value. If a density value is needed by the Buoyancy Package then it will use the concentration values in this AUXSPECIESNAME column in the density equation of state. For advanced stress packages (LAK, SFR, MAW, and UZF) that have an associated advanced transport package (LKT, SFT, MWT, and UZT), the FLOW_PACKAGE_AUXILIARY_NAME option in the advanced transport package can be used to transfer simulated concentrations into the flow package auxiliary variable. In this manner, the Buoyancy Package can calculate density values for lakes, streams, multi-aquifer wells, and unsaturated zone flow cells using simulated concentrations.

- **filename** (*String*) - File name for this package.
- **pname** (*String*) - Package name for this package.
- **parent_file** (MFPackage) - Parent package file that references this package. Only needed for utility packages (mfutl*). For example, mfutllaktab package must have a mfgwflak package parent_file.

density_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

dfn = [['header'], ['block options', 'name hhformulation_rhs', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name denseref', 'type double precision', 'reader urword', 'optional true', 'default_value 1000.'], ['block options', 'name density_filerecord', 'type record density fileout densityfile', 'shape', 'reader urword', 'tagged true', 'optional true'], ['block options', 'name density', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name fileout', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name densityfile', 'type string', 'preserve_case true', 'shape', 'in_record true', 'reader urword', 'tagged false', 'optional false'], ['block options', 'name dev_efh_formulation', 'type keyword', 'reader urword', 'optional true'], ['block dimensions', 'name nrhospecies', 'type integer', 'reader urword', 'optional false'], ['block packagedata', 'name packagedata', 'type recarray irhospec drhodc crhoref modelname auxspeciesname', 'shape (nrhospecies)', 'reader urword'], ['block packagedata', 'name irhospec', 'type integer', 'shape', 'tagged false', 'in_record true', 'reader urword', 'numeric_index true'], ['block packagedata', 'name drhodc', 'type double precision', 'shape', 'tagged false', 'in_record true', 'reader urword'], ['block packagedata', 'name crhoref', 'type double precision', 'shape', 'tagged false', 'in_record true', 'reader urword'], ['block packagedata', 'name modelname', 'type string', 'in_record true', 'tagged false', 'shape', 'reader urword'], ['block packagedata', 'name auxspeciesname', 'type string', 'in_record true', 'tagged false', 'shape', 'reader urword']]

dfn_file_name = 'gwf-buy.dfn'

package_abbr = 'gwfbuy'

packagedata = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

flopy.mf6.modflow.mfgwfchd module

class ModflowGwfchd(*model*, *loading_package=False*, *auxiliary=None*, *auxmultname=None*, *boundnames=None*, *print_input=None*, *print_flows=None*, *save_flows=None*, *timeseries=None*, *observations=None*, *maxbound=None*, *stress_period_data=None*, *filename=None*, *pname=None*, ***kwargs*)

Bases: *MFPackage*

ModflowGwfchd defines a chd package within a gwf6 model.

Parameters

- **model** (MFModel) - Model that this package is a part of. Package is automatically added to model when it is initialized.
- **loading_package** (*bool*) - Do not set this parameter. It is intended for debugging and internal processing purposes only.
- **auxiliary** (*[string]*) -

    - auxiliary (string) defines an array of one or more auxiliary variable names. There is no limit on the number of auxiliary variables that can be provided on this line; however, lists of information provided in subsequent blocks must have a column of data for each auxiliary variable name defined here. The number of auxiliary variables detected on this line determines the value for naux. Comments cannot be provided anywhere on this line as they will be interpreted as auxiliary variable names. Auxiliary variables may not be used by the package, but they will be available for use by other parts of the program. The program will terminate with an error if auxiliary variables are specified on more than one line in the options block.

- **auxmultname** (*string*) -
    - auxmultname (string) name of auxiliary variable to be used as multiplier of CHD head value.
- **boundnames** (*boolean*) -
    - boundnames (boolean) keyword to indicate that boundary names may be provided with the list of constant-head cells.
- **print_input** (*boolean*) -
    - print_input (boolean) keyword to indicate that the list of constant- head information will be written to the listing file immediately after it is read.
- **print_flows** (*boolean*) -
    - print_flows (boolean) keyword to indicate that the list of constant- head flow rates will be printed to the listing file for every stress period time step in which "BUDGET PRINT" is specified in Output Control. If there is no Output Control option and "PRINT_FLOWS" is specified, then flow rates are printed for the last time step of each stress period.
- **save_flows** (*boolean*) -
    - save_flows (boolean) keyword to indicate that constant-head flow terms will be written to the file specified with "BUDGET FILEOUT" in Output Control.
- **timeseries** (*{varname:data} or timeseries data*) -
    - Contains data for the ts package. Data can be stored in a dictionary containing data for the ts package with variable names as keys and package data as values. Data just for the timeseries variable is also acceptable. See ts package documentation for more information.
- **observations** (*{varname:data} or continuous data*) -
    - Contains data for the obs package. Data can be stored in a dictionary containing data for the obs package with variable names as keys and package data as values. Data just for the observations variable is also acceptable. See obs package documentation for more information.
- **maxbound** (*integer*) -

  - maxbound (integer) integer value specifying the maximum number of constant-head cells that will be specified for use during any stress period.

- **stress_period_data** (*[cellid, head, aux, boundname]*) -
  - cellid ((integer, ...)) is the cell identifier, and depends on the type of grid that is used for the simulation. For a structured grid that uses the DIS input file, CELLID is the layer, row, and column. For a grid that uses the DISV input file, CELLID is the layer and CELL2D number. If the model uses the unstructured discretization (DISU) input file, CELLID is the node number for the cell. This argument is an index variable, which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.
  - head (double) is the head at the boundary. If the Options block includes a TIMESERIESFILE entry (see the "Time-Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
  - aux (double) represents the values of the auxiliary variables for each constant head. The values of auxiliary variables must be present for each constant head. The values must be specified in the order of the auxiliary variables specified in the OPTIONS block. If the package supports time series and the Options block includes a TIMESERIESFILE entry (see the "Time-Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
  - boundname (string) name of the constant head boundary cell. BOUNDNAME is an ASCII character variable that can contain as many as 40 characters. If BOUNDNAME contains spaces in it, then the entire name must be enclosed within single quotes.
- **filename** (*String*) - File name for this package.
- **pname** (*String*) - Package name for this package.
- **parent_file** (MFPackage) - Parent package file that references this package. Only needed for utility packages (mfutl*). For example, mfutllaktab package must have a mfgwflak package parent_file.

auxiliary = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

dfn = [['header', 'multi-package', 'package-type stress-package'], ['block options', 'name auxiliary', 'type string', 'shape (naux)', 'reader urword', 'optional true'], ['block options', 'name auxmultname', 'type string', 'shape', 'reader urword', 'optional true'], ['block options', 'name boundnames', 'type keyword', 'shape', 'reader urword', 'optional true'], ['block options', 'name print_input', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name print_flows', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name save_flows', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name ts_filerecord', 'type record ts6 filein ts6_filename', 'shape', 'reader urword', 'tagged true', 'optional true', 'construct_package ts', 'construct_data timeseries', 'parameter_name timeseries'], ['block options', 'name ts6', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name filein', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name ts6_filename', 'type string', 'preserve_case true', 'in_record true', 'reader urword', 'optional false', 'tagged false'], ['block options', 'name obs_filerecord', 'type record obs6 filein obs6_filename', 'shape', 'reader urword', 'tagged true', 'optional true', 'construct_package obs', 'construct_data continuous', 'parameter_name observations'], ['block options', 'name obs6', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name obs6_filename', 'type string', 'preserve_case true', 'in_record true', 'tagged false', 'reader urword', 'optional false'], ['block dimensions', 'name maxbound', 'type integer', 'reader urword', 'optional false'], ['block period', 'name iper', 'type integer', 'block_variable True', 'in_record true', 'tagged false', 'shape', 'valid', 'reader urword', 'optional false'], ['block period', 'name stress_period_data', 'type recarray cellid head aux boundname', 'shape (maxbound)', 'reader urword'], ['block period', 'name cellid', 'type integer', 'shape (ncelldim)', 'tagged false', 'in_record true', 'reader urword'], ['block period', 'name head', 'type double precision', 'shape', 'tagged false', 'in_record true', 'reader urword', 'time_series true'], ['block period', 'name aux', 'type double precision', 'in_record true', 'tagged false', 'shape (naux)', 'reader urword', 'optional true', 'time_series true'], ['block period', 'name boundname', 'type string', 'shape', 'tagged false', 'in_record true', 'reader urword', 'optional true']]

dfn_file_name = 'gwf-chd.dfn'

obs_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

package_abbr = 'gwfchd'

stress_period_data = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

ts_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

flopy.mf6.modflow.mfgwfcsub module

class ModflowGwfcsub(*model*, *loading_package=False*, *boundnames=None*, *print_input=None*, *save_flows=None*, *gammaw=9806.65*, *beta=4.6512e-10*, *head_based=None*, *initial_preconsolidation_head=None*, *ndelaycells=None*, *compression_indices=None*, *update_material_properties=None*, *cell_fraction=None*, *specified_initial_interbed_state=None*, *specified_initial_preconsolidation_stress=None*, *specified_initial_delay_head=None*, *effective_stress_lag=None*, *strainib_filerecord=None*, *straincg_filerecord=None*, *compaction_filerecord=None*, *compaction_elastic_filerecord=None*, *compaction_inelastic_filerecord=None*, *compaction_interbed_filerecord=None*, *compaction_coarse_filerecord=None*, *zdisplacement_filerecord=None*, *package_convergence_filerecord=None*, *timeseries=None*, *observations=None*, *ninterbeds=None*, *maxsig0=None*, *cg_ske_cr=1e-05*, *cg_theta=0.2*, *sgm=None*, *sgs=None*, *packagedata=None*, *stress_period_data=None*, *filename=None*, *pname=None*, ***kwargs*)

Bases: *MFPackage*

ModflowGwfcsub defines a csub package within a gwf6 model.

Parameters

- **model** (MFModel) - Model that this package is a part of. Package is automatically added to model when it is initialized.
- **loading_package** (*bool*) - Do not set this parameter. It is intended for debugging and internal processing purposes only.
- **boundnames** (*boolean*) -
  - boundnames (boolean) keyword to indicate that boundary names may be provided with the list of CSUB cells.
- **print_input** (*boolean*) -
  - print_input (boolean) keyword to indicate that the list of CSUB information will be written to the listing file immediately after it is read.
- **save_flows** (*boolean*) -
  - save_flows (boolean) keyword to indicate that cell-by-cell flow terms will be written to the file specified with "BUDGET SAVE FILE" in Output Control.
- **gammaw** (*double*) -
  - gammaw (double) unit weight of water. For freshwater, GAMMAW is 9806.65 Newtons/cubic meters or 62.48 lb/cubic foot in SI and English units, respectively. By default, GAMMAW is 9806.65 Newtons/cubic meters.
- **beta** (*double*) -
  - beta (double) compressibility of water. Typical values of BETA are 4.6512e-10 1/Pa or 2.2270e-8 lb/square foot in SI and English units, respectively. By default, BETA is 4.6512e-10 1/Pa.

- **head_based** (*boolean*) -
  - head_based (boolean) keyword to indicate the head-based formulation will be used to simulate coarse-grained aquifer materials and no- delay and delay interbeds. Specifying HEAD_BASED also specifies the INITIAL_PRECONSOLIDATION_HEAD option.
- **initial_preconsolidation_head** (*boolean*) -
  - initial_preconsolidation_head (boolean) keyword to indicate that preconsolidation heads will be specified for no-delay and delay interbeds in the PACKAGEDATA block. If the SPECIFIED_INITIAL_INTERBED_STATE option is specified in the OPTIONS block, user-specified preconsolidation heads in the PACKAGEDATA block are absolute values. Otherwise, user-specified preconsolidation heads in the PACKAGEDATA block are relative to steady-state or initial heads.
- **ndelaycells** (*integer*) -
  - ndelaycells (integer) number of nodes used to discretize delay interbeds. If not specified, then a default value of 19 is assigned.
- **compression_indices** (*boolean*) -
  - compression_indices (boolean) keyword to indicate that the recompression (CR) and compression (CC) indices are specified instead of the elastic specific storage (SSE) and inelastic specific storage (SSV) coefficients. If not specified, then elastic specific storage (SSE) and inelastic specific storage (SSV) coefficients must be specified.
- **update_material_properties** (*boolean*) -
  - update_material_properties (boolean) keyword to indicate that the thickness and void ratio of coarse-grained and interbed sediments (delay and no-delay) will vary during the simulation. If not specified, the thickness and void ratio of coarse-grained and interbed sediments will not vary during the simulation.
- **cell_fraction** (*boolean*) -
  - cell_fraction (boolean) keyword to indicate that the thickness of interbeds will be specified in terms of the fraction of cell thickness. If not specified, interbed thicknness must be specified.
- **specified_initial_interbed_state** (*boolean*) -
  - specified_initial_interbed_state (boolean) keyword to indicate that absolute preconsolidation stresses (heads) and delay bed heads will be specified for interbeds defined in the PACKAGEDATA block. The SPECIFIED_INITIAL_INTERBED_STATE option is equivalent to specifying the SPECIFIED_INITIAL_PRECONSOLITATION_STRESS and SPECIFIED_INITIAL_DELAY_HEAD. If SPECIFIED_INITIAL_INTERBED_STATE is not specified then preconsolidation stress (head) and delay bed head values specified in the PACKAGEDATA block are relative

to simulated values of the first stress period if steady-state or initial stresses and GWF heads if the first stress period is transient.

- **specified_initial_preconsolidation_stress** (*boolean*) -
  - specified_initial_preconsolidation_stress (boolean) keyword to indicate that absolute preconsolidation stresses (heads) will be specified for interbeds defined in the PACKAGEDATA block. If SPECIFIED_INITIAL_PRECONSOLITATION_STRESS and SPECIFIED_INITIAL_INTERBED_STATE are not specified then preconsolidation stress (head) values specified in the PACKAGEDATA block are relative to simulated values if the first stress period is steady-state or initial stresses (heads) if the first stress period is transient.
- **specified_initial_delay_head** (*boolean*) -
  - specified_initial_delay_head (boolean) keyword to indicate that absolute initial delay bed head will be specified for interbeds defined in the PACKAGEDATA block. If SPECIFIED_INITIAL_DELAY_HEAD and SPECIFIED_INITIAL_INTERBED_STATE are not specified then delay bed head values specified in the PACKAGEDATA block are relative to simulated values if the first stress period is steady-state or initial GWF heads if the first stress period is transient.
- **effective_stress_lag** (*boolean*) -
  - effective_stress_lag (boolean) keyword to indicate the effective stress from the previous time step will be used to calculate specific storage values. This option can 1) help with convergence in models with thin cells and water table elevations close to land surface; 2) is identical to the approach used in the SUBWT package for MODFLOW-2005; and 3) is only used if the effective-stress formulation is being used. By default, current effective stress values are used to calculate specific storage values.
- **strainib_filerecord** (*[interbedstrain_filename]*) -
  - interbedstrain_filename (string) name of the comma-separated-values output file to write final interbed strain information.
- **straincg_filerecord** (*[coarsestrain_filename]*) -
  - coarsestrain_filename (string) name of the comma-separated-values output file to write final coarse-grained material strain information.
- **compaction_filerecord** (*[compaction_filename]*) -
  - compaction_filename (string) name of the binary output file to write compaction information.
- **compaction_elastic_filerecord** (*[elastic_compaction_filename]*) -
  - elastic_compaction_filename (string) name of the binary output file to write elastic interbed compaction information.

- **compaction_inelastic_filerecord** (*[inelastic_compaction_filename]*) -
  - inelastic_compaction_filename (string) name of the binary output file to write inelastic interbed compaction information.
- **compaction_interbed_filerecord** (*[interbed_compaction_filename]*) -
  - interbed_compaction_filename (string) name of the binary output file to write interbed compaction information.
- **compaction_coarse_filerecord** (*[coarse_compaction_filename]*) -
  - coarse_compaction_filename (string) name of the binary output file to write elastic coarse-grained material compaction information.
- **zdisplacement_filerecord** (*[zdisplacement_filename]*) -
  - zdisplacement_filename (string) name of the binary output file to write z-displacement information.
- **package_convergence_filerecord** (*[package_convergence_filename]*) -
  - package_convergence_filename (string) name of the comma spaced values output file to write package convergence information.
- **timeseries** (*{varname:data} or timeseries data*) -
  - Contains data for the ts package. Data can be stored in a dictionary containing data for the ts package with variable names as keys and package data as values. Data just for the timeseries variable is also acceptable. See ts package documentation for more information.
- **observations** (*{varname:data} or continuous data*) -
  - Contains data for the obs package. Data can be stored in a dictionary containing data for the obs package with variable names as keys and package data as values. Data just for the observations variable is also acceptable. See obs package documentation for more information.
- **ninterbeds** (*integer*) -
  - ninterbeds (integer) is the number of CSUB interbed systems. More than 1 CSUB interbed systems can be assigned to a GWF cell; however, only 1 GWF cell can be assigned to a single CSUB interbed system.
- **maxsig0** (*integer*) -
  - maxsig0 (integer) is the maximum number of cells that can have a specified stress offset. More than 1 stress offset can be assigned to a GWF cell. By default, MAXSIG0 is 0.
- **cg_ske_cr** (*[double]*) -
  - cg_ske_cr (double) is the initial elastic coarse-grained material specific storage or recompression index. The recompression index is specified if COMPRESSION_INDICES is specified in the OPTIONS block. Specified or calculated elastic coarse-grained material specific storage values are not adjusted

from initial values if HEAD_BASED is specified in the OPTIONS block.

- **cg_theta** (*[double]*) -
  - cg_theta (double) is the initial porosity of coarse-grained materials.
- **sgm** (*[double]*) -
  - sgm (double) is the specific gravity of moist or unsaturated sediments. If not specified, then a default value of 1.7 is assigned.
- **sgs** (*[double]*) -
  - sgs (double) is the specific gravity of saturated sediments. If not specified, then a default value of 2.0 is assigned.
- **packagedata** (*[icsubno, cellid, cdelay, pcs0, thick_frac, rnb, ssv_cc,)* -

  sse_cr, theta, kv, h0, boundname]

  - icsubno (integer) integer value that defines the CSUB interbed number associated with the specified PACKAGEDATA data on the line. CSUBNO must be greater than zero and less than or equal to NINTERBEDS. CSUB information must be specified for every CSUB cell or the program will terminate with an error. The program will also terminate with an error if information for a CSUB interbed number is specified more than once. This argument is an index variable, which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.
  - cellid ((integer, ...)) is the cell identifier, and depends on the type of grid that is used for the simulation. For a structured grid that uses the DIS input file, CELLID is the layer, row, and column. For a grid that uses the DISV input file, CELLID is the layer and CELL2D number. If the model uses the unstructured discretization (DISU) input file, CELLID is the node number for the cell. This argument is an index variable, which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.
  - cdelay (string) character string that defines the subsidence delay type for the interbed. Possible subsidence package CDELAY strings include: NODELAY-character keyword to indicate that delay will not be simulated in the interbed. DELAY-character keyword to indicate that delay will be simulated in the interbed.
  - pcs0 (double) is the initial offset from the calculated initial effective stress or initial preconsolidation stress in the interbed, in units of height of a column of water. PCS0 is the initial preconsolidation stress if SPECIFIED_INITIAL_INTERBED_STATE or

SPECIFIED_INITIAL_PRECONSOLIDATION_STRESS are specified in the OPTIONS block. If HEAD_BASED is specified in the OPTIONS block, PCS0 is the initial offset from the calculated initial head or initial preconsolidation head in the CSUB interbed and the initial preconsolidation stress is calculated from the calculated initial effective stress or calculated initial geostatic stress, respectively.

  – thick_frac (double) is the interbed thickness or cell fraction of the interbed. Interbed thickness is specified as a fraction of the cell thickness if CELL_FRACTION is specified in the OPTIONS block.
  – rnb (double) is the interbed material factor equivalent number of interbeds in the interbed system represented by the interbed. RNB must be greater than or equal to 1 if CDELAY is DELAY. Otherwise, RNB can be any value.
  – ssv_cc (double) is the initial inelastic specific storage or compression index of the interbed. The compression index is specified if COMPRESSION_INDICES is specified in the OPTIONS block. Specified or calculated interbed inelastic specific storage values are not adjusted from initial values if HEAD_BASED is specified in the OPTIONS block.
  – sse_cr (double) is the initial elastic coarse-grained material specific storage or recompression index of the interbed. The recompression index is specified if COMPRESSION_INDICES is specified in the OPTIONS block. Specified or calculated interbed elastic specific storage values are not adjusted from initial values if HEAD_BASED is specified in the OPTIONS block.
  – theta (double) is the initial porosity of the interbed.
  – kv (double) is the vertical hydraulic conductivity of the delay interbed. KV must be greater than 0 if CDELAY is DELAY. Otherwise, KV can be any value.
  – h0 (double) is the initial offset from the head in cell cellid or the initial head in the delay interbed. H0 is the initial head in the delay bed if SPECIFIED_INITIAL_INTERBED_STATE or SPECIFIED_INITIAL_DELAY_HEAD are specified in the OPTIONS block. H0 can be any value if CDELAY is NODELAY.
  – boundname (string) name of the CSUB cell. BOUNDNAME is an ASCII character variable that can contain as many as 40 characters. If BOUNDNAME contains spaces in it, then the entire name must be enclosed within single quotes.

• **stress_period_data** (*[cellid, sig0]*) -
  – cellid ((integer, ...)) is the cell identifier, and depends on the type of grid that is used for the simulation. For a structured grid that uses the DIS input file, CELLID is the layer, row, and column. For a grid that uses the DISV input file, CELLID is the layer and CELL2D number. If the model uses the unstructured discretization (DISU) input file, CELLID is the node number for the cell. This argument is an index variable,

which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.

  - sig0 (double) is the stress offset for the cell. SIG0 is added to the calculated geostatic stress for the cell. SIG0 is specified only if MAXSIG0 is specified to be greater than 0 in the DIMENSIONS block. If the Options block includes a TIMESERIESFILE entry (see the "Time- Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.

- **filename** (*String*) - File name for this package.
- **pname** (*String*) - Package name for this package.
- **parent_file** (MFPackage) - Parent package file that references this package. Only needed for utility packages (mfutl*). For example, mfutllaktab package must have a mfgwflak package parent_file.

cg_ske_cr = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

cg_theta = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

compaction_coarse_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

compaction_elastic_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

compaction_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

compaction_inelastic_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

compaction_interbed_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

```
dfn = [['header'], ['block options', 'name boundnames', 'type keyword', 'shape',
'reader urword', 'optional true'], ['block options', 'name print_input', 'type
keyword', 'reader urword', 'optional true'], ['block options', 'name save_flows',
'type keyword', 'reader urword', 'optional true'], ['block options', 'name gammaw',
'type double precision', 'reader urword', 'optional true', 'default_value 9806.65'],
['block options', 'name beta', 'type double precision', 'reader urword', 'optional
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'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block
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dfn_file_name = 'gwf-csub.dfn'

obs_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

package_abbr = 'gwfcsub'

package_convergence_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

packagedata = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

sgm = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

sgs = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

straincg_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

strainib_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

stress_period_data = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

ts_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

zdisplacement_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

flopy.mf6.modflow.mfgwfdis module

class ModflowGwfdis(*model, loading_package=False, length_units=None, nogrb=None, xorigin=None, yorigin=None, angrot=None, nlay=1, nrow=2, ncol=2, delr=1.0, delc=1.0, top=1.0, botm=0.0, idomain=None, filename=None, pname=None, **kwargs*)

Bases: *MFPackage*

ModflowGwfdis defines a dis package within a gwf6 model.

Parameters

- **model** (MFModel) – Model that this package is a part of. Package is automatically added to model when it is initialized.
- **loading_package** (*bool*) – Do not set this parameter. It is intended for debugging and internal processing purposes only.
- **length_units** (*string*) –
  – length_units (string) is the length units used for this model. Values can be "FEET", "METERS", or "CENTIMETERS". If not specified, the default is "UNKNOWN".
- **nogrb** (*boolean*) –
  – nogrb (boolean) keyword to deactivate writing of the binary grid file.
- **xorigin** (*double*) –

  - xorigin (double) x-position of the lower-left corner of the model grid. A default value of zero is assigned if not specified. The value for XORIGIN does not affect the model simulation, but it is written to the binary grid file so that postprocessors can locate the grid in space.

- **yorigin** (*double*) -
  - yorigin (double) y-position of the lower-left corner of the model grid. If not specified, then a default value equal to zero is used. The value for YORIGIN does not affect the model simulation, but it is written to the binary grid file so that postprocessors can locate the grid in space.

- **angrot** (*double*) -
  - angrot (double) counter-clockwise rotation angle (in degrees) of the lower-left corner of the model grid. If not specified, then a default value of 0.0 is assigned. The value for ANGROT does not affect the model simulation, but it is written to the binary grid file so that postprocessors can locate the grid in space.

- **nlay** (*integer*) -
  - nlay (integer) is the number of layers in the model grid.

- **nrow** (*integer*) -
  - nrow (integer) is the number of rows in the model grid.

- **ncol** (*integer*) -
  - ncol (integer) is the number of columns in the model grid.

- **delr** (*[double]*) -
  - delr (double) is the column spacing in the row direction.

- **delc** (*[double]*) -
  - delc (double) is the row spacing in the column direction.

- **top** (*[double]*) -
  - top (double) is the top elevation for each cell in the top model layer.

- **botm** (*[double]*) -
  - botm (double) is the bottom elevation for each cell.

- **idomain** (*[integer]*) -
  - idomain (integer) is an optional array that characterizes the existence status of a cell. If the IDOMAIN array is not specified, then all model cells exist within the solution. If the IDOMAIN value for a cell is 0, the cell does not exist in the simulation. Input and output values will be read and written for the cell, but internal to the program, the cell is excluded from the solution. If the IDOMAIN value for a cell is 1 or greater, the cell exists in the simulation. If the IDOMAIN value for a cell is -1, the cell does not exist in the simulation. Furthermore, the first existing cell above will be

connected to the first existing cell below. This type of cell is referred to as a "vertical pass through" cell.

- **filename** (*String*) - File name for this package.
- **pname** (*String*) - Package name for this package.
- **parent_file** (MFPackage) - Parent package file that references this package. Only needed for utility packages (mfutl*). For example, mfutllaktab package must have a mfgwflak package parent_file.

botm = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

delc = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

delr = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

dfn = [['header'], ['block options', 'name length_units', 'type string', 'reader urword', 'optional true'], ['block options', 'name nogrb', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name xorigin', 'type double precision', 'reader urword', 'optional true'], ['block options', 'name yorigin', 'type double precision', 'reader urword', 'optional true'], ['block options', 'name angrot', 'type double precision', 'reader urword', 'optional true'], ['block dimensions', 'name nlay', 'type integer', 'reader urword', 'optional false', 'default_value 1'], ['block dimensions', 'name nrow', 'type integer', 'reader urword', 'optional false', 'default_value 2'], ['block dimensions', 'name ncol', 'type integer', 'reader urword', 'optional false', 'default_value 2'], ['block griddata', 'name delr', 'type double precision', 'shape (ncol)', 'reader readarray', 'default_value 1.0'], ['block griddata', 'name delc', 'type double precision', 'shape (nrow)', 'reader readarray', 'default_value 1.0'], ['block griddata', 'name top', 'type double precision', 'shape (ncol, nrow)', 'reader readarray', 'default_value 1.0'], ['block griddata', 'name botm', 'type double precision', 'shape (ncol, nrow, nlay)', 'reader readarray', 'layered true', 'default_value 0.'], ['block griddata', 'name idomain', 'type integer', 'shape (ncol, nrow, nlay)', 'reader readarray', 'layered true', 'optional true']]

dfn_file_name = 'gwf-dis.dfn'

idomain = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

package_abbr = 'gwfdis'

top = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

flopy.mf6.modflow.mfgwfdisu module

class ModflowGwfdisu(*model*, *loading_package=False*, *length_units=None*, *nogrb=None*, *xorigin=None*, *yorigin=None*, *angrot=None*, *vertical_offset_tolerance=0.0*, *nodes=None*, *nja=None*, *nvert=None*, *top=None*, *bot=None*, *area=None*, *idomain=None*, *iac=None*, *ja=None*, *ihc=None*, *cl12=None*, *hwva=None*, *angldegx=None*, *vertices=None*, *cell2d=None*, *filename=None*, *pname=None*, ***kwargs*)

Bases: *MFPackage*

ModflowGwfdisu defines a disu package within a gwf6 model.

Parameters

- **model** (MFModel) - Model that this package is a part of. Package is automatically added to model when it is initialized.
- **loading_package** (*bool*) - Do not set this parameter. It is intended for debugging and internal processing purposes only.
- **length_units** (*string*) -
  - length_units (string) is the length units used for this model. Values can be "FEET", "METERS", or "CENTIMETERS". If not specified, the default is "UNKNOWN".
- **nogrb** (*boolean*) -
  - nogrb (boolean) keyword to deactivate writing of the binary grid file.
- **xorigin** (*double*) -
  - xorigin (double) x-position of the origin used for model grid vertices. This value should be provided in a real-world coordinate system. A default value of zero is assigned if not specified. The value for XORIGIN does not affect the model simulation, but it is written to the binary grid file so that postprocessors can locate the grid in space.
- **yorigin** (*double*) -
  - yorigin (double) y-position of the origin used for model grid vertices. This value should be provided in a real-world coordinate system. If not specified, then a default value equal to zero is used. The value for YORIGIN does not affect the model simulation, but it is written to the binary grid file so that postprocessors can locate the grid in space.
- **angrot** (*double*) -
  - angrot (double) counter-clockwise rotation angle (in degrees) of the model grid coordinate system relative to a real-world coordinate system. If not specified, then a default value of 0.0 is assigned. The value for ANGROT does not affect the model simulation, but it is written to the binary grid file so that postprocessors can locate the grid in space.
- **vertical_offset_tolerance** (*double*) -
  - vertical_offset_tolerance (double) checks are performed to ensure that the top of a cell is not higher than the bottom of an overlying cell. This option can be used to specify the tolerance that is used for checking. If top of a cell is above the bottom of an overlying cell by a value less than this tolerance, then the program will not terminate with an error. The default value is zero. This option should generally not be used.
- **nodes** (*integer*) -
  - nodes (integer) is the number of cells in the model grid.
- **nja** (*integer*) -

  - nja (integer) is the sum of the number of connections and NODES. When calculating the total number of connections, the connection between cell n and cell m is considered to be different from the connection between cell m and cell n. Thus, NJA is equal to the total number of connections, including n to m and m to n, and the total number of cells.

- **nvert** (*integer*) -
  - nvert (integer) is the total number of (x, y) vertex pairs used to define the plan-view shape of each cell in the model grid. If NVERT is not specified or is specified as zero, then the VERTICES and CELL2D blocks below are not read. NVERT and the accompanying VERTICES and CELL2D blocks should be specified for most simulations. If the XT3D or SAVE_SPECIFIC_DISCHARGE options are specified in the NPF Package, then this information is required.

- **top** (*[double]*) -
  - top (double) is the top elevation for each cell in the model grid.

- **bot** (*[double]*) -
  - bot (double) is the bottom elevation for each cell.

- **area** (*[double]*) -
  - area (double) is the cell surface area (in plan view).

- **idomain** (*[integer]*) -
  - idomain (integer) is an optional array that characterizes the existence status of a cell. If the IDOMAIN array is not specified, then all model cells exist within the solution. If the IDOMAIN value for a cell is 0, the cell does not exist in the simulation. Input and output values will be read and written for the cell, but internal to the program, the cell is excluded from the solution. If the IDOMAIN value for a cell is 1 or greater, the cell exists in the simulation. IDOMAIN values of -1 cannot be specified for the DISU Package.

- **iac** (*[integer]*) -
  - iac (integer) is the number of connections (plus 1) for each cell. The sum of all the entries in IAC must be equal to NJA.

- **ja** (*[integer]*) -
  - ja (integer) is a list of cell number (n) followed by its connecting cell numbers (m) for each of the m cells connected to cell n. The number of values to provide for cell n is IAC(n). This list is sequentially provided for the first to the last cell. The first value in the list must be cell n itself, and the remaining cells must be listed in an increasing order (sorted from lowest number to highest). Note that the cell and its connections are only supplied for the GWF cells and their connections to the other GWF cells. Also note that the JA list input may be divided such that every node and its connectivity list can be on a separate line for ease in readability of

the file. To further ease readability of the file, the node number of the cell whose connectivity is subsequently listed, may be expressed as a negative number, the sign of which is subsequently converted to positive by the code. This argument is an index variable, which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.

- **ihc** (*[integer]*) -
  - ihc (integer) is an index array indicating the direction between node n and all of its m connections. If IHC = 0 then cell n and cell m are connected in the vertical direction. Cell n overlies cell m if the cell number for n is less than m; cell m overlies cell n if the cell number for m is less than n. If IHC = 1 then cell n and cell m are connected in the horizontal direction. If IHC = 2 then cell n and cell m are connected in the horizontal direction, and the connection is vertically staggered. A vertically staggered connection is one in which a cell is horizontally connected to more than one cell in a horizontal connection.
- **cl12** (*[double]*) -
  - cl12 (double) is the array containing connection lengths between the center of cell n and the shared face with each adjacent m cell.
- **hwva** (*[double]*) -
  - hwva (double) is a symmetric array of size NJA. For horizontal connections, entries in HWVA are the horizontal width perpendicular to flow. For vertical connections, entries in HWVA are the vertical area for flow. Thus, values in the HWVA array contain dimensions of both length and area. Entries in the HWVA array have a one-to-one correspondence with the connections specified in the JA array. Likewise, there is a one-to-one correspondence between entries in the HWVA array and entries in the IHC array, which specifies the connection type (horizontal or vertical). Entries in the HWVA array must be symmetric; the program will terminate with an error if the value for HWVA for an n to m connection does not equal the value for HWVA for the corresponding n to m connection.
- **angldegx** (*[double]*) -
  - angldegx (double) is the angle (in degrees) between the horizontal x-axis and the outward normal to the face between a cell and its connecting cells. The angle varies between zero and 360.0 degrees, where zero degrees points in the positive x-axis direction, and 90 degrees points in the positive y-axis direction. ANGLDEGX is only needed if horizontal anisotropy is specified in the NPF Package, if the XT3D option is used in the NPF Package, or if the SAVE_SPECIFIC_DISCHARGE option is specifed in the NPF Package. ANGLDEGX does not need to be specified if these conditions are not met. ANGLDEGX is of size NJA; values specified for vertical connections and for

the diagonal position are not used. Note that ANGLDEGX is read in degrees, which is different from MODFLOW-USG, which reads a similar variable (ANGLEX) in radians.

- **vertices** (*[iv, xv, yv]*) -
  - iv (integer) is the vertex number. Records in the VERTICES block must be listed in consecutive order from 1 to NVERT. This argument is an index variable, which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.
  - xv (double) is the x-coordinate for the vertex.
  - yv (double) is the y-coordinate for the vertex.
- **cell2d** (*[icell2d, xc, yc, ncvert, icvert]*) -
  - icell2d (integer) is the cell2d number. Records in the CELL2D block must be listed in consecutive order from 1 to NODES. This argument is an index variable, which means that it should be treated as zero- based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.
  - xc (double) is the x-coordinate for the cell center.
  - yc (double) is the y-coordinate for the cell center.
  - ncvert (integer) is the number of vertices required to define the cell. There may be a different number of vertices for each cell.
  - icvert (integer) is an array of integer values containing vertex numbers (in the VERTICES block) used to define the cell. Vertices must be listed in clockwise order. This argument is an index variable, which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.
- **filename** (*String*) - File name for this package.
- **pname** (*String*) - Package name for this package.
- **parent_file** (MFPackage) - Parent package file that references this package. Only needed for utility packages (mfutl*). For example, mfutllaktab package must have a mfgwflak package parent_file.

angldegx = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

area = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

bot = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

cell2d = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

cl12 = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

dfn = [['header'], ['block options', 'name length_units', 'type string', 'reader urword', 'optional true'], ['block options', 'name nogrb', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name xorigin', 'type double precision', 'reader urword', 'optional true'], ['block options', 'name yorigin', 'type double precision', 'reader urword', 'optional true'], ['block options', 'name angrot', 'type double precision', 'reader urword', 'optional true'], ['block options', 'name vertical_offset_tolerance', 'type double precision', 'reader urword', 'optional true', 'default_value 0.0', 'mf6internal voffsettol'], ['block dimensions', 'name nodes', 'type integer', 'reader urword', 'optional false'], ['block dimensions', 'name nja', 'type integer', 'reader urword', 'optional false'], ['block dimensions', 'name nvert', 'type integer', 'reader urword', 'optional true'], ['block griddata', 'name top', 'type double precision', 'shape (nodes)', 'reader readarray'], ['block griddata', 'name bot', 'type double precision', 'shape (nodes)', 'reader readarray'], ['block griddata', 'name area', 'type double precision', 'shape (nodes)', 'reader readarray'], ['block griddata', 'name idomain', 'type integer', 'shape (nodes)', 'reader readarray', 'layered false', 'optional true'], ['block connectiondata', 'name iac', 'type integer', 'shape (nodes)', 'reader readarray'], ['block connectiondata', 'name ja', 'type integer', 'shape (nja)', 'reader readarray', 'numeric_index true', 'jagged_array iac'], ['block connectiondata', 'name ihc', 'type integer', 'shape (nja)', 'reader readarray', 'jagged_array iac'], ['block connectiondata', 'name cl12', 'type double precision', 'shape (nja)', 'reader readarray', 'jagged_array iac'], ['block connectiondata', 'name hwva', 'type double precision', 'shape (nja)', 'reader readarray', 'jagged_array iac'], ['block connectiondata', 'name angldegx', 'type double precision', 'optional true', 'shape (nja)', 'reader readarray', 'jagged_array iac'], ['block vertices', 'name vertices', 'type recarray iv xv yv', 'shape (nvert)', 'reader urword', 'optional false'], ['block vertices', 'name iv', 'type integer', 'in_record true', 'tagged false', 'reader urword', 'optional false', 'numeric_index true'], ['block vertices', 'name xv', 'type double precision', 'in_record true', 'tagged false', 'reader urword', 'optional false'], ['block vertices', 'name yv', 'type double precision', 'in_record true', 'tagged false', 'reader urword', 'optional false'], ['block cell2d', 'name cell2d', 'type recarray icell2d xc yc ncvert icvert', 'shape (nodes)', 'reader urword', 'optional false'], ['block cell2d', 'name icell2d', 'type integer', 'in_record true', 'tagged false', 'reader urword', 'optional false', 'numeric_index true'], ['block cell2d', 'name xc', 'type double precision', 'in_record true', 'tagged false', 'reader urword', 'optional false'], ['block cell2d', 'name yc', 'type double precision', 'in_record true', 'tagged false', 'reader urword', 'optional false'], ['block cell2d', 'name ncvert', 'type integer', 'in_record true', 'tagged false', 'reader urword', 'optional false'], ['block cell2d', 'name icvert', 'type integer', 'shape (ncvert)', 'in_record true', 'tagged false', 'reader urword', 'optional false', 'numeric_index true']]

dfn_file_name = 'gwf-disu.dfn'

hwva = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

iac = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

idomain = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

ihc = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

ja = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

package_abbr = 'gwfdisu'

top = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

vertices = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

flopy.mf6.modflow.mfgwfdisv module

class ModflowGwfdisv(*model*, *loading_package=False*, *length_units=None*, *nogrb=None*, *xorigin=None*, *yorigin=None*, *angrot=None*, *nlay=None*, *ncpl=None*, *nvert=None*, *top=None*, *botm=None*, *idomain=None*, *vertices=None*, *cell2d=None*, *filename=None*, *pname=None*, ***kwargs*)

Bases: *MFPackage*

ModflowGwfdisv defines a disv package within a gwf6 model.

Parameters

- **model** (MFModel) - Model that this package is a part of. Package is automatically added to model when it is initialized.
- **loading_package** (*bool*) - Do not set this parameter. It is intended for debugging and internal processing purposes only.
- **length_units** (*string*) -
  - length_units (string) is the length units used for this model. Values can be "FEET", "METERS", or "CENTIMETERS". If not specified, the default is "UNKNOWN".
- **nogrb** (*boolean*) -
  - nogrb (boolean) keyword to deactivate writing of the binary grid file.
- **xorigin** (*double*) -
  - xorigin (double) x-position of the origin used for model grid vertices. This value should be provided in a real-world coordinate system. A default value of zero is assigned if not specified. The value for XORIGIN does not affect the model simulation, but it is written to the binary grid file so that postprocessors can locate the grid in space.
- **yorigin** (*double*) -
  - yorigin (double) y-position of the origin used for model grid vertices. This value should be provided in a real-world coordinate system. If not specified, then a default value equal to zero is used. The value for YORIGIN does not affect the model simulation, but it is written to the binary grid file so that postprocessors can locate the grid in space.
- **angrot** (*double*) -
  - angrot (double) counter-clockwise rotation angle (in degrees) of the model grid coordinate system relative to a real-world coordinate system. If not specified, then a default value of 0.0 is assigned. The value for ANGROT does not affect the model

simulation, but it is written to the binary grid file so that postprocessors can locate the grid in space.

- **nlay** (*integer*) -
  - nlay (integer) is the number of layers in the model grid.
- **ncpl** (*integer*) -
  - ncpl (integer) is the number of cells per layer. This is a constant value for the grid and it applies to all layers.
- **nvert** (*integer*) -
  - nvert (integer) is the total number of (x, y) vertex pairs used to characterize the horizontal configuration of the model grid.
- **top** (*[double]*) -
  - top (double) is the top elevation for each cell in the top model layer.
- **botm** (*[double]*) -
  - botm (double) is the bottom elevation for each cell.
- **idomain** (*[integer]*) -
  - idomain (integer) is an optional array that characterizes the existence status of a cell. If the IDOMAIN array is not specified, then all model cells exist within the solution. If the IDOMAIN value for a cell is 0, the cell does not exist in the simulation. Input and output values will be read and written for the cell, but internal to the program, the cell is excluded from the solution. If the IDOMAIN value for a cell is 1 or greater, the cell exists in the simulation. If the IDOMAIN value for a cell is -1, the cell does not exist in the simulation. Furthermore, the first existing cell above will be connected to the first existing cell below. This type of cell is referred to as a "vertical pass through" cell.
- **vertices** (*[iv, xv, yv]*) -
  - iv (integer) is the vertex number. Records in the VERTICES block must be listed in consecutive order from 1 to NVERT. This argument is an index variable, which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.
  - xv (double) is the x-coordinate for the vertex.
  - yv (double) is the y-coordinate for the vertex.
- **cell2d** (*[icell2d, xc, yc, ncvert, icvert]*) -
  - icell2d (integer) is the CELL2D number. Records in the CELL2D block must be listed in consecutive order from the first to the last. This argument is an index variable, which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.

- xc (double) is the x-coordinate for the cell center.
- yc (double) is the y-coordinate for the cell center.
- ncvert (integer) is the number of vertices required to define the cell. There may be a different number of vertices for each cell.
- icvert (integer) is an array of integer values containing vertex numbers (in the VERTICES block) used to define the cell. Vertices must be listed in clockwise order. Cells that are connected must share vertices. This argument is an index variable, which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.

- **filename** (*String*) - File name for this package.
- **pname** (*String*) - Package name for this package.
- **parent_file** (MFPackage) - Parent package file that references this package. Only needed for utility packages (mfutl*). For example, mfutllaktab package must have a mfgwflak package parent_file.

botm = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

cell2d = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

dfn = [['header'], ['block options', 'name length_units', 'type string', 'reader urword', 'optional true'], ['block options', 'name nogrb', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name xorigin', 'type double precision', 'reader urword', 'optional true'], ['block options', 'name yorigin', 'type double precision', 'reader urword', 'optional true'], ['block options', 'name angrot', 'type double precision', 'reader urword', 'optional true'], ['block dimensions', 'name nlay', 'type integer', 'reader urword', 'optional false'], ['block dimensions', 'name ncpl', 'type integer', 'reader urword', 'optional false'], ['block dimensions', 'name nvert', 'type integer', 'reader urword', 'optional false'], ['block griddata', 'name top', 'type double precision', 'shape (ncpl)', 'reader readarray'], ['block griddata', 'name botm', 'type double precision', 'shape (ncpl, nlay)', 'reader readarray', 'layered true'], ['block griddata', 'name idomain', 'type integer', 'shape (ncpl, nlay)', 'reader readarray', 'layered true', 'optional true'], ['block vertices', 'name vertices', 'type recarray iv xv yv', 'shape (nvert)', 'reader urword', 'optional false'], ['block vertices', 'name iv', 'type integer', 'in_record true', 'tagged false', 'reader urword', 'optional false', 'numeric_index true'], ['block vertices', 'name xv', 'type double precision', 'in_record true', 'tagged false', 'reader urword', 'optional false'], ['block vertices', 'name yv', 'type double precision', 'in_record true', 'tagged false', 'reader urword', 'optional false'], ['block cell2d', 'name cell2d', 'type recarray icell2d xc yc ncvert icvert', 'shape (ncpl)', 'reader urword', 'optional false'], ['block cell2d', 'name icell2d', 'type integer', 'in_record true', 'tagged false', 'reader urword', 'optional false', 'numeric_index true'], ['block cell2d', 'name xc', 'type double precision', 'in_record true', 'tagged false', 'reader urword', 'optional false'], ['block cell2d', 'name yc', 'type double precision', 'in_record true', 'tagged false', 'reader urword', 'optional false'], ['block cell2d', 'name ncvert', 'type integer', 'in_record true', 'tagged false', 'reader urword', 'optional false'], ['block cell2d', 'name icvert', 'type integer', 'shape (ncvert)', 'in_record true', 'tagged false', 'reader urword', 'optional false', 'numeric_index true']]

dfn_file_name = 'gwf-disv.dfn'

idomain = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

package_abbr = 'gwfdisv'

top = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

vertices = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

flopy.mf6.modflow.mfgwfdrn module

class ModflowGwfdrn(*model*, *loading_package=False*, *auxiliary=None*, *auxmultname=None*, *auxdepthname=None*, *boundnames=None*, *print_input=None*, *print_flows=None*, *save_flows=None*, *timeseries=None*, *observations=None*, *mover=None*, *maxbound=None*, *stress_period_data=None*, *filename=None*, *pname=None*, ***kwargs*)

Bases: *MFPackage*

ModflowGwfdrn defines a drn package within a gwf6 model.

Parameters

- **model** (MFModel) - Model that this package is a part of. Package is automatically added to model when it is initialized.
- **loading_package** (*bool*) - Do not set this parameter. It is intended for debugging and internal processing purposes only.
- **auxiliary** (*[string]*) -
  - auxiliary (string) defines an array of one or more auxiliary variable names. There is no limit on the number of auxiliary variables that can be provided on this line; however, lists of information provided in subsequent blocks must have a column of data for each auxiliary variable name defined here. The number of auxiliary variables detected on this line determines the value for naux. Comments cannot be provided anywhere on this line as they will be interpreted as auxiliary variable names. Auxiliary variables may not be used by the package, but they will be available for use by other parts of the program. The program will terminate with an error if auxiliary variables are specified on more than one line in the options block.
- **auxmultname** (*string*) -
  - auxmultname (string) name of auxiliary variable to be used as multiplier of drain conductance.
- **auxdepthname** (*string*) -
  - auxdepthname (string) name of a variable listed in AUXILIARY that defines the depth at which drainage discharge will be scaled. If a positive value is specified for the AUXDEPTHNAME AUXILIARY variable, then ELEV is the elevation at which the drain starts to discharge and ELEV + DDRN (assuming DDRN is the AUXDEPTHNAME variable) is the elevation when the drain

conductance (COND) scaling factor is 1. If a negative drainage depth value is specified for DDRN, then ELEV + DDRN is the elevation at which the drain starts to discharge and ELEV is the elevation when the conductance (COND) scaling factor is 1. A linear- or cubic-scaling is used to scale the drain conductance (COND) when the Standard or Newton-Raphson Formulation is used, respectively. This discharge scaling option is described in more detail in Chapter 3 of the Supplemental Technical Information.

- **boundnames** (*boolean*) -
  - boundnames (boolean) keyword to indicate that boundary names may be provided with the list of drain cells.
- **print_input** (*boolean*) -
  - print_input (boolean) keyword to indicate that the list of drain information will be written to the listing file immediately after it is read.
- **print_flows** (*boolean*) -
  - print_flows (boolean) keyword to indicate that the list of drain flow rates will be printed to the listing file for every stress period time step in which "BUDGET PRINT" is specified in Output Control. If there is no Output Control option and "PRINT_FLOWS" is specified, then flow rates are printed for the last time step of each stress period.
- **save_flows** (*boolean*) -
  - save_flows (boolean) keyword to indicate that drain flow terms will be written to the file specified with "BUDGET FILEOUT" in Output Control.
- **timeseries** (*{varname:data} or timeseries data*) -
  - Contains data for the ts package. Data can be stored in a dictionary containing data for the ts package with variable names as keys and package data as values. Data just for the timeseries variable is also acceptable. See ts package documentation for more information.
- **observations** (*{varname:data} or continuous data*) -
  - Contains data for the obs package. Data can be stored in a dictionary containing data for the obs package with variable names as keys and package data as values. Data just for the observations variable is also acceptable. See obs package documentation for more information.
- **mover** (*boolean*) -
  - mover (boolean) keyword to indicate that this instance of the Drain Package can be used with the Water Mover (MVR) Package. When the MOVER option is specified, additional memory is allocated within the package to store the available, provided, and received water.
- **maxbound** (*integer*) -

- maxbound (integer) integer value specifying the maximum number of drains cells that will be specified for use during any stress period.

- **stress_period_data** (*[cellid, elev, cond, aux, boundname]*) -
  - cellid ((integer, ...)) is the cell identifier, and depends on the type of grid that is used for the simulation. For a structured grid that uses the DIS input file, CELLID is the layer, row, and column. For a grid that uses the DISV input file, CELLID is the layer and CELL2D number. If the model uses the unstructured discretization (DISU) input file, CELLID is the node number for the cell. This argument is an index variable, which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.
  - elev (double) is the elevation of the drain. If the Options block includes a TIMESERIESFILE entry (see the "Time-Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
  - cond (double) is the hydraulic conductance of the interface between the aquifer and the drain. If the Options block includes a TIMESERIESFILE entry (see the "Time-Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
  - aux (double) represents the values of the auxiliary variables for each drain. The values of auxiliary variables must be present for each drain. The values must be specified in the order of the auxiliary variables specified in the OPTIONS block. If the package supports time series and the Options block includes a TIMESERIESFILE entry (see the "Time-Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
  - boundname (string) name of the drain cell. BOUNDNAME is an ASCII character variable that can contain as many as 40 characters. If BOUNDNAME contains spaces in it, then the entire name must be enclosed within single quotes.
- **filename** (*String*) - File name for this package.
- **pname** (*String*) - Package name for this package.
- **parent_file** (MFPackage) - Parent package file that references this package. Only needed for utility packages (mfutl*). For example, mfutllaktab package must have a mfgwflak package parent_file.

auxiliary = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

dfn = [['header', 'multi-package', 'package-type stress-package'], ['block options', 'name auxiliary', 'type string', 'shape (naux)', 'reader urword', 'optional true'], ['block options', 'name auxmultname', 'type string', 'shape', 'reader urword', 'optional true'], ['block options', 'name auxdepthname', 'type string', 'shape', 'reader urword', 'optional true'], ['block options', 'name boundnames', 'type keyword', 'shape', 'reader urword', 'optional true'], ['block options', 'name print_input', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name print_flows', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name save_flows', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name ts_filerecord', 'type record ts6 filein ts6_filename', 'shape', 'reader urword', 'tagged true', 'optional true', 'construct_package ts', 'construct_data timeseries', 'parameter_name timeseries'], ['block options', 'name ts6', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name filein', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name ts6_filename', 'type string', 'preserve_case true', 'in_record true', 'reader urword', 'optional false', 'tagged false'], ['block options', 'name obs_filerecord', 'type record obs6 filein obs6_filename', 'shape', 'reader urword', 'tagged true', 'optional true', 'construct_package obs', 'construct_data continuous', 'parameter_name observations'], ['block options', 'name obs6', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name obs6_filename', 'type string', 'preserve_case true', 'in_record true', 'tagged false', 'reader urword', 'optional false'], ['block options', 'name mover', 'type keyword', 'tagged true', 'reader urword', 'optional true'], ['block dimensions', 'name maxbound', 'type integer', 'reader urword', 'optional false'], ['block period', 'name iper', 'type integer', 'block_variable True', 'in_record true', 'tagged false', 'shape', 'valid', 'reader urword', 'optional false'], ['block period', 'name stress_period_data', 'type recarray cellid elev cond aux boundname', 'shape (maxbound)', 'reader urword'], ['block period', 'name cellid', 'type integer', 'shape (ncelldim)', 'tagged false', 'in_record true', 'reader urword'], ['block period', 'name elev', 'type double precision', 'shape', 'tagged false', 'in_record true', 'reader urword', 'time_series true'], ['block period', 'name cond', 'type double precision', 'shape', 'tagged false', 'in_record true', 'reader urword', 'time_series true'], ['block period', 'name aux', 'type double precision', 'in_record true', 'tagged false', 'shape (naux)', 'reader urword', 'optional true', 'time_series true'], ['block period', 'name boundname', 'type string', 'shape', 'tagged false', 'in_record true', 'reader urword', 'optional true']]

dfn_file_name = 'gwf-drn.dfn'

obs_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

package_abbr = 'gwfdrn'

stress_period_data = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

ts_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

flopy.mf6.modflow.mfgwfevt module

class ModflowGwfevt(*model*, *loading_package=False*, *fixed_cell=None*, *auxiliary=None*, *auxmultname=None*, *boundnames=None*, *print_input=None*, *print_flows=None*, *save_flows=None*, *timeseries=None*, *observations=None*, *surf_rate_specified=None*, *maxbound=None*, *nseg=None*, *stress_period_data=None*, *filename=None*, *pname=None*, ***kwargs*)

Bases: *MFPackage*

ModflowGwfevt defines a evt package within a gwf6 model.

Parameters

- **model** (MFModel) - Model that this package is a part of. Package is automatically added to model when it is initialized.
- **loading_package** (*bool*) - Do not set this parameter. It is intended for debugging and internal processing purposes only.
- **fixed_cell** (*boolean*) -
  - fixed_cell (boolean) indicates that evapotranspiration will not be reassigned to a cell underlying the cell specified in the list if the specified cell is inactive.
- **auxiliary** (*[string]*) -
  - auxiliary (string) defines an array of one or more auxiliary variable names. There is no limit on the number of auxiliary variables that can be provided on this line; however, lists of information provided in subsequent blocks must have a column of data for each auxiliary variable name defined here. The number of auxiliary variables detected on this line determines the value for naux. Comments cannot be provided anywhere on this line as they will be interpreted as auxiliary variable names. Auxiliary variables may not be used by the package, but they will be available for use by other parts of the program. The program will terminate with an error if auxiliary variables are specified on more than one line in the options block.
- **auxmultname** (*string*) -
  - auxmultname (string) name of auxiliary variable to be used as multiplier of evapotranspiration rate.
- **boundnames** (*boolean*) -
  - boundnames (boolean) keyword to indicate that boundary names may be provided with the list of evapotranspiration cells.
- **print_input** (*boolean*) -
  - print_input (boolean) keyword to indicate that the list of evapotranspiration information will be written to the listing file immediately after it is read.
- **print_flows** (*boolean*) -
  - print_flows (boolean) keyword to indicate that the list of evapotranspiration flow rates will be printed to the listing file for every stress period time step in which "BUDGET PRINT"

is specified in Output Control. If there is no Output Control option and "PRINT_FLOWS" is specified, then flow rates are printed for the last time step of each stress period.

- **save_flows** (*boolean*) -
  - save_flows (boolean) keyword to indicate that evapotranspiration flow terms will be written to the file specified with "BUDGET FILEOUT" in Output Control.
- **timeseries** (*{varname:data} or timeseries data*) -
  - Contains data for the ts package. Data can be stored in a dictionary containing data for the ts package with variable names as keys and package data as values. Data just for the timeseries variable is also acceptable. See ts package documentation for more information.
- **observations** (*{varname:data} or continuous data*) -
  - Contains data for the obs package. Data can be stored in a dictionary containing data for the obs package with variable names as keys and package data as values. Data just for the observations variable is also acceptable. See obs package documentation for more information.
- **surf_rate_specified** (*boolean*) -
  - surf_rate_specified (boolean) indicates that the proportion of the evapotranspiration rate at the ET surface will be specified as PETM0 in list input.
- **maxbound** (*integer*) -
  - maxbound (integer) integer value specifying the maximum number of evapotranspiration cells cells that will be specified for use during any stress period.
- **nseg** (*integer*) -
  - nseg (integer) number of ET segments. Default is one. When NSEG is greater than 1, the PXDP and PETM arrays must be of size NSEG - 1 and be listed in order from the uppermost segment down. Values for PXDP must be listed first followed by the values for PETM. PXDP defines the extinction-depth proportion at the bottom of a segment. PETM defines the proportion of the maximum ET flux rate at the bottom of a segment.
- **stress_period_data** (*[cellid, surface, rate, depth, pxdp, petm, petm0, aux,)* -

  boundname]

  - cellid ((integer, ...)) is the cell identifier, and depends on the type of grid that is used for the simulation. For a structured grid that uses the DIS input file, CELLID is the layer, row, and column. For a grid that uses the DISV input file, CELLID is the layer and CELL2D number. If the model uses the unstructured discretization (DISU) input file, CELLID is the node number for the cell. This argument is an index variable, which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.

- surface (double) is the elevation of the ET surface (L). If the Options block includes a TIMESERIESFILE entry (see the "Time- Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
- rate (double) is the maximum ET flux rate (LT^{-1}). If the Options block includes a TIMESERIESFILE entry (see the "Time-Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
- depth (double) is the ET extinction depth (L). If the Options block includes a TIMESERIESFILE entry (see the "Time-Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
- pxdp (double) is the proportion of the ET extinction depth at the bottom of a segment (dimensionless). pxdp is an array of size (nseg - 1). Values in pxdp must be greater than 0.0 and less than 1.0. pxdp values for a cell must increase monotonically. If the Options block includes a TIMESERIESFILE entry (see the "Time-Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
- petm (double) is the proportion of the maximum ET flux rate at the bottom of a segment (dimensionless). petm is an array of size (nseg - 1). If the Options block includes a TIMESERIESFILE entry (see the "Time-Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
- petm0 (double) is the proportion of the maximum ET flux rate that will apply when head is at or above the ET surface (dimensionless). PETM0 is read only when the SURF_RATE_SPECIFIED option is used. If the Options block includes a TIMESERIESFILE entry (see the "Time- Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
- aux (double) represents the values of the auxiliary variables for each evapotranspiration. The values of auxiliary variables must be present for each evapotranspiration. The values must be specified in the order of the auxiliary variables specified in the OPTIONS block. If the package supports time series and the Options block includes a TIMESERIESFILE entry (see the "Time-Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
- boundname (string) name of the evapotranspiration cell. BOUNDNAME is an ASCII character variable that can contain

as many as 40 characters. If BOUNDNAME contains spaces in it, then the entire name must be enclosed within single quotes.

- **filename** (*String*) - File name for this package.
- **pname** (*String*) - Package name for this package.
- **parent_file** (MFPackage) - Parent package file that references this package. Only needed for utility packages (mfutl*). For example, mfutllaktab package must have a mfgwflak package parent_file.

auxiliary = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

dfn = [['header', 'multi-package', 'package-type stress-package'], ['block options', 'name fixed_cell', 'type keyword', 'shape', 'reader urword', 'optional true'], ['block options', 'name auxiliary', 'type string', 'shape (naux)', 'reader urword', 'optional true'], ['block options', 'name auxmultname', 'type string', 'shape', 'reader urword', 'optional true'], ['block options', 'name boundnames', 'type keyword', 'shape', 'reader urword', 'optional true'], ['block options', 'name print_input', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name print_flows', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name save_flows', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name ts_filerecord', 'type record ts6 filein ts6_filename', 'shape', 'reader urword', 'tagged true', 'optional true', 'construct_package ts', 'construct_data timeseries', 'parameter_name timeseries'], ['block options', 'name ts6', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name filein', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name ts6_filename', 'type string', 'preserve_case true', 'in_record true', 'reader urword', 'optional false', 'tagged false'], ['block options', 'name obs_filerecord', 'type record obs6 filein obs6_filename', 'shape', 'reader urword', 'tagged true', 'optional true', 'construct_package obs', 'construct_data continuous', 'parameter_name observations'], ['block options', 'name obs6', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name obs6_filename', 'type string', 'preserve_case true', 'in_record true', 'tagged false', 'reader urword', 'optional false'], ['block options', 'name surf_rate_specified', 'type keyword', 'reader urword', 'optional true'], ['block dimensions', 'name maxbound', 'type integer', 'reader urword', 'optional false'], ['block dimensions', 'name nseg', 'type integer', 'reader urword', 'optional false'], ['block period', 'name iper', 'type integer', 'block_variable True', 'in_record true', 'tagged false', 'shape', 'valid', 'reader urword', 'optional false'], ['block period', 'name stress_period_data', 'type recarray cellid surface rate depth pxdp petm petm0 aux boundname', 'shape (maxbound)', 'reader urword'], ['block period', 'name cellid', 'type integer', 'shape (ncelldim)', 'tagged false', 'in_record true', 'reader urword'], ['block period', 'name surface', 'type double precision', 'shape', 'tagged false', 'in_record true', 'reader urword', 'time_series true'], ['block period', 'name rate', 'type double precision', 'shape', 'tagged false', 'in_record true', 'reader urword', 'time_series true'], ['block period', 'name depth', 'type double precision', 'shape', 'tagged false', 'in_record true', 'reader urword', 'time_series true'], ['block period', 'name pxdp', 'type double precision', 'shape (nseg-1)', 'tagged false', 'in_record true', 'reader urword', 'time_series true'], ['block period', 'name petm', 'type double precision', 'shape (nseg-1)', 'tagged false', 'in_record true', 'reader urword', 'time_series true'], ['block period', 'name petm0', 'type double precision', 'shape', 'tagged false', 'in_record true', 'reader urword', 'optional true', 'time_series true'], ['block period', 'name aux', 'type double precision', 'in_record true', 'tagged false', 'shape (naux)', 'reader urword', 'optional true', 'time_series true'], ['block period', 'name boundname', 'type string', 'shape', 'tagged false', 'in_record true', 'reader urword', 'optional true']]

dfn_file_name = 'gwf-evt.dfn'

obs_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

package_abbr = 'gwfevt'

stress_period_data = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

ts_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

flopy.mf6.modflow.mfgwfevta module

class ModflowGwfevta(*model*, *loading_package=False*, *readasarrays=True*, *fixed_cell=None*, *auxiliary=None*, *auxmultname=None*, *print_input=None*, *print_flows=None*, *save_flows=None*, *timearrayseries=None*, *observations=None*, *ievt=None*, *surface=0.0*, *rate=0.001*, *depth=1.0*, *aux=None*, *filename=None*, *pname=None*, ***kwargs*)

Bases: *MFPackage*

ModflowGwfevta defines a evta package within a gwf6 model.

Parameters

- **model** (MFModel) - Model that this package is a part of. Package is automatically added to model when it is initialized.
- **loading_package** (*bool*) - Do not set this parameter. It is intended for debugging and internal processing purposes only.
- **readasarrays** (*boolean*) -
  - readasarrays (boolean) indicates that array-based input will be used for the Evapotranspiration Package. This keyword must be specified to use array-based input.
- **fixed_cell** (*boolean*) -
  - fixed_cell (boolean) indicates that evapotranspiration will not be reassigned to a cell underlying the cell specified in the list if the specified cell is inactive.
- **auxiliary** (*[string]*) -
  - auxiliary (string) defines an array of one or more auxiliary variable names. There is no limit on the number of auxiliary variables that can be provided on this line; however, lists of information provided in subsequent blocks must have a column of data for each auxiliary variable name defined here. The number of auxiliary variables detected on this line determines the value for naux. Comments cannot be provided anywhere on this line as they will be interpreted as auxiliary variable names. Auxiliary variables may not be used by the package, but they will be available for use by other parts of the program. The program will terminate with an error if auxiliary variables are specified on more than one line in the options block.
- **auxmultname** (*string*) -
  - auxmultname (string) name of auxiliary variable to be used as multiplier of evapotranspiration rate.
- **print_input** (*boolean*) -
  - print_input (boolean) keyword to indicate that the list of evapotranspiration information will be written to the listing file immediately after it is read.
- **print_flows** (*boolean*) -

  - print_flows (boolean) keyword to indicate that the list of evapotranspiration flow rates will be printed to the listing file for every stress period time step in which "BUDGET PRINT" is specified in Output Control. If there is no Output Control option and "PRINT_FLOWS" is specified, then flow rates are printed for the last time step of each stress period.

- **save_flows** (*boolean*) -
  - save_flows (boolean) keyword to indicate that evapotranspiration flow terms will be written to the file specified with "BUDGET FILEOUT" in Output Control.

- **timearrayseries** (*{varname:data} or tas_array data*) -
  - Contains data for the tas package. Data can be stored in a dictionary containing data for the tas package with variable names as keys and package data as values. Data just for the timearrayseries variable is also acceptable. See tas package documentation for more information.

- **observations** (*{varname:data} or continuous data*) -
  - Contains data for the obs package. Data can be stored in a dictionary containing data for the obs package with variable names as keys and package data as values. Data just for the observations variable is also acceptable. See obs package documentation for more information.

- **ievt** (*[integer]*) -
  - ievt (integer) IEVT is the layer number that defines the layer in each vertical column where evapotranspiration is applied. If IEVT is omitted, evapotranspiration by default is applied to cells in layer 1. If IEVT is specified, it must be specified as the first variable in the PERIOD block or MODFLOW will terminate with an error. This argument is an index variable, which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.

- **surface** (*[double]*) -
  - surface (double) is the elevation of the ET surface (L).

- **rate** (*[double]*) -
  - rate (double) is the maximum ET flux rate (LT^{-1}).

- **depth** (*[double]*) -
  - depth (double) is the ET extinction depth (L).

- **aux(iaux)** (*[double]*) -
  - aux(iaux) (double) is an array of values for auxiliary variable AUX(IAUX), where iaux is a value from 1 to NAUX, and AUX(IAUX) must be listed as part of the auxiliary variables. A separate array can be specified for each auxiliary variable. If an array is not specified for an auxiliary variable, then a value of zero is assigned. If the value specified here for the auxiliary

variable is the same as auxmultname, then the evapotranspiration rate will be multiplied by this array.

- **filename** (*String*) - File name for this package.
- **pname** (*String*) - Package name for this package.
- **parent_file** (MFPackage) - Parent package file that references this package. Only needed for utility packages (mfutl*). For example, mfutllaktab package must have a mfgwflak package parent_file.

aux = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

auxiliary = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

depth = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

dfn = [['header', 'multi-package', 'package-type stress-package'], ['block options', 'name readasarrays', 'type keyword', 'shape', 'reader urword', 'optional false', 'default_value True'], ['block options', 'name fixed_cell', 'type keyword', 'shape', 'reader urword', 'optional true'], ['block options', 'name auxiliary', 'type string', 'shape (naux)', 'reader urword', 'optional true'], ['block options', 'name auxmultname', 'type string', 'shape', 'reader urword', 'optional true'], ['block options', 'name print_input', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name print_flows', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name save_flows', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name tas_filerecord', 'type record tas6 filein tas6_filename', 'shape', 'reader urword', 'tagged true', 'optional true', 'construct_package tas', 'construct_data tas_array', 'parameter_name timearrayseries'], ['block options', 'name tas6', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name filein', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name tas6_filename', 'type string', 'preserve_case true', 'in_record true', 'reader urword', 'optional false', 'tagged false'], ['block options', 'name obs_filerecord', 'type record obs6 filein obs6_filename', 'shape', 'reader urword', 'tagged true', 'optional true', 'construct_package obs', 'construct_data continuous', 'parameter_name observations'], ['block options', 'name obs6', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name obs6_filename', 'type string', 'preserve_case true', 'in_record true', 'tagged false', 'reader urword', 'optional false'], ['block period', 'name iper', 'type integer', 'block_variable True', 'in_record true', 'tagged false', 'shape', 'valid', 'reader urword', 'optional false'], ['block period', 'name ievt', 'type integer', 'shape (ncol*nrow; ncpl)', 'reader readarray', 'numeric_index true', 'optional true'], ['block period', 'name surface', 'type double precision', 'shape (ncol*nrow; ncpl)', 'reader readarray', 'default_value 0.'], ['block period', 'name rate', 'type double precision', 'shape (ncol*nrow; ncpl)', 'reader readarray', 'default_value 1.e-3'], ['block period', 'name depth', 'type double precision', 'shape (ncol*nrow; ncpl)', 'reader readarray', 'default_value 1.0'], ['block period', 'name aux(iaux)', 'type double precision', 'shape (ncol*nrow; ncpl)', 'reader readarray']]

dfn_file_name = 'gwf-evta.dfn'

ievt = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

obs_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

package_abbr = 'gwfevta'

rate = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

surface = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

tas_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

flopy.mf6.modflow.mfgwfghb module

class **ModflowGwfghb**(*model*, *loading_package=False*, *auxiliary=None*, *auxmultname=None*, *boundnames=None*, *print_input=None*, *print_flows=None*, *save_flows=None*, *timeseries=None*, *observations=None*, *mover=None*, *maxbound=None*, *stress_period_data=None*, *filename=None*, *pname=None*, ***kwargs*)

Bases: *MFPackage*

ModflowGwfghb defines a ghb package within a gwf6 model.

Parameters

- **model** (MFModel) - Model that this package is a part of. Package is automatically added to model when it is initialized.
- **loading_package** (*bool*) - Do not set this parameter. It is intended for debugging and internal processing purposes only.
- **auxiliary** (*[string]*) -
  - auxiliary (string) defines an array of one or more auxiliary variable names. There is no limit on the number of auxiliary variables that can be provided on this line; however, lists of information provided in subsequent blocks must have a column of data for each auxiliary variable name defined here. The number of auxiliary variables detected on this line determines the value for naux. Comments cannot be provided anywhere on this line as they will be interpreted as auxiliary variable names. Auxiliary variables may not be used by the package, but they will be available for use by other parts of the program. The program will terminate with an error if auxiliary variables are specified on more than one line in the options block.
- **auxmultname** (*string*) -
  - auxmultname (string) name of auxiliary variable to be used as multiplier of general-head boundary conductance.
- **boundnames** (*boolean*) -
  - boundnames (boolean) keyword to indicate that boundary names may be provided with the list of general-head boundary cells.
- **print_input** (*boolean*) -
  - print_input (boolean) keyword to indicate that the list of general- head boundary information will be written to the listing file immediately after it is read.
- **print_flows** (*boolean*) -

  - print_flows (boolean) keyword to indicate that the list of general- head boundary flow rates will be printed to the listing file for every stress period time step in which "BUDGET PRINT" is specified in Output Control. If there is no Output Control option and "PRINT_FLOWS" is specified, then flow rates are printed for the last time step of each stress period.

- **save_flows** (*boolean*) -
  - save_flows (boolean) keyword to indicate that general-head boundary flow terms will be written to the file specified with "BUDGET FILEOUT" in Output Control.
- **timeseries** (*{varname:data} or timeseries data*) -
  - Contains data for the ts package. Data can be stored in a dictionary containing data for the ts package with variable names as keys and package data as values. Data just for the timeseries variable is also acceptable. See ts package documentation for more information.
- **observations** (*{varname:data} or continuous data*) -
  - Contains data for the obs package. Data can be stored in a dictionary containing data for the obs package with variable names as keys and package data as values. Data just for the observations variable is also acceptable. See obs package documentation for more information.
- **mover** (*boolean*) -
  - mover (boolean) keyword to indicate that this instance of the General-Head Boundary Package can be used with the Water Mover (MVR) Package. When the MOVER option is specified, additional memory is allocated within the package to store the available, provided, and received water.
- **maxbound** (*integer*) -
  - maxbound (integer) integer value specifying the maximum number of general-head boundary cells that will be specified for use during any stress period.
- **stress_period_data** (*[cellid, bhead, cond, aux, boundname]*) -
  - cellid ((integer, ...)) is the cell identifier, and depends on the type of grid that is used for the simulation. For a structured grid that uses the DIS input file, CELLID is the layer, row, and column. For a grid that uses the DISV input file, CELLID is the layer and CELL2D number. If the model uses the unstructured discretization (DISU) input file, CELLID is the node number for the cell. This argument is an index variable, which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.
  - bhead (double) is the boundary head. If the Options block includes a TIMESERIESFILE entry (see the "Time-Variable Input"

section), values can be obtained from a time series by entering the time-series name in place of a numeric value.

- cond (double) is the hydraulic conductance of the interface between the aquifer cell and the boundary. If the Options block includes a TIMESERIESFILE entry (see the "Time-Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
- aux (double) represents the values of the auxiliary variables for each general-head boundary. The values of auxiliary variables must be present for each general-head boundary. The values must be specified in the order of the auxiliary variables specified in the OPTIONS block. If the package supports time series and the Options block includes a TIMESERIESFILE entry (see the "Time-Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
- boundname (string) name of the general-head boundary cell. BOUNDNAME is an ASCII character variable that can contain as many as 40 characters. If BOUNDNAME contains spaces in it, then the entire name must be enclosed within single quotes.

- **filename** (*String*) - File name for this package.
- **pname** (*String*) - Package name for this package.
- **parent_file** (MFPackage) - Parent package file that references this package. Only needed for utility packages (mfutl*). For example, mfutllaktab package must have a mfgwflak package parent_file.

auxiliary = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

dfn = [['header', 'multi-package', 'package-type stress-package'], ['block options', 'name auxiliary', 'type string', 'shape (naux)', 'reader urword', 'optional true'], ['block options', 'name auxmultname', 'type string', 'shape', 'reader urword', 'optional true'], ['block options', 'name boundnames', 'type keyword', 'shape', 'reader urword', 'optional true'], ['block options', 'name print_input', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name print_flows', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name save_flows', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name ts_filerecord', 'type record ts6 filein ts6_filename', 'shape', 'reader urword', 'tagged true', 'optional true', 'construct_package ts', 'construct_data timeseries', 'parameter_name timeseries'], ['block options', 'name ts6', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name filein', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name ts6_filename', 'type string', 'preserve_case true', 'in_record true', 'reader urword', 'optional false', 'tagged false'], ['block options', 'name obs_filerecord', 'type record obs6 filein obs6_filename', 'shape', 'reader urword', 'tagged true', 'optional true', 'construct_package obs', 'construct_data continuous', 'parameter_name observations'], ['block options', 'name obs6', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name obs6_filename', 'type string', 'preserve_case true', 'in_record true', 'tagged false', 'reader urword', 'optional false'], ['block options', 'name mover', 'type keyword', 'tagged true', 'reader urword', 'optional true'], ['block dimensions', 'name maxbound', 'type integer', 'reader urword', 'optional false'], ['block period', 'name iper', 'type integer', 'block_variable True', 'in_record true', 'tagged false', 'shape', 'valid', 'reader urword', 'optional false'], ['block period', 'name stress_period_data', 'type recarray cellid bhead cond aux boundname', 'shape (maxbound)', 'reader urword'], ['block period', 'name cellid', 'type integer', 'shape (ncelldim)', 'tagged false', 'in_record true', 'reader urword'], ['block period', 'name bhead', 'type double precision', 'shape', 'tagged false', 'in_record true', 'reader urword', 'time_series true'], ['block period', 'name cond', 'type double precision', 'shape', 'tagged false', 'in_record true', 'reader urword', 'time_series true'], ['block period', 'name aux', 'type double precision', 'in_record true', 'tagged false', 'shape (naux)', 'reader urword', 'optional true', 'time_series true'], ['block period', 'name boundname', 'type string', 'shape', 'tagged false', 'in_record true', 'reader urword', 'optional true']]

dfn_file_name = 'gwf-ghb.dfn'

obs_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

package_abbr = 'gwfghb'

stress_period_data = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

ts_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

flopy.mf6.modflow.mfgwfgnc module

class GwfgncPackages(*model_or_sim*, *parent*, *pkg_type*, *filerecord*, *package=None*, *package_class=None*)

Bases: *MFChildPackages*

GwfgncPackages is a container class for the ModflowGwfgnc class.

initialize()

Initializes a new ModflowGwfgnc package removing any sibling child packages attached to the same parent package. See ModflowGwfgnc init documentation for definition of parameters.

append_package()

Adds a new ModflowGwfgnc package to the container. See ModflowGwfgnc init documentation for definition of parameters.

append_package(*print_input=None*, *print_flows=None*, *explicit=None*, *numgnc=None*, *numalphaj=None*, *gncdata=None*, *filename=None*, *pname=None*)

initialize(*print_input=None*, *print_flows=None*, *explicit=None*, *numgnc=None*, *numalphaj=None*, *gncdata=None*, *filename=None*, *pname=None*)

package_abbr = 'gwfgncpackages'

class ModflowGwfgnc(*model*, *loading_package=False*, *print_input=None*, *print_flows=None*, *explicit=None*, *numgnc=None*, *numalphaj=None*, *gncdata=None*, *filename=None*, *pname=None*, ***kwargs*)

Bases: *MFPackage*

ModflowGwfgnc defines a gnc package within a gwf6 model.

Parameters

- **model** (MFModel) – Model that this package is a part of. Package is automatically added to model when it is initialized.
- **loading_package** (*bool*) – Do not set this parameter. It is intended for debugging and internal processing purposes only.
- **print_input** (*boolean*) –
  - print_input (boolean) keyword to indicate that the list of GNC information will be written to the listing file immediately after it is read.
- **print_flows** (*boolean*) –
  - print_flows (boolean) keyword to indicate that the list of GNC flow rates will be printed to the listing file for every stress period time step in which "BUDGET PRINT" is specified in Output Control. If there is no Output Control option and "PRINT_FLOWS" is specified, then flow rates are printed for the last time step of each stress period.
- **explicit** (*boolean*) –
  - explicit (boolean) keyword to indicate that the ghost node correction is applied in an explicit manner on the right-hand side of the matrix. The explicit approach will likely require

additional outer iterations. If the keyword is not specified, then the correction will be applied in an implicit manner on the left-hand side. The implicit approach will likely converge better, but may require additional memory. If the EXPLICIT keyword is not specified, then the BICGSTAB linear acceleration option should be specified within the LINEAR block of the Sparse Matrix Solver.

- **numgnc** (*integer*) -
  - numgnc (integer) is the number of GNC entries.
- **numalphaj** (*integer*) -
  - numalphaj (integer) is the number of contributing factors.
- **gncdata** (*[cellidn, cellidm, cellidsj, alphasj]*) -
  - cellidn ((integer, ...)) is the cellid of the cell, n, in which the ghost node is located. For a structured grid that uses the DIS input file, CELLIDN is the layer, row, and column numbers of the cell. For a grid that uses the DISV input file, CELLIDN is the layer number and CELL2D number for the two cells. If the model uses the unstructured discretization (DISU) input file, then CELLIDN is the node number for the cell. This argument is an index variable, which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.
  - cellidm ((integer, ...)) is the cellid of the connecting cell, m, to which flow occurs from the ghost node. For a structured grid that uses the DIS input file, CELLIDM is the layer, row, and column numbers of the cell. For a grid that uses the DISV input file, CELLIDM is the layer number and CELL2D number for the two cells. If the model uses the unstructured discretization (DISU) input file, then CELLIDM is the node number for the cell. This argument is an index variable, which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.
  - cellidsj ((integer, ...)) is the array of CELLIDS for the contributing j cells, which contribute to the interpolated head value at the ghost node. This item contains one CELLID for each of the contributing cells of the ghost node. Note that if the number of actual contributing cells needed by the user is less than NUMALPHAJ for any ghost node, then a dummy CELLID of zero(s) should be inserted with an associated contributing factor of zero. For a structured grid that uses the DIS input file, CELLID is the layer, row, and column numbers of the cell. For a grid that uses the DISV input file, CELLID is the layer number and cell2d number for the two cells. If the model uses the unstructured discretization (DISU) input file, then CELLID is the node number for the cell. This argument is an index variable, which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically

subtract one when loading index variables and add one when writing index variables.

- alphasj (double) is the contributing factors for each contributing node in CELLIDSJ. Note that if the number of actual contributing cells is less than NUMALPHAJ for any ghost node, then dummy CELLIDS should be inserted with an associated contributing factor of zero. The sum of ALPHASJ should be less than one. This is because one minus the sum of ALPHASJ is equal to the alpha term (alpha n in equation 4-61 of the GWF Model report) that is multiplied by the head in cell n.

- **filename** (*String*) – File name for this package.
- **pname** (*String*) – Package name for this package.
- **parent_file** (MFPackage) – Parent package file that references this package. Only needed for utility packages (mfutl*). For example, mfutllaktab package must have a mfgwflak package parent_file.

dfn = [['header'], ['block options', 'name print_input', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name print_flows', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name explicit', 'type keyword', 'tagged true', 'reader urword', 'optional true'], ['block dimensions', 'name numgnc', 'type integer', 'reader urword', 'optional false'], ['block dimensions', 'name numalphaj', 'type integer', 'reader urword', 'optional false'], ['block gncdata', 'name gncdata', 'type recarray cellidn cellidm cellidsj alphasj', 'shape (maxbound)', 'reader urword'], ['block gncdata', 'name cellidn', 'type integer', 'shape', 'tagged false', 'in_record true', 'reader urword', 'numeric_index true'], ['block gncdata', 'name cellidm', 'type integer', 'shape', 'tagged false', 'in_record true', 'reader urword', 'numeric_index true'], ['block gncdata', 'name cellidsj', 'type integer', 'shape (numalphaj)', 'tagged false', 'in_record true', 'reader urword', 'numeric_index true'], ['block gncdata', 'name alphasj', 'type double precision', 'shape (numalphaj)', 'tagged false', 'in_record true', 'reader urword']]

dfn_file_name = 'gwf-gnc.dfn'

gncdata = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

package_abbr = 'gwfgnc'

flopy.mf6.modflow.mfgwfgwf module

class ModflowGwfgwf(*simulation, loading_package=False, exgtype='GWF6-GWF6', exgmnamea=None, exgmnameb=None, auxiliary=None, boundnames=None, print_input=None, print_flows=None, save_flows=None, cell_averaging=None, cvoptions=None, newton=None, xt3d=None, gncdata=None, perioddata=None, observations=None, dev_interfacemodel_on=None, nexg=None, exchangedata=None, filename=None, pname=None, **kwargs*)

Bases: *MFPackage*

ModflowGwfgwf defines a gwfgwf package.

Parameters

- **simulation** (MFSimulation) - Simulation that this package is a part of. Package is automatically added to simulation when it is initialized.
- **loading_package** (*bool*) - Do not set this parameter. It is intended for debugging and internal processing purposes only.
- **exgtype** (*<string>*) -
  - is the exchange type (GWF-GWF or GWF-GWT).
- **exgmnamea** (*<string>*) -
  - is the name of the first model that is part of this exchange.
- **exgmnameb** (*<string>*) -
  - is the name of the second model that is part of this exchange.
- **auxiliary** (*[string]*) -
  - auxiliary (string) an array of auxiliary variable names. There is no limit on the number of auxiliary variables that can be provided. Most auxiliary variables will not be used by the GWF-GWF Exchange, but they will be available for use by other parts of the program. If an auxiliary variable with the name "ANGLDEGX" is found, then this information will be used as the angle (provided in degrees) between the connection face normal and the x axis, where a value of zero indicates that a normal vector points directly along the positive x axis. The connection face normal is a normal vector on the cell face shared between the cell in model 1 and the cell in model 2 pointing away from the model 1 cell. Additional information on "ANGLDEGX" is provided in the description of the DISU Package. If an auxiliary variable with the name "CDIST" is found, then this information will be used as the straight-line connection distance, including the vertical component, between the two cell centers. Both ANGLDEGX and CDIST are required if specific discharge is calculated for either of the groundwater models.
- **boundnames** (*boolean*) -
  - boundnames (boolean) keyword to indicate that boundary names may be provided with the list of GWF Exchange cells.
- **print_input** (*boolean*) -
  - print_input (boolean) keyword to indicate that the list of exchange entries will be echoed to the listing file immediately after it is read.
- **print_flows** (*boolean*) -
  - print_flows (boolean) keyword to indicate that the list of exchange flow rates will be printed to the listing file for every stress period in which "SAVE BUDGET" is specified in Output Control.
- **save_flows** (*boolean*) -
  - save_flows (boolean) keyword to indicate that cell-by-cell flow terms will be written to the budget file for each model

provided that the Output Control for the models are set up with the "BUDGET SAVE FILE" option.

- **cell_averaging** (*string*) -
  - cell_averaging (string) is a keyword and text keyword to indicate the method that will be used for calculating the conductance for horizontal cell connections. The text value for CELL_AVERAGING can be "HARMONIC", "LOGARITHMIC", or "AMT-LMK", which means "arithmetic-mean thickness and logarithmic-mean hydraulic conductivity". If the user does not specify a value for CELL_AVERAGING, then the harmonic-mean method will be used.
- **cvoptions** (*[dewatered]*) -
  - dewatered (string) If the DEWATERED keyword is specified, then the vertical conductance is calculated using only the saturated thickness and properties of the overlying cell if the head in the underlying cell is below its top.
- **newton** (*boolean*) -
  - newton (boolean) keyword that activates the Newton-Raphson formulation for groundwater flow between connected, convertible groundwater cells. Cells will not dry when this option is used.
- **xt3d** (*boolean*) -
  - xt3d (boolean) keyword that activates the XT3D formulation between the cells connected with this GWF-GWF Exchange.
- **gncdata** (*{varname:data} or gncdata data*) -
  - Contains data for the gnc package. Data can be stored in a dictionary containing data for the gnc package with variable names as keys and package data as values. Data just for the gncdata variable is also acceptable. See gnc package documentation for more information.
- **perioddata** (*{varname:data} or perioddata data*) -
  - Contains data for the mvr package. Data can be stored in a dictionary containing data for the mvr package with variable names as keys and package data as values. Data just for the perioddata variable is also acceptable. See mvr package documentation for more information.
- **observations** (*{varname:data} or continuous data*) -
  - Contains data for the obs package. Data can be stored in a dictionary containing data for the obs package with variable names as keys and package data as values. Data just for the observations variable is also acceptable. See obs package documentation for more information.
- **dev_interfacemodel_on** (*boolean*) -
  - dev_interfacemodel_on (boolean) activates the interface model mechanism for calculating the coefficients at (and possibly near) the exchange. This keyword should only be used for development purposes.

- **nexg** (*integer*) -
  - nexg (integer) keyword and integer value specifying the number of GWF-GWF exchanges.
- **exchangedata** (*[cellidm1, cellidm2, ihc, cl1, cl2, hwva, aux, boundname]*) -
  - cellidm1 ((integer, ...)) is the cellid of the cell in model 1 as specified in the simulation name file. For a structured grid that uses the DIS input file, CELLIDM1 is the layer, row, and column numbers of the cell. For a grid that uses the DISV input file, CELLIDM1 is the layer number and CELL2D number for the two cells. If the model uses the unstructured discretization (DISU) input file, then CELLIDM1 is the node number for the cell. This argument is an index variable, which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.
  - cellidm2 ((integer, ...)) is the cellid of the cell in model 2 as specified in the simulation name file. For a structured grid that uses the DIS input file, CELLIDM2 is the layer, row, and column numbers of the cell. For a grid that uses the DISV input file, CELLIDM2 is the layer number and CELL2D number for the two cells. If the model uses the unstructured discretization (DISU) input file, then CELLIDM2 is the node number for the cell. This argument is an index variable, which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.
  - ihc (integer) is an integer flag indicating the direction between node n and all of its m connections. If IHC = 0 then the connection is vertical. If IHC = 1 then the connection is horizontal. If IHC = 2 then the connection is horizontal for a vertically staggered grid.
  - cl1 (double) is the distance between the center of cell 1 and the its shared face with cell 2.
  - cl2 (double) is the distance between the center of cell 2 and the its shared face with cell 1.
  - hwva (double) is the horizontal width of the flow connection between cell 1 and cell 2 if IHC > 0, or it is the area perpendicular to flow of the vertical connection between cell 1 and cell 2 if IHC = 0.
  - aux (double) represents the values of the auxiliary variables for each GWFGWF Exchange. The values of auxiliary variables must be present for each exchange. The values must be specified in the order of the auxiliary variables specified in the OPTIONS block.
  - boundname (string) name of the GWF Exchange cell. BOUNDNAME is an ASCII character variable that can contain as many as 40 characters. If BOUNDNAME contains spaces in it, then the entire name must be enclosed within single quotes.

- **filename** (*String*) - File name for this package.
- **pname** (*String*) - Package name for this package.
- **parent_file** (MFPackage) - Parent package file that references this package. Only needed for utility packages (mfutl*). For example, mfutllaktab package must have a mfgwflak package parent_file.

auxiliary = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

dfn = [['header', 'multi-package'], ['block options', 'name auxiliary', 'type string', 'shape (naux)', 'reader urword', 'optional true'], ['block options', 'name boundnames', 'type keyword', 'shape', 'reader urword', 'optional true'], ['block options', 'name print_input', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name print_flows', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name save_flows', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name cell_averaging', 'type string', 'valid harmonic logarithmic amt-lmk', 'reader urword', 'optional true'], ['block options', 'name cvoptions', 'type record variablecv dewatered', 'reader urword', 'optional true'], ['block options', 'name variablecv', 'in_record true', 'type keyword', 'reader urword'], ['block options', 'name dewatered', 'in_record true', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name newton', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name xt3d', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name gnc_filerecord', 'type record gnc6 filein gnc6_filename', 'shape', 'reader urword', 'tagged true', 'optional true', 'construct_package gnc', 'construct_data gncdata', 'parameter_name gncdata'], ['block options', 'name filein', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name gnc6', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name gnc6_filename', 'type string', 'preserve_case true', 'in_record true', 'tagged false', 'reader urword', 'optional false'], ['block options', 'name mvr_filerecord', 'type record mvr6 filein mvr6_filename', 'shape', 'reader urword', 'tagged true', 'optional true', 'construct_package mvr', 'construct_data perioddata', 'parameter_name perioddata'], ['block options', 'name mvr6', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name mvr6_filename', 'type string', 'preserve_case true', 'in_record true', 'tagged false', 'reader urword', 'optional false'], ['block options', 'name obs_filerecord', 'type record obs6 filein obs6_filename', 'shape', 'reader urword', 'tagged true', 'optional true', 'construct_package obs', 'construct_data continuous', 'parameter_name observations'], ['block options', 'name obs6', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name obs6_filename', 'type string', 'preserve_case true', 'in_record true', 'tagged false', 'reader urword', 'optional false'], ['block options', 'name dev_interfacemodel_on', 'type keyword', 'reader urword', 'optional true'], ['block dimensions', 'name nexg', 'type integer', 'reader urword', 'optional false'], ['block exchangedata', 'name exchangedata', 'type recarray cellidm1 cellidm2 ihc cl1 cl2 hwva aux boundname', 'reader urword', 'optional false'], ['block exchangedata', 'name cellidm1', 'type integer', 'in_record true', 'tagged false', 'reader urword', 'optional false', 'numeric_index true'], ['block exchangedata', 'name cellidm2', 'type integer', 'in_record true', 'tagged false', 'reader urword', 'optional false', 'numeric_index true'], ['block exchangedata', 'name ihc', 'type integer', 'in_record true', 'tagged false', 'reader urword', 'optional false'], ['block exchangedata', 'name cl1', 'type double precision', 'in_record true', 'tagged false', 'reader urword', 'optional false'], ['block exchangedata', 'name cl2', 'type double precision', 'in_record true', 'tagged false', 'reader urword', 'optional false'], ['block exchangedata', 'name hwva', 'type double precision', 'in_record true', 'tagged false', 'reader urword', 'optional false'], ['block exchangedata', 'name aux', 'type double precision', 'in_record true', 'tagged false', 'shape (naux)', 'reader urword', 'optional true'], ['block exchangedata', 'name boundname', 'type string', 'shape', 'tagged false', 'in_record true', 'reader urword', 'optional true']]

dfn_file_name = 'exg-gwfgwf.dfn'

exchangedata = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

gnc_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

mvr_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

obs_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

package_abbr = 'gwfgwf'

flopy.mf6.modflow.mfgwfgwt module

class **ModflowGwfgwt**(*simulation*, *loading_package=False*, *exgtype='GWF6-GWT6'*, *exgmnamea=None*, *exgmnameb=None*, *filename=None*, *pname=None*, ***kwargs*)

Bases: *MFPackage*

ModflowGwfgwt defines a gwfgwt package.

Parameters

- **simulation** (MFSimulation) - Simulation that this package is a part of. Package is automatically added to simulation when it is initialized.
- **loading_package** (*bool*) - Do not set this parameter. It is intended for debugging and internal processing purposes only.
- **exgtype** (*<string>*) -
  - is the exchange type (GWF-GWF or GWF-GWT).
- **exgmnamea** (*<string>*) -
  - is the name of the first model that is part of this exchange.
- **exgmnameb** (*<string>*) -
  - is the name of the second model that is part of this exchange.
- **filename** (*String*) - File name for this package.
- **pname** (*String*) - Package name for this package.
- **parent_file** (MFPackage) - Parent package file that references this package. Only needed for utility packages (mfutl*). For example, mfutllaktab package must have a mfgwflak package parent_file.

dfn = [['header']]

dfn_file_name = 'exg-gwfgwt.dfn'

package_abbr = 'gwfgwt'

flopy.mf6.modflow.mfgwfhfb module

class ModflowGwfhfb(*model*, *loading_package=False*, *print_input=None*, *maxhfb=None*, *stress_period_data=None*, *filename=None*, *pname=None*, ***kwargs*)

Bases: *MFPackage*

ModflowGwfhfb defines a hfb package within a gwf6 model.

Parameters

- **model** (MFModel) – Model that this package is a part of. Package is automatically added to model when it is initialized.
- **loading_package** (*bool*) – Do not set this parameter. It is intended for debugging and internal processing purposes only.
- **print_input** (*boolean*) –
  - print_input (boolean) keyword to indicate that the list of horizontal flow barriers will be written to the listing file immediately after it is read.
- **maxhfb** (*integer*) –
  - maxhfb (integer) integer value specifying the maximum number of horizontal flow barriers that will be entered in this input file. The value of MAXHFB is used to allocate memory for the horizontal flow barriers.
- **stress_period_data** (*[cellid1, cellid2, hydchr]*) –
  - cellid1 ((integer, ...)) identifier for the first cell. For a structured grid that uses the DIS input file, CELLID1 is the layer, row, and column numbers of the cell. For a grid that uses the DISV input file, CELLID1 is the layer number and CELL2D number for the two cells. If the model uses the unstructured discretization (DISU) input file, then CELLID1 is the node numbers for the cell. The barrier is located between cells designated as CELLID1 and CELLID2. For models that use the DIS and DISV grid types, the layer number for CELLID1 and CELLID2 must be the same. For all grid types, cells must be horizontally adjacent or the program will terminate with an error. This argument is an index variable, which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.
  - cellid2 ((integer, ...)) identifier for the second cell. See CELLID1 for description of how to specify. This argument is an index variable, which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.
  - hydchr (double) is the hydraulic characteristic of the horizontal- flow barrier. The hydraulic characteristic is the barrier hydraulic conductivity divided by the width of the horizontal-flow barrier. If the hydraulic characteristic is negative, then the absolute value of HYDCHR acts as a multiplier to the conductance between the two model cells specified as

containing the barrier. For example, if the value for HYDCHR was specified as -1.5, the conductance calculated for the two cells would be multiplied by 1.5.

- **filename** (*String*) – File name for this package.
- **pname** (*String*) – Package name for this package.
- **parent_file** (MFPackage) – Parent package file that references this package. Only needed for utility packages (mfutl*). For example, mfutllaktab package must have a mfgwflak package parent_file.

dfn = [['header'], ['block options', 'name print_input', 'type keyword', 'reader urword', 'optional true'], ['block dimensions', 'name maxhfb', 'type integer', 'reader urword', 'optional false'], ['block period', 'name iper', 'type integer', 'block_variable True', 'in_record true', 'tagged false', 'shape', 'valid', 'reader urword', 'optional false'], ['block period', 'name stress_period_data', 'type recarray cellid1 cellid2 hydchr', 'shape (maxhfb)', 'reader urword'], ['block period', 'name cellid1', 'type integer', 'shape (ncelldim)', 'tagged false', 'in_record true', 'reader urword'], ['block period', 'name cellid2', 'type integer', 'shape (ncelldim)', 'tagged false', 'in_record true', 'reader urword'], ['block period', 'name hydchr', 'type double precision', 'shape', 'tagged false', 'in_record true', 'reader urword']]

dfn_file_name = 'gwf-hfb.dfn'

package_abbr = 'gwfhfb'

stress_period_data = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

flopy.mf6.modflow.mfgwfic module

class ModflowGwfic(*model*, *loading_package=False*, *strt=1.0*, *filename=None*, *pname=None*, ***kwargs*)

Bases: *MFPackage*

ModflowGwfic defines a ic package within a gwf6 model.

Parameters

- **model** (MFModel) – Model that this package is a part of. Package is automatically added to model when it is initialized.
- **loading_package** (*bool*) – Do not set this parameter. It is intended for debugging and internal processing purposes only.
- **strt** (*[double]*) –
  - strt (double) is the initial (starting) head-that is, head at the beginning of the GWF Model simulation. STRT must be specified for all simulations, including steady-state simulations. One value is read for every model cell. For simulations in which the first stress period is steady state, the values used for STRT generally do not affect the simulation (exceptions may occur if cells go dry and (or) rewet). The execution time, however, will be less if STRT includes hydraulic heads that are close to the steady-state solution. A head value lower than the cell bottom can be provided if a cell should start as dry.

- **filename** (*String*) - File name for this package.
- **pname** (*String*) - Package name for this package.
- **parent_file** (MFPackage) - Parent package file that references this package. Only needed for utility packages (mfutl*). For example, mfutllaktab package must have a mfgwflak package parent_file.

dfn = [['header'], ['block griddata', 'name strt', 'type double precision', 'shape (nodes)', 'reader readarray', 'layered true', 'default_value 1.0']]

dfn_file_name = 'gwf-ic.dfn'

package_abbr = 'gwfic'

strt = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

flopy.mf6.modflow.mfgwflak module

class ModflowGwflak(*model*, *loading_package=False*, *auxiliary=None*, *boundnames=None*, *print_input=None*, *print_stage=None*, *print_flows=None*, *save_flows=None*, *stage_filerecord=None*, *budget_filerecord=None*, *budgetcsv_filerecord=None*, *package_convergence_filerecord=None*, *timeseries=None*, *observations=None*, *mover=None*, *surfdep=None*, *maximum_iterations=None*, *maximum_stage_change=None*, *time_conversion=None*, *length_conversion=None*, *nlakes=None*, *noutlets=None*, *ntables=None*, *packagedata=None*, *connectiondata=None*, *tables=None*, *outlets=None*, *perioddata=None*, *filename=None*, *pname=None*, ***kwargs*)

Bases: *MFPackage*

ModflowGwflak defines a lak package within a gwf6 model.

Parameters

- **model** (MFModel) - Model that this package is a part of. Package is automatically added to model when it is initialized.
- **loading_package** (*bool*) - Do not set this parameter. It is intended for debugging and internal processing purposes only.
- **auxiliary** (*[string]*) -
  - auxiliary (string) defines an array of one or more auxiliary variable names. There is no limit on the number of auxiliary variables that can be provided on this line; however, lists of information provided in subsequent blocks must have a column of data for each auxiliary variable name defined here. The number of auxiliary variables detected on this line determines the value for naux. Comments cannot be provided anywhere on this line as they will be interpreted as auxiliary variable names. Auxiliary variables may not be used by the package, but they will be available for use by other parts of the program. The program will terminate with an error if auxiliary variables are specified on more than one line in the options block.
- **boundnames** (*boolean*) -

  - boundnames (boolean) keyword to indicate that boundary names may be provided with the list of lake cells.
- **print_input** (*boolean*) -
  - print_input (boolean) keyword to indicate that the list of lake information will be written to the listing file immediately after it is read.
- **print_stage** (*boolean*) -
  - print_stage (boolean) keyword to indicate that the list of lake stages will be printed to the listing file for every stress period in which "HEAD PRINT" is specified in Output Control. If there is no Output Control option and PRINT_STAGE is specified, then stages are printed for the last time step of each stress period.
- **print_flows** (*boolean*) -
  - print_flows (boolean) keyword to indicate that the list of lake flow rates will be printed to the listing file for every stress period time step in which "BUDGET PRINT" is specified in Output Control. If there is no Output Control option and "PRINT_FLOWS" is specified, then flow rates are printed for the last time step of each stress period.
- **save_flows** (*boolean*) -
  - save_flows (boolean) keyword to indicate that lake flow terms will be written to the file specified with "BUDGET FILEOUT" in Output Control.
- **stage_filerecord** (*[stagefile]*) -
  - stagefile (string) name of the binary output file to write stage information.
- **budget_filerecord** (*[budgetfile]*) -
  - budgetfile (string) name of the binary output file to write budget information.
- **budgetcsv_filerecord** (*[budgetcsvfile]*) -
  - budgetcsvfile (string) name of the comma-separated value (CSV) output file to write budget summary information. A budget summary record will be written to this file for each time step of the simulation.
- **package_convergence_filerecord** (*[package_convergence_filename]*) -
  - package_convergence_filename (string) name of the comma spaced values output file to write package convergence information.
- **timeseries** (*{varname:data} or timeseries data*) -
  - Contains data for the ts package. Data can be stored in a dictionary containing data for the ts package with variable names as keys and package data as values. Data just for the timeseries variable is also acceptable. See ts package documentation for more information.

- **observations** (*{varname:data} or continuous data*) -
  - Contains data for the obs package. Data can be stored in a dictionary containing data for the obs package with variable names as keys and package data as values. Data just for the observations variable is also acceptable. See obs package documentation for more information.
- **mover** (*boolean*) -
  - mover (boolean) keyword to indicate that this instance of the LAK Package can be used with the Water Mover (MVR) Package. When the MOVER option is specified, additional memory is allocated within the package to store the available, provided, and received water.
- **surfdep** (*double*) -
  - surfdep (double) real value that defines the surface depression depth for VERTICAL lake-GWF connections. If specified, SURFDEP must be greater than or equal to zero. If SURFDEP is not specified, a default value of zero is used for all vertical lake-GWF connections.
- **maximum_iterations** (*integer*) -
  - maximum_iterations (integer) integer value that defines the maximum number of Newton-Raphson iterations allowed for a lake. By default, MAXIMUM_ITERATIONS is equal to 100. MAXIMUM_ITERATIONS would only need to be increased from the default value if one or more lakes in a simulation has a large water budget error.
- **maximum_stage_change** (*double*) -
  - maximum_stage_change (double) real value that defines the lake stage closure tolerance. By default, MAXIMUM_STAGE_CHANGE is equal to 1×10^{-5}. The MAXIMUM_STAGE_CHANGE would only need to be increased or decreased from the default value if the water budget error for one or more lakes is too small or too large, respectively.
- **time_conversion** (*double*) -
  - time_conversion (double) real value that is used to convert user- specified Manning's roughness coefficients or gravitational acceleration used to calculate outlet flows from seconds to model time units. TIME_CONVERSION should be set to 1.0, 60.0, 3,600.0, 86,400.0, and 31,557,600.0 when using time units (TIME_UNITS) of seconds, minutes, hours, days, or years in the simulation, respectively. CONVTIME does not need to be specified if no lake outlets are specified or TIME_UNITS are seconds.
- **length_conversion** (*double*) -
  - length_conversion (double) real value that is used to convert outlet user-specified Manning's roughness coefficients or gravitational acceleration used to calculate outlet flows from meters to model length units. LENGTH_CONVERSION

should be set to 3.28081, 1.0, and 100.0 when using length units (LENGTH_UNITS) of feet, meters, or centimeters in the simulation, respectively. LENGTH_CONVERSION does not need to be specified if no lake outlets are specified or LENGTH_UNITS are meters.

- **nlakes** (*integer*) -
  - nlakes (integer) value specifying the number of lakes that will be simulated for all stress periods.
- **noutlets** (*integer*) -
  - noutlets (integer) value specifying the number of outlets that will be simulated for all stress periods. If NOUTLETS is not specified, a default value of zero is used.
- **ntables** (*integer*) -
  - ntables (integer) value specifying the number of lakes tables that will be used to define the lake stage, volume relation, and surface area. If NTABLES is not specified, a default value of zero is used.
- **packagedata** (*[ifno, strt, nlakeconn, aux, boundname]*) -
  - ifno (integer) integer value that defines the feature (lake) number associated with the specified PACKAGEDATA data on the line. IFNO must be greater than zero and less than or equal to NLAKES. Lake information must be specified for every lake or the program will terminate with an error. The program will also terminate with an error if information for a lake is specified more than once. This argument is an index variable, which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.
  - strt (double) real value that defines the starting stage for the lake.
  - nlakeconn (integer) integer value that defines the number of GWF cells connected to this (IFNO) lake. There can only be one vertical lake connection to each GWF cell. NLAKECONN must be greater than zero.
  - aux (double) represents the values of the auxiliary variables for each lake. The values of auxiliary variables must be present for each lake. The values must be specified in the order of the auxiliary variables specified in the OPTIONS block. If the package supports time series and the Options block includes a TIMESERIESFILE entry (see the "Time-Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
  - boundname (string) name of the lake cell. BOUNDNAME is an ASCII character variable that can contain as many as 40 characters. If BOUNDNAME contains spaces in it, then the entire name must be enclosed within single quotes.

- **connectiondata** (*[ifno, iconn, cellid, claktype, bedleak, belev, telev,)* -

  connlen, connwidth]

  - ifno (integer) integer value that defines the feature (lake) number associated with the specified CONNECTIONDATA data on the line. IFNO must be greater than zero and less than or equal to NLAKES. Lake connection information must be specified for every lake connection to the GWF model (NLAKECONN) or the program will terminate with an error. The program will also terminate with an error if connection information for a lake connection to the GWF model is specified more than once. This argument is an index variable, which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.
  - iconn (integer) integer value that defines the GWF connection number for this lake connection entry. ICONN must be greater than zero and less than or equal to NLAKECONN for lake IFNO. This argument is an index variable, which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.
  - cellid ((integer, ...)) is the cell identifier, and depends on the type of grid that is used for the simulation. For a structured grid that uses the DIS input file, CELLID is the layer, row, and column. For a grid that uses the DISV input file, CELLID is the layer and CELL2D number. If the model uses the unstructured discretization (DISU) input file, CELLID is the node number for the cell. This argument is an index variable, which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.
  - claktype (string) character string that defines the lake-GWF connection type for the lake connection. Possible lake-GWF connection type strings include: VERTICAL-character keyword to indicate the lake-GWF connection is vertical and connection conductance calculations use the hydraulic conductivity corresponding to the K_{33} tensor component defined for CELLID in the NPF package. HORIZONTAL-character keyword to indicate the lake-GWF connection is horizontal and connection conductance calculations use the hydraulic conductivity corresponding to the K_{11} tensor component defined for CELLID in the NPF package. EMBEDDEDH-character keyword to indicate the lake-GWF connection is embedded in a single cell and connection conductance calculations use the hydraulic conductivity corresponding to the K_{11} tensor component defined for CELLID in the NPF package. EMBEDDEDV-character keyword to indicate the lake-GWF connection is embedded in a single cell and connection conductance calculations use the hydraulic conductivity corresponding to the K_{33} tensor component defined

for CELLID in the NPF package. Embedded lakes can only be connected to a single cell (NLAKECONN = 1) and there must be a lake table associated with each embedded lake.

  - bedleak (string) real value or character string that defines the bed leakance for the lake-GWF connection. BEDLEAK must be greater than or equal to zero, equal to the DNODATA value (3.0E+30), or specified to be NONE. If DNODATA or NONE is specified for BEDLEAK, the lake-GWF connection conductance is solely a function of aquifer properties in the connected GWF cell and lakebed sediments are assumed to be absent. Warning messages will be issued if NONE is specified. Eventually the ability to specify NONE will be deprecated and cause MODFLOW 6 to terminate with an error.
  - belev (double) real value that defines the bottom elevation for a HORIZONTAL lake-GWF connection. Any value can be specified if CLAKTYPE is VERTICAL, EMBEDDEDH, or EMBEDDEDV. If CLAKTYPE is HORIZONTAL and BELEV is not equal to TELEV, BELEV must be greater than or equal to the bottom of the GWF cell CELLID. If BELEV is equal to TELEV, BELEV is reset to the bottom of the GWF cell CELLID.
  - telev (double) real value that defines the top elevation for a HORIZONTAL lake-GWF connection. Any value can be specified if CLAKTYPE is VERTICAL, EMBEDDEDH, or EMBEDDEDV. If CLAKTYPE is HORIZONTAL and TELEV is not equal to BELEV, TELEV must be less than or equal to the top of the GWF cell CELLID. If TELEV is equal to BELEV, TELEV is reset to the top of the GWF cell CELLID.
  - connlen (double) real value that defines the distance between the connected GWF CELLID node and the lake for a HORIZONTAL, EMBEDDEDH, or EMBEDDEDV lake-GWF connection. CONLENN must be greater than zero for a HORIZONTAL, EMBEDDEDH, or EMBEDDEDV lake-GWF connection. Any value can be specified if CLAKTYPE is VERTICAL.
  - connwidth (double) real value that defines the connection face width for a HORIZONTAL lake-GWF connection. CONNWIDTH must be greater than zero for a HORIZONTAL lake-GWF connection. Any value can be specified if CLAKTYPE is VERTICAL, EMBEDDEDH, or EMBEDDEDV.

- **tables** (*[ifno, tab6_filename]*) -
  - ifno (integer) integer value that defines the feature (lake) number associated with the specified TABLES data on the line. IFNO must be greater than zero and less than or equal to NLAKES. The program will terminate with an error if table information for a lake is specified more than once or the number of specified tables is less than NTABLES. This argument is an index variable, which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.
  - tab6_filename (string) character string that defines the path

and filename for the file containing lake table data for the lake connection. The TAB6_FILENAME file includes the number of entries in the file and the relation between stage, volume, and surface area for each entry in the file. Lake table files for EMBEDDEDH and EMBEDDEDV lake-GWF connections also include lake-GWF exchange area data for each entry in the file. Instructions for creating the TAB6_FILENAME input file are provided in Lake Table Input File section.

- **outlets** (*[outletno, lakein, lakeout, couttype, invert, width, rough,*) -

  slope]

  - outletno (integer) integer value that defines the outlet number associated with the specified OUTLETS data on the line. OUTLETNO must be greater than zero and less than or equal to NOUTLETS. Outlet information must be specified for every outlet or the program will terminate with an error. The program will also terminate with an error if information for a outlet is specified more than once. This argument is an index variable, which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.
  - lakein (integer) integer value that defines the lake number that outlet is connected to. LAKEIN must be greater than zero and less than or equal to NLAKES. This argument is an index variable, which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.
  - lakeout (integer) integer value that defines the lake number that outlet discharge from lake outlet OUTLETNO is routed to. LAKEOUT must be greater than or equal to zero and less than or equal to NLAKES. If LAKEOUT is zero, outlet discharge from lake outlet OUTLETNO is discharged to an external boundary. This argument is an index variable, which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.
  - couttype (string) character string that defines the outlet type for the outlet OUTLETNO. Possible COUTTYPE strings include: SPECIFIED- character keyword to indicate the outlet is defined as a specified flow. MANNING-character keyword to indicate the outlet is defined using Manning’s equation. WEIR-character keyword to indicate the outlet is defined using a sharp weir equation.
  - invert (double) real value that defines the invert elevation for the lake outlet. Any value can be specified if COUTTYPE is SPECIFIED. If the Options block includes a TIMESERIESFILE entry (see the “Time- Variable Input” section), values can be obtained from a time series by entering the time-series name

in place of a numeric value.

  - width (double) real value that defines the width of the lake outlet. Any value can be specified if COUTTYPE is SPECIFIED. If the Options block includes a TIMESERIESFILE entry (see the "Time-Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
  - rough (double) real value that defines the roughness coefficient for the lake outlet. Any value can be specified if COUTTYPE is not MANNING. If the Options block includes a TIMESERIESFILE entry (see the "Time-Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
  - slope (double) real value that defines the bed slope for the lake outlet. Any value can be specified if COUTTYPE is not MANNING. If the Options block includes a TIMESERIESFILE entry (see the "Time-Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.

- **perioddata** (*[number, laksetting]*) -
  - number (integer) integer value that defines the lake or outlet number associated with the specified PERIOD data on the line. NUMBER must be greater than zero and less than or equal to NLAKES for a lake number and less than or equal to NOUTLETS for an outlet number. This argument is an index variable, which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.
  - laksetting (keystring) line of information that is parsed into a keyword and values. Keyword values that can be used to start the LAKSETTING string include both keywords for lake settings and keywords for outlet settings. Keywords for lake settings include: STATUS, STAGE, RAINFALL, EVAPORATION, RUNOFF, INFLOW, WITHDRAWAL, and AUXILIARY. Keywords for outlet settings include RATE, INVERT, WIDTH, SLOPE, and ROUGH.

    status
      [[string]]

      * status (string) keyword option to define lake status. STATUS can be ACTIVE, INACTIVE, or CONSTANT. By default, STATUS is ACTIVE.

    stage
      [[string]]

      * stage (string) real or character value that defines the stage for the lake. The specified STAGE is only applied if the lake is a constant stage lake. If the Options block includes a TIMESERIESFILE entry (see the "Time-Variable Input" section), values can be obtained

from a time series by entering the time-series name in place of a numeric value.

rainfall
[[string]]

* rainfall (string) real or character value that defines the rainfall rate (LT^{-1}) for the lake. Value must be greater than or equal to zero. If the Options block includes a TIMESERIESFILE entry (see the "Time-Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.

evaporation
[[string]]

* evaporation (string) real or character value that defines the maximum evaporation rate (LT^{-1}) for the lake. Value must be greater than or equal to zero. If the Options block includes a TIMESERIESFILE entry (see the "Time-Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.

runoff
[[string]]

* runoff (string) real or character value that defines the runoff rate (L^3T^{-1}) for the lake. Value must be greater than or equal to zero. If the Options block includes a TIMESERIESFILE entry (see the "Time-Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.

inflow
[[string]]

* inflow (string) real or character value that defines the volumetric inflow rate (L^3T^{-1}) for the lake. Value must be greater than or equal to zero. If the Options block includes a TIMESERIESFILE entry (see the "Time-Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value. By default, inflow rates are zero for each lake.

withdrawal
[[string]]

* withdrawal (string) real or character value that defines the maximum withdrawal rate (L^3T^{-1}) for the lake. Value must be greater than or equal to zero. If the Options block includes a TIMESERIESFILE entry (see the "Time-Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.

rate
[[string]]

* rate (string) real or character value that defines the extraction rate for the lake outflow. A positive value indicates inflow and a negative value indicates outflow from the lake. RATE only applies to outlets associated with active lakes (STATUS is ACTIVE). A specified RATE is only applied if COUTTYPE for the OUTLETNO is SPECIFIED. If the Options block includes a TIMESERIESFILE entry (see the "Time-Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value. By default, the RATE for each SPECIFIED lake outlet is zero.

invert
[[string]]

* invert (string) real or character value that defines the invert elevation for the lake outlet. A specified INVERT value is only used for active lakes if COUTTYPE for lake outlet OUTLETNO is not SPECIFIED. If the Options block includes a TIMESERIESFILE entry (see the "Time-Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.

width
[[string]]

* width (string) real or character value that defines the width of the lake outlet. A specified WIDTH value is only used for active lakes if COUTTYPE for lake outlet OUTLETNO is not SPECIFIED. If the Options block includes a TIMESERIESFILE entry (see the "Time-Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.

slope
[[string]]

* slope (string) real or character value that defines the bed slope for the lake outlet. A specified SLOPE value is only used for active lakes if COUTTYPE for lake outlet OUTLETNO is MANNING. If the Options block includes a TIMESERIESFILE entry (see the "Time-Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.

rough
[[string]]

* rough (string) real value that defines the roughness coefficient for the lake outlet. Any value can be specified if COUTTYPE is not MANNING. If the Options

block includes a TIMESERIESFILE entry (see the "Time-Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.

auxiliaryrecord
[[auxname, auxval]]

* auxname (string) name for the auxiliary variable to be assigned AUXVAL. AUXNAME must match one of the auxiliary variable names defined in the OPTIONS block. If AUXNAME does not match one of the auxiliary variable names defined in the OPTIONS block the data are ignored.
* auxval (double) value for the auxiliary variable. If the Options block includes a TIMESERIESFILE entry (see the "Time- Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.

- **filename** (*String*) - File name for this package.
- **pname** (*String*) - Package name for this package.
- **parent_file** (MFPackage) - Parent package file that references this package. Only needed for utility packages (mfutl*). For example, mfutllaktab package must have a mfgwflak package parent_file.

auxiliary = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

budget_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

budgetcsv_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

connectiondata = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

dfn = [['header', 'multi-package', 'package-type advanced-stress-package'], ['block options', 'name auxiliary', 'type string', 'shape (naux)', 'reader urword', 'optional true'], ['block options', 'name boundnames', 'type keyword', 'shape', 'reader urword', 'optional true'], ['block options', 'name print_input', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name print_stage', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name print_flows', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name save_flows', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name stage_filerecord', 'type record stage fileout stagefile', 'shape', 'reader urword', 'tagged true', 'optional true'], ['block options', 'name stage', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name stagefile', 'type string', 'preserve_case true', 'shape', 'in_record true', 'reader urword', 'tagged false', 'optional false'], ['block options', 'name budget_filerecord', 'type record budget fileout budgetfile', 'shape', 'reader urword', 'tagged true', 'optional true'], ['block options', 'name budget', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name fileout', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name budgetfile', 'type string', 'preserve_case true', 'shape', 'in_record true', 'reader urword', 'tagged false', 'optional false'], ['block options', 'name budgetcsv_filerecord', 'type record budgetcsv fileout budgetcsvfile', 'shape', 'reader urword', 'tagged true', 'optional true'], ['block options', 'name budgetcsv', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name budgetcsvfile', 'type string', 'preserve_case true', 'shape', 'in_record true', 'reader urword', 'tagged false', 'optional false'], ['block options', 'name package_convergence_filerecord', 'type record package_convergence fileout package_convergence_filename', 'shape', 'reader urword', 'tagged true', 'optional true'], ['block options', 'name package_convergence', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name package_convergence_filename', 'type string', 'shape', 'in_record true', 'reader urword', 'tagged false', 'optional false'], ['block options', 'name ts_filerecord', 'type record ts6 filein ts6_filename', 'shape', 'reader urword', 'tagged true', 'optional true', 'construct_package ts', 'construct_data timeseries', 'parameter_name timeseries'], ['block options', 'name ts6', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name filein', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name ts6_filename', 'type string', 'preserve_case true', 'in_record true', 'reader urword', 'optional false', 'tagged false'], ['block options', 'name obs_filerecord', 'type record obs6 filein obs6_filename', 'shape', 'reader urword', 'tagged true', 'optional true', 'construct_package obs', 'construct_data continuous', 'parameter_name observations'], ['block options', 'name obs6', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name obs6_filename', 'type string', 'preserve_case true', 'in_record true', 'tagged false', 'reader urword', 'optional false'], ['block options', 'name mover', 'type keyword', 'tagged true', 'reader urword', 'optional true'], ['block options', 'name surfdep', 'type double precision', 'reader urword', 'optional true'], ['block options', 'name maximum_iterations', 'type integer', 'reader urword', 'optional true'], ['block options', 'name maximum_stage_change', 'type double precision', 'reader urword', 'optional true'], ['block options', 'name time_conversion', 'type double precision', 'reader urword', 'optional true'], ['block options', 'name length_conversion', 'type double precision', 'reader urword', 'optional true'], ['block dimensions', 'name nlakes', 'type integer', 'reader urword', 'optional false'], ['block dimensions', 'name noutlets', 'type integer', 'reader urword', 'optional false'], ['block dimensions', 'name ntables', 'type integer', 'reader urword', 'optional false'], ['block packagedata', 'name packagedata', 'type recarray ifno strt nlakeconn aux boundname', 'shape (maxbound)', 'reader urword'], ['block packagedata', 'name ifno', 'type integer', 'shape', 'tagged false', 'in_record true', 'reader urword', 'numeric_index true'], ['block packagedata', 'name strt',

dfn_file_name = 'gwf-lak.dfn'

obs_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

outlets = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

package_abbr = 'gwflak'

package_convergence_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

packagedata = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

perioddata = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

stage_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

tables = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

ts_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

flopy.mf6.modflow.mfgwfmaw module

class ModflowGwfmaw(*model*, *loading_package=False*, *auxiliary=None*, *boundnames=None*, *print_input=None*, *print_head=None*, *print_flows=None*, *save_flows=None*, *head_filerecord=None*, *budget_filerecord=None*, *budgetcsv_filerecord=None*, *no_well_storage=None*, *flow_correction=None*, *flowing_wells=None*, *shutdown_theta=None*, *shutdown_kappa=None*, *mfrcsv_filerecord=None*, *timeseries=None*, *observations=None*, *mover=None*, *nmawwells=None*, *packagedata=None*, *connectiondata=None*, *perioddata=None*, *filename=None*, *pname=None*, ***kwargs*)

Bases: *MFPackage*

ModflowGwfmaw defines a maw package within a gwf6 model.

Parameters

- **model** (MFModel) – Model that this package is a part of. Package is automatically added to model when it is initialized.
- **loading_package** (*bool*) – Do not set this parameter. It is intended for debugging and internal processing purposes only.
- **auxiliary** (*[string]*) –
  - auxiliary (string) defines an array of one or more auxiliary variable names. There is no limit on the number of auxiliary variables that can be provided on this line; however, lists of information provided in subsequent blocks must have a column of data for each auxiliary variable name defined here. The number of auxiliary variables detected on this line determines the value for naux. Comments cannot be provided anywhere on this line as they will be interpreted as auxiliary variable names. Auxiliary variables may not be used by the package, but they will be available for use by other parts of the program. The program will terminate with an error if

auxiliary variables are specified on more than one line in the options block.

- **boundnames** (*boolean*) -
  - boundnames (boolean) keyword to indicate that boundary names may be provided with the list of multi-aquifer well cells.
- **print_input** (*boolean*) -
  - print_input (boolean) keyword to indicate that the list of multi- aquifer well information will be written to the listing file immediately after it is read.
- **print_head** (*boolean*) -
  - print_head (boolean) keyword to indicate that the list of multi- aquifer well heads will be printed to the listing file for every stress period in which "HEAD PRINT" is specified in Output Control. If there is no Output Control option and PRINT_HEAD is specified, then heads are printed for the last time step of each stress period.
- **print_flows** (*boolean*) -
  - print_flows (boolean) keyword to indicate that the list of multi- aquifer well flow rates will be printed to the listing file for every stress period time step in which "BUDGET PRINT" is specified in Output Control. If there is no Output Control option and "PRINT_FLOWS" is specified, then flow rates are printed for the last time step of each stress period.
- **save_flows** (*boolean*) -
  - save_flows (boolean) keyword to indicate that multi-aquifer well flow terms will be written to the file specified with "BUDGET FILEOUT" in Output Control.
- **head_filerecord** (*[headfile]*) -
  - headfile (string) name of the binary output file to write head information.
- **budget_filerecord** (*[budgetfile]*) -
  - budgetfile (string) name of the binary output file to write budget information.
- **budgetcsv_filerecord** (*[budgetcsvfile]*) -
  - budgetcsvfile (string) name of the comma-separated value (CSV) output file to write budget summary information. A budget summary record will be written to this file for each time step of the simulation.
- **no_well_storage** (*boolean*) -
  - no_well_storage (boolean) keyword that deactivates inclusion of well storage contributions to the multi-aquifer well package continuity equation.
- **flow_correction** (*boolean*) -

  - flow_correction (boolean) keyword that activates flow corrections in cases where the head in a multi-aquifer well is below the bottom of the screen for a connection or the head in a convertible cell connected to a multi-aquifer well is below the cell bottom. When flow corrections are activated, unit head gradients are used to calculate the flow between a multi-aquifer well and a connected GWF cell. By default, flow corrections are not made.

- **flowing_wells** (*boolean*) -
  - flowing_wells (boolean) keyword that activates the flowing wells option for the multi-aquifer well package.
- **shutdown_theta** (*double*) -
  - shutdown_theta (double) value that defines the weight applied to discharge rate for wells that limit the water level in a discharging well (defined using the HEAD_LIMIT keyword in the stress period data). SHUTDOWN_THETA is used to control discharge rate oscillations when the flow rate from the aquifer is less than the specified flow rate from the aquifer to the well. Values range between 0.0 and 1.0, and larger values increase the weight (decrease under-relaxation) applied to the well discharge rate. The HEAD_LIMIT option has been included to facilitate backward compatibility with previous versions of MODFLOW but use of the RATE_SCALING option instead of the HEAD_LIMIT option is recommended. By default, SHUTDOWN_THETA is 0.7.
- **shutdown_kappa** (*double*) -
  - shutdown_kappa (double) value that defines the weight applied to discharge rate for wells that limit the water level in a discharging well (defined using the HEAD_LIMIT keyword in the stress period data). SHUTDOWN_KAPPA is used to control discharge rate oscillations when the flow rate from the aquifer is less than the specified flow rate from the aquifer to the well. Values range between 0.0 and 1.0, and larger values increase the weight applied to the well discharge rate. The HEAD_LIMIT option has been included to facilitate backward compatibility with previous versions of MODFLOW but use of the RATE_SCALING option instead of the HEAD_LIMIT option is recommended. By default, SHUTDOWN_KAPPA is 0.0001.
- **mfrcsv_filerecord** (*[mfrcsvfile]*) -
  - mfrcsvfile (string) name of the comma-separated value (CSV) output file to write information about multi-aquifer well extraction or injection rates that have been reduced by the program. Entries are only written if the extraction or injection rates are reduced.
- **timeseries** (*{varname:data} or timeseries data*) -
  - Contains data for the ts package. Data can be stored in a dictionary containing data for the ts package with variable names as keys and package data as values. Data just for

the timeseries variable is also acceptable. See ts package documentation for more information.

- **observations** (*{varname:data} or continuous data*) -
  - Contains data for the obs package. Data can be stored in a dictionary containing data for the obs package with variable names as keys and package data as values. Data just for the observations variable is also acceptable. See obs package documentation for more information.
- **mover** (*boolean*) -
  - mover (boolean) keyword to indicate that this instance of the MAW Package can be used with the Water Mover (MVR) Package. When the MOVER option is specified, additional memory is allocated within the package to store the available, provided, and received water.
- **nmawwells** (*integer*) -
  - nmawwells (integer) integer value specifying the number of multi- aquifer wells that will be simulated for all stress periods.
- **packagedata** (*[ifno, radius, bottom, strt, condeqn, ngwfnodes, aux,)* -

  boundname]

  - ifno (integer) integer value that defines the feature (well) number associated with the specified PACKAGEDATA data on the line. IFNO must be greater than zero and less than or equal to NMAWWELLS. Multi- aquifer well information must be specified for every multi-aquifer well or the program will terminate with an error. The program will also terminate with an error if information for a multi-aquifer well is specified more than once. This argument is an index variable, which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.
  - radius (double) radius for the multi-aquifer well. The program will terminate with an error if the radius is less than or equal to zero.
  - bottom (double) bottom elevation of the multi-aquifer well. If CONDEQN is SPECIFIED, THIEM, SKIN, or COMPOSITE, BOTTOM is set to the cell bottom in the lowermost GWF cell connection in cases where the specified well bottom is above the bottom of this GWF cell. If CONDEQN is MEAN, BOTTOM is set to the lowermost GWF cell connection screen bottom in cases where the specified well bottom is above this value. The bottom elevation defines the lowest well head that will be simulated when the NEWTON UNDER_RELAXATION option is specified in the GWF model name file. The bottom elevation is also used to calculate volumetric storage in the well.

- strt (double) starting head for the multi-aquifer well. The program will terminate with an error if the starting head is less than the specified well bottom.
- condeqn (string) character string that defines the conductance equation that is used to calculate the saturated conductance for the multi-aquifer well. Possible multi-aquifer well CONDEQN strings include: SPECIFIED-character keyword to indicate the multi-aquifer well saturated conductance will be specified. THIEM-character keyword to indicate the multi-aquifer well saturated conductance will be calculated using the Thiem equation, which considers the cell top and bottom, aquifer hydraulic conductivity, and effective cell and well radius. SKIN-character keyword to indicate that the multi- aquifer well saturated conductance will be calculated using the cell top and bottom, aquifer and screen hydraulic conductivity, and well and skin radius. CUMULATIVE-character keyword to indicate that the multi-aquifer well saturated conductance will be calculated using a combination of the Thiem and SKIN equations. MEAN-character keyword to indicate the multi-aquifer well saturated conductance will be calculated using the aquifer and screen top and bottom, aquifer and screen hydraulic conductivity, and well and skin radius. The CUMULATIVE conductance equation is identical to the SKIN LOSSTYPE in the Multi-Node Well (MNW2) package for MODFLOW-2005. The program will terminate with an error condition if CONDEQN is SKIN or CUMULATIVE and the calculated saturated conductance is less than zero; if an error condition occurs, it is suggested that the THEIM or MEAN conductance equations be used for these multi-aquifer wells.
- ngwfnodes (integer) integer value that defines the number of GWF nodes connected to this (IFNO) multi-aquifer well. NGWFNODES must be greater than zero.
- aux (double) represents the values of the auxiliary variables for each multi-aquifer well. The values of auxiliary variables must be present for each multi-aquifer well. The values must be specified in the order of the auxiliary variables specified in the OPTIONS block. If the package supports time series and the Options block includes a TIMESERIESFILE entry (see the "Time-Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
- boundname (string) name of the multi-aquifer well cell. BOUNDNAME is an ASCII character variable that can contain as many as 40 characters. If BOUNDNAME contains spaces in it, then the entire name must be enclosed within single quotes.

• **connectiondata** (*[ifno, icon, cellid, scrn_top, scrn_bot, hk_skin,*) -

radius_skin]

- ifno (integer) integer value that defines the feature (well) number associated with the specified CONNECTIONDATA data on the line. IFNO must be greater than zero and less than or equal to NMAWWELLS. Multi- aquifer well connection information must be specified for every multi-aquifer well connection to the GWF model (NGWFNODES) or the program will terminate with an error. The program will also terminate with an error if connection information for a multi-aquifer well connection to the GWF model is specified more than once. This argument is an index variable, which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.
- icon (integer) integer value that defines the GWF connection number for this multi-aquifer well connection entry. ICONN must be greater than zero and less than or equal to NGWFNODES for multi-aquifer well IFNO. This argument is an index variable, which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.
- cellid ((integer, ...)) is the cell identifier, and depends on the type of grid that is used for the simulation. For a structured grid that uses the DIS input file, CELLID is the layer, row, and column. For a grid that uses the DISV input file, CELLID is the layer and CELL2D number. If the model uses the unstructured discretization (DISU) input file, CELLID is the node number for the cell. One or more screened intervals can be connected to the same CELLID if CONDEQN for a well is MEAN. The program will terminate with an error if MAW wells using SPECIFIED, THIEM, SKIN, or CUMULATIVE conductance equations have more than one connection to the same CELLID. This argument is an index variable, which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.
- scrn_top (double) value that defines the top elevation of the screen for the multi-aquifer well connection. If CONDEQN is SPECIFIED, THIEM, SKIN, or COMPOSITE, SCRN_TOP can be any value and is set to the top of the cell. If CONDEQN is MEAN, SCRN_TOP is set to the multi-aquifer well connection cell top if the specified value is greater than the cell top. The program will terminate with an error if the screen top is less than the screen bottom.
- scrn_bot (double) value that defines the bottom elevation of the screen for the multi-aquifer well connection. If CONDEQN is SPECIFIED, THIEM, SKIN, or COMPOSITE, SCRN_BOT can be any value is set to the bottom of the cell. If

CONDEQN is MEAN, SCRN_BOT is set to the multi-aquifer well connection cell bottom if the specified value is less than the cell bottom. The program will terminate with an error if the screen bottom is greater than the screen top.

- hk_skin (double) value that defines the skin (filter pack) hydraulic conductivity (if CONDEQN for the multi-aquifer well is SKIN, CUMULATIVE, or MEAN) or conductance (if CONDEQN for the multi-aquifer well is SPECIFIED) for each GWF node connected to the multi-aquifer well (NGWFNODES). If CONDEQN is SPECIFIED, HK_SKIN must be greater than or equal to zero. HK_SKIN can be any value if CONDEQN is THIEM. Otherwise, HK_SKIN must be greater than zero. If CONDEQN is SKIN, the contrast between the cell transmissivity (the product of geometric mean horizontal hydraulic conductivity and the cell thickness) and the well transmissivity (the product of HK_SKIN and the screen thicknesses) must be greater than one in node CELLID or the program will terminate with an error condition; if an error condition occurs, it is suggested that the HK_SKIN be reduced to a value less than K11 and K22 in node CELLID or the THEIM or MEAN conductance equations be used for these multi-aquifer wells.
- radius_skin (double) real value that defines the skin radius (filter pack radius) for the multi-aquifer well. RADIUS_SKIN can be any value if CONDEQN is SPECIFIED or THIEM. If CONDEQN is SKIN, CUMULATIVE, or MEAN, the program will terminate with an error if RADIUS_SKIN is less than or equal to the RADIUS for the multi-aquifer well.

- **perioddata** (*[ifno, mawsetting]*) -
  - ifno (integer) integer value that defines the well number associated with the specified PERIOD data on the line. IFNO must be greater than zero and less than or equal to NMAWWELLS. This argument is an index variable, which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.
  - mawsetting (keystring) line of information that is parsed into a keyword and values. Keyword values that can be used to start the MAWSETTING string include: STATUS, FLOWING_WELL, RATE, WELL_HEAD, HEAD_LIMIT, SHUT_OFF, RATE_SCALING, and AUXILIARY.

    status
      [[string]]

      * status (string) keyword option to define well status. STATUS can be ACTIVE, INACTIVE, or CONSTANT. By default, STATUS is ACTIVE.

    flowing_wellrecord
      [[fwelev, fwcond, fwrlen]]

      * fwelev (double) elevation used to determine whether

or not the well is flowing.

* fwcond (double) conductance used to calculate the discharge of a free flowing well. Flow occurs when the head in the well is above the well top elevation (FWELEV).
* fwrlen (double) length used to reduce the conductance of the flowing well. When the head in the well drops below the well top plus the reduction length, then the conductance is reduced. This reduction length can be used to improve the stability of simulations with flowing wells so that there is not an abrupt change in flowing well rates.

rate
[[double]]

* rate (double) is the volumetric pumping rate for the multi- aquifer well. A positive value indicates recharge and a negative value indicates discharge (pumping). RATE only applies to active (STATUS is ACTIVE) multi-aquifer wells. If the Options block includes a TIMESERIESFILE entry (see the "Time-Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value. By default, the RATE for each multi-aquifer well is zero.

well_head
[[double]]

* well_head (double) is the head in the multi-aquifer well. WELL_HEAD is only applied to constant head (STATUS is CONSTANT) and inactive (STATUS is INACTIVE) multi-aquifer wells. If the Options block includes a TIMESERIESFILE entry (see the "Time-Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value. The program will terminate with an error if WELL_HEAD is less than the bottom of the well.

head_limit
[[string]]

* head_limit (string) is the limiting water level (head) in the well, which is the minimum of the well RATE or the well inflow rate from the aquifer. HEAD_LIMIT can be applied to extraction wells (RATE < 0) or injection wells (RATE > 0). HEAD_LIMIT can be deactivated by specifying the text string 'OFF'. The HEAD_LIMIT option is based on the HEAD_LIMIT functionality available in the MNW2 (Konikow et al., 2009) package for MODFLOW-2005. The HEAD_LIMIT option has been included to facilitate backward compatibility with previous versions of MODFLOW

but use of the RATE_SCALING option instead of the HEAD_LIMIT option is recommended. By default, HEAD_LIMIT is 'OFF'.

shutoffrecord
[[minrate, maxrate]]

* minrate (double) is the minimum rate that a well must exceed to shutoff a well during a stress period. The well will shut down during a time step if the flow rate to the well from the aquifer is less than MINRATE. If a well is shut down during a time step, reactivation of the well cannot occur until the next time step to reduce oscillations. MINRATE must be less than maxrate.
* maxrate (double) is the maximum rate that a well must exceed to reactivate a well during a stress period. The well will reactivate during a timestep if the well was shutdown during the previous time step and the flow rate to the well from the aquifer exceeds maxrate. Reactivation of the well cannot occur until the next time step if a well is shutdown to reduce oscillations. maxrate must be greater than MINRATE.

rate_scalingrecord
[[pump_elevation, scaling_length]]

* pump_elevation (double) is the elevation of the multi-aquifer well pump (PUMP_ELEVATION). PUMP_ELEVATION should not be less than the bottom elevation (BOTTOM) of the multi-aquifer well.
* scaling_length (double) height above the pump elevation (SCALING_LENGTH). If the simulated well head is below this elevation (pump elevation plus the scaling length), then the pumping rate is reduced.

auxiliaryrecord
[[auxname, auxval]]

* auxname (string) name for the auxiliary variable to be assigned AUXVAL. AUXNAME must match one of the auxiliary variable names defined in the OPTIONS block. If AUXNAME does not match one of the auxiliary variable names defined in the OPTIONS block the data are ignored.
* auxval (double) value for the auxiliary variable. If the Options block includes a TIMESERIESFILE entry (see the "Time- Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.

- **filename** (*String*) - File name for this package.
- **pname** (*String*) - Package name for this package.

- **parent_file** (MFPackage) - Parent package file that references this package. Only needed for utility packages (mfutl*). For example, mfutllaktab package must have a mfgwflak package parent_file.

auxiliary = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

budget_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

budgetcsv_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

connectiondata = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

```
dfn = [['header', 'multi-package', 'package-type advanced-stress-package'], ['block
options', 'name auxiliary', 'type string', 'shape (naux)', 'reader urword',
'optional true'], ['block options', 'name boundnames', 'type keyword', 'shape',
'reader urword', 'optional true'], ['block options', 'name print_input', 'type
keyword', 'reader urword', 'optional true'], ['block options', 'name print_head',
'type keyword', 'reader urword', 'optional true'], ['block options', 'name
print_flows', 'type keyword', 'reader urword', 'optional true'], ['block options',
'name save_flows', 'type keyword', 'reader urword', 'optional true'], ['block
options', 'name head_filerecord', 'type record head fileout headfile', 'shape',
'reader urword', 'tagged true', 'optional true'], ['block options', 'name head',
'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional
false'], ['block options', 'name headfile', 'type string', 'preserve_case true',
'shape', 'in_record true', 'reader urword', 'tagged false', 'optional false'],
['block options', 'name budget_filerecord', 'type record budget fileout budgetfile',
'shape', 'reader urword', 'tagged true', 'optional true'], ['block options', 'name
budget', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true',
'optional false'], ['block options', 'name fileout', 'type keyword', 'shape',
'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block
options', 'name budgetfile', 'type string', 'preserve_case true', 'shape',
'in_record true', 'reader urword', 'tagged false', 'optional false'], ['block
options', 'name budgetcsv_filerecord', 'type record budgetcsv fileout
budgetcsvfile', 'shape', 'reader urword', 'tagged true', 'optional true'], ['block
options', 'name budgetcsv', 'type keyword', 'shape', 'in_record true', 'reader
urword', 'tagged true', 'optional false'], ['block options', 'name budgetcsvfile',
'type string', 'preserve_case true', 'shape', 'in_record true', 'reader urword',
'tagged false', 'optional false'], ['block options', 'name no_well_storage', 'type
keyword', 'reader urword', 'optional true'], ['block options', 'name
flow_correction', 'type keyword', 'reader urword', 'optional true'], ['block
options', 'name flowing_wells', 'type keyword', 'reader urword', 'optional true'],
['block options', 'name shutdown_theta', 'type double precision', 'reader urword',
'optional true'], ['block options', 'name shutdown_kappa', 'type double precision',
'reader urword', 'optional true'], ['block options', 'name mfrcsv_filerecord', 'type
record maw_flow_reduce_csv fileout mfrcsvfile', 'shape', 'reader urword', 'tagged
true', 'optional true'], ['block options', 'name maw_flow_reduce_csv', 'type
keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional
false'], ['block options', 'name mfrcsvfile', 'type string', 'preserve_case true',
'shape', 'in_record true', 'reader urword', 'tagged false', 'optional false'],
['block options', 'name ts_filerecord', 'type record ts6 filein ts6_filename',
'shape', 'reader urword', 'tagged true', 'optional true', 'construct_package ts',
'construct_data timeseries', 'parameter_name timeseries'], ['block options', 'name
ts6', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true',
'optional false'], ['block options', 'name filein', 'type keyword', 'shape',
'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block
options', 'name ts6_filename', 'type string', 'preserve_case true', 'in_record
true', 'reader urword', 'optional false', 'tagged false'], ['block options', 'name
obs_filerecord', 'type record obs6 filein obs6_filename', 'shape', 'reader urword',
'tagged true', 'optional true', 'construct_package obs', 'construct_data
continuous', 'parameter_name observations'], ['block options', 'name obs6', 'type
keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional
false'], ['block options', 'name obs6_filename', 'type string', 'preserve_case
true', 'in_record true', 'tagged false', 'reader urword', 'optional false'], ['block
options', 'name mover', 'type keyword', 'tagged true', 'reader urword', 'optional
true'], ['block dimensions', 'name nmawwells', 'type integer', 'reader urword',
'optional false'], ['block packagedata', 'name packagedata', 'type recarray ifno
radius bottom strt condeqn ngwfnodes aux boundname', 'shape (nmawwells)', 'reader
urword'], ['block packagedata', 'name ifno', 'type integer', 'shape', 'tagged
false', 'in_record true', 'reader urword', 'numeric_index true'], ['block
packagedata', 'name radius', 'type double precision', 'shape', 'tagged false',
'in_record true', 'reader urword'], ['block packagedata', 'name bottom', 'type
double precision', 'shape', 'tagged false', 'in_record true', 'reader urword'],
```

dfn_file_name = 'gwf-maw.dfn'

head_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

mfrcsv_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

obs_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

package_abbr = 'gwfmaw'

packagedata = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

perioddata = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

ts_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

flopy.mf6.modflow.mfgwfmvr module

class GwfmvrPackages(*model_or_sim*, *parent*, *pkg_type*, *filerecord*, *package=None*, *package_class=None*)

Bases: *MFChildPackages*

GwfmvrPackages is a container class for the ModflowGwfmvr class.

initialize()

Initializes a new ModflowGwfmvr package removing any sibling child packages attached to the same parent package. See ModflowGwfmvr init documentation for definition of parameters.

append_package()

Adds a new ModflowGwfmvr package to the container. See ModflowGwfmvr init documentation for definition of parameters.

append_package(*print_input=None*, *print_flows=None*, *modelnames=None*, *budget_filerecord=None*, *budgetcsv_filerecord=None*, *maxmvr=None*, *maxpackages=None*, *packages=None*, *perioddata=None*, *filename=None*, *pname=None*)

initialize(*print_input=None*, *print_flows=None*, *modelnames=None*, *budget_filerecord=None*, *budgetcsv_filerecord=None*, *maxmvr=None*, *maxpackages=None*, *packages=None*, *perioddata=None*, *filename=None*, *pname=None*)

package_abbr = 'gwfmvrpackages'

class ModflowGwfmvr(*parent_model_or_package*, *loading_package=False*, *print_input=None*, *print_flows=None*, *modelnames=None*, *budget_filerecord=None*, *budgetcsv_filerecord=None*, *maxmvr=None*, *maxpackages=None*, *packages=None*, *perioddata=None*, *filename=None*, *pname=None*, ***kwargs*)

Bases: *MFPackage*

ModflowGwfmvr defines a mvr package within a gwf6 model. This package can only be used to move water between packages within a single model. To move water between models use ModflowMvr.

Parameters

- **parent_model_or_package** (*MFModel/MFPackage*) - Parent_model_or_package that this package is a part of. Package is automatically added to parent_model_or_package when it is initialized.
- **loading_package** (*bool*) - Do not set this parameter. It is intended for debugging and internal processing purposes only.
- **print_input** (*boolean*) -
  - print_input (boolean) keyword to indicate that the list of MVR information will be written to the listing file immediately after it is read.
- **print_flows** (*boolean*) -
  - print_flows (boolean) keyword to indicate that the list of MVR flow rates will be printed to the listing file for every stress period time step in which "BUDGET PRINT" is specified in Output Control. If there is no Output Control option and "PRINT_FLOWS" is specified, then flow rates are printed for the last time step of each stress period.
- **modelnames** (*boolean*) -
  - modelnames (boolean) keyword to indicate that all package names will be preceded by the model name for the package. Model names are required when the Mover Package is used with a GWF-GWF Exchange. The MODELNAME keyword should not be used for a Mover Package that is for a single GWF Model.
- **budget_filerecord** (*[budgetfile]*) -
  - budgetfile (string) name of the output file to write budget information.
- **budgetcsv_filerecord** (*[budgetcsvfile]*) -
  - budgetcsvfile (string) name of the comma-separated value (CSV) output file to write budget summary information. A budget summary record will be written to this file for each time step of the simulation.
- **maxmvr** (*integer*) -
  - maxmvr (integer) integer value specifying the maximum number of water mover entries that will specified for any stress period.
- **maxpackages** (*integer*) -
  - maxpackages (integer) integer value specifying the number of unique packages that are included in this water mover input file.
- **packages** (*[mname, pname]*) -
  - mname (string) name of model containing the package. Model names are assigned by the user in the simulation name file.
  - pname (string) is the name of a package that may be included in a subsequent stress period block. The package name is assigned in the name file for the GWF Model. Package names

are optionally provided in the name file. If they are not provided by the user, then packages are assigned a default value, which is the package acronym followed by a hyphen and the package number. For example, the first Drain Package is named DRN-1. The second Drain Package is named DRN-2, and so forth.

- **perioddata** (*[mname1, pname1, id1, mname2, pname2, id2, mvrtype, value]*) -
  - mname1 (string) name of model containing the package, PNAME1.
  - pname1 (string) is the package name for the provider. The package PNAME1 must be designated to provide water through the MVR Package by specifying the keyword "MOVER" in its OPTIONS block.
  - id1 (integer) is the identifier for the provider. For the standard boundary packages, the provider identifier is the number of the boundary as it is listed in the package input file. (Note that the order of these boundaries may change by stress period, which must be accounted for in the Mover Package.) So the first well has an identifier of one. The second is two, and so forth. For the advanced packages, the identifier is the reach number (SFR Package), well number (MAW Package), or UZF cell number. For the Lake Package, ID1 is the lake outlet number. Thus, outflows from a single lake can be routed to different streams, for example. This argument is an index variable, which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.
  - mname2 (string) name of model containing the package, PNAME2.
  - pname2 (string) is the package name for the receiver. The package PNAME2 must be designated to receive water from the MVR Package by specifying the keyword "MOVER" in its OPTIONS block.
  - id2 (integer) is the identifier for the receiver. The receiver identifier is the reach number (SFR Package), Lake number (LAK Package), well number (MAW Package), or UZF cell number. This argument is an index variable, which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.
  - mvrtype (string) is the character string signifying the method for determining how much water will be moved. Supported values are "FACTOR" "EXCESS" "THRESHOLD" and "UPTO". These four options determine how the receiver flow rate, Q_R, is calculated. These options mirror the options defined for the cprior variable in the SFR package, with the term "FACTOR" being functionally equivalent to the "FRACTION" option for cprior.
  - value (double) is the value to be used in the equation for

calculating the amount of water to move. For the "FACTOR" option, VALUE is the α factor. For the remaining options, VALUE is the specified flow rate, Q_S.

- **filename** (*String*) - File name for this package.
- **pname** (*String*) - Package name for this package.
- **parent_file** (MFPackage) - Parent package file that references this package. Only needed for utility packages (mfutl*). For example, mfutllaktab package must have a mfgwflak package parent_file.

budget_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

budgetcsv_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

dfn = [['header'], ['block options', 'name print_input', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name print_flows', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name modelnames', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name budget_filerecord', 'type record budget fileout budgetfile', 'shape', 'reader urword', 'tagged true', 'optional true'], ['block options', 'name budget', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name fileout', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name budgetfile', 'type string', 'preserve_case true', 'shape', 'in_record true', 'reader urword', 'tagged false', 'optional false'], ['block options', 'name budgetcsv_filerecord', 'type record budgetcsv fileout budgetcsvfile', 'shape', 'reader urword', 'tagged true', 'optional true'], ['block options', 'name budgetcsv', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name budgetcsvfile', 'type string', 'preserve_case true', 'shape', 'in_record true', 'reader urword', 'tagged false', 'optional false'], ['block dimensions', 'name maxmvr', 'type integer', 'reader urword', 'optional false'], ['block dimensions', 'name maxpackages', 'type integer', 'reader urword', 'optional false'], ['block packages', 'name packages', 'type recarray mname pname', 'reader urword', 'shape (npackages)', 'optional false'], ['block packages', 'name mname', 'type string', 'reader urword', 'shape', 'tagged false', 'in_record true', 'optional true'], ['block packages', 'name pname', 'type string', 'reader urword', 'shape', 'tagged false', 'in_record true', 'optional false'], ['block period', 'name iper', 'type integer', 'block_variable True', 'in_record true', 'tagged false', 'shape', 'valid', 'reader urword', 'optional false'], ['block period', 'name perioddata', 'type recarray mname1 pname1 id1 mname2 pname2 id2 mvrtype value', 'shape (maxbound)', 'reader urword'], ['block period', 'name mname1', 'type string', 'reader urword', 'shape', 'tagged false', 'in_record true', 'optional true'], ['block period', 'name pname1', 'type string', 'shape', 'tagged false', 'in_record true', 'reader urword'], ['block period', 'name id1', 'type integer', 'shape', 'tagged false', 'in_record true', 'reader urword', 'numeric_index true'], ['block period', 'name mname2', 'type string', 'reader urword', 'shape', 'tagged false', 'in_record true', 'optional true'], ['block period', 'name pname2', 'type string', 'shape', 'tagged false', 'in_record true', 'reader urword'], ['block period', 'name id2', 'type integer', 'shape', 'tagged false', 'in_record true', 'reader urword', 'numeric_index true'], ['block period', 'name mvrtype', 'type string', 'shape', 'tagged false', 'in_record true', 'reader urword'], ['block period', 'name value', 'type double precision', 'shape', 'tagged false', 'in_record true', 'reader urword']]

dfn_file_name = 'gwf-mvr.dfn'

package_abbr = 'gwfmvr'

packages = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

perioddata = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

flopy.mf6.modflow.mfgwfnam module

class ModflowGwfnam(*model*, *loading_package=False*, *list=None*, *print_input=None*, *print_flows=None*, *save_flows=None*, *newtonoptions=None*, *packages=None*, *filename=None*, *pname=None*, ***kwargs*)

Bases: *MFPackage*

ModflowGwfnam defines a nam package within a gwf6 model.

Parameters

- **model** (MFModel) - Model that this package is a part of. Package is automatically added to model when it is initialized.
- **loading_package** (*bool*) - Do not set this parameter. It is intended for debugging and internal processing purposes only.
- **list** (*string*) -
  - list (string) is name of the listing file to create for this GWF model. If not specified, then the name of the list file will be the basename of the GWF model name file and the '.lst' extension. For example, if the GWF name file is called "my.model.nam" then the list file will be called "my.model.lst".
- **print_input** (*boolean*) -
  - print_input (boolean) keyword to indicate that the list of all model stress package information will be written to the listing file immediately after it is read.
- **print_flows** (*boolean*) -
  - print_flows (boolean) keyword to indicate that the list of all model package flow rates will be printed to the listing file for every stress period time step in which "BUDGET PRINT" is specified in Output Control. If there is no Output Control option and "PRINT_FLOWS" is specified, then flow rates are printed for the last time step of each stress period.
- **save_flows** (*boolean*) -
  - save_flows (boolean) keyword to indicate that all model package flow terms will be written to the file specified with "BUDGET FILEOUT" in Output Control.
- **newtonoptions** (*[under_relaxation]*) -
  - under_relaxation (string) keyword that indicates whether the groundwater head in a cell will be under-relaxed when water levels fall below the bottom of the model below any given cell. By default, Newton-Raphson UNDER_RELAXATION is not applied.

- **packages** (*[ftype, fname, pname]*) -
  - ftype (string) is the file type, which must be one of the following character values shown in table in mf6io.pdf. Ftype may be entered in any combination of uppercase and lowercase.
  - fname (string) is the name of the file containing the package input. The path to the file should be included if the file is not located in the folder where the program was run.
  - pname (string) is the user-defined name for the package. PNAME is restricted to 16 characters. No spaces are allowed in PNAME. PNAME character values are read and stored by the program for stress packages only. These names may be useful for labeling purposes when multiple stress packages of the same type are located within a single GWF Model. If PNAME is specified for a stress package, then PNAME will be used in the flow budget table in the listing file; it will also be used for the text entry in the cell-by-cell budget file. PNAME is case insensitive and is stored in all upper case letters.
- **filename** (*String*) - File name for this package.
- **pname** (*String*) - Package name for this package.
- **parent_file** (MFPackage) - Parent package file that references this package. Only needed for utility packages (mfutl*). For example, mfutllaktab package must have a mfgwflak package parent_file.

dfn = [['header'], ['block options', 'name list', 'type string', 'reader urword', 'optional true', 'preserve_case true'], ['block options', 'name print_input', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name print_flows', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name save_flows', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name newtonoptions', 'type record newton under_relaxation', 'reader urword', 'optional true'], ['block options', 'name newton', 'in_record true', 'type keyword', 'reader urword'], ['block options', 'name under_relaxation', 'in_record true', 'type keyword', 'reader urword', 'optional true'], ['block packages', 'name packages', 'type recarray ftype fname pname', 'reader urword', 'optional false'], ['block packages', 'name ftype', 'in_record true', 'type string', 'tagged false', 'reader urword'], ['block packages', 'name fname', 'in_record true', 'type string', 'preserve_case true', 'tagged false', 'reader urword'], ['block packages', 'name pname', 'in_record true', 'type string', 'tagged false', 'reader urword', 'optional true']]

dfn_file_name = 'gwf-nam.dfn'

package_abbr = 'gwfnam'

packages = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

flopy.mf6.modflow.mfgwfnpf module

class ModflowGwfnpf(*model, loading_package=False, save_flows=None, print_flows=None, alternative_cell_averaging=None, thickstrt=None, cvoptions=None, perched=None, rewet_record=None, xt3doptions=None, save_specific_discharge=None, save_saturation=None, k22overk=None, k33overk=None, perioddata=None, dev_no_newton=None, dev_modflowusg_upstream_weighted_saturation=None, dev_modflownwt_upstream_weighting=None, dev_minimum_saturated_thickness=None, dev_omega=None, icelltype=0, k=1.0, k22=None, k33=None, angle1=None, angle2=None, angle3=None, wetdry=None, filename=None, pname=None, **kwargs*)

Bases: *MFPackage*

ModflowGwfnpf defines a npf package within a gwf6 model.

Parameters

- **model** (MFModel) - Model that this package is a part of. Package is automatically added to model when it is initialized.
- **loading_package** (*bool*) - Do not set this parameter. It is intended for debugging and internal processing purposes only.
- **save_flows** (*boolean*) -
  - save_flows (boolean) keyword to indicate that budget flow terms will be written to the file specified with "BUDGET SAVE FILE" in Output Control.
- **print_flows** (*boolean*) -
  - print_flows (boolean) keyword to indicate that calculated flows between cells will be printed to the listing file for every stress period time step in which "BUDGET PRINT" is specified in Output Control. If there is no Output Control option and "PRINT_FLOWS" is specified, then flow rates are printed for the last time step of each stress period. This option can produce extremely large list files because all cell-by-cell flows are printed. It should only be used with the NPF Package for models that have a small number of cells.
- **alternative_cell_averaging** (*string*) -
  - alternative_cell_averaging (string) is a text keyword to indicate that an alternative method will be used for calculating the conductance for horizontal cell connections. The text value for ALTERNATIVE_CELL_AVERAGING can be "LOGARITHMIC", "AMT-LMK", or "AMT- HMK". "AMT-LMK" signifies that the conductance will be calculated using arithmetic-mean thickness and logarithmic-mean hydraulic conductivity. "AMT-HMK" signifies that the conductance will be calculated using arithmetic-mean thickness and harmonic-mean hydraulic conductivity. If the user does not specify a value for ALTERNATIVE_CELL_AVERAGING, then the harmonic-mean method will be used. This option cannot be used if the XT3D option is invoked.
- **thickstrt** (*boolean*) -

  - thickstrt (boolean) indicates that cells having a negative ICELLTYPE are confined, and their cell thickness for conductance calculations will be computed as STRT-BOT rather than TOP-BOT. This option should be used with caution as it only affects conductance calculations in the NPF Package.
- **cvoptions** (*[dewatered]*) -
  - dewatered (string) If the DEWATERED keyword is specified, then the vertical conductance is calculated using only the saturated thickness and properties of the overlying cell if the head in the underlying cell is below its top.
- **perched** (*boolean*) -
  - perched (boolean) keyword to indicate that when a cell is overlying a dewatered convertible cell, the head difference used in Darcy's Law is equal to the head in the overlying cell minus the bottom elevation of the overlying cell. If not specified, then the default is to use the head difference between the two cells.
- **rewet_record** (*[wetfct, iwetit, ihdwet]*) -
  - wetfct (double) is a keyword and factor that is included in the calculation of the head that is initially established at a cell when that cell is converted from dry to wet.
  - iwetit (integer) is a keyword and iteration interval for attempting to wet cells. Wetting is attempted every IWETIT iteration. This applies to outer iterations and not inner iterations. If IWETIT is specified as zero or less, then the value is changed to 1.
  - ihdwet (integer) is a keyword and integer flag that determines which equation is used to define the initial head at cells that become wet. If IHDWET is 0, h = BOT + WETFCT (hm - BOT). If IHDWET is not 0, h = BOT + WETFCT (THRESH).
- **xt3doptions** (*[rhs]*) -
  - rhs (string) If the RHS keyword is also included, then the XT3D additional terms will be added to the right-hand side. If the RHS keyword is excluded, then the XT3D terms will be put into the coefficient matrix.
- **save_specific_discharge** (*boolean*) -
  - save_specific_discharge (boolean) keyword to indicate that x, y, and z components of specific discharge will be calculated at cell centers and written to the budget file, which is specified with "BUDGET SAVE FILE" in Output Control. If this option is activated, then additional information may be required in the discretization packages and the GWF Exchange package (if GWF models are coupled). Specifically, ANGLDEGX must be specified in the CONNECTIONDATA block of the DISU Package; ANGLDEGX must also be specified for the GWF Exchange as an auxiliary variable.
- **save_saturation** (*boolean*) -

  - save_saturation (boolean) keyword to indicate that cell saturation will be written to the budget file, which is specified with "BUDGET SAVE FILE" in Output Control. Saturation will be saved to the budget file as an auxiliary variable saved with the DATA-SAT text label. Saturation is a cell variable that ranges from zero to one and can be used by post processing programs to determine how much of a cell volume is saturated. If ICELLTYPE is 0, then saturation is always one.

- **k22overk** (*boolean*) -
  - k22overk (boolean) keyword to indicate that specified K22 is a ratio of K22 divided by K. If this option is specified, then the K22 array entered in the NPF Package will be multiplied by K after being read.
- **k33overk** (*boolean*) -
  - k33overk (boolean) keyword to indicate that specified K33 is a ratio of K33 divided by K. If this option is specified, then the K33 array entered in the NPF Package will be multiplied by K after being read.
- **perioddata** (*{varname:data} or tvk_perioddata data*) -
  - Contains data for the tvk package. Data can be stored in a dictionary containing data for the tvk package with variable names as keys and package data as values. Data just for the perioddata variable is also acceptable. See tvk package documentation for more information.
- **dev_no_newton** (*boolean*) -
  - dev_no_newton (boolean) turn off Newton for unconfined cells
- **dev_modflowusg_upstream_weighted_saturation** (*boolean*) -
  - dev_modflowusg_upstream_weighted_saturation (boolean) use MODFLOW-USG upstream-weighted saturation approach
- **dev_modflownwt_upstream_weighting** (*boolean*) -
  - dev_modflownwt_upstream_weighting (boolean) use MODFLOW-NWT approach for upstream weighting
- **dev_minimum_saturated_thickness** (*double*) -
  - dev_minimum_saturated_thickness (double) set minimum allowed saturated thickness
- **dev_omega** (*double*) -
  - dev_omega (double) set saturation omega value
- **icelltype** (*[integer]*) -
  - icelltype (integer) flag for each cell that specifies how saturated thickness is treated. 0 means saturated thickness is held constant; >0 means saturated thickness varies with computed head when head is below the cell top; <0 means saturated thickness varies with computed head unless the THICKSTRT option is in effect. When THICKSTRT is in effect,

a negative value for ICELLTYPE indicates that the saturated thickness value used in conductance calculations in the NPF Package will be computed as STRT-BOT and held constant. If the THICKSTRT option is not in effect, then negative values provided by the user for ICELLTYPE are automatically reassigned by the program to a value of one.

- **k** (*[double]*) -
  - k (double) is the hydraulic conductivity. For the common case in which the user would like to specify the horizontal hydraulic conductivity and the vertical hydraulic conductivity, then K should be assigned as the horizontal hydraulic conductivity, K33 should be assigned as the vertical hydraulic conductivity, and K22 and the three rotation angles should not be specified. When more sophisticated anisotropy is required, then K corresponds to the K11 hydraulic conductivity axis. All included cells (IDOMAIN > 0) must have a K value greater than zero.
- **k22** (*[double]*) -
  - k22 (double) is the hydraulic conductivity of the second ellipsoid axis (or the ratio of K22/K if the K22OVERK option is specified); for an unrotated case this is the hydraulic conductivity in the y direction. If K22 is not included in the GRIDDATA block, then K22 is set equal to K. For a regular MODFLOW grid (DIS Package is used) in which no rotation angles are specified, K22 is the hydraulic conductivity along columns in the y direction. For an unstructured DISU grid, the user must assign principal x and y axes and provide the angle for each cell face relative to the assigned x direction. All included cells (IDOMAIN > 0) must have a K22 value greater than zero.
- **k33** (*[double]*) -
  - k33 (double) is the hydraulic conductivity of the third ellipsoid axis (or the ratio of K33/K if the K33OVERK option is specified); for an unrotated case, this is the vertical hydraulic conductivity. When anisotropy is applied, K33 corresponds to the K33 tensor component. All included cells (IDOMAIN > 0) must have a K33 value greater than zero.
- **angle1** (*[double]*) -
  - angle1 (double) is a rotation angle of the hydraulic conductivity tensor in degrees. The angle represents the first of three sequential rotations of the hydraulic conductivity ellipsoid. With the K11, K22, and K33 axes of the ellipsoid initially aligned with the x, y, and z coordinate axes, respectively, ANGLE1 rotates the ellipsoid about its K33 axis (within the x - y plane). A positive value represents counter-clockwise rotation when viewed from any point on the positive K33 axis, looking toward the center of the ellipsoid. A value of zero indicates that the K11 axis lies within the x - z plane. If ANGLE1 is not specified, default values of zero are assigned to ANGLE1, ANGLE2, and

ANGLE3, in which case the K11, K22, and K33 axes are aligned with the x, y, and z axes, respectively.

- **angle2** (*[double]*) -
  - angle2 (double) is a rotation angle of the hydraulic conductivity tensor in degrees. The angle represents the second of three sequential rotations of the hydraulic conductivity ellipsoid. Following the rotation by ANGLE1 described above, ANGLE2 rotates the ellipsoid about its K22 axis (out of the x - y plane). An array can be specified for ANGLE2 only if ANGLE1 is also specified. A positive value of ANGLE2 represents clockwise rotation when viewed from any point on the positive K22 axis, looking toward the center of the ellipsoid. A value of zero indicates that the K11 axis lies within the x - y plane. If ANGLE2 is not specified, default values of zero are assigned to ANGLE2 and ANGLE3; connections that are not user- designated as vertical are assumed to be strictly horizontal (that is, to have no z component to their orientation); and connection lengths are based on horizontal distances.
- **angle3** (*[double]*) -
  - angle3 (double) is a rotation angle of the hydraulic conductivity tensor in degrees. The angle represents the third of three sequential rotations of the hydraulic conductivity ellipsoid. Following the rotations by ANGLE1 and ANGLE2 described above, ANGLE3 rotates the ellipsoid about its K11 axis. An array can be specified for ANGLE3 only if ANGLE1 and ANGLE2 are also specified. An array must be specified for ANGLE3 if ANGLE2 is specified. A positive value of ANGLE3 represents clockwise rotation when viewed from any point on the positive K11 axis, looking toward the center of the ellipsoid. A value of zero indicates that the K22 axis lies within the x - y plane.
- **wetdry** (*[double]*) -
  - wetdry (double) is a combination of the wetting threshold and a flag to indicate which neighboring cells can cause a cell to become wet. If WETDRY < 0, only a cell below a dry cell can cause the cell to become wet. If WETDRY > 0, the cell below a dry cell and horizontally adjacent cells can cause a cell to become wet. If WETDRY is 0, the cell cannot be wetted. The absolute value of WETDRY is the wetting threshold. When the sum of BOT and the absolute value of WETDRY at a dry cell is equaled or exceeded by the head at an adjacent cell, the cell is wetted. WETDRY must be specified if "REWET" is specified in the OPTIONS block. If "REWET" is not specified in the options block, then WETDRY can be entered, and memory will be allocated for it, even though it is not used.
- **filename** (*String*) - File name for this package.
- **pname** (*String*) - Package name for this package.
- **parent_file** (MFPackage) - Parent package file that references this

package. Only needed for utility packages (mfutl*). For example, mfutllaktab package must have a mfgwflak package parent_file.

angle1 = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

angle2 = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

angle3 = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

```
dfn = [['header'], ['block options', 'name save_flows', 'type keyword', 'reader
urword', 'optional true', 'mf6internal ipakcb'], ['block options', 'name
print_flows', 'type keyword', 'reader urword', 'optional true', 'mf6internal
iprflow'], ['block options', 'name alternative_cell_averaging', 'type string',
'valid logarithmic amt-lmk amt-hmk', 'reader urword', 'optional true', 'mf6internal
cellavg'], ['block options', 'name thickstrt', 'type keyword', 'reader urword',
'optional true', 'mf6internal ithickstrt'], ['block options', 'name cvoptions',
'type record variablecv dewatered', 'reader urword', 'optional true'], ['block
options', 'name variablecv', 'in_record true', 'type keyword', 'reader urword',
'mf6internal ivarcv'], ['block options', 'name dewatered', 'in_record true', 'type
keyword', 'reader urword', 'optional true', 'mf6internal idewatcv'], ['block
options', 'name perched', 'type keyword', 'reader urword', 'optional true',
'mf6internal iperched'], ['block options', 'name rewet_record', 'type record rewet
wetfct iwetit ihdwet', 'reader urword', 'optional true'], ['block options', 'name
rewet', 'type keyword', 'in_record true', 'reader urword', 'optional false',
'mf6internal irewet'], ['block options', 'name wetfct', 'type double precision',
'in_record true', 'reader urword', 'optional false'], ['block options', 'name
iwetit', 'type integer', 'in_record true', 'reader urword', 'optional false'],
['block options', 'name ihdwet', 'type integer', 'in_record true', 'reader urword',
'optional false'], ['block options', 'name xt3doptions', 'type record xt3d rhs',
'reader urword', 'optional true'], ['block options', 'name xt3d', 'in_record true',
'type keyword', 'reader urword', 'mf6internal ixt3d'], ['block options', 'name rhs',
'in_record true', 'type keyword', 'reader urword', 'optional true', 'mf6internal
ixt3drhs'], ['block options', 'name save_specific_discharge', 'type keyword',
'reader urword', 'optional true', 'mf6internal isavspdis'], ['block options', 'name
save_saturation', 'type keyword', 'reader urword', 'optional true', 'mf6internal
isavsat'], ['block options', 'name k22overk', 'type keyword', 'reader urword',
'optional true', 'mf6internal ik22overk'], ['block options', 'name k33overk', 'type
keyword', 'reader urword', 'optional true', 'mf6internal ik33overk'], ['block
options', 'name tvk_filerecord', 'type record tvk6 filein tvk6_filename', 'shape',
'reader urword', 'tagged true', 'optional true', 'construct_package tvk',
'construct_data tvk_perioddata', 'parameter_name perioddata'], ['block options',
'name tvk6', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged
true', 'optional false'], ['block options', 'name filein', 'type keyword', 'shape',
'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block
options', 'name tvk6_filename', 'type string', 'preserve_case true', 'in_record
true', 'reader urword', 'optional false', 'tagged false'], ['block options', 'name
dev_no_newton', 'type keyword', 'reader urword', 'optional true', 'mf6internal
inewton'], ['block options', 'name dev_modflowusg_upstream_weighted_saturation',
'type keyword', 'reader urword', 'optional true', 'mf6internal iusgnrhc'], ['block
options', 'name dev_modflownwt_upstream_weighting', 'type keyword', 'reader urword',
'optional true', 'mf6internal inwtupw'], ['block options', 'name
dev_minimum_saturated_thickness', 'type double precision', 'reader urword',
'optional true', 'mf6internal satmin'], ['block options', 'name dev_omega', 'type
double precision', 'reader urword', 'optional true', 'mf6internal satomega'],
['block griddata', 'name icelltype', 'type integer', 'shape (nodes)', 'valid',
'reader readarray', 'layered true', 'optional', 'default_value 0'], ['block
griddata', 'name k', 'type double precision', 'shape (nodes)', 'valid', 'reader
readarray', 'layered true', 'optional', 'default_value 1.0'], ['block griddata',
'name k22', 'type double precision', 'shape (nodes)', 'valid', 'reader readarray',
'layered true', 'optional true'], ['block griddata', 'name k33', 'type double
precision', 'shape (nodes)', 'valid', 'reader readarray', 'layered true', 'optional
true'], ['block griddata', 'name angle1', 'type double precision', 'shape (nodes)',
'valid', 'reader readarray', 'layered true', 'optional true'], ['block griddata',
'name angle2', 'type double precision', 'shape (nodes)', 'valid', 'reader
readarray', 'layered true', 'optional true'], ['block griddata', 'name angle3',
'type double precision', 'shape (nodes)', 'valid', 'reader readarray', 'layered
true', 'optional true'], ['block griddata', 'name wetdry', 'type double precision',
'shape (nodes)', 'valid', 'reader readarray', 'layered true', 'optional true']]
```

dfn_file_name = 'gwf-npf.dfn'

icelltype = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

k = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

k22 = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

k33 = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

package_abbr = 'gwfnpf'

rewet_record = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

tvk_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

wetdry = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

flopy.mf6.modflow.mfgwfoc module

class **ModflowGwfoc**(*model*, *loading_package=False*, *budget_filerecord=None*, *budgetcsv_filerecord=None*, *head_filerecord=None*, *headprintrecord=None*, *saverecord=None*, *printrecord=None*, *filename=None*, *pname=None*, ***kwargs*)

Bases: *MFPackage*

ModflowGwfoc defines a oc package within a gwf6 model.

Parameters

- **model** (MFModel) - Model that this package is a part of. Package is automatically added to model when it is initialized.
- **loading_package** (*bool*) - Do not set this parameter. It is intended for debugging and internal processing purposes only.
- **budget_filerecord** (*[budgetfile]*) -
  - budgetfile (string) name of the output file to write budget information.
- **budgetcsv_filerecord** (*[budgetcsvfile]*) -
  - budgetcsvfile (string) name of the comma-separated value (CSV) output file to write budget summary information. A budget summary record will be written to this file for each time step of the simulation.
- **head_filerecord** (*[headfile]*) -
  - headfile (string) name of the output file to write head information.
- **headprintrecord** (*[columns, width, digits, format]*) -
  - columns (integer) number of columns for writing data.
  - width (integer) width for writing each number.
  - digits (integer) number of digits to use for writing a number.

- format (string) write format can be EXPONENTIAL, FIXED, GENERAL, or SCIENTIFIC.

- **saverecord** (*[rtype, ocsetting]*) -
  - rtype (string) type of information to save or print. Can be BUDGET or HEAD.
  - ocsetting (keystring) specifies the steps for which the data will be saved.

    all
    [[keyword]]

    * all (keyword) keyword to indicate save for all time steps in period.

    first
    [[keyword]]

    * first (keyword) keyword to indicate save for first step in period. This keyword may be used in conjunction with other keywords to print or save results for multiple time steps.

    last
    [[keyword]]

    * last (keyword) keyword to indicate save for last step in period. This keyword may be used in conjunction with other keywords to print or save results for multiple time steps.

    frequency
    [[integer]]

    * frequency (integer) save at the specified time step frequency. This keyword may be used in conjunction with other keywords to print or save results for multiple time steps.

    steps
    [[integer]]

    * steps (integer) save for each step specified in STEPS. This keyword may be used in conjunction with other keywords to print or save results for multiple time steps.

- **printrecord** (*[rtype, ocsetting]*) -
  - rtype (string) type of information to save or print. Can be BUDGET or HEAD.
  - ocsetting (keystring) specifies the steps for which the data will be saved.

    all
    [[keyword]]

    * all (keyword) keyword to indicate save for all time steps in period.

first
[[keyword]]

* first (keyword) keyword to indicate save for first step in period. This keyword may be used in conjunction with other keywords to print or save results for multiple time steps.

last
[[keyword]]

* last (keyword) keyword to indicate save for last step in period. This keyword may be used in conjunction with other keywords to print or save results for multiple time steps.

frequency
[[integer]]

* frequency (integer) save at the specified time step frequency. This keyword may be used in conjunction with other keywords to print or save results for multiple time steps.

steps
[[integer]]

* steps (integer) save for each step specified in STEPS. This keyword may be used in conjunction with other keywords to print or save results for multiple time steps.

- **filename** (*String*) - File name for this package.
- **pname** (*String*) - Package name for this package.
- **parent_file** (MFPackage) - Parent package file that references this package. Only needed for utility packages (mfutl*). For example, mfutllaktab package must have a mfgwflak package parent_file.

budget_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

budgetcsv_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

dfn = [['header'], ['block options', 'name budget_filerecord', 'type record budget fileout budgetfile', 'shape', 'reader urword', 'tagged true', 'optional true'], ['block options', 'name budget', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name fileout', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name budgetfile', 'type string', 'preserve_case true', 'shape', 'in_record true', 'reader urword', 'tagged false', 'optional false'], ['block options', 'name budgetcsv_filerecord', 'type record budgetcsv fileout budgetcsvfile', 'shape', 'reader urword', 'tagged true', 'optional true'], ['block options', 'name budgetcsv', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name budgetcsvfile', 'type string', 'preserve_case true', 'shape', 'in_record true', 'reader urword', 'tagged false', 'optional false'], ['block options', 'name head_filerecord', 'type record head fileout headfile', 'shape', 'reader urword', 'tagged true', 'optional true'], ['block options', 'name head', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name headfile', 'type string', 'preserve_case true', 'shape', 'in_record true', 'reader urword', 'tagged false', 'optional false'], ['block options', 'name headprintrecord', 'type record head print_format formatrecord', 'shape', 'reader urword', 'optional true'], ['block options', 'name print_format', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name formatrecord', 'type record columns width digits format', 'shape', 'in_record true', 'reader urword', 'tagged', 'optional false'], ['block options', 'name columns', 'type integer', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional'], ['block options', 'name width', 'type integer', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional'], ['block options', 'name digits', 'type integer', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional'], ['block options', 'name format', 'type string', 'shape', 'in_record true', 'reader urword', 'tagged false', 'optional false'], ['block period', 'name iper', 'type integer', 'block_variable True', 'in_record true', 'tagged false', 'shape', 'valid', 'reader urword', 'optional false'], ['block period', 'name saverecord', 'type record save rtype ocsetting', 'shape', 'reader urword', 'tagged false', 'optional true'], ['block period', 'name save', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block period', 'name printrecord', 'type record print rtype ocsetting', 'shape', 'reader urword', 'tagged false', 'optional true'], ['block period', 'name print', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block period', 'name rtype', 'type string', 'shape', 'in_record true', 'reader urword', 'tagged false', 'optional false'], ['block period', 'name ocsetting', 'type keystring all first last frequency steps', 'shape', 'tagged false', 'in_record true', 'reader urword'], ['block period', 'name all', 'type keyword', 'shape', 'in_record true', 'reader urword'], ['block period', 'name first', 'type keyword', 'shape', 'in_record true', 'reader urword'], ['block period', 'name last', 'type keyword', 'shape', 'in_record true', 'reader urword'], ['block period', 'name frequency', 'type integer', 'shape', 'tagged true', 'in_record true', 'reader urword'], ['block period', 'name steps', 'type integer', 'shape (<nstp)', 'tagged true', 'in_record true', 'reader urword']]

dfn_file_name = 'gwf-oc.dfn'

head_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

headprintrecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

package_abbr = 'gwfoc'

printrecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

saverecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

flopy.mf6.modflow.mfgwfrch module

class ModflowGwfrch(*model*, *loading_package=False*, *fixed_cell=None*, *auxiliary=None*, *auxmultname=None*, *boundnames=None*, *print_input=None*, *print_flows=None*, *save_flows=None*, *timeseries=None*, *observations=None*, *maxbound=None*, *stress_period_data=None*, *filename=None*, *pname=None*, ***kwargs*)

Bases: *MFPackage*

ModflowGwfrch defines a rch package within a gwf6 model.

Parameters

- **model** (MFModel) - Model that this package is a part of. Package is automatically added to model when it is initialized.
- **loading_package** (*bool*) - Do not set this parameter. It is intended for debugging and internal processing purposes only.
- **fixed_cell** (*boolean*) -
  - fixed_cell (boolean) indicates that recharge will not be reassigned to a cell underlying the cell specified in the list if the specified cell is inactive.
- **auxiliary** (*[string]*) -
  - auxiliary (string) defines an array of one or more auxiliary variable names. There is no limit on the number of auxiliary variables that can be provided on this line; however, lists of information provided in subsequent blocks must have a column of data for each auxiliary variable name defined here. The number of auxiliary variables detected on this line determines the value for naux. Comments cannot be provided anywhere on this line as they will be interpreted as auxiliary variable names. Auxiliary variables may not be used by the package, but they will be available for use by other parts of the program. The program will terminate with an error if auxiliary variables are specified on more than one line in the options block.
- **auxmultname** (*string*) -
  - auxmultname (string) name of auxiliary variable to be used as multiplier of recharge.
- **boundnames** (*boolean*) -
  - boundnames (boolean) keyword to indicate that boundary names may be provided with the list of recharge cells.
- **print_input** (*boolean*) -
  - print_input (boolean) keyword to indicate that the list of recharge information will be written to the listing file immediately after it is read.

- **print_flows** (*boolean*) -
  - print_flows (boolean) keyword to indicate that the list of recharge flow rates will be printed to the listing file for every stress period time step in which "BUDGET PRINT" is specified in Output Control. If there is no Output Control option and "PRINT_FLOWS" is specified, then flow rates are printed for the last time step of each stress period.
- **save_flows** (*boolean*) -
  - save_flows (boolean) keyword to indicate that recharge flow terms will be written to the file specified with "BUDGET FILEOUT" in Output Control.
- **timeseries** (*{varname:data} or timeseries data*) -
  - Contains data for the ts package. Data can be stored in a dictionary containing data for the ts package with variable names as keys and package data as values. Data just for the timeseries variable is also acceptable. See ts package documentation for more information.
- **observations** (*{varname:data} or continuous data*) -
  - Contains data for the obs package. Data can be stored in a dictionary containing data for the obs package with variable names as keys and package data as values. Data just for the observations variable is also acceptable. See obs package documentation for more information.
- **maxbound** (*integer*) -
  - maxbound (integer) integer value specifying the maximum number of recharge cells cells that will be specified for use during any stress period.
- **stress_period_data** (*[cellid, recharge, aux, boundname]*) -
  - cellid ((integer, ...)) is the cell identifier, and depends on the type of grid that is used for the simulation. For a structured grid that uses the DIS input file, CELLID is the layer, row, and column. For a grid that uses the DISV input file, CELLID is the layer and CELL2D number. If the model uses the unstructured discretization (DISU) input file, CELLID is the node number for the cell. This argument is an index variable, which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.
  - recharge (double) is the recharge flux rate (LT^{-1}). This rate is multiplied inside the program by the surface area of the cell to calculate the volumetric recharge rate. If the Options block includes a TIMESERIESFILE entry (see the "Time-Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.

  - aux (double) represents the values of the auxiliary variables for each recharge. The values of auxiliary variables must be present for each recharge. The values must be specified in the order of the auxiliary variables specified in the OPTIONS block. If the package supports time series and the Options block includes a TIMESERIESFILE entry (see the "Time-Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
  - boundname (string) name of the recharge cell. BOUNDNAME is an ASCII character variable that can contain as many as 40 characters. If BOUNDNAME contains spaces in it, then the entire name must be enclosed within single quotes.
- **filename** (*String*) - File name for this package.
- **pname** (*String*) - Package name for this package.
- **parent_file** (MFPackage) - Parent package file that references this package. Only needed for utility packages (mfutl*). For example, mfutllaktab package must have a mfgwflak package parent_file.

auxiliary = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

dfn = [['header', 'multi-package', 'package-type stress-package'], ['block options', 'name fixed_cell', 'type keyword', 'shape', 'reader urword', 'optional true'], ['block options', 'name auxiliary', 'type string', 'shape (naux)', 'reader urword', 'optional true'], ['block options', 'name auxmultname', 'type string', 'shape', 'reader urword', 'optional true'], ['block options', 'name boundnames', 'type keyword', 'shape', 'reader urword', 'optional true'], ['block options', 'name print_input', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name print_flows', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name save_flows', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name ts_filerecord', 'type record ts6 filein ts6_filename', 'shape', 'reader urword', 'tagged true', 'optional true', 'construct_package ts', 'construct_data timeseries', 'parameter_name timeseries'], ['block options', 'name ts6', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name filein', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name ts6_filename', 'type string', 'preserve_case true', 'in_record true', 'reader urword', 'optional false', 'tagged false'], ['block options', 'name obs_filerecord', 'type record obs6 filein obs6_filename', 'shape', 'reader urword', 'tagged true', 'optional true', 'construct_package obs', 'construct_data continuous', 'parameter_name observations'], ['block options', 'name obs6', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name obs6_filename', 'type string', 'preserve_case true', 'in_record true', 'tagged false', 'reader urword', 'optional false'], ['block dimensions', 'name maxbound', 'type integer', 'reader urword', 'optional false'], ['block period', 'name iper', 'type integer', 'block_variable True', 'in_record true', 'tagged false', 'shape', 'valid', 'reader urword', 'optional false'], ['block period', 'name stress_period_data', 'type recarray cellid recharge aux boundname', 'shape (maxbound)', 'reader urword'], ['block period', 'name cellid', 'type integer', 'shape (ncelldim)', 'tagged false', 'in_record true', 'reader urword'], ['block period', 'name recharge', 'type double precision', 'shape', 'tagged false', 'in_record true', 'reader urword', 'time_series true'], ['block period', 'name aux', 'type double precision', 'in_record true', 'tagged false', 'shape (naux)', 'reader urword', 'optional true', 'time_series true'], ['block period', 'name boundname', 'type string', 'shape', 'tagged false', 'in_record true', 'reader urword', 'optional true']]

dfn_file_name = 'gwf-rch.dfn'

obs_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

package_abbr = 'gwfrch'

stress_period_data = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

ts_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

flopy.mf6.modflow.mfgwfrcha module

class ModflowGwfrcha(*model*, *loading_package=False*, *readasarrays=True*, *fixed_cell=None*, *auxiliary=None*, *auxmultname=None*, *print_input=None*, *print_flows=None*, *save_flows=None*, *timearrayseries=None*, *observations=None*, *irch=None*, *recharge=0.001*, *aux=None*, *filename=None*, *pname=None*, ***kwargs*)

Bases: *MFPackage*

ModflowGwfrcha defines a rcha package within a gwf6 model.

Parameters

- **model** (MFModel) - Model that this package is a part of. Package is automatically added to model when it is initialized.
- **loading_package** (*bool*) - Do not set this parameter. It is intended for debugging and internal processing purposes only.
- **readasarrays** (*boolean*) -
  - readasarrays (boolean) indicates that array-based input will be used for the Recharge Package. This keyword must be specified to use array-based input.
- **fixed_cell** (*boolean*) -
  - fixed_cell (boolean) indicates that recharge will not be reassigned to a cell underlying the cell specified in the list if the specified cell is inactive.
- **auxiliary** (*[string]*) -
  - auxiliary (string) defines an array of one or more auxiliary variable names. There is no limit on the number of auxiliary variables that can be provided on this line; however, lists of information provided in subsequent blocks must have a column of data for each auxiliary variable name defined here. The number of auxiliary variables detected on this line determines the value for naux. Comments cannot be provided anywhere on this line as they will be interpreted as auxiliary variable names. Auxiliary variables may not be used by the package, but they will be available for use by other parts of the program. The program will terminate with an error if auxiliary variables are specified on more than one line in the options block.
- **auxmultname** (*string*) -
  - auxmultname (string) name of auxiliary variable to be used as multiplier of recharge.
- **print_input** (*boolean*) -
  - print_input (boolean) keyword to indicate that the list of recharge information will be written to the listing file immediately after it is read.
- **print_flows** (*boolean*) -
  - print_flows (boolean) keyword to indicate that the list of recharge flow rates will be printed to the listing file for

every stress period time step in which “BUDGET PRINT” is specified in Output Control. If there is no Output Control option and “PRINT_FLOWS” is specified, then flow rates are printed for the last time step of each stress period.

- **save_flows** (*boolean*) -
  - save_flows (boolean) keyword to indicate that recharge flow terms will be written to the file specified with “BUDGET FILEOUT” in Output Control.
- **timearrayseries** (*{varname:data} or tas_array data*) -
  - Contains data for the tas package. Data can be stored in a dictionary containing data for the tas package with variable names as keys and package data as values. Data just for the timearrayseries variable is also acceptable. See tas package documentation for more information.
- **observations** (*{varname:data} or continuous data*) -
  - Contains data for the obs package. Data can be stored in a dictionary containing data for the obs package with variable names as keys and package data as values. Data just for the observations variable is also acceptable. See obs package documentation for more information.
- **irch** (*[integer]*) -
  - irch (integer) IRCH is the layer number that defines the layer in each vertical column where recharge is applied. If IRCH is omitted, recharge by default is applied to cells in layer 1. IRCH can only be used if READASARRAYS is specified in the OPTIONS block. If IRCH is specified, it must be specified as the first variable in the PERIOD block or MODFLOW will terminate with an error. This argument is an index variable, which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.
- **recharge** (*[double]*) -
  - recharge (double) is the recharge flux rate (LT^{-1}). This rate is multiplied inside the program by the surface area of the cell to calculate the volumetric recharge rate. The recharge array may be defined by a time-array series (see the “Using Time-Array Series in a Package” section).
- **aux** (*[double]*) -
  - aux (double) is an array of values for auxiliary variable aux(iaux), where iaux is a value from 1 to naux, and aux(iaux) must be listed as part of the auxiliary variables. A separate array can be specified for each auxiliary variable. If an array is not specified for an auxiliary variable, then a value of zero is assigned. If the value specified here for the auxiliary variable is the same as auxmultname, then the recharge array will be multiplied by this array.

- **filename** (*String*) - File name for this package.
- **pname** (*String*) - Package name for this package.
- **parent_file** (MFPackage) - Parent package file that references this package. Only needed for utility packages (mfutl*). For example, mfutllaktab package must have a mfgwflak package parent_file.

aux = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

auxiliary = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

dfn = [['header', 'multi-package', 'package-type stress-package'], ['block options', 'name readasarrays', 'type keyword', 'shape', 'reader urword', 'optional false', 'default_value True'], ['block options', 'name fixed_cell', 'type keyword', 'shape', 'reader urword', 'optional true'], ['block options', 'name auxiliary', 'type string', 'shape (naux)', 'reader urword', 'optional true'], ['block options', 'name auxmultname', 'type string', 'shape', 'reader urword', 'optional true'], ['block options', 'name print_input', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name print_flows', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name save_flows', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name tas_filerecord', 'type record tas6 filein tas6_filename', 'shape', 'reader urword', 'tagged true', 'optional true', 'construct_package tas', 'construct_data tas_array', 'parameter_name timearrayseries'], ['block options', 'name tas6', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name filein', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name tas6_filename', 'type string', 'preserve_case true', 'in_record true', 'reader urword', 'optional false', 'tagged false'], ['block options', 'name obs_filerecord', 'type record obs6 filein obs6_filename', 'shape', 'reader urword', 'tagged true', 'optional true', 'construct_package obs', 'construct_data continuous', 'parameter_name observations'], ['block options', 'name obs6', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name obs6_filename', 'type string', 'preserve_case true', 'in_record true', 'tagged false', 'reader urword', 'optional false'], ['block period', 'name iper', 'type integer', 'block_variable True', 'in_record true', 'tagged false', 'shape', 'valid', 'reader urword', 'optional false'], ['block period', 'name irch', 'type integer', 'shape (ncol*nrow; ncpl)', 'reader readarray', 'numeric_index true', 'optional true'], ['block period', 'name recharge', 'type double precision', 'shape (ncol*nrow; ncpl)', 'reader readarray', 'default_value 1.e-3'], ['block period', 'name aux', 'type double precision', 'shape (ncol*nrow; ncpl)', 'reader readarray', 'optional true']]

dfn_file_name = 'gwf-rcha.dfn'

irch = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

obs_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

package_abbr = 'gwfrcha'

recharge = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

tas_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

flopy.mf6.modflow.mfgwfriv module

class ModflowGwfriv(*model*, *loading_package=False*, *auxiliary=None*, *auxmultname=None*, *boundnames=None*, *print_input=None*, *print_flows=None*, *save_flows=None*, *timeseries=None*, *observations=None*, *mover=None*, *maxbound=None*, *stress_period_data=None*, *filename=None*, *pname=None*, ***kwargs*)

Bases: *MFPackage*

ModflowGwfriv defines a riv package within a gwf6 model.

Parameters

- **model** (MFModel) - Model that this package is a part of. Package is automatically added to model when it is initialized.
- **loading_package** (*bool*) - Do not set this parameter. It is intended for debugging and internal processing purposes only.
- **auxiliary** (*[string]*) -
  - auxiliary (string) defines an array of one or more auxiliary variable names. There is no limit on the number of auxiliary variables that can be provided on this line; however, lists of information provided in subsequent blocks must have a column of data for each auxiliary variable name defined here. The number of auxiliary variables detected on this line determines the value for naux. Comments cannot be provided anywhere on this line as they will be interpreted as auxiliary variable names. Auxiliary variables may not be used by the package, but they will be available for use by other parts of the program. The program will terminate with an error if auxiliary variables are specified on more than one line in the options block.
- **auxmultname** (*string*) -
  - auxmultname (string) name of auxiliary variable to be used as multiplier of riverbed conductance.
- **boundnames** (*boolean*) -
  - boundnames (boolean) keyword to indicate that boundary names may be provided with the list of river cells.
- **print_input** (*boolean*) -
  - print_input (boolean) keyword to indicate that the list of river information will be written to the listing file immediately after it is read.
- **print_flows** (*boolean*) -
  - print_flows (boolean) keyword to indicate that the list of river flow rates will be printed to the listing file for every stress period time step in which "BUDGET PRINT" is specified in Output Control. If there is no Output Control option and "PRINT_FLOWS" is specified, then flow rates are printed for the last time step of each stress period.
- **save_flows** (*boolean*) -

  - save_flows (boolean) keyword to indicate that river flow terms will be written to the file specified with "BUDGET FILEOUT" in Output Control.

- **timeseries** (*{varname:data} or timeseries data*) -
  - Contains data for the ts package. Data can be stored in a dictionary containing data for the ts package with variable names as keys and package data as values. Data just for the timeseries variable is also acceptable. See ts package documentation for more information.
- **observations** (*{varname:data} or continuous data*) -
  - Contains data for the obs package. Data can be stored in a dictionary containing data for the obs package with variable names as keys and package data as values. Data just for the observations variable is also acceptable. See obs package documentation for more information.
- **mover** (*boolean*) -
  - mover (boolean) keyword to indicate that this instance of the River Package can be used with the Water Mover (MVR) Package. When the MOVER option is specified, additional memory is allocated within the package to store the available, provided, and received water.
- **maxbound** (*integer*) -
  - maxbound (integer) integer value specifying the maximum number of rivers cells that will be specified for use during any stress period.
- **stress_period_data** (*[cellid, stage, cond, rbot, aux, boundname]*) -
  - cellid ((integer, ...)) is the cell identifier, and depends on the type of grid that is used for the simulation. For a structured grid that uses the DIS input file, CELLID is the layer, row, and column. For a grid that uses the DISV input file, CELLID is the layer and CELL2D number. If the model uses the unstructured discretization (DISU) input file, CELLID is the node number for the cell. This argument is an index variable, which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.
  - stage (double) is the head in the river. If the Options block includes a TIMESERIESFILE entry (see the "Time-Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
  - cond (double) is the riverbed hydraulic conductance. If the Options block includes a TIMESERIESFILE entry (see the "Time-Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.

    - rbot (double) is the elevation of the bottom of the riverbed. If the Options block includes a TIMESERIESFILE entry (see the "Time-Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
    - aux (double) represents the values of the auxiliary variables for each river. The values of auxiliary variables must be present for each river. The values must be specified in the order of the auxiliary variables specified in the OPTIONS block. If the package supports time series and the Options block includes a TIMESERIESFILE entry (see the "Time-Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
    - boundname (string) name of the river cell. BOUNDNAME is an ASCII character variable that can contain as many as 40 characters. If BOUNDNAME contains spaces in it, then the entire name must be enclosed within single quotes.
- **filename** (*String*) - File name for this package.
- **pname** (*String*) - Package name for this package.
- **parent_file** (MFPackage) - Parent package file that references this package. Only needed for utility packages (mfutl*). For example, mfutllaktab package must have a mfgwflak package parent_file.

auxiliary = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

dfn = [['header', 'multi-package', 'package-type stress-package'], ['block options', 'name auxiliary', 'type string', 'shape (naux)', 'reader urword', 'optional true'], ['block options', 'name auxmultname', 'type string', 'shape', 'reader urword', 'optional true'], ['block options', 'name boundnames', 'type keyword', 'shape', 'reader urword', 'optional true'], ['block options', 'name print_input', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name print_flows', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name save_flows', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name ts_filerecord', 'type record ts6 filein ts6_filename', 'shape', 'reader urword', 'tagged true', 'optional true', 'construct_package ts', 'construct_data timeseries', 'parameter_name timeseries'], ['block options', 'name ts6', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name filein', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name ts6_filename', 'type string', 'preserve_case true', 'in_record true', 'reader urword', 'optional false', 'tagged false'], ['block options', 'name obs_filerecord', 'type record obs6 filein obs6_filename', 'shape', 'reader urword', 'tagged true', 'optional true', 'construct_package obs', 'construct_data continuous', 'parameter_name observations'], ['block options', 'name obs6', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name obs6_filename', 'type string', 'preserve_case true', 'in_record true', 'tagged false', 'reader urword', 'optional false'], ['block options', 'name mover', 'type keyword', 'tagged true', 'reader urword', 'optional true'], ['block dimensions', 'name maxbound', 'type integer', 'reader urword', 'optional false'], ['block period', 'name iper', 'type integer', 'block_variable True', 'in_record true', 'tagged false', 'shape', 'valid', 'reader urword', 'optional false'], ['block period', 'name stress_period_data', 'type recarray cellid stage cond rbot aux boundname', 'shape (maxbound)', 'reader urword'], ['block period', 'name cellid', 'type integer', 'shape (ncelldim)', 'tagged false', 'in_record true', 'reader urword'], ['block period', 'name stage', 'type double precision', 'shape', 'tagged false', 'in_record true', 'reader urword', 'time_series true'], ['block period', 'name cond', 'type double precision', 'shape', 'tagged false', 'in_record true', 'reader urword', 'time_series true'], ['block period', 'name rbot', 'type double precision', 'shape', 'tagged false', 'in_record true', 'reader urword', 'time_series true'], ['block period', 'name aux', 'type double precision', 'in_record true', 'tagged false', 'shape (naux)', 'reader urword', 'optional true', 'time_series true'], ['block period', 'name boundname', 'type string', 'shape', 'tagged false', 'in_record true', 'reader urword', 'optional true']]

dfn_file_name = 'gwf-riv.dfn'

obs_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

package_abbr = 'gwfriv'

stress_period_data = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

ts_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

flopy.mf6.modflow.mfgwfsfr module

class ModflowGwfsfr(*model*, *loading_package=False*, *auxiliary=None*, *boundnames=None*, *print_input=None*, *print_stage=None*, *print_flows=None*, *save_flows=None*, *stage_filerecord=None*, *budget_filerecord=None*, *budgetcsv_filerecord=None*, *package_convergence_filerecord=None*, *timeseries=None*, *observations=None*, *mover=None*, *maximum_picard_iterations=None*, *maximum_iterations=None*, *maximum_depth_change=None*, *unit_conversion=None*, *length_conversion=None*, *time_conversion=None*, *nreaches=None*, *packagedata=None*, *crosssections=None*, *connectiondata=None*, *diversions=None*, *perioddata=None*, *filename=None*, *pname=None*, ***kwargs*)

Bases: *MFPackage*

ModflowGwfsfr defines a sfr package within a gwf6 model.

Parameters

- **model** (MFModel) - Model that this package is a part of. Package is automatically added to model when it is initialized.
- **loading_package** (*bool*) - Do not set this parameter. It is intended for debugging and internal processing purposes only.
- **auxiliary** (*[string]*) -
  - auxiliary (string) defines an array of one or more auxiliary variable names. There is no limit on the number of auxiliary variables that can be provided on this line; however, lists of information provided in subsequent blocks must have a column of data for each auxiliary variable name defined here. The number of auxiliary variables detected on this line determines the value for naux. Comments cannot be provided anywhere on this line as they will be interpreted as auxiliary variable names. Auxiliary variables may not be used by the package, but they will be available for use by other parts of the program. The program will terminate with an error if auxiliary variables are specified on more than one line in the options block.
- **boundnames** (*boolean*) -
  - boundnames (boolean) keyword to indicate that boundary names may be provided with the list of stream reach cells.
- **print_input** (*boolean*) -
  - print_input (boolean) keyword to indicate that the list of stream reach information will be written to the listing file immediately after it is read.
- **print_stage** (*boolean*) -
  - print_stage (boolean) keyword to indicate that the list of stream reach stages will be printed to the listing file for every stress period in which "HEAD PRINT" is specified in Output Control. If there is no Output Control option and PRINT_STAGE is specified, then stages are printed for the last time step of each stress period.

- **print_flows** (*boolean*) -
  - print_flows (boolean) keyword to indicate that the list of stream reach flow rates will be printed to the listing file for every stress period time step in which "BUDGET PRINT" is specified in Output Control. If there is no Output Control option and "PRINT_FLOWS" is specified, then flow rates are printed for the last time step of each stress period.
- **save_flows** (*boolean*) -
  - save_flows (boolean) keyword to indicate that stream reach flow terms will be written to the file specified with "BUDGET FILEOUT" in Output Control.
- **stage_filerecord** (*[stagefile]*) -
  - stagefile (string) name of the binary output file to write stage information.
- **budget_filerecord** (*[budgetfile]*) -
  - budgetfile (string) name of the binary output file to write budget information.
- **budgetcsv_filerecord** (*[budgetcsvfile]*) -
  - budgetcsvfile (string) name of the comma-separated value (CSV) output file to write budget summary information. A budget summary record will be written to this file for each time step of the simulation.
- **package_convergence_filerecord** (*[package_convergence_filename]*) -
  - package_convergence_filename (string) name of the comma spaced values output file to write package convergence information.
- **timeseries** (*{varname:data} or timeseries data*) -
  - Contains data for the ts package. Data can be stored in a dictionary containing data for the ts package with variable names as keys and package data as values. Data just for the timeseries variable is also acceptable. See ts package documentation for more information.
- **observations** (*{varname:data} or continuous data*) -
  - Contains data for the obs package. Data can be stored in a dictionary containing data for the obs package with variable names as keys and package data as values. Data just for the observations variable is also acceptable. See obs package documentation for more information.
- **mover** (*boolean*) -
  - mover (boolean) keyword to indicate that this instance of the SFR Package can be used with the Water Mover (MVR) Package. When the MOVER option is specified, additional memory is allocated within the package to store the available, provided, and received water.
- **maximum_picard_iterations** (*integer*) -

  - maximum_picard_iterations (integer) integer value that defines the maximum number of Streamflow Routing picard iterations allowed when solving for reach stages and flows as part of the GWF formulate step. Picard iterations are used to minimize differences in SFR package results between subsequent GWF picard (non-linear) iterations as a result of non-optimal reach numbering. If reaches are numbered in order, from upstream to downstream, MAXIMUM_PICARD_ITERATIONS can be set to 1 to reduce model run time. By default, MAXIMUM_PICARD_ITERATIONS is equal to 100.

- **maximum_iterations** (*integer*) -
  - maximum_iterations (integer) integer value that defines the maximum number of Streamflow Routing Newton-Raphson iterations allowed for a reach. By default, MAXIMUM_ITERATIONS is equal to 100. MAXIMUM_ITERATIONS would only need to be increased from the default value if one or more reach in a simulation has a large water budget error.
- **maximum_depth_change** (*double*) -
  - maximum_depth_change (double) real value that defines the depth closure tolerance. By default, MAXIMUM_DEPTH_CHANGE is equal to 1×10^{-5}. The MAXIMUM_STAGE_CHANGE would only need to be increased or decreased from the default value if the water budget error for one or more reach is too small or too large, respectively.
- **unit_conversion** (*double*) -
  - unit_conversion (double) real value that is used to convert user- specified Manning's roughness coefficients from seconds per meters:math:^*{1/3}* to model length and time units. A constant of 1.486 is used for flow units of cubic feet per second, and a constant of 1.0 is used for units of cubic meters per second. The constant must be multiplied by 86,400 when using time units of days in the simulation.
- **length_conversion** (*double*) -
  - length_conversion (double) real value that is used to convert user- specified Manning's roughness coefficients from meters to model length units. LENGTH_CONVERSION should be set to 3.28081, 1.0, and 100.0 when using length units (LENGTH_UNITS) of feet, meters, or centimeters in the simulation, respectively. LENGTH_CONVERSION does not need to be specified if LENGTH_UNITS are meters.
- **time_conversion** (*double*) -
  - time_conversion (double) real value that is used to convert user- specified Manning's roughness coefficients from seconds to model time units. TIME_CONVERSION should be set to 1.0, 60.0, 3,600.0, 86,400.0, and 31,557,600.0 when using time units (TIME_UNITS) of seconds, minutes, hours, days, or years in the simulation, respectively. TIME_CONVERSION does not need to be specified if TIME_UNITS are seconds.

- **nreaches** (*integer*) -
  - nreaches (integer) integer value specifying the number of stream reaches. There must be NREACHES entries in the PACKAGEDATA block.
- **packagedata** (*[ifno, cellid, rlen, rwid, rgrd, rtp, rbth, rhk, man, ncon,)* -

  ustrf, ndv, aux, boundname]

  - ifno (integer) integer value that defines the feature (reach) number associated with the specified PACKAGEDATA data on the line. IFNO must be greater than zero and less than or equal to NREACHES. Reach information must be specified for every reach or the program will terminate with an error. The program will also terminate with an error if information for a reach is specified more than once. This argument is an index variable, which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.
  - cellid ((integer, ...)) is the cell identifier, and depends on the type of grid that is used for the simulation. For a structured grid that uses the DIS input file, CELLID is the layer, row, and column. For a grid that uses the DISV input file, CELLID is the layer and CELL2D number. If the model uses the unstructured discretization (DISU) input file, CELLID is the node number for the cell. For reaches that are not connected to an underlying GWF cell, a zero should be specified for each grid dimension. For example, for a DIS grid a CELLID of 0 0 0 should be specified. Reach-aquifer flow is not calculated for unconnected reaches. The keyword NONE can be still be specified to identify unconnected reaches for backward compatibility with previous versions of MODFLOW 6 but eventually NONE will be deprecated and will cause MODFLOW 6 to terminate with an error. This argument is an index variable, which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.
  - rlen (double) real value that defines the reach length. RLEN must be greater than zero.
  - rwid (double) real value that defines the reach width. RWID must be greater than zero.
  - rgrd (double) real value that defines the stream gradient (slope) across the reach. RGRD must be greater than zero.
  - rtp (double) real value that defines the bottom elevation of the reach.
  - rbth (double) real value that defines the thickness of the reach streambed. RBTH can be any value if the reach is not

connected to an underlying GWF cell. Otherwise, RBTH must be greater than zero.

  - rhk (double) real value that defines the hydraulic conductivity of the reach streambed. RHK can be any positive value if the reach is not connected to an underlying GWF cell. Otherwise, RHK must be greater than zero.
  - man (string) real or character value that defines the Manning's roughness coefficient for the reach. MAN must be greater than zero. If the Options block includes a TIMESERIESFILE entry (see the "Time- Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
  - ncon (integer) integer value that defines the number of reaches connected to the reach. If a value of zero is specified for NCON an entry for IFNO is still required in the subsequent CONNECTIONDATA block.
  - ustrf (double) real value that defines the fraction of upstream flow from each upstream reach that is applied as upstream inflow to the reach. The sum of all USTRF values for all reaches connected to the same upstream reach must be equal to one and USTRF must be greater than or equal to zero. If the Options block includes a TIMESERIESFILE entry (see the "Time-Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
  - ndv (integer) integer value that defines the number of downstream diversions for the reach.
  - aux (double) represents the values of the auxiliary variables for each stream reach. The values of auxiliary variables must be present for each stream reach. The values must be specified in the order of the auxiliary variables specified in the OPTIONS block. If the package supports time series and the Options block includes a TIMESERIESFILE entry (see the "Time-Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
  - boundname (string) name of the stream reach cell. BOUNDNAME is an ASCII character variable that can contain as many as 40 characters. If BOUNDNAME contains spaces in it, then the entire name must be enclosed within single quotes.

- **crosssections** (*[ifno, tab6_filename]*) -
  - ifno (integer) integer value that defines the feature (reach) number associated with the specified cross-section table file on the line. IFNO must be greater than zero and less than or equal to NREACHES. The program will also terminate with an error if table information for a reach is specified more than once. This argument is an index variable, which means that

it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.

– tab6_filename (string) character string that defines the path and filename for the file containing cross-section table data for the reach. The TAB6_FILENAME file includes the number of entries in the file and the station elevation data in terms of the fractional width and the reach depth. Instructions for creating the TAB6_FILENAME input file are provided in SFR Reach Cross-Section Table Input File section.

- **connectiondata** (*[ifno, ic]*) -
  – ifno (integer) integer value that defines the feature (reach) number associated with the specified CONNECTIONDATA data on the line. IFNO must be greater than zero and less than or equal to NREACHES. Reach connection information must be specified for every reach or the program will terminate with an error. The program will also terminate with an error if connection information for a reach is specified more than once. This argument is an index variable, which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.
  – ic (double_precision) integer value that defines the reach number of the reach connected to the current reach and whether it is connected to the upstream or downstream end of the reach. Negative IC numbers indicate connected reaches are connected to the downstream end of the current reach. Positive IC numbers indicate connected reaches are connected to the upstream end of the current reach. The absolute value of IC must be greater than zero and less than or equal to NREACHES. IC should not be specified when NCON is zero but must be specified otherwise. This argument is an index variable, which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.
- **diversions** (*[ifno, idv, iconr, cprior]*) -
  – ifno (integer) integer value that defines the feature (reach) number associated with the specified DIVERSIONS data on the line. IFNO must be greater than zero and less than or equal to NREACHES. Reach diversion information must be specified for every reach with a NDV value greater than 0 or the program will terminate with an error. The program will also terminate with an error if diversion information for a given reach diversion is specified more than once. This argument is an index variable, which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.
  – idv (integer) integer value that defines the downstream

diversion number for the diversion for reach IFNO. IDV must be greater than zero and less than or equal to NDV for reach IFNO. This argument is an index variable, which means that it should be treated as zero- based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.

- iconr (integer) integer value that defines the downstream reach that will receive the diverted water. IDV must be greater than zero and less than or equal to NREACHES. Furthermore, reach ICONR must be a downstream connection for reach IFNO. This argument is an index variable, which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.
- cprior (string) character string value that defines the the prioritization system for the diversion, such as when insufficient water is available to meet all diversion stipulations, and is used in conjunction with the value of FLOW value specified in the STRESS_PERIOD_DATA section. Available diversion options include: (1) CPRIOR = 'FRACTION', then the amount of the diversion is computed as a fraction of the streamflow leaving reach IFNO (Q_{DS}); in this case, 0.0 $\leq$ DIVFLOW $\leq$ 1.0. (2) CPRIOR = 'EXCESS', a diversion is made only if Q_{DS} for reach IFNO exceeds the value of DIVFLOW. If this occurs, then the quantity of water diverted is the excess flow ($Q_{DS}-$ DIVFLOW) and Q_{DS} from reach IFNO is set equal to DIVFLOW. This represents a flood-control type of diversion, as described by Danskin and Hanson (2002). (3) CPRIOR = 'THRESHOLD', then if Q_{DS} in reach IFNO is less than the specified diversion flow DIVFLOW, no water is diverted from reach IFNO. If Q_{DS} in reach IFNO is greater than or equal to DIVFLOW, DIVFLOW is diverted and Q_{DS} is set to the remainder ($Q_{DS}-$ DIVFLOW)). This approach assumes that once flow in the stream is sufficiently low, diversions from the stream cease, and is the 'priority' algorithm that originally was programmed into the STR1 Package (Prudic, 1989). (4) CPRIOR = 'UPTO' - if Q_{DS} in reach IFNO is greater than or equal to the specified diversion flow DIVFLOW, Q_{DS} is reduced by DIVFLOW. If Q_{DS} in reach IFNO is less than DIVFLOW, DIVFLOW is set to Q_{DS} and there will be no flow available for reaches connected to downstream end of reach IFNO.

- **perioddata** (*[ifno, sfrsetting]*) -
  - ifno (integer) integer value that defines the feature (reach) number associated with the specified PERIOD data on the line. IFNO must be greater than zero and less than or equal to NREACHES. This argument is an index variable, which means that it should be treated as zero- based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.

– sfrsetting (keystring) line of information that is parsed into a keyword and values. Keyword values that can be used to start the SFRSETTING string include: STATUS, MANNING, STAGE, INFLOW, RAINFALL, EVAPORATION, RUNOFF, DIVERSION, UPSTREAM_FRACTION, and AUXILIARY.

status
[[string]]

* status (string) keyword option to define stream reach status. STATUS can be ACTIVE, INACTIVE, or SIMPLE. The SIMPLE STATUS option simulates streamflow using a user-specified stage for a reach or a stage set to the top of the reach (depth = 0). In cases where the simulated leakage calculated using the specified stage exceeds the sum of inflows to the reach, the stage is set to the top of the reach and leakage is set equal to the sum of inflows. Upstream fractions should be changed using the UPSTREAM_FRACTION SFRSETTING if the status for one or more reaches is changed to ACTIVE or INACTIVE. For example, if one of two downstream connections for a reach is inactivated, the upstream fraction for the active and inactive downstream reach should be changed to 1.0 and 0.0, respectively, to ensure that the active reach receives all of the downstream outflow from the upstream reach. By default, STATUS is ACTIVE.

manning
[[string]]

* manning (string) real or character value that defines the Manning's roughness coefficient for the reach. MANNING must be greater than zero. If the Options block includes a TIMESERIESFILE entry (see the "Time-Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.

stage
[[string]]

* stage (string) real or character value that defines the stage for the reach. The specified STAGE is only applied if the reach uses the simple routing option. If STAGE is not specified for reaches that use the simple routing option, the specified stage is set to the top of the reach. If the Options block includes a TIMESERIESFILE entry (see the "Time- Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.

inflow
[[string]]

* inflow (string) real or character value that defines

the volumetric inflow rate for the streamflow routing reach. If the Options block includes a TIMESERIESFILE entry (see the "Time-Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value. By default, inflow rates are zero for each reach.

rainfall

[[string]]

* rainfall (string) real or character value that defines the volumetric rate per unit area of water added by precipitation directly on the streamflow routing reach. If the Options block includes a TIMESERIESFILE entry (see the "Time-Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value. By default, rainfall rates are zero for each reach.

evaporation

[[string]]

* evaporation (string) real or character value that defines the volumetric rate per unit area of water subtracted by evaporation from the streamflow routing reach. A positive evaporation rate should be provided. If the Options block includes a TIMESERIESFILE entry (see the "Time-Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value. If the volumetric evaporation rate for a reach exceeds the sources of water to the reach (upstream and specified inflows, rainfall, and runoff but excluding groundwater leakage into the reach) the volumetric evaporation rate is limited to the sources of water to the reach. By default, evaporation rates are zero for each reach.

runoff

[[string]]

* runoff (string) real or character value that defines the volumetric rate of diffuse overland runoff that enters the streamflow routing reach. If the Options block includes a TIMESERIESFILE entry (see the "Time-Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value. If the volumetric runoff rate for a reach is negative and exceeds inflows to the reach (upstream and specified inflows, and rainfall but excluding groundwater leakage into the reach) the volumetric runoff rate is limited to inflows to the reach and the volumetric evaporation rate for the reach is set to zero. By default, runoff rates are zero for each

reach.

diversionrecord
[[idv, divflow]]

* idv (integer) an integer value specifying which diversion of reach IFNO that DIVFLOW is being specified for. Must be less or equal to ndv for the current reach (IFNO). This argument is an index variable, which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.
* divflow (double) real or character value that defines the volumetric diversion (DIVFLOW) rate for the streamflow routing reach. If the Options block includes a TIMESERIESFILE entry (see the "Time-Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.

upstream_fraction
[[double]]

* upstream_fraction (double) real value that defines the fraction of upstream flow (USTRF) from each upstream reach that is applied as upstream inflow to the reach. The sum of all USTRF values for all reaches connected to the same upstream reach must be equal to one.

cross_sectionrecord
[[tab6_filename]]

* tab6_filename (string) character string that defines the path and filename for the file containing cross-section table data for the reach. The TAB6_FILENAME file includes the number of entries in the file and the station elevation data in terms of the fractional width and the reach depth. Instructions for creating the TAB6_FILENAME input file are provided in SFR Reach Cross-Section Table Input File section.

auxiliaryrecord
[[auxname, auxval]]

* auxname (string) name for the auxiliary variable to be assigned AUXVAL. AUXNAME must match one of the auxiliary variable names defined in the OPTIONS block. If AUXNAME does not match one of the auxiliary variable names defined in the OPTIONS block the data are ignored.
* auxval (double) value for the auxiliary variable. If the Options block includes a TIMESERIESFILE entry (see the "Time- Variable Input" section), values

can be obtained from a time series by entering the time-series name in place of a numeric value.

- **filename** (*String*) - File name for this package.
- **pname** (*String*) - Package name for this package.
- **parent_file** (MFPackage) - Parent package file that references this package. Only needed for utility packages (mfutl*). For example, mfutllaktab package must have a mfgwflak package parent_file.

auxiliary = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

budget_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

budgetcsv_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

connectiondata = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

crosssections = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

dfn = [['header', 'multi-package', 'package-type advanced-stress-package'], ['block options', 'name auxiliary', 'type string', 'shape (naux)', 'reader urword', 'optional true'], ['block options', 'name boundnames', 'type keyword', 'shape', 'reader urword', 'optional true'], ['block options', 'name print_input', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name print_stage', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name print_flows', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name save_flows', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name stage_filerecord', 'type record stage fileout stagefile', 'shape', 'reader urword', 'tagged true', 'optional true'], ['block options', 'name stage', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name stagefile', 'type string', 'preserve_case true', 'shape', 'in_record true', 'reader urword', 'tagged false', 'optional false'], ['block options', 'name budget_filerecord', 'type record budget fileout budgetfile', 'shape', 'reader urword', 'tagged true', 'optional true'], ['block options', 'name budget', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name fileout', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name budgetfile', 'type string', 'preserve_case true', 'shape', 'in_record true', 'reader urword', 'tagged false', 'optional false'], ['block options', 'name budgetcsv_filerecord', 'type record budgetcsv fileout budgetcsvfile', 'shape', 'reader urword', 'tagged true', 'optional true'], ['block options', 'name budgetcsv', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name budgetcsvfile', 'type string', 'preserve_case true', 'shape', 'in_record true', 'reader urword', 'tagged false', 'optional false'], ['block options', 'name package_convergence_filerecord', 'type record package_convergence fileout package_convergence_filename', 'shape', 'reader urword', 'tagged true', 'optional true'], ['block options', 'name package_convergence', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name package_convergence_filename', 'type string', 'shape', 'in_record true', 'reader urword', 'tagged false', 'optional false'], ['block options', 'name ts_filerecord', 'type record ts6 filein ts6_filename', 'shape', 'reader urword', 'tagged true', 'optional true', 'construct_package ts', 'construct_data timeseries', 'parameter_name timeseries'], ['block options', 'name ts6', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name filein', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name ts6_filename', 'type string', 'preserve_case true', 'in_record true', 'reader urword', 'optional false', 'tagged false'], ['block options', 'name obs_filerecord', 'type record obs6 filein obs6_filename', 'shape', 'reader urword', 'tagged true', 'optional true', 'construct_package obs', 'construct_data continuous', 'parameter_name observations'], ['block options', 'name obs6', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name obs6_filename', 'type string', 'preserve_case true', 'in_record true', 'tagged false', 'reader urword', 'optional false'], ['block options', 'name mover', 'type keyword', 'tagged true', 'reader urword', 'optional true'], ['block options', 'name maximum_picard_iterations', 'type integer', 'reader urword', 'optional true'], ['block options', 'name maximum_iterations', 'type integer', 'reader urword', 'optional true'], ['block options', 'name maximum_depth_change', 'type double precision', 'reader urword', 'optional true'], ['block options', 'name unit_conversion', 'type double precision', 'reader urword', 'optional true', 'deprecated 6.4.2'], ['block options', 'name length_conversion', 'type double precision', 'reader urword', 'optional true'], ['block options', 'name time_conversion', 'type double precision', 'reader urword', 'optional true'], ['block dimensions', 'name nreaches', 'type integer', 'reader urword', 'optional false'], ['block packagedata', 'name packagedata', 'type recarray ifno cellid rlen rwid rgrd rtp rbth rhk man ncon ustrf ndv aux boundname', 'shape (maxbound)', 'reader urword'], ['block packagedata', 'name ifno', 'type integer', 'shape', 'tagged false', 'in_record true', 'reader urword', 'numeric_index true'], ['block

dfn_file_name = 'gwf-sfr.dfn'

diversions = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

obs_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

package_abbr = 'gwfsfr'

package_convergence_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

packagedata = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

perioddata = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

stage_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

ts_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

flopy.mf6.modflow.mfgwfsto module

class **ModflowGwfsto**(*model*, *loading_package=False*, *save_flows=None*, *storagecoefficient=None*, *ss_confined_only=None*, *perioddata=None*, *iconvert=0*, *ss=1e-05*, *sy=0.15*, *steady_state=None*, *transient=None*, *filename=None*, *pname=None*, ***kwargs*)

Bases: *MFPackage*

ModflowGwfsto defines a sto package within a gwf6 model.

Parameters

- **model** (MFModel) – Model that this package is a part of. Package is automatically added to model when it is initialized.
- **loading_package** (*bool*) – Do not set this parameter. It is intended for debugging and internal processing purposes only.
- **save_flows** (*boolean*) –
  - save_flows (boolean) keyword to indicate that cell-by-cell flow terms will be written to the file specified with "BUDGET SAVE FILE" in Output Control.
- **storagecoefficient** (*boolean*) –
  - storagecoefficient (boolean) keyword to indicate that the SS array is read as storage coefficient rather than specific storage.
- **ss_confined_only** (*boolean*) –
  - ss_confined_only (boolean) keyword to indicate that compressible storage is only calculated for a convertible cell (ICONVERT>0) when the cell is under confined conditions (head greater than or equal to the top of the cell). This option has no effect on cells that are marked as being always confined (ICONVERT=0). This option is identical to the approach used to calculate storage changes under confined conditions in MODFLOW-2005.

- **perioddata** (*{varname:data} or tvs_perioddata data*) -
  - Contains data for the tvs package. Data can be stored in a dictionary containing data for the tvs package with variable names as keys and package data as values. Data just for the perioddata variable is also acceptable. See tvs package documentation for more information.
- **iconvert** (*[integer]*) -
  - iconvert (integer) is a flag for each cell that specifies whether or not a cell is convertible for the storage calculation. 0 indicates confined storage is used. >0 indicates confined storage is used when head is above cell top and a mixed formulation of unconfined and confined storage is used when head is below cell top.
- **ss** (*[double]*) -
  - ss (double) is specific storage (or the storage coefficient if STORAGECOEFFICIENT is specified as an option). Specific storage values must be greater than or equal to 0. If the CSUB Package is included in the GWF model, specific storage must be zero for every cell.
- **sy** (*[double]*) -
  - sy (double) is specific yield. Specific yield values must be greater than or equal to 0. Specific yield does not have to be specified if there are no convertible cells (ICONVERT=0 in every cell).
- **steady_state** (*boolean*) -
  - steady-state (boolean) keyword to indicate that stress period IPER is steady-state. Steady-state conditions will apply until the TRANSIENT keyword is specified in a subsequent BEGIN PERIOD block. If the CSUB Package is included in the GWF model, only the first and last stress period can be steady-state.
- **transient** (*boolean*) -
  - transient (boolean) keyword to indicate that stress period IPER is transient. Transient conditions will apply until the STEADY-STATE keyword is specified in a subsequent BEGIN PERIOD block.
- **filename** (*String*) - File name for this package.
- **pname** (*String*) - Package name for this package.
- **parent_file** (MFPackage) - Parent package file that references this package. Only needed for utility packages (mfutl*). For example, mfutllaktab package must have a mfgwflak package parent_file.

dfn = [['header'], ['block options', 'name save_flows', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name storagecoefficient', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name ss_confined_only', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name tvs_filerecord', 'type record tvs6 filein tvs_filename', 'shape', 'reader urword', 'tagged true', 'optional true', 'construct_package tvs', 'construct_data tvs_perioddata', 'parameter_name perioddata'], ['block options', 'name tvs6', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name filein', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name tvs_filename', 'type string', 'preserve_case true', 'in_record true', 'reader urword', 'optional false', 'tagged false'], ['block griddata', 'name iconvert', 'type integer', 'shape (nodes)', 'valid', 'reader readarray', 'layered true', 'optional false', 'default_value 0'], ['block griddata', 'name ss', 'type double precision', 'shape (nodes)', 'valid', 'reader readarray', 'layered true', 'optional false', 'default_value 1.e-5'], ['block griddata', 'name sy', 'type double precision', 'shape (nodes)', 'valid', 'reader readarray', 'layered true', 'optional false', 'default_value 0.15'], ['block period', 'name iper', 'type integer', 'block_variable True', 'in_record true', 'tagged false', 'shape', 'valid', 'reader urword', 'optional false'], ['block period', 'name steady-state', 'type keyword', 'shape', 'valid', 'reader urword', 'optional true'], ['block period', 'name transient', 'type keyword', 'shape', 'valid', 'reader urword', 'optional true']]

dfn_file_name = 'gwf-sto.dfn'

iconvert = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

package_abbr = 'gwfsto'

ss = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

sy = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

tvs_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

flopy.mf6.modflow.mfgwfuzf module

class ModflowGwfuzf(*model*, *loading_package=False*, *auxiliary=None*, *auxmultname=None*, *boundnames=None*, *print_input=None*, *print_flows=None*, *save_flows=None*, *wc_filerecord=None*, *budget_filerecord=None*, *budgetcsv_filerecord=None*, *package_convergence_filerecord=None*, *timeseries=None*, *observations=None*, *mover=None*, *simulate_et=None*, *linear_gwet=None*, *square_gwet=None*, *simulate_gwseep=None*, *unsat_etwc=None*, *unsat_etae=None*, *nuzfcells=None*, *ntrailwaves=7*, *nwavesets=40*, *packagedata=None*, *perioddata=None*, *filename=None*, *pname=None*, ***kwargs*)

Bases: *MFPackage*

ModflowGwfuzf defines a uzf package within a gwf6 model.

Parameters

- **model** (MFModel) – Model that this package is a part of. Package is automatically added to model when it is initialized.
- **loading_package** (*bool*) – Do not set this parameter. It is intended for debugging and internal processing purposes only.

- **auxiliary** (*[string]*) -
  - auxiliary (string) defines an array of one or more auxiliary variable names. There is no limit on the number of auxiliary variables that can be provided on this line; however, lists of information provided in subsequent blocks must have a column of data for each auxiliary variable name defined here. The number of auxiliary variables detected on this line determines the value for naux. Comments cannot be provided anywhere on this line as they will be interpreted as auxiliary variable names. Auxiliary variables may not be used by the package, but they will be available for use by other parts of the program. The program will terminate with an error if auxiliary variables are specified on more than one line in the options block.
- **auxmultname** (*string*) -
  - auxmultname (string) name of auxiliary variable to be used as multiplier of GWF cell area used by UZF cell.
- **boundnames** (*boolean*) -
  - boundnames (boolean) keyword to indicate that boundary names may be provided with the list of UZF cells.
- **print_input** (*boolean*) -
  - print_input (boolean) keyword to indicate that the list of UZF information will be written to the listing file immediately after it is read.
- **print_flows** (*boolean*) -
  - print_flows (boolean) keyword to indicate that the list of UZF flow rates will be printed to the listing file for every stress period time step in which "BUDGET PRINT" is specified in Output Control. If there is no Output Control option and "PRINT_FLOWS" is specified, then flow rates are printed for the last time step of each stress period.
- **save_flows** (*boolean*) -
  - save_flows (boolean) keyword to indicate that UZF flow terms will be written to the file specified with "BUDGET FILEOUT" in Output Control.
- **wc_filerecord** (*[wcfile]*) -
  - wcfile (string) name of the binary output file to write water content information.
- **budget_filerecord** (*[budgetfile]*) -
  - budgetfile (string) name of the binary output file to write budget information.
- **budgetcsv_filerecord** (*[budgetcsvfile]*) -
  - budgetcsvfile (string) name of the comma-separated value (CSV) output file to write budget summary information. A budget

summary record will be written to this file for each time step of the simulation.

- **package_convergence_filerecord** (*[package_convergence_filename]*) -
  - package_convergence_filename (string) name of the comma spaced values output file to write package convergence information.
- **timeseries** (*{varname:data} or timeseries data*) -
  - Contains data for the ts package. Data can be stored in a dictionary containing data for the ts package with variable names as keys and package data as values. Data just for the timeseries variable is also acceptable. See ts package documentation for more information.
- **observations** (*{varname:data} or continuous data*) -
  - Contains data for the obs package. Data can be stored in a dictionary containing data for the obs package with variable names as keys and package data as values. Data just for the observations variable is also acceptable. See obs package documentation for more information.
- **mover** (*boolean*) -
  - mover (boolean) keyword to indicate that this instance of the UZF Package can be used with the Water Mover (MVR) Package. When the MOVER option is specified, additional memory is allocated within the package to store the available, provided, and received water.
- **simulate_et** (*boolean*) -
  - simulate_et (boolean) keyword specifying that ET in the unsaturated (UZF) and saturated zones (GWF) will be simulated. ET can be simulated in the UZF cell and not the GWF cell by omitting keywords LINEAR_GWET and SQUARE_GWET.
- **linear_gwet** (*boolean*) -
  - linear_gwet (boolean) keyword specifying that groundwater ET will be simulated using the original ET formulation of MODFLOW-2005.
- **square_gwet** (*boolean*) -
  - square_gwet (boolean) keyword specifying that groundwater ET will be simulated by assuming a constant ET rate for groundwater levels between land surface (TOP) and land surface minus the ET extinction depth (TOP-EXTDP). Groundwater ET is smoothly reduced from the PET rate to zero over a nominal interval at TOP-EXTDP.
- **simulate_gwseep** (*boolean*) -
  - simulate_gwseep (boolean) keyword specifying that groundwater discharge (GWSEEP) to land surface will be simulated. Groundwater discharge is nonzero when groundwater head is greater than land surface. This option is no longer recommended; a better approach is to use the Drain Package with discharge scaling as a way to handle seepage to

land surface. The Drain Package with discharge scaling is described in Chapter 3 of the Supplemental Technical Information.

- **unsat_etwc** (*boolean*) -
  - unsat_etwc (boolean) keyword specifying that ET in the unsaturated zone will be simulated as a function of the specified PET rate while the water content (THETA) is greater than the ET extinction water content (EXTWC).
- **unsat_etae** (*boolean*) -
  - unsat_etae (boolean) keyword specifying that ET in the unsaturated zone will be simulated using a capillary pressure based formulation. Capillary pressure is calculated using the Brooks-Corey retention function.
- **nuzfcells** (*integer*) -
  - nuzfcells (integer) is the number of UZF cells. More than one UZF cell can be assigned to a GWF cell; however, only one GWF cell can be assigned to a single UZF cell. If more than one UZF cell is assigned to a GWF cell, then an auxiliary variable should be used to reduce the surface area of the UZF cell with the AUXMULTNAME option.
- **ntrailwaves** (*integer*) -
  - ntrailwaves (integer) is the number of trailing waves. A recommended value of 7 can be used for NTRAILWAVES. This value can be increased to lower mass balance error in the unsaturated zone.
- **nwavesets** (*integer*) -
  - nwavesets (integer) is the number of wave sets. A recommended value of 40 can be used for NWAVESETS. This value can be increased if more waves are required to resolve variations in water content within the unsaturated zone.
- **packagedata** (*[ifno, cellid, landflag, ivertcon, surfdep, vks, thtr, thts,*) -

  thti, eps, boundname]

    - ifno (integer) integer value that defines the feature (UZF object) number associated with the specified PACKAGEDATA data on the line. IFNO must be greater than zero and less than or equal to NUZFCELLS. UZF information must be specified for every UZF cell or the program will terminate with an error. The program will also terminate with an error if information for a UZF cell is specified more than once. This argument is an index variable, which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.
    - cellid ((integer, ...)) is the cell identifier, and depends on the type of grid that is used for the

simulation. For a structured grid that uses the DIS input file, CELLID is the layer, row, and column. For a grid that uses the DISV input file, CELLID is the layer and CELL2D number. If the model uses the unstructured discretization (DISU) input file, CELLID is the node number for the cell. This argument is an index variable, which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.

- landflag (integer) integer value set to one for land surface cells indicating that boundary conditions can be applied and data can be specified in the PERIOD block. A value of 0 specifies a non-land surface cell.
- ivertcon (integer) integer value set to specify underlying UZF cell that receives water flowing to bottom of cell. If unsaturated zone flow reaches the water table before the cell bottom, then water is added to the GWF cell instead of flowing to the underlying UZF cell. A value of 0 indicates the UZF cell is not connected to an underlying UZF cell. This argument is an index variable, which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.
- surfdep (double) is the surface depression depth of the UZF cell.
- vks (double) is the saturated vertical hydraulic conductivity of the UZF cell. This value is used with the Brooks-Corey function and the simulated water content to calculate the partially saturated hydraulic conductivity.
- thtr (double) is the residual (irreducible) water content of the UZF cell. This residual water is not available to plants and will not drain into underlying aquifer cells.
- thts (double) is the saturated water content of the UZF cell. The values for saturated and residual water content should be set in a manner that is consistent with the specific yield value specified in the Storage Package. The saturated water content must be greater than the residual content.
- thti (double) is the initial water content of the UZF cell. The value must be greater than or equal to the residual water content and less than or equal to the saturated water content.
- eps (double) is the exponent used in the Brooks-Corey function. The Brooks-Corey function is used by UZF to calculated hydraulic conductivity under partially saturated conditions as a function of water content and the user-specified saturated hydraulic conductivity.
- boundname (string) name of the UZF cell cell. BOUNDNAME is

an ASCII character variable that can contain as many as 40 characters. If BOUNDNAME contains spaces in it, then the entire name must be enclosed within single quotes.

- **perioddata** (*[ifno, finf, pet, extdp, extwc, ha, hroot, rootact, aux]*) -
  - ifno (integer) integer value that defines the feature (UZF object) number associated with the specified PERIOD data on the line. This argument is an index variable, which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.
  - finf (string) real or character value that defines the applied infiltration rate of the UZF cell (LT^{-1}). If the Options block includes a TIMESERIESFILE entry (see the "Time-Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
  - pet (string) real or character value that defines the potential evapotranspiration rate of the UZF cell and specified GWF cell. Evapotranspiration is first removed from the unsaturated zone and any remaining potential evapotranspiration is applied to the saturated zone. If IVERTCON is greater than zero then residual potential evapotranspiration not satisfied in the UZF cell is applied to the underlying UZF and GWF cells. PET is always specified, but is only used if SIMULATE_ET is specified in the OPTIONS block. If the Options block includes a TIMESERIESFILE entry (see the "Time-Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
  - extdp (string) real or character value that defines the evapotranspiration extinction depth of the UZF cell. If IVERTCON is greater than zero and EXTDP extends below the GWF cell bottom then remaining potential evapotranspiration is applied to the underlying UZF and GWF cells. EXTDP is always specified, but is only used if SIMULATE_ET is specified in the OPTIONS block. If the Options block includes a TIMESERIESFILE entry (see the "Time-Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
  - extwc (string) real or character value that defines the evapotranspiration extinction water content of the UZF cell. EXTWC is always specified, but is only used if SIMULATE_ET and UNSAT_ETWC are specified in the OPTIONS block. The evapotranspiration rate from the unsaturated zone will be set to zero when the calculated water content is at or less than this value. The value for EXTWC cannot be less than the residual water content, and if it is specified as being less than the residual water content it is set to the residual water content. If the Options block includes a TIMESERIESFILE entry (see the "Time-Variable Input" section), values can be

obtained from a time series by entering the time-series name in place of a numeric value.

- ha (string) real or character value that defines the air entry potential (head) of the UZF cell. HA is always specified, but is only used if SIMULATE_ET and UNSAT_ETAE are specified in the OPTIONS block. If the Options block includes a TIMESERIESFILE entry (see the "Time-Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
- hroot (string) real or character value that defines the root potential (head) of the UZF cell. HROOT is always specified, but is only used if SIMULATE_ET and UNSAT_ETAE are specified in the OPTIONS block. If the Options block includes a TIMESERIESFILE entry (see the "Time-Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
- rootact (string) real or character value that defines the root activity function of the UZF cell. ROOTACT is the length of roots in a given volume of soil divided by that volume. Values range from 0 to about 3 cm^{-2}, depending on the plant community and its stage of development. ROOTACT is always specified, but is only used if SIMULATE_ET and UNSAT_ETAE are specified in the OPTIONS block. If the Options block includes a TIMESERIESFILE entry (see the "Time- Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
- aux (double) represents the values of the auxiliary variables for each UZF. The values of auxiliary variables must be present for each UZF. The values must be specified in the order of the auxiliary variables specified in the OPTIONS block. If the package supports time series and the Options block includes a TIMESERIESFILE entry (see the "Time-Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.

- **filename** (*String*) - File name for this package.
- **pname** (*String*) - Package name for this package.
- **parent_file** (MFPackage) - Parent package file that references this package. Only needed for utility packages (mfutl*). For example, mfutllaktab package must have a mfgwflak package parent_file.

auxiliary = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

budget_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

budgetcsv_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

dfn = [['header', 'multi-package', 'package-type advanced-stress-package'], ['block options', 'name auxiliary', 'type string', 'shape (naux)', 'reader urword', 'optional true'], ['block options', 'name auxmultname', 'type string', 'shape', 'reader urword', 'optional true'], ['block options', 'name boundnames', 'type keyword', 'shape', 'reader urword', 'optional true'], ['block options', 'name print_input', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name print_flows', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name save_flows', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name wc_filerecord', 'type record water_content fileout wcfile', 'shape', 'reader urword', 'tagged true', 'optional true'], ['block options', 'name water_content', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name wcfile', 'type string', 'preserve_case true', 'shape', 'in_record true', 'reader urword', 'tagged false', 'optional false'], ['block options', 'name budget_filerecord', 'type record budget fileout budgetfile', 'shape', 'reader urword', 'tagged true', 'optional true'], ['block options', 'name budget', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name fileout', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name budgetfile', 'preserve_case true', 'type string', 'shape', 'in_record true', 'reader urword', 'tagged false', 'optional false'], ['block options', 'name budgetcsv_filerecord', 'type record budgetcsv fileout budgetcsvfile', 'shape', 'reader urword', 'tagged true', 'optional true'], ['block options', 'name budgetcsv', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name budgetcsvfile', 'type string', 'preserve_case true', 'shape', 'in_record true', 'reader urword', 'tagged false', 'optional false'], ['block options', 'name package_convergence_filerecord', 'type record package_convergence fileout package_convergence_filename', 'shape', 'reader urword', 'tagged true', 'optional true'], ['block options', 'name package_convergence', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name package_convergence_filename', 'type string', 'shape', 'in_record true', 'reader urword', 'tagged false', 'optional false'], ['block options', 'name ts_filerecord', 'type record ts6 filein ts6_filename', 'shape', 'reader urword', 'tagged true', 'optional true', 'construct_package ts', 'construct_data timeseries', 'parameter_name timeseries'], ['block options', 'name ts6', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name filein', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name ts6_filename', 'type string', 'preserve_case true', 'in_record true', 'reader urword', 'optional false', 'tagged false'], ['block options', 'name obs_filerecord', 'type record obs6 filein obs6_filename', 'shape', 'reader urword', 'tagged true', 'optional true', 'construct_package obs', 'construct_data continuous', 'parameter_name observations'], ['block options', 'name obs6', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name obs6_filename', 'type string', 'preserve_case true', 'in_record true', 'tagged false', 'reader urword', 'optional false'], ['block options', 'name mover', 'type keyword', 'tagged true', 'reader urword', 'optional true'], ['block options', 'name simulate_et', 'type keyword', 'tagged true', 'reader urword', 'optional true'], ['block options', 'name linear_gwet', 'type keyword', 'tagged true', 'reader urword', 'optional true'], ['block options', 'name square_gwet', 'type keyword', 'tagged true', 'reader urword', 'optional true'], ['block options', 'name simulate_gwseep', 'type keyword', 'tagged true', 'reader urword', 'optional true'], ['block options', 'name unsat_etwc', 'type keyword', 'tagged true', 'reader urword', 'optional true'], ['block options', 'name unsat_etae', 'type keyword', 'tagged true', 'reader urword', 'optional true'], ['block dimensions', 'name nuzfcells', 'type integer', 'reader urword', 'optional false'], ['block dimensions', 'name ntrailwaves', 'type integer', 'reader urword', 'optional false', 'default_value 7'], ['block dimensions', 'name nwavesets', 'type integer', 'reader urword', 'optional false', 'default_value 40'], ['block packagedata', 'name packagedata', 'type recarray ifno cellid landflag ivertcon surfdep vks thtr thts thti eps boundname',

dfn_file_name = 'gwf-uzf.dfn'

obs_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

package_abbr = 'gwfuzf'

package_convergence_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

packagedata = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

perioddata = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

ts_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

wc_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

flopy.mf6.modflow.mfgwfvsc module

class ModflowGwfvsc(*model*, *loading_package=False*, *viscref=1.0*, *temperature_species_name=None*, *thermal_formulation=None*, *thermal_a2=10.0*, *thermal_a3=248.37*, *thermal_a4=133.15*, *viscosity_filerecord=None*, *nviscspecies=None*, *packagedata=None*, *filename=None*, *pname=None*, ***kwargs*)

Bases: *MFPackage*

ModflowGwfvsc defines a vsc package within a gwf6 model.

Parameters

- **model** (MFModel) – Model that this package is a part of. Package is automatically added to model when it is initialized.
- **loading_package** (*bool*) – Do not set this parameter. It is intended for debugging and internal processing purposes only.
- **viscref** (*double*) –
  - viscref (double) fluid reference viscosity used in the equation of state. This value is set to 1.0 if not specified as an option.
- **temperature_species_name** (*string*) –
  - temperature_species_name (string) string used to identify the auxspeciesname in PACKAGEDATA that corresponds to the temperature species. There can be only one occurrence of this temperature species name in the PACKAGEDATA block or the program will terminate with an error. This value has no effect if viscosity does not depend on temperature.
- **thermal_formulation** (*string*) –
  - thermal_formulation (string) may be used for specifying which viscosity formulation to use for the temperature species. Can be either LINEAR or NONLINEAR. The LINEAR viscosity formulation is the default.
- **thermal_a2** (*double*) –

  - thermal_a2 (double) is an empirical parameter specified by the user for calculating viscosity using a nonlinear formulation. If A2 is not specified, a default value of 10.0 is assigned (Voss, 1984).
- **thermal_a3** (*double*) -
  - thermal_a3 (double) is an empirical parameter specified by the user for calculating viscosity using a nonlinear formulation. If A3 is not specified, a default value of 248.37 is assigned (Voss, 1984).
- **thermal_a4** (*double*) -
  - thermal_a4 (double) is an empirical parameter specified by the user for calculating viscosity using a nonlinear formulation. If A4 is not specified, a default value of 133.15 is assigned (Voss, 1984).
- **viscosity_filerecord** (*[viscosityfile]*) -
  - viscosityfile (string) name of the binary output file to write viscosity information. The viscosity file has the same format as the head file. Viscosity values will be written to the viscosity file whenever heads are written to the binary head file. The settings for controlling head output are contained in the Output Control option.
- **nviscspecies** (*integer*) -
  - nviscspecies (integer) number of species used in the viscosity equation of state. If either concentrations or temperature (or both) are used to update viscosity then then nrhospecies needs to be at least one.
- **packagedata** (*[iviscspec, dviscdc, cviscref, modelname, auxspeciesname]*) -
  - iviscspec (integer) integer value that defines the species number associated with the specified PACKAGEDATA data entered on each line. IVISCSPECIES must be greater than zero and less than or equal to NVISCSPECIES. Information must be specified for each of the NVISCSPECIES species or the program will terminate with an error. The program will also terminate with an error if information for a species is specified more than once. This argument is an index variable, which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.
  - dviscdc (double) real value that defines the slope of the line defining the linear relationship between viscosity and temperature or between viscosity and concentration, depending on the type of species entered on each line. If the value of AUXSPECIESNAME entered on a line corresponds to TEMPERATURE_SPECIES_NAME (in the OPTIONS block), this value will be used when VISCOSITY_FUNC is equal to LINEAR (the default) in the OPTIONS block. When VISCOSITY_FUNC is set

to NONLINEAR, a value for DVISCDC must be specified though it is not used.

– cviscref (double) real value that defines the reference temperature or reference concentration value used for this species in the viscosity equation of state. If AUXSPECIESNAME entered on a line corresponds to TEMPERATURE_SPECIES_NAME (in the OPTIONS block), then CVISCREF refers to a reference temperature, otherwise it refers to a reference concentration.

– modelname (string) name of a GWT model used to simulate a species that will be used in the viscosity equation of state. This name will have no effect if the simulation does not include a GWT model that corresponds to this GWF model.

– auxspeciesname (string) name of an auxiliary variable in a GWF stress package that will be used for this species to calculate the viscosity values. If a viscosity value is needed by the Viscosity Package then it will use the temperature or concentration values associated with this AUXSPECIESNAME in the viscosity equation of state. For advanced stress packages (LAK, SFR, MAW, and UZF) that have an associated advanced transport package (LKT, SFT, MWT, and UZT), the FLOW_PACKAGE_AUXILIARY_NAME option in the advanced transport package can be used to transfer simulated temperature or concentration(s) into the flow package auxiliary variable. In this manner, the Viscosity Package can calculate viscosity values for lakes, streams, multi-aquifer wells, and unsaturated zone flow cells using simulated concentrations.

- **filename** (*String*) - File name for this package.
- **pname** (*String*) - Package name for this package.
- **parent_file** (MFPackage) - Parent package file that references this package. Only needed for utility packages (mfutl*). For example, mfutllaktab package must have a mfgwflak package parent_file.

dfn = [['header'], ['block options', 'name viscref', 'type double precision', 'reader urword', 'optional true', 'default_value 1.0'], ['block options', 'name temperature_species_name', 'type string', 'shape', 'reader urword', 'optional true'], ['block options', 'name thermal_formulation', 'type string', 'shape', 'reader urword', 'optional true', 'valid linear nonlinear'], ['block options', 'name thermal_a2', 'type double precision', 'reader urword', 'optional true', 'default_value 10.'], ['block options', 'name thermal_a3', 'type double precision', 'reader urword', 'optional true', 'default_value 248.37'], ['block options', 'name thermal_a4', 'type double precision', 'reader urword', 'optional true', 'default_value 133.15'], ['block options', 'name viscosity_filerecord', 'type record viscosity fileout viscosityfile', 'shape', 'reader urword', 'tagged true', 'optional true'], ['block options', 'name viscosity', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name fileout', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name viscosityfile', 'type string', 'preserve_case true', 'shape', 'in_record true', 'reader urword', 'tagged false', 'optional false'], ['block dimensions', 'name nviscspecies', 'type integer', 'reader urword', 'optional false'], ['block packagedata', 'name packagedata', 'type recarray iviscspec dviscdc cviscref modelname auxspeciesname', 'shape (nrhospecies)', 'reader urword'], ['block packagedata', 'name iviscspec', 'type integer', 'shape', 'tagged false', 'in_record true', 'reader urword', 'numeric_index true'], ['block packagedata', 'name dviscdc', 'type double precision', 'shape', 'tagged false', 'in_record true', 'reader urword'], ['block packagedata', 'name cviscref', 'type double precision', 'shape', 'tagged false', 'in_record true', 'reader urword'], ['block packagedata', 'name modelname', 'type string', 'in_record true', 'tagged false', 'shape', 'reader urword'], ['block packagedata', 'name auxspeciesname', 'type string', 'in_record true', 'tagged false', 'shape', 'reader urword']]

dfn_file_name = 'gwf-vsc.dfn'

package_abbr = 'gwfvsc'

packagedata = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

viscosity_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

flopy.mf6.modflow.mfgwfwel module

class **ModflowGwfwel**(*model*, *loading_package=False*, *auxiliary=None*, *auxmultname=None*, *boundnames=None*, *print_input=None*, *print_flows=None*, *save_flows=None*, *auto_flow_reduce=None*, *afrcsv_filerecord=None*, *timeseries=None*, *observations=None*, *mover=None*, *maxbound=None*, *stress_period_data=None*, *filename=None*, *pname=None*, ***kwargs*)

Bases: *MFPackage*

ModflowGwfwel defines a wel package within a gwf6 model.

Parameters

- **model** (MFModel) – Model that this package is a part of. Package is automatically added to model when it is initialized.
- **loading_package** (*bool*) – Do not set this parameter. It is intended for debugging and internal processing purposes only.
- **auxiliary** (*[string]*) –

- auxiliary (string) defines an array of one or more auxiliary variable names. There is no limit on the number of auxiliary variables that can be provided on this line; however, lists of information provided in subsequent blocks must have a column of data for each auxiliary variable name defined here. The number of auxiliary variables detected on this line determines the value for naux. Comments cannot be provided anywhere on this line as they will be interpreted as auxiliary variable names. Auxiliary variables may not be used by the package, but they will be available for use by other parts of the program. The program will terminate with an error if auxiliary variables are specified on more than one line in the options block.

- **auxmultname** (*string*) -
  - auxmultname (string) name of auxiliary variable to be used as multiplier of well flow rate.
- **boundnames** (*boolean*) -
  - boundnames (boolean) keyword to indicate that boundary names may be provided with the list of well cells.
- **print_input** (*boolean*) -
  - print_input (boolean) keyword to indicate that the list of well information will be written to the listing file immediately after it is read.
- **print_flows** (*boolean*) -
  - print_flows (boolean) keyword to indicate that the list of well flow rates will be printed to the listing file for every stress period time step in which "BUDGET PRINT" is specified in Output Control. If there is no Output Control option and "PRINT_FLOWS" is specified, then flow rates are printed for the last time step of each stress period.
- **save_flows** (*boolean*) -
  - save_flows (boolean) keyword to indicate that well flow terms will be written to the file specified with "BUDGET FILEOUT" in Output Control.
- **auto_flow_reduce** (*double*) -
  - auto_flow_reduce (double) keyword and real value that defines the fraction of the cell thickness used as an interval for smoothly adjusting negative pumping rates to 0 in cells with head values less than or equal to the bottom of the cell. Negative pumping rates are adjusted to 0 or a smaller negative value when the head in the cell is equal to or less than the calculated interval above the cell bottom. AUTO_FLOW_REDUCE is set to 0.1 if the specified value is less than or equal to zero. By default, negative pumping rates are not reduced during a simulation.
- **afrcsv_filerecord** (*[afrcsvfile]*) -

  - afrcsvfile (string) name of the comma-separated value (CSV) output file to write information about well extraction rates that have been reduced by the program. Entries are only written if the extraction rates are reduced.

- **timeseries** (*{varname:data} or timeseries data*) -
  - Contains data for the ts package. Data can be stored in a dictionary containing data for the ts package with variable names as keys and package data as values. Data just for the timeseries variable is also acceptable. See ts package documentation for more information.
- **observations** (*{varname:data} or continuous data*) -
  - Contains data for the obs package. Data can be stored in a dictionary containing data for the obs package with variable names as keys and package data as values. Data just for the observations variable is also acceptable. See obs package documentation for more information.
- **mover** (*boolean*) -
  - mover (boolean) keyword to indicate that this instance of the Well Package can be used with the Water Mover (MVR) Package. When the MOVER option is specified, additional memory is allocated within the package to store the available, provided, and received water.
- **maxbound** (*integer*) -
  - maxbound (integer) integer value specifying the maximum number of wells cells that will be specified for use during any stress period.
- **stress_period_data** (*[cellid, q, aux, boundname]*) -
  - cellid ((integer, ...)) is the cell identifier, and depends on the type of grid that is used for the simulation. For a structured grid that uses the DIS input file, CELLID is the layer, row, and column. For a grid that uses the DISV input file, CELLID is the layer and CELL2D number. If the model uses the unstructured discretization (DISU) input file, CELLID is the node number for the cell. This argument is an index variable, which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.
  - q (double) is the volumetric well rate. A positive value indicates recharge (injection) and a negative value indicates discharge (extraction). If the Options block includes a TIMESERIESFILE entry (see the "Time-Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
  - aux (double) represents the values of the auxiliary variables for each well. The values of auxiliary variables must be present for each well. The values must be specified in the order of the auxiliary variables specified in the OPTIONS

block. If the package supports time series and the Options block includes a TIMESERIESFILE entry (see the "Time-Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.

  - boundname (string) name of the well cell. BOUNDNAME is an ASCII character variable that can contain as many as 40 characters. If BOUNDNAME contains spaces in it, then the entire name must be enclosed within single quotes.

- **filename** (*String*) - File name for this package.
- **pname** (*String*) - Package name for this package.
- **parent_file** (MFPackage) - Parent package file that references this package. Only needed for utility packages (mfutl*). For example, mfutllaktab package must have a mfgwflak package parent_file.

afrcsv_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

auxiliary = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

dfn = [['header', 'multi-package', 'package-type stress-package'], ['block options', 'name auxiliary', 'type string', 'shape (naux)', 'reader urword', 'optional true'], ['block options', 'name auxmultname', 'type string', 'shape', 'reader urword', 'optional true'], ['block options', 'name boundnames', 'type keyword', 'shape', 'reader urword', 'optional true'], ['block options', 'name print_input', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name print_flows', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name save_flows', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name auto_flow_reduce', 'type double precision', 'reader urword', 'optional true'], ['block options', 'name afrcsv_filerecord', 'type record auto_flow_reduce_csv fileout afrcsvfile', 'shape', 'reader urword', 'tagged true', 'optional true'], ['block options', 'name auto_flow_reduce_csv', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name fileout', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name afrcsvfile', 'type string', 'preserve_case true', 'shape', 'in_record true', 'reader urword', 'tagged false', 'optional false'], ['block options', 'name ts_filerecord', 'type record ts6 filein ts6_filename', 'shape', 'reader urword', 'tagged true', 'optional true', 'construct_package ts', 'construct_data timeseries', 'parameter_name timeseries'], ['block options', 'name ts6', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name filein', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name ts6_filename', 'type string', 'preserve_case true', 'in_record true', 'reader urword', 'optional false', 'tagged false'], ['block options', 'name obs_filerecord', 'type record obs6 filein obs6_filename', 'shape', 'reader urword', 'tagged true', 'optional true', 'construct_package obs', 'construct_data continuous', 'parameter_name observations'], ['block options', 'name obs6', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name obs6_filename', 'type string', 'preserve_case true', 'in_record true', 'tagged false', 'reader urword', 'optional false'], ['block options', 'name mover', 'type keyword', 'tagged true', 'reader urword', 'optional true'], ['block dimensions', 'name maxbound', 'type integer', 'reader urword', 'optional false'], ['block period', 'name iper', 'type integer', 'block_variable True', 'in_record true', 'tagged false', 'shape', 'valid', 'reader urword', 'optional false'], ['block period', 'name stress_period_data', 'type recarray cellid q aux boundname', 'shape (maxbound)', 'reader urword'], ['block period', 'name cellid', 'type integer', 'shape (ncelldim)', 'tagged false', 'in_record true', 'reader urword'], ['block period', 'name q', 'type double precision', 'shape', 'tagged false', 'in_record true', 'reader urword', 'time_series true'], ['block period', 'name aux', 'type double precision', 'in_record true', 'tagged false', 'shape (naux)', 'reader urword', 'optional true', 'time_series true'], ['block period', 'name boundname', 'type string', 'shape', 'tagged false', 'in_record true', 'reader urword', 'optional true']]

dfn_file_name = 'gwf-wel.dfn'

obs_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

package_abbr = 'gwfwel'

stress_period_data = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

ts_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

12.1.6 MODFLOW 6 Groundwater Transport Model Packages

MODFLOW 6 groundwater transport models support a number of required and optional packages. Once a MODFLOW 6 groundwater transport model object (mfgwt.ModflowGwt) has been constructed various packages associated with the groundwater transport model can be constructed.

Contents:

flopy.mf6.modflow.mfgwtadv module

class ModflowGwtadv(*model*, *loading_package=False*, *scheme=None*, *filename=None*, *pname=None*, ***kwargs*)

Bases: *MFPackage*

ModflowGwtadv defines a adv package within a gwt6 model.

Parameters

- **model** (MFModel) – Model that this package is a part of. Package is automatically added to model when it is initialized.
- **loading_package** (*bool*) – Do not set this parameter. It is intended for debugging and internal processing purposes only.
- **scheme** (*string*) –
  - scheme (string) scheme used to solve the advection term. Can be upstream, central, or TVD. If not specified, upstream weighting is the default weighting scheme.
- **filename** (*String*) – File name for this package.
- **pname** (*String*) – Package name for this package.
- **parent_file** (MFPackage) – Parent package file that references this package. Only needed for utility packages (mfutl*). For example, mfutllaktab package must have a mfgwflak package parent_file.

dfn = [['header'], ['block options', 'name scheme', 'type string', 'valid central upstream tvd', 'reader urword', 'optional true']]

dfn_file_name = 'gwt-adv.dfn'

package_abbr = 'gwtadv'

flopy.mf6.modflow.mfgwtapi module

class ModflowGwtapi(*model*, *loading_package=False*, *boundnames=None*, *print_input=None*, *print_flows=None*, *save_flows=None*, *observations=None*, *mover=None*, *maxbound=None*, *filename=None*, *pname=None*, ***kwargs*)

Bases: *MFPackage*

ModflowGwtapi defines a api package within a gwt6 model.

Parameters

- **model** (MFModel) – Model that this package is a part of. Package is automatically added to model when it is initialized.

- **loading_package** (*bool*) - Do not set this parameter. It is intended for debugging and internal processing purposes only.
- **boundnames** (*boolean*) -
  - boundnames (boolean) keyword to indicate that boundary names may be provided with the list of api boundary cells.
- **print_input** (*boolean*) -
  - print_input (boolean) keyword to indicate that the list of api boundary information will be written to the listing file immediately after it is read.
- **print_flows** (*boolean*) -
  - print_flows (boolean) keyword to indicate that the list of api boundary flow rates will be printed to the listing file for every stress period time step in which "BUDGET PRINT" is specified in Output Control. If there is no Output Control option and "PRINT_FLOWS" is specified, then flow rates are printed for the last time step of each stress period.
- **save_flows** (*boolean*) -
  - save_flows (boolean) keyword to indicate that api boundary flow terms will be written to the file specified with "BUDGET FILEOUT" in Output Control.
- **observations** (*{varname:data} or continuous data*) -
  - Contains data for the obs package. Data can be stored in a dictionary containing data for the obs package with variable names as keys and package data as values. Data just for the observations variable is also acceptable. See obs package documentation for more information.
- **mover** (*boolean*) -
  - mover (boolean) keyword to indicate that this instance of the api boundary Package can be used with the Water Mover (MVR) Package. When the MOVER option is specified, additional memory is allocated within the package to store the available, provided, and received water.
- **maxbound** (*integer*) -
  - maxbound (integer) integer value specifying the maximum number of api boundary cells that will be specified for use during any stress period.
- **filename** (*String*) - File name for this package.
- **pname** (*String*) - Package name for this package.
- **parent_file** (*MFPackage*) - Parent package file that references this package. Only needed for utility packages (mfutl*). For example, mfutllaktab package must have a mfgwflak package parent_file.

dfn = [['header'], ['block options', 'name boundnames', 'type keyword', 'shape', 'reader urword', 'optional true'], ['block options', 'name print_input', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name print_flows', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name save_flows', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name obs_filerecord', 'type record obs6 filein obs6_filename', 'shape', 'reader urword', 'tagged true', 'optional true', 'construct_package obs', 'construct_data continuous', 'parameter_name observations'], ['block options', 'name obs6', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name filein', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name obs6_filename', 'type string', 'preserve_case true', 'in_record true', 'tagged false', 'reader urword', 'optional false'], ['block options', 'name mover', 'type keyword', 'tagged true', 'reader urword', 'optional true'], ['block dimensions', 'name maxbound', 'type integer', 'reader urword', 'optional false']]

dfn_file_name = 'gwt-api.dfn'

obs_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

package_abbr = 'gwtapi'

flopy.mf6.modflow.mfgwtcnc module

class **ModflowGwtcnc**(*model*, *loading_package=False*, *auxiliary=None*, *auxmultname=None*, *boundnames=None*, *print_input=None*, *print_flows=None*, *save_flows=None*, *timeseries=None*, *observations=None*, *maxbound=None*, *stress_period_data=None*, *filename=None*, *pname=None*, ***kwargs*)

Bases: *MFPackage*

ModflowGwtcnc defines a cnc package within a gwt6 model.

Parameters

- **model** (MFModel) – Model that this package is a part of. Package is automatically added to model when it is initialized.
- **loading_package** (*bool*) – Do not set this parameter. It is intended for debugging and internal processing purposes only.
- **auxiliary** (*[string]*) –
  - auxiliary (string) defines an array of one or more auxiliary variable names. There is no limit on the number of auxiliary variables that can be provided on this line; however, lists of information provided in subsequent blocks must have a column of data for each auxiliary variable name defined here. The number of auxiliary variables detected on this line determines the value for naux. Comments cannot be provided anywhere on this line as they will be interpreted as auxiliary variable names. Auxiliary variables may not be used by the package, but they will be available for use by other parts of the program. The program will terminate with an error if auxiliary variables are specified on more than one line in the options block.
- **auxmultname** (*string*) –

  - auxmultname (string) name of auxiliary variable to be used as multiplier of concentration value.
- **boundnames** (*boolean*) -
  - boundnames (boolean) keyword to indicate that boundary names may be provided with the list of constant concentration cells.
- **print_input** (*boolean*) -
  - print_input (boolean) keyword to indicate that the list of constant concentration information will be written to the listing file immediately after it is read.
- **print_flows** (*boolean*) -
  - print_flows (boolean) keyword to indicate that the list of constant concentration flow rates will be printed to the listing file for every stress period time step in which "BUDGET PRINT" is specified in Output Control. If there is no Output Control option and "PRINT_FLOWS" is specified, then flow rates are printed for the last time step of each stress period.
- **save_flows** (*boolean*) -
  - save_flows (boolean) keyword to indicate that constant concentration flow terms will be written to the file specified with "BUDGET FILEOUT" in Output Control.
- **timeseries** (*{varname:data} or timeseries data*) -
  - Contains data for the ts package. Data can be stored in a dictionary containing data for the ts package with variable names as keys and package data as values. Data just for the timeseries variable is also acceptable. See ts package documentation for more information.
- **observations** (*{varname:data} or continuous data*) -
  - Contains data for the obs package. Data can be stored in a dictionary containing data for the obs package with variable names as keys and package data as values. Data just for the observations variable is also acceptable. See obs package documentation for more information.
- **maxbound** (*integer*) -
  - maxbound (integer) integer value specifying the maximum number of constant concentrations cells that will be specified for use during any stress period.
- **stress_period_data** (*[cellid, conc, aux, boundname]*) -
  - cellid ((integer, ...)) is the cell identifier, and depends on the type of grid that is used for the simulation. For a structured grid that uses the DIS input file, CELLID is the layer, row, and column. For a grid that uses the DISV input file, CELLID is the layer and CELL2D number. If the model uses the unstructured discretization (DISU) input file, CELLID is the node number for the cell. This argument is an index variable, which means that it should be treated as zero-based

when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.

  - conc (double) is the constant concentration value. If the Options block includes a TIMESERIESFILE entry (see the "Time-Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
  - aux (double) represents the values of the auxiliary variables for each constant concentration. The values of auxiliary variables must be present for each constant concentration. The values must be specified in the order of the auxiliary variables specified in the OPTIONS block. If the package supports time series and the Options block includes a TIMESERIESFILE entry (see the "Time-Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
  - boundname (string) name of the constant concentration cell. BOUNDNAME is an ASCII character variable that can contain as many as 40 characters. If BOUNDNAME contains spaces in it, then the entire name must be enclosed within single quotes.

- **filename** (*String*) - File name for this package.
- **pname** (*String*) - Package name for this package.
- **parent_file** (MFPackage) - Parent package file that references this package. Only needed for utility packages (mfutl*). For example, mfutllaktab package must have a mfgwflak package parent_file.

auxiliary = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

dfn = [['header'], ['block options', 'name auxiliary', 'type string', 'shape (naux)', 'reader urword', 'optional true'], ['block options', 'name auxmultname', 'type string', 'shape', 'reader urword', 'optional true'], ['block options', 'name boundnames', 'type keyword', 'shape', 'reader urword', 'optional true'], ['block options', 'name print_input', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name print_flows', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name save_flows', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name ts_filerecord', 'type record ts6 filein ts6_filename', 'shape', 'reader urword', 'tagged true', 'optional true', 'construct_package ts', 'construct_data timeseries', 'parameter_name timeseries'], ['block options', 'name ts6', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name filein', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name ts6_filename', 'type string', 'preserve_case true', 'in_record true', 'reader urword', 'optional false', 'tagged false'], ['block options', 'name obs_filerecord', 'type record obs6 filein obs6_filename', 'shape', 'reader urword', 'tagged true', 'optional true', 'construct_package obs', 'construct_data continuous', 'parameter_name observations'], ['block options', 'name obs6', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name obs6_filename', 'type string', 'preserve_case true', 'in_record true', 'tagged false', 'reader urword', 'optional false'], ['block dimensions', 'name maxbound', 'type integer', 'reader urword', 'optional false'], ['block period', 'name iper', 'type integer', 'block_variable True', 'in_record true', 'tagged false', 'shape', 'valid', 'reader urword', 'optional false'], ['block period', 'name stress_period_data', 'type recarray cellid conc aux boundname', 'shape (maxbound)', 'reader urword'], ['block period', 'name cellid', 'type integer', 'shape (ncelldim)', 'tagged false', 'in_record true', 'reader urword'], ['block period', 'name conc', 'type double precision', 'shape', 'tagged false', 'in_record true', 'reader urword', 'time_series true'], ['block period', 'name aux', 'type double precision', 'in_record true', 'tagged false', 'shape (naux)', 'reader urword', 'optional true', 'time_series true'], ['block period', 'name boundname', 'type string', 'shape', 'tagged false', 'in_record true', 'reader urword', 'optional true']]

dfn_file_name = 'gwt-cnc.dfn'

obs_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

package_abbr = 'gwtcnc'

stress_period_data = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

ts_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

flopy.mf6.modflow.mfgwtdis module

class ModflowGwtdis(*model*, *loading_package=False*, *length_units=None*, *nogrb=None*, *xorigin=None*, *yorigin=None*, *angrot=None*, *nlay=1*, *nrow=2*, *ncol=2*, *delr=1.0*, *delc=1.0*, *top=1.0*, *botm=0.0*, *idomain=None*, *filename=None*, *pname=None*, ***kwargs*)

Bases: *MFPackage*

ModflowGwtdis defines a dis package within a gwt6 model.

Parameters

- **model** (MFModel) - Model that this package is a part of. Package is automatically added to model when it is initialized.
- **loading_package** (*bool*) - Do not set this parameter. It is intended for debugging and internal processing purposes only.
- **length_units** (*string*) -
  - length_units (string) is the length units used for this model. Values can be "FEET", "METERS", or "CENTIMETERS". If not specified, the default is "UNKNOWN".
- **nogrb** (*boolean*) -
  - nogrb (boolean) keyword to deactivate writing of the binary grid file.
- **xorigin** (*double*) -
  - xorigin (double) x-position of the lower-left corner of the model grid. A default value of zero is assigned if not specified. The value for XORIGIN does not affect the model simulation, but it is written to the binary grid file so that postprocessors can locate the grid in space.
- **yorigin** (*double*) -
  - yorigin (double) y-position of the lower-left corner of the model grid. If not specified, then a default value equal to zero is used. The value for YORIGIN does not affect the model simulation, but it is written to the binary grid file so that postprocessors can locate the grid in space.
- **angrot** (*double*) -
  - angrot (double) counter-clockwise rotation angle (in degrees) of the lower-left corner of the model grid. If not specified, then a default value of 0.0 is assigned. The value for ANGROT does not affect the model simulation, but it is written to the binary grid file so that postprocessors can locate the grid in space.
- **nlay** (*integer*) -
  - nlay (integer) is the number of layers in the model grid.
- **nrow** (*integer*) -
  - nrow (integer) is the number of rows in the model grid.
- **ncol** (*integer*) -
  - ncol (integer) is the number of columns in the model grid.
- **delr** (*[double]*) -
  - delr (double) is the column spacing in the row direction.
- **delc** (*[double]*) -
  - delc (double) is the row spacing in the column direction.
- **top** (*[double]*) -

  - top (double) is the top elevation for each cell in the top model layer.
- **botm** (*[double]*) -
  - botm (double) is the bottom elevation for each cell.
- **idomain** (*[integer]*) -
  - idomain (integer) is an optional array that characterizes the existence status of a cell. If the IDOMAIN array is not specified, then all model cells exist within the solution. If the IDOMAIN value for a cell is 0, the cell does not exist in the simulation. Input and output values will be read and written for the cell, but internal to the program, the cell is excluded from the solution. If the IDOMAIN value for a cell is 1, the cell exists in the simulation. If the IDOMAIN value for a cell is -1, the cell does not exist in the simulation. Furthermore, the first existing cell above will be connected to the first existing cell below. This type of cell is referred to as a "vertical pass through" cell.
- **filename** (*String*) - File name for this package.
- **pname** (*String*) - Package name for this package.
- **parent_file** (MFPackage) - Parent package file that references this package. Only needed for utility packages (mfutl*). For example, mfutllaktab package must have a mfgwflak package parent_file.

botm = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

delc = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

delr = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

dfn = [['header'], ['block options', 'name length_units', 'type string', 'reader urword', 'optional true'], ['block options', 'name nogrb', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name xorigin', 'type double precision', 'reader urword', 'optional true'], ['block options', 'name yorigin', 'type double precision', 'reader urword', 'optional true'], ['block options', 'name angrot', 'type double precision', 'reader urword', 'optional true'], ['block dimensions', 'name nlay', 'type integer', 'reader urword', 'optional false', 'default_value 1'], ['block dimensions', 'name nrow', 'type integer', 'reader urword', 'optional false', 'default_value 2'], ['block dimensions', 'name ncol', 'type integer', 'reader urword', 'optional false', 'default_value 2'], ['block griddata', 'name delr', 'type double precision', 'shape (ncol)', 'reader readarray', 'default_value 1.0'], ['block griddata', 'name delc', 'type double precision', 'shape (nrow)', 'reader readarray', 'default_value 1.0'], ['block griddata', 'name top', 'type double precision', 'shape (ncol, nrow)', 'reader readarray', 'default_value 1.0'], ['block griddata', 'name botm', 'type double precision', 'shape (ncol, nrow, nlay)', 'reader readarray', 'layered true', 'default_value 0.'], ['block griddata', 'name idomain', 'type integer', 'shape (ncol, nrow, nlay)', 'reader readarray', 'layered true', 'optional true']]

dfn_file_name = 'gwt-dis.dfn'

idomain = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

package_abbr = 'gwtdis'

top = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

flopy.mf6.modflow.mfgwtdisu module

class ModflowGwtdisu(*model*, *loading_package=False*, *length_units=None*, *nogrb=None*, *xorigin=None*, *yorigin=None*, *angrot=None*, *vertical_offset_tolerance=0.0*, *nodes=None*, *nja=None*, *nvert=None*, *top=None*, *bot=None*, *area=None*, *idomain=None*, *iac=None*, *ja=None*, *ihc=None*, *cl12=None*, *hwva=None*, *angldegx=None*, *vertices=None*, *cell2d=None*, *filename=None*, *pname=None*, ***kwargs*)

Bases: *MFPackage*

ModflowGwtdisu defines a disu package within a gwt6 model.

Parameters

- **model** (MFModel) - Model that this package is a part of. Package is automatically added to model when it is initialized.
- **loading_package** (*bool*) - Do not set this parameter. It is intended for debugging and internal processing purposes only.
- **length_units** (*string*) -
  - length_units (string) is the length units used for this model. Values can be "FEET", "METERS", or "CENTIMETERS". If not specified, the default is "UNKNOWN".
- **nogrb** (*boolean*) -
  - nogrb (boolean) keyword to deactivate writing of the binary grid file.
- **xorigin** (*double*) -
  - xorigin (double) x-position of the origin used for model grid vertices. This value should be provided in a real-world coordinate system. A default value of zero is assigned if not specified. The value for XORIGIN does not affect the model simulation, but it is written to the binary grid file so that postprocessors can locate the grid in space.
- **yorigin** (*double*) -
  - yorigin (double) y-position of the origin used for model grid vertices. This value should be provided in a real-world coordinate system. If not specified, then a default value equal to zero is used. The value for YORIGIN does not affect the model simulation, but it is written to the binary grid file so that postprocessors can locate the grid in space.
- **angrot** (*double*) -
  - angrot (double) counter-clockwise rotation angle (in degrees) of the model grid coordinate system relative to a real-world coordinate system. If not specified, then a default value of 0.0 is assigned. The value for ANGROT does not affect the model simulation, but it is written to the binary grid file so that postprocessors can locate the grid in space.

- **vertical_offset_tolerance** (*double*) -
  - vertical_offset_tolerance (double) checks are performed to ensure that the top of a cell is not higher than the bottom of an overlying cell. This option can be used to specify the tolerance that is used for checking. If top of a cell is above the bottom of an overlying cell by a value less than this tolerance, then the program will not terminate with an error. The default value is zero. This option should generally not be used.
- **nodes** (*integer*) -
  - nodes (integer) is the number of cells in the model grid.
- **nja** (*integer*) -
  - nja (integer) is the sum of the number of connections and NODES. When calculating the total number of connections, the connection between cell n and cell m is considered to be different from the connection between cell m and cell n. Thus, NJA is equal to the total number of connections, including n to m and m to n, and the total number of cells.
- **nvert** (*integer*) -
  - nvert (integer) is the total number of (x, y) vertex pairs used to define the plan-view shape of each cell in the model grid. If NVERT is not specified or is specified as zero, then the VERTICES and CELL2D blocks below are not read. NVERT and the accompanying VERTICES and CELL2D blocks should be specified for most simulations. If the XT3D or SAVE_SPECIFIC_DISCHARGE options are specified in the NPF Package, then this information is required.
- **top** (*[double]*) -
  - top (double) is the top elevation for each cell in the model grid.
- **bot** (*[double]*) -
  - bot (double) is the bottom elevation for each cell.
- **area** (*[double]*) -
  - area (double) is the cell surface area (in plan view).
- **idomain** (*[integer]*) -
  - idomain (integer) is an optional array that characterizes the existence status of a cell. If the IDOMAIN array is not specified, then all model cells exist within the solution. If the IDOMAIN value for a cell is 0, the cell does not exist in the simulation. Input and output values will be read and written for the cell, but internal to the program, the cell is excluded from the solution. If the IDOMAIN value for a cell is 1 or greater, the cell exists in the simulation. IDOMAIN values of -1 cannot be specified for the DISU Package.
- **iac** (*[integer]*) -

  - iac (integer) is the number of connections (plus 1) for each cell. The sum of all the entries in IAC must be equal to NJA.

- **ja** (*[integer]*) -
  - ja (integer) is a list of cell number (n) followed by its connecting cell numbers (m) for each of the m cells connected to cell n. The number of values to provide for cell n is IAC(n). This list is sequentially provided for the first to the last cell. The first value in the list must be cell n itself, and the remaining cells must be listed in an increasing order (sorted from lowest number to highest). Note that the cell and its connections are only supplied for the GWT cells and their connections to the other GWT cells. Also note that the JA list input may be divided such that every node and its connectivity list can be on a separate line for ease in readability of the file. To further ease readability of the file, the node number of the cell whose connectivity is subsequently listed, may be expressed as a negative number, the sign of which is subsequently converted to positive by the code. This argument is an index variable, which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.

- **ihc** (*[integer]*) -
  - ihc (integer) is an index array indicating the direction between node n and all of its m connections. If IHC = 0 then cell n and cell m are connected in the vertical direction. Cell n overlies cell m if the cell number for n is less than m; cell m overlies cell n if the cell number for m is less than n. If IHC = 1 then cell n and cell m are connected in the horizontal direction. If IHC = 2 then cell n and cell m are connected in the horizontal direction, and the connection is vertically staggered. A vertically staggered connection is one in which a cell is horizontally connected to more than one cell in a horizontal connection.

- **cl12** (*[double]*) -
  - cl12 (double) is the array containing connection lengths between the center of cell n and the shared face with each adjacent m cell.

- **hwva** (*[double]*) -
  - hwva (double) is a symmetric array of size NJA. For horizontal connections, entries in HWVA are the horizontal width perpendicular to flow. For vertical connections, entries in HWVA are the vertical area for flow. Thus, values in the HWVA array contain dimensions of both length and area. Entries in the HWVA array have a one-to-one correspondence with the connections specified in the JA array. Likewise, there is a one-to-one correspondence between entries in the HWVA array and entries in the IHC array, which specifies the connection type (horizontal or vertical). Entries in the HWVA array must be symmetric; the program will terminate with an error if the

value for HWVA for an n to m connection does not equal the value for HWVA for the corresponding n to m connection.

- **angldegx** (*[double]*) -
  - angldegx (double) is the angle (in degrees) between the horizontal x-axis and the outward normal to the face between a cell and its connecting cells. The angle varies between zero and 360.0 degrees, where zero degrees points in the positive x-axis direction, and 90 degrees points in the positive y-axis direction. ANGLDEGX is only needed if horizontal anisotropy is specified in the NPF Package, if the XT3D option is used in the NPF Package, or if the SAVE_SPECIFIC_DISCHARGE option is specifed in the NPF Package. ANGLDEGX does not need to be specified if these conditions are not met. ANGLDEGX is of size NJA; values specified for vertical connections and for the diagonal position are not used. Note that ANGLDEGX is read in degrees, which is different from MODFLOW-USG, which reads a similar variable (ANGLEX) in radians.
- **vertices** (*[iv, xv, yv]*) -
  - iv (integer) is the vertex number. Records in the VERTICES block must be listed in consecutive order from 1 to NVERT. This argument is an index variable, which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.
  - xv (double) is the x-coordinate for the vertex.
  - yv (double) is the y-coordinate for the vertex.
- **cell2d** (*[icell2d, xc, yc, ncvert, icvert]*) -
  - icell2d (integer) is the cell2d number. Records in the CELL2D block must be listed in consecutive order from 1 to NODES. This argument is an index variable, which means that it should be treated as zero- based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.
  - xc (double) is the x-coordinate for the cell center.
  - yc (double) is the y-coordinate for the cell center.
  - ncvert (integer) is the number of vertices required to define the cell. There may be a different number of vertices for each cell.
  - icvert (integer) is an array of integer values containing vertex numbers (in the VERTICES block) used to define the cell. Vertices must be listed in clockwise order. This argument is an index variable, which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.
- **filename** (*String*) - File name for this package.
- **pname** (*String*) - Package name for this package.

- **parent_file** (MFPackage) - Parent package file that references this package. Only needed for utility packages (mfutl*). For example, mfutllaktab package must have a mfgwflak package parent_file.

anglde gx = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

area = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

bot = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

cell2d = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

cl12 = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

dfn = [['header'], ['block options', 'name length_units', 'type string', 'reader urword', 'optional true'], ['block options', 'name nogrb', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name xorigin', 'type double precision', 'reader urword', 'optional true'], ['block options', 'name yorigin', 'type double precision', 'reader urword', 'optional true'], ['block options', 'name angrot', 'type double precision', 'reader urword', 'optional true'], ['block options', 'name vertical_offset_tolerance', 'type double precision', 'reader urword', 'optional true', 'default_value 0.0', 'mf6internal voffsettol'], ['block dimensions', 'name nodes', 'type integer', 'reader urword', 'optional false'], ['block dimensions', 'name nja', 'type integer', 'reader urword', 'optional false'], ['block dimensions', 'name nvert', 'type integer', 'reader urword', 'optional true'], ['block griddata', 'name top', 'type double precision', 'shape (nodes)', 'reader readarray'], ['block griddata', 'name bot', 'type double precision', 'shape (nodes)', 'reader readarray'], ['block griddata', 'name area', 'type double precision', 'shape (nodes)', 'reader readarray'], ['block griddata', 'name idomain', 'type integer', 'shape (nodes)', 'reader readarray', 'layered false', 'optional true'], ['block connectiondata', 'name iac', 'type integer', 'shape (nodes)', 'reader readarray'], ['block connectiondata', 'name ja', 'type integer', 'shape (nja)', 'reader readarray', 'numeric_index true', 'jagged_array iac'], ['block connectiondata', 'name ihc', 'type integer', 'shape (nja)', 'reader readarray', 'jagged_array iac'], ['block connectiondata', 'name cl12', 'type double precision', 'shape (nja)', 'reader readarray', 'jagged_array iac'], ['block connectiondata', 'name hwva', 'type double precision', 'shape (nja)', 'reader readarray', 'jagged_array iac'], ['block connectiondata', 'name angldegx', 'type double precision', 'optional true', 'shape (nja)', 'reader readarray', 'jagged_array iac'], ['block vertices', 'name vertices', 'type recarray iv xv yv', 'shape (nvert)', 'reader urword', 'optional false'], ['block vertices', 'name iv', 'type integer', 'in_record true', 'tagged false', 'reader urword', 'optional false', 'numeric_index true'], ['block vertices', 'name xv', 'type double precision', 'in_record true', 'tagged false', 'reader urword', 'optional false'], ['block vertices', 'name yv', 'type double precision', 'in_record true', 'tagged false', 'reader urword', 'optional false'], ['block cell2d', 'name cell2d', 'type recarray icell2d xc yc ncvert icvert', 'shape (nodes)', 'reader urword', 'optional false'], ['block cell2d', 'name icell2d', 'type integer', 'in_record true', 'tagged false', 'reader urword', 'optional false', 'numeric_index true'], ['block cell2d', 'name xc', 'type double precision', 'in_record true', 'tagged false', 'reader urword', 'optional false'], ['block cell2d', 'name yc', 'type double precision', 'in_record true', 'tagged false', 'reader urword', 'optional false'], ['block cell2d', 'name ncvert', 'type integer', 'in_record true', 'tagged false', 'reader urword', 'optional false'], ['block cell2d', 'name icvert', 'type integer', 'shape (ncvert)', 'in_record true', 'tagged false', 'reader urword', 'optional false', 'numeric_index true']] dfn_file_name = 'gwt-disu.dfn'

hwva = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

iac = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

idomain = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

ihc = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

ja = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

package_abbr = 'gwtdisu'

top = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

vertices = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

flopy.mf6.modflow.mfgwtdisv module

class ModflowGwtdisv(*model*, *loading_package=False*, *length_units=None*, *nogrb=None*, *xorigin=None*, *yorigin=None*, *angrot=None*, *nlay=None*, *ncpl=None*, *nvert=None*, *top=None*, *botm=None*, *idomain=None*, *vertices=None*, *cell2d=None*, *filename=None*, *pname=None*, ***kwargs*)

Bases: *MFPackage*

ModflowGwtdisv defines a disv package within a gwt6 model.

Parameters

- **model** (MFModel) – Model that this package is a part of. Package is automatically added to model when it is initialized.
- **loading_package** (*bool*) – Do not set this parameter. It is intended for debugging and internal processing purposes only.
- **length_units** (*string*) –
  - length_units (string) is the length units used for this model. Values can be "FEET", "METERS", or "CENTIMETERS". If not specified, the default is "UNKNOWN".
- **nogrb** (*boolean*) –
  - nogrb (boolean) keyword to deactivate writing of the binary grid file.
- **xorigin** (*double*) –
  - xorigin (double) x-position of the origin used for model grid vertices. This value should be provided in a real-world coordinate system. A default value of zero is assigned if not specified. The value for XORIGIN does not affect the model simulation, but it is written to the binary grid file so that postprocessors can locate the grid in space.
- **yorigin** (*double*) –
  - yorigin (double) y-position of the origin used for model grid vertices. This value should be provided in a real-world coordinate system. If not specified, then a default value

equal to zero is used. The value for YORIGIN does not affect the model simulation, but it is written to the binary grid file so that postprocessors can locate the grid in space.

- **angrot** (*double*) -
  - angrot (double) counter-clockwise rotation angle (in degrees) of the model grid coordinate system relative to a real-world coordinate system. If not specified, then a default value of 0.0 is assigned. The value for ANGROT does not affect the model simulation, but it is written to the binary grid file so that postprocessors can locate the grid in space.
- **nlay** (*integer*) -
  - nlay (integer) is the number of layers in the model grid.
- **ncpl** (*integer*) -
  - ncpl (integer) is the number of cells per layer. This is a constant value for the grid and it applies to all layers.
- **nvert** (*integer*) -
  - nvert (integer) is the total number of (x, y) vertex pairs used to characterize the horizontal configuration of the model grid.
- **top** (*[double]*) -
  - top (double) is the top elevation for each cell in the top model layer.
- **botm** (*[double]*) -
  - botm (double) is the bottom elevation for each cell.
- **idomain** (*[integer]*) -
  - idomain (integer) is an optional array that characterizes the existence status of a cell. If the IDOMAIN array is not specified, then all model cells exist within the solution. If the IDOMAIN value for a cell is 0, the cell does not exist in the simulation. Input and output values will be read and written for the cell, but internal to the program, the cell is excluded from the solution. If the IDOMAIN value for a cell is 1, the cell exists in the simulation. If the IDOMAIN value for a cell is -1, the cell does not exist in the simulation. Furthermore, the first existing cell above will be connected to the first existing cell below. This type of cell is referred to as a “vertical pass through” cell.
- **vertices** (*[iv, xv, yv]*) -
  - iv (integer) is the vertex number. Records in the VERTICES block must be listed in consecutive order from 1 to NVERT. This argument is an index variable, which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.
  - xv (double) is the x-coordinate for the vertex.

  - yv (double) is the y-coordinate for the vertex.

- **cell2d** (*[icell2d, xc, yc, ncvert, icvert]*) -
  - icell2d (integer) is the CELL2D number. Records in the CELL2D block must be listed in consecutive order from the first to the last. This argument is an index variable, which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.
  - xc (double) is the x-coordinate for the cell center.
  - yc (double) is the y-coordinate for the cell center.
  - ncvert (integer) is the number of vertices required to define the cell. There may be a different number of vertices for each cell.
  - icvert (integer) is an array of integer values containing vertex numbers (in the VERTICES block) used to define the cell. Vertices must be listed in clockwise order. Cells that are connected must share vertices. This argument is an index variable, which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.
- **filename** (*String*) - File name for this package.
- **pname** (*String*) - Package name for this package.
- **parent_file** (*MFPackage*) - Parent package file that references this package. Only needed for utility packages (mfutl*). For example, mfutllaktab package must have a mfgwflak package parent_file.

botm = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

cell2d = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

dfn = [['header'], ['block options', 'name length_units', 'type string', 'reader urword', 'optional true'], ['block options', 'name nogrb', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name xorigin', 'type double precision', 'reader urword', 'optional true'], ['block options', 'name yorigin', 'type double precision', 'reader urword', 'optional true'], ['block options', 'name angrot', 'type double precision', 'reader urword', 'optional true'], ['block dimensions', 'name nlay', 'type integer', 'reader urword', 'optional false'], ['block dimensions', 'name ncpl', 'type integer', 'reader urword', 'optional false'], ['block dimensions', 'name nvert', 'type integer', 'reader urword', 'optional false'], ['block griddata', 'name top', 'type double precision', 'shape (ncpl)', 'reader readarray'], ['block griddata', 'name botm', 'type double precision', 'shape (ncpl, nlay)', 'reader readarray', 'layered true'], ['block griddata', 'name idomain', 'type integer', 'shape (ncpl, nlay)', 'reader readarray', 'layered true', 'optional true'], ['block vertices', 'name vertices', 'type recarray iv xv yv', 'shape (nvert)', 'reader urword', 'optional false'], ['block vertices', 'name iv', 'type integer', 'in_record true', 'tagged false', 'reader urword', 'optional false', 'numeric_index true'], ['block vertices', 'name xv', 'type double precision', 'in_record true', 'tagged false', 'reader urword', 'optional false'], ['block vertices', 'name yv', 'type double precision', 'in_record true', 'tagged false', 'reader urword', 'optional false'], ['block cell2d', 'name cell2d', 'type recarray icell2d xc yc ncvert icvert', 'shape (ncpl)', 'reader urword', 'optional false'], ['block cell2d', 'name icell2d', 'type integer', 'in_record true', 'tagged false', 'reader urword', 'optional false', 'numeric_index true'], ['block cell2d', 'name xc', 'type double precision', 'in_record true', 'tagged false', 'reader urword', 'optional false'], ['block cell2d', 'name yc', 'type double precision', 'in_record true', 'tagged false', 'reader urword', 'optional false'], ['block cell2d', 'name ncvert', 'type integer', 'in_record true', 'tagged false', 'reader urword', 'optional false'], ['block cell2d', 'name icvert', 'type integer', 'shape (ncvert)', 'in_record true', 'tagged false', 'reader urword', 'optional false', 'numeric_index true']]

dfn_file_name = 'gwt-disv.dfn'

idomain = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

package_abbr = 'gwtdisv'

top = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

vertices = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

flopy.mf6.modflow.mfgwtdsp module

class ModflowGwtdsp(*model*, *loading_package=False*, *xt3d_off=None*, *xt3d_rhs=None*, *diffc=None*, *alh=None*, *alv=None*, *ath1=None*, *ath2=None*, *atv=None*, *filename=None*, *pname=None*, ***kwargs*)

Bases: *MFPackage*

ModflowGwtdsp defines a dsp package within a gwt6 model.

Parameters

- **model** (MFModel) – Model that this package is a part of. Package is automatically added to model when it is initialized.
- **loading_package** (*bool*) – Do not set this parameter. It is intended for debugging and internal processing purposes only.

- **xt3d_off** (*boolean*) -
  - xt3d_off (boolean) deactivate the xt3d method and use the faster and less accurate approximation. This option may provide a fast and accurate solution under some circumstances, such as when flow aligns with the model grid, there is no mechanical dispersion, or when the longitudinal and transverse dispersivities are equal. This option may also be used to assess the computational demand of the XT3D approach by noting the run time differences with and without this option on.
- **xt3d_rhs** (*boolean*) -
  - xt3d_rhs (boolean) add xt3d terms to right-hand side, when possible. This option uses less memory, but may require more iterations.
- **diffc** (*[double]*) -
  - diffc (double) effective molecular diffusion coefficient.
- **alh** (*[double]*) -
  - alh (double) longitudinal dispersivity in horizontal direction. If flow is strictly horizontal, then this is the longitudinal dispersivity that will be used. If flow is not strictly horizontal or strictly vertical, then the longitudinal dispersivity is a function of both ALH and ALV. If mechanical dispersion is represented (by specifying any dispersivity values) then this array is required.
- **alv** (*[double]*) -
  - alv (double) longitudinal dispersivity in vertical direction. If flow is strictly vertical, then this is the longitudinal dispsersivity value that will be used. If flow is not strictly horizontal or strictly vertical, then the longitudinal dispersivity is a function of both ALH and ALV. If this value is not specified and mechanical dispersion is represented, then this array is set equal to ALH.
- **ath1** (*[double]*) -
  - ath1 (double) transverse dispersivity in horizontal direction. This is the transverse dispersivity value for the second ellipsoid axis. If flow is strictly horizontal and directed in the x direction (along a row for a regular grid), then this value controls spreading in the y direction. If mechanical dispersion is represented (by specifying any dispersivity values) then this array is required.
- **ath2** (*[double]*) -
  - ath2 (double) transverse dispersivity in horizontal direction. This is the transverse dispersivity value for the third ellipsoid axis. If flow is strictly horizontal and directed in the x direction (along a row for a regular grid), then this value controls spreading in the z direction. If this value is not specified and mechanical dispersion is represented, then this array is set equal to ATH1.

- **atv** (*[double]*) -
  - atv (double) transverse dispersivity when flow is in vertical direction. If flow is strictly vertical and directed in the z direction, then this value controls spreading in the x and y directions. If this value is not specified and mechanical dispersion is represented, then this array is set equal to ATH2.
- **filename** (*String*) - File name for this package.
- **pname** (*String*) - Package name for this package.
- **parent_file** (MFPackage) - Parent package file that references this package. Only needed for utility packages (mfutl*). For example, mfutllaktab package must have a mfgwflak package parent_file.

alh = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

alv = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

ath1 = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

ath2 = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

atv = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

dfn = [['header'], ['block options', 'name xt3d_off', 'type keyword', 'shape', 'reader urword', 'optional true'], ['block options', 'name xt3d_rhs', 'type keyword', 'shape', 'reader urword', 'optional true'], ['block griddata', 'name diffc', 'type double precision', 'shape (nodes)', 'reader readarray', 'layered true', 'optional true'], ['block griddata', 'name alh', 'type double precision', 'shape (nodes)', 'reader readarray', 'layered true', 'optional true'], ['block griddata', 'name alv', 'type double precision', 'shape (nodes)', 'reader readarray', 'layered true', 'optional true'], ['block griddata', 'name ath1', 'type double precision', 'shape (nodes)', 'reader readarray', 'layered true', 'optional true'], ['block griddata', 'name ath2', 'type double precision', 'shape (nodes)', 'reader readarray', 'layered true', 'optional true'], ['block griddata', 'name atv', 'type double precision', 'shape (nodes)', 'reader readarray', 'layered true', 'optional true']]

dfn_file_name = 'gwt-dsp.dfn'

diffc = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

package_abbr = 'gwtdsp'

flopy.mf6.modflow.mfgwtfmi module

class ModflowGwtfmi(*model*, *loading_package=False*, *save_flows=None*, *flow_imbalance_correction=None*, *packagedata=None*, *filename=None*, *pname=None*, ***kwargs*)

Bases: *MFPackage*

ModflowGwtfmi defines a fmi package within a gwt6 model.

Parameters

- **model** (MFModel) - Model that this package is a part of. Package is automatically added to model when it is initialized.

- **loading_package** (*bool*) - Do not set this parameter. It is intended for debugging and internal processing purposes only.
- **save_flows** (*boolean*) -
  - save_flows (boolean) keyword to indicate that FMI flow terms will be written to the file specified with "BUDGET FILEOUT" in Output Control.
- **flow_imbalance_correction** (*boolean*) -
  - flow_imbalance_correction (boolean) correct for an imbalance in flows by assuming that any residual flow error comes in or leaves at the concentration of the cell. When this option is activated, the GWT Model budget written to the listing file will contain two additional entries: FLOW-ERROR and FLOW-CORRECTION. These two entries will be equal but opposite in sign. The FLOW-CORRECTION term is a mass flow that is added to offset the error caused by an imprecise flow balance. If these terms are not relatively small, the flow model should be rerun with stricter convergence tolerances.
- **packagedata** (*[flowtype, fname]*) -
  - flowtype (string) is the word GWFBUDGET, GWFHEAD, GWFMOVER or the name of an advanced GWF stress package. If GWFBUDGET is specified, then the corresponding file must be a budget file from a previous GWF Model run. If an advanced GWF stress package name appears then the corresponding file must be the budget file saved by a LAK, SFR, MAW or UZF Package.
  - fname (string) is the name of the file containing flows. The path to the file should be included if the file is not located in the folder where the program was run.
- **filename** (*String*) - File name for this package.
- **pname** (*String*) - Package name for this package.
- **parent_file** (*MFPackage*) - Parent package file that references this package. Only needed for utility packages (mfutl*). For example, mfutllaktab package must have a mfgwflak package parent_file.

dfn = [['header'], ['block options', 'name save_flows', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name flow_imbalance_correction', 'type keyword', 'reader urword', 'optional true'], ['block packagedata', 'name packagedata', 'type recarray flowtype filein fname', 'reader urword', 'optional false'], ['block packagedata', 'name flowtype', 'in_record true', 'type string', 'tagged false', 'reader urword'], ['block packagedata', 'name filein', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block packagedata', 'name fname', 'in_record true', 'type string', 'preserve_case true', 'tagged false', 'reader urword']]

dfn_file_name = 'gwt-fmi.dfn'

package_abbr = 'gwtfmi'

packagedata = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

flopy.mf6.modflow.mfgwtgwt module

class ModflowGwtgwt(*simulation, loading_package=False, exgtype='GWT6-GWT6', exgmnamea=None, exgmnameb=None, gwfmodelname1=None, gwfmodelname2=None, auxiliary=None, boundnames=None, print_input=None, print_flows=None, save_flows=None, adv_scheme=None, dsp_xt3d_off=None, dsp_xt3d_rhs=None, filein=None, perioddata=None, observations=None, dev_interfacemodel_on=None, nexg=None, exchangedata=None, filename=None, pname=None, **kwargs*)

Bases: *MFPackage*

ModflowGwtgwt defines a gwtgwt package.

Parameters

- **simulation** (MFSimulation) - Simulation that this package is a part of. Package is automatically added to simulation when it is initialized.
- **loading_package** (*bool*) - Do not set this parameter. It is intended for debugging and internal processing purposes only.
- **exgtype** (*<string>*) -
  - is the exchange type (GWF-GWF or GWF-GWT).
- **exgmnamea** (*<string>*) -
  - is the name of the first model that is part of this exchange.
- **exgmnameb** (*<string>*) -
  - is the name of the second model that is part of this exchange.
- **gwfmodelname1** (*string*) -
  - gwfmodelname1 (string) keyword to specify name of first corresponding GWF Model. In the simulation name file, the GWT6-GWT6 entry contains names for GWT Models (exgmnamea and exgmnameb). The GWT Model with the name exgmnamea must correspond to the GWF Model with the name gwfmodelname1.
- **gwfmodelname2** (*string*) -
  - gwfmodelname2 (string) keyword to specify name of second corresponding GWF Model. In the simulation name file, the GWT6-GWT6 entry contains names for GWT Models (exgmnamea and exgmnameb). The GWT Model with the name exgmnameb must correspond to the GWF Model with the name gwfmodelname2.
- **auxiliary** (*[string]*) -
  - auxiliary (string) an array of auxiliary variable names. There is no limit on the number of auxiliary variables that can be provided. Most auxiliary variables will not be used by the GWF-GWF Exchange, but they will be available for use by other parts of the program. If an auxiliary variable with the name "ANGLDEGX" is found, then this information will be used as the angle (provided in degrees) between the connection face normal and the x axis, where a value of zero indicates that a normal vector points directly along the positive x axis. The connection face normal is a normal vector on the cell face

shared between the cell in model 1 and the cell in model 2 pointing away from the model 1 cell. Additional information on "ANGLDEGX" is provided in the description of the DISU Package. If an auxiliary variable with the name "CDIST" is found, then this information will be used as the straight-line connection distance, including the vertical component, between the two cell centers. Both ANGLDEGX and CDIST are required if specific discharge is calculated for either of the groundwater models.

- **boundnames** (*boolean*) -
  - boundnames (boolean) keyword to indicate that boundary names may be provided with the list of GWT Exchange cells.
- **print_input** (*boolean*) -
  - print_input (boolean) keyword to indicate that the list of exchange entries will be echoed to the listing file immediately after it is read.
- **print_flows** (*boolean*) -
  - print_flows (boolean) keyword to indicate that the list of exchange flow rates will be printed to the listing file for every stress period in which "SAVE BUDGET" is specified in Output Control.
- **save_flows** (*boolean*) -
  - save_flows (boolean) keyword to indicate that cell-by-cell flow terms will be written to the budget file for each model provided that the Output Control for the models are set up with the "BUDGET SAVE FILE" option.
- **adv_scheme** (*string*) -
  - adv_scheme (string) scheme used to solve the advection term. Can be upstream, central, or TVD. If not specified, upstream weighting is the default weighting scheme.
- **dsp_xt3d_off** (*boolean*) -
  - dsp_xt3d_off (boolean) deactivate the xt3d method for the dispersive flux and use the faster and less accurate approximation for this exchange.
- **dsp_xt3d_rhs** (*boolean*) -
  - dsp_xt3d_rhs (boolean) add xt3d dispersion terms to right-hand side, when possible, for this exchange.
- **filein** (*boolean*) -
  - filein (boolean) keyword to specify that an input filename is expected next.
- **perioddata** (*{varname:data} or perioddata data*) -
  - Contains data for the mvt package. Data can be stored in a dictionary containing data for the mvt package with variable names as keys and package data as values. Data just for

the perioddata variable is also acceptable. See mvt package documentation for more information.

- **observations** (*{varname:data} or continuous data*) -
  - Contains data for the obs package. Data can be stored in a dictionary containing data for the obs package with variable names as keys and package data as values. Data just for the observations variable is also acceptable. See obs package documentation for more information.
- **dev_interfacemodel_on** (*boolean*) -
  - dev_interfacemodel_on (boolean) activates the interface model mechanism for calculating the coefficients at (and possibly near) the exchange. This keyword should only be used for development purposes.
- **nexg** (*integer*) -
  - nexg (integer) keyword and integer value specifying the number of GWT-GWT exchanges.
- **exchangedata** (*[cellidm1, cellidm2, ihc, cl1, cl2, hwva, aux, boundname]*) -
  - cellidm1 ((integer, ...)) is the cellid of the cell in model 1 as specified in the simulation name file. For a structured grid that uses the DIS input file, CELLIDM1 is the layer, row, and column numbers of the cell. For a grid that uses the DISV input file, CELLIDM1 is the layer number and CELL2D number for the two cells. If the model uses the unstructured discretization (DISU) input file, then CELLIDM1 is the node number for the cell. This argument is an index variable, which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.
  - cellidm2 ((integer, ...)) is the cellid of the cell in model 2 as specified in the simulation name file. For a structured grid that uses the DIS input file, CELLIDM2 is the layer, row, and column numbers of the cell. For a grid that uses the DISV input file, CELLIDM2 is the layer number and CELL2D number for the two cells. If the model uses the unstructured discretization (DISU) input file, then CELLIDM2 is the node number for the cell. This argument is an index variable, which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.
  - ihc (integer) is an integer flag indicating the direction between node n and all of its m connections. If IHC = 0 then the connection is vertical. If IHC = 1 then the connection is horizontal. If IHC = 2 then the connection is horizontal for a vertically staggered grid.

- cl1 (double) is the distance between the center of cell 1 and the its shared face with cell 2.
- cl2 (double) is the distance between the center of cell 2 and the its shared face with cell 1.
- hwva (double) is the horizontal width of the flow connection between cell 1 and cell 2 if IHC > 0, or it is the area perpendicular to flow of the vertical connection between cell 1 and cell 2 if IHC = 0.
- aux (double) represents the values of the auxiliary variables for each GWTGWT Exchange. The values of auxiliary variables must be present for each exchange. The values must be specified in the order of the auxiliary variables specified in the OPTIONS block.
- boundname (string) name of the GWT Exchange cell. BOUNDNAME is an ASCII character variable that can contain as many as 40 characters. If BOUNDNAME contains spaces in it, then the entire name must be enclosed within single quotes.

• **filename** (*String*) - File name for this package.

• **pname** (*String*) - Package name for this package.

• **parent_file** (MFPackage) - Parent package file that references this package. Only needed for utility packages (mfutl*). For example, mfutllaktab package must have a mfgwflak package parent_file.

auxiliary = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

dfn = [['header', 'multi-package'], ['block options', 'name gwfmodelname1', 'type string', 'reader urword', 'optional false'], ['block options', 'name gwfmodelname2', 'type string', 'reader urword', 'optional false'], ['block options', 'name auxiliary', 'type string', 'shape (naux)', 'reader urword', 'optional true'], ['block options', 'name boundnames', 'type keyword', 'shape', 'reader urword', 'optional true'], ['block options', 'name print_input', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name print_flows', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name save_flows', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name adv_scheme', 'type string', 'valid upstream central tvd', 'reader urword', 'optional true'], ['block options', 'name dsp_xt3d_off', 'type keyword', 'shape', 'reader urword', 'optional true'], ['block options', 'name dsp_xt3d_rhs', 'type keyword', 'shape', 'reader urword', 'optional true'], ['block options', 'name filein', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name mvt_filerecord', 'type record mvt6 filein mvt6_filename', 'shape', 'reader urword', 'tagged true', 'optional true', 'construct_package mvt', 'construct_data perioddata', 'parameter_name perioddata'], ['block options', 'name mvt6', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name mvt6_filename', 'type string', 'preserve_case true', 'in_record true', 'tagged false', 'reader urword', 'optional false'], ['block options', 'name obs_filerecord', 'type record obs6 filein obs6_filename', 'shape', 'reader urword', 'tagged true', 'optional true', 'construct_package obs', 'construct_data continuous', 'parameter_name observations'], ['block options', 'name obs6', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name obs6_filename', 'type string', 'preserve_case true', 'in_record true', 'tagged false', 'reader urword', 'optional false'], ['block options', 'name dev_interfacemodel_on', 'type keyword', 'reader urword', 'optional true'], ['block dimensions', 'name nexg', 'type integer', 'reader urword', 'optional false'], ['block exchangedata', 'name exchangedata', 'type recarray cellidm1 cellidm2 ihc cl1 cl2 hwva aux boundname', 'reader urword', 'optional false'], ['block exchangedata', 'name cellidm1', 'type integer', 'in_record true', 'tagged false', 'reader urword', 'optional false', 'numeric_index true'], ['block exchangedata', 'name cellidm2', 'type integer', 'in_record true', 'tagged false', 'reader urword', 'optional false', 'numeric_index true'], ['block exchangedata', 'name ihc', 'type integer', 'in_record true', 'tagged false', 'reader urword', 'optional false'], ['block exchangedata', 'name cl1', 'type double precision', 'in_record true', 'tagged false', 'reader urword', 'optional false'], ['block exchangedata', 'name cl2', 'type double precision', 'in_record true', 'tagged false', 'reader urword', 'optional false'], ['block exchangedata', 'name hwva', 'type double precision', 'in_record true', 'tagged false', 'reader urword', 'optional false'], ['block exchangedata', 'name aux', 'type double precision', 'in_record true', 'tagged false', 'shape (naux)', 'reader urword', 'optional true'], ['block exchangedata', 'name boundname', 'type string', 'shape', 'tagged false', 'in_record true', 'reader urword', 'optional true']]

dfn_file_name = 'exg-gwtgwt.dfn'

exchangedata = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

mvt_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

obs_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

package_abbr = 'gwtgwt'

flopy.mf6.modflow.mfgwtic module

class ModflowGwtic(*model*, *loading_package=False*, *strt=0.0*, *filename=None*, *pname=None*, ***kwargs*)

Bases: *MFPackage*

ModflowGwtic defines a ic package within a gwt6 model.

Parameters

- **model** (MFModel) - Model that this package is a part of. Package is automatically added to model when it is initialized.
- **loading_package** (*bool*) - Do not set this parameter. It is intended for debugging and internal processing purposes only.
- **strt** (*[double]*) -
  - strt (double) is the initial (starting) concentration-that is, concentration at the beginning of the GWT Model simulation. STRT must be specified for all GWT Model simulations. One value is read for every model cell.
- **filename** (*String*) - File name for this package.
- **pname** (*String*) - Package name for this package.
- **parent_file** (MFPackage) - Parent package file that references this package. Only needed for utility packages (mfutl*). For example, mfutllaktab package must have a mfgwflak package parent_file.

dfn = [['header'], ['block griddata', 'name strt', 'type double precision', 'shape (nodes)', 'reader readarray', 'layered true', 'default_value 0.0']]

dfn_file_name = 'gwt-ic.dfn'

package_abbr = 'gwtic'

strt = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

flopy.mf6.modflow.mfgwtist module

class ModflowGwtist(*model*, *loading_package=False*, *save_flows=None*, *budget_filerecord=None*, *budgetcsv_filerecord=None*, *sorption=None*, *first_order_decay=None*, *zero_order_decay=None*, *cim_filerecord=None*, *cimprintrecord=None*, *porosity=None*, *volfrac=None*, *zetaim=None*, *cim=None*, *decay=None*, *decay_sorbed=None*, *bulk_density=None*, *distcoef=None*, *filename=None*, *pname=None*, ***kwargs*)

Bases: *MFPackage*

ModflowGwtist defines a ist package within a gwt6 model.

Parameters

- **model** (MFModel) - Model that this package is a part of. Package is automatically added to model when it is initialized.
- **loading_package** (*bool*) - Do not set this parameter. It is intended for debugging and internal processing purposes only.
- **save_flows** (*boolean*) -

  - save_flows (boolean) keyword to indicate that IST flow terms will be written to the file specified with "BUDGET FILEOUT" in Output Control.

- **budget_filerecord** (*[budgetfile]*) -
  - budgetfile (string) name of the binary output file to write budget information.
- **budgetcsv_filerecord** (*[budgetcsvfile]*) -
  - budgetcsvfile (string) name of the comma-separated value (CSV) output file to write budget summary information. A budget summary record will be written to this file for each time step of the simulation.
- **sorption** (*boolean*) -
  - sorption (boolean) is a text keyword to indicate that sorption will be activated. Use of this keyword requires that BULK_DENSITY and DISTCOEF are specified in the GRIDDATA block. The linear sorption isotherm is the only isotherm presently supported in the IST Package.
- **first_order_decay** (*boolean*) -
  - first_order_decay (boolean) is a text keyword to indicate that first- order decay will occur. Use of this keyword requires that DECAY and DECAY_SORBED (if sorption is active) are specified in the GRIDDATA block.
- **zero_order_decay** (*boolean*) -
  - zero_order_decay (boolean) is a text keyword to indicate that zero- order decay will occur. Use of this keyword requires that DECAY and DECAY_SORBED (if sorption is active) are specified in the GRIDDATA block.
- **cim_filerecord** (*[cimfile]*) -
  - cimfile (string) name of the output file to write immobile concentrations. This file is a binary file that has the same format and structure as a binary head and concentration file. The value for the text variable written to the file is CIM. Immobile domain concentrations will be written to this file at the same interval as mobile domain concentrations are saved, as specified in the GWT Model Output Control file.
- **cimprintrecord** (*[columns, width, digits, format]*) -
  - columns (integer) number of columns for writing data.
  - width (integer) width for writing each number.
  - digits (integer) number of digits to use for writing a number.
  - format (string) write format can be EXPONENTIAL, FIXED, GENERAL, or SCIENTIFIC.
- **porosity** (*[double]*) -
  - porosity (double) porosity of the immobile domain specified as the immobile domain pore volume per immobile domain volume.

- **volfrac** (*[double]*) -
  - volfrac (double) fraction of the cell volume that consists of this immobile domain. The sum of all immobile domain volume fractions must be less than one.
- **zetaim** (*[double]*) -
  - zetaim (double) mass transfer rate coefficient between the mobile and immobile domains, in dimensions of per time.
- **cim** (*[double]*) -
  - cim (double) initial concentration of the immobile domain in mass per length cubed. If CIM is not specified, then it is assumed to be zero.
- **decay** (*[double]*) -
  - decay (double) is the rate coefficient for first or zero-order decay for the aqueous phase of the immobile domain. A negative value indicates solute production. The dimensions of decay for first-order decay is one over time. The dimensions of decay for zero-order decay is mass per length cubed per time. Decay will have no effect on simulation results unless either first- or zero-order decay is specified in the options block.
- **decay_sorbed** (*[double]*) -
  - decay_sorbed (double) is the rate coefficient for first or zero-order decay for the sorbed phase of the immobile domain. A negative value indicates solute production. The dimensions of decay_sorbed for first-order decay is one over time. The dimensions of decay_sorbed for zero-order decay is mass of solute per mass of aquifer per time. If decay_sorbed is not specified and both decay and sorption are active, then the program will terminate with an error. decay_sorbed will have no effect on simulation results unless the SORPTION keyword and either first- or zero-order decay are specified in the options block.
- **bulk_density** (*[double]*) -
  - bulk_density (double) is the bulk density of this immobile domain in mass per length cubed. Bulk density is defined as the immobile domain solid mass per volume of the immobile domain. bulk_density is not required unless the SORPTION keyword is specified in the options block. If the SORPTION keyword is not specified in the options block, bulk_density will have no effect on simulation results.
- **distcoef** (*[double]*) -
  - distcoef (double) is the distribution coefficient for the equilibrium-controlled linear sorption isotherm in dimensions of length cubed per mass. distcoef is not required unless the SORPTION keyword is specified in the options block. If the SORPTION keyword is not specified in the options block, distcoef will have no effect on simulation results.

- **filename** (*String*) - File name for this package.
- **pname** (*String*) - Package name for this package.
- **parent_file** (MFPackage) - Parent package file that references this package. Only needed for utility packages (mfutl*). For example, mfutllaktab package must have a mfgwflak package parent_file.

budget_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

budgetcsv_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

bulk_density = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

cim = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

cim_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

cimprintrecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

decay = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

decay_sorbed = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

dfn = [['header'], ['block options', 'name save_flows', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name budget_filerecord', 'type record budget fileout budgetfile', 'shape', 'reader urword', 'tagged true', 'optional true'], ['block options', 'name budget', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name fileout', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name budgetfile', 'type string', 'preserve_case true', 'shape', 'in_record true', 'reader urword', 'tagged false', 'optional false'], ['block options', 'name budgetcsv_filerecord', 'type record budgetcsv fileout budgetcsvfile', 'shape', 'reader urword', 'tagged true', 'optional true'], ['block options', 'name budgetcsv', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name budgetcsvfile', 'type string', 'preserve_case true', 'shape', 'in_record true', 'reader urword', 'tagged false', 'optional false'], ['block options', 'name sorption', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name first_order_decay', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name zero_order_decay', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name cim_filerecord', 'type record cim fileout cimfile', 'shape', 'reader urword', 'tagged true', 'optional true'], ['block options', 'name cim', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name cimfile', 'type string', 'preserve_case true', 'shape', 'in_record true', 'reader urword', 'tagged false', 'optional false'], ['block options', 'name cimprintrecord', 'type record cim print_format formatrecord', 'shape', 'reader urword', 'optional true'], ['block options', 'name print_format', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name formatrecord', 'type record columns width digits format', 'shape', 'in_record true', 'reader urword', 'tagged', 'optional false'], ['block options', 'name columns', 'type integer', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional'], ['block options', 'name width', 'type integer', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional'], ['block options', 'name digits', 'type integer', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional'], ['block options', 'name format', 'type string', 'shape', 'in_record true', 'reader urword', 'tagged false', 'optional false'], ['block griddata', 'name porosity', 'type double precision', 'shape (nodes)', 'reader readarray', 'layered true'], ['block griddata', 'name volfrac', 'type double precision', 'shape (nodes)', 'reader readarray', 'layered true'], ['block griddata', 'name zetaim', 'type double precision', 'shape (nodes)', 'reader readarray', 'layered true'], ['block griddata', 'name cim', 'type double precision', 'shape (nodes)', 'reader readarray', 'optional true', 'layered true'], ['block griddata', 'name decay', 'type double precision', 'shape (nodes)', 'reader readarray', 'layered true', 'optional true'], ['block griddata', 'name decay_sorbed', 'type double precision', 'shape (nodes)', 'reader readarray', 'optional true', 'layered true'], ['block griddata', 'name bulk_density', 'type double precision', 'shape (nodes)', 'reader readarray', 'optional true', 'layered true'], ['block griddata', 'name distcoef', 'type double precision', 'shape (nodes)', 'reader readarray', 'optional true', 'layered true']]

dfn_file_name = 'gwt-ist.dfn'

distcoef = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

package_abbr = 'gwtist'

porosity = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

volfrac = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

zetaim = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

flopy.mf6.modflow.mfgwtlkt module

class ModflowGwtlkt(*model*, *loading_package=False*, *flow_package_name=None*, *auxiliary=None*, *flow_package_auxiliary_name=None*, *boundnames=None*, *print_input=None*, *print_concentration=None*, *print_flows=None*, *save_flows=None*, *concentration_filerecord=None*, *budget_filerecord=None*, *budgetcsv_filerecord=None*, *timeseries=None*, *observations=None*, *packagedata=None*, *lakeperioddata=None*, *filename=None*, *pname=None*, ***kwargs*)

Bases: *MFPackage*

ModflowGwtlkt defines a lkt package within a gwt6 model.

Parameters

- **model** (MFModel) - Model that this package is a part of. Package is automatically added to model when it is initialized.
- **loading_package** (*bool*) - Do not set this parameter. It is intended for debugging and internal processing purposes only.
- **flow_package_name** (*string*) -
  - flow_package_name (string) keyword to specify the name of the corresponding flow package. If not specified, then the corresponding flow package must have the same name as this advanced transport package (the name associated with this package in the GWT name file).
- **auxiliary** (*[string]*) -
  - auxiliary (string) defines an array of one or more auxiliary variable names. There is no limit on the number of auxiliary variables that can be provided on this line; however, lists of information provided in subsequent blocks must have a column of data for each auxiliary variable name defined here. The number of auxiliary variables detected on this line determines the value for naux. Comments cannot be provided anywhere on this line as they will be interpreted as auxiliary variable names. Auxiliary variables may not be used by the package, but they will be available for use by other parts of the program. The program will terminate with an error if auxiliary variables are specified on more than one line in the options block.
- **flow_package_auxiliary_name** (*string*) -
  - flow_package_auxiliary_name (string) keyword to specify the name of an auxiliary variable in the corresponding flow package. If specified, then the simulated concentrations from this advanced transport package will be copied into the auxiliary variable specified with this name. Note that the flow package must have an auxiliary variable with this name or the program will terminate with an error. If the flows

for this advanced transport package are read from a file, then this option will have no effect.

- **boundnames** (*boolean*) -
  - boundnames (boolean) keyword to indicate that boundary names may be provided with the list of lake cells.
- **print_input** (*boolean*) -
  - print_input (boolean) keyword to indicate that the list of lake information will be written to the listing file immediately after it is read.
- **print_concentration** (*boolean*) -
  - print_concentration (boolean) keyword to indicate that the list of lake concentration will be printed to the listing file for every stress period in which "CONCENTRATION PRINT" is specified in Output Control. If there is no Output Control option and PRINT_CONCENTRATION is specified, then concentration are printed for the last time step of each stress period.
- **print_flows** (*boolean*) -
  - print_flows (boolean) keyword to indicate that the list of lake flow rates will be printed to the listing file for every stress period time step in which "BUDGET PRINT" is specified in Output Control. If there is no Output Control option and "PRINT_FLOWS" is specified, then flow rates are printed for the last time step of each stress period.
- **save_flows** (*boolean*) -
  - save_flows (boolean) keyword to indicate that lake flow terms will be written to the file specified with "BUDGET FILEOUT" in Output Control.
- **concentration_filerecord** (*[concfile]*) -
  - concfile (string) name of the binary output file to write concentration information.
- **budget_filerecord** (*[budgetfile]*) -
  - budgetfile (string) name of the binary output file to write budget information.
- **budgetcsv_filerecord** (*[budgetcsvfile]*) -
  - budgetcsvfile (string) name of the comma-separated value (CSV) output file to write budget summary information. A budget summary record will be written to this file for each time step of the simulation.
- **timeseries** (*{varname:data} or timeseries data*) -
  - Contains data for the ts package. Data can be stored in a dictionary containing data for the ts package with variable names as keys and package data as values. Data just for the timeseries variable is also acceptable. See ts package documentation for more information.

- **observations** (*{varname:data} or continuous data*) -
  - Contains data for the obs package. Data can be stored in a dictionary containing data for the obs package with variable names as keys and package data as values. Data just for the observations variable is also acceptable. See obs package documentation for more information.
- **packagedata** (*[ifno, strt, aux, boundname]*) -
  - ifno (integer) integer value that defines the feature (lake) number associated with the specified PACKAGEDATA data on the line. IFNO must be greater than zero and less than or equal to NLAKES. Lake information must be specified for every lake or the program will terminate with an error. The program will also terminate with an error if information for a lake is specified more than once. This argument is an index variable, which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.
  - strt (double) real value that defines the starting concentration for the lake.
  - aux (double) represents the values of the auxiliary variables for each lake. The values of auxiliary variables must be present for each lake. The values must be specified in the order of the auxiliary variables specified in the OPTIONS block. If the package supports time series and the Options block includes a TIMESERIESFILE entry (see the "Time-Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
  - boundname (string) name of the lake cell. BOUNDNAME is an ASCII character variable that can contain as many as 40 characters. If BOUNDNAME contains spaces in it, then the entire name must be enclosed within single quotes.
- **lakeperioddata** (*[ifno, laksetting]*) -
  - ifno (integer) integer value that defines the feature (lake) number associated with the specified PERIOD data on the line. IFNO must be greater than zero and less than or equal to NLAKES. This argument is an index variable, which means that it should be treated as zero- based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.
  - laksetting (keystring) line of information that is parsed into a keyword and values. Keyword values that can be used to start the LAKSETTING string include: STATUS, CONCENTRATION, RAINFALL, EVAPORATION, RUNOFF, and AUXILIARY. These settings are used to assign the concentration of associated with the corresponding flow terms. Concentrations cannot be specified for all flow terms. For example, the Lake Package supports a "WITHDRAWAL" flow term. If this withdrawal term is active,

then water will be withdrawn from the lake at the calculated concentration of the lake.

status
[[string]]

* status (string) keyword option to define lake status. STATUS can be ACTIVE, INACTIVE, or CONSTANT. By default, STATUS is ACTIVE, which means that concentration will be calculated for the lake. If a lake is inactive, then there will be no solute mass fluxes into or out of the lake and the inactive value will be written for the lake concentration. If a lake is constant, then the concentration for the lake will be fixed at the user specified value.

concentration
[[string]]

* concentration (string) real or character value that defines the concentration for the lake. The specified CONCENTRATION is only applied if the lake is a constant concentration lake. If the Options block includes a TIMESERIESFILE entry (see the "Time-Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.

rainfall
[[string]]

* rainfall (string) real or character value that defines the rainfall solute concentration (ML^{-3}) for the lake. If the Options block includes a TIMESERIESFILE entry (see the "Time-Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.

evaporation
[[string]]

* evaporation (string) real or character value that defines the concentration of evaporated water (ML^{-3}) for the lake. If this concentration value is larger than the simulated concentration in the lake, then the evaporated water will be removed at the same concentration as the lake. If the Options block includes a TIMESERIESFILE entry (see the "Time-Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.

runoff
[[string]]

* runoff (string) real or character value that defines the concentration of runoff (ML^{-3}) for the lake. Value must be greater than or equal to zero. If

the Options block includes a TIMESERIESFILE entry (see the "Time-Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.

ext_inflow
[[string]]

* ext-inflow (string) real or character value that defines the concentration of external inflow (ML^{-3}) for the lake. Value must be greater than or equal to zero. If the Options block includes a TIMESERIESFILE entry (see the "Time- Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.

auxiliaryrecord
[[auxname, auxval]]

* auxname (string) name for the auxiliary variable to be assigned AUXVAL. AUXNAME must match one of the auxiliary variable names defined in the OPTIONS block. If AUXNAME does not match one of the auxiliary variable names defined in the OPTIONS block the data are ignored.
* auxval (double) value for the auxiliary variable. If the Options block includes a TIMESERIESFILE entry (see the "Time- Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.

- **filename** (*String*) - File name for this package.
- **pname** (*String*) - Package name for this package.
- **parent_file** (MFPackage) - Parent package file that references this package. Only needed for utility packages (mfutl*). For example, mfutllaktab package must have a mfgwflak package parent_file.

auxiliary = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

budget_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

budgetcsv_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

concentration_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

```
dfn = [['header', 'multi-package'], ['block options', 'name flow_package_name',
'type string', 'shape', 'reader urword', 'optional true'], ['block options', 'name
auxiliary', 'type string', 'shape (naux)', 'reader urword', 'optional true'],
['block options', 'name flow_package_auxiliary_name', 'type string', 'shape',
'reader urword', 'optional true'], ['block options', 'name boundnames', 'type
keyword', 'shape', 'reader urword', 'optional true'], ['block options', 'name
print_input', 'type keyword', 'reader urword', 'optional true'], ['block options',
'name print_concentration', 'type keyword', 'reader urword', 'optional true'],
['block options', 'name print_flows', 'type keyword', 'reader urword', 'optional
true'], ['block options', 'name save_flows', 'type keyword', 'reader urword',
'optional true'], ['block options', 'name concentration_filerecord', 'type record
concentration fileout concfile', 'shape', 'reader urword', 'tagged true', 'optional
true'], ['block options', 'name concentration', 'type keyword', 'shape', 'in_record
true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name
concfile', 'type string', 'preserve_case true', 'shape', 'in_record true', 'reader
urword', 'tagged false', 'optional false'], ['block options', 'name
budget_filerecord', 'type record budget fileout budgetfile', 'shape', 'reader
urword', 'tagged true', 'optional true'], ['block options', 'name budget', 'type
keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional
false'], ['block options', 'name fileout', 'type keyword', 'shape', 'in_record
true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name
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urword', 'tagged false', 'optional false'], ['block options', 'name
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'reader urword', 'tagged true', 'optional true'], ['block options', 'name
budgetcsv', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged
true', 'optional false'], ['block options', 'name budgetcsvfile', 'type string',
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'optional false'], ['block options', 'name ts_filerecord', 'type record ts6 filein
ts6_filename', 'shape', 'reader urword', 'tagged true', 'optional true',
'construct_package ts', 'construct_data timeseries', 'parameter_name timeseries'],
['block options', 'name ts6', 'type keyword', 'shape', 'in_record true', 'reader
urword', 'tagged true', 'optional false'], ['block options', 'name filein', 'type
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'in_record true', 'reader urword', 'optional false', 'tagged false'], ['block
options', 'name obs_filerecord', 'type record obs6 filein obs6_filename', 'shape',
'reader urword', 'tagged true', 'optional true', 'construct_package obs',
'construct_data continuous', 'parameter_name observations'], ['block options', 'name
obs6', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true',
'optional false'], ['block options', 'name obs6_filename', 'type string',
'preserve_case true', 'in_record true', 'tagged false', 'reader urword', 'optional
false'], ['block packagedata', 'name packagedata', 'type recarray ifno strt aux
boundname', 'shape (maxbound)', 'reader urword'], ['block packagedata', 'name ifno',
'type integer', 'shape', 'tagged false', 'in_record true', 'reader urword',
'numeric_index true'], ['block packagedata', 'name strt', 'type double precision',
'shape', 'tagged false', 'in_record true', 'reader urword'], ['block packagedata',
'name aux', 'type double precision', 'in_record true', 'tagged false', 'shape
(naux)', 'reader urword', 'time_series true', 'optional true'], ['block
packagedata', 'name boundname', 'type string', 'shape', 'tagged false', 'in_record
true', 'reader urword', 'optional true'], ['block period', 'name iper', 'type
integer', 'block_variable True', 'in_record true', 'tagged false', 'shape', 'valid',
'reader urword', 'optional false'], ['block period', 'name lakeperioddata', 'type
recarray ifno laksetting', 'shape', 'reader urword'], ['block period', 'name ifno',
'type integer', 'shape', 'tagged false', 'in_record true', 'reader urword',
'numeric_index true'], ['block period', 'name laksetting', 'type keystring status
concentration rainfall evaporation runoff ext-inflow auxiliaryrecord', 'shape',
'tagged false', 'in_record true', 'reader urword'], ['block period', 'name status',
'type string', 'shape', 'tagged true', 'in_record true', 'reader urword'], ['block
period', 'name concentration', 'type string', 'shape', 'tagged true', 'in_record
```

dfn_file_name = 'gwt-lkt.dfn'

lakeperioddata = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

obs_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

package_abbr = 'gwtlkt'

packagedata = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

ts_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

flopy.mf6.modflow.mfgwtmst module

class **ModflowGwtmst**(*model*, *loading_package=False*, *save_flows=None*, *first_order_decay=None*, *zero_order_decay=None*, *sorption=None*, *porosity=None*, *decay=None*, *decay_sorbed=None*, *bulk_density=None*, *distcoef=None*, *sp2=None*, *filename=None*, *pname=None*, ***kwargs*)

Bases: *MFPackage*

ModflowGwtmst defines a mst package within a gwt6 model.

Parameters

- **model** (MFModel) - Model that this package is a part of. Package is automatically added to model when it is initialized.
- **loading_package** (*bool*) - Do not set this parameter. It is intended for debugging and internal processing purposes only.
- **save_flows** (*boolean*) -
  - save_flows (boolean) keyword to indicate that MST flow terms will be written to the file specified with "BUDGET FILEOUT" in Output Control.
- **first_order_decay** (*boolean*) -
  - first_order_decay (boolean) is a text keyword to indicate that first- order decay will occur. Use of this keyword requires that DECAY and DECAY_SORBED (if sorption is active) are specified in the GRIDDATA block.
- **zero_order_decay** (*boolean*) -
  - zero_order_decay (boolean) is a text keyword to indicate that zero- order decay will occur. Use of this keyword requires that DECAY and DECAY_SORBED (if sorption is active) are specified in the GRIDDATA block.
- **sorption** (*string*) -
  - sorption (string) is a text keyword to indicate that sorption will be activated. Valid sorption options include LINEAR, FREUNDLICH, and LANGMUIR. Use of this keyword requires that BULK_DENSITY and DISTCOEF are specified in the GRIDDATA block. If sorption is specified as FREUNDLICH or LANGMUIR then SP2 is also required in the GRIDDATA block.
- **porosity** (*[double]*) -

  - porosity (double) is the mobile domain porosity, defined as the mobile domain pore volume per mobile domain volume. Additional information on porosity within the context of mobile and immobile domain transport simulations is included in the MODFLOW 6 Supplemental Technical Information document.

- **decay** (*[double]*) -
  - decay (double) is the rate coefficient for first or zero-order decay for the aqueous phase of the mobile domain. A negative value indicates solute production. The dimensions of decay for first-order decay is one over time. The dimensions of decay for zero-order decay is mass per length cubed per time. decay will have no effect on simulation results unless either first- or zero-order decay is specified in the options block.

- **decay_sorbed** (*[double]*) -
  - decay_sorbed (double) is the rate coefficient for first or zero-order decay for the sorbed phase of the mobile domain. A negative value indicates solute production. The dimensions of decay_sorbed for first-order decay is one over time. The dimensions of decay_sorbed for zero-order decay is mass of solute per mass of aquifer per time. If decay_sorbed is not specified and both decay and sorption are active, then the program will terminate with an error. decay_sorbed will have no effect on simulation results unless the SORPTION keyword and either first- or zero-order decay are specified in the options block.

- **bulk_density** (*[double]*) -
  - bulk_density (double) is the bulk density of the aquifer in mass per length cubed. bulk_density is not required unless the SORPTION keyword is specified. Bulk density is defined as the mobile domain solid mass per mobile domain volume. Additional information on bulk density is included in the MODFLOW 6 Supplemental Technical Information document.

- **distcoef** (*[double]*) -
  - distcoef (double) is the distribution coefficient for the equilibrium-controlled linear sorption isotherm in dimensions of length cubed per mass. distcoef is not required unless the SORPTION keyword is specified.

- **sp2** (*[double]*) -
  - sp2 (double) is the exponent for the Freundlich isotherm and the sorption capacity for the Langmuir isotherm.

- **filename** (*String*) - File name for this package.
- **pname** (*String*) - Package name for this package.
- **parent_file** (MFPackage) - Parent package file that references this package. Only needed for utility packages (mfutl*). For example, mfutllaktab package must have a mfgwflak package parent_file.

bulk_density = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

decay = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

decay_sorbed = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

dfn = [['header'], ['block options', 'name save_flows', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name first_order_decay', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name zero_order_decay', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name sorption', 'type string', 'valid linear freundlich langmuir', 'reader urword', 'optional true'], ['block griddata', 'name porosity', 'type double precision', 'shape (nodes)', 'reader readarray', 'layered true'], ['block griddata', 'name decay', 'type double precision', 'shape (nodes)', 'reader readarray', 'layered true', 'optional true'], ['block griddata', 'name decay_sorbed', 'type double precision', 'shape (nodes)', 'reader readarray', 'optional true', 'layered true'], ['block griddata', 'name bulk_density', 'type double precision', 'shape (nodes)', 'reader readarray', 'optional true', 'layered true'], ['block griddata', 'name distcoef', 'type double precision', 'shape (nodes)', 'reader readarray', 'layered true', 'optional true'], ['block griddata', 'name sp2', 'type double precision', 'shape (nodes)', 'reader readarray', 'layered true', 'optional true']]

dfn_file_name = 'gwt-mst.dfn'

distcoef = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

package_abbr = 'gwtmst'

porosity = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

sp2 = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

flopy.mf6.modflow.mfgwtmvt module

class **GwtmvtPackages**(*model_or_sim*, *parent*, *pkg_type*, *filerecord*, *package=None*, *package_class=None*)

Bases: *MFChildPackages*

GwtmvtPackages is a container class for the ModflowGwtmvt class.

initialize()

Initializes a new ModflowGwtmvt package removing any sibling child packages attached to the same parent package. See ModflowGwtmvt init documentation for definition of parameters.

append_package()

Adds a new ModflowGwtmvt package to the container. See ModflowGwtmvt init documentation for definition of parameters.

append_package(*print_input=None*, *print_flows=None*, *save_flows=None*, *budget_filerecord=None*, *budgetcsv_filerecord=None*, *filename=None*, *pname=None*)

initialize(*print_input=None*, *print_flows=None*, *save_flows=None*, *budget_filerecord=None*, *budgetcsv_filerecord=None*, *filename=None*, *pname=None*) package_abbr = 'gwtmvtpackages'

class ModflowGwtmvt(*parent_model_or_package*, *loading_package=False*, *print_input=None*, *print_flows=None*, *save_flows=None*, *budget_filerecord=None*, *budgetcsv_filerecord=None*, *filename=None*, *pname=None*, ***kwargs*)

Bases: *MFPackage*

ModflowGwtmvt defines a mvt package within a gwt6 model.

Parameters

- **parent_model_or_package** (*MFModel/MFPackage*) – Parent_model_or_package that this package is a part of. Package is automatically added to parent_model_or_package when it is initialized.
- **loading_package** (*bool*) – Do not set this parameter. It is intended for debugging and internal processing purposes only.
- **print_input** (*boolean*) –
  - print_input (boolean) keyword to indicate that the list of mover information will be written to the listing file immediately after it is read.
- **print_flows** (*boolean*) –
  - print_flows (boolean) keyword to indicate that the list of lake flow rates will be printed to the listing file for every stress period time step in which "BUDGET PRINT" is specified in Output Control. If there is no Output Control option and "PRINT_FLOWS" is specified, then flow rates are printed for the last time step of each stress period.
- **save_flows** (*boolean*) –
  - save_flows (boolean) keyword to indicate that lake flow terms will be written to the file specified with "BUDGET FILEOUT" in Output Control.
- **budget_filerecord** (*[budgetfile]*) –
  - budgetfile (string) name of the binary output file to write budget information.
- **budgetcsv_filerecord** (*[budgetcsvfile]*) –
  - budgetcsvfile (string) name of the comma-separated value (CSV) output file to write budget summary information. A budget summary record will be written to this file for each time step of the simulation.
- **filename** (*String*) – File name for this package.
- **pname** (*String*) – Package name for this package.
- **parent_file** (*MFPackage*) – Parent package file that references this package. Only needed for utility packages (mfutl*). For example, mfutllaktab package must have a mfgwflak package parent_file.

budget_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

budgetcsv_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

dfn = [['header'], ['block options', 'name print_input', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name print_flows', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name save_flows', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name budget_filerecord', 'type record budget fileout budgetfile', 'shape', 'reader urword', 'tagged true', 'optional true'], ['block options', 'name budget', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name fileout', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name budgetfile', 'type string', 'preserve_case true', 'shape', 'in_record true', 'reader urword', 'tagged false', 'optional false'], ['block options', 'name budgetcsv_filerecord', 'type record budgetcsv fileout budgetcsvfile', 'shape', 'reader urword', 'tagged true', 'optional true'], ['block options', 'name budgetcsv', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name budgetcsvfile', 'type string', 'preserve_case true', 'shape', 'in_record true', 'reader urword', 'tagged false', 'optional false']]

dfn_file_name = 'gwt-mvt.dfn'

package_abbr = 'gwtmvt'

flopy.mf6.modflow.mfgwtmwt module

class ModflowGwtmwt(*model*, *loading_package=False*, *flow_package_name=None*, *auxiliary=None*, *flow_package_auxiliary_name=None*, *boundnames=None*, *print_input=None*, *print_concentration=None*, *print_flows=None*, *save_flows=None*, *concentration_filerecord=None*, *budget_filerecord=None*, *budgetcsv_filerecord=None*, *timeseries=None*, *observations=None*, *packagedata=None*, *mwtperioddata=None*, *filename=None*, *pname=None*, ***kwargs*)

Bases: *MFPackage*

ModflowGwtmwt defines a mwt package within a gwt6 model.

Parameters

- **model** (MFModel) – Model that this package is a part of. Package is automatically added to model when it is initialized.
- **loading_package** (*bool*) – Do not set this parameter. It is intended for debugging and internal processing purposes only.
- **flow_package_name** (*string*) –
  – flow_package_name (string) keyword to specify the name of the corresponding flow package. If not specified, then the corresponding flow package must have the same name as this advanced transport package (the name associated with this package in the GWT name file).
- **auxiliary** (*[string]*) –
  – auxiliary (string) defines an array of one or more auxiliary variable names. There is no limit on the number of auxiliary variables that can be provided on this line; however, lists of information provided in subsequent blocks must have a column of data for each auxiliary variable name defined

here. The number of auxiliary variables detected on this line determines the value for naux. Comments cannot be provided anywhere on this line as they will be interpreted as auxiliary variable names. Auxiliary variables may not be used by the package, but they will be available for use by other parts of the program. The program will terminate with an error if auxiliary variables are specified on more than one line in the options block.

- **flow_package_auxiliary_name** (*string*) -
  - flow_package_auxiliary_name (string) keyword to specify the name of an auxiliary variable in the corresponding flow package. If specified, then the simulated concentrations from this advanced transport package will be copied into the auxiliary variable specified with this name. Note that the flow package must have an auxiliary variable with this name or the program will terminate with an error. If the flows for this advanced transport package are read from a file, then this option will have no effect.
- **boundnames** (*boolean*) -
  - boundnames (boolean) keyword to indicate that boundary names may be provided with the list of well cells.
- **print_input** (*boolean*) -
  - print_input (boolean) keyword to indicate that the list of well information will be written to the listing file immediately after it is read.
- **print_concentration** (*boolean*) -
  - print_concentration (boolean) keyword to indicate that the list of well concentration will be printed to the listing file for every stress period in which "CONCENTRATION PRINT" is specified in Output Control. If there is no Output Control option and PRINT_CONCENTRATION is specified, then concentration are printed for the last time step of each stress period.
- **print_flows** (*boolean*) -
  - print_flows (boolean) keyword to indicate that the list of well flow rates will be printed to the listing file for every stress period time step in which "BUDGET PRINT" is specified in Output Control. If there is no Output Control option and "PRINT_FLOWS" is specified, then flow rates are printed for the last time step of each stress period.
- **save_flows** (*boolean*) -
  - save_flows (boolean) keyword to indicate that well flow terms will be written to the file specified with "BUDGET FILEOUT" in Output Control.
- **concentration_filerecord** (*[concfile]*) -
  - concfile (string) name of the binary output file to write concentration information.

- **budget_filerecord** (*[budgetfile]*) -
  - budgetfile (string) name of the binary output file to write budget information.
- **budgetcsv_filerecord** (*[budgetcsvfile]*) -
  - budgetcsvfile (string) name of the comma-separated value (CSV) output file to write budget summary information. A budget summary record will be written to this file for each time step of the simulation.
- **timeseries** (*{varname:data} or timeseries data*) -
  - Contains data for the ts package. Data can be stored in a dictionary containing data for the ts package with variable names as keys and package data as values. Data just for the timeseries variable is also acceptable. See ts package documentation for more information.
- **observations** (*{varname:data} or continuous data*) -
  - Contains data for the obs package. Data can be stored in a dictionary containing data for the obs package with variable names as keys and package data as values. Data just for the observations variable is also acceptable. See obs package documentation for more information.
- **packagedata** (*[ifno, strt, aux, boundname]*) -
  - ifno (integer) integer value that defines the feature (well) number associated with the specified PACKAGEDATA data on the line. IFNO must be greater than zero and less than or equal to NMAWWELLS. Well information must be specified for every well or the program will terminate with an error. The program will also terminate with an error if information for a well is specified more than once. This argument is an index variable, which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.
  - strt (double) real value that defines the starting concentration for the well.
  - aux (double) represents the values of the auxiliary variables for each well. The values of auxiliary variables must be present for each well. The values must be specified in the order of the auxiliary variables specified in the OPTIONS block. If the package supports time series and the Options block includes a TIMESERIESFILE entry (see the "Time-Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
  - boundname (string) name of the well cell. BOUNDNAME is an ASCII character variable that can contain as many as 40 characters. If BOUNDNAME contains spaces in it, then the entire name must be enclosed within single quotes.
- **mwtperioddata** (*[ifno, mwtsetting]*) -

- ifno (integer) integer value that defines the feature (well) number associated with the specified PERIOD data on the line. IFNO must be greater than zero and less than or equal to NMAWWELLS. This argument is an index variable, which means that it should be treated as zero- based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.
- mwtsetting (keystring) line of information that is parsed into a keyword and values. Keyword values that can be used to start the MWTSETTING string include: STATUS, CONCENTRATION, RAINFALL, EVAPORATION, RUNOFF, and AUXILIARY. These settings are used to assign the concentration associated with the corresponding flow terms. Concentrations cannot be specified for all flow terms. For example, the Multi-Aquifer Well Package supports a "WITHDRAWAL" flow term. If this withdrawal term is active, then water will be withdrawn from the well at the calculated concentration of the well.

  status
  [[string]]

  * status (string) keyword option to define well status. STATUS can be ACTIVE, INACTIVE, or CONSTANT. By default, STATUS is ACTIVE, which means that concentration will be calculated for the well. If a well is inactive, then there will be no solute mass fluxes into or out of the well and the inactive value will be written for the well concentration. If a well is constant, then the concentration for the well will be fixed at the user specified value.

  concentration
  [[string]]

  * concentration (string) real or character value that defines the concentration for the well. The specified CONCENTRATION is only applied if the well is a constant concentration well. If the Options block includes a TIMESERIESFILE entry (see the "Time-Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.

  rate
  [[string]]

  * rate (string) real or character value that defines the injection solute concentration (ML^{-3}) for the well. If the Options block includes a TIMESERIESFILE entry (see the "Time-Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.

  auxiliaryrecord
  [[auxname, auxval]]

      * auxname (string) name for the auxiliary variable to be assigned AUXVAL. AUXNAME must match one of the auxiliary variable names defined in the OPTIONS block. If AUXNAME does not match one of the auxiliary variable names defined in the OPTIONS block the data are ignored.
      * auxval (double) value for the auxiliary variable. If the Options block includes a TIMESERIESFILE entry (see the "Time- Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.

- **filename** (*String*) - File name for this package.
- **pname** (*String*) - Package name for this package.
- **parent_file** (MFPackage) - Parent package file that references this package. Only needed for utility packages (mfutl*). For example, mfutllaktab package must have a mfgwflak package parent_file.

auxiliary = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

budget_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

budgetcsv_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

concentration_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

dfn = [['header', 'multi-package'], ['block options', 'name flow_package_name', 'type string', 'shape', 'reader urword', 'optional true'], ['block options', 'name auxiliary', 'type string', 'shape (naux)', 'reader urword', 'optional true'], ['block options', 'name flow_package_auxiliary_name', 'type string', 'shape', 'reader urword', 'optional true'], ['block options', 'name boundnames', 'type keyword', 'shape', 'reader urword', 'optional true'], ['block options', 'name print_input', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name print_concentration', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name print_flows', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name save_flows', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name concentration_filerecord', 'type record concentration fileout concfile', 'shape', 'reader urword', 'tagged true', 'optional true'], ['block options', 'name concentration', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name concfile', 'type string', 'preserve_case true', 'shape', 'in_record true', 'reader urword', 'tagged false', 'optional false'], ['block options', 'name budget_filerecord', 'type record budget fileout budgetfile', 'shape', 'reader urword', 'tagged true', 'optional true'], ['block options', 'name budget', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name fileout', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name budgetfile', 'type string', 'preserve_case true', 'shape', 'in_record true', 'reader urword', 'tagged false', 'optional false'], ['block options', 'name budgetcsv_filerecord', 'type record budgetcsv fileout budgetcsvfile', 'shape', 'reader urword', 'tagged true', 'optional true'], ['block options', 'name budgetcsv', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name budgetcsvfile', 'type string', 'preserve_case true', 'shape', 'in_record true', 'reader urword', 'tagged false', 'optional false'], ['block options', 'name ts_filerecord', 'type record ts6 filein ts6_filename', 'shape', 'reader urword', 'tagged true', 'optional true', 'construct_package ts', 'construct_data timeseries', 'parameter_name timeseries'], ['block options', 'name ts6', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name filein', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name ts6_filename', 'type string', 'preserve_case true', 'in_record true', 'reader urword', 'optional false', 'tagged false'], ['block options', 'name obs_filerecord', 'type record obs6 filein obs6_filename', 'shape', 'reader urword', 'tagged true', 'optional true', 'construct_package obs', 'construct_data continuous', 'parameter_name observations'], ['block options', 'name obs6', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name obs6_filename', 'type string', 'preserve_case true', 'in_record true', 'tagged false', 'reader urword', 'optional false'], ['block packagedata', 'name packagedata', 'type recarray ifno strt aux boundname', 'shape (maxbound)', 'reader urword'], ['block packagedata', 'name ifno', 'type integer', 'shape', 'tagged false', 'in_record true', 'reader urword', 'numeric_index true'], ['block packagedata', 'name strt', 'type double precision', 'shape', 'tagged false', 'in_record true', 'reader urword'], ['block packagedata', 'name aux', 'type double precision', 'in_record true', 'tagged false', 'shape (naux)', 'reader urword', 'time_series true', 'optional true'], ['block packagedata', 'name boundname', 'type string', 'shape', 'tagged false', 'in_record true', 'reader urword', 'optional true'], ['block period', 'name iper', 'type integer', 'block_variable True', 'in_record true', 'tagged false', 'shape', 'valid', 'reader urword', 'optional false'], ['block period', 'name mwtperioddata', 'type recarray ifno mwtsetting', 'shape', 'reader urword'], ['block period', 'name ifno', 'type integer', 'shape', 'tagged false', 'in_record true', 'reader urword', 'numeric_index true'], ['block period', 'name mwtsetting', 'type keystring status concentration rate auxiliaryrecord', 'shape', 'tagged false', 'in_record true', 'reader urword'], ['block period', 'name status', 'type string', 'shape', 'tagged true', 'in_record true', 'reader urword'], ['block period', 'name concentration', 'type string', 'shape', 'tagged true', 'in_record true', 'time_series true', 'reader dfn_file_name = 'gwt-mwt.dfn'

mwtperioddata = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

obs_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

package_abbr = 'gwtmwt'

packagedata = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

ts_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

flopy.mf6.modflow.mfgwtnam module

class **ModflowGwtnam**(*model*, *loading_package=False*, *list=None*, *print_input=None*, *print_flows=None*, *save_flows=None*, *packages=None*, *filename=None*, *pname=None*, ***kwargs*)

Bases: *MFPackage*

ModflowGwtnam defines a nam package within a gwt6 model.

Parameters

- **model** (MFModel) – Model that this package is a part of. Package is automatically added to model when it is initialized.
- **loading_package** (*bool*) – Do not set this parameter. It is intended for debugging and internal processing purposes only.
- **list** (*string*) –
  - list (string) is name of the listing file to create for this GWT model. If not specified, then the name of the list file will be the basename of the GWT model name file and the '.lst' extension. For example, if the GWT name file is called "my.model.nam" then the list file will be called "my.model.lst".
- **print_input** (*boolean*) –
  - print_input (boolean) keyword to indicate that the list of all model stress package information will be written to the listing file immediately after it is read.
- **print_flows** (*boolean*) –
  - print_flows (boolean) keyword to indicate that the list of all model package flow rates will be printed to the listing file for every stress period time step in which "BUDGET PRINT" is specified in Output Control. If there is no Output Control option and "PRINT_FLOWS" is specified, then flow rates are printed for the last time step of each stress period.
- **save_flows** (*boolean*) –
  - save_flows (boolean) keyword to indicate that all model package flow terms will be written to the file specified with "BUDGET FILEOUT" in Output Control.
- **packages** (*[ftype, fname, pname]*) –

   - ftype (string) is the file type, which must be one of the following character values shown in table in mf6io.pdf. Ftype may be entered in any combination of uppercase and lowercase.
   - fname (string) is the name of the file containing the package input. The path to the file should be included if the file is not located in the folder where the program was run.
   - pname (string) is the user-defined name for the package. PNAME is restricted to 16 characters. No spaces are allowed in PNAME. PNAME character values are read and stored by the program for stress packages only. These names may be useful for labeling purposes when multiple stress packages of the same type are located within a single GWT Model. If PNAME is specified for a stress package, then PNAME will be used in the flow budget table in the listing file; it will also be used for the text entry in the cell-by-cell budget file. PNAME is case insensitive and is stored in all upper case letters.

- **filename** (*String*) - File name for this package.
- **pname** (*String*) - Package name for this package.
- **parent_file** (MFPackage) - Parent package file that references this package. Only needed for utility packages (mfutl*). For example, mfutllaktab package must have a mfgwflak package parent_file.

dfn = [['header'], ['block options', 'name list', 'type string', 'reader urword', 'optional true', 'preserve_case true'], ['block options', 'name print_input', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name print_flows', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name save_flows', 'type keyword', 'reader urword', 'optional true'], ['block packages', 'name packages', 'type recarray ftype fname pname', 'reader urword', 'optional false'], ['block packages', 'name ftype', 'in_record true', 'type string', 'tagged false', 'reader urword'], ['block packages', 'name fname', 'in_record true', 'type string', 'preserve_case true', 'tagged false', 'reader urword'], ['block packages', 'name pname', 'in_record true', 'type string', 'tagged false', 'reader urword', 'optional true']]

dfn_file_name = 'gwt-nam.dfn'

package_abbr = 'gwtnam'

packages = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

flopy.mf6.modflow.mfgwtoc module

class ModflowGwtoc(*model*, *loading_package=False*, *budget_filerecord=None*, *budgetcsv_filerecord=None*, *concentration_filerecord=None*, *concentrationprintrecord=None*, *saverecord=None*, *printrecord=None*, *filename=None*, *pname=None*, ***kwargs*)

Bases: *MFPackage*

ModflowGwtoc defines a oc package within a gwt6 model.

Parameters

- **model** (MFModel) - Model that this package is a part of. Package is automatically added to model when it is initialized.

- **loading_package** (*bool*) - Do not set this parameter. It is intended for debugging and internal processing purposes only.
- **budget_filerecord** (*[budgetfile]*) -
  - budgetfile (string) name of the output file to write budget information.
- **budgetcsv_filerecord** (*[budgetcsvfile]*) -
  - budgetcsvfile (string) name of the comma-separated value (CSV) output file to write budget summary information. A budget summary record will be written to this file for each time step of the simulation.
- **concentration_filerecord** (*[concentrationfile]*) -
  - concentrationfile (string) name of the output file to write conc information.
- **concentrationprintrecord** (*[columns, width, digits, format]*) -
  - columns (integer) number of columns for writing data.
  - width (integer) width for writing each number.
  - digits (integer) number of digits to use for writing a number.
  - format (string) write format can be EXPONENTIAL, FIXED, GENERAL, or SCIENTIFIC.
- **saverecord** (*[rtype, ocsetting]*) -
  - rtype (string) type of information to save or print. Can be BUDGET or CONCENTRATION.
  - ocsetting (keystring) specifies the steps for which the data will be saved.

    all
      [[keyword]]
      * all (keyword) keyword to indicate save for all time steps in period.

    first
      [[keyword]]
      * first (keyword) keyword to indicate save for first step in period. This keyword may be used in conjunction with other keywords to print or save results for multiple time steps.

    last
      [[keyword]]
      * last (keyword) keyword to indicate save for last step in period. This keyword may be used in conjunction with other keywords to print or save results for multiple time steps.

    frequency
      [[integer]]

      * frequency (integer) save at the specified time step frequency. This keyword may be used in conjunction with other keywords to print or save results for multiple time steps.

    steps
      [[integer]]

      * steps (integer) save for each step specified in STEPS. This keyword may be used in conjunction with other keywords to print or save results for multiple time steps.

- **printrecord** (*[rtype, ocsetting]*) -
  - rtype (string) type of information to save or print. Can be BUDGET or CONCENTRATION.
  - ocsetting (keystring) specifies the steps for which the data will be saved.

    all
      [[keyword]]

      * all (keyword) keyword to indicate save for all time steps in period.

    first
      [[keyword]]

      * first (keyword) keyword to indicate save for first step in period. This keyword may be used in conjunction with other keywords to print or save results for multiple time steps.

    last
      [[keyword]]

      * last (keyword) keyword to indicate save for last step in period. This keyword may be used in conjunction with other keywords to print or save results for multiple time steps.

    frequency
      [[integer]]

      * frequency (integer) save at the specified time step frequency. This keyword may be used in conjunction with other keywords to print or save results for multiple time steps.

    steps
      [[integer]]

      * steps (integer) save for each step specified in STEPS. This keyword may be used in conjunction with other keywords to print or save results for multiple time steps.

- **filename** (*String*) - File name for this package.
- **pname** (*String*) - Package name for this package.

- **parent_file** (MFPackage) - Parent package file that references this package. Only needed for utility packages (mfutl*). For example, mfutllaktab package must have a mfgwflak package parent_file.

budget_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

budgetcsv_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

concentration_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

concentrationprintrecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

dfn = [['header'], ['block options', 'name budget_filerecord', 'type record budget fileout budgetfile', 'shape', 'reader urword', 'tagged true', 'optional true'], ['block options', 'name budget', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name fileout', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name budgetfile', 'type string', 'preserve_case true', 'shape', 'in_record true', 'reader urword', 'tagged false', 'optional false'], ['block options', 'name budgetcsv_filerecord', 'type record budgetcsv fileout budgetcsvfile', 'shape', 'reader urword', 'tagged true', 'optional true'], ['block options', 'name budgetcsv', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name budgetcsvfile', 'type string', 'preserve_case true', 'shape', 'in_record true', 'reader urword', 'tagged false', 'optional false'], ['block options', 'name concentration_filerecord', 'type record concentration fileout concentrationfile', 'shape', 'reader urword', 'tagged true', 'optional true'], ['block options', 'name concentration', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name concentrationfile', 'type string', 'preserve_case true', 'shape', 'in_record true', 'reader urword', 'tagged false', 'optional false'], ['block options', 'name concentrationprintrecord', 'type record concentration print_format formatrecord', 'shape', 'reader urword', 'optional true'], ['block options', 'name print_format', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name formatrecord', 'type record columns width digits format', 'shape', 'in_record true', 'reader urword', 'tagged', 'optional false'], ['block options', 'name columns', 'type integer', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional'], ['block options', 'name width', 'type integer', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional'], ['block options', 'name digits', 'type integer', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional'], ['block options', 'name format', 'type string', 'shape', 'in_record true', 'reader urword', 'tagged false', 'optional false'], ['block period', 'name iper', 'type integer', 'block_variable True', 'in_record true', 'tagged false', 'shape', 'valid', 'reader urword', 'optional false'], ['block period', 'name saverecord', 'type record save rtype ocsetting', 'shape', 'reader urword', 'tagged false', 'optional true'], ['block period', 'name save', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block period', 'name printrecord', 'type record print rtype ocsetting', 'shape', 'reader urword', 'tagged false', 'optional true'], ['block period', 'name print', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block period', 'name rtype', 'type string', 'shape', 'in_record true', 'reader urword', 'tagged false', 'optional false'], ['block period', 'name ocsetting', 'type keystring all first last frequency steps', 'shape', 'tagged false', 'in_record true', 'reader urword'], ['block period', 'name all', 'type keyword', 'shape', 'in_record true', 'reader urword'], ['block period', 'name first', 'type keyword', 'shape', 'in_record true', 'reader urword'], ['block period', 'name last', 'type keyword', 'shape', 'in_record true', 'reader urword'], ['block period', 'name frequency', 'type integer', 'shape', 'tagged true', 'in_record true', 'reader urword'], ['block period', 'name steps', 'type integer', 'shape (<nstp)', 'tagged true', 'in_record true', 'reader urword']]

dfn_file_name = 'gwt-oc.dfn'

package_abbr = 'gwtoc'

printrecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

saverecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

flopy.mf6.modflow.mfgwtsft module

class ModflowGwtsft(*model*, *loading_package=False*, *flow_package_name=None*, *auxiliary=None*, *flow_package_auxiliary_name=None*, *boundnames=None*, *print_input=None*, *print_concentration=None*, *print_flows=None*, *save_flows=None*, *concentration_filerecord=None*, *budget_filerecord=None*, *budgetcsv_filerecord=None*, *timeseries=None*, *observations=None*, *packagedata=None*, *reachperioddata=None*, *filename=None*, *pname=None*, ***kwargs*)

Bases: *MFPackage*

ModflowGwtsft defines a sft package within a gwt6 model.

Parameters

- **model** (MFModel) - Model that this package is a part of. Package is automatically added to model when it is initialized.
- **loading_package** (*bool*) - Do not set this parameter. It is intended for debugging and internal processing purposes only.
- **flow_package_name** (*string*) -
  - flow_package_name (string) keyword to specify the name of the corresponding flow package. If not specified, then the corresponding flow package must have the same name as this advanced transport package (the name associated with this package in the GWT name file).
- **auxiliary** (*[string]*) -
  - auxiliary (string) defines an array of one or more auxiliary variable names. There is no limit on the number of auxiliary variables that can be provided on this line; however, lists of information provided in subsequent blocks must have a column of data for each auxiliary variable name defined here. The number of auxiliary variables detected on this line determines the value for naux. Comments cannot be provided anywhere on this line as they will be interpreted as auxiliary variable names. Auxiliary variables may not be used by the package, but they will be available for use by other parts of the program. The program will terminate with an error if auxiliary variables are specified on more than one line in the options block.
- **flow_package_auxiliary_name** (*string*) -
  - flow_package_auxiliary_name (string) keyword to specify the name of an auxiliary variable in the corresponding flow package. If specified, then the simulated concentrations from this advanced transport package will be copied into the auxiliary variable specified with this name. Note that the flow package must have an auxiliary variable with this name or the program will terminate with an error. If the flows for this advanced transport package are read from a file, then this option will have no effect.

- **boundnames** (*boolean*) -
  - boundnames (boolean) keyword to indicate that boundary names may be provided with the list of reach cells.
- **print_input** (*boolean*) -
  - print_input (boolean) keyword to indicate that the list of reach information will be written to the listing file immediately after it is read.
- **print_concentration** (*boolean*) -
  - print_concentration (boolean) keyword to indicate that the list of reach concentration will be printed to the listing file for every stress period in which "CONCENTRATION PRINT" is specified in Output Control. If there is no Output Control option and PRINT_CONCENTRATION is specified, then concentration are printed for the last time step of each stress period.
- **print_flows** (*boolean*) -
  - print_flows (boolean) keyword to indicate that the list of reach flow rates will be printed to the listing file for every stress period time step in which "BUDGET PRINT" is specified in Output Control. If there is no Output Control option and "PRINT_FLOWS" is specified, then flow rates are printed for the last time step of each stress period.
- **save_flows** (*boolean*) -
  - save_flows (boolean) keyword to indicate that reach flow terms will be written to the file specified with "BUDGET FILEOUT" in Output Control.
- **concentration_filerecord** (*[concfile]*) -
  - concfile (string) name of the binary output file to write concentration information.
- **budget_filerecord** (*[budgetfile]*) -
  - budgetfile (string) name of the binary output file to write budget information.
- **budgetcsv_filerecord** (*[budgetcsvfile]*) -
  - budgetcsvfile (string) name of the comma-separated value (CSV) output file to write budget summary information. A budget summary record will be written to this file for each time step of the simulation.
- **timeseries** (*{varname:data} or timeseries data*) -
  - Contains data for the ts package. Data can be stored in a dictionary containing data for the ts package with variable names as keys and package data as values. Data just for the timeseries variable is also acceptable. See ts package documentation for more information.
- **observations** (*{varname:data} or continuous data*) -

  - Contains data for the obs package. Data can be stored in a dictionary containing data for the obs package with variable names as keys and package data as values. Data just for the observations variable is also acceptable. See obs package documentation for more information.

- **packagedata** (*[ifno, strt, aux, boundname]*) -
  - ifno (integer) integer value that defines the feature (reach) number associated with the specified PACKAGEDATA data on the line. IFNO must be greater than zero and less than or equal to NREACHES. Reach information must be specified for every reach or the program will terminate with an error. The program will also terminate with an error if information for a reach is specified more than once. This argument is an index variable, which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.
  - strt (double) real value that defines the starting concentration for the reach.
  - aux (double) represents the values of the auxiliary variables for each reach. The values of auxiliary variables must be present for each reach. The values must be specified in the order of the auxiliary variables specified in the OPTIONS block. If the package supports time series and the Options block includes a TIMESERIESFILE entry (see the "Time-Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.
  - boundname (string) name of the reach cell. BOUNDNAME is an ASCII character variable that can contain as many as 40 characters. If BOUNDNAME contains spaces in it, then the entire name must be enclosed within single quotes.
- **reachperioddata** (*[ifno, reachsetting]*) -
  - ifno (integer) integer value that defines the feature (reach) number associated with the specified PERIOD data on the line. IFNO must be greater than zero and less than or equal to NREACHES. This argument is an index variable, which means that it should be treated as zero- based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.
  - reachsetting (keystring) line of information that is parsed into a keyword and values. Keyword values that can be used to start the REACHSETTING string include: STATUS, CONCENTRATION, RAINFALL, EVAPORATION, RUNOFF, and AUXILIARY. These settings are used to assign the concentration of associated with the corresponding flow terms. Concentrations cannot be specified for all flow terms. For example, the Streamflow Package supports a "DIVERSION" flow term. Diversion water will be routed using the calculated concentration of the reach.

status
[[string]]

* status (string) keyword option to define reach status. STATUS can be ACTIVE, INACTIVE, or CONSTANT. By default, STATUS is ACTIVE, which means that concentration will be calculated for the reach. If a reach is inactive, then there will be no solute mass fluxes into or out of the reach and the inactive value will be written for the reach concentration. If a reach is constant, then the concentration for the reach will be fixed at the user specified value.

concentration
[[string]]

* concentration (string) real or character value that defines the concentration for the reach. The specified CONCENTRATION is only applied if the reach is a constant concentration reach. If the Options block includes a TIMESERIESFILE entry (see the "Time-Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.

rainfall
[[string]]

* rainfall (string) real or character value that defines the rainfall solute concentration (ML^{-3}) for the reach. If the Options block includes a TIMESERIESFILE entry (see the "Time-Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.

evaporation
[[string]]

* evaporation (string) real or character value that defines the concentration of evaporated water (ML^{-3}) for the reach. If this concentration value is larger than the simulated concentration in the reach, then the evaporated water will be removed at the same concentration as the reach. If the Options block includes a TIMESERIESFILE entry (see the "Time-Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.

runoff
[[string]]

* runoff (string) real or character value that defines the concentration of runoff (ML^{-3}) for the reach. Value must be greater than or equal to zero. If the Options block includes a TIMESERIESFILE entry

(see the "Time-Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.

inflow
[[string]]

* inflow (string) real or character value that defines the concentration of inflow (ML^{-3}) for the reach. Value must be greater than or equal to zero. If the Options block includes a TIMESERIESFILE entry (see the "Time-Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.

auxiliaryrecord
[[auxname, auxval]]

* auxname (string) name for the auxiliary variable to be assigned AUXVAL. AUXNAME must match one of the auxiliary variable names defined in the OPTIONS block. If AUXNAME does not match one of the auxiliary variable names defined in the OPTIONS block the data are ignored.

* auxval (double) value for the auxiliary variable. If the Options block includes a TIMESERIESFILE entry (see the "Time- Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.

- **filename** (*String*) - File name for this package.
- **pname** (*String*) - Package name for this package.
- **parent_file** (MFPackage) - Parent package file that references this package. Only needed for utility packages (mfutl*). For example, mfutllaktab package must have a mfgwflak package parent_file.

auxiliary = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

budget_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

budgetcsv_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

concentration_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

```
dfn = [['header', 'multi-package'], ['block options', 'name flow_package_name',
'type string', 'shape', 'reader urword', 'optional true'], ['block options', 'name
auxiliary', 'type string', 'shape (naux)', 'reader urword', 'optional true'],
['block options', 'name flow_package_auxiliary_name', 'type string', 'shape',
'reader urword', 'optional true'], ['block options', 'name boundnames', 'type
keyword', 'shape', 'reader urword', 'optional true'], ['block options', 'name
print_input', 'type keyword', 'reader urword', 'optional true'], ['block options',
'name print_concentration', 'type keyword', 'reader urword', 'optional true'],
['block options', 'name print_flows', 'type keyword', 'reader urword', 'optional
true'], ['block options', 'name save_flows', 'type keyword', 'reader urword',
'optional true'], ['block options', 'name concentration_filerecord', 'type record
concentration fileout concfile', 'shape', 'reader urword', 'tagged true', 'optional
true'], ['block options', 'name concentration', 'type keyword', 'shape', 'in_record
true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name
concfile', 'type string', 'preserve_case true', 'shape', 'in_record true', 'reader
urword', 'tagged false', 'optional false'], ['block options', 'name
budget_filerecord', 'type record budget fileout budgetfile', 'shape', 'reader
urword', 'tagged true', 'optional true'], ['block options', 'name budget', 'type
keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional
false'], ['block options', 'name fileout', 'type keyword', 'shape', 'in_record
true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name
budgetfile', 'type string', 'preserve_case true', 'shape', 'in_record true', 'reader
urword', 'tagged false', 'optional false'], ['block options', 'name
budgetcsv_filerecord', 'type record budgetcsv fileout budgetcsvfile', 'shape',
'reader urword', 'tagged true', 'optional true'], ['block options', 'name
budgetcsv', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged
true', 'optional false'], ['block options', 'name budgetcsvfile', 'type string',
'preserve_case true', 'shape', 'in_record true', 'reader urword', 'tagged false',
'optional false'], ['block options', 'name ts_filerecord', 'type record ts6 filein
ts6_filename', 'shape', 'reader urword', 'tagged true', 'optional true',
'construct_package ts', 'construct_data timeseries', 'parameter_name timeseries'],
['block options', 'name ts6', 'type keyword', 'shape', 'in_record true', 'reader
urword', 'tagged true', 'optional false'], ['block options', 'name filein', 'type
keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional
false'], ['block options', 'name ts6_filename', 'type string', 'preserve_case true',
'in_record true', 'reader urword', 'optional false', 'tagged false'], ['block
options', 'name obs_filerecord', 'type record obs6 filein obs6_filename', 'shape',
'reader urword', 'tagged true', 'optional true', 'construct_package obs',
'construct_data continuous', 'parameter_name observations'], ['block options', 'name
obs6', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true',
'optional false'], ['block options', 'name obs6_filename', 'type string',
'preserve_case true', 'in_record true', 'tagged false', 'reader urword', 'optional
false'], ['block packagedata', 'name packagedata', 'type recarray ifno strt aux
boundname', 'shape (maxbound)', 'reader urword'], ['block packagedata', 'name ifno',
'type integer', 'shape', 'tagged false', 'in_record true', 'reader urword',
'numeric_index true'], ['block packagedata', 'name strt', 'type double precision',
'shape', 'tagged false', 'in_record true', 'reader urword'], ['block packagedata',
'name aux', 'type double precision', 'in_record true', 'tagged false', 'shape
(naux)', 'reader urword', 'time_series true', 'optional true'], ['block
packagedata', 'name boundname', 'type string', 'shape', 'tagged false', 'in_record
true', 'reader urword', 'optional true'], ['block period', 'name iper', 'type
integer', 'block_variable True', 'in_record true', 'tagged false', 'shape', 'valid',
'reader urword', 'optional false'], ['block period', 'name reachperioddata', 'type
recarray ifno reachsetting', 'shape', 'reader urword'], ['block period', 'name
ifno', 'type integer', 'shape', 'tagged false', 'in_record true', 'reader urword',
'numeric_index true'], ['block period', 'name reachsetting', 'type keystring status
concentration rainfall evaporation runoff inflow auxiliaryrecord', 'shape', 'tagged
false', 'in_record true', 'reader urword'], ['block period', 'name status', 'type
string', 'shape', 'tagged true', 'in_record true', 'reader urword'], ['block
period', 'name concentration', 'type string', 'shape', 'tagged true', 'in_record
```

dfn_file_name = 'gwt-sft.dfn'

obs_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

package_abbr = 'gwtsft'

packagedata = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

reachperioddata = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

ts_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

flopy.mf6.modflow.mfgwtsrc module

class **ModflowGwtsrc**(*model*, *loading_package=False*, *auxiliary=None*, *auxmultname=None*, *boundnames=None*, *print_input=None*, *print_flows=None*, *save_flows=None*, *timeseries=None*, *observations=None*, *maxbound=None*, *stress_period_data=None*, *filename=None*, *pname=None*, ***kwargs*)

Bases: *MFPackage*

ModflowGwtsrc defines a src package within a gwt6 model.

Parameters

- **model** (MFModel) - Model that this package is a part of. Package is automatically added to model when it is initialized.
- **loading_package** (*bool*) - Do not set this parameter. It is intended for debugging and internal processing purposes only.
- **auxiliary** (*[string]*) -
  - auxiliary (string) defines an array of one or more auxiliary variable names. There is no limit on the number of auxiliary variables that can be provided on this line; however, lists of information provided in subsequent blocks must have a column of data for each auxiliary variable name defined here. The number of auxiliary variables detected on this line determines the value for naux. Comments cannot be provided anywhere on this line as they will be interpreted as auxiliary variable names. Auxiliary variables may not be used by the package, but they will be available for use by other parts of the program. The program will terminate with an error if auxiliary variables are specified on more than one line in the options block.
- **auxmultname** (*string*) -
  - auxmultname (string) name of auxiliary variable to be used as multiplier of mass loading rate.
- **boundnames** (*boolean*) -
  - boundnames (boolean) keyword to indicate that boundary names may be provided with the list of mass source cells.
- **print_input** (*boolean*) -

  - print_input (boolean) keyword to indicate that the list of mass source information will be written to the listing file immediately after it is read.
- **print_flows** (*boolean*) -
  - print_flows (boolean) keyword to indicate that the list of mass source flow rates will be printed to the listing file for every stress period time step in which "BUDGET PRINT" is specified in Output Control. If there is no Output Control option and "PRINT_FLOWS" is specified, then flow rates are printed for the last time step of each stress period.
- **save_flows** (*boolean*) -
  - save_flows (boolean) keyword to indicate that mass source flow terms will be written to the file specified with "BUDGET FILEOUT" in Output Control.
- **timeseries** (*{varname:data} or timeseries data*) -
  - Contains data for the ts package. Data can be stored in a dictionary containing data for the ts package with variable names as keys and package data as values. Data just for the timeseries variable is also acceptable. See ts package documentation for more information.
- **observations** (*{varname:data} or continuous data*) -
  - Contains data for the obs package. Data can be stored in a dictionary containing data for the obs package with variable names as keys and package data as values. Data just for the observations variable is also acceptable. See obs package documentation for more information.
- **maxbound** (*integer*) -
  - maxbound (integer) integer value specifying the maximum number of sources cells that will be specified for use during any stress period.
- **stress_period_data** (*[cellid, smassrate, aux, boundname]*) -
  - cellid ((integer, ...)) is the cell identifier, and depends on the type of grid that is used for the simulation. For a structured grid that uses the DIS input file, CELLID is the layer, row, and column. For a grid that uses the DISV input file, CELLID is the layer and CELL2D number. If the model uses the unstructured discretization (DISU) input file, CELLID is the node number for the cell. This argument is an index variable, which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.
  - smassrate (double) is the mass source loading rate. A positive value indicates addition of solute mass and a negative value indicates removal of solute mass. If the Options block includes a TIMESERIESFILE entry (see the "Time-Variable Input" section), values can be obtained from

a time series by entering the time-series name in place of a numeric value.

  – aux (double) represents the values of the auxiliary variables for each mass source. The values of auxiliary variables must be present for each mass source. The values must be specified in the order of the auxiliary variables specified in the OPTIONS block. If the package supports time series and the Options block includes a TIMESERIESFILE entry (see the "Time-Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.

  – boundname (string) name of the mass source cell. BOUNDNAME is an ASCII character variable that can contain as many as 40 characters. If BOUNDNAME contains spaces in it, then the entire name must be enclosed within single quotes.

- **filename** (*String*) - File name for this package.
- **pname** (*String*) - Package name for this package.
- **parent_file** (MFPackage) - Parent package file that references this package. Only needed for utility packages (mfutl*). For example, mfutllaktab package must have a mfgwflak package parent_file.

auxiliary = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

dfn = [['header'], ['block options', 'name auxiliary', 'type string', 'shape (naux)', 'reader urword', 'optional true'], ['block options', 'name auxmultname', 'type string', 'shape', 'reader urword', 'optional true'], ['block options', 'name boundnames', 'type keyword', 'shape', 'reader urword', 'optional true'], ['block options', 'name print_input', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name print_flows', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name save_flows', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name ts_filerecord', 'type record ts6 filein ts6_filename', 'shape', 'reader urword', 'tagged true', 'optional true', 'construct_package ts', 'construct_data timeseries', 'parameter_name timeseries'], ['block options', 'name ts6', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name filein', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name ts6_filename', 'type string', 'preserve_case true', 'in_record true', 'reader urword', 'optional false', 'tagged false'], ['block options', 'name obs_filerecord', 'type record obs6 filein obs6_filename', 'shape', 'reader urword', 'tagged true', 'optional true', 'construct_package obs', 'construct_data continuous', 'parameter_name observations'], ['block options', 'name obs6', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name obs6_filename', 'type string', 'preserve_case true', 'in_record true', 'tagged false', 'reader urword', 'optional false'], ['block dimensions', 'name maxbound', 'type integer', 'reader urword', 'optional false'], ['block period', 'name iper', 'type integer', 'block_variable True', 'in_record true', 'tagged false', 'shape', 'valid', 'reader urword', 'optional false'], ['block period', 'name stress_period_data', 'type recarray cellid smassrate aux boundname', 'shape (maxbound)', 'reader urword'], ['block period', 'name cellid', 'type integer', 'shape (ncelldim)', 'tagged false', 'in_record true', 'reader urword'], ['block period', 'name smassrate', 'type double precision', 'shape', 'tagged false', 'in_record true', 'reader urword', 'time_series true'], ['block period', 'name aux', 'type double precision', 'in_record true', 'tagged false', 'shape (naux)', 'reader urword', 'optional true', 'time_series true'], ['block period', 'name boundname', 'type string', 'shape', 'tagged false', 'in_record true', 'reader urword', 'optional true']]

dfn_file_name = 'gwt-src.dfn'

obs_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

package_abbr = 'gwtsrc'

stress_period_data = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

ts_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

flopy.mf6.modflow.mfgwtssm module

class **ModflowGwtssm**(*model*, *loading_package=False*, *print_flows=None*, *save_flows=None*, *sources=None*, *fileinput=None*, *filename=None*, *pname=None*, ***kwargs*)

Bases: *MFPackage*

ModflowGwtssm defines a ssm package within a gwt6 model.

Parameters

- **model** (MFModel) – Model that this package is a part of. Package is automatically added to model when it is initialized.

- **loading_package** (*bool*) - Do not set this parameter. It is intended for debugging and internal processing purposes only.
- **print_flows** (*boolean*) -
  - print_flows (boolean) keyword to indicate that the list of SSM flow rates will be printed to the listing file for every stress period time step in which "BUDGET PRINT" is specified in Output Control. If there is no Output Control option and "PRINT_FLOWS" is specified, then flow rates are printed for the last time step of each stress period.
- **save_flows** (*boolean*) -
  - save_flows (boolean) keyword to indicate that SSM flow terms will be written to the file specified with "BUDGET FILEOUT" in Output Control.
- **sources** (*[pname, srctype, auxname]*) -
  - pname (string) name of the flow package for which an auxiliary variable contains a source concentration. If this flow package is represented using an advanced transport package (SFT, LKT, MWT, or UZT), then the advanced transport package will override SSM terms specified here.
  - srctype (string) keyword indicating how concentration will be assigned for sources and sinks. Keyword must be specified as either AUX or AUXMIXED. For both options the user must provide an auxiliary variable in the corresponding flow package. The auxiliary variable must have the same name as the AUXNAME value that follows. If the AUX keyword is specified, then the auxiliary variable specified by the user will be assigned as the concentration value for groundwater sources (flows with a positive sign). For negative flow rates (sinks), groundwater will be withdrawn from the cell at the simulated concentration of the cell. The AUXMIXED option provides an alternative method for how to determine the concentration of sinks. If the cell concentration is larger than the user-specified auxiliary concentration, then the concentration of groundwater withdrawn from the cell will be assigned as the user-specified concentration. Alternatively, if the user-specified auxiliary concentration is larger than the cell concentration, then groundwater will be withdrawn at the cell concentration. Thus, the AUXMIXED option is designed to work with the Evapotranspiration (EVT) and Recharge (RCH) Packages where water may be withdrawn at a concentration that is less than the cell concentration.
  - auxname (string) name of the auxiliary variable in the package PNAME. This auxiliary variable must exist and be specified by the user in that package. The values in this auxiliary variable will be used to set the concentration associated with the flows for that boundary package.
- **fileinput** (*[pname, spc6_filename]*) -
  - pname (string) name of the flow package for which an SPC6 input file contains a source concentration. If this flow

package is represented using an advanced transport package (SFT, LKT, MWT, or UZT), then the advanced transport package will override SSM terms specified here.

- spc6_filename (string) character string that defines the path and filename for the file containing source and sink input data for the flow package. The SPC6_FILENAME file is a flexible input file that allows concentrations to be specified by stress period and with time series. Instructions for creating the SPC6_FILENAME input file are provided in the next section on file input for boundary concentrations.

- **filename** (*String*) - File name for this package.
- **pname** (*String*) - Package name for this package.
- **parent_file** (MFPackage) - Parent package file that references this package. Only needed for utility packages (mfutl*). For example, mfutllaktab package must have a mfgwflak package parent_file.

dfn = [['header'], ['block options', 'name print_flows', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name save_flows', 'type keyword', 'reader urword', 'optional true'], ['block sources', 'name sources', 'type recarray pname srctype auxname', 'reader urword', 'optional false'], ['block sources', 'name pname', 'in_record true', 'type string', 'tagged false', 'reader urword'], ['block sources', 'name srctype', 'in_record true', 'type string', 'tagged false', 'optional false', 'reader urword'], ['block sources', 'name auxname', 'in_record true', 'type string', 'tagged false', 'reader urword', 'optional false'], ['block fileinput', 'name fileinput', 'type recarray pname spc6 filein spc6_filename mixed', 'reader urword'], ['block fileinput', 'name pname', 'in_record true', 'type string', 'tagged false', 'reader urword'], ['block fileinput', 'name spc6', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block fileinput', 'name filein', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block fileinput', 'name spc6_filename', 'type string', 'preserve_case true', 'in_record true', 'reader urword', 'optional false', 'tagged false'], ['block fileinput', 'name mixed', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional true']]

dfn_file_name = 'gwt-ssm.dfn'

fileinput = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

package_abbr = 'gwtssm'

sources = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

flopy.mf6.modflow.mfgwtuzt module

class ModflowGwtuzt(*model, loading_package=False, flow_package_name=None, auxiliary=None, flow_package_auxiliary_name=None, boundnames=None, print_input=None, print_concentration=None, print_flows=None, save_flows=None, concentration_filerecord=None, budget_filerecord=None, budgetcsv_filerecord=None, timeseries=None, observations=None, packagedata=None, uztperioddata=None, filename=None, pname=None, **kwargs*)

Bases: *MFPackage*

ModflowGwtuzt defines a uzt package within a gwt6 model.

Parameters

- **model** (MFModel) - Model that this package is a part of. Package is automatically added to model when it is initialized.
- **loading_package** (*bool*) - Do not set this parameter. It is intended for debugging and internal processing purposes only.
- **flow_package_name** (*string*) -
  - flow_package_name (string) keyword to specify the name of the corresponding flow package. If not specified, then the corresponding flow package must have the same name as this advanced transport package (the name associated with this package in the GWT name file).
- **auxiliary** (*[string]*) -
  - auxiliary (string) defines an array of one or more auxiliary variable names. There is no limit on the number of auxiliary variables that can be provided on this line; however, lists of information provided in subsequent blocks must have a column of data for each auxiliary variable name defined here. The number of auxiliary variables detected on this line determines the value for naux. Comments cannot be provided anywhere on this line as they will be interpreted as auxiliary variable names. Auxiliary variables may not be used by the package, but they will be available for use by other parts of the program. The program will terminate with an error if auxiliary variables are specified on more than one line in the options block.
- **flow_package_auxiliary_name** (*string*) -
  - flow_package_auxiliary_name (string) keyword to specify the name of an auxiliary variable in the corresponding flow package. If specified, then the simulated concentrations from this advanced transport package will be copied into the auxiliary variable specified with this name. Note that the flow package must have an auxiliary variable with this name or the program will terminate with an error. If the flows for this advanced transport package are read from a file, then this option will have no effect.
- **boundnames** (*boolean*) -
  - boundnames (boolean) keyword to indicate that boundary names may be provided with the list of unsaturated zone flow cells.
- **print_input** (*boolean*) -
  - print_input (boolean) keyword to indicate that the list of unsaturated zone flow information will be written to the listing file immediately after it is read.
- **print_concentration** (*boolean*) -
  - print_concentration (boolean) keyword to indicate that the list of UZF cell concentration will be printed to the listing file for every stress period in which "CONCENTRATION PRINT"

is specified in Output Control. If there is no Output Control option and PRINT_CONCENTRATION is specified, then concentration are printed for the last time step of each stress period.

- **print_flows** (*boolean*) -
  - print_flows (boolean) keyword to indicate that the list of unsaturated zone flow rates will be printed to the listing file for every stress period time step in which "BUDGET PRINT" is specified in Output Control. If there is no Output Control option and "PRINT_FLOWS" is specified, then flow rates are printed for the last time step of each stress period.
- **save_flows** (*boolean*) -
  - save_flows (boolean) keyword to indicate that unsaturated zone flow terms will be written to the file specified with "BUDGET FILEOUT" in Output Control.
- **concentration_filerecord** (*[concfile]*) -
  - concfile (string) name of the binary output file to write concentration information.
- **budget_filerecord** (*[budgetfile]*) -
  - budgetfile (string) name of the binary output file to write budget information.
- **budgetcsv_filerecord** (*[budgetcsvfile]*) -
  - budgetcsvfile (string) name of the comma-separated value (CSV) output file to write budget summary information. A budget summary record will be written to this file for each time step of the simulation.
- **timeseries** (*{varname:data} or timeseries data*) -
  - Contains data for the ts package. Data can be stored in a dictionary containing data for the ts package with variable names as keys and package data as values. Data just for the timeseries variable is also acceptable. See ts package documentation for more information.
- **observations** (*{varname:data} or continuous data*) -
  - Contains data for the obs package. Data can be stored in a dictionary containing data for the obs package with variable names as keys and package data as values. Data just for the observations variable is also acceptable. See obs package documentation for more information.
- **packagedata** (*[ifno, strt, aux, boundname]*) -
  - ifno (integer) integer value that defines the feature (UZF object) number associated with the specified PACKAGEDATA data on the line. IFNO must be greater than zero and less than or equal to NUZFCELLS. Unsaturated zone flow information must be specified for every UZF cell or the program will terminate with an error. The program will also terminate with an error if information for a UZF cell is specified more than once.

This argument is an index variable, which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.

– strt (double) real value that defines the starting concentration for the unsaturated zone flow cell.

– aux (double) represents the values of the auxiliary variables for each unsaturated zone flow. The values of auxiliary variables must be present for each unsaturated zone flow. The values must be specified in the order of the auxiliary variables specified in the OPTIONS block. If the package supports time series and the Options block includes a TIMESERIESFILE entry (see the "Time-Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.

– boundname (string) name of the unsaturated zone flow cell. BOUNDNAME is an ASCII character variable that can contain as many as 40 characters. If BOUNDNAME contains spaces in it, then the entire name must be enclosed within single quotes.

- **uztperioddata** (*[ifno, uztsetting]*) –

  – ifno (integer) integer value that defines the feature (UZF object) number associated with the specified PERIOD data on the line. IFNO must be greater than zero and less than or equal to NUZFCELLS. This argument is an index variable, which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.

  – uztsetting (keystring) line of information that is parsed into a keyword and values. Keyword values that can be used to start the UZTSETTING string include: STATUS, CONCENTRATION, INFILTRATION, UZET, and AUXILIARY. These settings are used to assign the concentration of associated with the corresponding flow terms. Concentrations cannot be specified for all flow terms.

    status
    [[string]]

    * status (string) keyword option to define UZF cell status. STATUS can be ACTIVE, INACTIVE, or CONSTANT. By default, STATUS is ACTIVE, which means that concentration will be calculated for the UZF cell. If a UZF cell is inactive, then there will be no solute mass fluxes into or out of the UZF cell and the inactive value will be written for the UZF cell concentration. If a UZF cell is constant, then the concentration for the UZF cell will be fixed at the user specified value.

    concentration
    [[string]]

∗ concentration (string) real or character value that defines the concentration for the unsaturated zone flow cell. The specified CONCENTRATION is only applied if the unsaturated zone flow cell is a constant concentration cell. If the Options block includes a TIMESERIESFILE entry (see the "Time-Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.

infiltration
[[string]]

∗ infiltration (string) real or character value that defines the infiltration solute concentration (ML^{-3}) for the UZF cell. If the Options block includes a TIMESERIESFILE entry (see the "Time-Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.

uzet
[[string]]

∗ uzet (string) real or character value that defines the concentration of unsaturated zone evapotranspiration water (ML^{-3}) for the UZF cell. If this concentration value is larger than the simulated concentration in the UZF cell, then the unsaturated zone ET water will be removed at the same concentration as the UZF cell. If the Options block includes a TIMESERIESFILE entry (see the "Time-Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.

auxiliaryrecord
[[auxname, auxval]]

∗ auxname (string) name for the auxiliary variable to be assigned AUXVAL. AUXNAME must match one of the auxiliary variable names defined in the OPTIONS block. If AUXNAME does not match one of the auxiliary variable names defined in the OPTIONS block the data are ignored.

∗ auxval (double) value for the auxiliary variable. If the Options block includes a TIMESERIESFILE entry (see the "Time- Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.

- **filename** (*String*) - File name for this package.
- **pname** (*String*) - Package name for this package.
- **parent_file** (MFPackage) - Parent package file that references this package. Only needed for utility packages (mfutl*). For example, mfutllaktab package must have a mfgwflak package parent_file.

auxiliary = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

budget_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

budgetcsv_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

concentration_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

dfn = [['header', 'multi-package'], ['block options', 'name flow_package_name', 'type string', 'shape', 'reader urword', 'optional true'], ['block options', 'name auxiliary', 'type string', 'shape (naux)', 'reader urword', 'optional true'], ['block options', 'name flow_package_auxiliary_name', 'type string', 'shape', 'reader urword', 'optional true'], ['block options', 'name boundnames', 'type keyword', 'shape', 'reader urword', 'optional true'], ['block options', 'name print_input', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name print_concentration', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name print_flows', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name save_flows', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name concentration_filerecord', 'type record concentration fileout concfile', 'shape', 'reader urword', 'tagged true', 'optional true'], ['block options', 'name concentration', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name concfile', 'type string', 'preserve_case true', 'shape', 'in_record true', 'reader urword', 'tagged false', 'optional false'], ['block options', 'name budget_filerecord', 'type record budget fileout budgetfile', 'shape', 'reader urword', 'tagged true', 'optional true'], ['block options', 'name budget', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name fileout', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name budgetfile', 'type string', 'preserve_case true', 'shape', 'in_record true', 'reader urword', 'tagged false', 'optional false'], ['block options', 'name budgetcsv_filerecord', 'type record budgetcsv fileout budgetcsvfile', 'shape', 'reader urword', 'tagged true', 'optional true'], ['block options', 'name budgetcsv', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name budgetcsvfile', 'type string', 'preserve_case true', 'shape', 'in_record true', 'reader urword', 'tagged false', 'optional false'], ['block options', 'name ts_filerecord', 'type record ts6 filein ts6_filename', 'shape', 'reader urword', 'tagged true', 'optional true', 'construct_package ts', 'construct_data timeseries', 'parameter_name timeseries'], ['block options', 'name ts6', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name filein', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name ts6_filename', 'type string', 'preserve_case true', 'in_record true', 'reader urword', 'optional false', 'tagged false'], ['block options', 'name obs_filerecord', 'type record obs6 filein obs6_filename', 'shape', 'reader urword', 'tagged true', 'optional true', 'construct_package obs', 'construct_data continuous', 'parameter_name observations'], ['block options', 'name obs6', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name obs6_filename', 'type string', 'preserve_case true', 'in_record true', 'tagged false', 'reader urword', 'optional false'], ['block packagedata', 'name packagedata', 'type recarray ifno strt aux boundname', 'shape (maxbound)', 'reader urword'], ['block packagedata', 'name ifno', 'type integer', 'shape', 'tagged false', 'in_record true', 'reader urword', 'numeric_index true'], ['block packagedata', 'name strt', 'type double precision', 'shape', 'tagged false', 'in_record true', 'reader urword'], ['block packagedata', 'name aux', 'type double precision', 'in_record true', 'tagged false', 'shape (naux)', 'reader urword', 'time_series true', 'optional true'], ['block packagedata', 'name boundname', 'type string', 'shape', 'tagged false', 'in_record true', 'reader urword', 'optional true'], ['block period', 'name iper', 'type integer', 'block_variable True', 'in_record true', 'tagged false', 'shape', 'valid', 'reader urword', 'optional false'], ['block period', 'name uztperioddata', 'type recarray ifno uztsetting', 'shape', 'reader urword'], ['block period', 'name ifno', 'type integer', 'shape', 'tagged false', 'in_record true', 'reader urword', 'numeric_index true'], ['block period', 'name uztsetting', 'type keystring status concentration infiltration uzet auxiliaryrecord', 'shape', 'tagged false', 'in_record true', 'reader urword'], ['block period', 'name status', 'type string', 'shape', 'tagged true', 'in_record true', 'reader urword'], ['block period', 'name concentration', 'type string', 'shape', 'tagged true', 'in_record true',

dfn_file_name = 'gwt-uzt.dfn'

obs_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

package_abbr = 'gwtuzt'

packagedata = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

ts_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

uztperioddata = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

12.1.7 MODFLOW 6 Utility Packages

MODFLOW 6 has several utility packages that can be associated with other packages. This includes the obs package, which can be used to output model results specific to its parent package, and the time series and time array series packages, which can be used to provide time series input for other packages.

Contents:

flopy.mf6.modflow.mfutlats module

class ModflowUtlats(*parent_package*, *loading_package=False*, *maxats=1*, *perioddata=None*, *filename=None*, *pname=None*, ***kwargs*)

Bases: *MFPackage*

ModflowUtlats defines a ats package within a utl model.

Parameters

- **parent_package** (MFPackage) – Parent_package that this package is a part of. Package is automatically added to parent_package when it is initialized.
- **loading_package** (*bool*) – Do not set this parameter. It is intended for debugging and internal processing purposes only.
- **maxats** (*integer*) –
  - maxats (integer) is the number of records in the subsequent perioddata block that will be used for adaptive time stepping.
- **perioddata** (*[iperats, dt0, dtmin, dtmax, dtadj, dtfailadj]*) –
  - iperats (integer) is the period number to designate for adaptive time stepping. The remaining ATS values on this line will apply to period iperats. iperats must be greater than zero. A warning is printed if iperats is greater than nper. This argument is an index variable, which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.
  - dt0 (double) is the initial time step length for period iperats. If dt0 is zero, then the final step from the previous stress period will be used as the initial time step.

The program will terminate with an error message if dt0 is negative.

- dtmin (double) is the minimum time step length for this period. This value must be greater than zero and less than dtmax. dtmin must be a small value in order to ensure that simulation times end at the end of stress periods and the end of the simulation. A small value, such as 1.e-5, is recommended.
- dtmax (double) is the maximum time step length for this period. This value must be greater than dtmin.
- dtadj (double) is the time step multiplier factor for this period. If the number of outer solver iterations are less than the product of the maximum number of outer iterations (OUTER_MAXIMUM) and ATS_OUTER_MAXIMUM_FRACTION (an optional variable in the IMS input file with a default value of 1/3), then the time step length is multipled by dtadj. If the number of outer solver iterations are greater than the product of the maximum number of outer iterations and ATS_OUTER_MAXIMUM_FRACTION, then the time step length is divided by dtadj. dtadj must be zero, one, or greater than one. If dtadj is zero or one, then it has no effect on the simulation. A value between 2.0 and 5.0 can be used as an initial estimate.
- dtfailadj (double) is the divisor of the time step length when a time step fails to converge. If there is solver failure, then the time step will be tried again with a shorter time step length calculated as the previous time step length divided by dtfailadj. dtfailadj must be zero, one, or greater than one. If dtfailadj is zero or one, then time steps will not be retried with shorter lengths. In this case, the program will terminate with an error, or it will continue of the CONTINUE option is set in the simulation name file. Initial tests with this variable should be set to 5.0 or larger to determine if convergence can be achieved.

- **filename** (*String*) - File name for this package.
- **pname** (*String*) - Package name for this package.
- **parent_file** (MFPackage) - Parent package file that references this package. Only needed for utility packages (mfutl*). For example, mfutllaktab package must have a mfgwflak package parent_file.

dfn = [['header'], ['block dimensions', 'name maxats', 'type integer', 'reader urword', 'optional false', 'default_value 1'], ['block perioddata', 'name perioddata', 'type recarray iperats dt0 dtmin dtmax dtadj dtfailadj', 'reader urword', 'optional false'], ['block perioddata', 'name iperats', 'type integer', 'in_record true', 'tagged false', 'reader urword', 'optional false', 'numeric_index true'], ['block perioddata', 'name dt0', 'type double precision', 'in_record true', 'tagged false', 'reader urword', 'optional false'], ['block perioddata', 'name dtmin', 'type double precision', 'in_record true', 'tagged false', 'reader urword', 'optional false'], ['block perioddata', 'name dtmax', 'type double precision', 'in_record true', 'tagged false', 'reader urword', 'optional false'], ['block perioddata', 'name dtadj', 'type double precision', 'in_record true', 'tagged false', 'reader urword', 'optional false'], ['block perioddata', 'name dtfailadj', 'type double precision', 'in_record true', 'tagged false', 'reader urword', 'optional false']]

dfn_file_name = 'utl-ats.dfn'

package_abbr = 'utlats'

perioddata = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

class UtlatsPackages(*model_or_sim*, *parent*, *pkg_type*, *filerecord*, *package=None*, *package_class=None*)

Bases: *MFChildPackages*

UtlatsPackages is a container class for the ModflowUtlats class.

initialize()

Initializes a new ModflowUtlats package removing any sibling child packages attached to the same parent package. See ModflowUtlats init documentation for definition of parameters.

append_package()

Adds a new ModflowUtlats package to the container. See ModflowUtlats init documentation for definition of parameters.

append_package(*maxats=1*, *perioddata=None*, *filename=None*, *pname=None*)

initialize(*maxats=1*, *perioddata=None*, *filename=None*, *pname=None*)

package_abbr = 'utlatspackages'

flopy.mf6.modflow.mfutllaktab module

class ModflowUtllaktab(*model*, *loading_package=False*, *nrow=None*, *ncol=None*, *table=None*, *filename=None*, *pname=None*, ***kwargs*)

Bases: *MFPackage*

ModflowUtllaktab defines a laktab package within a utl model.

Parameters

- **model** (MFModel) – Model that this package is a part of. Package is automatically added to model when it is initialized.
- **loading_package** (*bool*) – Do not set this parameter. It is intended for debugging and internal processing purposes only.

- **nrow** (*integer*) -
  - nrow (integer) integer value specifying the number of rows in the lake table. There must be NROW rows of data in the TABLE block.
- **ncol** (*integer*) -
  - ncol (integer) integer value specifying the number of columns in the lake table. There must be NCOL columns of data in the TABLE block. For lakes with HORIZONTAL and/or VERTICAL CTYPE connections, NCOL must be equal to 3. For lakes with EMBEDDEDH or EMBEDDEDV CTYPE connections, NCOL must be equal to 4.
- **table** (*[stage, volume, sarea, barea]*) -
  - stage (double) real value that defines the stage corresponding to the remaining data on the line.
  - volume (double) real value that defines the lake volume corresponding to the stage specified on the line.
  - sarea (double) real value that defines the lake surface area corresponding to the stage specified on the line.
  - barea (double) real value that defines the lake-GWF exchange area corresponding to the stage specified on the line. BAREA is only specified if the CLAKTYPE for the lake is EMBEDDEDH or EMBEDDEDV.
- **filename** (*String*) - File name for this package.
- **pname** (*String*) - Package name for this package.
- **parent_file** (MFPackage) - Parent package file that references this package. Only needed for utility packages (mfutl*). For example, mfutllaktab package must have a mfgwflak package parent_file.

dfn = [['header', 'multi-package'], ['block dimensions', 'name nrow', 'type integer', 'reader urword', 'optional false'], ['block dimensions', 'name ncol', 'type integer', 'reader urword', 'optional false'], ['block table', 'name table', 'type recarray stage volume sarea barea', 'shape (nrow)', 'reader urword'], ['block table', 'name stage', 'type double precision', 'shape', 'tagged false', 'in_record true', 'reader urword'], ['block table', 'name volume', 'type double precision', 'shape', 'tagged false', 'in_record true', 'reader urword'], ['block table', 'name sarea', 'type double precision', 'shape', 'tagged false', 'in_record true', 'reader urword'], ['block table', 'name barea', 'type double precision', 'shape', 'tagged false', 'in_record true', 'reader urword', 'optional true']]

dfn_file_name = 'utl-laktab.dfn'

package_abbr = 'utllaktab'

table = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

flopy.mf6.modflow.mfutlobs module

class ModflowUtlobs(*parent_model_or_package*, *loading_package=False*, *digits=None*, *print_input=None*, *continuous=None*, *filename=None*, *pname=None*, ***kwargs*)

Bases: *MFPackage*

ModflowUtlobs defines a obs package within a utl model.

Parameters

- **parent_model_or_package** (*MFModel/MFPackage*) – Parent_model_or_package that this package is a part of. Package is automatically added to parent_model_or_package when it is initialized.
- **loading_package** (*bool*) – Do not set this parameter. It is intended for debugging and internal processing purposes only.
- **digits** (*integer*) –
  - digits (integer) Keyword and an integer digits specifier used for conversion of simulated values to text on output. If not specified, the default is the maximum number of digits stored in the program (as written with the G0 Fortran specifier). When simulated values are written to a comma-separated value text file specified in a CONTINUOUS block below, the digits specifier controls the number of significant digits with which simulated values are written to the output file. The digits specifier has no effect on the number of significant digits with which the simulation time is written for continuous observations. If DIGITS is specified as zero, then observations are written with the default setting, which is the maximum number of digits.
- **print_input** (*boolean*) –
  - print_input (boolean) keyword to indicate that the list of observation information will be written to the listing file immediately after it is read.
- **continuous** (*[obsname, obstype, id, id2]*) –
  - obsname (string) string of 1 to 40 nonblank characters used to identify the observation. The identifier need not be unique; however, identification and post-processing of observations in the output files are facilitated if each observation is given a unique name.
  - obstype (string) a string of characters used to identify the observation type.
  - id (string) Text identifying cell where observation is located. For packages other than NPF, if boundary names are defined in the corresponding package input file, ID can be a boundary name. Otherwise ID is a cellid. If the model discretization is type DIS, cellid is three integers (layer, row, column). If the discretization is DISV, cellid is two integers (layer, cell number). If the discretization is DISU, cellid is one integer (node number). This argument

is an index variable, which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.

– id2 (string) Text identifying cell adjacent to cell identified by ID. The form of ID2 is as described for ID. ID2 is used for intercell- flow observations of a GWF model, for three observation types of the LAK Package, for two observation types of the MAW Package, and one observation type of the UZF Package. This argument is an index variable, which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.

- **filename** (*String*) - File name for this package.
- **pname** (*String*) - Package name for this package.
- **parent_file** (MFPackage) - Parent package file that references this package. Only needed for utility packages (mfutl*). For example, mfutllaktab package must have a mfgwflak package parent_file.

continuous = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

dfn = [['header', 'multi-package'], ['block options', 'name digits', 'type integer', 'shape', 'reader urword', 'optional true'], ['block options', 'name print_input', 'type keyword', 'reader urword', 'optional true'], ['block continuous', 'name output', 'type record fileout obs_output_file_name binary', 'shape', 'block_variable true', 'in_record false', 'reader urword', 'optional false'], ['block continuous', 'name fileout', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block continuous', 'name obs_output_file_name', 'type string', 'preserve_case true', 'in_record true', 'shape', 'tagged false', 'reader urword'], ['block continuous', 'name binary', 'type keyword', 'in_record true', 'shape', 'reader urword', 'optional true'], ['block continuous', 'name continuous', 'type recarray obsname obstype id id2', 'shape', 'reader urword', 'optional false'], ['block continuous', 'name obsname', 'type string', 'shape', 'tagged false', 'in_record true', 'reader urword'], ['block continuous', 'name obstype', 'type string', 'shape', 'tagged false', 'in_record true', 'reader urword'], ['block continuous', 'name id', 'type string', 'shape', 'tagged false', 'in_record true', 'reader urword', 'numeric_index true'], ['block continuous', 'name id2', 'type string', 'shape', 'tagged false', 'in_record true', 'reader urword', 'optional true', 'numeric_index true']]

dfn_file_name = 'utl-obs.dfn'

package_abbr = 'utlobs'

class UtlobsPackages(*model_or_sim*, *parent*, *pkg_type*, *filerecord*, *package=None*, *package_class=None*)

Bases: *MFChildPackages*

UtlobsPackages is a container class for the ModflowUtlobs class.

initialize()

Initializes a new ModflowUtlobs package removing any sibling child packages attached to the same parent package. See ModflowUtlobs init documentation for definition of parameters.

initialize(*digits=None*, *print_input=None*, *continuous=None*, *filename=None*, *pname=None*)

package_abbr = 'utlobspackages'

flopy.mf6.modflow.mfutlsfrtab module

class ModflowUtlsfrtab(*model*, *loading_package=False*, *nrow=None*, *ncol=None*, *table=None*, *filename=None*, *pname=None*, ***kwargs*)

Bases: *MFPackage*

ModflowUtlsfrtab defines a sfrtab package within a utl model.

Parameters

- **model** (MFModel) - Model that this package is a part of. Package is automatically added to model when it is initialized.
- **loading_package** (*bool*) - Do not set this parameter. It is intended for debugging and internal processing purposes only.
- **nrow** (*integer*) -
  - nrow (integer) integer value specifying the number of rows in the reach cross-section table. There must be NROW rows of data in the TABLE block.
- **ncol** (*integer*) -
  - ncol (integer) integer value specifying the number of columns in the reach cross-section table. There must be NCOL columns of data in the TABLE block. NCOL must be equal to 2 if MANFRACTION is not specified or 3 otherwise.
- **table** (*[xfraction, height, manfraction]*) -
  - xfraction (double) real value that defines the station (x) data for the cross-section as a fraction of the width (RWID) of the reach. XFRACTION must be greater than or equal to zero but can be greater than one. XFRACTION values can be used to decrease or increase the width of a reach from the specified reach width (RWID).
  - height (double) real value that is the height relative to the top of the lowest elevation of the streambed (RTP) and corresponding to the station data on the same line. HEIGHT must be greater than or equal to zero and at least one cross-section height must be equal to zero.
  - manfraction (double) real value that defines the Manning's roughness coefficient data for the cross-section as a fraction of the Manning's roughness coefficient for the reach (MAN) and corresponding to the station data on the same line. MANFRACTION must be greater than zero. MANFRACTION is applied from the XFRACTION value on the same line to the XFRACTION value on the next line. Although a MANFRACTION value is specified on the last line, any value greater than zero can be applied to MANFRACTION(NROW). MANFRACTION is only specified if NCOL is 3. If MANFRACTION is not specified, the Manning's

roughness coefficient for the reach (MAN) is applied to the entire cross- section.

- **filename** (*String*) – File name for this package.
- **pname** (*String*) – Package name for this package.
- **parent_file** (MFPackage) – Parent package file that references this package. Only needed for utility packages (mfutl*). For example, mfutllaktab package must have a mfgwflak package parent_file.

dfn = [['header', 'multi-package'], ['block dimensions', 'name nrow', 'type integer', 'reader urword', 'optional false'], ['block dimensions', 'name ncol', 'type integer', 'reader urword', 'optional false'], ['block table', 'name table', 'type recarray xfraction height manfraction', 'shape (nrow)', 'reader urword'], ['block table', 'name xfraction', 'type double precision', 'shape', 'tagged false', 'in_record true', 'reader urword'], ['block table', 'name height', 'type double precision', 'shape', 'tagged false', 'in_record true', 'reader urword'], ['block table', 'name manfraction', 'type double precision', 'shape', 'tagged false', 'in_record true', 'reader urword', 'optional true']]

dfn_file_name = 'utl-sfrtab.dfn'

package_abbr = 'utlsfrtab'

table = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

flopy.mf6.modflow.mfutlspc module

class ModflowUtlspc(*model*, *loading_package=False*, *print_input=None*, *timeseries=None*, *maxbound=None*, *perioddata=None*, *filename=None*, *pname=None*, ***kwargs*)

Bases: *MFPackage*

ModflowUtlspc defines a spc package within a utl model.

Parameters

- **model** (MFModel) – Model that this package is a part of. Package is automatically added to model when it is initialized.
- **loading_package** (*bool*) – Do not set this parameter. It is intended for debugging and internal processing purposes only.
- **print_input** (*boolean*) –
  - print_input (boolean) keyword to indicate that the list of spc information will be written to the listing file immediately after it is read.
- **timeseries** (*{varname:data} or timeseries data*) –
  - Contains data for the ts package. Data can be stored in a dictionary containing data for the ts package with variable names as keys and package data as values. Data just for the timeseries variable is also acceptable. See ts package documentation for more information.
- **maxbound** (*integer*) –
  - maxbound (integer) integer value specifying the maximum number of spc cells that will be specified for use during any stress period.

- **perioddata** (*[bndno, spcsetting]*) -
  - bndno (integer) integer value that defines the boundary package feature number associated with the specified PERIOD data on the line. BNDNO must be greater than zero and less than or equal to MAXBOUND. This argument is an index variable, which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.
  - spcsetting (keystring) line of information that is parsed into a keyword and values. Keyword values that can be used to start the MAWSETTING string include: CONCENTRATION.

    concentration
      [[double]]

      * concentration (double) is the boundary concentration. If the Options block includes a TIMESERIESFILE entry (see the "Time- Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value. By default, the CONCENTRATION for each boundary feature is zero.
- **filename** (*String*) - File name for this package.
- **pname** (*String*) - Package name for this package.
- **parent_file** (MFPackage) - Parent package file that references this package. Only needed for utility packages (mfutl*). For example, mfutllaktab package must have a mfgwflak package parent_file.

dfn = [['header', 'multi-package'], ['block options', 'name print_input', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name ts_filerecord', 'type record ts6 filein ts6_filename', 'shape', 'reader urword', 'tagged true', 'optional true', 'construct_package ts', 'construct_data timeseries', 'parameter_name timeseries'], ['block options', 'name ts6', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name filein', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name ts6_filename', 'type string', 'preserve_case true', 'in_record true', 'reader urword', 'optional false', 'tagged false'], ['block dimensions', 'name maxbound', 'type integer', 'reader urword', 'optional false'], ['block period', 'name iper', 'type integer', 'block_variable True', 'in_record true', 'tagged false', 'shape', 'valid', 'reader urword', 'optional false'], ['block period', 'name perioddata', 'type recarray bndno spcsetting', 'shape', 'reader urword'], ['block period', 'name bndno', 'type integer', 'shape', 'tagged false', 'in_record true', 'reader urword', 'numeric_index true'], ['block period', 'name spcsetting', 'type keystring concentration', 'shape', 'tagged false', 'in_record true', 'reader urword'], ['block period', 'name concentration', 'type double precision', 'shape', 'tagged true', 'in_record true', 'reader urword', 'time_series true']]

dfn_file_name = 'utl-spc.dfn'

package_abbr = 'utlspc'

perioddata = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

ts_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

flopy.mf6.modflow.mfutlspca module

class ModflowUtlspca(*model*, *loading_package=False*, *readasarrays=True*, *print_input=None*, *timearrayseries=None*, *concentration=0.0*, *filename=None*, *pname=None*, ***kwargs*)

Bases: *MFPackage*

ModflowUtlspca defines a spca package within a utl model.

Parameters

- **model** (MFModel) – Model that this package is a part of. Package is automatically added to model when it is initialized.
- **loading_package** (*bool*) – Do not set this parameter. It is intended for debugging and internal processing purposes only.
- **readasarrays** (*boolean*) –
  - readasarrays (boolean) indicates that array-based input will be used for the SPC Package. This keyword must be specified to use array- based input.
- **print_input** (*boolean*) –
  - print_input (boolean) keyword to indicate that the list of spc information will be written to the listing file immediately after it is read.
- **timearrayseries** (*{varname:data} or tas_array data*) –
  - Contains data for the tas package. Data can be stored in a dictionary containing data for the tas package with variable names as keys and package data as values. Data just for the timearrayseries variable is also acceptable. See tas package documentation for more information.
- **concentration** (*[double]*) –
  - concentration (double) is the concentration of the associated Recharge or Evapotranspiration stress package. The concentration array may be defined by a time-array series (see the "Using Time- Array Series in a Package" section).
- **filename** (*String*) – File name for this package.
- **pname** (*String*) – Package name for this package.
- **parent_file** (MFPackage) – Parent package file that references this package. Only needed for utility packages (mfutl*). For example, mfutllaktab package must have a mfgwflak package parent_file.

concentration = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

dfn = [['header', 'multi-package'], ['block options', 'name readasarrays', 'type keyword', 'shape', 'reader urword', 'optional false', 'default_value True'], ['block options', 'name print_input', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name tas_filerecord', 'type record tas6 filein tas6_filename', 'shape', 'reader urword', 'tagged true', 'optional true', 'construct_package tas', 'construct_data tas_array', 'parameter_name timearrayseries'], ['block options', 'name tas6', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name filein', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name tas6_filename', 'type string', 'preserve_case true', 'in_record true', 'reader urword', 'optional false', 'tagged false'], ['block period', 'name iper', 'type integer', 'block_variable True', 'in_record true', 'tagged false', 'shape', 'valid', 'reader urword', 'optional false'], ['block period', 'name concentration', 'type double precision', 'shape (ncol*nrow; ncpl)', 'reader readarray', 'default_value 0.']]

dfn_file_name = 'utl-spca.dfn'

package_abbr = 'utlspca'

tas_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

flopy.mf6.modflow.mfutltas module

class ModflowUtltas(*parent_package*, *loading_package=False*, *time_series_namerecord=None*, *interpolation_methodrecord=None*, *sfacrecord=None*, *tas_array=None*, *filename=None*, *pname=None*, ***kwargs*)

Bases: *MFPackage*

ModflowUtltas defines a tas package within a utl model.

Parameters

- **parent_package** (MFPackage) – Parent_package that this package is a part of. Package is automatically added to parent_package when it is initialized.
- **loading_package** (*bool*) – Do not set this parameter. It is intended for debugging and internal processing purposes only.
- **time_series_namerecord** (*[time_series_name]*) –
  – time_series_name (string) Name by which a package references a particular time-array series. The name must be unique among all time- array series used in a package.
- **interpolation_methodrecord** (*[interpolation_method]*) –
  – interpolation_method (string) Interpolation method, which is either STEPWISE or LINEAR.
- **sfacrecord** (*[sfacval]*) –
  – sfacval (double) Scale factor, which will multiply all array values in time series. SFAC is an optional attribute; if omitted, SFAC = 1.0.
- **tas_array** (*[double]*) –

    – tas_array (double) An array of numeric, floating-point values, or a constant value, readable by the U2DREL array-reading utility.

- **filename** (*String*) - File name for this package.
- **pname** (*String*) - Package name for this package.
- **parent_file** (MFPackage) - Parent package file that references this package. Only needed for utility packages (mfutl*). For example, mfutllaktab package must have a mfgwflak package parent_file.

dfn = [['header', 'multi-package'], ['block attributes', 'name time_series_namerecord', 'type record name time_series_name', 'shape', 'reader urword', 'tagged false', 'optional false'], ['block attributes', 'name name', 'type keyword', 'shape', 'reader urword', 'optional false'], ['block attributes', 'name time_series_name', 'type string', 'shape any1d', 'tagged false', 'reader urword', 'optional false'], ['block attributes', 'name interpolation_methodrecord', 'type record method interpolation_method', 'shape', 'reader urword', 'tagged false', 'optional true'], ['block attributes', 'name method', 'type keyword', 'shape', 'reader urword', 'optional false'], ['block attributes', 'name interpolation_method', 'type string', 'valid stepwise linear linearend', 'shape', 'tagged false', 'reader urword', 'optional false'], ['block attributes', 'name sfacrecord', 'type record sfac sfacval', 'shape', 'reader urword', 'tagged true', 'optional true'], ['block attributes', 'name sfac', 'type keyword', 'shape', 'reader urword', 'optional false'], ['block attributes', 'name sfacval', 'type double precision', 'shape time_series_name', 'tagged false', 'reader urword', 'optional false'], ['block time', 'name time_from_model_start', 'type double precision', 'block_variable True', 'in_record true', 'shape', 'tagged false', 'valid', 'reader urword', 'optional false'], ['block time', 'name tas_array', 'type double precision', 'tagged false', 'just_data true', 'shape (unknown)', 'reader readarray', 'optional false', 'repeating true']]

dfn_file_name = 'utl-tas.dfn'

interpolation_methodrecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

package_abbr = 'utltas'

sfacrecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

tas_array = <flopy.mf6.data.mfdatautil.ArrayTemplateGenerator object>

time_series_namerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

class UtltasPackages(*model_or_sim*, *parent*, *pkg_type*, *filerecord*, *package=None*, *package_class=None*)

Bases: *MFChildPackages*

UtltasPackages is a container class for the ModflowUtltas class.

initialize()

Initializes a new ModflowUtltas package removing any sibling child packages attached to the same parent package. See ModflowUtltas init documentation for definition of parameters.

append_package()

Adds a new ModflowUtltas package to the container. See ModflowUtltas init documentation for definition of parameters.

append_package(*time_series_namerecord=None*, *interpolation_methodrecord=None*, *sfacrecord=None*, *tas_array=None*, *filename=None*, *pname=None*)

initialize(*time_series_namerecord=None*, *interpolation_methodrecord=None*, *sfacrecord=None*, *tas_array=None*, *filename=None*, *pname=None*)

package_abbr = 'utltaspackages'

flopy.mf6.modflow.mfutlts module

class **ModflowUtlts**(*parent_package*, *loading_package=False*, *time_series_namerecord=None*, *interpolation_methodrecord=None*, *interpolation_methodrecord_single=None*, *sfacrecord=None*, *sfacrecord_single=None*, *timeseries=None*, *filename=None*, *pname=None*, ***kwargs*)

Bases: *MFPackage*

ModflowUtlts defines a ts package within a utl model.

Parameters

- **parent_package** (MFPackage) – Parent_package that this package is a part of. Package is automatically added to parent_package when it is initialized.
- **loading_package** (*bool*) – Do not set this parameter. It is intended for debugging and internal processing purposes only.
- **time_series_namerecord** (*[time_series_names]*) –
  – time_series_names (string) Name by which a package references a particular time-array series. The name must be unique among all time- array series used in a package.
- **interpolation_methodrecord** (*[interpolation_method]*) –
  – interpolation_method (string) Interpolation method, which is either STEPWISE or LINEAR.
- **interpolation_methodrecord_single** (*[interpolation_method_single]*) –
  – interpolation_method_single (string) Interpolation method, which is either STEPWISE or LINEAR.
- **sfacrecord** (*[sfacval]*) –
  – sfacval (double) Scale factor, which will multiply all array values in time series. SFAC is an optional attribute; if omitted, SFAC = 1.0.
- **sfacrecord_single** (*[sfacval]*) –
  – sfacval (double) Scale factor, which will multiply all array values in time series. SFAC is an optional attribute; if omitted, SFAC = 1.0.

- **timeseries** (*[ts_time, ts_array]*) -
  - ts_time (double) A numeric time relative to the start of the simulation, in the time unit used in the simulation. Times must be strictly increasing.
  - ts_array (double) A 2-D array of numeric, floating-point values, or a constant value, readable by the U2DREL array-reading utility.
- **filename** (*String*) - File name for this package.
- **pname** (*String*) - Package name for this package.
- **parent_file** (MFPackage) - Parent package file that references this package. Only needed for utility packages (mfutl*). For example, mfutllaktab package must have a mfgwflak package parent_file.

dfn = [['header', 'multi-package'], ['block attributes', 'name time_series_namerecord', 'type record names time_series_names', 'shape', 'reader urword', 'tagged false', 'optional false'], ['block attributes', 'name names', 'other_names name', 'type keyword', 'shape', 'reader urword', 'optional false'], ['block attributes', 'name time_series_names', 'type string', 'shape any1d', 'tagged false', 'reader urword', 'optional false'], ['block attributes', 'name interpolation_methodrecord', 'type record methods interpolation_method', 'shape', 'reader urword', 'tagged false', 'optional true'], ['block attributes', 'name methods', 'type keyword', 'shape', 'reader urword', 'optional false'], ['block attributes', 'name interpolation_method', 'type string', 'valid stepwise linear linearend', 'shape time_series_names', 'tagged false', 'reader urword', 'optional false'], ['block attributes', 'name interpolation_methodrecord_single', 'type record method interpolation_method_single', 'shape', 'reader urword', 'tagged false', 'optional true'], ['block attributes', 'name method', 'type keyword', 'shape', 'reader urword', 'optional false'], ['block attributes', 'name interpolation_method_single', 'type string', 'valid stepwise linear linearend', 'shape', 'tagged false', 'reader urword', 'optional false'], ['block attributes', 'name sfacrecord', 'type record sfacs sfacval', 'shape', 'reader urword', 'tagged true', 'optional true'], ['block attributes', 'name sfacs', 'type keyword', 'shape', 'reader urword', 'optional false'], ['block attributes', 'name sfacval', 'type double precision', 'shape <time_series_name', 'tagged false', 'reader urword', 'optional false'], ['block attributes', 'name sfacrecord_single', 'type record sfac sfacval', 'shape', 'reader urword', 'tagged true', 'optional true'], ['block attributes', 'name sfac', 'type keyword', 'shape', 'tagged false', 'reader urword', 'optional false'], ['block timeseries', 'name timeseries', 'type recarray ts_time ts_array', 'shape', 'reader urword', 'tagged true', 'optional false'], ['block timeseries', 'name ts_time', 'type double precision', 'shape', 'tagged false', 'reader urword', 'optional false', 'repeating false'], ['block timeseries', 'name ts_array', 'type double precision', 'shape time_series_names', 'tagged false', 'reader urword', 'optional false']]

dfn_file_name = 'utl-ts.dfn'

interpolation_methodrecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

interpolation_methodrecord_single = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

package_abbr = 'utlts'

sfacrecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

sfacrecord_single = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

time_series_namerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

timeseries = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

class **UtltsPackages**(*model_or_sim*, *parent*, *pkg_type*, *filerecord*, *package=None*, *package_class=None*)

Bases: *MFChildPackages*

UtltsPackages is a container class for the ModflowUtlts class.

initialize()

Initializes a new ModflowUtlts package removing any sibling child packages attached to the same parent package. See ModflowUtlts init documentation for definition of parameters.

append_package()

Adds a new ModflowUtlts package to the container. See ModflowUtlts init documentation for definition of parameters.

append_package(*time_series_namerecord=None*, *interpolation_methodrecord=None*, *interpolation_methodrecord_single=None*, *sfacrecord=None*, *sfacrecord_single=None*, *timeseries=None*, *filename=None*, *pname=None*)

initialize(*time_series_namerecord=None*, *interpolation_methodrecord=None*, *interpolation_methodrecord_single=None*, *sfacrecord=None*, *sfacrecord_single=None*, *timeseries=None*, *filename=None*, *pname=None*)

package_abbr = 'utltspackages'

flopy.mf6.modflow.mfutltvk module

class **ModflowUtltvk**(*parent_package*, *loading_package=False*, *print_input=None*, *timeseries=None*, *perioddata=None*, *filename=None*, *pname=None*, ***kwargs*)

Bases: *MFPackage*

ModflowUtltvk defines a tvk package within a utl model.

Parameters

- **parent_package** (MFPackage) – Parent_package that this package is a part of. Package is automatically added to parent_package when it is initialized.
- **loading_package** (*bool*) – Do not set this parameter. It is intended for debugging and internal processing purposes only.
- **print_input** (*boolean*) –
  - print_input (boolean) keyword to indicate that information for each change to the hydraulic conductivity in a cell will be written to the model listing file.
- **timeseries** (*{varname:data} or timeseries data*) –

- Contains data for the ts package. Data can be stored in a dictionary containing data for the ts package with variable names as keys and package data as values. Data just for the timeseries variable is also acceptable. See ts package documentation for more information.

- **perioddata** (*[cellid, tvksetting]*) -
  - cellid ((integer, ...)) is the cell identifier, and depends on the type of grid that is used for the simulation. For a structured grid that uses the DIS input file, CELLID is the layer, row, and column. For a grid that uses the DISV input file, CELLID is the layer and CELL2D number. If the model uses the unstructured discretization (DISU) input file, CELLID is the node number for the cell. This argument is an index variable, which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.
  - tvksetting (keystring) line of information that is parsed into a property name keyword and values. Property name keywords that can be used to start the TVKSETTING string include: K, K22, and K33.

    k
    [[double]]

    * k (double) is the new value to be assigned as the cell's hydraulic conductivity from the start of the specified stress period, as per K in the NPF package. If the OPTIONS block includes a TS6 entry (see the "Time-Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.

    k22
    [[double]]

    * k22 (double) is the new value to be assigned as the cell's hydraulic conductivity of the second ellipsoid axis (or the ratio of K22/K if the K22OVERK NPF package option is specified) from the start of the specified stress period, as per K22 in the NPF package. For an unrotated case this is the hydraulic conductivity in the y direction. If the OPTIONS block includes a TS6 entry (see the "Time-Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.

    k33
    [[double]]

    * k33 (double) is the new value to be assigned as the cell's hydraulic conductivity of the third ellipsoid axis (or the ratio of K33/K if the K33OVERK NPF package option is specified) from the start of

the specified stress period, as per K33 in the NPF package. For an unrotated case, this is the vertical hydraulic conductivity. If the OPTIONS block includes a TS6 entry (see the "Time-Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.

- **filename** (*String*) - File name for this package.
- **pname** (*String*) - Package name for this package.
- **parent_file** (MFPackage) - Parent package file that references this package. Only needed for utility packages (mfutl*). For example, mfutllaktab package must have a mfgwflak package parent_file.

dfn = [['header'], ['block options', 'name print_input', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name ts_filerecord', 'type record ts6 filein ts6_filename', 'shape', 'reader urword', 'tagged true', 'optional true', 'construct_package ts', 'construct_data timeseries', 'parameter_name timeseries'], ['block options', 'name ts6', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name filein', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name ts6_filename', 'type string', 'preserve_case true', 'in_record true', 'reader urword', 'optional false', 'tagged false'], ['block period', 'name iper', 'type integer', 'block_variable True', 'in_record true', 'tagged false', 'shape', 'valid', 'reader urword', 'optional false'], ['block period', 'name perioddata', 'type recarray cellid tvksetting', 'shape', 'reader urword'], ['block period', 'name cellid', 'type integer', 'shape (ncelldim)', 'tagged false', 'in_record true', 'reader urword'], ['block period', 'name tvksetting', 'type keystring k k22 k33', 'shape', 'tagged false', 'in_record true', 'reader urword'], ['block period', 'name k', 'type double precision', 'shape', 'tagged true', 'in_record true', 'reader urword', 'time_series true'], ['block period', 'name k22', 'type double precision', 'shape', 'tagged true', 'in_record true', 'reader urword', 'time_series true'], ['block period', 'name k33', 'type double precision', 'shape', 'tagged true', 'in_record true', 'reader urword', 'time_series true']]

dfn_file_name = 'utl-tvk.dfn'

package_abbr = 'utltvk'

perioddata = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

ts_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

class UtltvkPackages(*model_or_sim*, *parent*, *pkg_type*, *filerecord*, *package=None*, *package_class=None*)

Bases: *MFChildPackages*

UtltvkPackages is a container class for the ModflowUtltvk class.

initialize()

Initializes a new ModflowUtltvk package removing any sibling child packages attached to the same parent package. See ModflowUtltvk init documentation for definition of parameters.

append_package()

Adds a new ModflowUtltvk package to the container. See ModflowUtltvk init documentation for definition of parameters.

append_package(*print_input=None*, *timeseries=None*, *perioddata=None*, *filename=None*, *pname=None*)

initialize(*print_input=None*, *timeseries=None*, *perioddata=None*, *filename=None*, *pname=None*)

package_abbr = 'utltvkpackages'

flopy.mf6.modflow.mfutltvs module

class ModflowUtltvs(*parent_package*, *loading_package=False*, *disable_storage_change_integration=None*, *print_input=None*, *timeseries=None*, *perioddata=None*, *filename=None*, *pname=None*, ***kwargs*)

Bases: *MFPackage*

ModflowUtltvs defines a tvs package within a utl model.

Parameters

- **parent_package** (MFPackage) – Parent_package that this package is a part of. Package is automatically added to parent_package when it is initialized.
- **loading_package** (*bool*) – Do not set this parameter. It is intended for debugging and internal processing purposes only.
- **disable_storage_change_integration** (*boolean*) –
  - disable_storage_change_integration (boolean) keyword that deactivates inclusion of storage derivative terms in the STO package matrix formulation. In the absence of this keyword (the default), the groundwater storage formulation will be modified to correctly adjust heads based on transient variations in stored water volumes arising from changes to SS and SY properties.
- **print_input** (*boolean*) –
  - print_input (boolean) keyword to indicate that information for each change to a storage property in a cell will be written to the model listing file.
- **timeseries** (*{varname:data} or timeseries data*) –
  - Contains data for the ts package. Data can be stored in a dictionary containing data for the ts package with variable names as keys and package data as values. Data just for the timeseries variable is also acceptable. See ts package documentation for more information.
- **perioddata** (*[cellid, tvssetting]*) –
  - cellid ((integer, ...)) is the cell identifier, and depends on the type of grid that is used for the simulation. For a structured grid that uses the DIS input file, CELLID is the

layer, row, and column. For a grid that uses the DISV input file, CELLID is the layer and CELL2D number. If the model uses the unstructured discretization (DISU) input file, CELLID is the node number for the cell. This argument is an index variable, which means that it should be treated as zero-based when working with FloPy and Python. Flopy will automatically subtract one when loading index variables and add one when writing index variables.

- tvssetting (keystring) line of information that is parsed into a property name keyword and values. Property name keywords that can be used to start the TVSSETTING string include: SS and SY.

  ss
  [[double]]

  * ss (double) is the new value to be assigned as the cell's specific storage (or storage coefficient if the STORAGECOEFFICIENT STO package option is specified) from the start of the specified stress period, as per SS in the STO package. Specific storage values must be greater than or equal to 0. If the OPTIONS block includes a TS6 entry (see the "Time-Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.

  sy
  [[double]]

  * sy (double) is the new value to be assigned as the cell's specific yield from the start of the specified stress period, as per SY in the STO package. Specific yield values must be greater than or equal to 0. If the OPTIONS block includes a TS6 entry (see the "Time-Variable Input" section), values can be obtained from a time series by entering the time-series name in place of a numeric value.

- **filename** (*String*) - File name for this package.
- **pname** (*String*) - Package name for this package.
- **parent_file** (MFPackage) - Parent package file that references this package. Only needed for utility packages (mfutl*). For example, mfutllaktab package must have a mfgwflak package parent_file.

dfn = [['header'], ['block options', 'name disable_storage_change_integration', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name print_input', 'type keyword', 'reader urword', 'optional true'], ['block options', 'name ts_filerecord', 'type record ts6 filein ts6_filename', 'shape', 'reader urword', 'tagged true', 'optional true', 'construct_package ts', 'construct_data timeseries', 'parameter_name timeseries'], ['block options', 'name ts6', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name filein', 'type keyword', 'shape', 'in_record true', 'reader urword', 'tagged true', 'optional false'], ['block options', 'name ts6_filename', 'type string', 'preserve_case true', 'in_record true', 'reader urword', 'optional false', 'tagged false'], ['block period', 'name iper', 'type integer', 'block_variable True', 'in_record true', 'tagged false', 'shape', 'valid', 'reader urword', 'optional false'], ['block period', 'name perioddata', 'type recarray cellid tvssetting', 'shape', 'reader urword'], ['block period', 'name cellid', 'type integer', 'shape (ncelldim)', 'tagged false', 'in_record true', 'reader urword'], ['block period', 'name tvssetting', 'type keystring ss sy', 'shape', 'tagged false', 'in_record true', 'reader urword'], ['block period', 'name ss', 'type double precision', 'shape', 'tagged true', 'in_record true', 'reader urword', 'time_series true'], ['block period', 'name sy', 'type double precision', 'shape', 'tagged true', 'in_record true', 'reader urword', 'time_series true']]

dfn_file_name = 'utl-tvs.dfn'

package_abbr = 'utltvs'

perioddata = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

ts_filerecord = <flopy.mf6.data.mfdatautil.ListTemplateGenerator object>

class UtltvsPackages(*model_or_sim*, *parent*, *pkg_type*, *filerecord*, *package=None*, *package_class=None*)

Bases: *MFChildPackages*

UtltvsPackages is a container class for the ModflowUtltvs class.

initialize()

Initializes a new ModflowUtltvs package removing any sibling child packages attached to the same parent package. See ModflowUtltvs init documentation for definition of parameters.

append_package()

Adds a new ModflowUtltvs package to the container. See ModflowUtltvs init documentation for definition of parameters.

append_package(*disable_storage_change_integration=None*, *print_input=None*, *timeseries=None*, *perioddata=None*, *filename=None*, *pname=None*)

initialize(*disable_storage_change_integration=None*, *print_input=None*, *timeseries=None*, *perioddata=None*, *filename=None*, *pname=None*)

package_abbr = 'utltvspackages'

12.1.8 MODFLOW 6 Utility Functions

MODFLOW 6 has a number of utilities useful for pre- or postprocessing.

Contents:

flopy.mf6.utils.binaryfile_utils module

class MFOutput(*mfdict*, *path*, *key*)

Bases: object

Wrapper class for Binary Arrays. This class enables directly getting slices from the binary output. It is intended to be called from the __getitem__ method of the SimulationDict() class. Implemented to conserve memory.

Parameters

- **path** (*binary file path location*) –
- **mfdict** (SimulationDict() *object*) –
- **key** (*dict key ex. ('flow15','CBC','FLOW RIGHT FACE')*) –

Returns

- *Xarray of [n,n,n,n] dimension*
- *Usage*
- *--*
- *>>> val = MFOutput(mfdict, path, key)*
- *>>> return val.data*
- *User interaction*
- *------*
- **>>> data[('flow15','CBC','FLOW RIGHT FACE')][** *(,0,1,:])*
- *or*
- *>>> data[('flow15','CBC','FLOW RIGHT FACE')]*

class MFOutputRequester(*mfdict*, *path*, *key*)

Bases: object

MFOutputRequest class is a helper function to enable the user to query binary data from the SimulationDict() object on the fly without actually storing it in the SimulationDict() object.

Parameters:

mfdict: dict
local instance of the SimulationDict() object

path:
pointer to the MFSimulationPath object

key: tuple
user requested data key

Methods:

MFOutputRequester.querybinarydata
returns: Xarray object

Examples:

```
>>> data = MFOutputRequester(mfdict, path, key)
>>> data.querybinarydata
```

static getkeys(*mfdict*, *path*, *print_keys=True*)

flopy.mf6.utils.binarygrid_util module

Module to read MODFLOW 6 binary grid files (*.grb) that define the model grid binary output files. The module contains the MfGrdFile class that can be accessed by the user.

class MfGrdFile(*filename*, *precision='double'*, *verbose=False*)

Bases: *FlopyBinaryData*

The MfGrdFile class.

Parameters

- **filename** (*str*) – Name of the MODFLOW 6 binary grid file
- **precision** (*string*) – 'single' or 'double'. Default is 'double'.
- **verbose** (*bool*) – Write information to standard output. Default is False.

Notes

The MfGrdFile class provides simple ways to retrieve data from binary MODFLOW 6 binary grid files (.grb). The binary grid file contains data that can be used for post processing MODFLOW 6 model results. For example, the ia and ja arrays for a model grid.

Examples

```
>>> import flopy
>>> gobj = flopy.utils.MfGrdFile('test.dis.grb')
```

property angrot

Model grid rotation angle. None if not defined in the MODFLOW 6 grid file.

Returns
angrot

Return type
float

property bot
Bottom of the model cells.

Returns
bot

Return type
ndarray of floats

property cell2d
cell2d data for a DISV grid. None for DIS and DISU grids.

Returns
cell2d

Return type
list of lists

property cellcenters
Cell centers (x,y).

Returns
cellcenters

Return type
ndarray of floats

property delc
Cell size in the column direction (x-direction). None if not defined in the MODFLOW 6 grid file.

Returns
delc

Return type
ndarray of floats

property delr
Cell size in the row direction (y-direction). None if not defined in the MODFLOW 6 grid file.

Returns
delr

Return type
ndarray of floats

property grid_type
Grid type defined in the MODFLOW 6 grid file.

Returns
grid_type

Return type
str

property ia
index array that defines indexes for *.ja*. Each ia value is the starting position of data for a cell. [ia[n]:ia[n+1]] would give you all data for a cell. ia[n] is also the location of data for the diagonal position. See *.ja* property documentation for an example of getting a cell's number and connected cells

Returns
: **ia**

Return type
: ndarray of ints

property iavert

index array that defines indexes for *.javart*. Each ia value is the starting position of data for a cell. [iavert[n]:iavert[n+1]] would give you all data for a cell. See *.javert* property documentation for an example of getting cell number and it's vertex numbers. Alternatively, the *.iverts* property can be used to get this information

Returns
: **iavert**

Return type
: ndarray of ints or None for structured grids

property idomain

IDOMAIN for the model grid. None if not defined in the MODFLOW 6 grid file.

Returns
: **idomain**

Return type
: ndarray of ints

property iverts

Vertex numbers comprising each cell for every cell in model grid.

Returns
: **iverts**

Return type
: list of lists of ints

property ja

Flat jagged connection array for a model. *.ja* for a cell includes the cell number and the cell number for all connected cells. Indexes for cells are stored in the *.ia* variable.

Returns
: **ja**

Return type
: ndarray of ints

Examples

```
>>> from flopy.mf6.utils import MfGrdFile
>>> grb = MfGrdFile("my_model.dis.grb")
>>> ia = grb.ia
>>> ja = grb.ja
>>> # get connections for node 0
>>> ja_node0 = ja[ia[0]:ia[1]]
>>> node = ja_node0[0]
>>> connections = ja_node0[1:]
```

property javert

Flat jagged array of vertex numbers that comprise all of the cells

Returns
javerts

Return type
ndarray of ints or None for structured grids

Examples

```
>>> from flopy.mf6.utils import MfGrdFile
>>> grb = MfGrdFile("my_model.dis.grb")
>>> iavert = self.iavert
>>> javert = self.javert
>>> # get vertex numbers for node 0
>>> vertnums = javert[iavert[0]:iavert[1]]
```

property modelgrid

Model grid object.

Returns
modelgrid

Return type
StructuredGrid, *VertexGrid*, *UnstructuredGrid*

property ncells

Number of cells.

Returns
ncells

Return type
int

property ncol

Number of columns. None for DISV and DISU grids.

Returns
ncol

Return type
int

property ncpl

Number of cells per layer. None for DISU grids.

Returns
ncpl

Return type
int

property nja

Number of non-zero entries JA vector array.

Returns
nja

Return type
int

property nlay
Number of layers. None for DISU grids.

Returns
nlay

Return type
int

property nodes
Number of nodes.

Returns
nodes

Return type
int

property nrow
Number of rows. None for DISV and DISU grids.

Returns
nrow

Return type
int

property shape
Shape of the model grid (tuple).

Returns
shape

Return type
tuple

property top
Top of the model cells in the upper model layer for DIS and DISV grids. Top of the model cells for DISU grids.

Returns
top

Return type
ndarray of floats

property verts
x,y location of each vertex that defines the model grid.

Returns
verts

Return type
ndarray of floats

property xorigin
x-origin of the model grid. None if not defined in the MODFLOW 6 grid file.

Returns
xorigin

Return type
float

property yorigin

y-origin of the model grid. None if not defined in the MODFLOW 6 grid file.

Returns
yorigin

Return type
float

flopy.mf6.utils.mfobservation module

class MFObservation(*mfdict*, *path*, *key*)

Bases: object

Wrapper class to request the MFObservation object: Class is called by the MFSimulation.SimulationDict() class and is not called by the user

Inputs:

mfdict: (dict) the sim.simulation_dict.mfdict object for the flopy project path: (object) the path object detailing model names and paths key: (tuple, stings) user supplied dictionary key to request observation utility data

Returns: --- self.data: (xarray) array of observations

class MFObservationRequester(*mfdict*, *path*, *key*, ***kwargs*)

Bases: object

Wrapper class for MFObservation.Observations. Class checks which observation data is available, and creates a dictionary key to access the set of observation data from the SimulationDict()

static getkeys(*mfdict*, *path*)

class Observations(*fi*)

Bases: object

Simple class to extract and view Observation files for Uzf models (possibly all obs/hobs)?

Input:

fi = (sting) name of the observation binary output file

Methods:

get_data(): (np.array) returns array of observation data
text = (str) specific modflow record name contained in Obs.out file idx = (int), (slice(start, stop)) integer or slice of data to be returned. corresponds to kstp*kper - 1 totim = (float) model time value to return data from

list_records(): prints a list of all valid record names contained within the Obs.out file get_times(): (list) returns list of time values contained in Obs.out get_nrecords(): (int) returns number of records get_ntimes(): (int) returns number of times get_nobs(): (int) returns total number of observations (ntimes * nrecords)

get_data(*key=None*, *idx=None*, *totim=None*)

Method to request and return array of data from an Observation output file

Parameters

- **key** (*(str) dictionary key for a specific observation contained within*) – the observation file (optional)
- **idx** (*(int) time index (optional)*) –
- **totim** (*(float) simulation time (optional)*) –

Returns
data

Return type
(list) observation file data in list

get_dataframe(*keys=None*, *idx=None*, *totim=None*, *start_datetime=None*, *timeunit='D'*)

Creates a pandas dataframe object from the observation data, useful backend if the user does not like the x-array format!

Parameters

- **keys** (*(string) sting of dictionary/observation keys separated by comma.*) – (optional)
- **idx** (*(int) time index location (optional)*) –
- **totim** (*(float) simulation time (optional)*) –
- **start_datetime** (*(string) format is 'dd/mm/yyyy' or*) – 'dd/mm/yyyy hh:mm:ss' (optional)
- **timeunit** (*(string) specifies the time unit associated with totim when*) – setting a datetime

Return type
pd.DataFrame

get_nobs()

get_nrecords()

get_ntimes()

get_obs_data(*key=None*, *idx=None*, *totim=None*)

Method to request observation output data as an x-array :param key: within the observation file (optional) :type key: (string) dictionary key for a specific observation contained :param idx: :type idx: (int) time index (optional) :param totim: :type totim: (float) simulation time (optional)

Returns
xarray.DataArray

Return type
(NxN) dimensions are totim, header == keys*

get_times()

list_records()

try_float(*data*)

flopy.mf6.utils.output_util module

class **MF6Output**(*obj*)

Bases: object

A class that uses meta programming to get output

Parameters
obj (*PackageInterface object*) –

property **csv_names**

Method to get csv file names

Return type
list

methods()

Method that returns a list of available method calls

Return type
list

property **obs_names**

Method to get obs file names

Return type
list

flopy.mf6.utils.postprocessing module

get_residuals(*flowja*, *grb_file=None*, *ia=None*, *ja=None*, *shape=None*, *verbose=False*)

Get the residual from the MODFLOW 6 flowja flows. The residual is stored in the diagonal position of the flowja vector.

Parameters

- **flowja** (*ndarray*) – flowja array for a structured MODFLOW 6 model
- **grbfile** (*str*) – MODFLOW 6 binary grid file path
- **ia** (*list or ndarray*) – CRS row pointers. Only required if grb_file is not provided.

- **ja** (*list or ndarray*) – CRS column pointers. Only required if grb_file is not provided.
- **shape** (*tuple*) – shape of returned residual. A flat array is returned if shape is None and grbfile is None.
- **verbose** (*bool*) – Write information to standard output

Returns
residual – Residual for each cell

Return type
ndarray

get_structured_faceflows(*flowja*, *grb_file=None*, *ia=None*, *ja=None*, *nlay=None*, *nrow=None*, *ncol=None*, *verbose=False*)

Get the face flows for the flow right face, flow front face, and flow lower face from the MODFLOW 6 flowja flows. This method can be useful for building face flow arrays for MT3DMS, MT3D-USGS, and RT3D. This method only works for a structured MODFLOW 6 model.

Parameters

- **flowja** (*ndarray*) – flowja array for a structured MODFLOW 6 model
- **grbfile** (*str*) – MODFLOW 6 binary grid file path
- **ia** (*list or ndarray*) – CRS row pointers. Only required if grb_file is not provided.
- **ja** (*list or ndarray*) – CRS column pointers. Only required if grb_file is not provided.
- **nlay** (*int*) – number of layers in the grid. Only required if grb_file is not provided.
- **nrow** (*int*) – number of rows in the grid. Only required if grb_file is not provided.
- **ncol** (*int*) – number of columns in the grid. Only required if grb_file is not provided.
- **verbose** (*bool*) – Write information to standard output

Returns

- **frf** (*ndarray*) – right face flows
- **fff** (*ndarray*) – front face flows
- **flf** (*ndarray*) – lower face flows

flopy.mf6.utils.reference module

Module spatial referencing for flopy model objects

class SpatialReference(*delr=1.0*, *delc=1.0*, *xvdict=None*, *yvdict=None*, *lenuni=1*, *nlay=1*, *xul=None*, *yul=None*, *xadj=0.0*, *yadj=0.0*, *rotation=0.0*, *proj4_str=None*, *distype='structured'*)

Bases: object

A dynamic inheritance class that locates a gridded model in space

delr
[numpy ndarray] the model discretization delr vector

delc
[numpy ndarray] the model discretization delc vector

lenuni
[int] the length units flag from the discretization package

xul
[float] the x coordinate of the upper left corner of the grid

yul
[float] the y coordinate of the upper left corner of the grid

rotation
[float] the counter-clockwise rotation (in degrees) of the grid

proj4_str: str
a PROJ4 string that identifies the grid in space. warning: case sensitive!

xadj
[float] vertex grid: x vertex adjustment factor

yadj
[float] vertex grid: y vertex adjustment factor

xvdict: dict
dictionary of x-vertices by cellnum ex. {0: (0,1,1,0)}

yvdict: dict
dictionary of y-vertices by cellnum ex. {0: (1,1,0,0)}

distype: str
model grid discretization type

class **StructuredSpatialReference**(*delr=1.0*, *delc=1.0*, *lenuni=1*, *nlay=1*, *xul=None*, *yul=None*, *rotation=0.0*, *proj4_str=None*, ***kwargs*)

Bases: object

a simple class to locate the model grid in x-y space

Parameters

- **delr** (*numpy ndarray*) – the model discretization delr vector
- **delc** (*numpy ndarray*) – the model discretization delc vector
- **lenuni** (*int*) – the length units flag from the discretization package
- **xul** (*float*) – the x coordinate of the upper left corner of the grid
- **yul** (*float*) – the y coordinate of the upper left corner of the grid
- **rotation** (*float*) – the counter-clockwise rotation (in degrees) of the grid
- **proj4_str** (*str*) – a PROJ4 string that identifies the grid in space. warning: case sensitive!

xedge
array of column edges

Type
ndarray

yedge
array of row edges

Type
ndarray

xgrid
numpy meshgrid of xedges

Type
ndarray

ygrid
numpy meshgrid of yedges

Type
ndarray

xcenter
array of column centers

Type
ndarray

ycenter
array of row centers

Type
ndarray

xcentergrid
numpy meshgrid of column centers

Type
ndarray

ycentergrid
numpy meshgrid of row centers

Type
ndarray

Notes

xul and yul can be explicitly (re)set after SpatialReference instantiation, but only before any of the other attributes and methods are accessed

property attribute_dict

classmethod from_gridspec(*gridspec_file*, *lenuni=0*)

classmethod from_namfile_header(*namefile*)

get_extent()

Get the extent of the rotated and offset grid

Return (xmin, xmax, ymin, ymax)

get_grid_lines()

get the grid lines as a list

get_vertices(*i*, *j*)

get_xcenter_array()

Return a numpy one-dimensional float array that has the cell center x coordinate for every column in the grid in model space - not offset or rotated.

get_xedge_array()

Return a numpy one-dimensional float array that has the cell edge x coordinates for every column in the grid in model space - not offset or rotated. Array is of size (ncol + 1)

get_ycenter_array()

Return a numpy one-dimensional float array that has the cell center x coordinate for every row in the grid in model space - not offset of rotated.

get_yedge_array()

Return a numpy one-dimensional float array that has the cell edge y coordinates for every row in the grid in model space - not offset or rotated. Array is of size (nrow + 1)

interpolate(*a*, *xi*, *method='nearest'*)

Use the griddata method to interpolate values from an array onto the points defined in xi. For any values outside of the grid, use 'nearest' to find a value for them.

Parameters

- **a** (*numpy.ndarray*) – array to interpolate from. It must be of size nrow, ncol
- **xi** (*numpy.ndarray*) – array containing x and y point coordinates of size (npts, 2). xi also works with broadcasting so that if a is a 2d array, then xi can be passed in as (xgrid, ygrid).
- **method** (*{'linear', 'nearest', 'cubic'}*) – method to use for interpolation (default is 'nearest')

Returns

b – array of size (npts)

Return type

numpy.ndarray

property ncol

property nrow

reset(***kwargs*)

static rotate(*x*, *y*, *theta*, *xorigin=0.0*, *yorigin=0.0*)

Given x and y array-like values calculate the rotation about an arbitrary origin and then return the rotated coordinates. theta is in degrees.

set_spatialreference(*xul=None*, *yul=None*, *rotation=0.0*)

set spatial reference - can be called from model instance

write_gridSpec(*filename*)

write a PEST-style grid specification file

property xcenter

property xcentergrid

property xedge

property xgrid

property ycenter

property ycentergrid

property yedge

property ygrid

class VertexSpatialReference(*xvdict=None*, *yvdict=None*, *nlay=1*, *xadj=0*, *yadj=0*, *rotation=0.0*, *lenuni=1.0*, *proj4_str=None*, ***kwargs*)

Bases: object

a simple class to locate the model grid in x-y space

Parameters

- **xvdict** (*dictionary*) - dictionary of x-vertices {1: (0,1,1,0)}
- **yvdict** (*dictionary*) - dictionary of y-vertices {1: (1,0,1,0)}
- **lenuni** (*int*) - the length units flag from the discretization package
- **xadj** (*float*) - the x coordinate of the upper left corner of the grid
- **yadj** (*float*) - the y coordinate of the upper left corner of the grid
- **rotation** (*float*) - the counter-clockwise rotation (in degrees) of the grid
- **proj4_str** (*str*) - a PROJ4 string that identifies the grid in space. warning: case sensitive!

xedge

array of column edges

Type

ndarray

yedge

array of row edges

Type

ndarray

xgrid

numpy meshgrid of xedges

Type
ndarray

ygrid

numpy meshgrid of yedges

Type
ndarray

xcenter

array of column centers

Type
ndarray

ycenter

array of row centers

Type
ndarray

xcentergrid

numpy meshgrid of column centers

Type
ndarray

ycentergrid

numpy meshgrid of row centers

Type
ndarray

Notes

xadj and yuadj can be explicitly (re)set after SpatialReference instantiation, but only before any of the other attributes and methods are accessed

classmethod from_namfile_header(*namefile*)

get_extent()

Get the extent of the rotated and offset grid

Return (xmin, xmax, ymin, ymax)

property ncpl

static rotate(*x*, *y*, *theta*, *xorigin=0.0*, *yorigin=0.0*)

Given x and y array-like values calculate the rotation about an arbitrary origin and then return the rotated coordinates. theta is in degrees.

set_spatialreference(*xadj=0.0*, *yadj=0.0*, *rotation=0.0*)

set spatial reference - can be called from model instance xadj, yadj should be named xadj, yadj since they represent an adjustment factor

property xarr

property xcenter_array

property xdict

property xydict

property yarr

property ycenter_array

property ydict

flopy.mf6.utils.lakpak_utils module

get_lak_connections(*modelgrid*, *lake_map*, *idomain=None*, *bedleak=None*)

Function to create lake package connection data from a zero-based integer array of lake numbers. If the shape of lake number array is equal to (nrow, ncol) or (ncpl) then the lakes are on top of the model and are vertically connected to cells at the top of the model. Otherwise the lakes are embedded in the grid.

TODO: implement embedded lakes for VertexGrid

TODO: add support for UnstructuredGrid

Parameters

- **modelgrid** (StructuredGrid, VertexGrid) – model grid
- **lake_map** (*MaskedArray*, *ndarray*, *list*, *tuple*) – location and zero-based lake number for lakes in the model domain. If lake_map is of size (nrow, ncol) or (ncpl) lakes are located on top of the model and vertically connected to cells in model layer 1. If lake_map is of size (nlay, nrow, ncol) or (nlay, ncpl) lakes are embedded in the model domain and horizontal and vertical lake connections are defined.
- **idomain** (*int or ndarray*) – location of inactive cells, which are defined with a zero value. If a ndarray is passed it must be of size (nlay, nrow, ncol) or (nlay, ncpl).
- **bedleak** (*ndarray*, *list*, *tuple*, *float*) – bed leakance for lakes in the model domain. If bedleak is a float the same bed leakance is applied to each lake connection in the model. If bedleak is of size (nrow, ncol) or (ncpl) then all lake connections for the cellid are given the same bed leakance value. If bedleak is None, lake conductance is only a function of aquifer properties for all lakes. Can also pass mixed values as list or ndarray of size (nrow, ncol) or (ncpl) with floats and 'none' strings.

Returns

- **idomain** (*ndarry*) – idomain adjusted to inactivate cells with lakes
- **connection_dict** (*dict*) – dictionary with the zero-based lake number keys and number of connections in a lake values
- **connectiondata** (*list of lists*) – connectiondata block for the lake package

flopy.mf6.utils.model_splitter module

class Mf6Splitter(*sim*, *modelname=None*)

Bases: object

A class for splitting a single model into a multi-model simulation

Parameters

- **sim** (*flopy.mf6.MFSimulation*) –
- **modelname** (*str*, *None*) – name of model to split

load_node_mapping(*sim*, *filename*)

Method to load a saved json node mapping file and populate mapping dictionaries for reconstructing arrays and recarrays

Parameters

- **sim** (*flopy.mf6.MFSimulation*) – MFSimulation instance with split models
- **filename** (*str*, *Path*) – JSON file name

property new_simulation

Returns the new simulation object after model splitting

optimize_splitting_mask(*nparts*)

Method to create a splitting array with a balanced number of active cells per model. This method uses the program METIS and pymetis to create the subsetting array

Parameters

nparts (*int*) –

Return type

np.ndarray

property original_modelgrid

Method to return the original model's modelgrid object. This is used for re-assembling the split models when analyzing output

recarray_bc_array(*recarray*, *pkgtype=None*, *color='c'*)

Method to take a reconstructed recarray and create a plottable boundary condition location array from it.

Parameters

- **recarray** (*np.recarray*) –
- **pkgtype** (*str*) – optional package type. used to apply flopy's default color to package

Returns

tuple

Return type

numpy array and a dict of matplotlib kwargs

reconstruct_array(*arrays*)

Method to reconstruct model output arrays into a single array with the dimensions of the original model

arrays
[dict] dictionary of model number and the associated array

Return type
np.ndarray of original model shape

reconstruct_recarray(*recarrays*)

Method to reconstruct model recarrays into a single recarray that represents the original model data

Parameters
recarrays (*dict*) – dictionary of model number and recarray

Return type
np.recarray

property reversed_node_map

original node}}

Type
Returns a lookup table of {model number

Type
{model node

save_node_mapping(*filename*)

Method to save the Mf6Splitter's node mapping to file for use in reconstructing arrays

Parameters
filename (*str, Path*) – JSON file name

Return type
None

split_model(*array*)

User method to split a model based on an array

Parameters
array (*np.ndarray*) – integer array of new model numbers. Array must either be of dimension (NROW, NCOL), (NCPL), or (NNODES for unstructured grid models).

Return type
MFSimulation object

switch_models(*modelname*, *remap_nodes=False*)

Method to switch which model within a simulation that is being split. Models must be congruent. Ex. GWF model followed by a GWT model. If the models are not congruent remap_nodes must be set to True.

Parameters

- **modelname** (*str*) – model name to switch to
- **remap_nodes** (*bool*) – boolean flag to force the class to remap the node look up table. This is used when models do not overlap (ex. two separate GWF models). Exchanges between original models are not preserved currently.

Return type
None

12.1.9 MODFLOW 6 Data

FloPy for MODFLOW 6 data objects (MFDataArray, MFDataList, MFDataScalar) are automatically constructed by FloPy when you construct a package. These data objects provide an interface for getting MODFLOW 6 data in different formats and setting MODFLOW 6 data.

Contents:

flopy.mf6.data.mfdataarray module

class MFArray(*sim_data*, *model_or_sim*, *structure*, *data=None*, *enable=True*, *path=None*, *dimensions=None*, *block=None*)

Bases: MFMultiDimVar

Provides an interface for the user to access and update MODFLOW array data. MFArray objects are not designed to be directly constructed by the end user. When a FloPy for MODFLOW 6 package object is constructed, the appropriate MFArray objects are automatically built.

Parameters

- **sim_data** (MFSimulationData) – data contained in the simulation
- **structure** (*MFDataStructure*) – describes the structure of the data
- **data** (*list or ndarray*) – actual data
- **enable** (*bool*) – enable/disable the array
- **path** (*tuple*) – path in the data dictionary to this MFArray
- **dimensions** (*MFDataDimensions*) – dimension information related to the model, package, and array

property data

Returns array data. Calls get_data with default parameters.

property data_type

Type of data (DataType) stored in the array

property dtype

Type of data (numpy.dtype) stored in the array

get_data(*layer=None*, *apply_mult=False*, ***kwargs*)

Returns the data associated with layer "layer". If "layer" is None, returns all data.

Parameters
layer (*int*) –

Returns
data – Array data in an ndarray

Return type
ndarray

get_file_entry(*layer=None*, *ext_file_action=ExtFileAction.copy_relative_paths*)

Returns a string containing the data in layer "layer" formatted for a MODFLOW 6 file. For unlayered data do not pass in "layer".

Parameters

- **layer** (*int*) – The layer to return file entry for.
- **ext_file_action** (ExtFileAction) – How to handle external paths.

Returns
file entry

Return type
str

get_record(*layer=None*)

Returns the data record associated with layer "layer". If "layer" is None, returns all data.

Parameters
layer (*int*) –

Returns
data_record – Dictionary containing data record for specified layer or dictionary containing layer numbers (keys) and data record for that layer (values).

Return type
dict

has_data(*layer=None*)

Returns whether layer "layer_num" has any data associated with it.

Parameters
layer_num (*int*) – Layer number to check for data. For unlayered data do not pass anything in

Returns
has data – Returns if there is data.

Return type
bool

load(*first_line*, *file_handle*, *block_header*, *pre_data_comments=None*, *external_file_info=None*)

Loads data from first_line (the first line of data) and open file file_handle which is pointing to the second line of data. Returns a tuple with the first item indicating whether all data was read and the second item being the last line of text read from the file. This method is for internal flopy use and is not intended for the end user.

Parameters

- **first_line** (*str*) – A string containing the first line of data in this array.
- **file_handle** (*file descriptor*) – A file handle for the data file which points to the second line of data for this array

- **block_header** (MFBlockHeader) - Block header object that contains block header information for the block containing this data
- **pre_data_comments** (*MFComment*) - Comments immediately prior to the data
- **external_file_info** (*list*) - Contains information about storing files externally

Returns

- **more data** (*bool,*)
- **next data line** (*str*)

make_layered()

Changes the data to be stored by layer instead of as a single array.

new_simulation(*sim_data*)

Initialize MFArray object for a new simulation

Parameters

sim_data (MFSimulationData) - Data dictionary containing simulation data.

plot(*filename_base=None*, *file_extension=None*, *mflay=None*, *fignum=None*, *title=None*, ***kwargs*)

Plot 3-D model input data

Parameters

- **filename_base** (*str*) - Base file name that will be used to automatically generate file names for output image files. Plots will be exported as image files if file_name_base is not None. (default is None)
- **file_extension** (*str*) - Valid matplotlib.pyplot file extension for savefig(). Only used if filename_base is not None. (default is 'png')
- **mflay** (*int*) - MODFLOW zero-based layer number to return. If None, then all all layers will be included. (default is None)
- ****kwargs** (*dict*) -

  axes
  [list of matplotlib.pyplot.axis] List of matplotlib.pyplot.axis that will be used to plot data for each layer. If axes=None axes will be generated. (default is None)

  pcolor
  [bool] Boolean used to determine if matplotlib.pyplot.pcolormesh plot will be plotted. (default is True)

  colorbar
  [bool] Boolean used to determine if a color bar will be added to the matplotlib.pyplot.pcolormesh. Only used if pcolor=True. (default is False)

inactive
[bool] Boolean used to determine if a black overlay in inactive cells in a layer will be displayed. (default is True)

contour
[bool] Boolean used to determine if matplotlib.pyplot.contour plot will be plotted. (default is False)

clabel
[bool] Boolean used to determine if matplotlib.pyplot.clabel will be plotted. Only used if contour=True. (default is False)

grid
[bool] Boolean used to determine if the model grid will be plotted on the figure. (default is False)

masked_values
[list] List of unique values to be excluded from the plot.

Returns
out – Empty list is returned if filename_base is not None. Otherwise a list of matplotlib.pyplot.axis is returned.

Return type
list

property plottable
If the array is plottable

set_data(*data*, *multiplier=None*, *layer=None*)
Sets the contents of the data at layer *layer* to *data* with multiplier *multiplier*. For unlayered data do not pass in *layer*. Data can have the following formats: 1) ndarray - numpy ndarray containing all of the data 2) [data] - python list containing all of the data 3) val - a single constant value to be used for all of the data

Parameters

- **data** (*ndarray/list*) – An ndarray or nested lists containing the data to set.
- **multiplier** (*float*) – Multiplier to apply to data
- **layer** (*int*) – Data layer that is being set

set_layered_data(*layered_data*)
Sets whether this MFArray supports layered data

Parameters
layered_data (*bool*) – Whether data is layered or not.

set_record(*data_record*)
Sets the contents of the data and metadata to the contents of 'data_record`. For unlayered data do not pass in *layer*. For unlayered data 'data_record' is a dictionary with either of the following key/value pairs: 1) {'filename':filename, 'factor':fct, 'iprn':print, 'data':data} - dictionary defining external file information 2) {'data':data, 'factor':fct,

'iprn':print)}- dictionary defining internal information. Data that is layered can also be set by defining For layered data data_record must be a dictionary of dictionaries with zero-based layer numbers for the outer dictionary keys and the inner dictionary as described above:

{0: {'data':data_lay_0, 'factor':fct_lay_0, 'iprn':prn_lay_0)},
1: {'data':data_lay_1, 'factor':fct_lay_1, 'iprn':prn_lay_1)}, 2: {'data':data_lay_2, 'factor':fct_lay_2, 'iprn':prn_lay_2)}}

Parameters
data_record (*dict*) – An dictionary of data record information or a dictionary of layers (keys) with a dictionary of data record information for each layer (values).

store_as_external_file(*external_file_path*, *layer=None*, *binary=False*, *replace_existing_external=True*, *check_data=True*)

Stores data from layer *layer* to an external file at *external_file_path*. For unlayered data do not pass in *layer*. If layer is not specified all layers will be stored with each layer as a separate file. If replace_existing_external is set to False, this method will not do anything if the data is already in an external file.

Parameters

- **external_file_path** (*str*) – Path to external file
- **layer** (*int*) – Which layer to store in external file, *None* value stores all layers.
- **binary** (*bool*) – Store data in a binary file
- **replace_existing_external** (*bool*) – Whether to replace an existing external file.
- **check_data** (*bool*) – Verify data prior to storing

store_internal(*layer=None*, *check_data=True*)

Stores data from layer *layer* internally. For unlayered data do not pass in *layer*. If layer is not specified all layers will be stored internally

Parameters

- **layer** (*int*) – Which layer to store in external file, *None* value stores all layers.
- **check_data** (*bool*) – Verify data prior to storing

supports_layered()

Returns whether this MFArray supports layered data

Returns
layered data supported – Whether or not this data object supports layered data

Return type
bool

class **MFTransientArray**(*sim_data*, *model_or_sim*, *structure*, *enable=True*, *path=None*, *dimensions=None*, *block=None*)

Bases: *MFArray*, MFTransient

Provides an interface for the user to access and update MODFLOW transient array data. MFTransientArray objects are not designed to be directly constructed by the end user. When a FloPy for MODFLOW 6 package object is constructed, the appropriate MFArray objects are automatically built.

Parameters

- **sim_data** (MFSimulationData) – data contained in the simulation
- **structure** (*MFDataStructure*) – describes the structure of the data
- **data** (*list or ndarray*) – actual data
- **enable** (*bool*) – enable/disable the array
- **path** (*tuple*) – path in the data dictionary to this MFArray
- **dimensions** (*MFDataDimensions*) – dimension information related to the model, package, and array

Examples

add_transient_key(*transient_key*)

Adds a new transient time allowing data for that time to be stored and retrieved using the key *transient_key*. This method is intended for internal library usage only.

Parameters

transient_key (*int*) – Zero-based stress period

property data_type

Type of data (DataType) stored in the array

get_data(*key=None*, *apply_mult=True*, ***kwargs*)

Returns the data associated with stress period key *key*.

Parameters

- **key** (*int*) – Zero-based stress period of data to return
- **apply_mult** (*bool*) – Whether to apply multiplier to data prior to returning it

get_file_entry(*key=0*, *ext_file_action=ExtFileAction.copy_relative_paths*)

Returns a string containing the data in stress period "key".

Parameters

- **key** (*int*) – The stress period to return file entry for.
- **ext_file_action** (ExtFileAction) – How to handle external paths.

Returns

file entry

Return type

str

get_record(*key=None*)

Returns the data record (data and metadata) associated with stress period key *layer*. If *layer* is None, returns all data for time *layer*.

Parameters
key (*int*) – Zero-based stress period of data to return

has_data(*layer=None*)

Returns whether layer "layer_num" has any data associated with it.

Parameters
layer_num (*int*) – Layer number to check for data. For unlayered data do not pass anything in

Returns
has data – Returns if there is data.

Return type
bool

load(*first_line*, *file_handle*, *block_header*, *pre_data_comments=None*, *external_file_info=None*)

Loads data from first_line (the first line of data) and open file handle which is pointing to the second line of data. Returns a tuple with the first item indicating whether all data was read and the second item being the last line of text read from the file. This method is for internal flopy use and is not intended to be called by the end user.

Parameters

- **first_line** (*str*) – A string containing the first line of data in this array.
- **file_handle** (*file descriptor*) – A file handle for the data file which points to the second line of data for this array
- **block_header** (MFBlockHeader) – Block header object that contains block header information for the block containing this data
- **pre_data_comments** (*MFComment*) – Comments immediately prior to the data
- **external_file_info** (*list*) – Contains information about storing files externally

Returns

- **more data** (*bool,*)
- **next data line** (*str*)

plot(*kper=None*, *filename_base=None*, *file_extension=None*, *mflay=None*, *fignum=None*, ***kwargs*)

Plot transient array model input data

Parameters

- **transient2d** (*flopy.utils.util_array.Transient2D object*) –
- **filename_base** (*str*) – Base file name that will be used to automatically generate file names for output image files.

Plots will be exported as image files if file_name_base is not None. (default is None)

- **file_extension** (*str*) - Valid matplotlib.pyplot file extension for savefig(). Only used if filename_base is not None. (default is 'png')
- ****kwargs** (*dict*) -

axes
[list of matplotlib.pyplot.axis] List of matplotlib.pyplot.axis that will be used to plot data for each layer. If axes=None axes will be generated. (default is None)

pcolor
[bool] Boolean used to determine if matplotlib.pyplot.pcolormesh plot will be plotted. (default is True)

colorbar
[bool] Boolean used to determine if a color bar will be added to the matplotlib.pyplot.pcolormesh. Only used if pcolor=True. (default is False)

inactive
[bool] Boolean used to determine if a black overlay in inactive cells in a layer will be displayed. (default is True)

contour
[bool] Boolean used to determine if matplotlib.pyplot.contour plot will be plotted. (default is False)

clabel
[bool] Boolean used to determine if matplotlib.pyplot.clabel will be plotted. Only used if contour=True. (default is False)

grid
[bool] Boolean used to determine if the model grid will be plotted on the figure. (default is False)

masked_values
[list] List of unique values to be excluded from the plot.

kper
[str] MODFLOW zero-based stress period number to return. If kper='all' then data for all stress period will be extracted. (default is zero).

Returns
axes - Empty list is returned if filename_base is not None. Otherwise a list of matplotlib.pyplot.axis is returned.

Return type
list

remove_transient_key(*transient_key*)

Removes a new transient time *transient_key* and any data stored at that time. This method is intended for internal library usage only.

Parameters

transient_key (*int*) – Zero-based stress period

set_data(*data*, *multiplier=None*, *layer=None*, *key=None*)

Sets the contents of the data at layer *layer* and time *key* to *data* with multiplier *multiplier*. For unlayered data do not pass in *layer*.

Parameters

- **data** (*dict*, *ndarray*, *list*) – Data being set. Data can be a dictionary with keys as zero-based stress periods and values as the data. If data is an ndarray or list of lists, it will be assigned to the the stress period specified in *key*. If any is set to None, that stress period of data will be removed.
- **multiplier** (*int*) – multiplier to apply to data
- **layer** (*int*) – Layer of data being set. Keep default of None of data is not layered.
- **key** (*int*) – Zero based stress period to assign data too. Does not apply if *data* is a dictionary.

set_record(*data_record*)

Sets data and metadata at layer *layer* and time *key* to *data_record*. For unlayered data do not pass in *layer*.

Parameters

data_record (*dict*) – Data record being set. Data must be a dictionary with keys as zero-based stress periods and values as a dictionary of data and metadata (factor, iprn, filename, binary, data) for a given stress period. How to define the dictionary of data and metadata is described in the MFData class's set_record method.

store_as_external_file(*external_file_path*, *layer=None*, *binary=False*, *replace_existing_external=True*, *check_data=True*)

Stores data from layer *layer* to an external file at *external_file_path*. For unlayered data do not pass in *layer*. If layer is not specified all layers will be stored with each layer as a separate file. If replace_existing_external is set to False, this method will not do anything if the data is already in an external file.

Parameters

- **external_file_path** (*str*) – Path to external file
- **layer** (*int*) – Which layer to store in external file, *None* value stores all layers.
- **binary** (*bool*) – Store data in a binary file
- **replace_existing_external** (*bool*) – Whether to replace an existing external file.
- **check_data** (*bool*) – Verify data prior to storing

store_internal(*layer=None*, *check_data=True*)

Stores data from layer *layer* internally. For unlayered data do not pass in *layer*. If layer is not specified all layers will be stored internally.

Parameters

- **layer** (*int*) – Which layer to store internally file, *None* value stores all layers.
- **check_data** (*bool*) – Verify data prior to storing

flopy.mf6.data.mfdatalist module

class MFList(*sim_data*, *model_or_sim*, *structure*, *data=None*, *enable=True*, *path=None*, *dimensions=None*, *package=None*, *block=None*)

Bases: MFMultiDimVar, DataListInterface

Provides an interface for the user to access and update MODFLOW list data. MFList objects are not designed to be directly constructed by the end user. When a flopy for MODFLOW 6 package object is constructed, the appropriate MFList objects are automatically built.

Parameters

- **sim_data** (MFSimulationData) – data contained in the simulation
- **structure** (*MFDataStructure*) – describes the structure of the data
- **data** (*list or ndarray or None*) – actual data
- **enable** (*bool*) – enable/disable the array
- **path** (*tuple*) – path in the data dictionary to this MFArray
- **dimensions** (*MFDataDimensions*) – dimension information related to the model, package, and array

append_data(*data*)

Appends "data" to the end of this list. Assumes data is in a format that can be appended directly to a numpy recarray.

Parameters

data (*list(tuple)*) – Data to append.

append_list_as_record(*record*)

Appends the list *record* as a single record in this list's recarray. Assumes "data" has the correct dimensions.

Parameters

record (*list*) – List to be appended as a single record to the data's existing recarray.

property data_type

Type of data (DataType) stored in the list

property dtype

Type of data (numpy.dtype) stored in the list

get_data(*apply_mult=False*, ***kwargs*)

Returns the list's data.

Parameters
apply_mult (*bool*) – Whether to apply a multiplier.

Returns
data

Return type
recarray

get_file_entry(*ext_file_action=ExtFileAction.copy_relative_paths*)

Returns a string containing the data formatted for a MODFLOW 6 file.

Parameters
ext_file_action (ExtFileAction) – How to handle external paths.

Returns
file entry

Return type
str

get_record()

Returns the list's data and metadata in a dictionary. Data is in key "data" and metadata in keys "filename" and "binary".

Returns
data_record

Return type
dict

has_data(*key=None*)

Returns whether this MFList has any data associated with it.

load(*first_line*, *file_handle*, *block_header*, *pre_data_comments=None*, *external_file_info=None*)

Loads data from first_line (the first line of data) and open file file_handle which is pointing to the second line of data. Returns a tuple with the first item indicating whether all data was read and the second item being the last line of text read from the file. This method was only designed for internal FloPy use and is not recommended for end users.

Parameters

- **first_line** (*str*, *None*) – A string containing the first line of data in this list.
- **file_handle** (*file descriptor*) – A file handle for the data file which points to the second line of data for this list
- **block_header** (MFBlockHeader) – Block header object that contains block header information for the block containing this data
- **pre_data_comments** (*MFComment*) – Comments immediately prior to the data
- **external_file_info** (*list*) – Contains information about storing files externally

Returns

- **more data** (*bool,*)
- **next data line** (*str*)

new_simulation(*sim_data*)

Initialize MFList object for a new simulation.

Parameters

sim_data (MFSimulationData) – Simulation data object for the simulation containing this data.

property package

Package object that this data belongs to.

plot(*key=None*, *names=None*, *filename_base=None*, *file_extension=None*, *mflay=None*, ***kwargs*)

Plot boundary condition (MfList) data

Parameters

- **key** (*str*) – MfList dictionary key. (default is None)
- **names** (*list*) – List of names for figure titles. (default is None)
- **filename_base** (*str*) – Base file name that will be used to automatically generate file names for output image files. Plots will be exported as image files if file_name_base is not None. (default is None)
- **file_extension** (*str*) – Valid matplotlib.pyplot file extension for savefig(). Only used if filename_base is not None. (default is 'png')
- **mflay** (*int*) – MODFLOW zero-based layer number to return. If None, then all all layers will be included. (default is None)
- ****kwargs** (*dict*) –

  axes
  [list of matplotlib.pyplot.axis] List of matplotlib.pyplot.axis that will be used to plot data for each layer. If axes=None axes will be generated. (default is None)

  pcolor
  [bool] Boolean used to determine if matplotlib.pyplot.pcolormesh plot will be plotted. (default is True)

  colorbar
  [bool] Boolean used to determine if a color bar will be added to the matplotlib.pyplot.pcolormesh. Only used if pcolor=True. (default is False)

  inactive
  [bool] Boolean used to determine if a black overlay in inactive cells in a layer will be displayed. (default is True)

  contour
  [bool] Boolean used to determine if

matplotlib.pyplot.contour plot will be plotted. (default is False)

clabel
[bool] Boolean used to determine if matplotlib.pyplot.clabel will be plotted. Only used if contour=True. (default is False)

grid
[bool] Boolean used to determine if the model grid will be plotted on the figure. (default is False)

masked_values
[list] List of unique values to be excluded from the plot.

Returns
out - Empty list is returned if filename_base is not None. Otherwise a list of matplotlib.pyplot.axis is returned.

Return type
list

property plottable
If this list data is plottable

search_data(*search_term*, *col=None*)
Searches the list data at column "col" for "search_term". If col is None search_data searches the entire list.

Parameters

- **search_term** (*str*) - String to search for
- **col** (*int*) - Column number to search

set_data(*data*, *autofill=False*, *check_data=True*)
Sets the contents of the data to "data". Data can have the following formats:

1) recarray - recarray containing the datalist
2) [(line_one), (line_two), ...] - list where each line of the datalist is a tuple within the list

If the data is transient, a dictionary can be used to specify each stress period where the dictionary key is <stress period> - 1 and the dictionary value is the datalist data defined above: {0:ndarray, 1:[(line_one), (line_two), ...], 2:{'filename':filename})

Parameters

- **data** (*ndarray/list/dict*) - Data to set
- **autofill** (*bool*) - Automatically correct data
- **check_data** (*bool*) - Whether to verify the data

set_record(*data_record*, *autofill=False*, *check_data=True*)
Sets the contents of the data and metadata to "data_record". Data_record is a dictionary with has the following format:

{'filename':filename, 'binary':True/False, 'data'=data}

To store to file include 'filename' in the dictionary.

Parameters

- **data_record** (*ndarray/list/dict*) – Data and metadata to set
- **autofill** (*bool*) – Automatically correct data
- **check_data** (*bool*) – Whether to verify the data

store_as_external_file(*external_file_path*, *binary=False*, *replace_existing_external=True*, *check_data=True*)

Store all data externally in file external_file_path. the binary allows storage in a binary file. If replace_existing_external is set to False, this method will not do anything if the data is already in an external file.

Parameters

- **external_file_path** (*str*) – Path to external file
- **binary** (*bool*) – Store data in a binary file
- **replace_existing_external** (*bool*) – Whether to replace an existing external file.
- **check_data** (*bool*) – Verify data prior to storing

store_internal(*check_data=True*)

Store all data internally.

Parameters
check_data (*bool*) – Verify data prior to storing

to_array(*kper=0*, *mask=False*)

Convert stress period boundary condition (MFDataList) data for a specified stress period to a 3-D numpy array.

Parameters

- **kper** (*int*) – MODFLOW zero-based stress period number to return. (default is zero)
- **mask** (*bool*) – return array with np.NaN instead of zero

Returns
out – Dictionary of 3-D numpy arrays containing the stress period data for a selected stress period. The dictionary keys are the MFDataList dtype names for the stress period data.

Return type
dict of numpy.ndarrays

update_record(*record*, *key_index*)

Updates a record at index "key_index" with the contents of "record". If the index does not exist update_record appends the contents of "record" to this list's recarray.

Parameters

- **record** (*list*) – New record to update data with
- **key_index** (*int*) – Stress period key of record to update. Only used in transient data types.

class MFMultipleList(*sim_data*, *model_or_sim*, *structure*, *enable=True*, *path=None*, *dimensions=None*, *package=None*, *block=None*)

Bases: *MFTransientList*

Provides an interface for the user to access and update MODFLOW multiple list data. This is list data that is in the same format as the MFTransientList, but is not time based.

Parameters

- **sim_data** (MFSimulationData) – data contained in the simulation
- **structure** (*MFDataStructure*) – describes the structure of the data
- **data** (*list or ndarray*) – actual data
- **enable** (*bool*) – enable/disable the array
- **path** (*tuple*) – path in the data dictionary to this MFArray
- **dimensions** (*MFDataDimensions*) – dimension information related to the model, package, and array

get_data(*key=None*, *apply_mult=False*, ***kwargs*)

Returns the data for stress period *key*.

Parameters

- **key** (*int*) – Zero-based stress period to return data from.
- **apply_mult** (*bool*) – Apply multiplier

Returns

data

Return type

ndarray

class MFTransientList(*sim_data*, *model_or_sim*, *structure*, *enable=True*, *path=None*, *dimensions=None*, *package=None*, *block=None*)

Bases: *MFList*, MFTransient, DataListInterface

Provides an interface for the user to access and update MODFLOW transient list data.

Parameters

- **sim_data** (MFSimulationData) – data contained in the simulation
- **structure** (*MFDataStructure*) – describes the structure of the data
- **data** (*list or ndarray*) – actual data
- **enable** (*bool*) – enable/disable the array
- **path** (*tuple*) – path in the data dictionary to this MFArray
- **dimensions** (*MFDataDimensions*) – dimension information related to the model, package, and array

add_transient_key(*transient_key*)

Adds a new transient time allowing data for that time to be stored and retrieved using the key *transient_key*. Method is used internally by FloPy and is not intended to the end user.

Parameters

transient_key (*int*) – Zero-based stress period to add

append_list_as_record(*record*, *key=0*)

Appends the list *data* as a single record in this list's recarray at time *key*. Assumes *data* has the correct dimensions.

Parameters

- **data** (*list*) – Data to append
- **key** (*int*) – Zero based stress period to append data too.

property data

Returns list data. Calls get_data with default parameters.

property data_type

Type of data (DataType) stored in the list

property dtype

Type of data (numpy.dtype) stored in the list

get_data(*key=None*, *apply_mult=False*, ***kwargs*)

Returns the data for stress period *key*.

Parameters

- **key** (*int*) – Zero-based stress period to return data from.
- **apply_mult** (*bool*) – Apply multiplier

Returns

data

Return type

recarray

get_file_entry(*key=0*, *ext_file_action=ExtFileAction.copy_relative_paths*)

Returns a string containing the data at time *key* formatted for a MODFLOW 6 file.

Parameters

- **key** (*int*) – Zero based stress period to return data from.
- **ext_file_action** (ExtFileAction) – How to handle external paths.

Returns

file entry

Return type

str

get_record(*key=None*)

Returns the data for stress period *key*. If no key is specified returns all records in a dictionary with zero-based stress period numbers as keys. See MFList's get_record documentation for more information on the format of each record returned.

Parameters

key (*int*) – Zero-based stress period to return data from.

Returns

data_record

Return type
dict

has_data(*key=None*)

Returns whether this MFList has any data associated with it in key "key".

load(*first_line*, *file_handle*, *block_header*, *pre_data_comments=None*, *external_file_info=None*)

Loads data from first_line (the first line of data) and open file file_handle which is pointing to the second line of data. Returns a tuple with the first item indicating whether all data was read and the second item being the last line of text read from the file.

Parameters

- **first_line** (*str*) – A string containing the first line of data in this list.
- **file_handle** (*file descriptor*) – A file handle for the data file which points to the second line of data for this array
- **block_header** (MFBlockHeader) – Block header object that contains block header information for the block containing this data
- **pre_data_comments** (*MFComment*) – Comments immediately prior to the data
- **external_file_info** (*list*) – Contains information about storing files externally

property masked_4D_arrays

Returns list data as a masked 4D array.

masked_4D_arrays_itr()

Returns list data as an iterator of a masked 4D array.

plot(*key=None*, *names=None*, *kper=0*, *filename_base=None*, *file_extension=None*, *mflay=None*, ***kwargs*)

Plot stress period boundary condition (MfList) data for a specified stress period

Parameters

- **key** (*str*) – MfList dictionary key. (default is None)
- **names** (*list*) – List of names for figure titles. (default is None)
- **kper** (*int*) – MODFLOW zero-based stress period number to return. (default is zero)
- **filename_base** (*str*) – Base file name that will be used to automatically generate file names for output image files. Plots will be exported as image files if file_name_base is not None. (default is None)
- **file_extension** (*str*) – Valid matplotlib.pyplot file extension for savefig(). Only used if filename_base is not None. (default is 'png')

- **mflay** (*int*) - MODFLOW zero-based layer number to return. If None, then all all layers will be included. (default is None)
- ****kwargs** (*dict*) -

  axes
  : [list of matplotlib.pyplot.axis] List of matplotlib.pyplot.axis that will be used to plot data for each layer. If axes=None axes will be generated. (default is None)

  pcolor
  : [bool] Boolean used to determine if matplotlib.pyplot.pcolormesh plot will be plotted. (default is True)

  colorbar
  : [bool] Boolean used to determine if a color bar will be added to the matplotlib.pyplot.pcolormesh. Only used if pcolor=True. (default is False)

  inactive
  : [bool] Boolean used to determine if a black overlay in inactive cells in a layer will be displayed. (default is True)

  contour
  : [bool] Boolean used to determine if matplotlib.pyplot.contour plot will be plotted. (default is False)

  clabel
  : [bool] Boolean used to determine if matplotlib.pyplot.clabel will be plotted. Only used if contour=True. (default is False)

  grid
  : [bool] Boolean used to determine if the model grid will be plotted on the figure. (default is False)

  masked_values
  : [list] List of unique values to be excluded from the plot.

Returns
: **out** - Empty list is returned if filename_base is not None. Otherwise a list of matplotlib.pyplot.axis is returned.

Return type
: list

remove_transient_key(*transient_key*)

Remove transient stress period key. Method is used internally by FloPy and is not intended to the end user.

set_data(*data*, *key=None*, *autofill=False*)

Sets the contents of the data at time *key* to *data*.

Parameters

- **data** (*dict*, *recarray*, *list*) - Data being set. Data can be a dictionary with keys as zero-based stress periods and values as the data. If data is a recarray or list of tuples, it will be assigned to the stress period specified in *key*. If any is set to None, that stress period of data will be removed.

- **key** (*int*) – Zero based stress period to assign data too. Does not apply if *data* is a dictionary.
- **autofill** (*bool*) – Automatically correct data.

set_record(*data_record*, *autofill=False*, *check_data=True*)

Sets the contents of the data based on the contents of 'data_record`.

Parameters

- **data_record** (*dict*) – Data_record being set. Data_record must be a dictionary with keys as zero-based stress periods and values as dictionaries containing the data and metadata. See MFList's set_record documentation for more information on the format of the values.
- **autofill** (*bool*) – Automatically correct data
- **check_data** (*bool*) – Whether to verify the data

store_as_external_file(*external_file_path*, *binary=False*, *replace_existing_external=True*, *check_data=True*)

Store all data externally in file external_file_path. the binary allows storage in a binary file. If replace_existing_external is set to False, this method will not do anything if the data is already in an external file.

Parameters

- **external_file_path** (*str*) – Path to external file
- **binary** (*bool*) – Store data in a binary file
- **replace_existing_external** (*bool*) – Whether to replace an existing external file.
- **check_data** (*bool*) – Verify data prior to storing

store_internal(*check_data=True*)

Store all data internally.

Parameters

check_data (*bool*) – Verify data prior to storing

to_array(*kper=0*, *mask=False*)

Returns list data as an array.

update_record(*record*, *key_index*, *key=0*)

Updates a record at index *key_index* and time *key* with the contents of *record*. If the index does not exist update_record appends the contents of *record* to this list's recarray.

Parameters

- **record** (*list*) – Record to append
- **key_index** (*int*) – Index to update
- **key** (*int*) – Zero based stress period to append data too

flopy.mf6.data.mfdatascalar module

class MFScalar(*sim_data*, *model_or_sim*, *structure*, *data=None*, *enable=True*, *path=None*, *dimensions=None*)

Bases: MFData

Provides an interface for the user to access and update MODFLOW scalar data. MFScalar objects are not designed to be directly constructed by the end user. When a flopy for MODFLOW 6 package object is constructed, the appropriate MFScalar objects are automatically built.

Parameters

- **sim_data** (MFSimulationData) – data contained in the simulation
- **structure** (*MFDataStructure*) – describes the structure of the data
- **data** (*list or ndarray*) – actual data
- **enable** (*bool*) – enable/disable the array
- **path** (*tuple*) – path in the data dictionary to this MFArray
- **dimensions** (*MFDataDimensions*) – dimension information related to the model, package, and array

add_one()

Adds one if this is an integer scalar

property data

Returns the scalar data. Calls get_data with default parameters.

property data_type

Type of data (DataType) stored in the scalar

property dtype

The scalar's numpy data type (numpy.dtype).

get_data(*apply_mult=False*, ***kwargs*)

Returns the data associated with this object.

Parameters

apply_mult (*bool*) – Parameter does not apply to scalar data.

Returns

data

Return type

str, int, float, recarray

get_file_entry(*values_only=False*, *one_based=False*, *ext_file_action=ExtFileAction.copy_relative_paths*)

Returns a string containing the data formatted for a MODFLOW 6 file.

Parameters

- **values_only** (*bool*) – Return values only excluding keywords
- **one_based** (*bool*) – Return one-based integer values
- **ext_file_action** (ExtFileAction) – How to handle external paths.

Returns
    file entry

Return type
    str

has_data(*key=None*)

Returns whether this object has data associated with it.

load(*first_line*, *file_handle*, *block_header*, *pre_data_comments=None*, *external_file_info=None*)

Loads data from first_line (the first line of data) and open file file_handle which is pointing to the second line of data. Returns a tuple with the first item indicating whether all data was read and the second item being the last line of text read from the file. This method was only designed for internal FloPy use and is not recommended for end users.

Parameters

- **first_line** (*str*) – A string containing the first line of data.
- **file_handle** (*file descriptor*) – A file handle for the data file which points to the second line of data
- **block_header** (MFBlockHeader) – Block header object that contains block header information for the block containing this data
- **pre_data_comments** (*MFComment*) – Comments immediately prior to the data
- **external_file_info** (*list*) – Contains information about storing files externally

Returns

- **more data** (*bool,*)
- **next data line** (*str*)

plot(*filename_base=None*, *file_extension=None*, ***kwargs*)

Helper method to plot scalar objects

Parameters

- **scalar** – flopy.mf6.data.mfscalar object
- **filename_base** – str Base file name that will be used to automatically generate file names for output image files. Plots will be exported as image files if file_name_base is not None. (default is None)
- **file_extension** – str Valid matplotlib.pyplot file extension for savefig(). Only used if filename_base is not None. (default is 'png')

Returns
    list matplotlib.axes object

Return type
    axes

property plottable

If the scalar is plottable. Currently all scalars are not plottable.

set_data(*data*)

Sets the contents of the data to *data*.

Parameters
data (*str/int/float/recarray/list*) – Data to set

class MFScalarTransient(*sim_data*, *model_or_sim*, *structure*, *enable=True*, *path=None*, *dimensions=None*)

Bases: *MFScalar*, MFTransient

Provides an interface for the user to access and update MODFLOW transient scalar data. Transient scalar data is used internally by FloPy and should not be used directly by the end user.

Parameters

- **sim_data** (MFSimulationData) – data contained in the simulation
- **structure** (*MFDataStructure*) – describes the structure of the data
- **data** (*list or ndarray*) – actual data
- **enable** (*bool*) – enable/disable the array
- **path** (*tuple*) – path in the data dictionary to this MFArray
- **dimensions** (*MFDataDimensions*) – dimension information related to the model, package, and array

add_one(*key=0*)

Adds one to the data stored at key *key*. Method is used internally by FloPy and is not intended to the end user.

Parameters
key (*int*) – Zero-based stress period to add

add_transient_key(*key*)

Adds a new transient time allowing data for that time to be stored and retrieved using the key *key*. Method is used internally by FloPy and is not intended to the end user.

Parameters
key (*int*) – Zero-based stress period to add

property data_type

Type of data (DataType) stored in the scalar

get_data(*key=0*, ***kwargs*)

Returns the data for stress period *key*.

Parameters
key (*int*) – Zero-based stress period to return data from.

Returns
data

Return type
str/int/float/recarray

get_file_entry(*key=None*, *ext_file_action=ExtFileAction.copy_relative_paths*)

Returns a string containing the data at time *key* formatted for a MODFLOW 6 file.

Parameters

- **key** (*int*) – Zero based stress period to return data from.
- **ext_file_action** (ExtFileAction) – How to handle external paths.

Returns
file entry

Return type
str

has_data(*key=None*)

Returns whether this object has data associated with it.

load(*first_line*, *file_handle*, *block_header*, *pre_data_comments=None*, *external_file_info=None*)

Loads data from first_line (the first line of data) and open file file_handle which is pointing to the second line of data. Returns a tuple with the first item indicating whether all data was read and the second item being the last line of text read from the file.

Parameters

- **first_line** (*str*) – A string containing the first line of data in this scalar.
- **file_handle** (*file descriptor*) – A file handle for the data file which points to the second line of data for this array
- **block_header** (MFBlockHeader) – Block header object that contains block header information for the block containing this data
- **pre_data_comments** (*MFComment*) – Comments immediately prior to the data
- **external_file_info** (*list*) – Contains information about storing files externally

plot(*filename_base=None*, *file_extension=None*, *kper=0*, *fignum=None*, ***kwargs*)

Plot transient scalar model data

Parameters

- **transientscalar** (*flopy.mf6.data.mfdatascalar.MFScalarTransient object*) –
- **filename_base** (*str*) – Base file name that will be used to automatically generate file names for output image files. Plots will be exported as image files if file_name_base is not None. (default is None)
- **file_extension** (*str*) – Valid matplotlib.pyplot file extension for savefig(). Only used if filename_base is not None. (default is 'png')

- **kwargs** (*dict*) –

  axes
  [list of matplotlib.pyplot.axis] List of matplotlib.pyplot.axis that will be used to plot data for each layer. If axes=None axes will be generated. (default is None)

  pcolor
  [bool] Boolean used to determine if matplotlib.pyplot.pcolormesh plot will be plotted. (default is True)

  colorbar
  [bool] Boolean used to determine if a color bar will be added to the matplotlib.pyplot.pcolormesh. Only used if pcolor=True. (default is False)

  inactive
  [bool] Boolean used to determine if a black overlay in inactive cells in a layer will be displayed. (default is True)

  contour
  [bool] Boolean used to determine if matplotlib.pyplot.contour plot will be plotted. (default is False)

  clabel
  [bool] Boolean used to determine if matplotlib.pyplot.clabel will be plotted. Only used if contour=True. (default is False)

  grid
  [bool] Boolean used to determine if the model grid will be plotted on the figure. (default is False)

  masked_values
  [list] List of unique values to be excluded from the plot.

  kper
  [str] MODFLOW zero-based stress period number to return. If kper='all' then data for all stress period will be extracted. (default is zero).

Returns
axes – Empty list is returned if filename_base is not None. Otherwise a list of matplotlib.pyplot.axis is returned.

Return type
list

property plottable

If the scalar is plottable

set_data(*data*, *key=None*)

Sets the contents of the data at time *key* to *data*.

Parameters

- **data** (*str/int/float/recarray/list*) - Data being set. Data can be a dictionary with keys as zero-based stress periods and values as the data. If data is a string, integer, double, recarray, or list of tuples, it will be assigned to the the stress period specified in *key*. If any is set to None, that stress period of data will be removed.
- **key** (*int*) - Zero based stress period to assign data too. Does not apply if *data* is a dictionary.

12.1.10 Build MODFLOW 6 Classes

MODFLOW 6 FloPy classes can be rebuild from MODFLOW 6 definition files. This will allow creation of MODFLOW 6 FloPy classes for development versions of MODFLOW 6.

Contents:

flopy.mf6.utils.createpackages module

createpackages.py is a utility script that reads in the file definition metadata in the .dfn files and creates the package classes in the modflow folder. Run this script any time changes are made to the .dfn files.

To create a new package that is part of an existing model, first create a new dfn file for the package in the mf6/data/dfn folder. 1) Follow the file naming convention <model abbr>-<package abbr>.dfn. 2) Run this script (createpackages.py), and check in your new dfn file, and

    the package class and updated __init__.py that createpackages.py created.

A subpackage is a package referenced by another package (vs being referenced in the name file). The tas, ts, and obs packages are examples of subpackages. There are a few additional steps required when creating a subpackage definition file. First, verify that the parent package's dfn file has a file record for the subpackage to the option block. For example, for the time series package the file record definition starts with:

    block options name ts_filerecord type record ts6 filein ts6_filename

Verify that the same naming convention is followed as the example above, specifically:

    name <subpackage-abbr>_filerecord record <subpackage-abbr>6 filein
    <subpackage-abbr>6_filename

Next, create the child package definition file in the mf6/data/dfn folder following the naming convention above.

When your child package is ready for release follow the same procedure as other packages along with these a few additional steps required for subpackages.

At the top of the child dfn file add two lines describing how the parent and child packages are related. The first line determines how the subpackage is linked to the package:

flopy subpackage <parent record> <abbreviation> <child data> <data name>

- Parent record is the MF6 record name of the filerecord in parent package that references the child packages file name
- Abbreviation is the short abbreviation of the new subclass

- Child data is the name of the child class data that can be passed in as parameter to the parent class. Passing in this parameter to the parent class automatically creates the child class with the data provided.
- Data name is the parent class parameter name that automatically creates the child class with the data provided.

The example below is the first line from the ts subpackage dfn:

flopy subpackage ts_filerecord ts timeseries timeseries

The second line determines the variable name of the subpackage's parent and the type of parent (the parent package's object oriented parent):

flopy parent_name_type <parent package variable name> <parent package type>

An example below is the second line in the ts subpackage dfn:

flopy parent_name_type parent_package MFPackage

There are three possible types (or combination of them) that can be used for "parent package type", MFPackage, MFModel, and MFSimulation. If a package supports multiple types of parents (for example, it can be either in the model namefile or in a package, like the obs package), include all the types supported, seperating each type with a / (MFPackage/MFModel).

To create a new type of model choose a unique three letter model abbreviation ("gwf", "gwt", ...). Create a name file dfn with the naming convention <model abbr>-nam.dfn. The name file must have only an options and packages block (see gwf-nam.dfn as an example). Create a new dfn file for each of the packages in your new model, following the naming convention described above.

When your model is ready for release make sure all the dfn files are in the flopy/mf6/data/dfn folder, run createpackages.py, and check in your new dfn files, the package classes, and updated init.py that createpackages.py created.

class PackageLevel(*value*, *names=None*, ***, *module=None*, *qualname=None*, *type=None*, *start=1*, *boundary=None*)

Bases: Enum

model_level = 1

sim_level = 0

add_var(*init_vars*, *class_vars*, *options_param_list*, *init_param_list*, *package_properties*, *doc_string*, *data_structure_dict*, *default_value*, *name*, *python_name*, *description*, *path*, *data_type*, *basic_init=False*, *construct_package=None*, *construct_data=None*, *parameter_name=None*, *set_param_list=None*)

build_dfn_string(*dfn_list*, *header*, *package_abbr*, *flopy_dict*)

build_doc_string(*param_name*, *param_type*, *param_desc*, *indent*)

build_init_string(*init_string*, *init_param_list*, *whitespace=' '*)

build_model_init_vars(*param_list*)

build_model_load(*model_type*)

build_sim_load()

clean_class_string(*name*)

create_basic_init(*clean_ds_name*)

create_init_var(*clean_ds_name*, *data_structure_name*, *init_val=None*)

create_package_init_var(*parameter_name*, *package_abbr*, *data_name*, *clean_ds_name*)

create_packages()

create_property(*clean_ds_name*)

format_var_list(*base_string*, *var_list*, *is_tuple=False*)

generator_type(*data_type*)

flopy.mf6.utils.generate_classes module

backup_existing_dfns(*flopy_dfn_path*)

cli_main()

Command-line interface for generate_classes().

delete_files(*files*, *pth*, *allow_failure=False*, *exclude=None*)

delete_mf6_classes()

download_dfn(*owner*, *repo*, *ref*, *new_dfn_pth*)

generate_classes(*owner='MODFLOW-USGS'*, *repo='modflow6'*, *branch=None*, *ref='master'*, *dfnpath=None*, *backup=True*)

Generate the MODFLOW 6 flopy classes using definition files from the MODFLOW 6 GitHub repository or a set of definition files in a folder provided by the user.

Parameters

- **owner** (*str*, *default "MODFLOW-USGS"*) – Owner of the MODFLOW 6 repository to use to update the definition files and generate the MODFLOW 6 classes.
- **repo** (*str*, *default "modflow6"*) – Name of the MODFLOW 6 repository to use to update the definition.
- **branch** (*str*, *optional*) – Branch name of the MODFLOW 6 repository to use to update the definition files and generate the MODFLOW 6 classes.

  Deprecated since version 3.5.0: Use ref instead.
- **ref** (*str*, *default "master"*) – Branch name, tag, or commit hash to use to update the definition.
- **dfnpath** (*str*) – Path to a definition file folder that will be used to generate the MODFLOW 6 classes. Default is none, which means that the branch will be used instead. dfnpath will take precedence over branch if dfnpath is specified.
- **backup** (*bool*, *default True*) – Keep a backup of the definition files in dfn_backup with a date and timestamp from when the definition files were replaced.

list_files(*pth*, *exts=['py']*)

replace_dfn_files(*new_dfn_pth*, *flopy_dfn_path*)

12.2 Previous Versions of MODFLOW

12.2.1 MODFLOW Base Classes

Contents:

flopy.mbase module

mbase module

This module contains the base model class from which all of the other models inherit from.

class BaseModel(*modelname='modflowtest'*, *namefile_ext='nam'*, *exe_name: str | PathLike = 'mf2005'*, *model_ws: str | PathLike = '.'*, *structured=True*, *verbose=False*, ***kwargs*)

Bases: *ModelInterface*

MODFLOW-based models base class.

Parameters

- **modelname** (*str, default "modflowtest"*) – Name of the model, which is also used for model file names.
- **namefile_ext** (*str, default "nam"*) – Name file extension, without "."
- **exe_name** (*str or PathLike, default "mf2005"*) – Name or path of the modflow executable. If a name is provided, the executable must be on the system path.
- **model_ws** (*str or PathLike, optional, default "."*) – Path to the model workspace. Model files will be created in this directory. Default is the current working directory.
- **structured** (*bool, default True*) – Specify if model grid is structured (default) or unstructured.
- **verbose** (*bool, default False*) – Print additional information to the screen.
- ****kwargs** (*dict, optional*) – Used to define: xll/yll for the x- and y-coordinates of the lower-left corner of the grid, xul/yul for the x- and y-coordinates of the upper-left corner of the grid (deprecated), rotation for the grid rotation (default 0.0), crs for the coordinate reference system, and start_datetime for model start date (default "1-1-1970").

add_existing_package(*filename: str | PathLike*, *ptype=None*, *copy_to_model_ws=True*)

Add an existing package to a model instance.

Parameters

- **filename** (*str or PathLike*) – Path of the file to add as a package
- **ptype** (*optional*) – Model package type (e.g. "lpf", "wel", etc). If None then the file extension of the filename arg is used
- **copy_to_model_ws** (*bool*) – Copy the package file into the model workspace.

Return type
None

add_external(*fname: str | PathLike*, *unit*, *binflag=False*, *output=False*)

Assign an external array so that it will be listed as a DATA or DATA(BINARY) entry in the name file. This will allow an outside file package to refer to it.

Parameters

- **fname** (*str or PathLike*) – Path of external array
- **unit** (*int*) – Unit number of external array
- **binflag** (*boolean, optional*) – Binary or not, default is False

add_output(*fname: str | PathLike*, *unit*, *binflag=False*, *package=None*)

Assign an external array so that it will be listed as a DATA or DATA(BINARY) entry in the name file. This will allow an outside file package to refer to it.

Parameters

- **fname** (*str*) – filename of external array
- **unit** (*int*) – unit number of external array
- **binflag** (*boolean*) – binary or not. (default is False)

add_output_file(*unit*, *fname: str | PathLike | None = None*, *extension='cbc'*, *binflag=True*, *package=None*)

Add an ascii or binary output file for a package

Parameters

- **unit** (*int*) – Unit number of external array
- **fname** (*str or PathLike, optional*) – Path of external array, default is None
- **extension** (*str*) – Extension to use for the cell-by-cell file. Only used if fname is None, default is cbc
- **binflag** (*bool*) – Whether the output file is a binary file, efault is True
- **package** (*str*) – The package the output file is attached to, default is None

add_package(*p*)

Add a package.

Parameters
p (*Package object*) –

add_pop_key_list(*key*)

Add a external file unit number to a list that will be used to remove model output (typically binary) files from ext_unit_dict.

Parameters
key (*int*) – file unit number

Examples

change_model_ws(*new_pth: str | PathLike | None = '.'*, *reset_external=False*)

Change the model work space.

Parameters
new_pth (*str or PathLike*) – Path of the new model workspace. If this path does not exist, it will be created. If no value (None) is given, the default is the present working directory.

Returns
val – Can be used to see what packages are in the model, and can then be used with get_package to pull out individual packages.

Return type
list of strings

check(*f: str | PathLike | None = None*, *verbose=True*, *level=1*)

Check model data for common errors.

Parameters

- **f** (*str or PathLike, optional, default None*) – String defining file name or file handle for summary file of check method output. If a string is passed a file handle is created. If f is None, check method does not write results to a summary file. (default is None)
- **verbose** (*bool*) – Boolean flag used to determine if check method results are written to the screen
- **level** (*int*) – Check method analysis level. If level=0, summary checks are performed. If level=1, full checks are performed.

Return type
None

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow.load('model.nam')
>>> m.check()
```

property exename: str

export(*f: str | PathLike*, ***kwargs*)

Method to export a model to netcdf or shapefile based on the extension of the file name (.shp for shapefile, .nc for netcdf)

Parameters

- **f** (*str or PathLike*) – The file path
- **kwargs** (*keyword arguments*) –

  modelgrid
  [flopy.discretization.Grid instance] user supplied modelgrid which can be used for exporting in lieu of the modelgrid associated with the model object

Return type
None or Netcdf object

get_ext_dict_attr(*ext_unit_dict=None*, *unit=None*, *filetype=None*, *pop_key=True*)

get_name_file_entries()
Get a string representation of the name file.

get_output(*fname: str | PathLike | None = None*, *unit=None*)
Get an output file from the model by specifying either the file name or the unit number.

Parameters

- **fname** (*str or PathLike, optional*) – Path of output array
- **unit** (*int, optional*) – Unit number of output array

get_output_attribute(*fname: str | PathLike | None = None*, *unit=None*, *attr=None*)
Get an attribute of a model output file by specifying either the file name or the unit number.

Parameters

- **fname** (*str or PathLike, optional*) – path of output array
- **unit** (*int, optional*) – Unit number of output array

get_package(*name*)
Get a package.

Parameters
name (*str*) – Name of the package, 'RIV', 'LPF', etc. (case-insensitive).

Returns
pp – Package object of type *flopy.pakbase.Package*

Return type
Package object

has_package(*name*)
Check if package name is in package list.

Parameters
name (*str*) – Name of the package, 'DIS', 'BAS6', etc. (case-insensitive).

Returns
True if package name exists, otherwise False if not found.

Return type
bool

property hdry

property hnoflo

property laycbd

property laytyp

load_results()

property model_ws: str

property modelgrid

property modeltime

property name

Get model name

Returns
name – name of model

Return type
str

property namefile: str

next_ext_unit()

Function to encapsulate next_ext_unit attribute

next_unit(*i=None*)

property packagelist

plot(*SelPackList=None*, ***kwargs*)

Plot 2-D, 3-D, transient 2-D, and stress period list (MfList) model input data

Parameters

- **SelPackList** (*bool or list*) – List of of packages to plot. If SelPackList=None all packages are plotted. (default is None)
- ****kwargs** (*dict*) –

filename_base
[str] Base file name that will be used to automatically generate file names for output image files. Plots will be exported as image files if file_name_base is not None. (default is None)

file_extension
[str] Valid matplotlib.pyplot file extension for savefig(). Only used if filename_base is not None. (default is 'png')

mflay
[int] MODFLOW zero-based layer number to return. If None, then all all layers will be included. (default is None)

kper
[int] MODFLOW zero-based stress period number to return. (default is zero)

key
[str] MfList dictionary key. (default is None)

Returns
axes - Empty list is returned if filename_base is not None. Otherwise a list of matplotlib.pyplot.axis are returned.

Return type
list

Notes

Examples

```
>>> import flopy
>>> ml = flopy.modflow.Modflow.load('test.nam')
>>> ml.plot()
```

remove_external(*fname: str | PathLike | None = None*, *unit=None*)

Remove an external file from the model by specifying either the file name or the unit number.

Parameters

- **fname** (*str or PathLike, optional*) - Path of external array
- **unit** (*int, optional*) - Unit number of external array

remove_output(*fname: str | PathLike | None = None*, *unit=None*)

Remove an output file from the model by specifying either the file name or the unit number.

Parameters

- **fname** (*str or PathLike, optional*) - Path of output array
- **unit** (*int, optional*) - Unit number of output array

remove_package(*pname*)

Remove a package from this model

Parameters
pname (*string*) - Name of the package, such as 'RIV', 'BAS6', etc.

run_model(*silent=False*, *pause=False*, *report=False*, *normal_msg='normal termination'*) → Tuple[bool, List[str]]

This method will run the model using subprocess.Popen.

Parameters

- **silent** (*boolean*) - Echo run information to screen (default is True).
- **pause** (*boolean, optional*) - Pause upon completion (default is False).
- **report** (*boolean, optional*) - Save stdout lines to a list (buff) which is returned by the method . (default is False).

- **normal_msg** (*str*) – Normal termination message used to determine if the run terminated normally. (default is 'normal termination')

Returns

- **success** (*boolean*)
- **buff** (*list of lines of stdout*)

set_model_units()

Every model needs its own set_model_units method

set_output_attribute(*fname: str | PathLike | None = None*, *unit=None*, *attr=None*)

Set a variable in an output file from the model by specifying either the file name or the unit number and a dictionary with attributes to change.

Parameters

- **fname** (*str or PathLike, optional*) – Path of output array
- **unit** (*int, optional*) – Unit number of output array

set_version(*version*)

to_shapefile(*filename: str | PathLike*, *package_names=None*, ***kwargs*)

Wrapper function for writing a shapefile for the model grid. If package_names is not None, then search through the requested packages looking for arrays that can be added to the shapefile as attributes

Parameters

- **filename** (*str or PathLike*) – Path of the shapefile to write
- **package_names** (*list of package names (e.g. ["dis","lpf"])*) – Packages to export data arrays to shapefile. (default is None)

Return type

None

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow()
>>> m.to_shapefile('model.shp', SelPackList)
```

property verbose

property version

write_input(*SelPackList=False*, *check=False*)

Write the input.

Parameters

SelPackList (*False or list of packages*) –

write_name_file()

Every Package needs its own writenamefile function

class FileData

Bases: object

add_file(*fname*, *unit*, *binflag=False*, *output=False*, *package=None*)

class FileDataEntry(*fname*, *unit*, *binflag=False*, *output=False*, *package=None*)

Bases: object

class ModelInterface

Bases: object

abstract check(*f=None*, *verbose=True*, *level=1*)

abstract property exename

abstract export(*f*, ***kwargs*)

get_package_list(*ftype=None*)

Get a list of all the package names.

Parameters
ftype (*str*) – Type of package, 'RIV', 'LPF', etc.

Returns
val – Can be used to see what packages are in the model, and can then be used with get_package to pull out individual packages.

Return type
list of strings

abstract property hdry

abstract property hnoflo

abstract property laycbd

abstract property laytyp

abstract property model_ws

abstract property modelgrid

abstract property namefile

abstract property packagelist

abstract property solver_tols

update_modelgrid()

abstract property verbose

abstract property version

exception PackageLoadException(*error*, *location=''*)

Bases: Exception

FloPy package load exception.

resolve_exe(*exe_name: str | PathLike*, *forgive: bool = False*) → str

Resolves the absolute path of the executable, raising FileNotFoundError if the executable cannot be found (set forgive to True to return None and warn instead of raising an error).

Parameters

- **exe_name** (*str or PathLike*) – The executable's name or path. If only the name is provided, the executable must be on the system path.
- **forgive** (*bool*) – If True and executable cannot be found, return None and warn rather than raising a FileNotFoundError. Defaults to False.

Returns

str

Return type

absolute path to the executable

run_model(*exe_name: str | PathLike*, *namefile: str | None*, *model_ws: str | PathLike = '.'*, *silent=False*, *pause=False*, *report=False*, *processors=None*, *normal_msg='normal termination'*, *use_async=False*, *cargs=None*) → Tuple[bool, List[str]]

Run the model using subprocess.Popen, optionally collecting stdout and printing timestamped progress. Model workspace, namefile, executable to use, and several other options may be configured, and additional command line arguments may also be provided.

Parameters

- **exe_name** (*str or PathLike*) – Executable name or path. If the executable name is provided, the executable must be on the system path. Alternatively, a full path to the executable may be provided.
- **namefile** (*str, optional*) – Name of the name file of model to run. The name may be None to run models that don't require a control file (name file)
- **model_ws** (*str or PathLike, optional, default '.'*) – Path to the parent directory of the namefile. (default is the current working directory '.')
- **silent** (*boolean, default True*) – Whether to suppress model output. (Default is True)
- **pause** (*boolean, optional, default False*) – Pause and wait for keystroke upon completion. (Default is False)
- **report** (*boolean, optional, default False*) – Save stdout lines to a list (buff) returned by the method. (Default is False)
- **processors** (*int*) – Number of processors. Parallel simulations are only supported for MODFLOW 6 simulations. (default is None)
- **normal_msg** (*str or list*) – Termination message used to determine if the model terminated normally. More than one message can be provided using a list. (Default is 'normal termination')
- **use_async** (*boolean*) – Asynchronously read model stdout and report with timestamps. Good for models taking a long time to run, not

good for models that run quickly.

- **cargs** (*str or list, optional, default None*) – Additional command line arguments to pass to the executable. (Default is None)

Returns

- **success** (*boolean*)
- **buff** (*list of lines of stdout (empty if report is False)*)

flopy.pakbase module

pakbase module
This module contains the base package class from which all of the other packages inherit from.

class Package(*parent*, *extension='glo'*, *name='GLOBAL'*, *unit_number=1*, *filenames=None*, *allowDuplicates=False*)

Bases: *PackageInterface*

Base package class from which most other packages are derived.

Parameters

- **parent** (*object*) – Parent model object.
- **extension** (*str or list, default "glo"*) – File extension, without ".", use list to describe more than one.
- **name** (*str or list, default "GLOBAL"*) – Package name, use list to describe more than one.
- **unit_number** (*int or list, default 1*) – Unit number, use list to describe more than one.
- **filenames** (*str or list, default None*) –
- **allowDuplicates** (*bool, default False*) – Allow more than one instance of package in parent.

static add_to_dtype(*dtype*, *field_names*, *field_types*)

Add one or more fields to a structured array data type

Parameters

- **dtype** (*numpy.dtype*) – Input structured array datatype to add to.
- **field_names** (*str or list*) – One or more field names.
- **field_types** (*numpy.dtype or list*) – One or more data types. If one data type is supplied, it is repeated for each field name.

property data_list

export(*f*, ***kwargs*)

Method to export a package to netcdf or shapefile based on the extension of the file name (.shp for shapefile, .nc for netcdf)

Parameters

- **f** (*str*) – filename

- **kwargs** (*keyword arguments*) –

  modelgrid
  : [flopy.discretization.Grid instance] user supplied modelgrid which can be used for exporting in lieu of the modelgrid associated with the model object

Return type
: None or Netcdf object

level1_arraylist(*idx*, *v*, *name*, *txt*)

static **load**(*f: str | bytes | PathLike*, *model*, *pak_type*, *ext_unit_dict=None*, ***kwargs*)
: Default load method for standard boundary packages.

property **name**

property **package_type**

property **parent**

plot(***kwargs*)
: Plot 2-D, 3-D, transient 2-D, and stress period list (MfList) package input data

Parameters
: ****kwargs** (*dict*) –

  filename_base
  : [str] Base file name that will be used to automatically generate file names for output image files. Plots will be exported as image files if file_name_base is not None. (default is None)

  file_extension
  : [str] Valid matplotlib.pyplot file extension for savefig(). Only used if filename_base is not None. (default is 'png')

  mflay
  : [int] MODFLOW zero-based layer number to return. If None, then all all layers will be included. (default is None)

  kper
  : [int] MODFLOW zero-based stress period number to return. (default is zero)

  key
  : [str] MfList dictionary key. (default is None)

Returns
: **axes** – Empty list is returned if filename_base is not None. Otherwise a list of matplotlib.pyplot.axis are returned.

Return type
: list

Notes

Examples

```
>>> import flopy
>>> ml = flopy.modflow.Modflow.load('test.nam')
>>> ml.dis.plot()
```

property plottable

set_cbc_output_file(*ipakcb*, *model*, *fname*)

to_shapefile(*filename*, ***kwargs*)

Export 2-D, 3-D, and transient 2-D model data to shapefile (polygons). Adds an attribute for each layer in each data array

Parameters
filename (*str*) – Shapefile name to write

Return type
None

Notes

Examples

```
>>> import flopy
>>> ml = flopy.modflow.Modflow.load('test.nam')
>>> ml.lpf.to_shapefile('test_hk.shp')
```

webdoc()

Open the web documentation.

write_file(*f=None*, *check=False*)

Every Package needs its own write_file function

class PackageInterface

Bases: object

check(*f=None*, *verbose=True*, *level=1*, *checktype=None*)

Check package data for common errors.

Parameters

- **f** (*str or file handle*) – String defining file name or file handle for summary file of check method output. If a sting is passed a file handle is created. If f is None, check method does not write results to a summary file. (default is None)
- **verbose** (*bool*) – Boolean flag used to determine if check method results are written to the screen
- **level** (*int*) – Check method analysis level. If level=0, summary checks are performed. If level=1, full checks are performed.

- **checktype** (check) – Checker type to be used. By default class check is used from check.py.

Return type
None

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow.load('model.nam')
>>> m.dis.check()
```

abstract property data_list

abstract export(*f*, ***kwargs*)

property has_stress_period_data

abstract property name

abstract property package_type

abstract property parent

abstract property plottable

12.2.2 MODFLOW Packages

Contents:

flopy.modflow.mf module

mf module. Contains the ModflowGlobal, ModflowList, and Modflow classes.

class Modflow(*modelname='modflowtest'*, *namefile_ext='nam'*, *version='mf2005'*, *exe_name: str | PathLike = 'mf2005'*, *structured=True*, *listunit=2*, *model_ws: str | PathLike = '.'*, *external_path: str | PathLike | None = None*, *verbose=False*, ***kwargs*)

Bases: *BaseModel*

MODFLOW Model Class.

Parameters

- **modelname** (*str, default "modflowtest"*) – Name of model. This string will be used to name the MODFLOW input that are created with write_model.
- **namefile_ext** (*str, default "nam"*) – Extension for the namefile.
- **version** (*str, default "mf2005"*) – MODFLOW version. Choose one of: “mf2k”, “mf2005” (default), “mfnwt”, or “mfusg”.
- **exe_name** (*str or PathLike, default "mf2005"*) – The name or path of the executable to use.
- **structured** (*bool, default True*) – Specify if model grid is structured (default) or unstructured.

- **listunit** (*int*, *default 2*) – Unit number for the list file.
- **model_ws** (*str or PathLike*, *default "."*) – Model workspace. Directory name to create model data sets. (default is the present working directory).
- **external_path** (*str or PathLike*, *optional*) – Location for external files.
- **verbose** (*bool*, *default False*) – Print additional information to the screen.

Notes

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow()
```

get_ifrefm()

get_nrow_ncol_nlay_nper()

classmethod load(*f: str*, *version='mf2005'*, *exe_name: str | PathLike = 'mf2005'*, *verbose=False*, *model_ws: str | PathLike = '.'*, *load_only=None*, *forgive=False*, *check=True*)

Load an existing MODFLOW model.

Parameters

- **f** (*str*) – Path to MODFLOW name file to load.
- **version** (*str*, *default "mf2005"*) – MODFLOW version. Choose one of: "mf2k", "mf2005" (default), or "mfnwt". Note that this can be modified on loading packages unique to different MODFLOW versions.
- **exe_name** (*str or PathLike*, *default "mf2005"*) – MODFLOW executable name or path.
- **verbose** (*bool*, *default False*) – Show messages that can be useful for debugging.
- **model_ws** (*str or PathLike*, *default "."*) – Model workspace path. Default is the current directory.
- **load_only** (*list*, *str or None*) – List of case insensitive packages to load, e.g. ["bas6", "lpf"]. One package can also be specified, e.g. "rch". Default is None, which attempts to load all files. An empty list [] will not load any additional packages than is necessary. At a minimum, "dis" is always loaded.
- **forgive** (*bool*, *optional*) – Option to raise exceptions on package load failure, which can be useful for debugging. Default False.
- **check** (*boolean*, *optional*) – Check model input for common errors. Default True.

Return type
flopy.modflow.mf.Modflow

Examples

```
>>> import flopy
>>> ml = flopy.modflow.Modflow.load('model.nam')
```

load_results(***kwargs*)

property modelgrid

property modeltime

property ncol

property ncpl

property nlay

property nper

property nrow

property nrow_ncol_nlay_nper

set_ifrefm(*value=True*)

set_model_units(*iunit0=None*)
Write the model name file.

property solver_tols

write_name_file()
Write the model name file.

class ModflowGlobal(*model*, *extension='glo'*)
Bases: *Package*

ModflowGlobal Package class

write_file()
Every Package needs its own write_file function

class ModflowList(*model*, *extension='list'*, *unitnumber=2*)
Bases: *Package*

ModflowList Package class

write_file()
Every Package needs its own write_file function

flopy.modflow.mfaddoutsidefile module

class mfaddoutsidefile(*model*, *name*, *extension*, *unitnumber*)

Bases: *Package*

Add a file for which you have a MODFLOW input file

write_file()

Every Package needs its own write_file function

flopy.modflow.mfag module

mfag module which contains the ModflowAg class.

Note that the user can access the ModflowAg class as *flopy.modflow.ModflowAg*.

Additional information for this MODFLOW package can be found at <https://www.sciencedirect.com/science/article/pii/S1364815219305080>`_.

class ModflowAg(*model*, *options=None*, *time_series=None*, *well_list=None*, *irrdiversion=None*, *irrwell=None*, *supwell=None*, *extension='ag'*, *unitnumber=None*, *filenames=None*, *nper=0*)

Bases: *Package*

The ModflowAg class is used to build read, write, and edit data from the MODFLOW-NWT AG package.

Parameters

- **model** (*flopy.modflow.Modflow object*) – model object
- **options** (*flopy.utils.OptionBlock object*) – option block object
- **time_series** (*np.recarray or pd.DataFrame*) – numpy recarray for the time series block
- **well_list** (*np.recarray or pd.DataFrame*) – recarray of the well_list block
- **irrdiversion** (*dict {per: np.recarray}*) – dictionary of the irrdiversion block
- **irrwell** (*dict {per: np.recarray}*) – dictionary of the irrwell block
- **supwell** (*dict {per: np.recarray}*) – dictionary of the supwell block
- **extension** (*str*, *optional*) – default is .ag
- **unitnumber** (*list*, *optional*) – fortran unit number for modflow, default 69
- **filenames** (*list*, *optional*) – file name for ModflowAwu package to write input
- **nper** (*int*) – number of stress periods in the model

Examples

load a ModflowAg file

```
>>> import flopy
>>> ml = flopy.modflow.Modflow('agtest')
>>> ag = flopy.modflow.ModflowAg.load('test.ag', ml, nper=2)
```

static get_default_dtype(*maxells=0*, *block='well'*)

Function that gets a default dtype for a block

Parameters

- **maxells** (*int*) – maximum number of irrigation links
- **block** (*str*) – str which indicates data set valid options are "well" "tabfile_well" "timeseries" "irrdiversion" "irrwell" "supwell"

Returns
dtype

Return type
(list, tuple)

static get_empty(*numrecords*, *maxells=0*, *block='well'*)

Creates an empty record array corresponding to the block data type it is associated with.

Parameters

- **numrecords** (*int*) – number of records to create recarray with
- **maxells** (*int*, *optional*) – maximum number of irrigation links
- **block** (*str*) – str which indicates data set valid options are "well" , "tabfile_well" , "timeseries" , "irrdiversion_modflow" , "irrdiversion_gsflow" , "irrwell_modflow" , "irrwell_gsflow" , "supwell"

Return type
np.recarray

classmethod load(*f*, *model*, *nper=0*, *ext_unit_dict=None*)

Method to load the AG package from file

Parameters

- **f** (*str*) – filename
- **model** (*gsflow.modflow.Modflow object*) – model to attach the ag pacakge to
- **nper** (*int*) – number of stress periods in model
- **ext_unit_dict** (*dict*, *optional*) –

Return type
ModflowAg object

property plottable

property segment_list

Method to get a unique list of segments from irrdiversion

Return type
list

write_file(*check=False*)

Write method for ModflowAg

Parameters
check (*bool*) – not implemented

flopy.modflow.mfbas module

mfbas module. Contains the ModflowBas class. Note that the user can access the ModflowBas class as *flopy.modflow.ModflowBas*.

Additional information for this MODFLOW package can be found at the Online MODFLOW Guide.

class ModflowBas(*model*, *ibound=1*, *strt=1.0*, *ifrefm=True*, *ixsec=False*, *ichflg=False*, *stoper=None*, *hnoflo=-999.99*, *extension='bas'*, *unitnumber=None*, *filenames=None*)

Bases: *Package*

MODFLOW Basic Package Class.

Parameters

- **model** (*model object*) – The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.
- **ibound** (*array of ints, optional*) – The ibound array (the default is 1).
- **strt** (*array of floats, optional*) – An array of starting heads (the default is 1.0).
- **ifrefm** (*bool, optional*) – Indication if data should be read using free format (the default is True).
- **ixsec** (*bool, optional*) – Indication of whether model is cross sectional or not (the default is False).
- **ichflg** (*bool, optional*) – Flag indicating that flows between constant head cells should be calculated (the default is False).
- **stoper** (*float*) – percent discrepancy that is compared to the budget percent discrepancy continue when the solver convergence criteria are not met. Execution will unless the budget percent discrepancy is greater than stoper (default is None). MODFLOW-2005 only
- **hnoflo** (*float*) – Head value assigned to inactive cells (default is -999.99).
- **extension** (*str, optional*) – File extension (default is 'bas').
- **unitnumber** (*int, optional*) – FORTRAN unit number for this package (default is None).

- **filenames** (*str or list of str*) – Filenames to use for the package. If filenames=None the package name will be created using the model name and package extension. If a single string is passed the package name will be set to the string. Default is None.

heading

Text string written to top of package input file.

Type
str

options

Can be either or a combination of XSECTION, CHTOCH or FREE.

Type
list of str

ifrefm

Indicates whether or not packages will be written as free format.

Type
bool

Notes

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow()
>>> bas = flopy.modflow.ModflowBas(m)
```

check(*f=None*, *verbose=True*, *level=1*, *checktype=None*)

Check package data for common errors.

Parameters

- **f** (*str or file handle*) – String defining file name or file handle for summary file of check method output. If a sting is passed a file handle is created. If f is None, check method does not write results to a summary file. (default is None)
- **verbose** (*bool*) – Boolean flag used to determine if check method results are written to the screen
- **level** (*int*) – Check method analysis level. If level=0, summary checks are performed. If level=1, full checks are performed.

Return type
None

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow.load('model.nam')
>>> m.bas6.check()
```

property ifrefm

classmethod load(*f*, *model*, *ext_unit_dict=None*, *check=True*, ***kwargs*)

Load an existing package.

Parameters

- **f** (*filename or file handle*) – File to load.
- **model** (*model object*) – The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.
- **ext_unit_dict** (*dictionary, optional*) – If the arrays in the file are specified using EXTERNAL, or older style array control records, then *f* should be a file handle. In this case ext_unit_dict is required, which can be constructed using the function *flopy.utils.mfreadnam.parsenamefile*.
- **check** (*boolean*) – Check package data for common errors. (default True)
- **kwargs** (*dictionary*) – Keyword arguments that are passed to load. Possible keyword arguments are nlay, nrow, and ncol. If not provided, then the model must contain a discretization package with correct values for these parameters.

Returns

bas – ModflowBas object (of type flopy.modflow.ModflowBas)

Return type

ModflowBas object

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow()
>>> bas = flopy.modflow.ModflowBas.load('test.bas', m, nlay=1, nrow=10,
>>>                                     ncol=10)
```

write_file(*check=True*)

Write the package file.

Parameters

check (*boolean*) – Check package data for common errors. (default True)

Return type

None

flopy.modflow.mfbcf module

class ModflowBcf(*model*, *ipakcb=None*, *intercellt=0*, *laycon=3*, *trpy=1.0*, *hdry=-1e+30*, *iwdflg=0*, *wetfct=0.1*, *iwetit=1*, *ihdwet=0*, *tran=1.0*, *hy=1.0*, *vcont=1.0*, *sf1=1e-05*, *sf2=0.15*, *wetdry=-0.01*, *extension='bcf'*, *unitnumber=None*, *filenames=None*, *add_package=True*)

Bases: *Package*

MODFLOW Block Centered Flow Package Class.

Parameters

- **model** (*model object*) - The model object (of type flopy.modflow.Modflow) to which this package will be added.
- **ipakcb** (*int, optional*) - Toggles whether cell-by-cell budget data should be saved. If None or zero, budget data will not be saved (default is None).
- **intercellt** (*int*) - Intercell transmissivities, harmonic mean (0), arithmetic mean (1), logarithmic mean (2), combination (3). (default is 0)
- **laycon** (*int*) - Layer type, confined (0), unconfined (1), constant T, variable S (2), variable T, variable S (default is 3)
- **trpy** (*float or array of floats (nlay)*) - horizontal anisotropy ratio (default is 1.0)
- **hdry** (*float*) - head assigned when cell is dry - used as indicator(default is -1E+30)
- **iwdflg** (*int*) - flag to indicate if wetting is inactive (0) or not (non zero) (default is 0)
- **wetfct** (*float*) - factor used when cell is converted from dry to wet (default is 0.1)
- **iwetit** (*int*) - iteration interval in wetting/drying algorithm (default is 1)
- **ihdwet** (*int*) - flag to indicate how initial head is computed for cells that become wet (default is 0)
- **tran** (*float or array of floats (nlay, nrow, ncol), optional*) - transmissivity (only read if laycon is 0 or 2) (default is 1.0)
- **hy** (*float or array of floats (nlay, nrow, ncol)*) - hydraulic conductivity (only read if laycon is 1 or 3) (default is 1.0)
- **vcont** (*float or array of floats (nlay-1, nrow, ncol)*) - vertical leakance between layers (default is 1.0)
- **sf1** (*float or array of floats (nlay, nrow, ncol)*) - specific storage (confined) or storage coefficient (unconfined), read when there is at least one transient stress period. (default is 1e-5)
- **sf2** (*float or array of floats (nrow, ncol)*) - specific yield, only read when laycon is 2 or 3 and there is at least one transient stress period (default is 0.15)

- **wetdry** (*float*) – a combination of the wetting threshold and a flag to indicate which neighboring cells can cause a cell to become wet (default is -0.01)
- **extension** (*string*) – Filename extension (default is 'bcf')
- **unitnumber** (*int*) – File unit number (default is None).
- **filenames** (*str or list of str*) – Filenames to use for the package and the output files. If filenames=None the package name will be created using the model name and package extension and the cbc output name will be created using the model name and .cbc extension (for example, modflowtest.cbc), if ipakcb is a number greater than zero. If a single string is passed the package will be set to the string and cbc output name will be created using the model name and .cbc extension, if ipakcb is a number greater than zero. To define the names for all package files (input and output) the length of the list of strings should be 2. Default is None.
- **add_package** (*bool*) – Flag to add the initialised package object to the parent model object. Default is True.

Notes

Examples

```
>>> import flopy
>>> ml = flopy.modflow.Modflow()
>>> bcf = flopy.modflow.ModflowBcf(ml)
```

classmethod load(*f*, *model*, *ext_unit_dict=None*)

Load an existing package.

Parameters

- **f** (*filename or file handle*) – File to load.
- **model** (*model object*) – The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.
- **nper** (*int*) – The number of stress periods. If nper is None, then nper will be obtained from the model object. (default is None).
- **ext_unit_dict** (*dictionary, optional*) – If the arrays in the file are specified using EXTERNAL, or older style array control records, then *f* should be a file handle. In this case ext_unit_dict is required, which can be constructed using the function *flopy.utils.mfreadnam.parsenamefile*.

Returns

wel – ModflowBcf object.

Return type

ModflowBcf object

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow()
>>> wel = flopy.modflow.ModflowBcf.load('test.bcf', m)
```

write_file(*f=None*)

Write the package file.

Return type
None

flopy.modflow.mfbct module

class ModflowBct(*model*, *itrnsp=1*, *ibctcb=0*, *mcomp=1*, *ic_ibound_flg=1*, *itvd=1*, *iadsorb=0*, *ict=0*, *cinact=-999.0*, *ciclose=1e-06*, *idisp=1*, *ixdisp=0*, *diffnc=0.0*, *izod=0*, *ifod=0*, *icbund=1*, *porosity=0.1*, *bulkd=1.0*, *arad=0.0*, *dlh=0.0*, *dlv=0.0*, *dth=0.0*, *dtv=0.0*, *sconc=0.0*, *extension='bct'*, *unitnumber=None*)

Bases: *Package*

Block centered transport package class for MODFLOW-USG

write_file()

Write the package file.

Return type
None

flopy.modflow.mfchd module

mfchd module. Contains the ModflowChd class. Note that the user can access the ModflowChd class as *flopy.modflow.ModflowChd*.

Additional information for this MODFLOW package can be found at the Online MODFLOW Guide.

class ModflowChd(*model*, *stress_period_data=None*, *dtype=None*, *options=None*, *extension='chd'*, *unitnumber=None*, *filenames=None*, ***kwargs*)

Bases: *Package*

MODFLOW Constant Head Package Class.

Parameters

- **model** (*model object*) – The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.
- **stress_period_data** (*list*, *recarray*, *dataframe*, *or dictionary of boundaries.*) – Each chd cell is defined through definition of layer (int), row (int), column (int), shead (float), ehead (float) shead is the head at the start of the stress period, and ehead is the head at the end of the stress period. The simplest form is a dictionary with a lists of boundaries for each stress period, where each list of boundaries itself is a list of boundaries. Indices of the dictionary are the numbers of the stress period. This gives the form of:

```
stress_period_data =
{0: [
    [lay, row, col, shead, ehead],
    [lay, row, col, shead, ehead],
    [lay, row, col, shead, ehead]
    ],
1:  [
    [lay, row, col, shead, ehead],
    [lay, row, col, shead, ehead],
    [lay, row, col, shead, ehead]
    ], ...
kper:
    [
    [lay, row, col, shead, ehead],
    [lay, row, col, shead, ehead],
    [lay, row, col, shead, ehead]
    ]
}
```

Note that if the number of lists is smaller than the number of stress periods, then the last list of chds will apply until the end of the simulation. Full details of all options to specify stress_period_data can be found in the flopy3 boundaries Notebook in the basic subdirectory of the examples directory.

- **extension** (*string*) – Filename extension (default is 'chd')
- **unitnumber** (*int*) – File unit number (default is None).
- **filenames** (*str or list of str*) – Filenames to use for the package. If filenames=None the package name will be created using the model name and package extension. If a single string is passed the package will be set to the string. Default is None.

mxactc

Maximum number of chds for all stress periods. This is calculated automatically by FloPy based on the information in stress_period_data.

Type

int

Notes

Parameters are supported in Flopy only when reading in existing models. Parameter values are converted to native values in Flopy and the connection to "parameters" is thus nonexistent.

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow()
>>> lrcd = {0:[[2, 3, 4, 10., 10.1]]}   #this chd will be applied to all
>>>                                     #stress periods
>>> chd = flopy.modflow.ModflowChd(m, stress_period_data=lrcd)
```

add_record(*kper*, *index*, *values*)

static get_default_dtype(*structured=True*)

static get_empty(*ncells=0*, *aux_names=None*, *structured=True*)

classmethod load(*f*, *model*, *nper=None*, *ext_unit_dict=None*, *check=True*)

Load an existing package.

Parameters

- **f** (*filename or file handle*) – File to load.
- **model** (*model object*) – The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.
- **nper** (*int*) – The number of stress periods. If nper is None, then nper will be obtained from the model object. (default is None).
- **ext_unit_dict** (*dictionary, optional*) – If the arrays in the file are specified using EXTERNAL, or older style array control records, then *f* should be a file handle. In this case ext_unit_dict is required, which can be constructed using the function *flopy.utils.mfreadnam.parsenamefile*.

Returns

chd – ModflowChd object.

Return type

ModflowChd object

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow()
>>> wel = flopy.modflow.ModflowChd.load('test.chd', m)
```

write_file()

Write the package file.

Return type

None

flopy.modflow.mfde4 module

mfde4 module. Contains the ModflowDe4 class. Note that the user can access the ModflowDe4 class as *flopy.modflow.ModflowDe4*.

Additional information for this MODFLOW package can be found at the Online MODFLOW Guide.

class ModflowDe4(*model*, *itmx=50*, *mxup=0*, *mxlow=0*, *mxbw=0*, *ifreq=3*, *mutd4=0*, *accl=1.0*, *hclose=1e-05*, *iprd4=1*, *extension='de4'*, *unitnumber=None*, *filenames=None*)

Bases: *Package*

MODFLOW DE4 - Direct Solver Package

Parameters

- **model** (*model object*) – The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.
- **itmx** (*int*) – Maximum number of iterations for each time step. Specify ITMAX = 1 if iteration is not desired. Ideally iteration would not be required for direct solution. However, it is necessary to iterate if the flow equation is nonlinear or if computer precision limitations result in inaccurate calculations as indicated by a large water budget error (default is 50).
- **mxup** (*int*) – Maximum number of equations in the upper part of the equations to be solved. This value impacts the amount of memory used by the DE4 Package. If specified as 0, the program will calculate MXUP as half the number of cells in the model, which is an upper limit (default is 0).
- **mxlow** (*int*) – Maximum number of equations in the lower part of equations to be solved. This value impacts the amount of memory used by the DE4 Package. If specified as 0, the program will calculate MXLOW as half the number of cells in the model, which is an upper limit (default is 0).
- **mxbw** (*int*) – Maximum band width plus 1 of the lower part of the head coefficients matrix. This value impacts the amount of memory used by the DE4 Package. If specified as 0, the program will calculate MXBW as the product of the two smallest grid dimensions plus 1, which is an upper limit (default is 0).
- **ifreq** (*int*) – Flag indicating the frequency at which coefficients in head matrix change. IFREQ = 1 indicates that the flow equations are linear and that coefficients of simulated head for all stress terms are constant for all stress periods. IFREQ = 2 indicates that the flow equations are linear, but coefficients of simulated head for some stress terms may change at the start of each stress period. IFREQ = 3 indicates that a nonlinear flow equation is being solved, which means that some terms in the head coefficients matrix depend on simulated head (default is 3).
- **mutd4** (*int*) – Flag that indicates the quantity of information that is printed when convergence information is printed for a time step. MUTD4 = 0 indicates that the number of iterations in the time step and the maximum head change each iteration are printed. MUTD4 = 1 indicates that only the number of iterations in the time

step is printed. MUTD4 = 2 indicates no information is printed (default is 0).

- **accl** (*int*) – Multiplier for the computed head change for each iteration. Normally this value is 1. A value greater than 1 may be useful for improving the rate of convergence when using external iteration to solve nonlinear problems (default is 1).
- **hclose** (*float*) – Head change closure criterion. If iterating (ITMX > 1), iteration stops when the absolute value of head change at every node is less than or equal to HCLOSE. HCLOSE is not used if not iterating, but a value must always be specified (default is 1e-5).
- **iprd4** (*int*) – Time step interval for printing out convergence information when iterating (ITMX > 1). If IPRD4 is 2, convergence information is printed every other time step. A value must always be specified even if not iterating (default is 1).
- **extension** (*string*) – Filename extension (default is 'de4')
- **unitnumber** (*int*) – File unit number (default is None).
- **filenames** (*str or list of str*) – Filenames to use for the package. If filenames=None the package name will be created using the model name and package extension. If a single string is passed the package will be set to the string. Default is None.

Notes

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow()
>>> de4 = flopy.modflow.ModflowDe4(m)
```

classmethod load(*f*, *model*, *ext_unit_dict=None*)

Load an existing package.

Parameters

- **f** (*filename or file handle*) – File to load.
- **model** (*model object*) – The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.
- **ext_unit_dict** (*dictionary, optional*) – If the arrays in the file are specified using EXTERNAL, or older style array control records, then *f* should be a file handle. In this case ext_unit_dict is required, which can be constructed using the function *flopy.utils.mfreadnam.parsenamefile*.

Returns
de4

Return type
ModflowDe4 object

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow()
>>> de4 = flopy.modflow.ModflowDe4.load('test.de4', m)
```

write_file()

Write the package file.

Return type
None

flopy.modflow.mfdis module

mfdis module. Contains the ModflowDis class. Note that the user can access the ModflowDis class as *flopy.modflow.ModflowDis*.

Additional information for this MODFLOW package can be found at the Online MODFLOW Guide.

class ModflowDis(*model*, *nlay=1*, *nrow=2*, *ncol=2*, *nper=1*, *delr=1.0*, *delc=1.0*, *laycbd=0*, *top=1*, *botm=0*, *perlen=1*, *nstp=1*, *tsmult=1*, *steady=True*, *itmuni=4*, *lenuni=2*, *extension='dis'*, *unitnumber=None*, *filenames=None*, *xul=None*, *yul=None*, *rotation=None*, *crs=None*, *prjfile=None*, *start_datetime=None*, ***kwargs*)

Bases: *Package*

MODFLOW Discretization Package Class.

Parameters

- **model** (*model object*) – The model object (of type flopy.modflow.Modflow) to which this package will be added.
- **nlay** (*int*) – Number of model layers (the default is 1).
- **nrow** (*int*) – Number of model rows (the default is 2).
- **ncol** (*int*) – Number of model columns (the default is 2).
- **nper** (*int*) – Number of model stress periods (the default is 1).
- **delr** (*float or array of floats (ncol), optional*) – An array of spacings along a row (the default is 1.0).
- **delc** (*float or array of floats (nrow), optional*) – An array of spacings along a column (the default is 0.0).
- **laycbd** (*int or array of ints (nlay), optional*) – An array of flags indicating whether or not a layer has a Quasi-3D confining bed below it. 0 indicates no confining bed, and not zero indicates a confining bed. LAYCBD for the bottom layer must be 0. (the default is 0)
- **top** (*float or array of floats (nrow, ncol), optional*) – An array of the top elevation of layer 1. For the common situation in which the top layer represents a water-table aquifer, it may be reasonable to set Top equal to land-surface elevation (the default is 1.0)

- **botm** (*float or array of floats (nlay, nrow, ncol), optional*) - An array of the bottom elevation for each model cell (the default is 0.)
- **perlen** (*float or array of floats (nper)*) - An array of the stress period lengths.
- **nstp** (*int or array of ints (nper)*) - Number of time steps in each stress period (default is 1).
- **tsmult** (*float or array of floats (nper)*) - Time step multiplier (default is 1.0).
- **steady** (*bool or array of bool (nper)*) - true or False indicating whether or not stress period is steady state (default is True).
- **itmuni** (*int*) - Time units, default is days (4)
- **lenuni** (*int*) - Length units, default is meters (2)
- **extension** (*string*) - Filename extension (default is 'dis')
- **unitnumber** (*int*) - File unit number (default is None).
- **filenames** (*str or list of str*) - Filenames to use for the package. If filenames=None the package name will be created using the model name and package extension. If a single string is passed the package will be set to the string. Default is None.
- **xul** (*float*) - x coordinate of upper left corner of the grid, default is None, which means xul will be set to zero.
- **yul** (*float*) - y coordinate of upper-left corner of the grid, default is None, which means yul will be calculated as the sum of the delc array. This default, combined with the xul and rotation defaults will place the lower-left corner of the grid at (0, 0).
- **rotation** (*float*) - counter-clockwise rotation (in degrees) of the grid about the lower- left corner. default is 0.0
- **crs** (pyproj.CRS, int, str, optional if *prjfile* is specified) - Coordinate reference system (CRS) for the model grid (must be projected; geographic CRS are not supported). The value can be anything accepted by pyproj.CRS.from_user_input(), such as an authority string (eg "EPSG:26916") or a WKT string.
- **prjfile** (str or pathlike, optional if *crs* is specified) - ESRI-style projection file with well-known text defining the CRS for the model grid (must be projected; geographic CRS are not supported).
- **start_datetime** (*str*) - starting datetime of the simulation. default is '1/1/1970'
- ****kwargs** (*dict, optional*) - Support deprecated keyword options.

  Deprecated since version 3.5: proj4_str will be removed for FloPy 3.6, use crs instead.

heading

Text string written to top of package input file.

Type

str

Notes

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow()
>>> dis = flopy.modflow.ModflowDis(m)
```

check(*f=None*, *verbose=True*, *level=1*, *checktype=None*)

Check dis package data for zero and negative thicknesses.

Parameters

- **f** (*str or file handle*) – String defining file name or file handle for summary file of check method output. If a sting is passed a file handle is created. If f is None, check method does not write results to a summary file. (default is None)
- **verbose** (*bool*) – Boolean flag used to determine if check method results are written to the screen
- **level** (*int*) – Check method analysis level. If level=0, summary checks are performed. If level=1, full checks are performed.

Return type

None

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow.load('model.nam')
>>> m.dis.check()
```

checklayerthickness()

Check layer thickness.

get_cell_volumes()

Get an array of cell volumes.

Returns

vol

Return type

array of floats (nlay, nrow, ncol)

get_final_totim()

Get the totim at the end of the simulation

Returns

totim – maximum simulation totim

Return type

float

get_kstp_kper_toffset(*t=0.0*, *use_cached_totim=False*)

Get the stress period, time step, and time offset from passed time.

Parameters

- **t** (*float*) – totim to return the stress period, time step, and toffset for based on time discretization data. Default is 0.
- **use_cached_totim** (*bool*) – optional flag to use a cached calculation of totim, vs. dynamically calculating totim. Setting to True significantly speeds up looped operations that call this function (default is False).

Returns

- **kstp** (*int*) – time step in stress period corresponding to passed totim
- **kper** (*int*) – stress period corresponding to passed totim
- **toffset** (*float*) – time offset of passed totim from the beginning of kper

get_layer(*i*, *j*, *elev*)

Return the layer for an elevation at an i, j location.

Parameters

- **i** (*row index (zero-based)*) –
- **j** (*column index*) –
- **elev** (*elevation (in same units as model)*) –

Returns
k

Return type
zero-based layer index

get_lrc(*nodes*)

Get zero-based layer, row, column from a list of zero-based MODFLOW node numbers.

Returns
v – and column (j) for each node in the input list

Return type
list of tuples containing the layer (k), row (i),

get_node(*lrc_list*)

Get zero-based node number from a list of zero-based MODFLOW layer, row, column tuples.

Returns
v – and column (j) tuple in the input list

Return type
list of MODFLOW nodes for each layer (k), row (i),

get_node_coordinates()

Get y, x, and z cell centroids in local model coordinates.

Returns

- **y** (*list of cell y-centroids*)
- **x** (*list of cell x-centroids*)
- **z** (*array of floats (nlay, nrow, ncol)*)

get_rc_from_node_coordinates(*x*, *y*, *local=True*)

Get the row and column of a point or sequence of points in model coordinates.

Parameters

- **x** (*float or sequence of floats*) – x coordinate(s) of points to find in model grid
- **y** (*float or sequence floats*) – y coordinate(s) of points to find in model grid
- **local** (*bool*) – x and y coordinates are in model local coordinates. If false, then x and y are in world coordinates. (default is True)

Returns

- **r** (*row or sequence of rows (zero-based)*)
- **c** (*column or sequence of columns (zero-based)*)

get_totim(*use_cached=False*)

Get the totim at the end of each time step

Parameters

use_cached (*bool*) – method to use cached totim values instead of calculating totim dynamically

Returns

totim – numpy array with simulation totim at the end of each time step

Return type

numpy array

get_totim_from_kper_toffset(*kper=0*, *toffset=0.0*, *use_cached_totim=False*)

Get totim from a passed kper and time offset from the beginning of a stress period

Parameters

- **kper** (*int*) – stress period. Default is 0
- **toffset** (*float*) – time offset relative to the beginning of kper
- **use_cached_totim** (*bool*) – optional flag to use a cached calculation of totim, vs. dynamically calculating totim. Setting to True significantly speeds up looped operations that call this function (default is False).

Returns

t – totim to return the stress period, time step, and toffset for based on time discretization data. Default is 0.

Return type

float

getbotm(*k=None*)

Get the bottom array.

Returns

- **botm** (*array of floats (nlay, nrow, ncol), or*)
- **botm** (*array of floats (nrow, ncol) if k is not none*)

gettop()

Get the top array.

Returns
top

Return type
array of floats (nrow, ncol)

classmethod load(*f*, *model*, *ext_unit_dict=None*, *check=True*)

Load an existing package.

Parameters

- **f** (*filename or file handle*) – File to load.
- **model** (*model object*) – The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.
- **ext_unit_dict** (*dictionary*, *optional*) – If the arrays in the file are specified using EXTERNAL, or older style array control records, then *f* should be a file handle. In this case ext_unit_dict is required, which can be constructed using the function *flopy.utils.mfreadnam.parsenamefile*.
- **check** (*bool*) – Check package data for common errors. (default True)

Returns
dis – ModflowDis object.

Return type
ModflowDis object

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow()
>>> dis = flopy.modflow.ModflowDis.load('test.dis', m)
```

write_file(*check=True*)

Write the package file.

Parameters
check (*bool*) – Check package data for common errors. (default True)

Return type
None

property zcentroids

get_layer(*dis*, *i*, *j*, *elev*)

Return the layers for elevations at i, j locations.

Parameters

- **dis** (*flopy.modflow.ModflowDis object*) –
- **i** (*scaler or sequence*) – row index (zero-based)
- **j** (*scaler or sequence*) – column index
- **elev** (*scaler or sequence*) – elevation (in same units as model)

Returns

k – zero-based layer index

Return type

np.ndarray (1-D) or scalar

flopy.modflow.mfdrn module

mfdrn module. Contains the ModflowDrn class. Note that the user can access the ModflowDrn class as *flopy.modflow.ModflowDrn*.

Additional information for this MODFLOW package can be found at the Online MODFLOW Guide.

class ModflowDrn(*model*, *ipakcb=None*, *stress_period_data=None*, *dtype=None*, *extension='drn'*, *unitnumber=None*, *options=None*, *filenames=None*, ***kwargs*)

Bases: *Package*

MODFLOW Drain Package Class.

Parameters

- **model** (*model object*) – The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.
- **ipakcb** (*int*, *optional*) – Toggles whether cell-by-cell budget data should be saved. If None or zero, budget data will not be saved (default is None).
- **stress_period_data** (*list*, *recarray*, *dataframe or dictionary of boundaries.*) – Each drain cell is defined through definition of layer(int), row(int), column(int), elevation(float), conductance(float). The simplest form is a dictionary with a lists of boundaries for each stress period, where each list of boundaries itself is a list of boundaries. Indices of the dictionary are the numbers of the stress period. This gives the form of:

```
stress_period_data =
{0: [
    [lay, row, col, stage, cond],
    [lay, row, col, stage, cond],
    [lay, row, col, stage, cond],
    ],
1:  [
    [lay, row, col, stage, cond],
    [lay, row, col, stage, cond],
```

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```
    [lay, row, col, stage, cond],
    ], ...
kper:
    [
    [lay, row, col, stage, cond],
    [lay, row, col, stage, cond],
    [lay, row, col, stage, cond],
    ]
}
```

Note that if no values are specified for a certain stress period, then the list of boundaries for the previous stress period for which values were defined is used. Full details of all options to specify stress_period_data can be found in the flopy3boundaries Notebook in the basic subdirectory of the examples directory.

- **dtype** (*dtype definition*) - if data type is different from default
- **options** (*list of strings*) - Package options. (default is None).
- **extension** (*string*) - Filename extension (default is 'drn')
- **unitnumber** (*int*) - File unit number (default is None).
- **filenames** (*str or list of str*) - Filenames to use for the package and the output files. If filenames=None the package name will be created using the model name and package extension and the cbc output name will be created using the model name and .cbc extension (for example, modflowtest.cbc), if ipakcb is a number greater than zero. If a single string is passed the package will be set to the string and cbc output names will be created using the model name and .cbc extension, if ipakcb is a number greater than zero. To define the names for all package files (input and output) the length of the list of strings should be 2. Default is None.

Notes

Parameters are not supported in FloPy. If "RETURNFLOW" in passed in options, the drain return package (DRT) activated, which expects a different (longer) dtype for stress_period_data

Examples

```
>>> import flopy
>>> ml = flopy.modflow.Modflow()
>>> lrcec = {0:[2, 3, 4, 10., 100.]}  #this drain will be applied to all
>>>                                   #stress periods
>>> drn = flopy.modflow.ModflowDrn(ml, stress_period_data=lrcec)
```

add_record(*kper*, *index*, *values*)

static get_default_dtype(*structured=True*, *is_drt=False*)

static get_empty(*ncells=0*, *aux_names=None*, *structured=True*, *is_drt=False*)

classmethod load(*f*, *model*, *nper=None*, *ext_unit_dict=None*, *check=True*)

Load an existing package.

Parameters

- **f** (*filename or file handle*) – File to load.
- **model** (*model object*) – The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.
- **ext_unit_dict** (*dictionary*, *optional*) – If the arrays in the file are specified using EXTERNAL, or older style array control records, then *f* should be a file handle. In this case ext_unit_dict is required, which can be constructed using the function *flopy.utils.mfreadnam.parsenamefile*.
- **check** (*boolean*) – Check package data for common errors. (default True)

Returns

drn – ModflowDrn object.

Return type

ModflowDrn object

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow()
>>> drn = flopy.modflow.ModflowDrn.load('test.drn', m)
```

write_file(*check=True*)

Write the package file.

Parameters

check (*boolean*) – Check package data for common errors. (default True)

Return type

None

flopy.modflow.mfdrt module

mfdrt module. Contains the ModflowDrt class. Note that the user can access the ModflowDrt class as *flopy.modflow.ModflowDrt*.

Additional information for this MODFLOW package can be found at the Online MODFLOW Guide.

class ModflowDrt(*model*, *ipakcb=None*, *stress_period_data=None*, *dtype=None*, *extension='drt'*, *unitnumber=None*, *options=None*, *filenames=None*, ***kwargs*)

Bases: *Package*

MODFLOW Drain Return Package Class.

Parameters

- **model** (*model object*) – The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.
- **ipakcb** (*int, optional*) – Toggles whether cell-by-cell budget data should be saved. If None or zero, budget data will not be saved (default is None).
- **stress_period_data** (*list, recarray, dataframe or dictionary of boundaries.*) – Each drain return cell is defined through definition of layer(int), row(int), column(int), elevation(float), conductance(float), layerR (int) , rowR (int), colR (int) and rfprop (float). The simplest form is a dictionary with a lists of boundaries for each stress period, where each list of boundaries itself is a list of boundaries. Indices of the dictionary are the numbers of the stress period. This gives the form of:

```
stress_period_data =
{0: [
    [lay, row, col, stage, cond, layerr, rowr, colr, rfprop],
    [lay, row, col, stage, cond, layerr, rowr, colr, rfprop],
    [lay, row, col, stage, cond, layerr, rowr, colr, rfprop],
    ],
1:  [
    [lay, row, col, stage, cond, layerr, rowr, colr, rfprop],
    [lay, row, col, stage, cond, layerr, rowr, colr, rfprop],
    [lay, row, col, stage, cond, layerr, rowr, colr, rfprop],
    ], ...
kper:
    [
    [lay, row, col, stage, cond, layerr, rowr, colr, rfprop],
    [lay, row, col, stage, cond, layerr, rowr, colr, rfprop],
    [lay, row, col, stage, cond, layerr, rowr, colr, rfprop],
    ]
}
```

  Note that if no values are specified for a certain stress period, then the list of boundaries for the previous stress period for which values were defined is used. Full details of all options to specify stress_period_data can be found in the flopy3boundaries Notebook in the basic subdirectory of the examples directory.

- **dtype** (*dtype definition*) – if data type is different from default
- **options** (*list of strings*) – Package options. (default is None).
- **extension** (*string*) – Filename extension (default is 'drt')
- **unitnumber** (*int*) – File unit number (default is None).
- **filenames** (*str or list of str*) – Filenames to use for the package and the output files. If filenames=None the package name will be created using the model name and package extension and the cbc output name will be created using the model name and .cbc extension (for example, modflowtest.cbc), if ipakcb is a number greater than zero. If a single string is passed the package will be set to the string and cbc output names will be created using the model name and .cbc extension, if ipakcb is a number greater than zero. To define the names for all package files (input and

output) the length of the list of strings should be 2. Default is None.

Notes

Parameters are not supported in FloPy.

Examples

```
>>> import flopy
>>> ml = flopy.modflow.Modflow()
>>> lrcec = {0:[2, 3, 4, 10., 100., 1 ,1 ,1, 1.0]}  #this drain will be applied to␣
↪all
>>>                                     #stress periods
>>> drt = flopy.modflow.ModflowDrt(ml, stress_period_data=lrcec)
```

add_record(*kper*, *index*, *values*)

static **get_default_dtype**(*structured=True*)

static **get_empty**(*ncells=0*, *aux_names=None*, *structured=True*, *is_drt=False*)

classmethod **load**(*f*, *model*, *nper=None*, *ext_unit_dict=None*, *check=True*)

Load an existing package.

Parameters

- **f** (*filename or file handle*) – File to load.
- **model** (*model object*) – The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.
- **ext_unit_dict** (*dictionary, optional*) – If the arrays in the file are specified using EXTERNAL, or older style array control records, then *f* should be a file handle. In this case ext_unit_dict is required, which can be constructed using the function *flopy.utils.mfreadnam.parsenamefile*.
- **check** (*boolean*) – Check package data for common errors. (default True)

Returns

drn – ModflowDrt object.

Return type

ModflowDrt object

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow()
>>> drn = flopy.modflow.ModflowDrt.load('test.drt', m)
```

write_file(*check=True*)

Write the package file.

Parameters
check (*boolean*) – Check package data for common errors. (default True)

Return type
None

flopy.modflow.mfevt module

mfghb module. Contains the ModflowEvt class. Note that the user can access the ModflowEvt class as *flopy.modflow.ModflowEvt*.

Additional information for this MODFLOW package can be found at the Online MODFLOW Guide.

class ModflowEvt(*model*, *nevtop=3*, *ipakcb=None*, *surf=0.0*, *evtr=0.001*, *exdp=1.0*, *ievt=1*, *extension='evt'*, *unitnumber=None*, *filenames=None*, *external=True*)

Bases: *Package*

MODFLOW Evapotranspiration Package Class.

Parameters

- **model** (*model object*) – The model object (of type flopy.modflow.mf.ModflowEvt) to which this package will be added.
- **ipakcb** (*int*) – A flag that is used to determine if cell-by-cell budget data should be saved. If ipakcb is non-zero cell-by-cell budget data will be saved. (default is 0).
- **nevtop** (*int*) – is the recharge option code. 1: ET is calculated only for cells in the top grid layer 2: ET to layer defined in ievt 3: ET to highest active cell (default is 3).
- **surf** (*float or filename or ndarray or dict keyed on kper (zero-based)*) – is the ET surface elevation. (default is 0.0, which is used for all stress periods).
- **evtr** (*float or filename or ndarray or dict keyed on kper (zero-based)*) – is the maximum ET flux (default is 1e-3, which is used for all stress periods).
- **exdp** (*float or filename or ndarray or dict keyed on kper (zero-based)*) – is the ET extinction depth (default is 1.0, which is used for all stress periods).
- **ievt** (*int or filename or ndarray or dict keyed on kper (zero-based)*) – is the layer indicator variable (default is 1, which is used for all stress periods).
- **extension** (*string*) – Filename extension (default is 'evt')

- **unitnumber** (*int*) – File unit number (default is None).
- **filenames** (*str or list of str*) – Filenames to use for the package and the output files. If filenames=None the package name will be created using the model name and package extension and the cbc output name will be created using the model name and .cbc extension (for example, modflowtest.cbc), if ipakcbc is a number greater than zero. If a single string is passed the package will be set to the string and cbc output names will be created using the model name and .cbc extension, if ipakcbc is a number greater than zero. To define the names for all package files (input and output) the length of the list of strings should be 2. Default is None.

Notes

Parameters are not supported in FloPy.

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow()
>>> evt = flopy.modflow.ModflowEvt(m, nevtop=3, evtr=1.2e-4)
```

classmethod load(*f*, *model*, *nper=None*, *ext_unit_dict=None*)

Load an existing package.

Parameters

- **f** (*filename or file handle*) – File to load.
- **model** (*model object*) – The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.
- **nper** (*int*) – The number of stress periods. If nper is None, then nper will be obtained from the model object. (default is None).
- **ext_unit_dict** (*dictionary, optional*) – If the arrays in the file are specified using EXTERNAL, or older style array control records, then *f* should be a file handle. In this case ext_unit_dict is required, which can be constructed using the function *flopy.utils.mfreadnam.parsenamefile*.

Returns

evt – ModflowEvt object.

Return type

ModflowEvt object

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow()
>>> evt = flopy.modflow.mfevt.load('test.evt', m)
```

write_file(*f=None*)

Write the package file.

Return type
None

flopy.modflow.mffhb module

mffhb module. Contains the ModflowFhb class. Note that the user can access the ModflowFhb class as *flopy.modflow.ModflowFhb*.

Additional information for this MODFLOW package can be found at the Online MODFLOW Guide.

class ModflowFhb(*model*, *nbdtim=1*, *nflw=0*, *nhed=0*, *ifhbss=0*, *ipakcb=None*, *nfhbx1=0*, *nfhbx2=0*, *ifhbpt=0*, *bdtimecnstm=1.0*, *bdtime=[0.0]*, *cnstm5=1.0*, *ds5=None*, *cnstm7=1.0*, *ds7=None*, *extension='fhb'*, *unitnumber=None*, *filenames=None*)

Bases: *Package*

MODFLOW Flow and Head Boundary Package Class.

Parameters

- **model** (*model object*) – The model object (of type flopy.modflow.mf.ModflowFhb) to which this package will be added.
- **nbdtim** (*int*) – The number of times at which flow and head will be specified for all selected cells. (default is 1)
- **nflw** (*int*) – Number of cells at which flows will be specified. (default is 0)
- **nhed** (*int*) – Number of cells at which heads will be specified. (default is 0)
- **ifhbss** (*int*) – FHB steady-state option flag. If the simulation includes any transient-state stress periods, the flag is read but not used; in this case, specified-flow, specified-head, and auxiliary-variable values will be interpolated for steady-state stress periods in the same way that values are interpolated for transient stress periods. If the simulation includes only steady-state stress periods, the flag controls how flow, head, and auxiliary-variable values will be computed for each steady-state solution. (default is 0)
- **ipakcb** (*int, optional*) – Toggles whether cell-by-cell budget data should be saved. If None or zero, budget data will not be saved (default is None).
- **nfhbx1** (*int*) – Number of auxiliary variables whose values will be computed for each time step for each specified-flow cell.

Auxiliary variables are currently not supported. (default is 0)

- **nfhbx2** (*int*) - Number of auxiliary variables whose values will be computed for each time step for each specified-head cell. Auxiliary variables are currently not supported. (default is 0)
- **ifhbpt** (*int*) - Flag for printing values of data list. Applies to datasets 4b, 5b, 6b, 7b, and 8b. If ifhbpt > 0, datasets read at the beginning of the simulation will be printed. Otherwise, the datasets will not be printed. (default is 0).
- **bdtimecnstm** (*float*) - A constant multiplier for data list bdtime. (default is 1.0)
- **bdtime** (*float or list of floats*) - Simulation time at which values of specified flow and (or) values of specified head will be read. nbdtim values are required. (default is 0.0)
- **cnstm5** (*float*) - A constant multiplier for data list flwrat. (default is 1.0)
- **ds5** (*list or numpy array or recarray or pandas dataframe*) - Each FHB flwrat cell (dataset 5) is defined through definition of layer(int), row(int), column(int), iaux(int), flwrat[nbdtime](float). There should be nflw entries. (default is None) The simplest form is a list of lists with the FHB flow boundaries. This gives the form of:

```
ds5 =
[
    [lay, row, col, iaux, flwrat1, flwra2, ..., flwrat(nbdtime)],
    [lay, row, col, iaux, flwrat1, flwra2, ..., flwrat(nbdtime)],
    [lay, row, col, iaux, flwrat1, flwra2, ..., flwrat(nbdtime)],
    [lay, row, col, iaux, flwrat1, flwra2, ..., flwrat(nbdtime)]
]
```

- **cnstm7** (*float*) - A constant multiplier for data list sbhedt. (default is 1.0)
- **ds7** (*list or numpy array or recarray or pandas dataframe*) - Each FHB sbhed cell (dataset 7) is defined through definition of layer(int), row(int), column(int), iaux(int), sbhed[nbdtime](float). There should be nhed entries. (default is None) The simplest form is a list of lists with the FHB flow boundaries. This gives the form of:

```
ds7 =
[
    [lay, row, col, iaux, sbhed1, sbhed2, ..., sbhed(nbdtime)],
    [lay, row, col, iaux, sbhed1, sbhed2, ..., sbhed(nbdtime)],
    [lay, row, col, iaux, sbhed1, sbhed2, ..., sbhed(nbdtime)],
    [lay, row, col, iaux, sbhed1, sbhed2, ..., sbhed(nbdtime)]
]
```

- **extension** (*string*) - Filename extension (default is 'fhb')

- **unitnumber** (*int*) – File unit number (default is None).
- **filenames** (*str or list of str*) – Filenames to use for the package and the output files. If filenames=None the package name will be created using the model name and package extension and the cbc output name will be created using the model name and .cbc extension (for example, modflowtest.cbc), if ipakcb is a number greater than zero. If a single string is passed the package will be set to the string and cbc output names will be created using the model name and .cbc extension, if ipakcb is a number greater than zero. To define the names for all package files (input and output) the length of the list of strings should be 2. Default is None.

Notes

Parameters are not supported in FloPy.

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow()
>>> fhb = flopy.modflow.ModflowFhb(m)
```

static get_default_dtype(*nbdtim=1*, *structured=True*, *head=False*)

static get_empty(*ncells=0*, *nbdtim=1*, *structured=True*, *head=False*)

classmethod load(*f*, *model*, *nper=None*, *ext_unit_dict=None*)

Load an existing package.

Parameters

- **f** (*filename or file handle*) – File to load.
- **model** (*model object*) – The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.
- **nper** (*int*) – The number of stress periods. If nper is None, then nper will be obtained from the model object. (default is None).
- **ext_unit_dict** (*dictionary, optional*) – If the arrays in the file are specified using EXTERNAL, or older style array control records, then *f* should be a file handle. In this case ext_unit_dict is required, which can be constructed using the function *flopy.utils.mfreadnam.parsenamefile*.

Returns

fhb – ModflowFhb object.

Return type

ModflowFhb object

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow()
>>> fhb = flopy.modflow.ModflowFhb.load('test.fhb', m)
```

write_file()

Write the package file.

Return type
None

flopy.modflow.mfflwob module

class ModflowFlwob(*model*, *nqfb=0*, *nqcfb=0*, *nqtfb=0*, *iufbobsv=0*, *tomultfb=1.0*, *nqobfb=None*, *nqclfb=None*, *obsnam=None*, *irefsp=None*, *toffset=None*, *flwobs=None*, *layer=None*, *row=None*, *column=None*, *factor=None*, *flowtype=None*, *extension=None*, *no_print=False*, *options=None*, *filenames=None*, *unitnumber=None*)

Bases: *Package*

Head-dependent flow boundary Observation package class. Minimal working example that will be refactored in a future version.

Parameters

- **nqfb** (*int*) – Number of cell groups for the head-dependent flow boundary observations
- **nqcfb** (*int*) – Greater than or equal to the total number of cells in all cell groups
- **nqtfb** (*int*) – Total number of head-dependent flow boundary observations for all cell groups
- **iufbobsv** (*int*) – unit number where output is saved
- **tomultfb** (*float*) – Time-offset multiplier for head-dependent flow boundary observations. The product of tomultfb and toffset must produce a time value in units consistent with other model input. tomultfb can be dimensionless or can be used to convert the units of toffset to the time unit used in the simulation.
- **nqobfb** (*int list of length nqfb*) – The number of times at which flows are observed for the group of cells
- **nqclfb** (*int list of length nqfb*) – Is a flag, and the absolute value of nqclfb is the number of cells in the group. If nqclfb is less than zero, factor = 1.0 for all cells in the group.
- **obsnam** (*string list of length nqtfb*) – Observation name
- **irefsp** (*int of length nqtfb*) – The zero-based stress period to which the observation time is referenced. The reference point is the beginning of the specified stress period.
- **toffset** (*float list of length nqtfb*) – Is the time from the beginning of the stress period irefsp to the time of the observation. toffset must be in units such that the product of

toffset and tomultfb are consistent with other model input. For steady state observations, specify irefsp as the steady state stress period and toffset less than or equal to perlen of the stress period. If perlen is zero, set toffset to zero. If the observation falls within a time step, linearly interpolation is used between values at the beginning and end of the time step.

- **flwobs** (*float list of length nqtfb*) - Observed flow value from the head-dependent flow boundary into the aquifer (+) or the flow from the aquifer into the boundary (-)
- **layer** (*int list of length(nqfb, nqclfb)*) - The zero-based layer index for the cell included in the cell group.
- **row** (*int list of length(nqfb, nqclfb)*) - The zero-based row index for the cell included in the cell group.
- **column** (*int list of length(nqfb, nqclfb)*) - The zero-based column index of the cell included in the cell group.
- **factor** (*float list of length(nqfb, nqclfb)*) - Is the portion of the simulated gain or loss in the cell that is included in the total gain or loss for this cell group (fn of eq. 5).
- **flowtype** (*string*) - String that corresponds to the head-dependent flow boundary condition type (CHD, GHB, DRN, RIV)
- **extension** (*list of string*) - Filename extension. If extension is None, extension is set to ['chob','obc','gbob','obg','drob','obd', 'rvob','obr'] (default is None).
- **no_print** (*boolean*) - When True or 1, a list of flow observations will not be written to the Listing File (default is False)
- **options** (*list of strings*) - Package options (default is None).
- **unitnumber** (*list of int*) - File unit number. If unitnumber is None, unitnumber is set to [40, 140, 41, 141, 42, 142, 43, 143] (default is None).
- **filenames** (*str or list of str*) - Filenames to use for the package and the output files. If filenames=None the package name will be created using the model name and package extension and the flwob output name will be created using the model name and .out extension (for example, modflowtest.out), if iufbobsv is a number greater than zero. If a single string is passed the package will be set to the string and flwob output name will be created using the model name and .out extension, if iufbobsv is a number greater than zero. To define the names for all package files (input and output) the length of the list of strings should be 2. Default is None.

Notes

This represents a minimal working example that will be refactored in a future version.

ftype()

classmethod load(*f*, *model*, *ext_unit_dict=None*, *check=True*)

Load an existing package.

Parameters

- **f** (*filename or file handle*) – File to load.
- **model** (*model object*) – The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.
- **ext_unit_dict** (*dictionary, optional*) – If the arrays in the file are specified using EXTERNAL, or older style array control records, then *f* should be a file handle. In this case ext_unit_dict is required, which can be constructed using the function *flopy.utils.mfreadnam.parsenamefile*.
- **check** (*boolean*) – Check package data for common errors. (default True)

Returns

flwob – ModflowFlwob package object.

Return type

ModflowFlwob package object

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow()
>>> hobs = flopy.modflow.ModflowFlwob.load('test.drob', m)
```

write_file()

Write the package file

Return type

None

flopy.modflow.mfgage module

mfgage module. Contains the ModflowGage class. Note that the user can access the ModflowGage class as *flopy.modflow.ModflowGage*.

Additional information for this MODFLOW package can be found at the Online MODFLOW Guide.

class ModflowGage(*model*, *numgage=0*, *gage_data=None*, *files=None*, *extension='gage'*, *unitnumber=None*, *filenames=None*, ***kwargs*)

Bases: *Package*

MODFLOW Gage Package Class.

Parameters

- **model** (*model object*) – The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.
- **numgage** (*int*) – The total number of gages included in the gage file (default is 0).
- **gage_data** (*list or numpy array or recarray or pandas dataframe*) – data for dataset 2a and 2b in the gage package. If a list is provided then the list includes 2 to 3 entries (LAKE UNIT [OUTTYPE]) for each LAK Package entry and 4 entries (GAGESEG GAGERCH UNIT OUTTYPE) for each SFR Package entry. If a numpy array it passed each gage location must have 4 entries, where LAK Package gages can have any value for the second column. The numpy array can be created using the get_empty() method available in ModflowGage. Default is None
- **files** (*list of strings*) – Names of gage output files. A file name must be provided for each gage. If files are not provided and filenames=None then a gage name will be created using the model name and the gage number (for example, modflowtest.gage1.go). Default is None.
- **extension** (*string*) – Filename extension (default is 'gage')
- **unitnumber** (*int*) – File unit number (default is None).
- **filenames** (*str or list of str*) – Filenames to use for the package and the output files. If filenames=None the package name will be created using the model name and package extension and gage output names will be created using the model name and the gage number (for example, modflowtest.gage1.go). If a single string is passed the package will be set to the string and gage output names will be created using the model name and the gage number. To define the names for all gage files (input and output) the length of the list of strings should be numgage + 1. Default is None.

Notes

Parameters are not supported in FloPy.

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow()
>>> gages = [[-1,  -26, 1], [-2,  -27, 1]]
>>> files = ['gage1.go', 'gage2.go']
>>> gage = flopy.modflow.ModflowGage(m, numgage=2,
>>>                                  gage_data=gages, files=files)
```

static get_default_dtype()

static get_empty(*ncells=0*, *aux_names=None*, *structured=True*)

classmethod load(*f*, *model*, *nper=None*, *ext_unit_dict=None*)

Load an existing package.

Parameters

- **f** (*filename or file handle*) – File to load.
- **model** (*model object*) – The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.
- **nper** (*int*) – The number of stress periods. If nper is None, then nper will be obtained from the model object. (default is None).
- **ext_unit_dict** (*dictionary, optional*) – If the arrays in the file are specified using EXTERNAL, or older style array control records, then *f* should be a file handle. In this case ext_unit_dict is required, which can be constructed using the function *flopy.utils.mfreadnam.parsenamefile*.

Returns
str – ModflowStr object.

Return type
ModflowStr object

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow()
>>> gage = flopy.modflow.ModflowGage.load('test.gage', m)
```

write_file()

Write the package file.

Return type
None

flopy.modflow.mfghb module

mfghb module. Contains the ModflowGhb class. Note that the user can access the ModflowGhb class as *flopy.modflow.ModflowGhb*.

Additional information for this MODFLOW package can be found at the Online MODFLOW Guide.

class ModflowGhb(*model*, *ipakcb=None*, *stress_period_data=None*, *dtype=None*, *no_print=False*, *options=None*, *extension='ghb'*, *unitnumber=None*, *filenames=None*)

Bases: *Package*

MODFLOW General-Head Boundary Package Class.

Parameters

- **model** (*model object*) – The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.
- **ipakcb** (*int, optional*) – Toggles whether cell-by-cell budget data should be saved. If None or zero, budget data will not be saved (default is None).

- **stress_period_data** (*list, recarray, dataframe or dictionary of boundaries.*) - Each ghb cell is defined through definition of layer(int), row(int), column(int), stage(float), conductance(float) The simplest form is a dictionary with a lists of boundaries for each stress period, where each list of boundaries itself is a list of boundaries. Indices of the dictionary are the numbers of the stress period. This gives the form of:

```
stress_period_data =
{0: [
    [lay, row, col, stage, cond],
    [lay, row, col, stage, cond],
    [lay, row, col, stage, cond],
    ],
1:  [
    [lay, row, col, stage, cond],
    [lay, row, col, stage, cond],
    [lay, row, col, stage, cond],
    ], ...
kper:
    [
    [lay, row, col, stage, cond],
    [lay, row, col, stage, cond],
    [lay, row, col, stage, cond],
    ]
}
```

  Note that if no values are specified for a certain stress period, then the list of boundaries for the previous stress period for which values were defined is used. Full details of all options to specify stress_period_data can be found in the flopy3boundaries Notebook in the basic subdirectory of the examples directory

- **dtype** (*dtype definition*) - if data type is different from default
- **options** (*list of strings*) - Package options. (default is None).
- **extension** (*string*) - Filename extension (default is 'ghb')
- **unitnumber** (*int*) - File unit number (default is None).
- **filenames** (*str or list of str*) - Filenames to use for the package and the output files. If filenames=None the package name will be created using the model name and package extension and the cbc output name will be created using the model name and .cbc extension (for example, modflowtest.cbc), if ipakcb is a number greater than zero. If a single string is passed the package will be set to the string and cbc output names will be created using the model name and .cbc extension, if ipakcb is a number greater than zero. To define the names for all package files (input and output) the length of the list of strings should be 2. Default is None.

Notes

Parameters are not supported in FloPy.

Examples

```
>>> import flopy
>>> ml = flopy.modflow.Modflow()
>>> lrcsc = {0:[2, 3, 4, 10., 100.]}  #this ghb will be applied to all
>>>                                    #stress periods
>>> ghb = flopy.modflow.ModflowGhb(ml, stress_period_data=lrcsc)
```

add_record(*kper*, *index*, *values*)

static get_default_dtype(*structured=True*)

static get_empty(*ncells=0*, *aux_names=None*, *structured=True*)

classmethod load(*f*, *model*, *nper=None*, *ext_unit_dict=None*, *check=True*)

Load an existing package.

Parameters

- **f** (*filename or file handle*) – File to load.
- **model** (*model object*) – The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.
- **nper** (*int*) – The number of stress periods. If nper is None, then nper will be obtained from the model object. (default is None).
- **ext_unit_dict** (*dictionary, optional*) – If the arrays in the file are specified using EXTERNAL, or older style array control records, then *f* should be a file handle. In this case ext_unit_dict is required, which can be constructed using the function *flopy.utils.mfreadnam.parsenamefile*.
- **check** (*boolean*) – Check package data for common errors. (default True)

Returns

ghb – ModflowGhb object.

Return type

ModflowGhb object

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow()
>>> ghb = flopy.modflow.ModflowGhb.load('test.ghb', m)
```

write_file(*check=True*)

Write the package file.

Parameters
check (*boolean*) – Check package data for common errors. (default True)

Return type
None

flopy.modflow.mfgmg module

mfgmg module. Contains the ModflowGmg class. Note that the user can access the ModflowGmg class as *flopy.modflow.ModflowGmg*.

Additional information for this MODFLOW package can be found at the Online MODFLOW Guide.

class ModflowGmg(*model*, *mxiter=50*, *iiter=30*, *iadamp=0*, *hclose=1e-05*, *rclose=1e-05*, *relax=1.0*, *ioutgmg=0*, *iunitmhc=None*, *ism=0*, *isc=0*, *damp=1.0*, *dup=0.75*, *dlow=0.01*, *chglimit=1.0*, *extension='gmg'*, *unitnumber=None*, *filenames=None*)

Bases: *Package*

MODFLOW GMG Package Class.

Parameters

- **model** (*model object*) – The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.
- **mxiter** (*int*) – maximum number of outer iterations. (default is 50)
- **iiter** (*int*) – maximum number of inner iterations. (default is 30)
- **iadamp** (*int*) – is a flag that controls adaptive damping. The possible values of iadamp are.

  If iadamp = 0, then the value assigned to DAMP is used as a constant damping parameter.

  If iadamp = 1, the value of damp is used for the first nonlinear iteration. The damping parameter is adaptively varied on the basis of the head change, using Cooley's method as described in Mehl and Hill (2001), for subsequent iterations.

  If iadamp = 2, the relative reduced residual damping method documented in Mehl and Hill (2001) and modified by Banta (2006) is used.

  When iadamp is specified as 2 and the value specified for DAMP is less than 0.5, the closure criterion for the inner iterations (drclose) is assigned simply as rclose. When damp is between 0.5 and 1.0, inclusive, or when iadamp is specified as 0 or 1, drclose is calculated according to equation 20 on p. 9 of Wilson and Naff (2004).
- **hclose** (*float*) – is the head change criterion for convergence. (default is 1e-5).
- **rclose** (*float*) – is the residual criterion for convergence. (default is 1e-5)

- **relax** (*float*) - is a relaxation parameter for the ILU preconditioned conjugate gradient method. The relax parameter can be used to improve the spectral condition number of the ILU preconditioned system. The value of relax should be approximately one. However, the relaxation parameter can cause the factorization to break down. If this happens, then the gmg solver will report an assembly error and a value smaller than one for relax should be tried. This item is read only if isc = 4.
- **ioutgmg** (*int*) - is a flag that controls the output of the gmg solver. The possible values of ioutgmg are.

  If ioutgmg = 0, then only the solver inputs are printed.

  If ioutgmg = 1, then for each linear solve, the number of pcg iterations, the value of the damping parameter, the l2norm of the residual, and the maxnorm of the head change and its location (column, row, layer) are printed. At the end of a time/stress period, the total number of gmg calls, pcg iterations, and a running total of pcg iterations for all time/stress periods are printed.

  If ioutgmg = 2, then the convergence history of the pcg iteration is printed, showing the l2norm of the residual and the convergence factor for each iteration.

  ioutgmg = 3 is the same as ioutgmg = 1 except output is sent to the terminal instead of the modflow list output file.

  ioutgmg = 4 is the same as ioutgmg = 2 except output is sent to the terminal instead of the modflow list output file.

  (default is 0)
- **iunitmhc** (*int*) - is a flag and a unit number, which controls output of maximum head change values. If iunitmhc = 0, maximum head change values are not written to an output file. If iunitmhc > 0, maximum head change values are written to unit iunitmhc. Unit iunitmhc should be listed in the Name file with 'DATA' as the file type. If iunitmhc < 0 or is not present, iunitmhc defaults to 0. (default is 0)
- **ism** (*int*) - is a flag that controls the type of smoother used in the multigrid preconditioner. If ism = 0, then ilu(0) smoothing is implemented in the multigrid preconditioner; this smoothing requires an additional ector on each multigrid level to store the pivots in the ilu factorization. If ism = 1, then symmetric gaussseidel (sgs) smoothing is implemented in the multigrid preconditioner. No additional storage is required if ism = 1; users may want to use this option if available memory is exceeded or nearly exceeded when using ism = 0. Using sgs smoothing is not as robust as ilu smoothing; additional iterations are likely to be required in reducing the residuals. In extreme cases, the solver may fail to converge as the residuals cannot be reduced sufficiently. (default is 0)
- **isc** (*int*) - is a flag that controls semicoarsening in the multigrid preconditioner. If isc = 0, then the rows, columns and layers are all coarsened. If isc = 1, then the rows and

columns are coarsened, but the layers are not. If isc = 2, then the columns and layers are coarsened, but the rows are not. If isc = 3, then the rows and layers are coarsened, but the columns are not. If isc = 4, then there is no coarsening. Typically, the value of isc should be 0 or 1. In the case that there are large vertical variations in the hydraulic conductivities, then a value of 1 should be used. If no coarsening is implemented (isc = 4), then the gmg solver is comparable to the pcg2 ilu(0) solver described in Hill (1990) and uses the least amount of memory. (default is 0)

- **damp** (*float*) - is the value of the damping parameter. For linear problems, a value of 1.0 should be used. For nonlinear problems, a value less than 1.0 but greater than 0.0 may be necessary to achieve convergence. A typical value for nonlinear problems is 0.5. Damping also helps control the convergence criterion of the linear solve to alleviate excessive pcg iterations. (default 1.)
- **dup** (*float*) - is the maximum damping value that should be applied at any iteration when the solver is not oscillating; it is dimensionless. An appropriate value for dup will be problem-dependent. For moderately nonlinear problems, reasonable values for dup would be in the range 0.5 to 1.0. For a highly nonlinear problem, a reasonable value for dup could be as small as 0.1. When the solver is oscillating, a damping value as large as 2.0 x DUP may be applied. (default is 0.75)
- **dlow** (*float*) - is the minimum damping value to be generated by the adaptive-damping procedure; it is dimensionless. An appropriate value for dlow will be problem-dependent and will be smaller than the value specified for dup. For a highly nonlinear problem, an appropriate value for dlow might be as small as 0.001. Note that the value specified for the variable, chglimit, could result in application of a damping value smaller than dlow. (default is 0.01)
- **chglimit** (*float*) - is the maximum allowed head change at any cell between outer iterations; it has units of length. The effect of chglimit is to determine a damping value that, when applied to all elements of the head-change vector, will produce an absolute maximum head change equal to chglimit. (default is 1.0)
- **extension** (*list string*) - Filename extension (default is 'gmg')
- **unitnumber** (*int*) - File unit number (default is None).
- **filenames** (*str or list of str*) - Filenames to use for the package and the output files. If filenames=None the package name will be created using the model name and package extension and the gmg output name will be created using the model name and .cbc extension (for example, modflowtest.gmg.out), if iunitmhc is a number greater than zero. If a single string is passed the package will be set to the string and gmg output names will be created using the model name and .gmg.out extension, if iunitmhc is a number greater than zero. To define the names for all package files (input and output) the length of the list of strings should be 2. Default is None.

Return type
None

Notes

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow()
>>> gmg = flopy.modflow.ModflowGmg(m)
```

classmethod load(*f*, *model*, *ext_unit_dict=None*)

Load an existing package.

Parameters

- **f** (*filename or file handle*) – File to load.
- **model** (*model object*) – The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.
- **ext_unit_dict** (*dictionary, optional*) – If the arrays in the file are specified using EXTERNAL, or older style array control records, then *f* should be a file handle. In this case ext_unit_dict is required, which can be constructed using the function *flopy.utils.mfreadnam.parsenamefile*.

Returns
gmg

Return type
ModflowGmg object

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow()
>>> gmg = flopy.modflow.ModflowGmg.load('test.gmg', m)
```

write_file()

Write the package file.

Return type
None

flopy.modflow.mfhfb module

mfhfb module. Contains the ModflowHfb class. Note that the user can access the ModflowHfb class as *flopy.modflow.ModflowHfb*.

Additional information for this MODFLOW package can be found at the Online MODFLOW Guide.

class ModflowHfb(*model*, *nphfb=0*, *mxfb=0*, *nhfbnp=0*, *hfb_data=None*, *nacthfb=0*, *no_print=False*, *options=None*, *extension='hfb'*, *unitnumber=None*, *filenames=None*)

Bases: *Package*

MODFLOW HFB6 - Horizontal Flow Barrier Package

Parameters

- **model** (*model object*) – The model object (of type: class:*flopy.modflow.mf.Modflow* or *flopy.mfusg.MfUsg*) to which this package will be added.
- **nphfb** (*int*) – Number of horizontal-flow barrier parameters. Note that for an HFB parameter to have an effect in the simulation, it must be defined and made active using NACTHFB to have an effect in the simulation (default is 0).
- **mxfb** (*int*) – Maximum number of horizontal-flow barrier barriers that will be defined using parameters (default is 0).
- **nhfbnp** (*int*) – Number of horizontal-flow barriers not defined by parameters. This is calculated automatically by FloPy based on the information in layer_row_column_data (default is 0).
- **hfb_data** (*list of records*) – In its most general form, this is a list of horizontal-flow barrier records. A barrier is conceptualized as being located on the boundary between two adjacent finite difference cells in the same layer. The innermost list is the layer, row1, column1, row2, column2, and hydrologic characteristics for a single hfb between the cells. The hydraulic characteristic is the barrier hydraulic conductivity divided by the width of the horizontal-flow barrier. (default is None). For a structured model, this gives the form of:

```
hfb_data = [
            [lay, row1, col1, row2, col2, hydchr],
            [lay, row1, col1, row2, col2, hydchr],
            [lay, row1, col1, row2, col2, hydchr],
           ].
```

  Or for unstructured (mfusg) models::

  hfb_data = [

  [node1, node2, hydchr], [node1, node2, hydchr], [node1, node2, hydchr],

  ].

- **nacthfb** (*int*) – The number of active horizontal-flow barrier parameters (default is 0).

- **no_print** (*boolean*) – When True or 1, a list of horizontal flow barriers will not be written to the Listing File (default is False)
- **options** (*list of strings*) – Package options (default is None).
- **extension** (*string*) – Filename extension (default is 'hfb').
- **unitnumber** (*int*) – File unit number (default is None).
- **filenames** (*str or list of str*) – Filenames to use for the package. If filenames=None the package name will be created using the model name and package extension. If a single string is passed the package will be set to the string. Default is None.

Notes

Parameters are supported in Flopy only when reading in existing models. Parameter values are converted to native values in Flopy and the connection to "parameters" is thus nonexistent.

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow()
>>> hfb_data = [[0, 10, 4, 10, 5, 0.01],[1, 10, 4, 10, 5, 0.01]]
>>> hfb = flopy.modflow.ModflowHfb(m, hfb_data=hfb_data)
```

static get_default_dtype(*structured=True*)

Get the default dtype for hfb data

static get_empty(*ncells=0, aux_names=None, structured=True*)

Get an empty recarray that corresponds to hfb dtype and has been extended to include aux variables and associated aux names.

classmethod load(*f, model, ext_unit_dict=None*)

Load an existing package.

Parameters

- **f** (*filename or file handle*) – File to load.
- **model** (*model object*) – The model object (of type: class:*flopy.modflow.mf.Modflow*) to which this package will be added.
- **ext_unit_dict** (*dictionary, optional*) – If the arrays in the file are specified using EXTERNAL, or older style array control records, then *f* should be a file handle. In this case ext_unit_dict is required, which can be constructed using the function *flopy.utils.mfreadnam.parsenamefile*.

Returns

hfb – ModflowHfb object (of type flopy.modflow.mfbas.ModflowHfb)

Return type

ModflowHfb object

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow()
>>> hfb = flopy.modflow.ModflowHfb.load('test.hfb', m)
```

write_file()

Write the package file.

Return type
None

flopy.modflow.mfhob module

class HeadObservation(*model*, *tomulth=1.0*, *obsname='HOBS'*, *layer=0*, *row=0*, *column=0*, *irefsp=None*, *roff=0.0*, *coff=0.0*, *itt=1*, *tmax=None*, *mlay=None*, *time_series_data=None*, *names=None*)

Bases: object

Create single HeadObservation instance from a time series array. A list of HeadObservation instances are passed to the ModflowHob package.

Parameters

- **tomulth** (*float*) – Time-offset multiplier for head observations. Default is 1.
- **obsname** (*string*) – Observation name. Default is 'HOBS'
- **layer** (*int*) – The zero-based layer index of the cell in which the head observation is located. If layer is less than zero, hydraulic heads from multiple layers are combined to calculate a simulated value. The number of layers equals the absolute value of layer, or abs(layer). Default is 0.
- **row** (*int*) – The zero-based row index for the observation. Default is 0.
- **column** (*int*) – The zero-based column index of the observation. Default is 0.
- **irefsp** (*int*) – The zero-based stress period to which the observation time is referenced.
- **roff** (*float*) – Fractional offset from center of cell in Y direction (between rows). Default is 0.
- **coff** (*float*) – Fractional offset from center of cell in X direction (between columns). Default is 0.
- **itt** (*int*) – Flag that identifies whether head or head changes are used as observations. itt = 1 specified for heads and itt = 2 specified if initial value is head and subsequent changes in head. Only specified if irefsp is < 0. Default is 1.
- **tmax** (*float*) – Maximum simulation time calculated using get_final_totim function of ModflowDis. Added to avoid repetitive calls.

- **mlay** (*dictionary of length (abs(irefsp))*) – Key represents zero-based layer numbers for multilayer observations and value represents the fractional value for each layer of multilayer observations. If mlay is None, a default mlay of {0: 1.} will be used (default is None).
- **time_series_data** (*list or numpy array*) – Two-dimensional list or numpy array containing the simulation time of the observation and the observed head [[totim, hob]]. If time_series_dataDefault is None, a default observation of 0. at totim 0. will be created (default is None).
- **names** (*list*) – List of specified observation names. If names is None, observation names will be automatically generated from obsname and the order of the timeseries data (default is None).

Returns
obs – HeadObservation object.

Return type
HeadObservation

Examples

```
>>> import flopy
>>> model = flopy.modflow.Modflow()
>>> dis = flopy.modflow.ModflowDis(model, nlay=1, nrow=11, ncol=11, nper=2,
...                                perlen=[1,1])
>>> tsd = [[1.,54.4], [2., 55.2]]
>>> obsdata = flopy.modflow.HeadObservation(model, layer=0, row=5,
...                                         column=5, time_series_data=tsd)
```

class ModflowHob(*model*, *iuhobsv=None*, *hobdry=0*, *tomulth=1.0*, *obs_data=None*, *hobname=None*, *extension='hob'*, *no_print=False*, *options=None*, *unitnumber=None*, *filenames=None*)

Bases: *Package*

Head Observation package class

Parameters

- **iuhobsv** (*int*) – unit number where output is saved. If iuhobsv is None, a unit number will be assigned (default is None).
- **hobdry** (*float*) – Value of the simulated equivalent written to the observation output file when the observation is omitted because a cell is dry (default is 0).
- **tomulth** (*float*) – Time step multiplier for head observations. The product of tomulth and toffset must produce a time value in units consistent with other model input. tomulth can be dimensionless or can be used to convert the units of toffset to the time unit used in the simulation (default is 1).
- **obs_data** (*HeadObservation or list of HeadObservation instances*) – A single HeadObservation instance or a list of HeadObservation instances containing all of the data for each observation. If obs_data is None a default HeadObservation with an observation in

layer, row, column (0, 0, 0) and a head value of 0 at totim 0 will be created (default is None).

- **hobname** (*str*) – Name of head observation output file. If iuhobsv is greater than 0, and hobname is None, the model basename with a '.hob.out' extension will be used (default is None).
- **extension** (*string*) – Filename extension (default is hob)
- **no_print** (*boolean*) – When True or 1, a list of head observations will not be written to the Listing File (default is False)
- **options** (*list of strings*) – Package options (default is None).
- **unitnumber** (*int*) – File unit number (default is None)
- **filenames** (*str or list of str*) – Filenames to use for the package and the output files. If filenames is None the package name will be created using the model name and package extension and the hob output name will be created using the model name and .hob.out extension (for example, modflowtest.hob.out), if iuhobsv is a number greater than zero. If a single string is passed the package will be set to the string and hob output name will be created using the model name and .hob.out extension, if iuhobsv is a number greater than zero. To define the names for all package files (input and output) the length of the list of strings should be 2. Default is None.

See also:

Notes

Examples

```
>>> import flopy
>>> model = flopy.modflow.Modflow()
>>> dis = flopy.modflow.ModflowDis(model, nlay=1, nrow=11, ncol=11, nper=2,
...                                perlen=[1,1])
>>> tsd = [[1.,54.4], [2., 55.2]]
>>> obsdata = flopy.modflow.HeadObservation(model, layer=0, row=5,
...                                         column=5, time_series_data=tsd)
>>> hob = flopy.modflow.ModflowHob(model, iuhobsv=51, hobdry=-9999.,
...                                obs_data=obsdata)
```

classmethod load(*f*, *model*, *ext_unit_dict=None*, *check=True*)

Load an existing package.

Parameters

- **f** (*filename or file handle*) – File to load.
- **model** (*model object*) – The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.
- **ext_unit_dict** (*dictionary, optional*) – If the arrays in the file are specified using EXTERNAL, or older style array control records, then *f* should be a file handle. In this case ext_unit_dict is required, which can be constructed using the function *flopy.utils.mfreadnam.parsenamefile*.

- **check** (*boolean*) – Check package data for common errors. (default True)

Returns
    hob – ModflowHob package object.

Return type
    ModflowHob package object

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow()
>>> hobs = flopy.modflow.ModflowHob.load('test.hob', m)
```

write_file()
    Write the package file

Return type
    None

flopy.modflow.mfhyd module

mfhyd module. Contains the ModflowHydclass. Note that the user can access the ModflowHyd class as *flopy.modflow.ModflowHyd*.

Additional information for this MODFLOW package can be found at the Online MODFLOW Guide.

class ModflowHyd(*model*, *nhyd=1*, *ihydun=None*, *hydnoh=-999.0*, *obsdata=[['BAS', 'HD', 'I', 0, 0.0, 0.0, 'HOBS1']]*, *extension=['hyd', 'hyd.bin']*, *unitnumber=None*, *filenames=None*)

Bases: *Package*

MODFLOW HYDMOD (HYD) Package Class.

Parameters

- **model** (*model object*) – The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.
- **nhyd** (*int*) – the maximum number of observation points. (default is 1).
- **ihydun** (*int*) – A flag that is used to determine if hydmod data should be saved. If ihydun is non-zero hydmod data will be saved. (default is 1).
- **hydnoh** (*float*) – is a user-specified value that is output if a value cannot be computed at a hydrograph location. For example, the cell in which the hydrograph is located may be a no-flow cell. (default is -999.)
- **obsdata** – Each row of obsdata includes data defining pckg (3 character string), arr (2 character string), intyp (1 character string) klay (int), xl (float), yl (float), hydlbl (14 character string) for each observation.

pckg
[str] is a 3-character flag to indicate which package is to be addressed by hydmod for the hydrograph of each observation point.

arr
[str] is a text code indicating which model data value is to be accessed for the hydrograph of each observation point.

intyp
[str] is a 1-character value to indicate how the data from the specified feature are to be accessed; The two options are 'I' for interpolated value or 'C' for cell value (intyp must be 'C' for STR and SFR Package hydrographs.

klay
[int] is the layer sequence number (zero-based) of the array to be addressed by HYDMOD.

xl
[float] is the coordinate of the hydrograph point in model units of length measured parallel to model rows, with the origin at the lower left corner of the model grid.

yl
[float] is the coordinate of the hydrograph point in model units of length measured parallel to model columns, with the origin at the lower left corner of the model grid.

hydlbl
[str] is used to form a label for the hydrograph.

extension
[list string] Filename extension (default is ['hyd', 'hyd.bin'])

unitnumber
[int] File unit number (default is None).

filenames
[str or list of str] Filenames to use for the package and the output files. If filenames=None the package name will be created using the model name and package extension and the hydmod output name will be created using the model name and .hyd.bin extension (for example, modflowtest.hyd.bin). If a single string is passed the package will be set to the string and hydmod output name will be created using the model name and .hyd.bin extension. To define the names for all package files (input and output) the length of the list of strings should be 2. Default is None.

Notes

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow()
>>> hyd = flopy.modflow.ModflowHyd(m)
```

static get_default_dtype()

static get_empty(*ncells=0*)

classmethod load(*f*, *model*, *ext_unit_dict=None*)

Load an existing package.

Parameters

- **f** (*filename or file handle*) – File to load.
- **model** (*model object*) – The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.
- **ext_unit_dict** (*dictionary, optional*) – If the arrays in the file are specified using EXTERNAL, or older style array control records, then *f* should be a file handle. In this case ext_unit_dict is required, which can be constructed using the function *flopy.utils.mfreadnam.parsenamefile*.

Returns
hyd

Return type
ModflowHyd object

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow()
>>> hyd = flopy.modflow.ModflowHyd.load('test.hyd', m)
```

write_file()

Write the package file.

Return type
None

flopy.modflow.mflak module

mflak module. Contains the ModflowLak class. Note that the user can access the ModflowLak class as *flopy.modflow.ModflowLak*.

Additional information for this MODFLOW package can be found at the Online MODFLOW Guide.

class ModflowLak(*model*, *nlakes=1*, *ipakcb=None*, *theta=-1.0*, *nssitr=0*, *sscncr=0.0*, *surfdep=0.0*, *stages=1.0*, *stage_range=None*, *tab_files=None*, *tab_units=None*, *lakarr=None*, *bdlknc=None*, *sill_data=None*, *flux_data=None*, *extension='lak'*, *unitnumber=None*, *filenames=None*, *options=None*, *lwrt=0*, ***kwargs*)

Bases: *Package*

MODFLOW Lake Package Class.

Parameters

- **model** (*model object*) – The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.

- **nlakes** (*int*) - NLAKES Number of separate lakes. Sublakes of multiple-lake systems are considered separate lakes for input purposes. The variable NLAKES is used, with certain internal assumptions and approximations, to dimension arrays for the simulation.
- **ipakcb** (*int, optional*) - Toggles whether cell-by-cell budget data should be saved. If None or zero, budget data will not be saved (default is None).
- **lwrt** (*int or list of ints (one per SP)*) - lwrt > 0, suppresses printout from the lake package. Default is 0 (to print budget information)
- **theta** (*float*) - Explicit (THETA = 0.0), semi-implicit (0.0 < THETA < 1.0), or implicit (THETA = 1.0) solution for lake stages. SURFDEPTH is read only if THETA is assigned a negative value (the negative value of THETA is then changed to a positive value internally by the code). * A new method of solving for lake stage uses only the time-weighting

    factor THETA (Merritt and Konikow, 2000, p. 52) for transient simulations. THETA is automatically set to a value of 1.0 for all steady-state stress periods. For transient stress periods, Explicit (THETA = 0.0), semi-implicit (0.0 < THETA < 1.0), or implicit (THETA = 1.0) solutions can be used to calculate lake stages. The option to specify negative values for THETA is supported to allow specification of additional variables (NSSITER, SSCNCR, SURFDEP) for simulations that only include transient stress periods. If THETA is specified as a negative value, then it is converted to a positive value for calculations of lake stage.

  - In MODFLOW-2000 and later, ISS is not part of the input. Instead NSSITR or SSCNCR should be included if one or more stress periods is a steady state stress period as defined in Ss/tr in the Discretization file.
  - SSCNCR and NSSITR can be read for a transient only simulation by placing a negative sign immediately in front of THETA. A negative THETA sets a flag which assumes input values for NSSITR and SSCNCR will follow THETA in the format as described by Merritt and Konikow (p. 52). A negative THETA is automatically reset to a positive value after values of NSSITR and SSCNCR are read.

- **nssitr** (*int*) - Maximum number of iterations for Newton's method of solution for equilibrium lake stages in each MODFLOW iteration for steady-state aquifer head solution. Only read if ISS (option flag input to DIS Package of MODFLOW indicating steady-state solution) is not zero or if THETA is specified as a negative value. * NSSITR and SSCNCR may be omitted for transient solutions (ISS = 0). * In MODFLOW-2000 and later, ISS is not part of the input.

    Instead NSSITR or SSCNCR should be included if one or more stress periods is a steady state stress period as defined in Ss/tr in the Discretization file.

- SSCNCR and NSSITR can be read for a transient only simulation by placing a negative sign immediately in front of THETA. A negative THETA sets a flag which assumes input values for NSSITR and SSCNCR will follow THETA in the format as described by Merritt and Konikow (p. 52). A negative THETA is automatically reset to a positive value after values of NSSITR and SSCNCR are read.
- If NSSITR = 0, a value of 100 will be used instead.

- **sscncr** (*float*) - Convergence criterion for equilibrium lake stage solution by Newton's method. Only read if ISS is not zero or if THETA is specified as a negative value. See notes above for nssitr.
- **surfdepth** (*float*) - The height of small topological variations (undulations) in lake-bottom elevations that can affect groundwater discharge to lakes. SURFDEPTH decreases the lakebed conductance for vertical flow across a horizontal lakebed caused both by a groundwater head that is between the lakebed and the lakebed plus SURFDEPTH and a lake stage that is also between the lakebed and the lakebed plus SURFDEPTH. This method provides a smooth transition from a condition of no groundwater discharge to a lake, when groundwater head is below the lakebed, to a condition of increasing groundwater discharge to a lake as groundwater head becomes greater than the elevation of the dry lakebed. The method also allows for the transition of seepage from a lake to groundwater when the lake stage decreases to the lakebed elevation. Values of SURFDEPTH ranging from 0.01 to 0.5 have been used successfully in test simulations. SURFDEP is read only if THETA is specified as a negative value.
- **stages** (*float or list of floats*) - The initial stage of each lake at the beginning of the run.
- **stage_range** (*list of tuples (ssmn, ssmx) of length nlakes*) - Where ssmn and ssmx are the minimum and maximum stages allowed for each lake in steady-state solution. * SSMN and SSMX are not needed for a transient run and must be

  omitted when the solution is transient.

  - When the first stress period is a steady-state stress period, SSMN is defined in record 3.

  For subsequent steady-state stress periods, SSMN is defined in record 9a.
- **lakarr** (*array of integers (nlay, nrow, ncol)*) - LKARR A value is read in for every grid cell. If LKARR(I,J,K) = 0, the grid cell is not a lake volume cell. If LKARR(I,J,K) > 0, its value is the identification number of the lake occupying the grid cell. LKARR(I,J,K) must not exceed the value NLAKES. If it does, or if LKARR(I,J,K) < 0, LKARR(I,J,K) is set to zero. Lake cells cannot be overlain by non-lake cells in a higher layer. Lake cells must

be inactive cells (IBOUND = 0) and should not be convertible to active cells (WETDRY = 0).

The Lake package can be used when all or some of the model layers containing the lake are confined. The authors recommend using the Layer-Property Flow Package (LPF) for this case, although the BCF and HUF Packages will work too. However, when using the BCF6 package to define aquifer properties, lake/aquifer conductances in the lateral direction are based solely on the lakebed leakance (and not on the lateral transmissivity of the aquifer layer). As before, when the BCF6 package is used, vertical lake/aquifer conductances are based on lakebed conductance and on the vertical hydraulic conductivity of the aquifer layer underlying the lake when the wet/dry option is implemented, and only on the lakebed leakance when the wet/dry option is not implemented.

- **bdlknc** (*array of floats (nlay, nrow, ncol)*) - BDLKNC A value is read in for every grid cell. The value is the lakebed leakance that will be assigned to lake/aquifer interfaces that occur in the corresponding grid cell. If the wet-dry option flag (IWDFLG) is not active (cells cannot rewet if they become dry), then the BDLKNC values are assumed to represent the combined leakances of the lakebed material and the aquifer material between the lake and the centers of the underlying grid cells, i. e., the vertical conductance values (CV) will not be used in the computation of conductances across lake/aquifer boundary faces in the vertical direction.

  IBOUND and WETDRY should be set to zero for every cell for which LKARR is not equal to zero. IBOUND is defined in the input to the Basic Package of MODFLOW. WETDRY is defined in the input to the BCF or other flow package of MODFLOW if the IWDFLG option is active. When used with the HUF package, the Lake Package has been modified to compute effective lake-aquifer conductance solely on the basis of the user-specified value of lakebed leakance; aquifer hydraulic conductivities are not used in this calculation. An appropriate informational message is now printed after the lakebed conductances are written to the main output file.

- **sill_data** (*dict*) - (dataset 8 in documentation) Dict of lists keyed by stress period. Each list has a tuple of dataset 8a, 8b for every multi-lake system, where dataset 8a is another tuple of

  IC
  [int] The number of sublakes

  ISUB
  [list of ints] The identification numbers of the sublakes in the sublake system being described in this record. The center lake number is listed first.

  And dataset 8b contains

  SILLVT
  [sequence of floats] A sequence of sill elevations for each sublakes that determines whether the center lake is connected with a given sublake. Values are entered for

each sublake in the order the sublakes are listed in the previous record.

- **flux_data** (*dict*) – (dataset 9 in documentation) Dict of lists keyed by stress period. The list for each stress period is a list of lists, with each list containing the variables PRCPLK EVAPLK RNF WTHDRW [SSMN] [SSMX] from the documentation.

  PRCPLK
  [float] The rate of precipitation per unit area at the surface of a lake (L/T).

  EVAPLK
  [float] The rate of evaporation per unit area from the surface of a lake (L/T).

  RNF
  [float] Overland runoff from an adjacent watershed entering the lake. If RNF > 0, it is specified directly as a volumetric rate, or flux (L3 /T). If RNF < 0, its absolute value is used as a dimensionless multiplier applied to the product of the lake precipitation rate per unit area (PRCPLK) and the surface area of the lake at its full stage (occupying all layer 1 lake cells). When RNF is entered as a dimensionless multiplier (RNF < 0), it is considered to be the product of two proportionality factors. The first is the ratio of the area of the basin contributing runoff to the surface area of the lake when it is at full stage. The second is the fraction of the current rainfall rate that becomes runoff to the lake. This procedure provides a means for the automated computation of runoff rate from a watershed to a lake as a function of varying rainfall rate. For example, if the basin area is 10 times greater than the surface area of the lake, and 20 percent of the precipitation on the basin becomes overland runoff directly into the lake, then set RNF = -2.0.

  WTHDRW
  [float] The volumetric rate, or flux (L3 /T), of water removal from a lake by means other than rainfall, evaporation, surface outflow, or groundwater seepage. A negative value indicates augmentation. Normally, this would be used to specify the rate of artificial withdrawal from a lake for human water use, or if negative, artificial augmentation of a lake volume for aesthetic or recreational purposes.

  SSMN
  [float] Minimum stage allowed for each lake in steady-state solution. See notes on ssmn and ssmx above.

  SSMX
  [float] SSMX Maximum stage allowed for each lake in steady-state solution.

- **options** (*list of strings*) – Package options. (default is None).
- **extension** (*string*) – Filename extension (default is 'lak')
- **unitnumber** (*int*) – File unit number (default is None).
- **filenames** (*str or list of str*) – Filenames to use for the package and the output files. If filenames=None the package name will be created using the model name and package extension and the cbc output name will be created using the model name and .cbc extension (for example, modflowtest.cbc), if ipakcb is a number greater than zero. If a single string is passed the package will be set to the string and cbc output names will be created using the model name and .cbc extension, if ipakcb is a number greater than zero. To define the names for all package files (input and output) the length of the list of strings should be 2. Default is None.

Notes

Parameters are not supported in FloPy.

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow()
>>> lak = {}
>>> lak[0] = [[2, 3, 4, 15.6, 1050., -4]]  #this lake boundary will be
>>>                                        #applied to all stress periods
>>> lak = flopy.modflow.ModflowLak(m, nstress_period_data=strd)
```

classmethod load(*f*, *model*, *nper=None*, *ext_unit_dict=None*)

Load an existing package.

Parameters

- **f** (*filename or file handle*) – File to load.
- **model** (*model object*) – The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.
- **nper** (*int*) – The number of stress periods. If nper is None, then nper will be obtained from the model object. (default is None).
- **ext_unit_dict** (*dictionary, optional*) – If the arrays in the file are specified using EXTERNAL, or older style array control records, then *f* should be a file handle. In this case ext_unit_dict is required, which can be constructed using the function *flopy.utils.mfreadnam.parsenamefile*.

Returns

str – ModflowLak object.

Return type

ModflowLak object

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow()
>>> lak = flopy.modflow.ModflowStr.load('test.lak', m)
```

write_file()

Write the package file.

Return type
None

flopy.modflow.mflmt module

mflmt module. Contains the ModflowLmt class. Note that the user can access the ModflowLmt class as *flopy.modflow.ModflowLmt*.

Additional information for this MODFLOW package can be found at the Online MODFLOW Guide.

class ModflowLmt(*model*, *output_file_name='mt3d_link.ftl'*, *output_file_unit=54*, *output_file_header='extended'*, *output_file_format='unformatted'*, *extension='lmt6'*, *package_flows=[]*, *unitnumber=None*, *filenames=None*)

Bases: *Package*

MODFLOW Link-MT3DMS Package Class.

Parameters

- **model** (*model object*) – The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.
- **output_file_name** (*string*) – Filename for output file (default is 'mt3d_link.ftl')
- **unitnumber** (*int*) – File unit number (default is 24).
- **output_file_unit** (*int*) – Output file unit number, pertaining to the file identified by output_file_name (default is 54).
- **output_file_header** (*string*) – Header for the output file (default is 'extended')
- **output_file_format** (*{'formatted', 'unformatted'}*) – Format of the output file (default is 'unformatted')
- **package_flows** (*['sfr', 'lak', 'uzf']*) – Specifies which of the advanced package flows should be added to the flow-transport link (FTL) file. The addition of these flags may quickly increase the FTL file size. Thus, the user must specifically request their amendment within the FTL file. Default is not to add these terms to the FTL file by omitting the keyword package_flows from the LMT input file. One or multiple strings can be passed as a list to the argument.
- **extension** (*string*) – Filename extension (default is 'lmt6')
- **unitnumber** – File unit number (default is None).

- **filenames** (*str or list of str*) – Filenames to use for the package. If filenames=None the package name will be created using the model name and package extension. If a single string is passed the package will be set to the string. Default is None.

Notes

Parameters are supported in Flopy only when reading in existing models. Parameter values are converted to native values in Flopy and the connection to "parameters" is thus nonexistent.

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow()
>>> lmt = flopy.modflow.ModflowLmt(m, output_file_name='mt3d_linkage.ftl')
```

classmethod load(*f*, *model*, *ext_unit_dict=None*)

Load an existing package.

Parameters

- **f** (*filename or file handle*) – File to load.
- **model** (*model object*) – The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.
- **ext_unit_dict** (*dictionary, optional*) – If the arrays in the file are specified using EXTERNAL, or older style array control records, then *f* should be a file handle. In this case ext_unit_dict is required, which can be constructed using the function *flopy.utils.mfreadnam.parsenamefile*.

Returns
lmt – ModflowLmt object.

Return type
ModflowLmt object

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow()
>>> lmt = flopy.modflow.ModflowGhb.load('test.lmt', m)
```

write_file()

Write the package file.

Return type
None

flopy.modflow.mflpf module

mflpf module. Contains the ModflowLpf class. Note that the user can access the ModflowLpf class as *flopy.modflow.ModflowLpf*.

Additional information for this MODFLOW package can be found at the Online MODFLOW Guide.

class ModflowLpf(*model*, *laytyp=0*, *layavg=0*, *chani=1.0*, *layvka=0*, *laywet=0*, *ipakcb=None*, *hdry=-1e+30*, *iwdflg=0*, *wetfct=0.1*, *iwetit=1*, *ihdwet=0*, *hk=1.0*, *hani=1.0*, *vka=1.0*, *ss=1e-05*, *sy=0.15*, *vkcb=0.0*, *wetdry=-0.01*, *storagecoefficient=False*, *constantcv=False*, *thickstrt=False*, *nocvcorrection=False*, *novfc=False*, *extension='lpf'*, *unitnumber=None*, *filenames=None*, *add_package=True*)

Bases: *Package*

MODFLOW Layer Property Flow Package Class.

Parameters

- **model** (*model object*) – The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.
- **ipakcb** (*int*, *optional*) – Toggles whether cell-by-cell budget data should be saved. If None or zero, budget data will not be saved (default is None).
- **hdry** (*float*) – Is the head that is assigned to cells that are converted to dry during a simulation. Although this value plays no role in the model calculations, it is useful as an indicator when looking at the resulting heads that are output from the model. HDRY is thus similar to HNOFLO in the Basic Package, which is the value assigned to cells that are no-flow cells at the start of a model simulation. (default is -1.e30).
- **laytyp** (*int or array of ints (nlay)*) – Layer type, contains a flag for each layer that specifies the layer type. 0 confined >0 convertible <0 convertible unless the THICKSTRT option is in effect. (default is 0).
- **layavg** (*int or array of ints (nlay)*) – Layer average 0 is harmonic mean 1 is logarithmic mean 2 is arithmetic mean of saturated thickness and logarithmic mean of of hydraulic conductivity (default is 0).
- **chani** (*float or array of floats (nlay)*) – contains a value for each layer that is a flag or the horizontal anisotropy. If CHANI is less than or equal to 0, then variable HANI defines horizontal anisotropy. If CHANI is greater than 0, then CHANI is the horizontal anisotropy for the entire layer, and HANI is not read. If any HANI parameters are used, CHANI for all layers must be less than or equal to 0. Use as many records as needed to enter a value of CHANI for each layer. The horizontal anisotropy is the ratio of the hydraulic conductivity along columns (the Y direction) to the hydraulic conductivity along rows (the X direction). (default is 1).
- **layvka** (*int or array of ints (nlay)*) – a flag for each layer that indicates whether variable VKA is vertical hydraulic conductivity or the ratio of horizontal to vertical hydraulic conductivity. 0:

VKA is vertical hydraulic conductivity not 0: VKA is the ratio of horizontal to vertical hydraulic conductivity (default is 0).

- **laywet** (*int or array of ints (nlay)*) - contains a flag for each layer that indicates if wetting is active. 0 wetting is inactive not 0 wetting is active (default is 0).
- **wetfct** (*float*) - is a factor that is included in the calculation of the head that is initially established at a cell when it is converted from dry to wet. (default is 0.1).
- **iwetit** (*int*) - is the iteration interval for attempting to wet cells. Wetting is attempted every IWETIT iteration. If using the PCG solver (Hill, 1990), this applies to outer iterations, not inner iterations. If IWETIT less than or equal to 0, it is changed to 1. (default is 1).
- **ihdwet** (*int*) - is a flag that determines which equation is used to define the initial head at cells that become wet. (default is 0)
- **hk** (*float or array of floats (nlay, nrow, ncol)*) - is the hydraulic conductivity along rows. HK is multiplied by horizontal anisotropy (see CHANI and HANI) to obtain hydraulic conductivity along columns. (default is 1.0).
- **hani** (*float or array of floats (nlay, nrow, ncol)*) - is the ratio of hydraulic conductivity along columns to hydraulic conductivity along rows, where HK of item 10 specifies the hydraulic conductivity along rows. Thus, the hydraulic conductivity along columns is the product of the values in HK and HANI. (default is 1.0).
- **vka** (*float or array of floats (nlay, nrow, ncol)*) - is either vertical hydraulic conductivity or the ratio of horizontal to vertical hydraulic conductivity depending on the value of LAYVKA. (default is 1.0).
- **ss** (*float or array of floats (nlay, nrow, ncol)*) - is specific storage unless the STORAGECOEFFICIENT option is used. When STORAGECOEFFICIENT is used, Ss is confined storage coefficient. (default is 1.e-5).
- **sy** (*float or array of floats (nlay, nrow, ncol)*) - is specific yield. (default is 0.15).
- **vkcb** (*float or array of floats (nlay, nrow, ncol)*) - is the vertical hydraulic conductivity of a Quasi-three-dimensional confining bed below a layer. (default is 0.0). Note that if an array is passed for vkcb it must be of size (nlay, nrow, ncol) even though the information for the bottom layer is not needed.
- **wetdry** (*float or array of floats (nlay, nrow, ncol)*) - is a combination of the wetting threshold and a flag to indicate which neighboring cells can cause a cell to become wet. (default is -0.01).
- **storagecoefficient** (*boolean*) - indicates that variable Ss and SS parameters are read as storage coefficient rather than specific storage. (default is False).

- **constantcv** (*boolean*) – indicates that vertical conductance for an unconfined cell is computed from the cell thickness rather than the saturated thickness. The CONSTANTCV option automatically invokes the NOCVCORRECTION option. (default is False).
- **thickstrt** (*boolean*) – indicates that layers having a negative LAYTYP are confined, and their cell thickness for conductance calculations will be computed as STRT-BOT rather than TOP-BOT. (default is False).
- **nocvcorrection** (*boolean*) – indicates that vertical conductance is not corrected when the vertical flow correction is applied. (default is False).
- **novfc** (*boolean*) – turns off the vertical flow correction under dewatered conditions. This option turns off the vertical flow calculation described on p. 5-8 of USGS Techniques and Methods Report 6-A16 and the vertical conductance correction described on p. 5-18 of that report. (default is False).
- **extension** (*string*) – Filename extension (default is 'lpf')
- **unitnumber** (*int*) – File unit number (default is None).
- **filenames** (*str or list of str*) – Filenames to use for the package and the output files. If filenames=None the package name will be created using the model name and package extension and the cbc output name will be created using the model name and .cbc extension (for example, modflowtest.cbc), if ipakcb is a number greater than zero. If a single string is passed the package will be set to the string and cbc output name will be created using the model name and .cbc extension, if ipakcb is a number greater than zero. To define the names for all package files (input and output) the length of the list of strings should be 2. Default is None.
- **add_package** (*bool*) – Flag to add the initialised package object to the parent model object. Default is True.

Notes

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow()
>>> lpf = flopy.modflow.ModflowLpf(m)
```

classmethod load(*f*, *model*, *ext_unit_dict=None*, *check=True*)

Load an existing package.

Parameters

- **f** (*filename or file handle*) – File to load.
- **model** (*model object*) – The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.

- **ext_unit_dict** (*dictionary, optional*) – If the arrays in the file are specified using EXTERNAL, or older style array control records, then *f* should be a file handle. In this case ext_unit_dict is required, which can be constructed using the function *flopy.utils.mfreadnam.parsenamefile*.
- **check** (*boolean*) – Check package data for common errors. (default True)

Returns
lpf – ModflowLpf object.

Return type
ModflowLpf object

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow()
>>> lpf = flopy.modflow.ModflowLpf.load('test.lpf', m)
```

write_file(*check=True*, *f=None*)
Write the package file.

Parameters
check (*boolean*) – Check package data for common errors. (default True)

Return type
None

flopy.modflow.mfmlt module

mfmlt module. Contains the ModflowMlt class. Note that the user can access the ModflowMlt class as *flopy.modflow.ModflowMlt*.

Additional information for this MODFLOW package can be found at the Online MODFLOW Guide.

class ModflowMlt(*model*, *mult_dict=None*, *extension='mlt'*, *unitnumber=None*, *filenames=None*)
Bases: *Package*

MODFLOW Mult Package Class.

Parameters

- **model** (*model object*) – The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.
- **mult_dict** (*dict*) – Dictionary with mult data for the model. mult_dict is typically instantiated using load method.
- **extension** (*string*) – Filename extension (default is 'drn')
- **unitnumber** (*int*) – File unit number (default is 21).

Notes

Parameters are supported in Flopy only when reading in existing models. Parameter values are converted to native values in Flopy and the connection to "parameters" is thus nonexistent.

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow()
>>> mltdict = flopy.modflow.ModflowZon(m, mult_dict=mult_dict)
```

classmethod load(*f*, *model*, *nrow=None*, *ncol=None*, *ext_unit_dict=None*)

Load an existing package.

Parameters

- **f** (*filename or file handle*) – File to load.
- **model** (*model object*) – The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.
- **nrow** (*int*) – number of rows. If not specified it will be retrieved from the model object. (default is None).
- **ncol** (*int*) – number of columns. If not specified it will be retrieved from the model object. (default is None).
- **ext_unit_dict** (*dictionary, optional*) – If the arrays in the file are specified using EXTERNAL, or older style array control records, then *f* should be a file handle. In this case ext_unit_dict is required, which can be constructed using the function *flopy.utils.mfreadnam.parsenamefile*.

Returns

zone

Return type

ModflowMult dict

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow()
>>> mlt = flopy.modflow.ModflowMlt.load('test.mlt', m)
```

static mult_function(*mult_dict*, *line*)

Construct a multiplier for the 'FUNCTION' option

write_file()

Write the package file.

Return type

None

Notes

Not implemented because parameters are only supported on load

flopy.modflow.mfmnw1 module

class ModflowMnw1(*model*, *mxmnw=0*, *ipakcb=None*, *iwelpt=0*, *nomoiter=0*, *kspref=1*, *wel1_bynode_qsum=None*, *losstype='skin'*, *stress_period_data=None*, *dtype=None*, *mnwname=None*, *extension='mnw1'*, *unitnumber=None*, *filenames=None*)

Bases: *Package*

MODFLOW Multi-Node Well 1 Package Class.

Parameters

- **model** (*model object*) – The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.
- **mxmnw** (*integer*) – maximum number of multi-node wells to be simulated
- **ipakcb** (*int, optional*) – Toggles whether cell-by-cell budget data should be saved. If None or zero, budget data will not be saved (default is None).
- **iwelpt** (*integer*) – verbosity flag
- **nomoiter** (*integer*) – the number of iterations for which flow in MNW wells is calculated
- **kspref** (*string*) – which set of water levels are to be used as reference values for calculating drawdown
- **losstype** (*string*) – head loss type for each well
- **wel1_bynode_qsum** (*list of lists or None*) – nested list containing file names, unit numbers, and ALLTIME flag for auxiliary output, e.g. [['test.ByNode',92,'ALLTIME']] if None, these optional external filenames and unit numbers are not written out
- **itmp** (*array*) – number of wells to be simulated for each stress period (shape : (NPER))
- **lay_row_col_qdes_mn_multi** (*list of arrays*) – lay, row, col, qdes, and MN or MULTI flag for all well nodes (length : NPER)
- **mnwname** (*string*) – prefix name of file for outputting time series data from MNW1
- **extension** (*string*) – Filename extension (default is 'mnw1')
- **unitnumber** (*int*) – File unit number (default is 33).
- **filenames** (*string or list of strings*) – File name of the package (with extension) or a list with the filename of the package and the cell-by-cell budget file for ipakcb. Default is None.

Notes

Parameters are not supported in FloPy.

The functionality of the ADD flag in data set 4 is not supported. Also not supported are all water-quality parameters (Qwval Iqwgrp), water-level limitations (Hlim, Href, DD), non-linear well losses, and pumping limitations (QCUT, Q-%CUT, Qfrcmn, Qfrcmx, DEFAULT).

Examples

```
>>> import flopy
>>> ml = flopy.modflow.Modflow()
>>> mnw1 = flopy.modflow.ModflowMnw1(ml, ...)
```

static get_default_dtype(*structured=True*)

static get_empty_stress_period_data(*itmp*, *structured=True*, *default_value=0*)

classmethod load(*f*, *model*, *nper=None*, *gwt=False*, *nsol=1*, *ext_unit_dict=None*)

Default load method for standard boundary packages.

write_file()

Write the package file.

Return type
None

skipcomments(*line*, *f*)

flopy.modflow.mfmnw2 module

exception ItmpError(*itmp*, *nactivewells*)

Bases: Exception

class Mnw(*wellid*, *nnodes=1*, *nper=1*, *losstype='skin'*, *pumploc=0*, *qlimit=0*, *ppflag=0*, *pumpcap=0*, *rw=1*, *rskin=2*, *kskin=10*, *B=None*, *C=0*, *P=2.0*, *cwc=None*, *pp=1*, *k=0*, *i=0*, *j=0*, *ztop=0*, *zbotm=0*, *node_data=None*, *stress_period_data=None*, *pumplay=0*, *pumprow=0*, *pumpcol=0*, *zpump=None*, *hlim=None*, *qcut=None*, *qfrcmn=None*, *qfrcmx=None*, *hlift=None*, *liftq0=None*, *liftqmax=None*, *hwtol=None*, *liftn=None*, *qn=None*, *mnwpackage=None*)

Bases: object

Multi-Node Well object class

Parameters

- **wellid** (*str or int*) – is the name of the well. This is a unique alphanumeric identification label for each well. The text string is limited to 20 alphanumeric characters. If the name of the well includes spaces, then enclose the name in quotes. Flopy converts wellid string to lower case.
- **nnodes** (*int*) – is the number of cells (nodes) associated with this well. NNODES normally is > 0, but for the case of a vertical borehole, setting NNODES < 0 will allow the user to specify

the elevations of the tops and bottoms of well screens or open intervals (rather than grid layer numbers), and the absolute value of NNODES equals the number of open intervals (or well screens) to be specified in dataset 2d. If this option is used, then the model will compute the layers in which the open intervals occur, the lengths of the open intervals, and the relative vertical position of the open interval within a model layer (for example, see figure 14 and related discussion).

- **losstype** (*str*) - is a character flag to determine the user-specified model for well loss (equation 2). Available options (that is, place one of the following approved words in this field) are: NONE there are no well corrections and the head in the well is

  assumed to equal the head in the cell. This option (hWELL = hn) is only valid for a single-node well (NNODES = 1). (This is equivalent to using the original WEL Package of MODFLOW, but specifying the single-node well within the MNW2 Package enables the use of constraints.)

  THIEM this option allows for only the cell-to-well correction at the
  well based on the Thiem (1906) equation; head in the well is determined from equation 2 as (hWELL = hn + AQn), and the model computes A on the basis of the user-specified well radius (Rw) and previously defined values of cell transmissivity and grid spacing. Coefficients B and C in equation 2 are automatically set = 0.0. User must define Rw in dataset 2c or 2d.

  SKIN this option allows for formation damage or skin corrections at
  the well. hWELL = hn + AQn + BQn (from equation 2), where A is determined by the model from the value of Rw, and B is determined by the model from Rskin and Kskin. User must define Rw, Rskin, and Kskin in dataset 2c or 2d.

  GENERAL head loss is defined with coefficients A, B, and C and power
  exponent P (hWELL = hn + AQn + BQn + CQnP). A is determined by the model from the value of Rw. User must define Rw, B, C, and P in dataset 2c or 2d. A value of P = 2.0 is suggested if no other data are available (the model allows 1.0 <= P <= 3.5). Entering a value of C = 0 will result in a "linear" model in which the value of B is entered directly (rather than entering properties of the skin, as with the SKIN option).

  SPECIFYcwc the user specifies an effective conductance value
  (equivalent to the combined effects of the A, B, and C well-loss coefficients expressed in equation 15) between the well and the cell representing the aquifer, CWC. User must define CWC in dataset 2c or 2d. If there are multiple screens within the grid cell or if partial penetration corrections are to be made, then the effective value of CWC for the node may be further adjusted automatically by MNW2.

- **pumploc** (*int*) - is an integer flag pertaining to the location along the borehole of the pump intake (if any). If PUMPLOC = 0, then either there is no pump or the intake location (or discharge point for an injection well) is assumed to occur above the first active node associated with the multi- node well (that is, the node closest to the land surface or to the wellhead). If PUMPLOC > 0, then the cell in which the intake (or outflow) is located will be specified in dataset 2e as a LAY-ROW-COL grid location. For a vertical well only, specifying PUMPLOC < 0, will enable the option to define the vertical position of the pump intake (or outflow) as an elevation in dataset 2e (for the given spatial grid location [ROW-COL] defined for this well in 2d).

- **qlimit** (*int*) - is an integer flag that indicates whether the water level (head) in the well will be used to constrain the pumping rate. If Qlimit = 0, then there are no constraints for this well. If Qlimit > 0, then pumpage will be limited (constrained) by the water level in the well, and relevant parameters are constant in time and defined below in dataset 2f. If Qlimit < 0, then pumpage will be limited (constrained) by the water level in the well, and relevant parameters can vary with time and are defined for every stress period in dataset 4b.
- **ppflag** (*int*) - is an integer flag that determines whether the calculated head in the well will be corrected for the effect of partial penetration of the well screen in the cell. If PPFLAG = 0, then the head in the well will not be adjusted for the effects of partial penetration. If PPFLAG > 0, then the head in the well will be adjusted for the effects of partial penetration if the section of well containing the well screen is vertical (as indicated by identical row-column locations in the grid). If NNODES < 0 (that is, the open intervals of the well are defined by top and bottom elevations), then the model will automatically calculate the fraction of penetration for each node and the relative vertical position of the well screen. If NNODES > 0, then the fraction of penetration for each node must be defined in dataset 2d (see below) and the well screen will be assumed to be centered vertically within the thickness of the cell (except if the well is located in the uppermost model layer that is under unconfined conditions, in which case the bottom of the well screen will be assumed to be aligned with the bottom boundary of the cell and the assumed length of well screen will be based on the initial head in that cell).
- **pumpcap** (*int*) - is an integer flag and value that determines whether the discharge of a pumping (withdrawal) well (Q < 0.0) will be adjusted for changes in the lift (or total dynamic head) with time. If PUMPCAP = 0, then the discharge from the well will not be adjusted on the basis of changes in lift. If PUMPCAP > 0 for a withdrawal well, then the discharge from the well will be adjusted on the basis of the lift, as calculated from the most recent water level in the well. In this case, data describing the head-capacity relation for the pump must be listed in datasets 2g and 2h, and the use of that relation can be switched on or off for each stress period using a flag in dataset 4a. The number of entries (lines) in dataset 2h corresponds to the value of PUMPCAP. If PUMPCAP does not equal 0, it must be set to an integer value of

between 1 and 25, inclusive.

- **rw** (*float*) - radius of the well (losstype == 'THIEM', 'SKIN', or 'GENERAL')
- **rskin** (*float*) - radius to the outer limit of the skin (losstype == 'SKIN')
- **kskin** (*float*) - hydraulic conductivity of the skin
- **B** (*float*) - coefficient of the well-loss eqn. (eqn. 2 in MNW2 documentation) (losstype == 'GENERAL')
- **C** (*float*) - coefficient of the well-loss eqn. (eqn. 2 in MNW2 documentation) (losstype == 'GENERAL')
- **P** (*float*) - coefficient of the well-loss eqn. (eqn. 2 in MNW2 documentation) (losstype == 'GENERAL')
- **cwc** (*float*) - cell-to-well conductance. (losstype == 'SPECIFYcwc')
- **pp** (*float*) - fraction of partial penetration for the cell. Only specify if PFLAG > 0 and NNODES > 0.
- **k** (*int*) - layer index of well (zero-based)
- **i** (*int*) - row index of well (zero-based)
- **j** (*int*) - column index of well (zero-based)
- **ztop** (*float*) - top elevation of open intervals of vertical well.
- **zbotm** (*float*) - bottom elevation of open intervals of vertical well.
- **node_data** (*numpy record array*) - table containing MNW data by node. A blank node_data template can be created via the ModflowMnw2.get_empty_mnw_data() static method.

  Note: Variables in dataset 2d (e.g. rw) can be entered as a single value for the entire well (above), or in node_data (or dataset 2d) by node. Variables not in dataset 2d (such as pumplay) can be included in node data for convenience (to allow construction of MNW2 package from a table), but are only written to MNW2 as a single variable. When writing non-dataset 2d variables to MNW2 input, the first value for the well will be used.

  Other variables (e.g. hlim) can be entered here as constant for all stress periods, or by stress period below in stress_period_data. See MNW2 input instructions for more details.

  Columns are:

  k
  [int] layer index of well (zero-based)

  i
  [int] row index of well (zero-based)

  j
  [int] column index of well (zero-based)

ztop
[float] top elevation of open intervals of vertical well.

zbotm
[float] bottom elevation of open intervals of vertical well.

wellid : str losstype : str pumploc : int qlimit : int ppflag : int pumpcap : int rw : float rskin : float kskin : float B : float C : float P : float cwc : float pp : float pumplay : int pumprow : int pumpcol : int zpump : float hlim : float qcut : int qfrcmn : float qfrcmx : float hlift : float liftq0 : float liftqmax : float hwtol : float liftn : float qn : float

- **stress_period_data** (*numpy record array*) - table containing MNW pumping data for all stress periods (dataset 4 in the MNW2 input instructions). A blank stress_period_data template can be created via the Mnw.get_empty_stress_period_data() static method. Columns are:

  per
  [int] stress period

  qdes
  [float] is the actual (or maximum desired, if constraints are to be applied) volumetric pumping rate (negative for withdrawal or positive for injection) at the well (L3/T). Qdes should be set to 0 for nonpumping wells. If constraints are applied, then the calculated volumetric withdrawal or injection rate may be adjusted to range from 0 to Qdes and is not allowed to switch directions between withdrawal and injection conditions during any stress period. When PUMPCAP > 0, in the first stress period in which Qdes is specified with a negative value, Qdes represents the maximum operating discharge for the pump; in subsequent stress periods, any different negative values of Qdes are ignored, although values are subject to adjustment for CapMult. If Qdes >= 0.0, then pump-capacity adjustments are not applied.

  capmult
  [int] is a flag and multiplier for implementing head-capacity relations during a given stress period. Only specify if PUMPCAP > 0 for this well. If CapMult <= 0, then head-capacity relations are ignored for this stress period. If CapMult = 1.0, then head-capacity relations defined in datasets 2g and 2h are used. If CapMult equals any other positive value (for example, 0.6 or 1.1), then head-capacity relations are used but adjusted and shifted by multiplying the discharge value indicated by the head-capacity curve by the value of CapMult.

  cprime
  [float] is the concentration in the injected fluid.

Only specify if Qdes > 0 and GWT process is active.

hlim : float qcut : int qfrcmn : float qfrcmx : float

Note: If auxiliary variables are also being used, additional columns for these must be included.

- **pumplay** (*int*) -
- **pumprow** (*int*) -
- **pumpcol** (*int*) - PUMPLAY, PUMPROW, and PUMPCOL are the layer, row, and column numbers, respectively, of the cell (node) in this multi-node well where the pump intake (or outflow) is located. The location defined in dataset 2e should correspond with one of the nodes listed in 2d for this multi-node well. These variables are only read if PUMPLOC > 0 in 2b.
- **zpump** (*float*) - is the elevation of the pump intake (or discharge pipe location for an injection well). Zpump is read only if PUMPLOC < 0; in this case, the model assumes that the borehole is vertical and will compute the layer of the grid in which the pump intake is located.
- **hlim** (*float*) - is the limiting water level (head) in the well, which is a minimum for discharging wells and a maximum for injection wells. For example, in a discharging well, when hWELL falls below hlim, the flow from the well is constrained.
- **qcut** (*int*) - is an integer flag that indicates how pumping limits Qfrcmn and Qfrcmx will be specified. If pumping limits are to be specified as a rate (L3/T), then set QCUT > 0; if pumping limits are to be specified as a fraction of the specified pumping rate (Qdes), then set QCUT < 0. If there is not a minimum pumping rate below which the pump becomes inactive, then set QCUT = 0.
- **qfrcmn** (*float*) - is the minimum pumping rate or fraction of original pumping rate (a choice that depends on QCUT) that a well must exceed to remain active during a stress period. The absolute value of Qfrcmn must be less than the absolute value of Qfrcmx (defined next). Only specify if QCUT != 0.
- **qfrcmx** (*float*) - is the minimum pumping rate or fraction of original pumping rate that must be exceeded to reactivate a well that had been shut off based on Qfrcmn during a stress period. The absolute value of Qfrcmx must be greater than the absolute value of Qfrcmn. Only specify if QCUT != 0.
- **hlift** (*float*) - is the reference head (or elevation) corresponding to the discharge point for the well. This is typically at or above the land surface, and can be increased to account for additional head loss due to friction in pipes.
- **liftq0** (*float*) - is the value of lift (total dynamic head) that exceeds the capacity of the pump. If the calculated lift equals or exceeds this value, then the pump is shut off and discharge from the well ceases.
- **liftqmax** (*float*) - is the value of lift (total dynamic head) corresponding to the maximum pumping (discharge) rate for the

pump. If the calculated lift is less than or equal to LIFTqmax, then the pump will operate at its design capacity, assumed to equal the user-specified value of Qdes (in dataset 4a). LIFTqmax will be associated with the value of Qdes in the first stress period in which Qdes for the well is less than 0.0.

- **hwtol** (*float*) - is a minimum absolute value of change in the computed water level in the well allowed between successive iterations; if the value of hWELL changes from one iteration to the next by a value smaller than this tolerance, then the value of discharge computed from the head capacity curves will be locked for the remainder of that time step. It is recommended that HWtol be set equal to a value approximately one or two orders of magnitude larger than the value of HCLOSE, but if the solution fails to converge, then this may have to be adjusted.
- **liftn** (*float*) - is a value of lift (total dynamic head) that corresponds to a known value of discharge (Qn) for the given pump, specified as the second value in this line.
- **qn** (*float*) - is the value of discharge corresponding to the height of lift (total dynamic head) specified previously on this line. Sign (positive or negative) is ignored.
- **mnwpackage** (*ModflowMnw2 instance*) - package that mnw is attached to

Return type
None

by_node_variables = ['k', 'i', 'j', 'ztop', 'zbotm', 'rw', 'rskin', 'kskin', 'B', 'C', 'P', 'cwc', 'pp']

check(*f=None*, *verbose=True*, *level=1*, *checktype=None*)

Check mnw object for common errors.

Parameters

- **f** (*str or file handle*) - String defining file name or file handle for summary file of check method output. If a string is passed a file handle is created. If f is None, check method does not write results to a summary file. (default is None)
- **verbose** (*bool*) - Boolean flag used to determine if check method results are written to the screen
- **level** (*int*) - Check method analysis level. If level=0, summary checks are performed. If level=1, full checks are performed.

Returns
chk

Return type
flopy.utils.check object

static get_default_spd_dtype(*structured=True*)

Get the default stress period data dtype

Parameters
structured (*bool*) – Boolean that defines if a structured (True) or unstructured (False) dtype will be created (default is True). Not implemented for unstructured.

Returns
dtype

Return type
np.dtype

static get_empty_stress_period_data(*nper=0*, *aux_names=None*, *structured=True*, *default_value=0*)

Get an empty stress_period_data recarray that corresponds to dtype

Parameters

- **nper** (*int*) –
- **aux_names** –
- **structured** –
- **default_value** –

Returns
ra – Recarray

Return type
np.recarray

static get_item2_names(*mnw2obj=None*, *node_data=None*)

Get names for unknown things...

Parameters

- **mnw2obj** (*Mnw object*) – Mnw object (default is None)
- **node_data** (*unknown*) – Unknown what is in this parameter (default is None)

Returns

- **names** (*list*)
- *List of dtype names.*

static get_nnodes(*node_data*)

Get the number of MNW2 nodes.

Parameters
node_data (*list*) – List of nodes???

Returns
nnodes – Number of MNW2 nodes

Return type
int

make_node_data()

Make the node data array from variables entered individually.

Return type
None

static **sort_node_data**(*node_data*)

class **ModflowMnw2**(*model*, *mnwmax=0*, *nodtot=None*, *ipakcb=None*, *mnwprnt=0*, *aux=[]*, *node_data=None*, *mnw=None*, *stress_period_data=None*, *itmp=[]*, *extension='mnw2'*, *unitnumber=None*, *filenames=None*, *gwt=False*)

Bases: *Package*

Multi-Node Well 2 Package Class

Parameters

- **model** (*model object*) – The model object (of type :class:'flopy.modflow.mf.Modflow') to which this package will be added.
- **mnwmax** (*int*) – The absolute value of MNWMAX is the maximum number of multi-node wells (MNW) to be simulated. If MNWMAX is a negative number, NODTOT is read.
- **nodtot** (*int*) – Maximum number of nodes. The code automatically estimates the maximum number of nodes (NODTOT) as required for allocation of arrays. However, if a large number of horizontal wells are being simulated, or possibly for other reasons, this default estimate proves to be inadequate, a new input option has been added to allow the user to directly specify a value for NODTOT. If this is a desired option, then it can be implemented by specifying a negative value for "MNWMAX"-the first value listed in Record 1 (Line 1) of the MNW2 input data file. If this is done, then the code will assume that the very next value on that line will be the desired value of "NODTOT". The model will then reset "MNWMAX" to its absolute value. The value of "ipakcb" will become the third value on that line, etc.
- **ipakcb** (*int, optional*) – Toggles whether cell-by-cell budget data should be saved. If None or zero, budget data will not be saved (default is None).
- **mnwprnt** (*integer*) – Flag controlling the level of detail of information about multi-node wells to be written to the main MODFLOW listing (output) file. If MNWPRNT = 0, then only basic well information will be printed in the main MODFLOW output file; increasing the value of MNWPRNT yields more information, up to a maximum level of detail corresponding with MNWPRNT = 2. (default is 0)
- **aux** (*list of strings*) – (listed as "OPTION" in MNW2 input instructions) is an optional list of character values in the style of "AUXILIARY abc" or "AUX abc" where "abc" is the name of an auxiliary parameter to be read for each multi-node well as part of dataset 4a. Up to 20 parameters can be specified, each of which must be preceded by "AUXILIARY" or "AUX." These parameters will not be used by the MNW2 Package, but they will be available for use by other packages. (default is None)
- **node_data** (*numpy record array*) – master table describing multi-node wells in package. Same format as node_data tables for each Mnw object. See Mnw class documentation for more information.

- **mnw** (*list or dict of Mnw objects*) - Can be supplied instead of node_data and stress_period_data tables (in which case the tables are constructed from the Mnw objects). Otherwise the a dict of Mnw objects (keyed by wellid) is constructed from the tables.
- **stress_period_data** (*dict of numpy record arrays*) - master dictionary of record arrays (keyed by stress period) containing transient input for multi-node wells. Format is the same as stress period data for individual Mnw objects, except the 'per' column is replaced by 'wellid' (containing wellid for each MNW). See Mnw class documentation for more information.
- **itmp** (*list of ints*) - is an integer value for reusing or reading multi-node well data; it can change each stress period. ITMP must be >= 0 for the first stress period of a simulation. if ITMP > 0, then ITMP is the total number of active multi-node wells

    simulated during the stress period, and only wells listed in dataset 4a will be active during the stress period. Characteristics of each well are defined in datasets 2 and 4.

  if ITMP = 0, then no multi-node wells are active for the stress period
    and the following dataset is skipped.

  if ITMP < 0, then the same number of wells and well information will
    be reused from the previous stress period and dataset 4 is skipped.

- **extension** (*string*) - Filename extension (default is 'mnw2')
- **unitnumber** (*int*) - File unit number (default is None).
- **filenames** (*str or list of str*) - Filenames to use for the package and the output files. If filenames=None the package name will be created using the model name and package extension and the cbc output name will be created using the model name and .cbc extension (for example, modflowtest.cbc), if ipakcb is a number greater than zero. If a single string is passed the package will be set to the string and cbc output names will be created using the model name and .cbc extension, if ipakcb is a number greater than zero. To define the names for all package files (input and output) the length of the list of strings should be 2. Default is None.
- **gwt** (*boolean*) - Flag indicating whether GW transport process is active

Notes

Examples

```
>>> import flopy
>>> ml = flopy.modflow.Modflow()
>>> mnw2 = flopy.modflow.ModflowMnw2(ml, ...)
```

check(*f=None*, *verbose=True*, *level=1*, *checktype=None*)

Check mnw2 package data for common errors.

Parameters

- **f** (*str or file handle*) – String defining file name or file handle for summary file of check method output. If a string is passed a file handle is created. If f is None, check method does not write results to a summary file. (default is None)
- **verbose** (*bool*) – Boolean flag used to determine if check method results are written to the screen
- **level** (*int*) – Check method analysis level. If level=0, summary checks are performed. If level=1, full checks are performed.

Returns
chk

Return type
check object

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow.load('model.nam')
>>> m.mnw2.check()
```

export(*f*, ***kwargs*)

Export MNW2 data

Parameters

- **f** (*file*) –
- **kwargs** –

Returns
e

Return type
export object

get_allnode_data()

Get a version of the node_data array that has all MNW2 nodes listed explicitly. For example, MNWs with open intervals encompassing multiple layers would have a row entry for each layer. Ztop and zbotm values indicate the top and bottom elevations of the node (these are the same as the layer top and bottom if the node fully penetrates that layer).

Returns
allnode_data - Numpy record array of same form as node_data, except each row represents only one node.

Return type
np.recarray

static get_default_node_dtype(*structured=True*)
Get default dtype for node data

Parameters
structured (*bool*) - Boolean indicating if a structured (True) or unstructured (False) model (default is True).

Returns
dtype - node data dtype

Return type
np.dtype

static get_default_spd_dtype(*structured=True*)
Get default dtype for stress period data

Parameters
structured (*bool*) - Boolean indicating if a structured (True) or unstructured (False) model (default is True).

Returns
dtype - node data dtype

Return type
np.dtype

static get_empty_node_data(*maxnodes=0*, *aux_names=None*, *structured=True*, *default_value=0*)
get an empty recarray that corresponds to dtype

Parameters

- **maxnodes** (*int*) - Total number of nodes to be simulated (default is 0)
- **aux_names** (*list*) - List of aux name strings (default is None)
- **structured** (*bool*) - Boolean indicating if a structured (True) or unstructured (False) model (default is True).
- **default_value** (*float*) - Default value for float variables (default is 0).

Returns
r - Recarray of default dtype of shape maxnode

Return type
np.recarray

static get_empty_stress_period_data(*itmp=0*, *aux_names=None*, *structured=True*, *default_value=0*)
Get an empty stress period data recarray

Parameters

- **itmp** (*int*) – Number of entries in this stress period (default is 0).
- **aux_names** (*list*) – List of aux names (default is None).
- **structured** (*bool*) – Boolean indicating if a structured (True) or unstructured (False) model (default is True).
- **default_value** (*float*) – Default value for float variables (default is 0).

Returns
r – Recarray of default dtype of shape itmp

Return type
np.recarray

classmethod load(*f*, *model*, *nper=None*, *gwt=False*, *nsol=1*, *ext_unit_dict=None*)

Parameters

- **f** (*filename or file handle*) – File to load.
- **model** (*model object*) – The model object (of type flopy.modflow.ModflowMnw2) to which this package will be added.
- **nper** (*int*) – Number of periods
- **gwt** (*bool*) –
- **nsol** (*int*) –
- **ext_unit_dict** (*dictionary, optional*) – If the arrays in the file are specified using EXTERNAL, or older style array control records, then *f* should be a file handle. In this case ext_unit_dict is required, which can be constructed using the function *flopy.utils.mfreadnam.parsenamefile*.

make_mnw_objects()

Make a Mnw object

Return type
None

make_node_data(*mnwobjs*)

Make node_data recarray from Mnw objects

Parameters
mnwobjs (*Mnw object*) –

Return type
None

make_stress_period_data(*mnwobjs*)

Make stress_period_data recarray from Mnw objects

Parameters
mnwobjs (*Mnw object*) –

Return type
None

write_file(*filename=None*, *float_format=' {:15.7E}'*, *use_tables=True*)

Write the package file.

Parameters

- **filename** (*str*) –
- **float_format** –
- **use_tables** –

Return type

None

flopy.modflow.mfmnwi module

class ModflowMnwi(*model*, *wel1flag=None*, *qsumflag=None*, *byndflag=None*, *mnwobs=1*, *wellid_unit_qndflag_qhbflag_concflag=None*, *extension='mnwi'*, *unitnumber=None*, *filenames=None*)

Bases: *Package*

'Multi-Node Well Information Package Class'

Parameters

- **model** (*model object*) – The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.
- **wel1flag** (*integer*) – Flag indicating output to be written for each MNW node at the end of each stress period
- **qsumflag** (*integer*) – Flag indicating output to be written for each multi-node well
- **byndflag** (*integer*) – Flag indicating output to be written for each MNW node
- **mnwobs** (*integer*) – Number of multi-node wells for which detailed flow, head, and solute data to be saved
- **wellid_unit_qndflag_qhbflag_concflag** (*list of lists*) – Containing wells and related information to be output (length : [MNWOBS][4or5])
- **extension** (*string*) – Filename extension (default is 'mnwi')
- **unitnumber** (*int*) – File unit number (default is None).
- **filenames** (*str or list of str*) – Filenames to use for the package and the output files. If filenames=None the package name will be created using the model name and package extension and the output names will be created using the model name and output extensions. Default is None.

Notes

Examples

```
>>> import flopy
>>> ml = flopy.modflow.Modflow()
>>> ghb = flopy.modflow.ModflowMnwi(ml, ...)
```

check(*f=None*, *verbose=True*, *level=1*, *checktype=None*)

Check mnwi package data for common errors.

Parameters

- **f** (*str or file handle*) – String defining file name or file handle for summary file of check method output. If a string is passed a file handle is created. If f is None, check method does not write results to a summary file. (default is None)
- **verbose** (*bool*) – Boolean flag used to determine if check method results are written to the screen
- **level** (*int*) – Check method analysis level. If level=0, summary checks are performed. If level=1, full checks are performed.

Return type

None

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow.load('model.nam')
>>> m.mnwi.check()
```

classmethod load(*f*, *model*, *nper=None*, *gwt=False*, *nsol=1*, *ext_unit_dict=None*)

Default load method for standard boundary packages.

write_file()

Write the package file.

Return type

None

flopy.modflow.mfnwt module

mfnwt module. Contains the ModflowNwt class. Note that the user can access the ModflowNwt class as *flopy.modflow.ModflowNwt*.

Additional information for this MODFLOW package can be found at the Online MODFLOW Guide.

class ModflowNwt(*model*, *headtol=0.01*, *fluxtol=500*, *maxiterout=100*, *thickfact=1e-05*, *linmeth=1*, *iprnwt=0*, *ibotav=0*, *options='COMPLEX'*, *Continue=False*, *dbdtheta=0.4*, *dbdkappa=1e-05*, *dbdgamma=0.0*, *momfact=0.1*, *backflag=1*, *maxbackiter=50*, *backtol=1.1*, *backreduce=0.7*, *maxitinner=50*, *ilumethod=2*, *levfill=5*, *stoptol=1e-10*, *msdr=15*, *iacl=2*, *norder=1*, *level=5*, *north=7*, *iredsys=0*, *rrctols=0.0*, *idroptol=1*, *epsrn=0.0001*, *hclosexmd=0.0001*, *mxiterxmd=50*, *extension='nwt'*, *unitnumber=None*, *filenames=None*)

Bases: *Package*

MODFLOW Nwt Package Class.

Parameters

- **model** (*model object*) – The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.
- **headtol** (*float*) – is the maximum head change between outer iterations for solution of the nonlinear problem. (default is 1e-4).
- **fluxtol** (*float*) – is the maximum l2 norm for solution of the nonlinear problem. (default is 500).
- **maxiterout** (*int*) – is the maximum number of iterations to be allowed for solution of the outer (nonlinear) problem. (default is 100).
- **thickfact** (*float*) – is the portion of the cell thickness (length) used for smoothly adjusting storage and conductance coefficients to zero. (default is 1e-5).
- **linmeth** (*int*) – is a flag that determines which matrix solver will be used. A value of 1 indicates GMRES will be used A value of 2 indicates XMD will be used. (default is 1).
- **iprnwt** (*int*) – is a flag that indicates whether additional information about solver convergence will be printed to the main listing file. (default is 0).
- **ibotav** (*int*) – is a flag that indicates whether corrections will be made to groundwater head relative to the cell-bottom altitude if the cell is surrounded by dewatered cells (integer). A value of 1 indicates that a correction will be made and a value of 0 indicates no correction will be made. (default is 0).
- **options** (*string*) – SPECIFIED indicates that the optional solver input values listed for items 1 and 2 will be specified in the NWT input file by the user. SIMPLE indicates that default solver input values will be defined that work well for nearly linear models. This would be used for models that do not include nonlinear stress packages, and models that are either confined or consist of a single unconfined layer that is thick enough to contain the water table within a single layer. MODERATE indicates that default solver input values will be defined that work well for moderately nonlinear models. This would be used for models that include nonlinear stress packages, and models that consist of one or more unconfined layers. The MODERATE option should be used when the SIMPLE option does not result in successful convergence. COMPLEX indicates that default solver input values will be defined that work well for highly nonlinear models. This would be used

for models that include nonlinear stress packages, and models that consist of one or more unconfined layers representing complex geology and sw/gw interaction. The COMPLEX option should be used when the MODERATE option does not result in successful convergence. (default is COMPLEX).

- **Continue** (*bool*) - if the model fails to converge during a time step then it will continue to solve the following time step. (default is False). Note the capital C on this option so that it doesn't conflict with a reserved Python language word.
- **dbdtheta** (*float*) - is a coefficient used to reduce the weight applied to the head change between nonlinear iterations. dbdtheta is used to control oscillations in head. Values range between 0.0 and 1.0, and larger values increase the weight (decrease under-relaxation) applied to the head change. (default is 0.4).
- **dbdkappa** (*float*) - is a coefficient used to increase the weight applied to the head change between nonlinear iterations. dbdkappa is used to control oscillations in head. Values range between 0.0 and 1.0, and larger values increase the weight applied to the head change. (default is 1.e-5).
- **dbdgamma** (*float*) - is a factor (used to weight the head change for the previous and current iteration. Values range between 0.0 and 1.0, and greater values apply more weight to the head change calculated during the current iteration. (default is 0.)
- **momfact** (*float*) - is the momentum coefficient and ranges between 0.0 and 1.0. Greater values apply more weight to the head change for the current iteration. (default is 0.1).
- **backflag** (*int*) - is a flag used to specify whether residual control will be used. A value of 1 indicates that residual control is active and a value of 0 indicates residual control is inactive. (default is 1).
- **maxbackiter** (*int*) - is the maximum number of reductions (backtracks) in the head change between nonlinear iterations (integer). A value between 10 and 50 works well. (default is 50).
- **backtol** (*float*) - is the proportional decrease in the root-mean-squared error of the groundwater-flow equation used to determine if residual control is required at the end of a nonlinear iteration. (default is 1.1).
- **backreduce** (*float*) - is a reduction factor used for residual control that reduces the head change between nonlinear iterations. Values should be between 0.0 and 1.0, where smaller values result in smaller head-change values. (default 0.7).
- **maxitinner** (*int*) - (GMRES) is the maximum number of iterations for the linear solution. (default is 50).
- **ilumethod** (*int*) - (GMRES) is the index for selection of the method for incomplete factorization (ILU) used as a preconditioner. (default is 2).

ilumethod = 1 is ILU with drop tolerance and fill limit. Fill-in terms less than drop tolerance times the diagonal are discarded. The number of fill-in terms in each row of L and U is limited to the fill limit. The fill-limit largest elements are kept in the L and U factors.

ilumethod=2 is ILU(k) order k incomplete LU factorization. Fill-in terms of higher order than k in the factorization are discarded.

- **levfill** (*int*) - (GMRES) is the fill limit for ILUMETHOD = 1 and is the level of fill for ilumethod = 2. Recommended values: 5-10 for method 1, 0-2 for method 2. (default is 5).
- **stoptol** (*float*) - (GMRES) is the tolerance for convergence of the linear solver. This is the residual of the linear equations scaled by the norm of the root mean squared error. Usually 1.e-8 to 1.e-12 works well. (default is 1.e-10).
- **msdr** (*int*) - (GMRES) is the number of iterations between restarts of the GMRES Solver. (default is 15).
- **iacl** (*int*) - (XMD) is a flag for the acceleration method: 0 is conjugate gradient, 1 is ORTHOMIN, 2 is Bi-CGSTAB. (default is 2).
- **norder** (*int*) - (XMD) is a flag for the scheme of ordering the unknowns: 0 is original ordering, 1 is RCM ordering, 2 is Minimum Degree ordering. (default is 1).
- **level** (*int*) - (XMD) is the level of fill for incomplete LU factorization. (default is 5).
- **north** (*int*) - (XMD) is the number of orthogonalization for the ORTHOMIN acceleration scheme. A number between 4 and 10 is appropriate. Small values require less storage but more iterations may be required. This number should equal 2 for the other acceleration methods. (default is 7).
- **iredsys** (*int*) - (XMD) is a flag for reduced system preconditioning (integer): 0-do not apply reduced system preconditioning, 1-apply reduced system preconditioning. (default is 0)
- **rrctols** (*int*) - (XMD) is the residual reduction-convergence criteria. (default is 0.).
- **idroptol** (*int*) - (XMD) is a flag for using drop tolerance in the preconditioning: 0-don't use drop tolerance, 1-use drop tolerance. (default is 1).
- **epsrn** (*float*) - (XMD) is the drop tolerance for preconditioning. (default is 1.e-4).
- **hclosexmd** (*float*) - (XMD) is the head closure criteria for inner (linear) iterations. (default is 1.e-4).
- **mxiterxmd** (*int*) - (XMD) is the maximum number of iterations for the linear solution. (default is 50).
- **extension** (*list string*) - Filename extension (default is 'nwt')
- **unitnumber** (*int*) - File unit number (default is None).

- **filenames** (*str or list of str*) – Filenames to use for the package. If filenames=None the package name will be created using the model name and package extension. If a single string is passed the package will be set to the string. Default is None.

Notes

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow()
>>> nwt = flopy.modflow.ModflowNwt(m)
```

classmethod load(*f*, *model*, *ext_unit_dict=None*)

Load an existing package.

Parameters

- **f** (*filename or file handle*) – File to load.
- **model** (*model object*) – The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.
- **ext_unit_dict** (*dictionary, optional*) – If the arrays in the file are specified using EXTERNAL, or older style array control records, then *f* should be a file handle. In this case ext_unit_dict is required, which can be constructed using the function *flopy.utils.mfreadnam.parsenamefile*.

Returns

nwt

Return type

ModflowNwt object

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow()
>>> nwt = flopy.modflow.ModflowPcg.load('test.nwt', m)
```

write_file()

Write the package file.

Return type

None

flopy.modflow.mfoc module

mfoc module. Contains the ModflowOc class. Note that the user can access the ModflowOc class as *flopy.modflow.ModflowOc*.

Additional information for this MODFLOW package can be found at the Online MODFLOW Guide.

class ModflowOc(*model*, *ihedfm=0*, *iddnfm=0*, *chedfm=None*, *cddnfm=None*, *cboufm=None*, *compact=True*, *stress_period_data={(0, 0): ['save head']}*, *extension=['oc', 'hds', 'ddn', 'cbc', 'ibo']*, *unitnumber=None*, *filenames=None*, *label='LABEL'*, ***kwargs*)

Bases: *Package*

MODFLOW Output Control Package Class.

Parameters

- **model** (*model object*) – The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.
- **ihedfm** (*int*) – is a code for the format in which heads will be printed. (default is 0).
- **iddnfm** (*int*) – is a code for the format in which drawdown will be printed. (default is 0).
- **chedfm** (*string*) – is a character value that specifies the format for saving heads. The format must contain 20 characters or less and must be a valid Fortran format that is enclosed in parentheses. The format must be enclosed in apostrophes if it contains one or more blanks or commas. The optional word LABEL after the format is used to indicate that each layer of output should be preceded with a line that defines the output (simulation time, the layer being output, and so forth). If there is no record specifying CHEDFM, then heads are written to a binary (unformatted) file. Binary files are usually more compact than text files, but they are not generally transportable among different computer operating systems or different Fortran compilers. (default is None)
- **cddnfm** (*string*) – is a character value that specifies the format for saving drawdown. The format must contain 20 characters or less and must be a valid Fortran format that is enclosed in parentheses. The format must be enclosed in apostrophes if it contains one or more blanks or commas. The optional word LABEL after the format is used to indicate that each layer of output should be preceded with a line that defines the output (simulation time, the layer being output, and so forth). If there is no record specifying CDDNFM, then drawdowns are written to a binary (unformatted) file. Binary files are usually more compact than text files, but they are not generally transportable among different computer operating systems or different Fortran compilers. (default is None)
- **cboufm** (*string*) – is a character value that specifies the format for saving ibound. The format must contain 20 characters or less and must be a valid Fortran format that is enclosed in parentheses. The format must be enclosed in apostrophes if

it contains one or more blanks or commas. The optional word LABEL after the format is used to indicate that each layer of output should be preceded with a line that defines the output (simulation time, the layer being output, and so forth). If there is no record specifying CBOUFM, then ibounds are written to a binary (unformatted) file. Binary files are usually more compact than text files, but they are not generally transportable among different computer operating systems or different Fortran compilers. (default is None)

- **stress_period_data** (*dictionary of lists*) - Dictionary key is a tuple with the zero-based period and step (IPEROC, ITSOC) for each print/save option list. If stress_period_data is None, then heads are saved for the last time step of each stress period. (default is None)

  The list can have any valid MODFLOW OC print/save option:

  PRINT HEAD PRINT DRAWDOWN PRINT BUDGET SAVE HEAD SAVE DRAWDOWN SAVE BUDGET SAVE IBOUND

  The lists can also include (1) DDREFERENCE in the list to reset drawdown reference to the period and step and (2) a list of layers for PRINT HEAD, SAVE HEAD, PRINT DRAWDOWN, SAVE DRAWDOWN, and SAVE IBOUND.

  stress_period_data = {(0,1):['save head']}) would save the head for the second timestep in the first stress period.

- **compact** (*boolean*) - Save results in compact budget form. (default is True).
- **extension** (*list of strings*) - (default is ['oc', 'hds', 'ddn', 'cbc', 'ibo']).
- **unitnumber** (*list of ints*) - (default is [14, 51, 52, 53, 0]).
- **filenames** (*str or list of str*) - Filenames to use for the package and the head, drawdown, budget (not used), and ibound output files. If filenames=None the package name will be created using the model name and package extension and the output file names will be created using the model name and extensions. If a single string is passed the package will be set to the string and output names will be created using the model name and head, drawdown, budget, and ibound extensions. To define the names for all package files (input and output) the length of the list of strings should be 5. Default is None.

Notes

The "words" method for specifying output control is the only option available. Also, the "compact" budget should normally be used as it produces files that are typically much smaller. The compact budget form is also a requirement for using the MODPATH particle tracking program.

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow()
>>> spd = {(0, 0): ['print head'],
...   (0, 1): [],
...   (0, 249): ['print head'],
...   (0, 250): [],
...   (0, 499): ['print head', 'save ibound'],
...   (0, 500): [],
...   (0, 749): ['print head', 'ddreference'],
...   (0, 750): [],
...   (0, 999): ['print head']}
>>> oc = flopy.modflow.ModflowOc(m, stress_period_data=spd, cboufm='(20i5)')
```

check(*f=None*, *verbose=True*, *level=1*, *checktype=None*)

Check package data for common errors.

Parameters

- **f** (*str or file handle*) – String defining file name or file handle for summary file of check method output. If a string is passed a file handle is created. If f is None, check method does not write results to a summary file. (default is None)
- **verbose** (*bool*) – Boolean flag used to determine if check method results are written to the screen.
- **level** (*int*) – Check method analysis level. If level=0, summary checks are performed. If level=1, full checks are performed.

Return type

None

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow.load('model.nam')
>>> m.oc.check()
```

get_budgetunit()

Get the budget file unit number(s).

Parameters

None –

Returns

iubud – Unit number or list of cell-by-cell budget output unit numbers. None is returned if ipakcb is less than one for all packages.

Return type

integer ot list of integers

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow()
>>> dis = flopy.modflow.ModflowDis(m)
>>> bas = flopy.modflow.ModflowBas(m)
>>> lpf = flopy.modflow.ModflowLpf(m, ipakcb=100)
>>> wel_data = {0: [[0, 0, 0, -1000.]]}
>>> wel = flopy.modflow.ModflowWel(m, ipakcb=101,
... stress_period_data=wel_data)
>>> spd = {(0, 0): ['save head', 'save budget']}
>>> oc = flopy.modflow.ModflowOc(m, stress_period_data=spd)
>>> oc.get_budgetunit()
[100, 101]
```

static get_ocoutput_units(*f*, *ext_unit_dict=None*)

Get head and drawdown units from a OC file.

Parameters

- **f** (*filename or file handle*) – File to load.
- **ext_unit_dict** (*dictionary, optional*) – If the arrays in the file are specified using EXTERNAL, or older style array control records, then *f* should be a file handle. In this case ext_unit_dict is required, which can be constructed using the function *flopy.utils.mfreadnam.parsenamefile*.

Returns

- **ihedun** (*integer*) – Unit number of the head file.
- **fhead** (*str*) – File name of the head file. Is only defined if ext_unit_dict is passed and the unit number is a valid key. , headfilename, oc : ModflowOc object ModflowOc object.
- **iddnun** (*integer*) – Unit number of the drawdown file.
- **fddn** (*str*) – File name of the drawdown file. Is only defined if ext_unit_dict is passed and the unit number is a valid key.

Examples

```
>>> import flopy
>>> ihds, hf, iddn, df = flopy.modflow.ModflowOc.get_ocoutput_units('test.oc')
```

classmethod load(*f*, *model*, *nper=None*, *nstp=None*, *nlay=None*, *ext_unit_dict=None*)

Load an existing package.

Parameters

- **f** (*filename or file handle*) – File to load.
- **model** (*model object*) – The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.

- **nper** (*int*) – The number of stress periods. If nper is None, then nper will be obtained from the model object. (default is None).
- **nstp** (*int or list of ints*) – Integer of list of integers containing the number of time steps in each stress period. If nstp is None, then nstp will be obtained from the DIS or DISU packages attached to the model object. The length of nstp must be equal to nper. (default is None).
- **nlay** (*int*) – The number of model layers. If nlay is None, then nnlay will be obtained from the model object. nlay only needs to be specified if an empty model object is passed in and the oc file being loaded is defined using numeric codes. (default is None).
- **ext_unit_dict** (*dictionary, optional*) – If the arrays in the file are specified using EXTERNAL, or older style array control records, then *f* should be a file handle. In this case ext_unit_dict is required, which can be constructed using the function *flopy.utils.mfreadnam.parsenamefile*.

Returns
oc – ModflowOc object.

Return type
ModflowOc object

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow()
>>> oc = flopy.modflow.ModflowOc.load('test.oc', m)
```

reset_budgetunit(*budgetunit=None*, *fname=None*)

Reset the cell-by-cell budget unit (ipakcb) for every package that can write cell-by-cell data when SAVE BUDGET is specified in the OC file to the specified budgetunit.

Parameters

- **budgetunit** (*int, optional*) – Unit number for cell-by-cell output data. If budgetunit is None then the next available external unit number is assigned. Default is None
- **fname** (*string, optional*) – Filename to use for cell-by-cell output file. If fname=None the cell-by-cell output file will be created using the model name and a '.cbc' file extension. Default is None.

Return type
None

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow()
>>> dis = flopy.modflow.ModflowDis(m)
>>> bas = flopy.modflow.ModflowBas(m)
>>> lpf = flopy.modflow.ModflowLpf(m, ipakcb=100)
>>> wel_data = {0: [[0, 0, 0, -1000.]]}
>>> wel = flopy.modflow.ModflowWel(m, ipakcb=101,
... stress_period_data=wel_data)
>>> spd = {(0, 0): ['save head', 'save budget']}
>>> oc = flopy.modflow.ModflowOc(m, stress_period_data=spd)
>>> oc.reset_budgetunit(budgetunit=1053, fname='test.cbc')
```

write_file()

Write the package file.

Return type
None

flopy.modflow.mfpar module

mfpar module. Contains the ModflowPar class. Note that the user can access the ModflowPar class as *flopy.modflow.ModflowPar*.

class ModflowPar

Bases: object

Class for loading mult, zone, pval, and parameter data for MODFLOW packages that use array data (LPF, UPW, RCH, EVT). Class also includes methods to create data arrays using mult, zone, pval, and parameter data (not used for boundary conditions).

Notes

Parameters are supported in Flopy only when reading in existing models. Parameter values are converted to native values in Flopy and the connection to “parameters” is thus nonexistent.

static load(*f*, *npar*, *verbose=False*)

Load property parameters from an existing package.

Parameters

- **f** (*file handle*) –
- **npar** (*int*) – The number of parameters.
- **verbose** (*bool*) – Boolean flag to control output. (default is False)

Returns

- **list** (*list object of unique par_types in file f*)
- **dictionary** (*dictionary object with parameters in file f*)

Examples

>>>par_types, parm_dict = flopy.modflow.mfpar.ModflowPar.load(f, np)

static parameter_fill(*model*, *shape*, *findkey*, *parm_dict*, *findlayer=None*)

Fill an array with parameters using zone, mult, and pval data.

Parameters

- **model** (*model object*) – The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.
- **shape** (*tuple*) – The shape of the returned data array. Typically shape is (nrow, ncol)
- **findkey** (*string*) – the parameter array to be constructed,
- **parm_dict** (*dict*) – dictionary that includes all of the parameter data for a package
- **findlayer** (*int*) – Layer that will be filled. Not required for array boundary condition data.

Returns

data – Filled array resulting from applications of zone, mult, pval, and parameter data.

Return type

numpy array

Examples

for lpf and upw:

```
>>> data = flopy.modflow.mfpar.ModflowPar.parameter_fill(m, (nrow, ncol), 'vkcb
↪',
>>> .................................................parm_dict,␣
↪findlayer=1)
```

set_mult(*model*, *ext_unit_dict*)

Load an existing mult package and set mult data for a model.

Parameters

- **model** (*model object*) – The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.
- **ext_unit_dict** (*dictionary*, *optional*) – If the arrays in the file are specified using EXTERNAL, or older style array control records, then *f* should be a file handle. In this case ext_unit_dict is required, which can be constructed using the function *flopy.utils.mfreadnam.parsenamefile*.

Examples

```
>>> ml.mfpar.set_mult(ml, ext_unit_dict)
```

set_pval(*model*, *ext_unit_dict*)

Load an existing pval package and set pval data for a model.

Parameters

- **model** (*model object*) – The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.
- **ext_unit_dict** (*dictionary, optional*) – If the arrays in the file are specified using EXTERNAL, or older style array control records, then *f* should be a file handle. In this case ext_unit_dict is required, which can be constructed using the function *flopy.utils.mfreadnam.parsenamefile*.

Examples

```
>>> ml.mfpar.set_pval(ml, ext_unit_dict)
```

set_zone(*model*, *ext_unit_dict*)

Load an existing zone package and set zone data for a model.

Parameters

- **model** (*model object*) – The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.
- **ext_unit_dict** (*dictionary, optional*) – If the arrays in the file are specified using EXTERNAL, or older style array control records, then *f* should be a file handle. In this case ext_unit_dict is required, which can be constructed using the function *flopy.utils.mfreadnam.parsenamefile*.

Examples

```
>>> ml.mfpar.set_zone(ml, ext_unit_dict)
```

flopy.modflow.mfparbc module

mfparbc module. Contains the ModflowParBc class. Note that the user can access the ModflowParBc class as *flopy.modflow.ModflowParBc*.

class ModflowParBc(*bc_parms*)

Bases: object

Class for loading boundary condition parameter data for MODFLOW packages that use list data (WEL, GHB, DRN, etc.). This Class is also used to create hfb6 data from hfb parameters. Class also includes methods to create data arrays using pval and boundary condition parameter data.

Notes

Parameters are supported in Flopy only when reading in existing models. Parameter values are converted to native values in Flopy and the connection to "parameters" is thus nonexistent.

get(*fkey*)

overload get to return a value from the bc_parms dictionary

classmethod load(*f*, *npar*, *dt*, *model*, *ext_unit_dict=None*, *verbose=False*)

Load bc property parameters from an existing bc package that uses list data (e.g. WEL, RIV, etc.).

Parameters

- **f** (*file handle*) –
- **npar** (*int*) – The number of parameters.
- **dt** (*numpy.dtype*) – numpy.dtype for the particular list boundary condition.
- **verbose** (*bool*) – Boolean flag to control output. (default is False)

Returns
dictionary

Return type
dictionary object with parameters in file f

Examples

static loadarray(*f*, *npar*, *verbose=False*)

Load bc property parameters from an existing bc package that uses array data (e.g. RCH, EVT).

Parameters

- **f** (*file handle*) –
- **npar** (*int*) – The number of parameters.
- **verbose** (*bool*) – Boolean flag to control output. (default is False)

Returns
dictionary

Return type
dictionary object with parameters in file f

Examples

static parameter_bcfill(*model*, *shape*, *parm_dict*, *pak_parms*)

Fill an array with parameters using zone, mult, and pval data.

Parameters

- **model** (*model object*) – The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.
- **shape** (*tuple*) – The shape of the returned data array. Typically shape is (nrow, ncol)
- **parm_dict** (*list*) – dictionary of parameter instances
- **pak_parms** (*dict*) – dictionary that includes all of the parameter data for a package

Returns

data – Filled array resulting from applications of zone, mult, pval, and parameter data.

Return type

numpy array

Examples

for rch and evt >>> data = flopy.modflow.mfparbc.ModflowParBc.parameter_bcfill(m, (nrow, ncol), >>> …….'rech', parm_dict, pak_parms)

flopy.modflow.mfpbc module

class ModflowPbc(*model*, *layer_row_column_data=None*, *layer_row_column_shead_ehead=None*, *cosines=None*, *extension='pbc'*, *unitnumber=None*, *zerobase=True*)

Bases: *Package*

Periodic boundary condition class

write_file()

Write the package file.

Return type

None

flopy.modflow.mfpcg module

mfpcg module. Contains the ModflowPcg class. Note that the user can access the ModflowPcg class as *flopy.modflow.ModflowPcg*.

Additional information for this MODFLOW package can be found at the Online MODFLOW Guide.

class ModflowPcg(*model*, *mxiter=50*, *iter1=30*, *npcond=1*, *hclose=1e-05*, *rclose=1e-05*, *relax=1.0*, *nbpol=0*, *iprpcg=0*, *mutpcg=3*, *damp=1.0*, *dampt=1.0*, *ihcofadd=0*, *extension='pcg'*, *unitnumber=None*, *filenames=None*)

Bases: *Package*

MODFLOW Pcg Package Class.

Parameters

- **model** (*model object*) - The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.
- **mxiter** (*int*) - maximum number of outer iterations. (default is 50)
- **iter1** (*int*) - maximum number of inner iterations. (default is 30)
- **npcond** (*int*) - flag used to select the matrix conditioning method. (default is 1). specify npcond = 1 for Modified Incomplete Cholesky. specify npcond = 2 for Polynomial.
- **hclose** (*float*) - is the head change criterion for convergence. (default is 1e-5).
- **rclose** (*float*) - is the residual criterion for convergence. (default is 1e-5)
- **relax** (*float*) - is the relaxation parameter used with npcond = 1. (default is 1.0)
- **nbpol** (*int*) - is only used when npcond = 2 to indicate whether the estimate of the upper bound on the maximum eigenvalue is 2.0, or whether the estimate will be calculated. nbpol = 2 is used to specify the value is 2.0; for any other value of nbpol, the estimate is calculated. Convergence is generally insensitive to this parameter. (default is 0).
- **iprpcg** (*int*) - solver print out interval. (default is 0).
- **mutpcg** (*int*) - If mutpcg = 0, tables of maximum head change and residual will be printed each iteration. If mutpcg = 1, only the total number of iterations will be printed. If mutpcg = 2, no information will be printed. If mutpcg = 3, information will only be printed if convergence fails. (default is 3).
- **damp** (*float*) - is the steady-state damping factor. (default is 1.)
- **dampt** (*float*) - is the transient damping factor. (default is 1.)
- **ihcofadd** (*int*) - is a flag that determines what happens to an active cell that is surrounded by dry cells. (default is 0). If ihcofadd=0, cell converts to dry regardless of HCOF value. This is the default, which is the way PCG2 worked prior to the addition of this option. If ihcofadd<>0, cell converts to dry only if HCOF has no head-dependent stresses or storage terms.
- **extension** (*list string*) - Filename extension (default is 'pcg')
- **unitnumber** (*int*) - File unit number (default is None).
- **filenames** (*str or list of str*) - Filenames to use for the package. If filenames=None the package name will be created using the model name and package extension. If a single string is passed the package will be set to the string. Default is None.

Notes

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow()
>>> pcg = flopy.modflow.ModflowPcg(m)
```

classmethod load(*f*, *model*, *ext_unit_dict=None*)

Load an existing package.

Parameters

- **f** (*filename or file handle*) – File to load.
- **model** (*model object*) – The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.
- **ext_unit_dict** (*dictionary, optional*) – If the arrays in the file are specified using EXTERNAL, or older style array control records, then *f* should be a file handle. In this case ext_unit_dict is required, which can be constructed using the function *flopy.utils.mfreadnam.parsenamefile*.

Returns
pcg

Return type
ModflowPcg object

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow()
>>> pcg = flopy.modflow.ModflowPcg.load('test.pcg', m)
```

write_file()

Write the package file.

Return type
None

flopy.modflow.mfpcgn module

mfpcgn module. Contains the ModflowPcgn class. Note that the user can access the ModflowStr class as *flopy.modflow.ModflowPcgn*.

Additional information for this MODFLOW package can be found at the Online MODFLOW Guide.

class ModflowPcgn(*model*, *iter_mo=50*, *iter_mi=30*, *close_r=1e-05*, *close_h=1e-05*, *relax=1.0*, *ifill=0*, *unit_pc=None*, *unit_ts=None*, *adamp=0*, *damp=1.0*, *damp_lb=0.001*, *rate_d=0.1*, *chglimit=0.0*, *acnvg=0*, *cnvg_lb=0.001*, *mcnvg=2*, *rate_c=-1.0*, *ipunit=None*, *extension='pcgn'*, *unitnumber=None*, *filenames=None*)

Bases: *Package*

MODFLOW Pcgn Package Class.

Parameters

- **model** (*model object*) - The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.
- **iter_mo** (*int*) - The maximum number of picard (outer) iterations allowed. For nonlinear problems, this variable must be set to some number greater than one, depending on the problem size and degree of nonlinearity. If iter_mo is set to 1, then the pcgn solver assumes that the problem is linear and the input requirements are greatly truncated. (default is 50)
- **iter_mi** (*int*) - maximum number of pcg (inner) iterations allowed. Generally, this variable is set to some number greater than one, depending on the matrix size, degree of convergence called for, and the nature of the problem. For a nonlinear problem, iter_mi should be set large enough that the pcg iteration converges freely with the relative convergence parameter epsilon described in the Parameters Related to Convergence of Inner Iteration: Line 4 subsection. (default is 30)
- **close_r** (*float*) - The residual-based stopping criterion for iteration. This parameter is used differently, depending on whether it is applied to a linear or nonlinear problem.

  If iter_mo = 1: For a linear problem, the variant of the conjugate gradient method outlined in algorithm 2 is employed, but uses the absolute convergence criterion in place of the relative convergence criterion. close_r is used as the value in the absolute convergence criterion for quitting the pcg iterative solver. close_r is compared to the square root of the weighted residual norm. In particular, if the square root of the weighted residual norm is less than close_r, then the linear Pcg iterative solve is said to have converged, causing the pcg iteration to cease and control of the program to pass out of the pcg solver.

  If iter_mo > 1: For a nonlinear problem, close_r is used as a criterion for quitting the picard (outer) iteration. close_r is compared to the square root of the inner product of the residuals (the residual norm) as calculated on entry to the pcg solver at the beginning of every picard iteration. if this norm is less than close_r, then the picard iteration is considered to have converged.
- **close_h** (*float*) - close_h is used as an alternate stopping criterion for the picard iteration needed to solve a nonlinear problem. The maximum value of the head change is obtained for each picard iteration, after completion of the inner, pcg iteration. If this maximum head change is less than close_h, then the picard iteration is considered tentatively to have converged. However, as nonlinear problems can demonstrate oscillation in the head solution, the picard iteration is not declared to have converged unless the maximum head change is less than close_h for three picard iterations. If these picard iterations are

sequential, then a good solution is assumed to have been obtained. If the picard iterations are not sequential, then a warning is issued advising that the convergence is conditional and the user is urged to examine the mass balance of the solution.

- **relax** (*float*) - is the relaxation parameter used with npcond = 1. (default is 1.0)
- **ifill** (*int*) - is the fill level of the mic preconditioner. Preconditioners with fill levels of 0 and 1 are available (ifill = 0 and ifill = 1, respectively). (default is 0)
- **unit_pc** (*int*) - is the unit number of an optional output file where progress for the inner PCG iteration can be written. (default is 0)
- **unit_ts** (*int*) - is the unit number of an optional output file where the actual time in the PCG solver is accumulated. (default is 0)
- **adamp** (*int*) - defines the mode of damping applied to the linear solution. In general, damping determines how much of the head changes vector shall be applied to the hydraulic head vector hj in picard iteration j. If adamp = 0, Ordinary damping is employed and a constant value of damping parameter will be used throughout the picard iteration; this option requires a valid value for damp. If adamp = 1, Adaptive damping is employed. If adamp = 2: Enhanced damping algorithm in which the damping value is increased (but never decreased) provided the picard iteration is proceeding satisfactorily. (default is 0)
- **damp** (*float*) - is the damping factor. (default is 1.)
- **damp_lb** (*float*) - is the lower bound placed on the dampening; generally, 0 < damp_lb < damp. (default is 0.001)
- **rate_d** (*float*) - is a rate parameter; generally, 0 < rate_d < 1. (default is 0.1)
- **chglimit** (*float*) - this variable limits the maximum head change applicable to the updated hydraulic heads in a Picard iteration. If chglimit = 0.0, then adaptive damping proceeds without this feature. (default is 0.)
- **acnvg** (*int*) - defines the mode of convergence applied to the PCG solver. (default is 0)
- **cnvg_lb** (*int*) - is the minimum value that the relative convergence is allowed to take under the self-adjusting convergence option. cnvg_lb is used only in convergence mode acnvg = 1. (default is 0.001)
- **mcnvg** (*float*) - increases the relative PCG convergence criteria by a power equal to MCNVG. MCNVG is used only in convergence mode acnvg = 2. (default is 2)
- **rate_c** (*float*) - this option results in variable enhancement of epsilon. If 0 < rate_c < 1, then enhanced relative convergence is allowed to decrease by increasing epsilon(j) = epsilon(j-1) + rate_c epsilon(j-1), where j is the Picarditeration number;

this change in epsilon occurs so long as the Picard iteration is progressing satisfactorily. If rate_c <= 0, then the value of epsilon set by mcnvg remains unchanged through the picard iteration. It should be emphasized that rate_c must have a value greater than 0 for the variable enhancement to be ffected; otherwise epsilon remains constant. rate_c is used only in convergence mode acnvg = 2. (default is -1.)

- **ipunit** (*int*) – enables progress reporting for the picard iteration. If ipunit >= 0, then a record of progress made by the picard iteration for each time step is printed in the MODFLOW Listing file (Harbaugh and others, 2000). This record consists of the total number of dry cells at the end of each time step as well as the total number of PCG iterations necessary to obtain convergence. In addition, if ipunit > 0, then extensive diagnostics for each Picard iteration is also written in comma-separated format to a file whose unit number corresponds to ipunit; the name for this file, along with its unit number and type 'data' should be entered in the modflow Name file. If ipunit < 0 then printing of all progress concerning the Picard iteration is suppressed, as well as information on the nature of the convergence of the picard iteration. (default is 0)
- **extension** (*list string*) – Filename extension (default is 'pcgn')
- **unitnumber** (*int*) – File unit number (default is None).
- **filenames** (*str or list of str*) – Filenames to use for the package and the output files. If filenames=None the package name will be created using the model name and package extension and the pcgn output names will be created using the model name and .pcgni, .pcgnt, and .pcgno extensions. If a single string is passed the package will be set to the string and pcgn output names will be created using the model name and pcgn output extensions. To define the names for all package files (input and output) the length of the list of strings should be 4. Default is None.

Notes

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow()
>>> pcgn = flopy.modflow.ModflowPcgn(m)
```

classmethod load(*f*, *model*, *ext_unit_dict=None*)

Load an existing package.

Parameters

- **f** (*filename or file handle*) – File to load.
- **model** (*model object*) – The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.
- **ext_unit_dict** (*dictionary, optional*) – If the arrays in the file are specified using EXTERNAL, or older style array

control records, then *f* should be a file handle. In this case ext_unit_dict is required, which can be constructed using the function *flopy.utils.mfreadnam.parsenamefile*.

Returns
pcgn

Return type
ModflowPcgn object

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow()
>>> pcgn = flopy.modflow.ModflowPcgn.load('test.pcgn', m)
```

write_file()

Write the package file.

Return type
None

flopy.modflow.mfpks module

mfpks module. Contains the ModflowPks class. Note that the user can access the ModflowPks class as *flopy.modflow.ModflowPks*.

class ModflowPks(*model*, *mxiter=100*, *innerit=50*, *isolver=1*, *npc=2*, *iscl=0*, *iord=0*, *ncoresm=1*, *ncoresv=1*, *damp=1.0*, *dampt=1.0*, *relax=0.97*, *ifill=0*, *droptol=0.0*, *hclose=0.001*, *rclose=0.1*, *l2norm=None*, *iprpks=0*, *mutpks=3*, *mpi=False*, *partopt=0*, *novlapimpsol=1*, *stenimpsol=2*, *verbose=0*, *partdata=None*, *extension='pks'*, *unitnumber=None*, *filenames=None*)

Bases: *Package*

MODFLOW Pks Package Class.

Parameters

- **model** (*model object*) – The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.
- **mxiter** (*int*) – maximum number of outer iterations. (default is 100)
- **innerit** (*int*) – maximum number of inner iterations. (default is 30)
- **hclose** (*float*) – is the head change criterion for convergence. (default is 1.e-3).
- **rclose** (*float*) – is the residual criterion for convergence. (default is 1.e-1)
- **relax** (*float*) – is the relaxation parameter used with npcond = 1. (default is 1.0)
- **.** –
- **.** –

- **.** –
- **iprpks** (*int*) – solver print out interval. (default is 0).
- **mutpks** (*int*) –

  If mutpcg = 0, tables of maximum head change and residual will be
  printed each iteration.

  If mutpcg = 1, only the total number of iterations will be printed. If mutpcg = 2, no information will be printed. If mutpcg = 3, information will only be printed if convergence fails.

  (default is 3).
- **damp** (*float*) – is the steady-state damping factor. (default is 1.)
- **dampt** (*float*) – is the transient damping factor. (default is 1.)
- **extension** (*list string*) – Filename extension (default is 'pks')
- **unitnumber** (*int*) – File unit number (default is 27).
- **filenames** (*str or list of str*) – Filenames to use for the package. If filenames=None the package name will be created using the model name and package extension. If a single string is passed the package will be set to the string. Default is None.

Notes

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow()
>>> pks = flopy.modflow.ModflowPks(m)
```

classmethod load(*f*, *model*, *ext_unit_dict=None*)

Load an existing package.

Parameters

- **f** (*filename or file handle*) – File to load.
- **model** (*model object*) – The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.
- **ext_unit_dict** (*dictionary, optional*) – If the arrays in the file are specified using EXTERNAL, or older style array control records, then *f* should be a file handle. In this case ext_unit_dict is required, which can be constructed using the function *flopy.utils.mfreadnam.parsenamefile*.

Returns

pks

Return type

ModflowPks object

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow()
>>> pks = flopy.modflow.ModflowPks.load('test.pks', m)
```

write_file()

Write the package file.

Return type
None

flopy.modflow.mfpval module

mfpval module. Contains the ModflowPval class. Note that the user can access the ModflowPval class as *flopy.modflow.ModflowPval*.

Additional information for this MODFLOW package can be found at the Online MODFLOW Guide.

class ModflowPval(*model*, *pval_dict=None*, *extension='pval'*, *unitnumber=None*, *filenames=None*)

Bases: *Package*

MODFLOW Mult Package Class.

Parameters

- **model** (*model object*) – The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.
- **pval_dict** (*dict*) – Dictionary with pval data for the model. pval_dict is typically instantiated using load method.
- **extension** (*string*) – Filename extension (default is 'pval')
- **unitnumber** (*int*) – File unit number (default is None).
- **filenames** (*str or list of str*) – Filenames to use for the package. If filenames=None the package name will be created using the model name and package extension. If a single string is passed the package will be set to the string. Default is None.

Notes

Parameters are supported in Flopy only when reading in existing models. Parameter values are converted to native values in Flopy and the connection to "parameters" is thus nonexistent.

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow()
>>> pval_dict = flopy.modflow.ModflowZon(m, pval_dict=pval_dict)
```

classmethod load(*f*, *model*, *ext_unit_dict=None*)

Load an existing package.

Parameters

- **f** (*filename or file handle*) – File to load.
- **model** (*model object*) – The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.
- **ext_unit_dict** (*dictionary, optional*) – If the arrays in the file are specified using EXTERNAL, or older style array control records, then *f* should be a file handle. In this case ext_unit_dict is required, which can be constructed using the function *flopy.utils.mfreadnam.parsenamefile*.

Returns

pval

Return type

ModflowPval dict

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow()
>>> mlt = flopy.modflow.ModflowPval.load('test.pval', m)
```

write_file()

Write the package file.

Return type

None

Notes

Not implemented because parameters are only supported on load

flopy.modflow.mfrch module

mfrch module. Contains the ModflowRch class. Note that the user can access the ModflowRch class as *flopy.modflow.ModflowRch*.

Additional information for this MODFLOW package can be found at the Online MODFLOW Guide.

class ModflowRch(*model*, *nrchop=3*, *ipakcb=None*, *rech=0.001*, *irch=0*, *extension='rch'*, *unitnumber=None*, *filenames=None*)

Bases: *Package*

MODFLOW Recharge Package Class.

Parameters

- **model** (*model object*) – The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.
- **ipakcb** (*int, optional*) – Toggles whether cell-by-cell budget data should be saved. If None or zero, budget data will not be saved (default is None).
- **nrchop** (*int*) – is the recharge option code. 1: Recharge to top grid layer only 2: Recharge to layer defined in irch 3: Recharge to highest active cell (default is 3).
- **rech** (*float or filename or ndarray or dict keyed on kper (zero-based)*) – Recharge flux (default is 1.e-3, which is used for all stress periods)
- **irch** (*int or filename or ndarray or dict keyed on kper (zero-based)*) – Layer (for an unstructured grid) or node (for an unstructured grid) to which recharge is applied in each vertical column (only used when nrchop=2). Default is 0, which is used for all stress periods.
- **extension** (*string*) – Filename extension (default is 'rch')
- **unitnumber** (*int*) – File unit number (default is None).
- **filenames** (*str or list of str*) – Filenames to use for the package and the output files. If filenames=None the package name will be created using the model name and package extension and the cbc output name will be created using the model name and .cbc extension (for example, modflowtest.cbc), if ipakcb is a number greater than zero. If a single string is passed the package will be set to the string and cbc output names will be created using the model name and .cbc extension, if ipakcb is a number greater than zero. To define the names for all package files (input and output) the length of the list of strings should be 2. Default is None.

Notes

Parameters are supported in Flopy only when reading in existing models. Parameter values are converted to native values in Flopy and the connection to "parameters" is thus nonexistent.

Examples

```
>>> #steady state
>>> import flopy
>>> m = flopy.modflow.Modflow()
>>> rch = flopy.modflow.ModflowRch(m, nrchop=3, rech=1.2e-4)
```

```
>>> #transient with time-varying recharge
>>> import flopy
>>> rech = {}
>>> rech[0] = 1.2e-4 #stress period 1 to 4
>>> rech[4] = 0.0 #stress period 5 and 6
>>> rech[6] = 1.2e-3 #stress period 7 to the end
>>> m = flopy.modflow.Modflow()
>>> rch = flopy.modflow.ModflowRch(m, nrchop=3, rech=rech)
```

check(*f=None*, *verbose=True*, *level=1*, *RTmin=2e-08*, *RTmax=0.0002*, *checktype=None*)

Check package data for common errors.

Parameters

- **f** (*str or file handle*) – String defining file name or file handle for summary file of check method output. If a sting is passed a file handle is created. If f is None, check method does not write results to a summary file. (default is None)
- **verbose** (*bool*) – Boolean flag used to determine if check method results are written to the screen
- **level** (*int*) – Check method analysis level. If level=0, summary checks are performed. If level=1, full checks are performed.
- **RTmin** (*float*) – Minimum product of recharge and transmissivity. Default is 2e-8
- **RTmax** (*float*) – Maximum product of recharge and transmissivity. Default is 2e-4

Return type

None

Notes

Unstructured models not checked for extreme recharge transmissivity ratios.

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow.load('model.nam')
>>> m.rch.check()
```

classmethod load(*f*, *model*, *nper=None*, *ext_unit_dict=None*, *check=True*)

Load an existing package.

Parameters

- **f** (*filename or file handle*) – File to load.
- **model** (*model object*) – The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.
- **nper** (*int*) – The number of stress periods. If nper is None, then nper will be obtained from the model object. (default is None).
- **ext_unit_dict** (*dictionary, optional*) – If the arrays in the file are specified using EXTERNAL, or older style array control records, then *f* should be a file handle. In this case ext_unit_dict is required, which can be constructed using the function *flopy.utils.mfreadnam.parsenamefile*.
- **check** (*boolean*) – Check package data for common errors. (default True)

Returns

rch – ModflowRch object.

Return type

ModflowRch object

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow()
>>> rch = flopy.modflow.ModflowRch.load('test.rch', m)
```

write_file(*check=True*, *f=None*)

Write the package file.

Parameters

check (*boolean*) – Check package data for common errors. (default True)

Return type

None

flopy.modflow.mfriv module

mfriv module. Contains the ModflowRiv class. Note that the user can access the ModflowRiv class as *flopy.modflow.ModflowRiv*.

Additional information for this MODFLOW package can be found at the Online MODFLOW Guide.

class ModflowRiv(*model*, *ipakcb=None*, *stress_period_data=None*, *dtype=None*, *extension='riv'*, *options=None*, *unitnumber=None*, *filenames=None*, ***kwargs*)

Bases: *Package*

MODFLOW River Package Class.

Parameters

- **model** (*model object*) – The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.
- **ipakcb** (*int*, *optional*) – Toggles whether cell-by-cell budget data should be saved. If None or zero, budget data will not be saved (default is None).
- **stress_period_data** (*list*, *recarray*, *dataframe*, *or dictionary of boundaries.*) – Each river cell is defined through definition of layer (int), row (int), column (int), stage (float), cond (float), rbot (float). The simplest form is a dictionary with a lists of boundaries for each stress period, where each list of boundaries itself is a list of boundaries. Indices of the dictionary are the numbers of the stress period. This gives the form of:

```
stress_period_data =
{0: [
    [lay, row, col, stage, cond, rbot],
    [lay, row, col, stage, cond, rbot],
    [lay, row, col, stage, cond, rbot]
    ],
1:  [
    [lay, row, col, stage, cond, rbot],
    [lay, row, col, stage, cond, rbot],
    [lay, row, col, stage, cond, rbot]
    ], ...
kper:
    [
    [lay, row, col, stage, cond, rbot],
    [lay, row, col, stage, cond, rbot],
    [lay, row, col, stage, cond, rbot]
    ]
}
```

  Note that if the number of lists is smaller than the number of stress periods, then the last list of rivers will apply until the end of the simulation. Full details of all options to specify stress_period_data can be found in the flopy3 boundaries Notebook in the basic subdirectory of the examples directory.

- **dtype** (*custom datatype of stress_period_data.*) – (default is None) If None the default river datatype will be applied.

- **naux** (*int*) – number of auxiliary variables
- **extension** (*string*) – Filename extension (default is 'riv')
- **options** (*list of strings*) – Package options. (default is None).
- **unitnumber** (*int*) – File unit number (default is None).
- **filenames** (*str or list of str*) – Filenames to use for the package and the output files. If filenames=None the package name will be created using the model name and package extension and the cbc output name will be created using the model name and .cbc extension (for example, modflowtest.cbc), if ipakcb is a number greater than zero. If a single string is passed the package will be set to the string and cbc output names will be created using the model name and .cbc extension, if ipakcb is a number greater than zero. To define the names for all package files (input and output) the length of the list of strings should be 2. Default is None.

mxactr

Maximum number of river cells for a stress period. This is calculated automatically by FloPy based on the information in layer_row_column_data.

Type
int

Notes

Parameters are not supported in FloPy.

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow()
>>> lrcd = {}
>>> lrcd[0] = [[2, 3, 4, 15.6, 1050., -4]]  #this river boundary will be
>>>                                         #applied to all stress periods
>>> riv = flopy.modflow.ModflowRiv(m, stress_period_data=lrcd)
```

add_record(*kper*, *index*, *values*)

check(*f=None*, *verbose=True*, *level=1*, *checktype=None*)

Check package data for common errors.

Parameters

- **f** (*str or file handle*) – String defining file name or file handle for summary file of check method output. If a string is passed a file handle is created. If f is None, check method does not write results to a summary file. (default is None)
- **verbose** (*bool*) – Boolean flag used to determine if check method results are written to the screen.

- **level** (*int*) – Check method analysis level. If level=0, summary checks are performed. If level=1, full checks are performed.

Return type
None

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow.load('model.nam')
>>> m.riv.check()
```

static get_default_dtype(*structured=True*)

static get_empty(*ncells=0, aux_names=None, structured=True*)

classmethod load(*f, model, nper=None, ext_unit_dict=None, check=True*)

Load an existing package.

Parameters

- **f** (*filename or file handle*) – File to load.
- **model** (*model object*) – The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.
- **nper** (*int*) – The number of stress periods. If nper is None, then nper will be obtained from the model object. (default is None).
- **ext_unit_dict** (*dictionary, optional*) – If the arrays in the file are specified using EXTERNAL, or older style array control records, then *f* should be a file handle. In this case ext_unit_dict is required, which can be constructed using the function *flopy.utils.mfreadnam.parsenamefile*.
- **check** (*boolean*) – Check package data for common errors. (default True)

Returns
rch – ModflowRiv object.

Return type
ModflowRiv object

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow()
>>> riv = flopy.modflow.ModflowRiv.load('test.riv', m)
```

write_file(*check=True*)

Write the package file.

Parameters
check (*boolean*) – Check package data for common errors. (default True)

Return type
None

flopy.modflow.mfsfr2 module

class ModflowSfr2(*model*, *nstrm=-2*, *nss=1*, *nsfrpar=0*, *nparseg=0*, *const=None*, *dleak=0.0001*, *ipakcb=None*, *istcb2=None*, *isfropt=0*, *nstrail=10*, *isuzn=1*, *nsfrsets=30*, *irtflg=0*, *numtim=2*, *weight=0.75*, *flwtol=0.0001*, *reach_data=None*, *segment_data=None*, *channel_geometry_data=None*, *channel_flow_data=None*, *dataset_5=None*, *irdflag=0*, *iptflag=0*, *reachinput=False*, *transroute=False*, *tabfiles=False*, *tabfiles_dict=None*, *extension='sfr'*, *unit_number=None*, *filenames=None*, *options=None*)

Bases: *Package*

Streamflow-Routing (SFR2) Package Class

Parameters

- **model** (*model object*) – The model object (of type :class:'flopy.modflow.mf.Modflow') to which this package will be added.
- **nstrm** (*integer*) – An integer value that can be specified to be positive or negative. The absolute value of NSTRM is equal to the number of stream reaches (finite-difference cells) that are active during the simulation and the number of lines of data to be included in Item 2, described below. When NSTRM is specified to be a negative integer, it is also used as a flag for changing the format of the data input, for simulating unsaturated flow beneath streams, and (or) for simulating transient streamflow routing (for MODFLOW-2005 simulations only), depending on the values specified for variables ISFROPT and IRTFLG, as described below. When NSTRM is negative, NSFRPAR must be set to zero, which means that parameters cannot be specified. By default, nstrm is set to negative.
- **nss** (*integer*) – An integer value equal to the number of stream segments (consisting of one or more reaches) that are used to define the complete stream network. The value of NSS represents the number of segments that must be defined through a combination of parameters and variables in Item 4 or variables in Item 6.
- **nparseg** (*integer*) – An integer value equal to (or exceeding) the number of stream-segment definitions associated with all parameters. This number can be more than the total number of segments (NSS) in the stream network because the same segment can be defined in multiple parameters, and because parameters can be time-varying. NPARSEG must equal or exceed the sum of NLST x N for all parameters, where N is the greater of 1 and NUMINST; that is, NPARSEG must equal or exceed the total number of repetitions of item 4b. This variable must be zero when NSTRM is negative.

- **const** (*float*) - A real value (or conversion factor) used in calculating stream depth for stream reach. If stream depth is not calculated using Manning's equation for any stream segment (that is, ICALC does not equal 1 or 2), then a value of zero can be entered. If Manning's equation is used, a constant of 1.486 is used for flow units of cubic feet per second, and a constant of 1.0 is used for units of cubic meters per second. The constant must be multiplied by 86,400 when using time units of days in the simulation. An explanation of time units used in MODFLOW is given by Harbaugh and others (2000, p. 10).
- **dleak** (*float*) - A real value equal to the tolerance level of stream depth used in computing leakage between each stream reach and active model cell. Value is in units of length. Usually a value of 0.0001 is sufficient when units of feet or meters are used in model.
- **ipakcb** (*int, optional*) - Toggles whether cell-by-cell budget data should be saved. If None or zero, budget data will not be saved (default is None).
- **istcb2** (*integer*) - An integer value used as a flag for writing to a separate formatted file all information on inflows and outflows from each reach; on stream depth, width, and streambed conductance; and on head difference and gradient across the streambed. If ISTCB2 > 0, then ISTCB2 also represents the unit number to which all information for each stream reach will be saved to a separate file when a cell-by-cell budget has been specified in Output Control. If ISTCB2 < 0, it is the unit number to which unformatted streamflow out of each reach will be saved to a file whenever the cell-by-cell budget has been specified in Output Control. Unformatted output will be saved to <model name>.sfq.
- **isfropt** (*integer*) - An integer value that defines the format of the input data and whether or not unsaturated flow is simulated beneath streams. Values of ISFROPT are defined as follows

  0 No vertical unsaturated flow beneath streams. Streambed elevations,
  stream slope, streambed thickness, and streambed hydraulic conductivity are read for each stress period using variables defined in Items 6b and 6c; the optional variables in Item 2 are not used.

  1 No vertical unsaturated flow beneath streams. Streambed elevation,
  stream slope, streambed thickness, and streambed hydraulic conductivity are read for each reach only once at the beginning of the simulation using optional variables defined in Item 2; Items 6b and 6c are used to define stream width and depth for ICALC = 0 and stream width for ICALC = 1.

  2 Streambed and unsaturated-zone properties are read for each reach
  only once at the beginning of the simulation using optional variables defined in Item 2; Items 6b and 6c are used to define stream width and depth for ICALC = 0 and stream width for ICALC = 1. When using the LPF Package, saturated vertical hydraulic conductivity for the unsaturated zone is the same as

the vertical hydraulic conductivity of the corresponding layer in LPF and input variable UHC is not read.

3 Same as 2 except saturated vertical hydraulic conductivity for the
unsaturated zone (input variable UHC) is read for each reach.

4 Streambed and unsaturated-zone properties are read for the
beginning and end of each stream segment using variables defined in Items 6b and 6c; the optional variables in Item 2 are not used. Streambed properties can vary each stress period. When using the LPF Package, saturated vertical hydraulic conductivity for the unsaturated zone is the same as the vertical hydraulic conductivity of the corresponding layer in LPF and input variable UHC1 is not read.

5 Same as 4 except saturated vertical hydraulic conductivity for the
unsaturated zone (input variable UHC1) is read for each segment at the beginning of the first stress period only.

- **nstrail** (*integer*) - An integer value that is the number of trailing wave increments used to represent a trailing wave. Trailing waves are used to represent a decrease in the surface infiltration rate. The value can be increased to improve mass balance in the unsaturated zone. Values between 10 and 20 work well and result in unsaturated-zone mass balance errors beneath streams ranging between 0.001 and 0.01 percent. Please see Smith (1983) for further details. (default is 10; for MODFLOW-2005 simulations only when isfropt > 1)
- **isuzn** (*integer*) - An integer value that is the maximum number of vertical cells used to define the unsaturated zone beneath a stream reach. If ICALC is 1 for all segments then ISUZN should be set to 1. (default is 1; for MODFLOW-2005 simulations only when isfropt > 1)
- **nsfrsets** (*integer*) - An integer value that is the maximum number of different sets of trailing waves used to allocate arrays. Arrays are allocated by multiplying NSTRAIL by NSFRSETS. A value of 30 is sufficient for problems where the stream depth varies often. NSFRSETS does not affect model run time. (default is 30; for MODFLOW-2005 simulations only when isfropt > 1)
- **irtflg** (*integer*) - An integer value that indicates whether transient streamflow routing is active. IRTFLG must be specified if NSTRM < 0. If IRTFLG > 0, streamflow will be routed using the kinematic-wave equation (see USGS Techniques and Methods 6-D1, p. 68-69); otherwise, IRTFLG should be specified as 0. Transient streamflow routing is only available for MODFLOW-2005; IRTFLG can be left blank for MODFLOW-2000 simulations. (default is 1)
- **numtim** (*integer*) - An integer value equal to the number of sub time steps used to route streamflow. The time step that will be used to route streamflow will be equal to the MODFLOW time step divided by NUMTIM. (default is 2; for MODFLOW-2005 simulations only when irtflg > 0)
- **weight** (*float*) - A real number equal to the time weighting factor used to calculate the change in channel storage. WEIGHT has a

value between 0.5 and 1. Please refer to equation 83 in USGS Techniques and Methods 6-D1 for further details. (default is 0.75; for MODFLOW-2005 simulations only when irtflg > 0)

- **flwtol** (*float*) - A real number equal to the streamflow tolerance for convergence of the kinematic wave equation used for transient streamflow routing. A value of 0.00003 cubic meters per second has been used successfully in test simulations (and would need to be converted to whatever units are being used in the particular simulation). (default is 0.0001; for MODFLOW-2005 simulations only when irtflg > 0)
- **reach_data** (*recarray or dataframe*) - Numpy record array of length equal to nstrm, with columns for each variable entered in item 2 (see SFR package input instructions). In following flopy convention, layer, row, column and node number (for unstructured grids) are zero-based; segment and reach are one-based.
- **segment_data** (*recarray or dataframe*) - Numpy record array of length equal to nss, with columns for each variable entered in items 6a, 6b and 6c (see SFR package input instructions). Segment numbers are one-based.
- **channel_geometry_data** (*dict of dicts containing lists*) - Optional. Outer dictionary keyed by stress period (0-based); inner dictionaries keyed by segment number (1-based), for which 8-point channel cross section geometries are desired. Inner dict values are lists of shape (2,8) - with the first dimension referring to two lists: one of 8 XCPT values, and the other of 8 ZCPT values. Example structure: {kper: {segment: [[xcpt1...xcpt8],[zcpt1...zcpt8]]}}. Note that for these to be applied, the user must also specify an icalc value of 2 for each corresponding segment in segment_data for the relevant stress periods.
- **dataset_5** (*dict of lists*) - Optional; will be built automatically from segment_data unless specified. Dict of lists, with key for each stress period. Each list contains the variables [itmp, irdflag, iptflag]. (see SFR documentation for more details):
- **itmp** (*list of integers (len = NPER)*) - For each stress period, an integer value for reusing or reading stream segment data that can change each stress period. If ITMP = 0 then all stream segment data are defined by Item 4 (NSFRPAR > 0; number of stream parameters is greater than 0). If ITMP > 0, then stream segment data are not defined in Item 4 and must be defined in Item 6 below for a number of segments equal to the value of ITMP. If ITMP < 0, then stream segment data not defined in Item 4 will be reused from the last stress period (Item 6 is not read for the current stress period). ITMP must be defined >= 0 for the first stress period of a simulation.
- **irdflag** (*int or list of integers (len = NPER)*) - For each stress period, an integer value for printing input data specified for this stress period. If IRDFLG = 0, input data for this stress period will be printed. If IRDFLG > 0, then input data for this stress period will not be printed.

- **iptflag** (*int or list of integers (len = NPER)*) - For each stress period, an integer value for printing streamflow- routing results during this stress period. If IPTFLG = 0, or whenever the variable ICBCFL or "Save Budget" is specified in Output Control, the results for specified time steps during this stress period will be printed. If IPTFLG > 0, then the results during this stress period will not be printed.
- **extension** (*string*) - Filename extension (default is 'sfr')
- **unit_number** (*int*) - File unit number (default is None).
- **filenames** (*str or list of str*) - Filenames to use for the package and the output files. If filenames=None the package name will be created using the model name and package extension and the cbc output and sfr output name will be created using the model name and .cbc the .sfr.bin/.sfr.out extensions (for example, modflowtest.cbc, and modflowtest.sfr.bin), if ipakcb and istcb2 are numbers greater than zero. If a single string is passed the package name will be set to the string and other uzf output files will be set to the model name with the appropriate output file extensions. To define the names for all package files (input and output) the length of the list of strings should be 3. Default is None.

outlets

Contains the outlet for each SFR segment; format is {per: {segment: outlet}} This attribute is created by the get_outlets() method.

Type
nested dictionary

outsegs

Each array is of shape nss rows x maximum of nss columns. The first column contains the SFR segments, the second column contains the outsegs of those segments; the third column the outsegs of the outsegs, and so on, until all outlets have been encountered, or nss is reached. The latter case indicates circular routing. This attribute is created by the get_outlets() method.

Type
dictionary of arrays

Notes

Parameters are not supported in FloPy.

MODFLOW-OWHM is not supported.

The Ground-Water Transport (GWT) process is not supported.

Limitations on which features are supported...

Examples

```
>>> import flopy
>>> ml = flopy.modflow.Modflow()
>>> sfr2 = flopy.modflow.ModflowSfr2(ml, ...)
```

assign_layers(*adjust_botms=False*, *pad=1.0*)

Assigns the appropriate layer for each SFR reach, based on cell bottoms at location of reach.

Parameters

- **adjust_botms** (*bool*) – Streambed bottom elevations below the model bottom will cause an error in MODFLOW. If True, adjust bottom elevations in lowest layer of the model so they are at least pad distance below any co-located streambed elevations.
- **pad** (*scalar*) – Minimum distance below streambed bottom to set any conflicting model bottom elevations.

Notes

Streambed bottom = strtop - strthick This routine updates the elevations in the botm array of the flopy.model.ModflowDis instance. To produce a new DIS package file, model.write() or flopy.model.ModflowDis.write() must be run.

check(*f=None*, *verbose=True*, *level=1*, *checktype=None*)

Check sfr2 package data for common errors.

Parameters

- **f** (*str or file handle*) – String defining file name or file handle for summary file of check method output. If a string is passed a file handle is created. If f is None, check method does not write results to a summary file. (default is None)
- **verbose** (*bool*) – Boolean flag used to determine if check method results are written to the screen
- **level** (*int*) – Check method analysis level. If level=0, summary checks are performed. If level=1, full checks are performed.

Return type

None

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow.load('model.nam')
>>> m.sfr2.check()
```

property const

property dataset_5

auto-update itmp so it is consistent with segment_data.

deactivate_ibound_above()

Sets ibound to 0 for all cells above active SFR cells.

Parameters
none –

Notes

This routine updates the ibound array of the flopy.model.ModflowBas6 instance. To produce a new BAS6 package file, model.write() or flopy.model.ModflowBas6.write() must be run.

default_value = 0.0

property df

export(*f*, ***kwargs*)

Method to export a package to netcdf or shapefile based on the extension of the file name (.shp for shapefile, .nc for netcdf)

Parameters

- **f** (*str*) – filename
- **kwargs** (*keyword arguments*) –

modelgrid
[flopy.discretization.Grid instance] user supplied modelgrid which can be used for exporting in lieu of the modelgrid associated with the model object

Return type
None or Netcdf object

export_linkages(*f*, ***kwargs*)

Export linework shapefile showing all routing connections between SFR reaches. A length field containing the distance between connected reaches can be used to filter for the longest connections in a GIS.

export_outlets(*f*, ***kwargs*)

Export point shapefile showing locations where streamflow is leaving the model (outset=0).

export_transient_variable(*f*, *varname*, ***kwargs*)

Export point shapefile showing locations with a given segment_data variable applied. For example, segments where streamflow is entering or leaving the upstream end of a stream segment (FLOW) or where RUNOFF is applied. Cell centroids of the first reach of segments with non-zero terms of varname are exported; values of varname are exported by stress period in the attribute fields (e.g. flow0, flow1, flow2... for FLOW in stress periods 0, 1, 2...

Parameters

- **f** (*str, filename*) –
- **varname** (*str*) – Variable in SFR Package dataset 6a (see SFR package documentation)

static get_default_reach_dtype(*structured=True*)

static get_default_segment_dtype()

static get_empty_reach_data(*nreaches=0, aux_names=None, structured=True, default_value=0.0*)

static get_empty_segment_data(*nsegments=0, aux_names=None, default_value=0.0*)

get_outlets(*level=0, verbose=True*)

Traces all routing connections from each headwater to the outlet.

get_slopes(*default_slope=0.001, minimum_slope=0.0001, maximum_slope=1.0*)

Compute slopes by reach using values in strtop (streambed top) and rchlen (reach length) columns of reach_data. The slope for a reach n is computed as strtop(n+1) - strtop(n) / rchlen(n). Slopes for outlet reaches are set equal to a default value (default_slope). Populates the slope column in reach_data.

Parameters

- **default_slope** (*float*) – Slope value applied to outlet reaches (where water leaves the model). Default value is 0.001
- **minimum_slope** (*float*) – Assigned to reaches with computed slopes less than this value. This ensures that the Manning's equation won't produce unreasonable values of stage (in other words, that stage is consistent with assumption that streamflow is primarily drive by the streambed gradient). Default value is 0.0001.
- **maximum_slope** (*float*) – Assigned to reaches with computed slopes more than this value. Default value is 1.

get_upsegs()

From segment_data, returns nested dict of all upstream segments by segment, by stress period.

Returns

all_upsegs – Nested dictionary of form {stress period: {segment: [list of upsegs]}}

Return type

dict

Notes

This method will not work if there are instances of circular routing.

get_variable_by_stress_period(*varname*)

property graph

Dictionary of routing connections between segments.

len_const = {1: 1.486, 2: 1.0, 3: 100.0}

classmethod load(*f*, *model*, *nper=None*, *gwt=False*, *nsol=1*, *ext_unit_dict=None*)

Default load method for standard boundary packages.

property nper

nsfrpar = 0

property nss

property nstrm

property paths

plot_path(*start_seg=None*, *end_seg=0*, *plot_segment_lines=True*)

Plot a profile of streambed elevation and model top along a path of segments.

Parameters

- **start_seg** (*int*) – Number of first segment in path.
- **end_seg** (*int*) – Number of last segment in path (defaults to 0/outlet).
- **plot_segment_lines** (*bool*) – Controls plotting of segment end locations along profile. (default True)

Returns

ax

Return type

matplotlib.axes._subplots.AxesSubplot object

renumber_segments()

Renumber segments so that segment numbering is continuous and always increases in the downstream direction. This may speed convergence of the NWT solver in some situations.

Returns

r

Return type

dictionary mapping old segment numbers to new

repair_outsegs()

reset_reaches()

set_outreaches()

Determine the outreach for each SFR reach (requires a reachID column in reach_data). Uses the segment routing specified for the first stress period to route reaches between segments.

time_const = {1: 1.0, 2: 60.0, 3: 3600.0, 4: 86400.0, 5: 31557600.0}

write_file(*filename=None*)

Write the package file.

Return type
None

class **check**(*sfrpackage*, *verbose=True*, *level=1*)

Bases: object

Check SFR2 package for common errors

Parameters

- **sfrpackage** (*object*) - Instance of Flopy ModflowSfr2 class.
- **verbose** (*bool*) - Boolean flag used to determine if check method results are written to the screen
- **level** (*int*) - Check method analysis level. If level=0, summary checks are performed. If level=1, full checks are performed.

Notes

Daniel Feinstein's top 10 SFR problems (7/16/2014): 1) cell gaps btw adjacent reaches in a single segment 2) cell gaps btw routed segments. possibly because of re-entry problems at domain edge 3) adjacent reaches with STOP sloping the wrong way 4) routed segments with end/start sloping the wrong way 5) STOP>TOP1 violations, i.e.,floaters 6) STOP<<TOP1 violations, i.e., exaggerated incisions 7) segments that end within one diagonal cell distance from another segment, inviting linkage 8) circular routing of segments 9) multiple reaches with non-zero conductance in a single cell 10) reaches in inactive cells

Also after running the model they will want to check for backwater effects.

elevations(*min_strtop=-10*, *max_strtop=15000*)

Checks streambed elevations for downstream rises and inconsistencies with model grid

for_nans()

Check for nans in reach or segment data

numbering()

Checks for continuity in segment and reach numbering

overlapping_conductance(*tol=1e-06*)

Checks for multiple SFR reaches in one cell; and whether more than one reach has Cond > 0

routing()

Checks for breaks in routing and does comprehensive check for circular routing

run_all()

slope(*minimum_slope=0.0001*, *maximum_slope=1.0*)

Checks that streambed slopes are greater than or equal to a specified minimum value. Low slope values can cause "backup" or unrealistic stream stages with icalc options where stage is computed.

find_path(*graph*, *start*, *end=0*)

Get a path through the routing network, from a segment to an outlet.

Parameters

- **graph** (*dict*) – Dictionary of seg : outseg numbers
- **start** (*int*) – Starting segment
- **end** (*int*) – Ending segment (default 0)

Returns

path – List of segment numbers along routing path.

Return type

list

flopy.modflow.mfsip module

mfsip module. Contains the ModflowSip class. Note that the user can access the ModflowSip class as *flopy.modflow.ModflowSip*.

Additional information for this MODFLOW package can be found at the Online MODFLOW Guide.

class ModflowSip(*model*, *mxiter=200*, *nparm=5*, *accl=1*, *hclose=1e-05*, *ipcalc=1*, *wseed=0*, *iprsip=0*, *extension='sip'*, *unitnumber=None*, *filenames=None*)

Bases: *Package*

MODFLOW Strongly Implicit Procedure Package Class.

Parameters

- **model** (*model object*) – The model object (of type :class:flopy.modflow.mf.Modflow) to which this package will be added.
- **mxiter** (*integer*) – The maximum number of times through the iteration loop in one time step in an attempt to solve the system of finite-difference equations. (default is 200)
- **nparm** (*integer*) – The number of iteration variables to be used. Five variables are generally sufficient. (default is 5)
- **accl** (*float*) – The acceleration variable, which must be greater than zero and is generally equal to one. If a zero is entered, it is changed to one. (default is 1)
- **hclose** (*float > 0*) – The head change criterion for convergence. When the maximum absolute value of head change from all nodes during an iteration is less than or equal to hclose, iteration stops. (default is 1e-5)
- **ipcalc** (*0 or 1*) – A flag indicating where the seed for calculating iteration variables will come from. 0 is the seed entered by the user will be used. 1 is the seed will be calculated at the start of the simulation from problem variables. (default is 0)
- **wseed** (*float > 0*) – The seed for calculating iteration variables. wseed is always read, but is used only if ipcalc is equal to zero. (default is 0)

- **iprsip** (*integer > 0*) – the printout interval for sip. iprsip, if equal to zero, is changed to 999. The maximum head change (positive or negative) is printed for each iteration of a time step whenever the time step is an even multiple of iprsip. This printout also occurs at the end of each stress period regardless of the value of iprsip. (default is 0)
- **extension** (*string*) – Filename extension (default is 'sip')
- **unitnumber** (*int*) – File unit number (default is None).
- **filenames** (*str or list of str*) – Filenames to use for the package. If filenames=None the package name will be created using the model name and package extension. If a single string is passed the package will be set to the string. Default is None.

Notes

Examples

```
>>> import flopy
>>> ml = flopy.modflow.Modflow()
>>> sip = flopy.modflow.ModflowSip(ml, mxiter=100, hclose=0.0001)
```

classmethod load(*f*, *model*, *ext_unit_dict=None*)

Load an existing package.

Parameters

- **f** (*filename or file handle*) – File to load.
- **model** (*model object*) – The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.
- **ext_unit_dict** (*dictionary, optional*) – If the arrays in the file are specified using EXTERNAL, or older style array control records, then *f* should be a file handle. In this case ext_unit_dict is required, which can be constructed using the function *flopy.utils.mfreadnam.parsenamefile*.

Returns

sip

Return type

ModflowSip object

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow()
>>> sip = flopy.modflow.ModflowSip.load('test.sip', m)
```

write_file()

Write the package file.

Return type

None

flopy.modflow.mfsor module

mfsor module. Contains the ModflowSor class. Note that the user can access the ModflowSor class as *flopy.modflow.ModflowSor*.

Additional information for this MODFLOW package can be found at the Online MODFLOW Guide.

class ModflowSor(*model*, *mxiter=200*, *accl=1*, *hclose=1e-05*, *iprsor=0*, *extension='sor'*, *unitnumber=None*, *filenames=None*)

Bases: *Package*

MODFLOW Slice-successive overrelaxation Package Class.

Parameters

- **model** (*model object*) – The model object (of type :class:flopy.modflow.mf.Modflow) to which this package will be added.
- **mxiter** (*integer*) – The maximum number of iterations allowed in a time step. (default is 200)
- **accl** (*float*) – The acceleration variable, which must be greater than zero and is generally between 1. and 2. (default is 1)
- **hclose** (*float > 0*) – The head change criterion for convergence. When the maximum absolute value of head change from all nodes during an iteration is less than or equal to hclose, iteration stops. (default is 1e-5)
- **iprsor** (*integer > 0*) – the printout interval for sor. iprsor, if equal to zero, is changed to 999. The maximum head change (positive or negative) is printed for each iteration of a time step whenever the time step is an even multiple of iprsor. This printout also occurs at the end of each stress period regardless of the value of iprsor. (default is 0)
- **extension** (*string*) – Filename extension (default is 'sor')
- **unitnumber** (*int*) – File unit number (default is None).
- **filenames** (*str or list of str*) – Filenames to use for the package. If filenames=None the package name will be created using the model name and package extension. If a single string is passed the package will be set to the string. Default is None.

Notes

Examples

```
>>> import flopy
>>> ml = flopy.modflow.Modflow()
>>> sor = flopy.modflow.ModflowSor(ml)
```

classmethod load(*f*, *model*, *ext_unit_dict=None*)

Load an existing package.

Parameters

- **f** (*filename or file handle*) – File to load.
- **model** (*model object*) – The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.
- **ext_unit_dict** (*dictionary, optional*) – If the arrays in the file are specified using EXTERNAL, or older style array control records, then *f* should be a file handle. In this case ext_unit_dict is required, which can be constructed using the function *flopy.utils.mfreadnam.parsenamefile*.

Returns
sor

Return type
ModflowSor object

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow()
>>> sor = flopy.modflow.ModflowSor.load('test.sor', m)
```

write_file()

Write the package file.

Return type
None

flopy.modflow.mfstr module

mfstr module. Contains the ModflowStr class. Note that the user can access the ModflowStr class as *flopy.modflow.ModflowStr*.

Additional information for this MODFLOW package can be found at the Online MODFLOW Guide.

class ModflowStr(*model*, *mxacts=0*, *nss=0*, *ntrib=0*, *ndiv=0*, *icalc=0*, *const=86400.0*, *ipakcb=None*, *istcb2=None*, *dtype=None*, *stress_period_data=None*, *segment_data=None*, *irdflg=None*, *iptflg=None*, *extension='str'*, *unitnumber=None*, *filenames=None*, *options=None*, ***kwargs*)

Bases: *Package*

MODFLOW Stream Package Class.

Parameters

- **model** (*model object*) – The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.
- **mxacts** (*int*) – Maximum number of stream reaches that will be in use during any stress period. (default is 0)
- **nss** (*int*) – Number of stream segments. (default is 0)
- **ntrib** (*int*) – The number of stream tributaries that can connect to one segment. The program is currently dimensioned so that NTRIB cannot exceed 10. (default is 0)

- **ndiv** (*int*) - A flag, which when positive, specifies that diversions from segments are to be simulated. (default is 0)
- **icalc** (*int*) - A flag, which when positive, specifies that stream stages in reaches are to be calculated. (default is 0)
- **const** (*float*) - Constant value used in calculating stream stage in reaches whenever ICALC is greater than 0. This constant is 1.486 for flow units of cubic feet per second and 1.0 for units of cubic meters per second. The constant must be multiplied by 86,400 when using time units of days in the simulation. If ICALC is 0, const can be any real value. (default is 86400.)
- **ipakcb** (*int, optional*) - Toggles whether cell-by-cell budget data should be saved. If None or zero, budget data will not be saved (default is None).
- **istcb2** (*int*) - A flag that is used flag and a unit number for the option to store streamflow out of each reach in an unformatted (binary) file. If istcb2 is greater than zero streamflow data will be saved. (default is None).
- **dtype** (*tuple, list, or numpy array of numpy dtypes*) - is a tuple, list, or numpy array containing the dtype for datasets 6 and 8 and the dtype for datasets 9 and 10 data in stress_period_data and segment_data dictionaries. (default is None)
- **irdflg** (*integer or dictionary*) - is a integer or dictionary containing a integer flag, when positive suppresses printing of the stream input data for a stress period. If an integer is passed, all stress periods will use the same value. If a dictionary is passed, stress periods not in the dictionary will assigned a value of 1. Default is None which will assign a value of 1 to all stress periods.
- **iptflg** (*integer or dictionary*) - is a integer or dictionary containing a integer flag, when positive suppresses printing of stream results for a stress period. If an integer is passed, all stress periods will use the same value. If a dictionary is passed, stress periods not in the dictionary will assigned a value of 1. Default is None which will assign a value of 1 to all stress periods.
- **stress_period_data** (*dictionary of reach data*) - Each dictionary contains a list of str reach data for a stress period.

  Each stress period in the dictionary data contains data for datasets 6 and 8.

  The value for stress period data for a stress period can be an integer (-1 or 0), a list of lists, a numpy array or recarray, or a pandas dataframe. If data for a stress period contains an integer, a -1 denotes data from the previous stress period will be reused and a 0 indicates there are no str reaches for this stress period.

  Otherwise stress period data for a stress period should contain mxacts or fewer rows of data containing data for each reach. Reach data are specified through definition of layer (int), row (int), column (int), segment number (int), sequential reach number (int), flow entering a segment (float), stream stage (float), streambed hydraulic conductance (float), streambed bottom elevation (float), streambed top elevation (float), stream width (float), stream slope (float), roughness coefficient (float), and auxiliary variable data for auxiliary variables defined in options (float).

If icalc=0 is specified, stream width, stream slope, and roughness coefficients, are not used and can be any value for each stress period. If data are specified for dataset 6 for a given stress period and icalc>0, then stream width, stream slope, and roughness coefficients should be appropriately set.

The simplest form is a dictionary with a lists of boundaries for each stress period, where each list of boundaries itself is a list of boundaries. Indices of the dictionary are the numbers of the stress period. For example, if mxacts=3 this gives the form of:

```
stress_period_data =
{0: [
    [lay, row, col, seg, reach, flow, stage, cond, sbot, stop,␣
↪width, slope, rough],
    [lay, row, col, seg, reach, flow, stage, cond, sbot, stop,␣
↪width, slope, rough],
    [lay, row, col, seg, reach, flow, stage, cond, sbot, stop,␣
↪width, slope, rough]]
    ],
1:  [
    [lay, row, col, seg, reach, flow, stage, cond, sbot, stop,␣
↪width, slope, rough],
    [lay, row, col, seg, reach, flow, stage, cond, sbot, stop,␣
↪width, slope, rough],
    [lay, row, col, seg, reach, flow, stage, cond, sbot, stop,␣
↪width, slope, rough]]
    ], ...
kper:
    [
    [lay, row, col, seg, reach, flow, stage, cond, sbot, stop,␣
↪width, slope, rough],
    [lay, row, col, seg, reach, flow, stage, cond, sbot, stop,␣
↪width, slope, rough],
    [lay, row, col, seg, reach, flow, stage, cond, sbot, stop,␣
↪width, slope, rough]]
    ]
}
```

- **segment_data** (*dictionary of str segment data*) – Each dictionary contains a list of segment str data for a stress period.

  Each stress period in the dictionary data contains data for datasets 9, and 10. Segment data for a stress period are ignored if a integer value is specified for stress period data.

  The value for segment data for a stress period can be an integer (-1 or 0), a list of lists, a numpy array, or a numpy recarray.

If segment data for a stress period contains an integer, a -1 denotes data from the previous stress period will be reused and a 0 indicates there are no str segments for this stress period.

Otherwise stress period data for a stress period should contain nss rows of data containing data for each segment. Segment data are specified through definition of itrib (int) data for up to 10 tributaries and iupseg (int) data.

If ntrib=0 is specified, itrib values are not used and can be any value for each stress period. If data are specified for dataset 6 for a given stress period and ntrib>0, then itrib data should be specified for columns 0:ntrib.

If ndiv=0 is specified, iupseg values are not used and can be any value for each stress period. If data are specified for dataset 6 for a given stress period and ndiv>0, then iupseg data should be specified for the column in the dataset [10].

The simplest form is a dictionary with a lists of boundaries for each stress period, where each list of boundaries itself is a list of boundaries. Indices of the dictionary are the numbers of the stress period. For example, if nss=2 and ntrib>0 and/or ndiv>0 this gives the form of:

```
segment_data =
{0: [
    [itrib1, itrib2, itrib3, itrib4, itrib5, itrib6, itrib7,␣
↪itrib8, itrib9, itrib10, iupseg],
    [itrib1, itrib2, itrib3, itrib4, itrib5, itrib6, itrib7,␣
↪itrib8, itrib9, itrib10, iupseg],
    ],
1:  [
    [itrib1, itrib2, itrib3, itrib4, itrib5, itrib6, itrib7,␣
↪itrib8, itrib9, itrib10, iupseg],
    [itrib1, itrib2, itrib3, itrib4, itrib5, itrib6, itrib7,␣
↪itrib8, itrib9, itrib10, iupseg],
    ], ...
kper:
    [
    [itrib1, itrib2, itrib3, itrib4, itrib5, itrib6, itrib7,␣
↪itrib8, itrib9, itrib10, iupseg],
    [itrib1, itrib2, itrib3, itrib4, itrib5, itrib6, itrib7,␣
↪itrib8, itrib9, itrib10, iupseg],
    ]
}
```

- **options** (*list of strings*) – Package options. Auxiliary variables included as options should be constructed as options=['AUXILIARY IFACE', 'AUX xyx']. Either 'AUXILIARY' or 'AUX' can be specified (case insensitive). (default is None).
- **extension** (*string*) – Filename extension (default is 'str')
- **unitnumber** (*int*) – File unit number (default is None).
- **filenames** (*str or list of str*) – Filenames to use for the package and the output files. If filenames=None the package

name will be created using the model name and package extension and the cbc output and str output name will be created using the model name and .cbc the .sfr.bin/.sfr.out extensions (for example, modflowtest.cbc, and modflowtest.str.bin), if ipakcb and istcb2 are numbers greater than zero. If a single string is passed the package will be set to the string and cbc and sf routput names will be created using the model name and .cbc and .str.bin/.str.out extensions, if ipakcb and istcb2 are numbers greater than zero. To define the names for all package files (input and output) the length of the list of strings should be 3. Default is None.

Notes

Parameters are not supported in FloPy.

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow()
>>> strd = {}
>>> strd[0] = [[2, 3, 4, 15.6, 1050., -4]]  #this str boundary will be
>>>                                         #applied to all stress periods
>>> str = flopy.modflow.ModflowStr(m, stress_period_data=strd)
```

static get_default_dtype(*structured=True*)

static get_empty(*ncells=0*, *nss=0*, *aux_names=None*, *structured=True*)

classmethod load(*f*, *model*, *nper=None*, *ext_unit_dict=None*)

Load an existing package.

Parameters

- **f** (*filename or file handle*) – File to load.
- **model** (*model object*) – The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.
- **nper** (*int*) – The number of stress periods. If nper is None, then nper will be obtained from the model object. (default is None).
- **ext_unit_dict** (*dictionary, optional*) – If the arrays in the file are specified using EXTERNAL, or older style array control records, then *f* should be a file handle. In this case ext_unit_dict is required, which can be constructed using the function *flopy.utils.mfreadnam.parsenamefile*.

Returns

str – ModflowStr object.

Return type

ModflowStr object

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow()
>>> strm = flopy.modflow.ModflowStr.load('test.str', m)
```

write_file()

Write the package file.

Return type
None

flopy.modflow.mfsub module

mfsub module. Contains the ModflowSub class. Note that the user can access the ModflowSub class as *flopy.modflow.ModflowSub*.

Additional information for this MODFLOW package can be found at the Online MODFLOW Guide.

class ModflowSub(*model*, *ipakcb=None*, *isuboc=0*, *idsave=None*, *idrest=None*, *idbit=None*, *nndb=1*, *ndb=1*, *nmz=1*, *nn=20*, *ac1=0.0*, *ac2=1.0*, *itmin=5*, *ln=0*, *ldn=0*, *rnb=1*, *hc=100000.0*, *sfe=0.0001*, *sfv=0.001*, *com=0.0*, *dp=[[1e-06, 6e-06, 0.0006]]*, *dstart=1.0*, *dhc=100000.0*, *dcom=0.0*, *dz=1.0*, *nz=1*, *ids15=None*, *ids16=None*, *extension='sub'*, *unitnumber=None*, *filenames=None*)

Bases: *Package*

MODFLOW SUB Package Class.

Parameters

- **model** (*model object*) – The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.
- **ipakcb** (*int, optional*) – Toggles whether cell-by-cell budget data should be saved. If None or zero, budget data will not be saved (default is None).
- **isuboc** (*int*) – isuboc is a flag used to control output of information generated by the SUB Package. (default is 0).
- **idsave** (*int*) – idsave is a flag and a unit number on which restart records for delay interbeds will be saved at the end of the simulation. (default is 0).
- **idrest** (*int*) – idrest is a flag and a unit number on which restart records for delay interbeds will be read in at the start of the simulation (default is 0).
- **idbit** (*int*) – idrest is an optional flag that defines if iteration will be used for the delay bed solution of heads. If idbit is 0 or less than 0, iteration will not be used (this is is identical to the approach used in MODFLOW-2005 versions less than 1.13. if idbit is greater than 0, iteration of the delay bed solution will continue until convergence is achieved. (default is 0).
- **nndb** (*int*) – nndb is the number of systems of no-delay interbeds. (default is 1).

- **ndb** (*int*) - ndb is the number of systems of delay interbeds. (default is 1).
- **nmz** (*int*) - nmz is the number of material zones that are needed to define the hydraulic properties of systems of delay interbeds. Each material zone is defined by a combination of vertical hydraulic conductivity, elastic specific storage, and inelastic specific storage. (default is 1).
- **nn** (*int*) - nn is the number of nodes used to discretize the half space to approximate the head distributions in systems of delay interbeds. (default is 20).
- **ac1** (*float*) - ac1 is an acceleration parameter. This parameter is used to predict the aquifer head at the interbed boundaries on the basis of the head change computed for the previous iteration. A value of 0.0 results in the use of the aquifer head at the previous iteration. Limited experience indicates that optimum values may range from 0.0 to 0.6. (default is 0).
- **ac2** (*float*) - ac2 is an acceleration parameter. This acceleration parameter is a multiplier for the head changes to compute the head at the new iteration. Values are normally between 1.0 and 2.0, but the optimum is probably closer to 1.0 than to 2.0. However this parameter also can be used to help convergence of the iterative solution by using values between 0 and 1. (default is 1.0).
- **itmin** (*int*) - ITMIN is the minimum number of iterations for which one-dimensional equations will be solved for flow in interbeds when the Strongly Implicit Procedure (SIP) is used to solve the ground-water flow equations. If the current iteration level is greater than ITMIN and the SIP convergence criterion for head closure (HCLOSE) is met at a particular cell, the one-dimensional equations for that cell will not be solved. The previous solution will be used. The value of ITMIN is not used if a solver other than SIP is used to solve the ground-water flow equations. (default is 5).
- **ln** (*int or array of ints (nndb)*) - ln is a one-dimensional array specifying the model layer assignments for each system of no-delay interbeds. (default is 0).
- **ldn** (*int or array of ints (ndb)*) - ldn is a one-dimensional array specifying the model layer assignments for each system of delay interbeds.(default is 0).
- **rnb** (*float or array of floats (ndb, nrow, ncol)*) - rnb is an array specifying the factor nequiv at each cell for each system of delay interbeds. The array also is used to define the areal extent of each system of interbeds. For cells beyond the areal extent of the system of interbeds, enter a number less than 1.0 in the corresponding element of this array. (default is 1).
- **hc** (*float or array of floats (nndb, nrow, ncol)*) - hc is an array specifying the preconsolidation head or preconsolidation stress in terms of head in the aquifer for systems of no-delay interbeds. For any model cells in which specified HC is greater than the

corresponding value of starting head, the value of HC will be set to that of starting head. (default is 100000).

- **sfe** (*float or array of floats (nndb, nrow, ncol)*) - sfe is an array specifying the dimensionless elastic skeletal storage coefficient for systems of no-delay interbeds. (default is 1.e-4).
- **sfv** (*float or array of floats (nndb, nrow, ncol)*) - sfv is an array specifying the dimensionless inelastic skeletal storage coefficient for systems of no-delay interbeds. (default is 1.e-3).
- **com** (*float or array of floats (nndb, nrow, ncol)*) - com is an array specifying the starting compaction in each system of no-delay interbeds. Compaction values computed by the package are added to values in this array so that printed or stored values of compaction and land subsidence may include previous components. Values in this array do not affect calculations of storage changes or resulting compaction. For simulations in which output values are to reflect compaction and subsidence since the start of the simulation, enter zero values for all elements of this array. (default is 0).
- **dp** (*list or array of floats (nmz, 3)*) - Data item includes nmz records, each with a value of vertical hydraulic conductivity, elastic specific storage, and inelastic specific storage. (default is [1.e-6, 6.e-6, 6.e-4]).
- **dstart** (*float or array of floats (ndb, nrow, ncol)*) - dstart is an array specifying starting head in interbeds for systems of delay interbeds. For a particular location in a system of interbeds, the starting head is applied to every node in the string of nodes that approximates flow in half of a doubly draining interbed. (default is 1).
- **dhc** (*float or array of floats (ndb, nrow, ncol)*) - dhc is an array specifying the starting preconsolidation head in interbeds for systems of delay interbeds. For a particular location in a system of interbeds, the starting preconsolidation head is applied to every node in the string of nodes that approximates flow in half of a doubly draining interbed. For any location at which specified starting preconsolidation head is greater than the corresponding value of the starting head, Dstart, the value of the starting preconsolidation head will be set to that of the starting head. (default is 100000).
- **dcom** (*float or array of floats (ndb, nrow, ncol)*) - dcom is an array specifying the starting compaction in each system of delay interbeds. Compaction values computed by the package are added to values in this array so that printed or stored values of compaction and land subsidence may include previous components. Values in this array do not affect calculations of storage changes or resulting compaction. For simulations in which output values are to reflect compaction and subsidence since the start of the simulation, enter zero values for all elements of this array. (default is 0).

- **dz** (*float or array of floats (ndb, nrow, ncol)*) - dz is an array specifying the equivalent thickness for a system of delay interbeds. (default is 1).
- **nz** (*int or array of ints (ndb, nrow, ncol)*) - nz is an array specifying the material zone numbers for systems of delay interbeds. The zone number for each location in the model grid selects the hydraulic conductivity, elastic specific storage, and inelastic specific storage of the interbeds. (default is 1).
- **ids15** (*list or array of ints (12)*) - Format codes and unit numbers for subsidence, compaction by model layer, compaction by interbed system, vertical displacement, no-delay preconsolidation, and delay preconsolidation will be printed. If ids15 is None and isuboc>0 then print code 0 will be used for all data which is output to the binary subsidence output file (unit=1051). The 12 entries in ids15 correspond to ifm1, iun1, ifm2, iun2, ifm3, iun3, ifm4, iun4, ifm5, iun5, ifm6, and iun6 variables. (default is None).
- **ids16** (*list or array of ints (isuboc, 17)*) - Stress period and time step range and print and save flags used to control printing and saving of information generated by the SUB Package during program execution. Each row of ids16 corresponds to isp1, isp2, its1, its2, ifl1, ifl2, ifl3, ifl4, ifl5, ifl6, ifl7, ifl8, ifl9, ifl10, ifl11, ifl12, and ifl13 variables for isuboc entries. isp1, isp2, its1, and its2 are stress period and time step ranges. ifl1 and ifl2 control subsidence printing and saving. ifl3 and ifl4 control compaction by model layer printing and saving. ifl5 and ifl6 control compaction by interbed system printing and saving. ifl7 and ifl8 control vertical displacement printing and saving. ifl9 and ifl10 control critical head for no-delay interbeds printing and saving. ifl11 and ifl12 control critical head for delay interbeds printing and saving. ifl13 controls volumetric budget for delay interbeds printing. If ids16 is None and isuboc>0 then all available subsidence output will be printed and saved to the binary subsidence output file (unit=1051). (default is None).
- **unitnumber** (*int*) - File unit number (default is None).
- **filenames** (*str or list of str*) - Filenames to use for the package and the output files. If filenames=None the package name will be created using the model name and package extension and the cbc output name and other sub output files will be created using the model name and .cbc and swt output extensions (for example, modflowtest.cbc), if ipakcbc and other sub output files (dataset 15) are numbers greater than zero. If a single string is passed the package name will be set to the string and other sub output files will be set to the model name with the appropriate output file extensions. To define the names for all package files (input and output) the length of the list of strings should be 9. Default is None.

Notes

Parameters are supported in Flopy only when reading in existing models. Parameter values are converted to native values in Flopy and the connection to "parameters" is thus nonexistent. Parameters are not supported in the SUB Package.

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow()
>>> sub = flopy.modflow.ModflowSub(m)
```

classmethod load(*f*, *model*, *ext_unit_dict=None*)

Load an existing package.

Parameters

- **f** (*filename or file handle*) – File to load.
- **model** (*model object*) – The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.
- **ext_unit_dict** (*dictionary, optional*) – If the arrays in the file are specified using EXTERNAL, or older style array control records, then *f* should be a file handle. In this case ext_unit_dict is required, which can be constructed using the function *flopy.utils.mfreadnam.parsenamefile*.

Returns

sub

Return type

ModflowSub object

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow()
>>> sub = flopy.modflow.ModflowSub.load('test.sub', m)
```

write_file(*check=False*, *f=None*)

Write the package file.

Return type

None

flopy.modflow.mfswi2 module

mfswi2 module. Contains the ModflowSwi2 class. Note that the user can access the ModflowSwi2 class as *flopy.modflow.ModflowSwi2*.

Additional information for this MODFLOW package can be found at the Online MODFLOW Guide.

class ModflowSwi2(*model*, *nsrf=1*, *istrat=1*, *nobs=0*, *iswizt=None*, *ipakcb=None*, *iswiobs=0*, *options=None*, *nsolver=1*, *iprsol=0*, *mutsol=3*, *solver2params={'damp': 1.0, 'dampt': 1.0, 'iter1': 20, 'mxiter': 100, 'nbpol': 2, 'npcond': 1, 'rclose': 0.0001, 'relax': 1.0, 'zclose': 0.001}*, *toeslope=0.05*, *tipslope=0.05*, *alpha=None*, *beta=0.1*, *nadptmx=1*, *nadptmn=1*, *adptfct=1.0*, *nu=0.025*, *zeta=[0.0]*, *ssz=0.25*, *isource=0*, *obsnam=None*, *obslrc=None*, *npln=None*, *extension='swi2'*, *unitnumber=None*, *filenames=None*)

Bases: *Package*

MODFLOW SWI2 Package Class.

Parameters

- **model** (*model object*) – The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.
- **nsrf** (*int*) – number of active surfaces (interfaces). This equals the number of zones minus one. (default is 1).
- **istrat** (*int*) – flag indicating the density distribution. (default is 1).
- **iswizt** (*int*) – unit number for zeta output. (default is None).
- **ipakcb** (*int, optional*) – Toggles whether cell-by-cell budget data should be saved. If None or zero, budget data will not be saved (default is None).
- **iswiobs** (*int*) – flag and unit number SWI2 observation output. (default is 0).
- **options** (*list of strings*) – Package options. If 'adaptive' is one of the options adaptive SWI2 time steps will be used. (default is None).
- **nsolver** (*int*) – DE4 solver is used if nsolver=1. PCG solver is used if nsolver=2. (default is 1).
- **iprsol** (*int*) – solver print out interval. (default is 0).
- **mutsol** (*int*) – If MUTSOL = 0, tables of maximum head change and residual will be printed each iteration. If MUTSOL = 1, only the total number of iterations will be printed. If MUTSOL = 2, no information will be printed. If MUTSOL = 3, information will only be printed if convergence fails. (default is 3).
- **solver2parameters** (*dict*) – only used if nsolver = 2

  mxiter
  [int] maximum number of outer iterations. (default is 100)

  iter1
  [int] maximum number of inner iterations. (default is 20)

npcond
[int] flag used to select the matrix conditioning method. (default is 1). specify NPCOND = 1 for Modified Incomplete Cholesky. specify NPCOND = 2 for Polynomial.

zclose
[float] is the ZETA change criterion for convergence. (default is 1e-3).

rclose
[float] is the residual criterion for convergence. (default is 1e-4)

relax
[float] is the relaxation parameter used with NPCOND = 1. (default is 1.0)

nbpol
[int] is only used when NPCOND = 2 to indicate whether the estimate of the upper bound on the maximum eigenvalue is 2.0, or whether the estimate will be calculated. NBPOL = 2 is used to specify the value is 2.0; for any other value of NBPOL, the estimate is calculated. Convergence is generally insensitive to this parameter. (default is 2).

damp
[float] is the steady-state damping factor. (default is 1.)

dampt
[float] is the transient damping factor. (default is 1.)

- **toeslope** (*float*) - Maximum slope of toe cells. (default is 0.05)
- **tipslope** (*float*) - Maximum slope of tip cells. (default is 0.05)
- **alpha** (*float*) - fraction of threshold used to move the tip and toe to adjacent empty cells when the slope exceeds user-specified TOESLOPE and TIPSLOPE values. (default is None)
- **beta** (*float*) - Fraction of threshold used to move the toe to adjacent non-empty cells when the surface is below a minimum value defined by the user-specified TOESLOPE value. (default is 0.1).
- **nadptmx** (*int*) - only used if adaptive is True. Maximum number of SWI2 time steps per MODFLOW time step. (default is 1).
- **nadptmn** (*int*) - only used if adaptive is True. Minimum number of SWI2 time steps per MODFLOW time step. (default is 1).
- **adptfct** (*float*) - is the factor used to evaluate tip and toe thicknesses and control the number of SWI2 time steps per MODFLOW time step. When the maximum tip or toe thickness exceeds the product of TOESLOPE or TIPSLOPE the cell size and ADPTFCT, the number of SWI2 time steps are increased to a value less than or equal to NADPT. When the maximum tip or toe thickness is less than the product of TOESLOPE or TIPSLOPE the cell size and ADPTFCT, the number of SWI2 time steps is decreased in the next MODFLOW time step to a value greater than or equal to 1. ADPTFCT must be greater than 0.0 and is reset to 1.0 if NADPTMX is equal to NADPTMN. (default is 1.0).

- **nu** (*array of floats*) - if istart = 1, density of each zone (nsrf + 1 values). if istrat = 0, density along top of layer, each surface, and bottom of layer (nsrf + 2 values). (default is 0.025)
- **zeta** (*list of floats or list of array of floats [(nlay, nrow, ncol),)* - (nlay, nrow, ncol)] initial elevations of the active surfaces. The list should contain an entry for each surface and be of size nsrf. (default is [0.])
- **ssz** (*float or array of floats (nlay, nrow, ncol)*) - effective porosity. (default is 0.25)
- **isource** (*integer or array of integers (nlay, nrow, ncol)*) - Source type of any external sources or sinks, specified with any outside package (i.e. WEL Package, RCH Package, GHB Package). (default is 0).

  If ISOURCE > 0 sources and sinks have the same fluid density as the zone ISOURCE. If such a zone is not present in the cell, sources and sinks have the same fluid density as the active zone at the top of the aquifer. If ISOURCE = 0 sources and sinks have the same fluid density as the active zone at the top of the aquifer. If ISOURCE < 0 sources have the same fluid density as the zone with a number equal to the absolute value of ISOURCE. Sinks have the same fluid density as the active zone at the top of the aquifer. This option is useful for the modeling of the ocean bottom where infiltrating water is salt, yet exfiltrating water is of the same type as the water at the top of the aquifer.
- **obsnam** (*list of strings*) - names for nobs observations.
- **obslrc** (*list of lists*) - zero-based [layer, row, column] lists for nobs observations.
- **extension** (*string*) - Filename extension (default is 'swi2')
- **npln** (*int*) - Deprecated - use nsrf instead.
- **unitnumber** (*int*) - File unit number (default is None).
- **filenames** (*str or list of str*) - Filenames to use for the package and the zeta, cbc, obs output files. If filenames=None the package name will be created using the model name and package extension and the output file names will be created using the model name and output extensions. If a single string is passed the package will be set to the string and output names will be created using the model name and zeta, cbc, and observation extensions. To define the names for all package files (input and output) the length of the list of strings should be 4. Default is None.

Notes

Parameters are supported in Flopy only when reading in existing models. Parameter values are converted to native values in Flopy and the connection to "parameters" is thus nonexistent.

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow()
>>> swi2 = flopy.modflow.ModflowSwi2(m)
```

classmethod load(*f*, *model*, *ext_unit_dict=None*)

Load an existing package.

Parameters

- **f** (*filename or file handle*) – File to load.
- **model** (*model object*) – The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.
- **ext_unit_dict** (*dictionary, optional*) – If the arrays in the file are specified using EXTERNAL, or older style array control records, then *f* should be a file handle. In this case ext_unit_dict is required, which can be constructed using the function *flopy.utils.mfreadnam.parsenamefile*.

Returns
swi2

Return type
ModflowSwi2 object

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow()
>>> swi2 = flopy.modflow.ModflowSwi2.load('test.swi2', m)
```

write_file(*check=True*, *f=None*)

Write the package file.

Parameters
check (*boolean*) – Check package data for common errors. (default True)

Return type
None

flopy.modflow.mfswr1 module

mfswr module. Contains the ModflowSwr1 class. Note that the user can access the ModflowSwr1 class as *flopy.modflow.ModflowSwr1*.

Additional information for this MODFLOW process can be found at the Online MODFLOW Guide.

class ModflowSwr1(*model*, *extension='swr'*, *unitnumber=None*, *filenames=None*)

Bases: *Package*

MODFLOW Surface-Water Routing Class.

Parameters

- **model** (*model object*) – The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.
- **extension** (*string*) – Filename extension (default is 'swr')
- **unitnumber** (*int*) – File unit number (default is None).
- **filenames** (*str or list of str*) – Filenames to use for the package. If filenames=None the package name will be created using the model name and package extension. If a single string is passed the package will be set to the string. Default is None.

Notes

SWR1 Class is only used to write SWR1 filename to name file. Full functionality still needs to be implemented.

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow()
>>> swr = flopy.modflow.ModflowSwr1(m)
```

classmethod load(*f*, *model*, *ext_unit_dict=None*)

Load an existing package.

Parameters

- **f** (*filename or file handle*) – File to load.
- **model** (*model object*) – The model object (of type: class:*flopy.modflow.mf.Modflow*) to which this package will be added.
- **ext_unit_dict** (*dictionary, optional*) – If the arrays in the file are specified using EXTERNAL, or older style array control records, then *f* should be a file handle. In this case ext_unit_dict is required, which can be constructed using the function *flopy.utils.mfreadnam.parsenamefile*.

Returns

swr – ModflowSwr1 object (of type flopy.modflow.mfbas.ModflowSwr1)

Return type
ModflowSwr1 object

Notes

Load method still needs to be implemented.

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow()
>>> swr = flopy.modflow.ModflowSwr1.load('test.swr', m)
```

write_file()
Write the package file.

Return type
None

flopy.modflow.mfswt module

mfswt module. Contains the ModflowSwt class. Note that the user can access the ModflowSub class as *flopy.modflow.ModflowSwt*.

Additional information for this MODFLOW package can be found at the Online MODFLOW Guide.

class ModflowSwt(*model, ipakcb=None, iswtoc=0, nsystm=1, ithk=0, ivoid=0, istpcs=1, icrcc=0, lnwt=0, izcfl=0, izcfm=0, iglfl=0, iglfm=0, iestfl=0, iestfm=0, ipcsfl=0, ipcsfm=0, istfl=0, istfm=0, gl0=0.0, sgm=1.7, sgs=2.0, thick=1.0, sse=1.0, ssv=1.0, cr=0.01, cc=0.25, void=0.82, sub=0.0, pcsoff=0.0, pcs=0.0, ids16=None, ids17=None, extension='swt', unitnumber=None, filenames=None*)

Bases: *Package*

MODFLOW SUB-WT Package Class.

Parameters

- **model** (*model object*) – The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.
- **ipakcb** (*int, optional*) – Toggles whether cell-by-cell budget data should be saved. If None or zero, budget data will not be saved (default is None).
- **iswtoc** (*int*) – iswtoc is a flag used to control output of information generated by the SUB Package. (default is 0).
- **nystm** (*int*) – nsystm is the number of systems of interbeds. (default is 1).
- **ithk** (*int*) – ithk is a flag to determine how thicknesses of compressible sediments vary in response to changes in saturated thickness. If ithk < 1, thickness of compressible sediments is constant. If ithk > 0, thickness of compressible sediments varies in response to changes in saturated thickness. (default is 1).

- **ivoid** (*int*) - ivoid is a flag to determine how void ratios of compressible sediments vary in response to changes in saturated thickness. If ivoid < 1, void ratio will be treated as a constant. If ivoid > 0, void ratio will be treated as a variable. (default is 0).
- **nn** (*int*) - nn is the number of nodes used to discretize the half space to approximate the head distributions in systems of delay interbeds. (default is 20).
- **istpcs** (*int*) - istpcs is a flag to determine how initial preconsolidation stress will be obtained. If istpcs does not equal 0, an array of offset values will be read in for each model layer. The offset values will be added to the initial effective stress to get initial preconsolidation stress. If istpcs = 0, an array with initial preconsolidation stress values will be read. (default is 1).
- **icrcc** (*int*) - icrcc is a flag to determine how recompression and compression indices will be obtained. If ICRCC is not equal to 0, arrays of elastic specific storage and inelastic skeletal specific storage will be read for each system of interbeds; the recompression index and compression index will not be read. If icrcc = 0, arrays of recompression index and compression index will be read for each system of interbeds; elastic skeletal specific storage and inelastic skeletal specific storage will not be read. (default is 0).
- **lnwt** (*int or array of ints (nsystm)*) - lnwt is a one-dimensional array specifying the model layer assignments for each system of interbeds. (default is 0).
- **izcfl** (*int*) - izcfl is a flag to specify whether or not initial calculated values of layer-center elevation will be printed. (default is 0).
- **izcfm** (*int*) - izcfm is is a code for the format in which layer-center elevation will be printed. (default is 0).
- **iglfl** (*int*) - iglfl is a flag to specify whether or not initial calculated values of geostatic stress will be printed. (default is 0).
- **iglfm** (*int*) - iglfm is a code for the format in which geostatic stress will be printed. (default is 0).
- **iestfl** (*int*) - iestfl is a flag to specify whether or not initial calculated values of effective stress will be printed. (default is 0).
- **iestfm** (*int*) - iestfm is a code for the format in which effective stress will be printed. (default is 0).
- **ipcsfl** (*int*) - ipcsfl is a flag to specify whether or not initial calculated values of preconsolidation stress will be printed. (default is 0).
- **ipcsfm** (*int*) - ipcsfm is a code for the format in which preconsolidation stress will be printed. (default is 0).

- **istfl** (*int*) - istfl is a flag to specify whether or not initial equivalent storage properties will be printed for each system of interbeds. If icrcc is not equal to 0, the equivalent storage properties that can be printed are recompression and compression indices (cr and cc), which are calculated from elastic and inelastic skeletal specific storage (sske and sskv). If icrcc = 0, equivalent storage properties that can be printed are elastic and inelastic skeletal specific storage, which are calculated from the recompression and compression indices. (default is 0).
- **istfm** (*int*) - istfm is a code for the format in which equivalent storage properties will be printed. (default is 0).
- **gl0** (*float or array of floats (nrow, ncol)*) - gl0 is an array specifying the geostatic stress above model layer 1. If the top of model layer 1 is the land surface, enter values of zero for this array. (default is 0.).
- **sgm** (*float or array of floats (nrow, ncol)*) - sgm is an array specifying the specific gravity of moist or unsaturated sediments. (default is 1.7).
- **sgs** (*float or array of floats (nrow, ncol)*) - sgs is an array specifying the specific gravity of saturated sediments. (default is 2.).
- **thick** (*float or array of floats (nsystm, nrow, ncol)*) - thick is an array specifying the thickness of compressible sediments. (default is 1.).
- **sse** (*float or array of floats (nsystm, nrow, ncol)*) - sse is an array specifying the initial elastic skeletal specific storage of compressible beds. sse is not used if icrcc = 0. (default is 1.).
- **ssv** (*float or array of floats (nsystm, nrow, ncol)*) - ssv is an array specifying the initial inelastic skeletal specific storage of compressible beds. ssv is not used if icrcc = 0. (default is 1.).
- **cr** (*float or array of floats (nsystm, nrow, ncol)*) - cr is an array specifying the recompression index of compressible beds. cr is not used if icrcc is not equal to 0. (default is 0.01).
- **cc** (*float or array of floats (nsystm, nrow, ncol)*) - cc is an array specifying the compression index of compressible beds cc is not used if icrcc is not equal to 0. (default is 0.25).
- **void** (*float or array of floats (nsystm, nrow, ncol)*) - void is an array specifying the initial void ratio of compressible beds. (default is 0.82).
- **sub** (*float or array of floats (nsystm, nrow, ncol)*) - sub is an array specifying the initial compaction in each system of interbeds. Compaction values computed by the package are added to values in this array so that printed or stored values of compaction and land subsidence may include previous components. Values in this array do not affect calculations of storage changes or resulting compaction. For simulations in which output values

will reflect compaction and subsidence since the start of the simulation, enter zero values for all elements of this array. (default is 0.).

- **pcsoff** (*float or array of floats (nlay, nrow, ncol)*) - pcsoff is an array specifying the offset from initial effective stress to initial preconsolidation stress at the bottom of the model layer in units of height of a column of water. pcsoff is not used if istpcs=0. (default is 0.).
- **pcs** (*float or array of floats (nlay, nrow, ncol)*) - pcs is an array specifying the initial preconsolidation stress, in units of height of a column of water, at the bottom of the model layer. pcs is not used if istpcs is not equal to 0. (default is 0.).
- **ids16** (*list or array of ints (26)*) - Format codes and unit numbers for swtsidence, compaction by model layer, compaction by interbed system, vertical displacement, preconsolidation stress, change in preconsolidation stress, geostatic stress, change in geostatic stress, effective stress, void ration, thickness of compressible sediments, and layer-center elevation will be printed. If ids16 is None and iswtoc>0 then print code 0 will be used for all data which is output to the binary swtsidence output file (unit=1054). The 26 entries in ids16 correspond to ifm1, iun1, ifm2, iun2, ifm3, iun3, ifm4, iun4, ifm5, iun5, ifm6, iun6, ifm7, iun7, ifm8, iun8, ifm9, iun9, ifm10, iun11, ifm12, iun12, ifm13, and iun13 variables. (default is None).
- **ids17** (*list or array of ints (iswtoc, 30)*) - Stress period and time step range and print and save flags used to control printing and saving of information generated by the SUB-WT Package during program execution. Each row of ids17 corresponds to isp1, isp2, its1, its2, ifl1, ifl2, ifl3, ifl4, ifl5, ifl6, ifl7, ifl8, ifl9, ifl10, ifl11, ifl12, ifl13, ifl14, ifl15, ifl16, ifl17, ifl18, ifl9, ifl20, ifl21, ifl22, ifl23, ifl24, ifl25, and ifl26 variables for iswtoc entries. isp1, isp2, its1, and its2 are stress period and time step ranges. ifl1 and ifl2 control subsidence printing and saving. ifl3 and ifl4 control compaction by model layer printing and saving. ifl5 and ifl6 control compaction by interbed system printing and saving. ifl7 and ifl8 control vertical displacement printing and saving. ifl9 and ifl10 control preconsolidation stress printing and saving. ifl11 and ifl12 control change in preconsolidation stress printing and saving. ifl13 and ifl14 control geostatic stress printing and saving. ifl15 and ifl16 control change in geostatic stress printing and saving. ifl17 and ifl18 control effective stress printing and saving. ifl19 and ifl20 control change in effective stress printing and saving. ifl21 and ifl22 control void ratio printing and saving. ifl23 and ifl24 control compressible bed thickness printing and saving. ifl25 and ifl26 control layer-center elevation printing and saving. If ids17 is None and iswtoc>0 then all available subsidence output will be printed and saved to the binary subsidence output file (unit=1054). (default is None).
- **unitnumber** (*int*) - File unit number (default is None).

- **filenames** (*str or list of str*) – Filenames to use for the package and the output files. If filenames=None the package name will be created using the model name and package extension and the cbc output name and other swt output files will be created using the model name and .cbc and swt output extensions (for example, modflowtest.cbc), if ipakcb and other swt output files (dataset 16) are numbers greater than zero. If a single string is passed the package name will be set to the string and other swt output files will be set to the model name with the appropriate output file extensions. To define the names for all package files (input and output) the length of the list of strings should be 15. Default is None.

Notes

Parameters are supported in Flopy only when reading in existing models. Parameter values are converted to native values in Flopy and the connection to "parameters" is thus nonexistent. Parameters are not supported in the SUB-WT Package.

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow()
>>> swt = flopy.modflow.ModflowSwt(m)
```

classmethod load(*f*, *model*, *ext_unit_dict=None*)

Load an existing package.

Parameters

- **f** (*filename or file handle*) – File to load.
- **model** (*model object*) – The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.
- **ext_unit_dict** (*dictionary, optional*) – If the arrays in the file are specified using EXTERNAL, or older style array control records, then *f* should be a file handle. In this case ext_unit_dict is required, which can be constructed using the function *flopy.utils.mfreadnam.parsenamefile*.

Returns

swt

Return type

ModflowSwt object

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow()
>>> swt = flopy.modflow.ModflowSwt.load('test.swt', m)
```

write_file(*f=None*)

Write the package file.

Return type
None

flopy.modflow.mfupw module

mfupw module. Contains the ModflowUpw class. Note that the user can access the ModflowUpw class as *flopy.modflow.ModflowUpw*.

Additional information for this MODFLOW package can be found at the Online MODFLOW Guide.

class ModflowUpw(*model*, *laytyp=0*, *layavg=0*, *chani=1.0*, *layvka=0*, *laywet=0*, *ipakcb=None*, *hdry=-1e+30*, *iphdry=0*, *hk=1.0*, *hani=1.0*, *vka=1.0*, *ss=1e-05*, *sy=0.15*, *vkcb=0.0*, *noparcheck=False*, *extension='upw'*, *unitnumber=None*, *filenames=None*)

Bases: *Package*

Upstream weighting package class

Parameters

- **model** (*model object*) – The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.
- **ipakcb** (*int, optional*) – Toggles whether cell-by-cell budget data should be saved. If None or zero, budget data will not be saved (default is None).
- **hdry** (*float*) – Is the head that is assigned to cells that are converted to dry during a simulation. Although this value plays no role in the model calculations, it is useful as an indicator when looking at the resulting heads that are output from the model. HDRY is thus similar to HNOFLO in the Basic Package, which is the value assigned to cells that are no-flow cells at the start of a model simulation. (default is -1.e30).
- **iphdry** (*int*) – iphdry is a flag that indicates whether groundwater head will be set to hdry when the groundwater head is less than 0.0001 above the cell bottom (units defined by lenuni in the discretization package). If iphdry=0, then head will not be set to hdry. If iphdry>0, then head will be set to hdry. If the head solution from one simulation will be used as starting heads for a subsequent simulation, or if the Observation Process is used (Harbaugh and others, 2000), then hdry should not be printed to the output file for dry cells (that is, the upw package input variable should be set as iphdry=0). (default is 0)

- **noparcheck** (*bool*) - noparcheck turns off the checking that a value is defined for all cells when parameters are used to define layer data.
- **laytyp** (*int or array of ints (nlay)*) - Layer type (default is 0).
- **layavg** (*int or array of ints (nlay)*) - Layer average (default is 0). 0 is harmonic mean 1 is logarithmic mean 2 is arithmetic mean of saturated thickness and logarithmic mean of of hydraulic conductivity
- **chani** (*float or array of floats (nlay)*) - contains a value for each layer that is a flag or the horizontal anisotropy. If CHANI is less than or equal to 0, then variable HANI defines horizontal anisotropy. If CHANI is greater than 0, then CHANI is the horizontal anisotropy for the entire layer, and HANI is not read. If any HANI parameters are used, CHANI for all layers must be less than or equal to 0. Use as many records as needed to enter a value of CHANI for each layer. The horizontal anisotropy is the ratio of the hydraulic conductivity along columns (the Y direction) to the hydraulic conductivity along rows (the X direction).
- **layvka** (*int or array of ints (nlay)*) - a flag for each layer that indicates whether variable VKA is vertical hydraulic conductivity or the ratio of horizontal to vertical hydraulic conductivity.
- **laywet** (*int or array of ints (nlay)*) - contains a flag for each layer that indicates if wetting is active. laywet should always be zero for the UPW Package because all cells initially active are wettable.
- **hk** (*float or array of floats (nlay, nrow, ncol)*) - is the hydraulic conductivity along rows. HK is multiplied by horizontal anisotropy (see CHANI and HANI) to obtain hydraulic conductivity along columns. (default is 1.0).
- **hani** (*float or array of floats (nlay, nrow, ncol)*) - is the ratio of hydraulic conductivity along columns to hydraulic conductivity along rows, where HK of item 10 specifies the hydraulic conductivity along rows. Thus, the hydraulic conductivity along columns is the product of the values in HK and HANI. (default is 1.0).
- **vka** (*float or array of floats (nlay, nrow, ncol)*) - is either vertical hydraulic conductivity or the ratio of horizontal to vertical hydraulic conductivity depending on the value of LAYVKA. (default is 1.0).
- **ss** (*float or array of floats (nlay, nrow, ncol)*) - is specific storage unless the STORAGECOEFFICIENT option is used. When STORAGECOEFFICIENT is used, Ss is confined storage coefficient. (default is 1.e-5).
- **sy** (*float or array of floats (nlay, nrow, ncol)*) - is specific yield. (default is 0.15).
- **vkcb** (*float or array of floats (nlay, nrow, ncol)*) - is the vertical hydraulic conductivity of a Quasi-three-dimensional

confining bed below a layer. (default is 0.0).

- **extension** (*string*) – Filename extension (default is 'upw')
- **unitnumber** (*int*) – File unit number (default is None).
- **filenames** (*str or list of str*) – Filenames to use for the package and the output files. If filenames=None the package name will be created using the model name and package extension and the cbc output name will be created using the model name and .cbc extension (for example, modflowtest.cbc), if ipakcb is a number greater than zero. If a single string is passed the package will be set to the string and cbc output name will be created using the model name and .cbc extension, if ipakcb is a number greater than zero. To define the names for all package files (input and output) the length of the list of strings should be 2. Default is None.

Notes

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow()
>>> lpf = flopy.modflow.ModflowLpf(m)
```

classmethod load(*f*, *model*, *ext_unit_dict=None*, *check=True*)

Load an existing package.

Parameters

- **f** (*filename or file handle*) – File to load.
- **model** (*model object*) – The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.
- **ext_unit_dict** (*dictionary, optional*) – If the arrays in the file are specified using EXTERNAL, or older style array control records, then *f* should be a file handle. In this case ext_unit_dict is required, which can be constructed using the function *flopy.utils.mfreadnam.parsenamefile*.
- **check** (*boolean*) – Check package data for common errors. (default True)

Returns

dis – ModflowLpf object.

Return type

ModflowUPW object

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow()
>>> upw = flopy.modflow.ModflowUpw.load('test.upw', m)
```

write_file(*check=True*, *f=None*)

Write the package file.

Parameters
check (*boolean*) – Check package data for common errors. (default True)

Return type
None

flopy.modflow.mfuzf1 module

mfuzf1 module. Contains the ModflowUzf1 class. Note that the user can access the ModflowUzf1 class as *flopy.modflow.ModflowUzf1*.

Additional information for this MODFLOW package can be found at the Online MODFLOW Guide.

class ModflowUzf1(*model*, *nuztop=1*, *iuzfopt=0*, *irunflg=0*, *ietflg=0*, *ipakcb=None*, *iuzfcb2=None*, *ntrail2=10*, *nsets=20*, *surfdep=1.0*, *iuzfbnd=1*, *irunbnd=0*, *vks=1e-06*, *eps=3.5*, *thts=0.35*, *thtr=0.15*, *thti=0.2*, *specifythtr=False*, *specifythti=False*, *nosurfleak=False*, *finf=1e-08*, *pet=5e-08*, *extdp=15.0*, *extwc=0.1*, *air_entry=0.0*, *hroot=0.0*, *rootact=0.0*, *specifysurfk=False*, *rejectsurfk=False*, *seepsurfk=False*, *etsquare=None*, *netflux=None*, *capillaryuzet=False*, *nuzgag=None*, *uzgag=None*, *extension='uzf'*, *unitnumber=None*, *filenames=None*, *options=None*, *surfk=0.1*)

Bases: *Package*

MODFLOW Unsaturated Zone Flow 1 Boundary Package Class.

Parameters

- **model** (*model object*) – The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.
- **nuztop** (*integer*) – used to define which cell in a vertical column that recharge and discharge is simulated. (default is 1)

  1 Recharge to and discharge from only the top model layer. This
  option assumes land surface is defined as top of layer 1.

  2 Recharge to and discharge from the specified layer in variable
  IUZFBND. This option assumes land surface is defined as top of layer specified in IUZFBND.

  3 Recharge to and discharge from the highest active cell in each
  vertical column. Land surface is determined as top of layer specified in IUZFBND. A constant head node intercepts any recharge and prevents deeper percolation.

- **iuzfopt** (*integer*) – equal to 1 or 2. A value of 1 indicates that the vertical hydraulic conductivity will be specified within the UZF1 Package input file using array VKS. A value of 2 indicates that the vertical hydraulic conductivity will be specified within either the BCF or LPF Package input file. (default is 0)

- **irunflg** (*integer*) - specifies whether ground water that discharges to land surface will be routed to stream segments or lakes as specified in the IRUNBND array (IRUNFLG not equal to zero) or if ground-water discharge is removed from the model simulation and accounted for in the ground-water budget as a loss of water (IRUNFLG=0). The Streamflow-Routing (SFR2) and(or) the Lake (LAK3) Packages must be active if IRUNFLG is not zero. (default is 0)
- **ietflg** (*integer*) - specifies whether or not evapotranspiration (ET) will be simulated. ET will not be simulated if IETFLG is zero, otherwise it will be simulated. (default is 0)
- **ipakcb** (*int, optional*) - Toggles whether cell-by-cell budget data should be saved. If None or zero, budget data will not be saved (default is None).
- **iuzfcb2** (*integer*) - flag for writing ground-water recharge, ET, and ground-water discharge to land surface rates to a separate unformatted file using module UBDSV3. If IUZFCB2>0, it is the unit number to which cell-by-cell rates will be written when 'SAVE BUDGET' or a non-zero value for ICBCFL is specified in Output Control. If IUZFCB2 less than or equal to 0, cell-by-cell rates will not be written to file. (default is 0)
- **ntrail2** (*integer*) - equal to the number of trailing waves used to define the water-content profile following a decrease in the infiltration rate. The number of trailing waves varies depending on the problem, but a range between 10 and 20 is usually adequate. More trailing waves may decrease mass-balance error and will increase computational requirements and memory usage. (default is 10)
- **nsets** (*integer*) - equal to the number of wave sets used to simulate multiple infiltration periods. The number of wave sets should be set to 20 for most problems involving time varying infiltration. The total number of waves allowed within an unsaturated zone cell is equal to NTRAIL2*NSETS2. An error will occur if the number of waves in a cell exceeds this value. (default is 20)
- **surfdep** (*float*) - The average height of undulations, D (Figure 1 in UZF documentation), in the land surface altitude. (default is 1.0)
- **iuzfbnd** (*integer*) - used to define the aerial extent of the active model in which recharge and discharge will be simulated. (default is 1)
- **irunbnd** (*integer*) - used to define the stream segments within the Streamflow-Routing (SFR2) Package or lake numbers in the Lake (LAK3) Package that overland runoff from excess infiltration and ground-water discharge to land surface will be added. A positive integer value identifies the stream segment and a negative integer value identifies the lake number. (default is 0)

- **vks** (*float*) - used to define the saturated vertical hydraulic conductivity of the unsaturated zone (LT-1). (default is 1.0E-6)
- **eps** (*float*) - values for each model cell used to define the Brooks-Corey epsilon of the unsaturated zone. Epsilon is used in the relation of water content to hydraulic conductivity (Brooks and Corey, 1966). (default is 3.5)
- **thts** (*float*) - used to define the saturated water content of the unsaturated zone in units of volume of water to total volume (L3L-3). (default is 0.35)
- **thtr** (*float*) - used to define the residual water content for each vertical column of cells in units of volume of water to total volume (L3L-3). THTR is the irreducible water content and the unsaturated water content cannot drain to water contents less than THTR. This variable is not included unless the key word SPECIFYTHTR is specified. (default is 0.15)
- **thti** (*float*) - used to define the initial water content for each vertical column of cells in units of volume of water at start of simulation to total volume (L3L-3). THTI should not be specified for steady-state simulations. (default is 0.20)
- **row_col_iftunit_iuzopt** (*list*) - used to specify where information will be printed for each time step. row and col are zero-based. IUZOPT specifies what that information will be. (default is []) IUZOPT is

  1 Prints time, ground-water head, and thickness of unsaturated zone,
  and cumulative volumes of infiltration, recharge, storage, change in storage and ground-water discharge to land surface.

  2 Same as option 1 except rates of infiltration, recharge, change in
  storage, and ground-water discharge also are printed.

  3 Prints time, ground-water head, thickness of unsaturated zone,
  followed by a series of depths and water contents in the unsaturated zone.

- **specifythtr** (*boolean*) - key word for specifying optional input variable THTR (default is 0)
- **specifythti** (*boolean*) - key word for specifying optional input variable THTI. (default is 0)
- **nosurfleak** (*boolean*) - key word for inactivating calculation of surface leakage. (default is 0)
- **specifysurfk** (*boolean*) - (MODFLOW-NWT version 1.1 and MODFLOW-2005 1.12 or later) An optional character variable. When SPECIFYSURFK is specified, the variable SURFK is specified in Data Set 4b.
- **rejectsurfk** (*boolean*) - (MODFLOW-NWT version 1.1 and MODFLOW-2005 1.12 or later) An optional character variable. When REJECTSURFK is specified, SURFK instead of VKS is used for calculating rejected infiltration. REJECTSURFK only is included if SPECIFYSURFK is included.
- **seepsurfk** (*boolean*) - (MODFLOW-NWT version 1.1 and MODFLOW-2005 1.12 or later) An optional character variable. When SEEPSURFK is

specified, SURFK instead of VKS is used for calculating surface leakage. SEEPSURFK only is included if SPECIFYSURFK is included.

- **etsquare** (*float (smoothfact)*) - (MODFLOW-NWT version 1.1 and MODFLOW-2005 1.12 or later) An optional character variable. When ETSQUARE is specified, groundwater ET is simulated using a constant potential ET rate, and is smoothed over a specified smoothing interval. This option is recommended only when using the NWT solver.

  etsquare is activated in flopy by specifying a real value for smoothfact (default is None). For example, if the interval factor (smoothfact) is specified as smoothfact=0.1 (recommended), then the smoothing interval will be calculated as: SMOOTHINT = 0.1*EXTDP and is applied over the range for groundwater head (h): * h < CELTOP-EXTDP, ET is zero; * CELTOP-EXTDP < h < CELTOP-EXTDP+SMOOTHINT, ET is smoothed; CELTOP-EXTDP+SMOOTHINT < h, ET is equal to potential ET.

- **uzgage** (*dict of lists or list of lists*) - Dataset 8 in UZF Package documentation. Each entry in the dict is keyed by iftunit.

  > Dict of lists: If iftunit is negative, the list is empty. If iftunit is positive, the list includes [IUZROW, IUZCOL, IUZOPT] List of lists: Lists follow the format described in the documentation: [[IUZROW, IUZCOL, IFTUNIT, IUZOPT]] or [[-IFTUNIT]]

- **netflux** (*list of [Unitrech (int), Unitdis (int)]*) - (MODFLOW-NWT version 1.1 and MODFLOW-2005 1.12 or later) An optional character variable. When NETFLUX is specified, the sum of recharge (L3/T) and the sum of discharge (L3/T) is written to separate unformatted files using module UBDSV3.

  netflux is activated in flopy by specifying a list for Unitrech and Unitdis (default is None). Unitrech and Unitdis are the unit numbers to which these values are written when "SAVE BUDGET" is specified in Output Control. Values written to Unitrech are the sum of recharge values for the UZF, SFR2, and LAK packages, and values written to Unitdis are the sum of discharge values for the UZF, SFR2, and LAK packages. Values are averaged over the period between output times.

  [NETFLUX unitrech unitdis]

- **finf** (*float, 2-D array, or dict of {kper:value}*) - where kper is the zero-based stress period to assign a value to. Value should be cast-able to Util2d instance can be a scalar, list, or ndarray is the array value is constant in time. Used to define the infiltration rates (LT-1) at land surface for each vertical column of cells. If FINF is specified as being greater than the vertical hydraulic conductivity then FINF is set equal to the vertical unsaturated hydraulic conductivity. Excess water is routed to streams or lakes when IRUNFLG is not zero, and if SFR2 or LAK3 is active. (default is 1.0E-8)

- **pet** (*float, 2-D array, or dict of {kper:value}*) - where kper is the zero-based stress period to assign a value to. Value should be cast-able to Util2d instance can be a scalar, list, or ndarray is the array value is constant in time. Used to define the ET demand rates (L1T-1) within the ET extinction depth interval for each vertical column of cells. (default is 5.0E-8)

- **extdp** (*float, 2-D array, or dict of {kper:value}*) - where kper is the zero-based stress period to assign a value to. Value should be cast-able to Util2d instance can be a scalar, list, or ndarray is the array value is constant in time. Used to define the ET extinction depths. The quantity of ET removed from a cell is limited by the volume of water stored in the unsaturated zone above the extinction depth. If ground water is within the ET extinction depth, then the rate removed is based on a linear decrease in the maximum rate at land surface and zero at the ET extinction depth. The linear decrease is the same method used in the Evapotranspiration Package (McDonald and Harbaugh, 1988, chap. 10). (default is 15.0)
- **extwc** (*float, 2-D array, or dict of {kper:value}*) -

  where kper is the zero-based stress period
  to assign a value to. Value should be cast-able to Util2d instance can be a scalar, list, or ndarray is the array value is constant in time. Used to define the extinction water content below which ET cannot be removed from the unsaturated zone. EXTWC must have a value between (THTS-Sy) and THTS, where Sy is the specific yield specified in either the LPF or BCF Package. (default is 0.1)

  air_entry
  [float, 2-D array, or dict of {kper: value}] where kper is the zero-based stress period. Used to define the air entry pressure of the unsaturated zone in MODFLOW-NWT simulations
- **hroot** (*float, 2-D array, or dict of {kper: value}*) - where kper is the zero-based stress period. Used to define the pressure potential at roots in the unsaturated zone in MODFLOW-NWT simulations
- **rootact** (*float, 2-D array, or dict of {kper: value}*) - where kper is the zero-based stress period. Used to define the root activity in the unsaturated zone in MODFLOW-NWT simulations
- **uzfbud_ext** (*list*) - appears to be used for sequential naming of budget output files (default is [])
- **extension** (*string*) - Filename extension (default is 'uzf')
- **unitnumber** (*int*) - File unit number (default is None).
- **filenames** (*str or list of str*) - Filenames to use for the package and the output files. If filenames=None the package name will be created using the model name and package extension and the cbc output, uzf output, and uzf observation names will be created using the model name and .cbc, uzfcb2.bin, and .uzf#.out extensions (for example, modflowtest.cbc, and modflowtest.uzfcd2.bin), if ipakcb, iuzfcb2, and len(uzgag) are numbers greater than zero. For uzf observations the file

extension is created using the uzf observation file unit number (for example, for uzf observations written to unit 123 the file extension would be .uzf123.out). If a single string is passed the package name will be set to the string and other uzf output files will be set to the model name with the appropriate output file extensions. To define the names for all package files (input and output) the length of the list of strings should be 3 + len(uzgag). Default is None.

- **surfk** (*float*) – An optional array of positive real values used to define the hydraulic conductivity (LT-1). SURFK is used for calculating the rejected infiltration and/or surface leakage. IF SURFK is set greater than VKS then it is set equal to VKS. Only used if SEEPSURFK is True.

nuzgag

equal to the number of cells (one per vertical column) that will be specified for printing detailed information on the unsaturated zone water budget and water content. A gage also may be used to print the budget summed over all model cells. (default is None)

Type

integer (deprecated - counter is set based on length of uzgage)

Notes

Parameters are not supported in FloPy.

Examples

```
>>> import flopy
>>> ml = flopy.modflow.Modflow()
>>> uzf = flopy.modflow.ModflowUzf1(ml, ...)
```

classmethod load(*f*, *model*, *ext_unit_dict=None*, *check=False*)

Load an existing package.

Parameters

- **f** (*filename or file handle*) – File to load.
- **model** (*model object*) – The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.
- **ext_unit_dict** (*dictionary, optional*) – If the arrays in the file are specified using EXTERNAL, or older style array control records, then *f* should be a file handle. In this case ext_unit_dict is required, which can be constructed using the function *flopy.utils.mfreadnam.parsenamefile*.

Returns

uzf – ModflowUZF1 object.

Return type

ModflowUZF1 object

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow()
>>> uzf = flopy.modflow.ModflowUZF1.load('test.uzf', m)
```

property nuzgag

Number of uzf gages

Returns
nuzgag – Number of uzf gages

Return type
int

property uzgag

Get the uzf gage data

Returns
uzgag – Dictionary containing uzf gage data for each gage

Return type
dict

write_file(*f=None*)

Write the package file.

Return type
None

flopy.modflow.mfwel module

mfwel module. Contains the ModflowWel class. Note that the user can access the ModflowWel class as *flopy.modflow.ModflowWel*.

Additional information for this MODFLOW package can be found at the Online MODFLOW Guide.

class ModflowWel(*model*, *ipakcb=None*, *stress_period_data=None*, *dtype=None*, *extension='wel'*, *options=None*, *binary=False*, *unitnumber=None*, *filenames=None*, *add_package=True*)

Bases: *Package*

MODFLOW Well Package Class.

Parameters

- **model** (*model object*) – The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.
- **ipakcb** (*int*, *optional*) – Toggles whether cell-by-cell budget data should be saved. If None or zero, budget data will not be saved (default is None).
- **stress_period_data** (*list*, *recarray*, *dataframe or dictionary of boundaries.*) – Each well is defined through definition of layer (int), row (int), column (int), flux (float). The simplest form is a dictionary with a lists of boundaries for each stress period, where each list of boundaries itself is a list of boundaries.

Indices of the dictionary are the numbers of the stress period. This gives the form of:

stress_period_data = {0: [

[lay, row, col, flux], [lay, row, col, flux], [lay, row, col, flux]],

1: [
[lay, row, col, flux], [lay, row, col, flux], [lay, row, col, flux]], ...

kper:
[[lay, row, col, flux], [lay, row, col, flux], [lay, row, col, flux]]

}

Note that if the number of lists is smaller than the number of stress periods, then the last list of wells will apply until the end of the simulation. Full details of all options to specify stress_period_data can be found in the flopy3 boundaries Notebook in the basic subdirectory of the examples directory

- **dtype** (*custom datatype of stress_period_data.*) – If None the default well datatype will be applied (default is None).
- **extension** (*string*) – Filename extension (default is 'wel')
- **options** (*list of strings*) – Package options (default is None).
- **unitnumber** (*int*) – File unit number (default is None).
- **filenames** (*str or list of str*) – Filenames to use for the package and the output files. If filenames=None the package name will be created using the model name and package extension and the cbc output name will be created using the model name and .cbc extension (for example, modflowtest.cbc), if ipakcb is a number greater than zero. If a single string is passed the package will be set to the string and cbc output names will be created using the model name and .cbc extension, if ipakcb is a number greater than zero. To define the names for all package files (input and output) the length of the list of strings should be 2. Default is None.
- **add_package** (*bool*) – Flag to add the initialised package object to the parent model object. Default is True.

mxactw

Maximum number of wells for a stress period. This is calculated automatically by FloPy based on the information in stress_period_data.

Type
int

Notes

Parameters are not supported in FloPy.

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow()
>>> lrcq = {0:[[2, 3, 4, -100.]], 1:[[2, 3, 4, -100.]]}
>>> wel = flopy.modflow.ModflowWel(m, stress_period_data=lrcq)
```

add_record(*kper*, *index*, *values*)

static get_default_dtype(*structured=True*)

static get_empty(*ncells=0*, *aux_names=None*, *structured=True*)

classmethod load(*f*, *model*, *nper=None*, *ext_unit_dict=None*, *check=True*)

Load an existing package.

Parameters

- **f** (*filename or file handle*) – File to load.
- **model** (*model object*) – The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.
- **nper** (*int*) – The number of stress periods. If nper is None, then nper will be obtained from the model object. (default is None).
- **ext_unit_dict** (*dictionary, optional*) – If the arrays in the file are specified using EXTERNAL, or older style array control records, then *f* should be a file handle. In this case ext_unit_dict is required, which can be constructed using the function *flopy.utils.mfreadnam.parsenamefile*.

Returns

wel – ModflowWel object.

Return type

ModflowWel object

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow()
>>> wel = flopy.modflow.ModflowWel.load('test.wel', m)
```

write_file(*f=None*)

Write the package file.

Parameters

f – (str) optional file name

Return type

None

flopy.modflow.mfzon module

mfzon module. Contains the ModflowZone class. Note that the user can access the ModflowZone class as *flopy.modflow.ModflowZone*.

Additional information for this MODFLOW package can be found at the Online MODFLOW Guide.

class ModflowZon(*model*, *zone_dict=None*, *extension='zon'*, *unitnumber=None*, *filenames=None*)

Bases: *Package*

MODFLOW Zone Package Class.

Parameters

- **model** (*model object*) – The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.
- **zone_dict** (*dict*) – Dictionary with zone data for the model. zone_dict is typically instantiated using load method.
- **extension** (*string*) – Filename extension (default is 'zon')
- **unitnumber** (*int*) – File unit number (default is None).
- **filenames** (*str or list of str*) – Filenames to use for the package. If filenames=None the package name will be created using the model name and package extension. If a single string is passed the package will be set to the string. Default is None.

Notes

Parameters are supported in Flopy only when reading in existing models. Parameter values are converted to native values in Flopy and the connection to "parameters" is thus nonexistent.

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow()
>>> zonedict = flopy.modflow.ModflowZon(m, zone_dict=zone_dict)
```

classmethod load(*f*, *model*, *nrow=None*, *ncol=None*, *ext_unit_dict=None*)

Load an existing package.

Parameters

- **f** (*filename or file handle*) – File to load.
- **model** (*model object*) – The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.
- **nrow** (*int*) – number of rows. If not specified it will be retrieved from the model object. (default is None).
- **ncol** (*int*) – number of columns. If not specified it will be retrieved from the model object. (default is None).

- **ext_unit_dict** (*dictionary, optional*) – If the arrays in the file are specified using EXTERNAL, or older style array control records, then *f* should be a file handle. In this case ext_unit_dict is required, which can be constructed using the function *flopy.utils.mfreadnam.parsenamefile*.

Returns
zone

Return type
ModflowZone dict

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow()
>>> zon = flopy.modflow.ModflowZon.load('test.zon', m)
```

write_file()
Write the package file.

Return type
None

Notes

Not implemented because parameters are only supported on load

12.2.3 MT3DMS Packages

Contents:

flopy.mt3d.mt module

class Mt3dList(*model*, *extension='list'*, *listunit=7*)
Bases: *Package*

List package class

write_file()
Every Package needs its own write_file function

class Mt3dms(*modelname='mt3dtest'*, *namefile_ext='nam'*, *modflowmodel=None*, *ftlfilename='mt3d_link.ftl'*, *ftlfree=False*, *version='mt3dms'*, *exe_name='mt3dms'*, *structured=True*, *listunit=16*, *ftlunit=10*, *model_ws='.'*, *external_path=None*, *verbose=False*, *load=True*, *silent=0*)
Bases: *BaseModel*

MT3DMS Model Class.

Parameters

- **modelname** (*str, default "mt3dtest"*) – Name of model. This string will be used to name the MODFLOW input that are created with write_model.

- **namefile_ext** (*str, default "nam"*) – Extension for the namefile.
- **modflowmodel** (*flopy.modflow.mf.Modflow*) – This is a flopy Modflow model object upon which this Mt3dms model is based.
- **ftlfilename** (*str, default "mt3d_link.ftl"*) – Name of flow-transport link file.
- **ftlfree** (*TYPE, default False*) – If flow-link transport file is formatted (True) or unformatted (False, default).
- **version** (*str, default "mt3dms"*) – Mt3d version. Choose one of: "mt3dms" (default) or "mt3d-usgs".
- **exe_name** (*str, default "mt3dms"*) – The name of the executable to use.
- **structured** (*bool, default True*) – Specify if model grid is structured (default) or unstructured.
- **listunit** (*int, default 16*) – Unit number for the list file.
- **ftlunit** (*int, default 10*) – Unit number for flow-transport link file.
- **model_ws** (*str, optional*) – Model workspace. Directory name to create model data sets. Default is the present working directory.
- **external_path** (*str, optional*) – Location for external files.
- **verbose** (*bool, default False*) – Print additional information to the screen.
- **load** (*bool, default True*) – Load model.
- **silent** (*int, default 0*) – Silent option.

Notes

Examples

```
>>> import flopy
>>> m = flopy.mt3d.mt.Mt3dms()
```

get_nrow_ncol_nlay_nper()

classmethod load(*f*, *version='mt3dms'*, *exe_name='mt3dms'*, *verbose=False*, *model_ws='.'*, *load_only=None*, *forgive=False*, *modflowmodel=None*)

Load an existing model.

Parameters

- **f** (*str*) – Path to MT3D name file to load.
- **version** (*str, default "mt3dms"*) – Mt3d version. Choose one of: "mt3dms" (default) or "mt3d-usgs".
- **exe_name** (*str, default "mt3dms"*) – The name of the executable to use.
- **verbose** (*bool, default False*) – Print information on the load process if True.

- **model_ws** (*str, default "."*) – Model workspace path. Default is the current directory.
- **load_only** (*list of str, optional*) – Packages to load (e.g. ['btn', 'adv']). Default None means that all packages will be loaded.
- **forgive** (*bool, default False*) – Option to raise exceptions on package load failure, which can be useful for debugging.
- **modflowmodel** (*flopy.modflow.mf.Modflow, optional*) – This is a flopy Modflow model object upon which this Mt3dms model is based.

Return type
flopy.mt3d.mt.Mt3dms

Notes

The load method does not retain the name for the MODFLOW-generated FTL file. This can be added manually after the MT3D model has been loaded. The syntax for doing this manually is mt.ftlfilename = 'example.ftl'.

Examples

```
>>> import flopy
>>> mt = flopy.mt3d.mt.Mt3dms.load('example.nam')
>>> mt.ftlfilename = 'example.ftl'
```

static load_mas(*fname*)

Load an mt3d mas file and return a numpy recarray

Parameters
fname (*str*) – name of MT3D mas file

Returns
r

Return type
np.ndarray

static load_obs(*fname*)

Load an mt3d obs file and return a numpy recarray

Parameters
fname (*str*) – name of MT3D obs file

Returns
r

Return type
np.ndarray

load_results(***kwargs*)

property mcomp

property modelgrid

property modeltime

property ncol

property ncomp

property nlay

property nper

property nrow

property nrow_ncol_nlay_nper

property solver_tols

write_name_file()

Write the name file.

flopy.mt3d.mtadv module

class Mt3dAdv(*model*, *mixelm=3*, *percel=0.75*, *mxpart=800000*, *nadvfd=1*, *itrack=3*, *wd=0.5*, *dceps=1e-05*, *nplane=2*, *npl=10*, *nph=40*, *npmin=5*, *npmax=80*, *nlsink=0*, *npsink=15*, *dchmoc=0.0001*, *extension='adv'*, *unitnumber=None*, *filenames=None*)

Bases: *Package*

MT3DMS Advection Package Class.

Parameters

- **model** (*model object*) - The model object (of type *flopy.mt3d.mt.Mt3dms*) to which this package will be added.
- **mixelm** (*int*) - MIXELM is an integer flag for the advection solution option. MIXELM = 0, the standard finite-difference method with upstream or central-in-space weighting, depending on the value of NADVFD; = 1, the forward-tracking method of characteristics (MOC); = 2, the backward-tracking modified method of characteristics (MMOC); = 3, the hybrid method of characteristics (HMOC) with MOC or MMOC automatically and dynamically selected; = -1, the third-order TVD scheme (ULTIMATE).
- **percel** (*float*) - PERCEL is the Courant number (i.e., the number of cells, or a fraction of a cell) advection will be allowed in any direction in one transport step. For implicit finite-difference or particle-tracking-based schemes, there is no limit on PERCEL, but for accuracy reasons, it is generally not set much greater than one. Note, however, that the PERCEL limit is checked over the entire model grid. Thus, even if PERCEL > 1, advection may not be more than one cell's length at most model locations. For the explicit finite-difference or the third-order TVD scheme, PERCEL is also a stability constraint which must not exceed one and will be automatically reset to one if a value greater than one is specified.
- **mxpart** (*int*) - MXPART is the maximum total number of moving particles allowed and is used only when MIXELM = 1 or 3.

- **nadvfd** (*int*) - NADVFD is an integer flag indicating which weighting scheme should be used; it is needed only when the advection term is solved using the implicit finite- difference method. NADVFD = 0 or 1, upstream weighting (default); = 2,central-in-space weighting.
- **itrack** (*int*) - ITRACK is a flag indicating which particle-tracking algorithm is selected for the Eulerian-Lagrangian methods. ITRACK = 1, the first-order Euler algorithm is used. = 2, the fourth-order Runge-Kutta algorithm is used; this option is computationally demanding and may be needed only when PERCEL is set greater than one. = 3, the hybrid first- and fourth-order algorithm is used; the Runge-Kutta algorithm is used in sink/source cells and the cells next to sinks/sources while the Euler algorithm is used elsewhere.
- **wd** (*float*) - is a concentration weighting factor between 0.5 and 1. It is used for operator splitting in the particle- tracking-based methods. The value of 0.5 is generally adequate. The value of WD may be adjusted to achieve better mass balance. Generally, it can be increased toward 1.0 as advection becomes more dominant.
- **dceps** (*float*) - is a small Relative Cell Concentration Gradient below which advective transport is considered
- **nplane** (*int*) - NPLANE is a flag indicating whether the random or fixed pattern is selected for initial placement of moving particles. If NPLANE = 0, the random pattern is selected for initial placement. Particles are distributed randomly in both the horizontal and vertical directions by calling a random number generator (Figure 18b). This option is usually preferred and leads to smaller mass balance discrepancy in nonuniform or diverging/converging flow fields. If NPLANE > 0, the fixed pattern is selected for initial placement. The value of NPLANE serves as the number of vertical 'planes' on which initial particles are placed within each cell block (Figure 18a). The fixed pattern may work better than the random pattern only in relatively uniform flow fields. For two-dimensional simulations in plan view, set NPLANE = 1. For cross sectional or three-dimensional simulations, NPLANE = 2 is normally adequate. Increase NPLANE if more resolution in the vertical direction is desired.
- **npl** (*int*) - NPL is the number of initial particles per cell to be placed at cells where the Relative Cell Concentration Gradient is less than or equal to DCEPS. Generally, NPL can be set to zero since advection is considered insignificant when the Relative Cell Concentration Gradient is less than or equal to DCEPS. Setting NPL equal to NPH causes a uniform number of particles to be placed in every cell over the entire grid (i.e., the uniform approach).
- **nph** (*int*) - NPH is the number of initial particles per cell to be placed at cells where the Relative Cell Concentration Gradient is greater than DCEPS. The selection of NPH depends on the nature of the flow field and also the computer memory limitation. Generally, a smaller number should be used in

relatively uniform flow fields and a larger number should be used in relatively nonuniform flow fields. However, values exceeding 16 in two-dimensional simulation or 32 in three- dimensional simulation are rarely necessary. If the random pattern is chosen, NPH particles are randomly distributed within the cell block. If the fixed pattern is chosen, NPH is divided by NPLANE to yield the number of particles to be placed per vertical plane, which is rounded to one of the values shown in Figure 30.

- **npmin** (*int*) - is the minimum number of particles allowed per cell. If the number of particles in a cell at the end of a transport step is fewer than NPMIN, new particles are inserted into that cell to maintain a sufficient number of particles. NPMIN can be set to zero in relatively uniform flow fields and to a number greater than zero in diverging/converging flow fields. Generally, a value between zero and four is adequate.
- **npmax** (*int*) - NPMAX is the maximum number of particles allowed per cell. If the number of particles in a cell exceeds NPMAX, all particles are removed from that cell and replaced by a new set of particles equal to NPH to maintain mass balance. Generally, NPMAX can be set to approximately two times of NPH.
- **interp** (*int*) - is a flag indicating the concentration interpolation method for use in the MMOC scheme. Currently, only linear interpolation is implemented.
- **nlsink** (*int*) - s a flag indicating whether the random or fixed pattern is selected for initial placement of particles to approximate sink cells in the MMOC scheme. The convention is the same as that for NPLANE. It is generally adequate to set NLSINK equivalent to NPLANE.
- **npsink** (*int*) - is the number of particles used to approximate sink cells in the MMOC scheme. The convention is the same as that for NPH. It is generally adequate to set NPSINK equivalent to NPH.
- **dchmoc** (*float*) - DCHMOC is the critical Relative Concentration Gradient for controlling the selective use of either MOC or MMOC in the HMOC solution scheme. The MOC solution is selected at cells where the Relative Concentration Gradient is greater than DCHMOC. The MMOC solution is selected at cells where the Relative Concentration Gradient is less than or equal to DCHMOC.
- **extension** (*string*) - Filename extension (default is 'adv')
- **unitnumber** (*int*) - File unit number (default is None).
- **filenames** (*str or list of str*) - Filenames to use for the package. If filenames=None the package name will be created using the model name and package extension. If a single string is passed the package will be set to the string. Default is None.

Notes

Examples

```
>>> import flopy
>>> m = flopy.mt3d.Mt3dms()
>>> adv = flopy.mt3d.Mt3dAdv(m)
```

classmethod load(*f*, *model*, *ext_unit_dict=None*)

Load an existing package.

Parameters

- **f** (*filename or file handle*) – File to load.
- **model** (*model object*) – The model object (of type *flopy.mt3d.mt.Mt3dms*) to which this package will be added.
- **ext_unit_dict** (*dictionary*, *optional*) – If the arrays in the file are specified using EXTERNAL, or older style array control records, then *f* should be a file handle. In this case ext_unit_dict is required, which can be constructed using the function *flopy.utils.mfreadnam.parsenamefile*.

Returns
adv – Mt3dAdv object.

Return type
Mt3dAdv object

Examples

```
>>> import flopy
>>> mt = flopy.mt3d.Mt3dms()
>>> adv = flopy.mt3d.Mt3dAdv.load('test.adv', m)
```

write_file()

Write the package file

Return type
None

flopy.mt3d.mtbtn module

mtbtn module. Contains the Mt3dBtn class. Note that the user can access the Mt3dBtn class as *flopy.mt3d.Mt3dBtn*.

Additional information for this MT3DMS package can be found in the MT3DMS User's Manual.

class Mt3dBtn(*model*, *MFStyleArr=False*, *DRYCell=False*, *Legacy99Stor=False*, *FTLPrint=False*, *NoWetDryPrint=False*, *OmitDryBud=False*, *AltWTSorb=False*, *nlay=None*, *nrow=None*, *ncol=None*, *nper=None*, *ncomp=1*, *mcomp=1*, *tunit='D'*, *lunit='M'*, *munit='KG'*, *laycon=None*, *delr=None*, *delc=None*, *htop=None*, *dz=None*, *prsity=0.3*, *icbund=1*, *sconc=0.0*, *cinact=1e+30*, *thkmin=0.01*, *ifmtcn=0*, *ifmtnp=0*, *ifmtrf=0*, *ifmtdp=0*, *savucn=True*, *nprs=0*, *timprs=None*, *obs=None*, *nprobs=1*, *chkmas=True*, *nprmas=1*, *perlen=None*, *nstp=None*, *tsmult=None*, *ssflag=None*, *dt0=0*, *mxstrn=50000*, *ttsmult=1.0*, *ttsmax=0*, *species_names=None*, *extension='btn'*, *unitnumber=None*, *filenames=None*, ***kwargs*)

Bases: *Package*

Basic Transport Package Class.

Parameters

- **model** (*model object*) – The model object (of type flopy.mt3dms.mt.Mt3dms) to which this package will be added.
- **MFStyleArr** (*str*) – Specifies whether or not to read arrays using the MODFLOW array reader format or the original MT3DMS array reader
- **DRYCell** (*str*) – Specifies whether or not to route mass through dry cells. When MF-NWT is used to generate the flow-transport link file, this is a distinct possibility.
- **Legacy99Stor** (*str*) – Specifies whether or not to use the storage formulation used in MT3DMS
- **FTLPrint** (*str*) – Specifies if flow-transport link terms (cell-by-cell flows) should be echoed to the MT3D-USGS listing file.
- **NoWetDryPrint** (*str*) – Specifies whether or not to suppress wet/dry messaging in the MT3D-USGS listing file.
- **OmitDryBudg** (*str*) – Specifies whether or not to include the mass flux terms through dry cells in the mass budget written to the listing file.
- **AltWTSorb** (*str*) – Specifies whether or not to use the MT3DMS formulation (this keyword omitted) for the solid phase, whereby the entire cell thickness is available for interacting with the aqueous phase, even though the aqueous phase may only occupy a portion of the cell's thickness. When used, only the saturated portion of the cell is available for sorbing
- **ncomp** (*int*) – The total number of chemical species in the simulation. (default is None, will be changed to 1 if sconc is single value)
- **mcomp** (*int*) – The total number of 'mobile' species (default is 1). mcomp must be equal or less than ncomp.
- **tunit** (*str*) – The name of unit for time (default is 'D', for 'days'). Used for identification purposes only.
- **lunit** (*str*) – The name of unit for length (default is 'M', for 'meters'). Used for identification purposes only.

- **munit** (*str*) - The name of unit for mass (default is 'KG', for 'kilograms'). Used for identification purposes only.
- **prsity** (*float or array of floats (nlay, nrow, ncol)*) - The effective porosity of the porous medium in a single porosity system, or the mobile porosity in a dual-porosity medium (the immobile porosity is defined through the Chemical Reaction Package. (default is 0.25).
- **icbund** (*int or array of ints (nlay, nrow, ncol)*) - The icbund array specifies the boundary condition type for solute species (shared by all species). If icbund = 0, the cell is an inactive concentration cell; If icbund < 0, the cell is a constant-concentration cell; If icbund > 0, the cell is an active concentration cell where the concentration value will be calculated. (default is 1).
- **sconc** (*float, array of (nlay, nrow, ncol), or filename*) - sconc is the starting concentration for the first species. To specify starting concentrations for other species in a multi-species simulation, include additional keywords, such as sconc2, sconc3, and so forth.
- **cinact** (*float*) - The value for indicating an inactive concentration cell. (default is 1e30).
- **thkmin** (*float*) - The minimum saturated thickness in a cell, expressed as the decimal fraction of its thickness, below which the cell is considered inactive. (default is 0.01).
- **ifmtcn** (*int*) - A flag/format code indicating how the calculated concentration should be printed to the standard output text file. Format codes for printing are listed in Table 3 of the MT3DMS manual. If ifmtcn > 0 printing is in wrap form; ifmtcn < 0 printing is in strip form; if ifmtcn = 0 concentrations are not printed. (default is 0).
- **ifmtnp** (*int*) - A flag/format code indicating how the number of particles should be printed to the standard output text file. The convention is the same as for ifmtcn. (default is 0).
- **ifmtrf** (*int*) - A flag/format code indicating how the calculated retardation factor should be printed to the standard output text file. The convention is the same as for ifmtcn. (default is 0).
- **ifmtdp** (*int*) - A flag/format code indicating how the distance-weighted dispersion coefficient should be printed to the standard output text file. The convention is the same as for ifmtcn. (default is 0).
- **savucn** (*bool*) - A logical flag indicating whether the concentration solution should be saved in an unformatted file. (default is True).
- **nprs** (*int*) - A flag indicating (i) the frequency of the output and (ii) whether the output frequency is specified in terms of total elapsed simulation time or the transport step number. If nprs > 0 results will be saved at the times as specified in timprs; if nprs = 0, results will not be saved except at the end of simulation; if

NPRS < 0, simulation results will be saved whenever the number of transport steps is an even multiple of nprs. (default is 0).

- **timprs** (*list of floats*) - The total elapsed time at which the simulation results are saved. The number of entries in timprs must equal nprs. (default is None).
- **obs** (*array of int*) - An array with the cell indices (layer, row, column) for which the concentration is to be printed at every transport step. (default is None). obs indices must be entered as zero-based numbers as a 1 is added to them before writing to the btn file.
- **nprobs** (*int*) - An integer indicating how frequently the concentration at the specified observation points should be saved. (default is 1).
- **chkmas** (*bool*) - A logical flag indicating whether a one-line summary of mass balance information should be printed. (default is True).
- **nprmas** (*int*) - An integer indicating how frequently the mass budget information should be saved. (default is 1).
- **dt0** (*float*) - The user-specified initial transport step size within each time-step of the flow solution. (default is 0).
- **mxstrn** (*int*) - The maximum number of transport steps allowed within one time step of the flow solution. (default is 50000).
- **ttsmult** (*float*) - The multiplier for successive transport steps within a flow time-step if the GCG solver is used and the solution option for the advection term is the standard finite-difference method. (default is 1.0).
- **ttsmax** (*float*) - The maximum transport step size allowed when transport step size multiplier TTSMULT > 1.0. (default is 0).
- **species_names** (*list of str*) - A list of names for every species in the simulation.
- **extension** (*string*) - Filename extension (default is 'btn')
- **unitnumber** (*int*) - File unit number (default is None).
- **filenames** (*str or list of str*) - Filenames to use for the package. If filenames=None the package name will be created using the model name and package extension. If a single string is passed the package will be set to the string. Default is None.

Notes

Examples

```
>>> import flopy
>>> mt = flopy.mt3dms.Mt3dms()
>>> btn = flopy.mt3dms.Mt3dBtn(mt)
```

classmethod load(*f*, *model*, *ext_unit_dict=None*)

Load an existing package.

Parameters

- **f** (*filename or file handle*) – File to load.
- **model** (*model object*) – The model object (of type *flopy.mt3d.mt.Mt3dms*) to which this package will be added.
- **ext_unit_dict** (*dictionary, optional*) – If the arrays in the file are specified using EXTERNAL, or older style array control records, then *f* should be a file handle. In this case ext_unit_dict is required, which can be constructed using the function *flopy.utils.mfreadnam.parsenamefile*.

Returns
btn – Mt3dBtn object.

Return type
Mt3dBtn object

Examples

```
>>> import flopy
>>> mt = flopy.mt3d.Mt3dms()
>>> btn = flopy.mt3d.Mt3dBtn.load('test.btn', mt)
```

setmodflowvars(*nlay*, *nrow*, *ncol*, *nper*, *laycon*, *delr*, *delc*, *htop*, *dz*, *perlen*, *nstp*, *tsmult*)

Set these variables from the MODFLOW model, if it exists

write_file()

Write the package file

Return type
None

flopy.mt3d.mtcts module

class Mt3dCts

Bases: *Package*

MT3D-USGS Contaminant Treatment System package class

Parameters

- **model** (*model object*) – The model object (of type flopy.mt3dms.mt.Mt3dms) to which this package will be added.
- **mxcts** (*int*) – The maximum number of contaminant transport systems implemented in a simulation.
- **ictsout** (*int*) – The unit number on which well-by-well output information is written. The default file extension assigned to the output file is TSO
- **mxext** (*int*) – The maximum number of extraction wells specified as part of a contaminant treatment system
- **mxinj** (*int*) – The maximum number of injection wells specified as part of a contaminant treatment system
- **mxwel** (*int*) – The maximum number of wells in the flow model. MXWEL is recommended to be set equal to MXWEL as specified in the WEL file
- **iforce** (*int*) – A flag to force concentration in treatment systems to satisfy specified concentration/mass values based on the treatment option selected without considering whether treatment is necessary or not. This flag is ignored if 'no treatment' option is selected.

  0 Concentration for all injection wells is set to satisfy
  treatment levels only if blended concentration exceeds the desired concentration/mass level for a treatment system. If the blended concentration in a treatment system is less than the specified concentration/mass level, then injection wells inject water with blended concentrations.

  1 Concentration for all injection wells is forced to satisfy
  specified concentration/mass values.
- **ncts** (*int*) – The number of contaminant treatment systems. If NCTS >= 0, NCTS is the number of contaminant treatment systems. If NCTS = -1, treatment system information from the previous stress period is reused for the current stress period.
- **icts** (*int*) – The contaminant treatment system index number.
- **next** (*int*) – The number of extraction wells for the treatment system number ICTS.
- **ninj** (*int*) – The number of injection wells for the treatment system number ICTS.
- **itrtinj** (*int*) – Is the level of treatment provided for the treatment system number ICTS. Each treatment system blends concentration collected from all extraction wells contributing

to the treatment system and assigns a treated concentration to all injection wells associated with that treatment system based on the treatment option selected

> 0 no treatment is provided 1 same level of treatment is provided to all injection wells. 2 different level of treatment can be provided to each
>
> > individual injection well.

- **qincts** (*float*) - The external flow entering a treatment system. External flow may be flow entering a treatment system that is not a part of the model domain but plays an important role in influencing the blended concentration of a treatment system
- **cincts** (*float*) - The concentration with which the external flow enters a treatment system
- **ioptinj** (*int*) - Is a treatment option. Negative values indicate removal of concentration/mass and positive values indicate addition of concentration/mass.

  1 Percentage concentration/mass addition/removal is performed.
  Percentages must be specified as fractions. Example, for 50% concentration/mass removal is desired, -0.5 must be specified.

  2 Concentration is added/removed from the blended concentration.
  Specified concentration CMCHGINJ is added to the blended concentration. If the specified concentration removal, CMCHGINJ, is greater than the blended concentration, the treated concentration is set to zero.

  3 Mass is added/removed from the blended concentration.
  Specified mass CMCHGINJ is added to the blended concentration. If the specified mass removal, CMCHGINJ, is greater than the blended total mass, the treated concentration is set to zero.

  4 Specified concentration is set equal to the entered value
  CMCHGINJ. A positive value is expected for CMCHGINJ with this option.

- **cmchginj** (*float*) - Is the addition, removal, or specified concentration/mass values set for the treatment system. Concentration/mass is added, removed, or used as specified concentrations depending on the treatment option IOPTINJ. Note that concentration/mass values as specified by CMCHGINJ are enforced if the option IFORCE is set to 1. If IFORCE is set to 0, then CMCHGINJ is enforced only when the blended concentration exceeds the specified concentration CNTE.
- **cnte** (*float*) - The concentration that is not to be exceeded for a treatment system. Treatment is applied to blended concentration only if it exceeds CNTE, when IFORCE is set to 0.
- **kinj** (*int*) - Layer index for a CTS injection well
- **iinj** (*int*) - Row index for a CTS injection well

- **jinj** (*int*) - Column index for a CTS injection well
- **iwinj** (*int*) - The well index number. This number corresponds to the well number as it appears in the WEL file of the flow model.
- **qoutcts** (*float*) - the flow rate of outflow from a treatment system to an external sink. This flow rate must be specified to maintain an overall treatment system mass balance. QOUTCTS must be set equal to total inflow into a treatment system minus total outflow to all injection wells for a treatment system

Notes

Parameters are not supported in FloPy.

Examples

```
>>>
>>>
>>>
>>>
```

static get_default_CTS_dtype(*ncomp=1*, *iforce=0*)

Construct a dtype for the recarray containing the list of cts systems

classmethod load(*f*, *model*, *nlay=None*, *nrow=None*, *ncol=None*, *nper=None*, *ncomp=None*, *ext_unit_dict=None*)

Load an existing package.

Parameters

- **f** (*filename or file handle*) - File to load.
- **model** (*model object*) - The model object (of type *flopy.mt3d.mt.Mt3dms*) to which this package will be added.
- **ext_unit_dict** (*dictionary, optional*) - If the arrays in the file are specified using EXTERNAL, or older style array control records, then *f* should be a file handle. In this case ext_unit_dict is required, which can be constructed using the function *flopy.utils.mfreadnam.parsenamefile*.

Returns

cts - Mt3dCts object

Return type

Mt3dCts object

Examples

```
>>>
```

flopy.mt3d.mtdsp module

class Mt3dDsp(*model*, *al=0.01*, *trpt=0.1*, *trpv=0.01*, *dmcoef=1e-09*, *extension='dsp'*, *multiDiff=False*, *nocross=False*, *unitnumber=None*, *filenames=None*, ***kwargs*)

Bases: *Package*

MT3DMS Dispersion Package Class.

Parameters

- **model** (*model object*) – The model object (of type *flopy.mt3d.mt.Mt3dms*) to which this package will be added.
- **al** (*float or array of floats (nlay, nrow, ncol)*) – AL is the longitudinal dispersivity, for every cell of the model grid (unit, L). (default is 0.01)
- **trpt** (*float or array of floats (nlay)*) – s a 1D real array defining the ratio of the horizontal transverse dispersivity to the longitudinal dispersivity. Each value in the array corresponds to one model layer. Some recent field studies suggest that TRPT is generally not greater than 0.1. (default is 0.1)
- **trpv** (*float or array of floats (nlay)*) – is the ratio of the vertical transverse dispersivity to the longitudinal dispersivity. Each value in the array corresponds to one model layer. Some recent field studies suggest that TRPT is generally not greater than 0.01. Set TRPV equal to TRPT to use the standard isotropic dispersion model (Equation 10 in Chapter 2). Otherwise, the modified isotropic dispersion model is used (Equation 11 in Chapter 2). (default is 0.01)
- **dmcoef** (*float or array of floats (nlay) or (nlay, nrow, ncol) if the*) – multiDiff option is used. DMCOEF is the effective molecular diffusion coefficient (unit, L2T-1). Set DMCOEF = 0 if the effect of molecular diffusion is considered unimportant. Each value in the array corresponds to one model layer. The value for dmcoef applies only to species 1. See kwargs for entering dmcoef for other species. (default is 1.e-9).
- **multiDiff** (*boolean*) – To activate the component-dependent diffusion option, a keyword input record must be inserted to the beginning of the Dispersion (DSP) input file. The symbol $ in the first column of an input line signifies a keyword input record containing one or more predefined keywords. Above the keyword input record, comment lines marked by the symbol # in the first column are allowed. Comment lines are processed but have no effect on the simulation. Furthermore, blank lines are also acceptable above the keyword input record. Below the keyword input record, the format of the DSP input file must remain unchanged from the previous versions except for the diffusion coefficient as explained below. If no keyword input record is specified, the input file remains backward compatible with all

previous versions of MT3DMS. The predefined keyword for the component-dependent diffusion option is MultiDiffusion. The keyword is case insensitive so ‘’MultiDiffusion” is equivalent to either ‘’Multidiffusion” or ‘’multidiffusion”. If this keyword is specified in the keyword input record that has been inserted into the beginning of the DSP input file, the component-dependent diffusion option has been activated and the user needs to specify one diffusion coefficient for each mobile solute component and at each model cell. This is done by specifying one mobile component at a time, from the first component to the last component (MCOMP). For each mobile component, the real array reader utility (RARRAY) is used to input the 3-D diffusion coefficient array, one model layer at a time. (default is False)

- **nocross** (*boolean*) - To disable cross-dispersion terms, a keyword input record must be input record must be inserted to the beginning of the Dispersion (DSP) input file. The symbol $ in the first column of an input line signifies a keyword input record containing one or more predefined keywords. Above the keyword input record, comment lines marked by the symbol # in the first column are allowed. Comment lines are processed but have no effect on the simulation. Furthermore, blank lines are also acceptable above the keyword input record. Below the keyword input record, the format of the DSP input file must remain unchanged from the previous versions except for the diffusion coefficient as explained below. If no keyword input record is specified, the input file remains backward compatible with all previous versions of MT3DMS. The predefined keyword to turn off calculation of the cross- dispersion terms is ‘’nocross”. The keyword is case insensitive so ‘’Nocross” is equivalent to either ‘’NOCROSS” or ‘’nocross”. (default is False, which means cross-dispersion coefficients are calculated).
- **extension** (*string*) - Filename extension (default is ‘dsp’)
- **unitnumber** (*int*) - File unit number (default is None).
- **filenames** (*str or list of str*) - Filenames to use for the package. If filenames=None the package name will be created using the model name and package extension. If a single string is passed the package will be set to the string. Default is None.
- **kwargs** (*dictionary*) - If a multi-species simulation, then dmcoef values can be specified for other species as dmcoef2, dmcoef3, etc. For example: dmcoef1=1.e-10, dmcoef2=4.e-10, ... If a value is not specified, then dmcoef is set to 0.0.

Notes

Examples

```
>>> import flopy
>>> m = flopy.mt3d.Mt3dms()
>>> dsp = flopy.mt3d.Mt3dDsp(m)
```

classmethod load(*f*, *model*, *nlay=None*, *nrow=None*, *ncol=None*, *ext_unit_dict=None*)

Load an existing package.

Parameters

- **f** (*filename or file handle*) – File to load.
- **model** (*model object*) – The model object (of type *flopy.mt3d.mt.Mt3dms*) to which this package will be added.
- **nlay** (*int*) – number of model layers. If None it will be retrieved from the model.
- **nrow** (*int*) – number of model rows. If None it will be retrieved from the model.
- **ncol** (*int*) – number of model columns. If None it will be retrieved from the model.
- **ext_unit_dict** (*dictionary, optional*) – If the arrays in the file are specified using EXTERNAL, or older style array control records, then *f* should be a file handle. In this case ext_unit_dict is required, which can be constructed using the function *flopy.utils.mfreadnam.parsenamefile*.

Returns

dsk – Mt3dDsp object.

Return type

Mt3dDsp object

Examples

```
>>> import flopy
>>> mt = flopy.mt3d.Mt3dms()
>>> dsp = flopy.mt3d.Mt3dAdv.load('test.dsp', m)
```

write_file()

Write the package file

Return type

None

flopy.mt3d.mtgcg module

class Mt3dGcg(*model*, *mxiter=1*, *iter1=50*, *isolve=3*, *ncrs=0*, *accl=1*, *cclose=1e-05*, *iprgcg=0*, *extension='gcg'*, *unitnumber=None*, *filenames=None*)

Bases: *Package*

MT3DMS Generalized Conjugate Gradient Package Class.

Parameters

- **model** (*model object*) – The model object (of type *flopy.mt3d.mt.Mt3dms*) to which this package will be added.
- **mxiter** (*int*) – is the maximum number of outer iterations; it should be set to an integer greater than one only when a nonlinear sorption isotherm is included in simulation. (default is 1)
- **iter1** (*int*) – is the maximum number of inner iterations; a value of 30-50 should be adequate for most problems. (default is 50)
- **isolve** (*int*) – is the type of preconditioners to be used with the Lanczos/ORTHOMIN acceleration scheme: = 1, Jacobi = 2, SSOR = 3, Modified Incomplete Cholesky (MIC) (MIC usually converges faster, but it needs significantly more memory) (default is 3)
- **ncrs** (*int*) – is an integer flag for treatment of dispersion tensor cross terms: = 0, lump all dispersion cross terms to the right-hand-side (approximate but highly efficient). = 1, include full dispersion tensor (memory intensive). (default is 0)
- **accl** (*float*) – is the relaxation factor for the SSOR option; a value of 1.0 is generally adequate. (default is 1)
- **cclose** (*float*) – is the convergence criterion in terms of relative concentration; a real value between 10-4 and 10-6 is generally adequate. (default is 1.E-5)
- **iprgcg** (*int*) – IPRGCG is the interval for printing the maximum concentration changes of each iteration. Set IPRGCG to zero as default for printing at the end of each stress period. (default is 0)
- **extension** (*string*) – Filename extension (default is 'gcg')
- **unitnumber** (*int*) – File unit number (default is None).
- **filenames** (*str or list of str*) – Filenames to use for the package. If filenames=None the package name will be created using the model name and package extension. If a single string is passed the package will be set to the string. Default is None.

Notes

Examples

```
>>> import flopy
>>> m = flopy.mt3d.Mt3dms()
>>> gcg = flopy.mt3d.Mt3dGcg(m)
```

classmethod load(*f*, *model*, *ext_unit_dict=None*)

Load an existing package.

Parameters

- **f** (*filename or file handle*) – File to load.
- **model** (*model object*) – The model object (of type *flopy.mt3d.mt.Mt3dms*) to which this package will be added.
- **ext_unit_dict** (*dictionary, optional*) – If the arrays in the file are specified using EXTERNAL, or older style array control records, then *f* should be a file handle. In this case ext_unit_dict is required, which can be constructed using the function *flopy.utils.mfreadnam.parsenamefile*.

Returns
gcg – Mt3dGcg object.

Return type
Mt3dGcg object

Examples

```
>>> import flopy
>>> mt = flopy.mt3d.Mt3dms()
>>> gcg = flopy.mt3d.Mt3dGcg.load('test.gcg', m)
```

unitnumber = 35

write_file()

Write the package file

Return type
None

flopy.mt3d.mtlkt module

class Mt3dLkt(*model*, *nlkinit=0*, *mxlkbc=0*, *icbclk=None*, *ietlak=0*, *coldlak=0.0*, *lk_stress_period_data=None*, *dtype=None*, *extension='lkt'*, *unitnumber=None*, *filenames=None*, *iprn=-1*, ***kwargs*)

Bases: *Package*

MT3D-USGS LaKe Transport package class

Parameters

- **model** (*model object*) – The model object (of type flopy.mt3dms.mt.Mt3dms) to which this package will be added.

- **nlkinit** (*int*) - is equal to the number of simulated lakes as specified in the flow simulation
- **mxlkbc** (*int*) - must be greater than or equal to the sum total of boundary conditions applied to each lake
- **icbclk** (*int*) - is equal to the unit number on which lake-by-lake transport information will be printed. This unit number must appear in the NAM input file required for every MT3D-USGS simulation.
- **ietlak** (*int*) - specifies whether or not evaporation as simulated in the flow solution will act as a mass sink. = 0, Mass does not exit the model via simulated lake evaporation != 0, Mass may leave the lake via simulated lake evaporation
- **coldlak** (*array of floats*) - is a vector of real numbers representing the initial concentrations in the simulated lakes. The length of the vector is equal to the number of simulated lakes, NLKINIT. Initial lake concentrations should be in the same order as the lakes appearing in the LAK input file corresponding to the MODFLOW simulation.
- **ntmp** (*int*) - is an integer value corresponding to the number of specified lake boundary conditions to follow. For the first stress period, this value must be greater than or equal to zero, but may be less than zero in subsequent stress periods.
- **ilkbc** (*int*) - is the lake number for which the current boundary condition will be specified
- **ilkbctyp** (*int*) -

  specifies what the boundary condition type is for ilakbc

  1 a precipitation boundary. If precipitation directly to lakes
  is simulated in the flow model and a non-zero concentration (default is zero) is desired, use ISFBCTYP = 1;

  2 a runoff boundary condition that is not the same thing as
  runoff simulated in the UZF1 package and routed to a lake (or stream) using the IRNBND array. Users who specify runoff in the LAK input via the RNF variable appearing in record set 9a and want to assign a non-zero concentration (default is zero) associated with this specified source, use ISFBCTYP=2;

  3 a Pump boundary condition. Users who specify a withdrawal
  from a lake via the WTHDRW variable appearing in record set 9a and want to assign a non-zero concentration (default is zero) associated with this specified source, use ISFBCTYP=2;

  4 an evaporation boundary condition. In models where evaporation
  is simulated directly from the surface of the lake, users can use this boundary condition to specify a non-zero concentration (default is zero) associated with the evaporation losses.

- **extension** (*string*) - Filename extension (default is 'lkt')

- **unitnumber** (*int*) – File unit number (default is None).
- **filenames** (*str or list of str*) – Filenames to use for the package and the output files. If filenames=None the package name will be created using the model name and package extension and the lake output name will be created using the model name and lake concentration observation extension (for example, modflowtest.cbc and modflowtest.lkcobs.out), if icbclk is a number greater than zero. If a single string is passed the package will be set to the string and lake concentration observation output name will be created using the model name and .lkcobs.out extension, if icbclk is a number greater than zero. To define the names for all package files (input and output) the length of the list of strings should be 2. Default is None.

Notes

Parameters are not supported in FloPy.

Examples

```
>>> import flopy
>>> mt = flopy.mt3d.Mt3dms()
>>> lkt = flopy.mt3d.Mt3dLkt(mt)
```

static get_default_dtype(*ncomp=1*)

Construct a dtype for the recarray containing the list of boundary conditions interacting with the lake (i.e., pumps, specified runoff...)

classmethod load(*f, model, nlak=None, nper=None, ncomp=None, ext_unit_dict=None*)

Load an existing package.

Parameters

- **f** (*filename or file handle*) – File to load.
- **model** (*model object*) – The model object (of type *flopy.mt3d.mt.Mt3dms*) to which this package will be added.
- **nlak** (*int*) – number of lakes to be simulated
- **nper** (*int*) – number of stress periods
- **ncomp** (*int*) – number of species to be simulated
- **ext_unit_dict** (*dictionary, optional*) – If the arrays in the file are specified using EXTERNAL, or older style array control records, then *f* should be a file handle. In this case ext_unit_dict is required, which can be constructed using the function *flopy.utils.mfreadnam.parsenamefile*.

Returns

lkt – MT3D-USGS object.

Return type

MT3D-USGS object

Examples

```
>>> import flopy
>>> datadir = 'examples/data/mt3d_test/mfnwt_mt3dusgs/lkt'
>>> mt = flopy.mt3d.Mt3dms.load(
...     'lkt_mt.nam', exe_name='mt3d-usgs_1.0.00.exe',
...     model_ws=datadir, load_only='btn')
>>> lkt = flopy.mt3d.Mt3dLkt.load('test.lkt', mt)
```

write_file()

Write the package file

Return type
None

flopy.mt3d.mtphc module

class Mt3dPhc(*model*, *os=2*, *temp=25*, *asbin=0*, *eps_aqu=0*, *eps_ph=0*, *scr_output=1*, *cb_offset=0*, *smse=['pH', 'pe']*, *mine=[]*, *ie=[]*, *surf=[]*, *mobkin=[]*, *minkin=[]*, *surfkin=[]*, *imobkin=[]*, *extension='phc'*, *unitnumber=None*, *filenames=None*)

Bases: *Package*

PHC package class for PHT3D

unitnumber = 38

write_file()

Write the package file

Return type
None

flopy.mt3d.mtrct module

class Mt3dRct(*model*, *isothm=0*, *ireact=0*, *igetsc=1*, *rhob=None*, *prsity2=None*, *srconc=None*, *sp1=None*, *sp2=None*, *rc1=None*, *rc2=None*, *extension='rct'*, *unitnumber=None*, *filenames=None*, ***kwargs*)

Bases: *Package*

Chemical reaction package class.

Parameters

- **model** (*model object*) – The model object (of type flopy.mt3dms.mt.Mt3dms) to which this package will be added.
- **isothm** (*int*) – isothm is a flag indicating which type of sorption (or dual-domain mass transfer) is simulated: isothm = 0, no sorption is simulated; isothm = 1, linear isotherm (equilibrium-controlled); isothm = 2, Freundlich isotherm (equilibrium-controlled); isothm = 3, Langmuir isotherm (equilibrium-controlled); isothm = 4, first-order kinetic sorption (nonequilibrium); isothm = 5, dual-domain mass transfer (without sorption); isothm = 6, dual-domain mass transfer (with sorption). (default is 0).

- **ireact** (*int*) - ireact is a flag indicating which type of kinetic rate reaction is simulated: ireact = 0, no kinetic rate reaction is simulated; ireact = 1, first-order irreversible reaction, ireact = 100, zero-order reactions (decay or production). Note that this reaction package is not intended for modeling chemical reactions between species. An add-on reaction package developed specifically for that purpose may be used. (default is 0).
- **igetsc** (*int*) - igetsc is an integer flag indicating whether the initial concentration for the nonequilibrium sorbed or immobile phase of all species should be read when nonequilibrium sorption (isothm = 4) or dual-domain mass transfer (isothm = 5 or 6) is simulated: igetsc = 0, the initial concentration for the sorbed or immobile phase is not read. By default, the sorbed phase is assumed to be in equilibrium with the dissolved phase (isothm = 4), and the immobile domain is assumed to have zero concentration (isothm = 5 or 6). igetsc > 0, the initial concentration for the sorbed phase or immobile liquid phase of all species will be read. (default is 1).
- **rhob** (*float or array of floats (nlay, nrow, ncol)*) - rhob is the bulk density of the aquifer medium (unit, ML-3). rhob is used if isothm = 1, 2, 3, 4, or 6. If rhob is not user-specified and isothm is not 5 then rhob is set to 1.8e3. (default is None)
- **prsity2** (*float or array of floats (nlay, nrow, ncol)*) - prsity2 is the porosity of the immobile domain (the ratio of pore spaces filled with immobile fluids over the bulk volume of the aquifer medium) when the simulation is intended to represent a dual-domain system. prsity2 is used if isothm = 5 or 6. If prsity2 is not user- specified and isothm = 5 or 6 then prsity2 is set to 0.1. (default is None)
- **srconc** (*float or array of floats (nlay, nrow, ncol)*) - srconc is the user-specified initial concentration for the sorbed phase of the first species if isothm = 4 (unit, MM-1). Note that for equilibrium-controlled sorption, the initial concentration for the sorbed phase cannot be specified. srconc is the user-specified initial concentration of the first species for the immobile liquid phase if isothm = 5 or 6 (unit, ML-3). If srconc is not user-specified and isothm = 4, 5, or 6 then srconc is set to 0. (default is None).
- **sp1** (*float or array of floats (nlay, nrow, ncol)*) - sp1 is the first sorption parameter for the first species. The use of sp1 depends on the type of sorption selected (the value of isothm). For linear sorption (isothm = 1) and nonequilibrium sorption (isothm = 4), sp1 is the distribution coefficient (Kd) (unit, L3M-1). For Freundlich sorption (isothm = 2), sp1 is the Freundlich equilibrium constant (Kf) (the unit depends on the Freundlich exponent a). For Langmuir sorption (isothm = 3), sp1 is the Langmuir equilibrium constant (Kl) (unit, L3M-1). For dual-domain mass transfer without sorption (isothm = 5), sp1 is not used, but still must be entered. For dual-domain mass transfer with sorption (isothm = 6), sp1 is also the distribution coefficient (Kd) (unit, L3M-1). If sp1 is not specified and

isothm > 0 then sp1 is set to 0. (default is None).

- **sp2** (*float or array of floats (nlay, nrow, ncol)*) - sp2 is the second sorption or dual-domain model parameter for the first species. The use of sp2 depends on the type of sorption or dual-domain model selected. For linear sorption (isothm = 1), sp2 is read but not used. For Freundlich sorption (isothm = 2), sp2 is the Freundlich exponent a. For Langmuir sorption (isothm = 3), sp2 is the total concentration of the sorption sites available (S) (unit, MM-1). For nonequilibrium sorption (isothm = 4), sp2 is the first-order mass transfer rate between the dissolved and sorbed phases (unit, T-1). For dual-domain mass transfer (isothm = 5 or 6), sp2 is the first-order mass transfer rate between the two domains (unit, T-1). If sp2 is not specified and isothm > 0 then sp2 is set to 0. (default is None).
- **rc1** (*float or array of floats (nlay, nrow, ncol)*) - rc1 is the first-order reaction rate for the dissolved (liquid) phase for the first species (unit, T-1). rc1 is not used ireact = 0. If a dual-domain system is simulated, the reaction rates for the liquid phase in the mobile and immobile domains are assumed to be equal. If rc1 is not specified and ireact > 0 then rc1 is set to 0. (default is None).
- **rc2** (*float or array of floats (nlay, nrow, ncol)*) - rc2 is the first-order reaction rate for the sorbed phase for the first species (unit, T-1). rc2 is not used ireact = 0. If a dual-domain system is simulated, the reaction rates for the sorbed phase in the mobile and immobile domains are assumed to be equal. Generally, if the reaction is radioactive decay, rc2 should be set equal to rc1, while for biodegradation, rc2 may be different from rc1. Note that rc2 is read but not used, if no sorption is included in the simulation. If rc2 is not specified and ireact > 0 then rc2 is set to 0. (default is None).
- **extension** (*string*) - Filename extension (default is 'rct')
- **unitnumber** (*int*) -

  File unit number. If file unit number is None then an unused unit
  number if used. (default is None).
- **srconcn** (*float or array of floats (nlay, nrow, ncol)*) - srconcn is the user-specified initial concentration for the sorbed phase of species n. If srconcn is not passed as a **kwarg and isothm = 4, 5, or 6 then srconc for species n is set to 0. See description of srconc for a more complete description of srconcn.
- **sp1n** (*float or array of floats (nlay, nrow, ncol)*) - sp1n is the first sorption parameter for species n. If sp1n is not passed as a **kwarg and isothm > 0 then sp1 for species n is set to 0. See description of sp1 for a more complete description of sp1n.
- **sp2n** (*float or array of floats (nlay, nrow, ncol)*) - sp2n is the second sorption or dual-domain model parameter for species n. If sp2n is not passed as a **kwarg and isothm > 0 then sp2 for species n is set to 0. See description of sp2 for a more complete description of sp2n.

- **rc1n** (*float or array of floats (nlay, nrow, ncol)*) – rc1n is the first-order reaction rate for the dissolved (liquid) phase for species n. If rc1n is not passed as a **kwarg and ireact > 0 then rc1 for species n is set to 0. See description of rc1 for a more complete description of rc1n.
- **rc2n** (*float or array of floats (nlay, nrow, ncol)*) – rc2n is the first-order reaction rate for the sorbed phase for species n. If rc2n is not passed as a **kwarg and ireact > 0 then rc2 for species n is set to 0. See description of rc2 for a more complete description of rc2n.

Notes

Examples

```
>>> import flopy
>>> mt = flopy.mt3dms.Mt3dms()
>>> rct = flopy.mt3dms.Mt3dRct(mt)
```

classmethod load(*f*, *model*, *nlay=None*, *nrow=None*, *ncol=None*, *ncomp=None*, *ext_unit_dict=None*)

Load an existing package.

Parameters

- **f** (*filename or file handle*) – File to load.
- **model** (*model object*) – The model object (of type *flopy.mt3d.mt.Mt3dms*) to which this package will be added.
- **nlay** (*int*) – Number of model layers in the reaction package. If nlay is not specified, the number of layers in the passed model object is used. (default is None).
- **nrow** (*int*) – Number of model rows in the reaction package. If nrow is not specified, the number of rows in the passed model object is used. (default is None).
- **ncol** (*int*) – Number of model columns in the reaction package. If nlay is not specified, the number of columns in the passed model object is used. (default is None).
- **ext_unit_dict** (*dictionary, optional*) – If the arrays in the file are specified using EXTERNAL, or older style array control records, then *f* should be a file handle. In this case ext_unit_dict is required, which can be constructed using the function *flopy.utils.mfreadnam.parsenamefile*.

Returns

rct – Mt3dRct object.

Return type

Mt3dRct object

Examples

```
>>> import flopy
>>> mt = flopy.mt3d.Mt3dms()
>>> rct = flopy.mt3d.Mt3dRct.load('test.rct', mt)
```

write_file()

Write the package file

Return type
None

flopy.mt3d.mtsft module

class Mt3dSft(*model*, *nsfinit=0*, *mxsfbc=0*, *icbcsf=0*, *ioutobs=0*, *ietsfr=0*, *isfsolv=1*, *wimp=0.5*, *wups=1.0*, *cclosesf=1e-06*, *mxitersf=10*, *crntsf=1.0*, *iprtxmd=0*, *coldsf=0.0*, *dispsf=0.0*, *nobssf=0*, *obs_sf=None*, *sf_stress_period_data=None*, *unitnumber=None*, *filenames=None*, *dtype=None*, *extension='sft'*, ***kwargs*)

Bases: *Package*

MT3D-USGS StreamFlow Transport package class

Parameters

- **model** (*model object*) – The model object (of type flopy.mt3dms.mt.Mt3dms) to which this package will be added.
- **nsfinit** (*int*) – Is the number of simulated stream reaches (in SFR2, the number of stream reaches is greater than or equal to the number of stream segments). This is equal to NSTRM found on the first line of the SFR2 input file. If NSFINIT > 0 then surface-water transport is solved in the stream network while taking into account groundwater exchange and precipitation and evaporation sources and sinks. Otherwise, if NSFINIT < 0, the surface-water network as represented by the SFR2 flow package merely acts as a boundary condition to the groundwater transport problem; transport in the surface-water network is not simulated.
- **mxsfbc** (*int*) – Is the maximum number of stream boundary conditions.
- **icbcsf** (*int*) – Is an integer value that directs MT3D-USGS to write reach-by-reach concentration information to unit ICBCSF.
- **ioutobs** (*int*) – Is the unit number of the output file for simulated concentrations at specified gage locations. The NAM file must also list the unit number to which observation information will be written.
- **ietsfr** (*int*) – Specifies whether or not mass will exit the surface-water network with simulated evaporation. If IETSFR = 0, then mass does not leave via stream evaporation. If IETSFR > 0, then mass is allowed to exit the simulation with the simulated evaporation.
- **isfsolv** (*int*) – Specifies the numerical technique that will be used to solve the transport problem in the surface water network. The first release of MT3D-USGS (version 1.0) only allows for

a finite-difference formulation and regardless of what value the user specifies, the variable defaults to 1, meaning the finite-difference solution is invoked.

- **wimp** (*float*) - Is the stream solver time weighting factor. Ranges between 0.0 and 1.0. Values of 0.0, 0.5, or 1.0 correspond to explicit, Crank-Nicolson, and fully implicit schemes, respectively.
- **wups** (*float*) - Is the space weighting factor employed in the stream network solver. Ranges between 0.0 and 1.0. Values of 0.0 and 1.0 correspond to a central-in-space and upstream weighting factors, respectively.
- **cclosesf** (*float*) - Is the closure criterion for the SFT solver
- **mxitersf** (*int*) - Limits the maximum number of iterations the SFT solver can use to find a solution of the stream transport problem.
- **crntsf** (*float*) - Is the Courant constraint specific to the SFT time step, its value has no bearing upon the groundwater transport solution time step.
- **iprtxmd** (*int*) - A flag to print SFT solution information to the standard output file. IPRTXMD = 0 means no SFT solution information is printed; IPRTXMD = 1 means SFT solution summary information is printed at the end of every MT3D-USGS outer iteration; and IPRTXMD = 2 means SFT solution details are written for each SFT outer iteration that calls the xMD solver that solved SFT equations.
- **coldsf** (*array of floats*) - Represents the initial concentrations in the surface water network. The length of the array is equal to the number of stream reaches and starting concentration values should be entered in the same order that individual reaches are entered for record set 2 in the SFR2 input file. To specify starting concentrations for other species in a multi-species simulation, include additional keywords, such as coldsf2, coldsf3, and so forth.
- **dispsf** (*array of floats*) - Is the dispersion coefficient [L2 T-1] for each stream reach in the simulation and can vary for each simulated component of the simulation. That is, the length of the array is equal to the number of simulated stream reaches times the number of simulated components. Values of dispersion for each reach should be entered in the same order that individual reaches are entered for record set 2 in the SFR2 input file. To specify dispsf for other species in a multi-species simulation, include additional keywords, such as dispsf2, dispsf3, and so forth.
- **nobssf** (*int*) - Specifies the number of surface flow observation points for monitoring simulated concentrations in streams.
- **isobs** (*int*) - The segment number for each stream flow concentration observation point.
- **irobs** (*int*) - The reach number for each stream flow concentration observation point.

- **ntmp** (*int*) - The number of specified stream boundary conditions to follow. For the first stress period, this value must be greater than or equal to zero, but may be less than zero in subsequent stress periods.
- **isegbc** (*int*) - Is the segment number for which the current boundary condition will be applied.
- **irchbc** (*int*) - Is the reach number for which the current boundary condition will be applied.
- **isfbctyp** (*int*) -

  Specifies, for ISEGBC/IRCHBC, what the boundary condition type is

  0 A headwater boundary. That is, for streams entering at the
  boundary of the simulated domain that need a specified concentration, use ISFBCTYP = 0

  1 a precipitation boundary. If precipitation directly to
  channels is simulated in the flow model and a non-zero concentration (default is zero) is desired, use ISFBCTYP = 1

  2 a runoff boundary condition that is not the same thing as
  runoff simulated in the UZF1 package and routed to a stream (or lake) using the IRNBND array. Users who specify runoff in the SFR2 input via the RUNOFF variable appearing in either record sets 4b or 6a and want to assign a non-zero concentration (default is zero) associated with this specified source, use ISFBCTYP=2;

  3 a constant-concentration boundary. Any ISEGBC/IRCHBC
  combination may set equal to a constant concentration boundary condition.

  4 a pumping boundary condition. 5 an evaporation boundary condition. In models where

  evaporation is simulated directly from the surface of the channel, users can use this boundary condition to specify a non-zero concentration (default is zero) associated with the evaporation losses.

- **cbcsf** (*float*) - Is the specified concentration associated with the current boundary condition entry. Repeat CBCSF for each simulated species (NCOMP).
- **extension** (*string*) - Filename extension (default is 'sft')
- **unitnumber** (*int*) - File unit number (default is None).
- **filenames** (*str or list of str*) - Filenames to use for the package and the output files. If filenames=None the package name will be created using the model name and package extension and the sfr output name will be created using the model name and lake concentration observation extension (for example, modflowtest.cbc and modflowtest.sftcobs.out), if ioutobs is a number greater than zero. If a single string is passed the package will be set to the string and sfr concentration observation output name will be created using the model name and .sftcobs.out extension, if

ioutobs is a number greater than zero. To define the names for all package files (input and output) the length of the list of strings should be 2. Default is None.

Notes

Parameters are not supported in FloPy.

Examples

```
>>> import flopy
>>> datadir = 'examples/data/mt3d_test/mfnwt_mt3dusgs/sft_crnkNic'
>>> mf = flopy.modflow.Modflow.load(
...     'CrnkNic.nam', model_ws=datadir, load_only=['dis', 'bas6'])
>>> sfr = flopy.modflow.ModflowSfr2.load('CrnkNic.sfr2', mf)
>>> chk = sfr.check()
>>> # initialize an MT3D-USGS model
>>> mt = flopy.mt3d.Mt3dms.load(
...     'CrnkNic.mtnam', exe_name='mt3d-usgs_1.0.00.exe',
>>>     model_ws=datadir, load_only='btn')
>>> sft = flopy.mt3d.Mt3dSft.load(mt, 'CrnkNic.sft')
```

static get_default_dtype(*ncomp=1*)

Construct a dtype for the recarray containing the list of surface water boundary conditions.

classmethod load(*f*, *model*, *nsfinit=None*, *nper=None*, *ncomp=None*, *ext_unit_dict=None*)

Load an existing package.

Parameters

- **f** (*filename or file handle*) – File to load.
- **model** (*model object*) – The model object (of type *flopy.mt3d.mt.Mt3dms*) to which this package will be added.
- **nsfinit** (*int*) – number of simulated stream reaches in the surface-water transport process.
- **isfsolv** (*int*) – Specifies the numerical technique that will be used to solve the transport problem in the surface water network. The first release of MT3D-USGS (version 1.0) only allows for a finite-difference formulation and regardless of what value the user specifies, the variable defaults to 1, meaning the finite-difference solution is invoked.
- **wimp** (*float*) – Is the stream solver time weighting factor. Ranges between 0.0 and 1.0. Values of 0.0, 0.5, or 1.0 correspond to explicit, Crank-Nicolson, and fully implicit schemes, respectively.
- **wups** (*float*) – Is the space weighting factor employed in the stream network solver. Ranges between 0.0 and 1.0. Values of 0.0 and 1.0 correspond to a central-in-space and upstream weighting factors, respectively.

- **cclosesf** (*float*) - Is the closure criterion for the SFT solver
- **mxitersf** (*int*) - Limits the maximum number of iterations the SFT solver can use to find a solution of the stream transport problem.
- **crntsf** (*float*) - Is the Courant constraint specific to the SFT time step, its value has no bearing upon the groundwater transport solution time step.
- **iprtxmd** (*int*) - a flag to print SFT solution information to the standard output file. IPRTXMD can equal 0, 1, or 2, and will write increasing amounts of solver information to the standard output file, respectively.

Returns
sft - MT3D-USGS object

Return type
MT3D-USGS object

Examples

```
>>> import os
>>> import flopy
>>> mf = flopy.modflow.Modflow.load('CrnkNic_mf.nam',
...                                 load_only=['dis', 'bas6'])
>>> sfr = flopy.modflow.ModflowSfr2.load('CrnkNic.sfr2', mf)
>>> mt = flopy.mt3d.Mt3dms.load('CrnkNic_mt.nam', load_only='btn')
>>> sft = flopy.mt3d.Mt3dSft.load('CrnkNic.sft', mt)
```

write_file()

Write the package file

Return type
None

Examples

```
>>> import flopy
>>> datadir = .examples/data/mt3d_test/mfnwt_mt3dusgs/sft_crnkNic
>>> mt = flopy.mt3d.Mt3dms.load(
...     'CrnkNic.mtnam', exe_name='mt3d-usgs_1.0.00.exe',
...     model_ws=datadir, verbose=True)
>>> mt.name = 'CrnkNic_rewrite'
>>> mt.sft.dispsf.fmtin = '(10F12.2)'
>>> mt.write_input()
```

flopy.mt3d.mtssm module

class Mt3dSsm(*model*, *crch=None*, *cevt=None*, *mxss=None*, *stress_period_data=None*, *dtype=None*, *extension='ssm'*, *unitnumber=None*, *filenames=None*, ***kwargs*)

Bases: *Package*

MT3DMS Source and Sink Mixing Package Class.

Parameters

- **model** (*model object*) – The model object (of type *flopy.mt3d.mt.Mt3dms*) to which this package will be added.
- **crch** (Transient2d, *scalar*, *array of floats*, *or dictionary*) – CRCH is the concentration of recharge for species 1. If the recharge flux is positive, it acts as a source whose concentration can be specified as desired. If the recharge flux is negative, it acts as a sink (discharge) whose concentration is always set equal to the concentration of groundwater at the cell where discharge occurs. Note that the location and flow rate of recharge/discharge are obtained from the flow model directly through the unformatted flow-transport link file. crch can be specified as an array, if the array is constant for the entire simulation. If crch changes by stress period, then the user must provide a dictionary, where the key is the stress period number (zero based) and the value is the recharge array. The recharge concentration can be specified for additional species by passing additional arguments to the Mt3dSsm constructor. For example, to specify the recharge concentration for species two one could use crch2={0: 0., 1: 10*np.ones((nrow, ncol), dtype=float)} as and additional keyword argument that is passed to Mt3dSsm when making the ssm object.
- **cevt** (Transient2d, *scalar*, *array of floats*, *or dictionary*) – is the concentration of evapotranspiration flux for species 1. Evapotranspiration is the only type of sink whose concentration may be specified externally. Note that the concentration of a sink cannot be greater than that of the aquifer at the sink cell. Thus, if the sink concentration is specified greater than that of the aquifer, it is automatically set equal to the concentration of the aquifer. Also note that the location and flow rate of evapotranspiration are obtained from the flow model directly through the unformatted flow-transport link file. For multi-species simulations, see crch for a description of how to specify additional concentrations arrays for each species.
- **stress_period_data** (*dictionary*) – Keys in the dictionary are stress zero-based stress period numbers; values in the dictionary are recarrays of SSM boundaries. The dtype for the recarray can be obtained using ssm.dtype (after the ssm package has been created). The default dtype for the recarray is np.dtype([('k', int), ("i", int), ("j", int), ("css", np.float32), ("itype", int), ((cssms(n), float), n=1, ncomp)]) If there are more than one component species, then additional entries will be added to the dtype as indicated by cssm(n). Note that if the number of dictionary entries is less than the number of stress periods, then the last recarray of boundaries will apply until the end

of the simulation. Full details of all options to specify stress_period_data can be found in the flopy3_multi-component_SSM ipython notebook in the Notebook subdirectory of the examples directory. css is the specified source concentration or mass-loading rate, depending on the value of ITYPE, in a single-species simulation, (For a multispecies simulation, CSS is not used, but a dummy value still needs to be entered here.) Note that for most types of sources, CSS is interpreted as the source concentration with the unit of mass per unit volume (ML-3), which, when multiplied by its corresponding flow rate (L3T-1) from the flow model, yields the mass-loading rate (MT-1) of the source. For a special type of sources (ITYPE = 15), CSS is taken directly as the mass-loading rate (MT-1) of the source so that no flow rate is required from the flow model. Furthermore, if the source is specified as a constant-concentration cell (itype = -1), the specified value of CSS is assigned directly as the concentration of the designated cell. If the designated cell is also associated with a sink/source term in the flow model, the flow rate is not used. itype is an integer indicating the type of the point source. An itype dictionary can be retrieved from the ssm object as itype = mt3d.Mt3dSsm.itype_dict() (CSSMS(n), n=1, NCOMP) defines the concentrations of a point source for multispecies simulation with NCOMP>1. In a multispecies simulation, it is necessary to define the concentrations of all species associated with a point source. As an example, if a chemical of a certain species is injected into a multispecies system, the concentration of that species is assigned a value greater than zero while the concentrations of all other species are assigned zero. CSSMS(n) can be entered in free format, separated by a comma or space between values. Several important notes on assigning concentration for the constant-concentration condition (ITYPE = -1) are listed below: The constant-concentration condition defined in this input file takes precedence to that defined in the Basic Transport Package input file. In a multiple stress period simulation, a constant-concentration cell, once defined, will remain a constant- concentration cell in the duration of the simulation, but its concentration value can be specified to vary in different stress periods. In a multispecies simulation, if it is only necessary to define different constant-concentration conditions for selected species at the same cell location, specify the desired concentrations for those species, and assign a negative value for all other species. The negative value is a flag used by MT3DMS to skip assigning the constant-concentration condition for the designated species.

- **dtype** (*np.dtype*) - dtype to use for the recarray of boundaries. If left as None (the default) then the dtype will be automatically constructed.
- **extension** (*string*) - Filename extension (default is 'ssm')
- **unitnumber** (*int*) - File unit number (default is None).
- **filenames** (*str or list of str*) - Filenames to use for the package. If filenames=None the package name will be created using the model name and package extension. If a single string

is passed the package will be set to the string. Default is None.

Notes

Examples

```
>>> import flopy
>>> m = flopy.mt3d.Mt3dms()
>>> itype = mt3d.Mt3dSsm.itype_dict()
>>> ssm_data = {}
>>> ssm_data[0] = [(4, 4, 4, 1.0, itype['GHB'], 1.0, 100.0)]
>>> ssm_data[5] = [(4, 4, 4, 0.5, itype['GHB'], 0.5, 200.0)]
>>> ssm = flopy.mt3d.Mt3dSsm(m, stress_period_data=ssm_data)
```

from_package(*package*, *ncomp_aux_names*)

read the point source and sink info from a package ncomp_aux_names (list): the aux variable names in the package that are the component concentrations

static get_default_dtype(*ncomp=1*)

Construct a dtype for the recarray containing the list of sources and sinks

static itype_dict()

classmethod load(*f*, *model*, *nlay=None*, *nrow=None*, *ncol=None*, *nper=None*, *ncomp=None*, *ext_unit_dict=None*)

Load an existing package.

Parameters

- **f** (*filename or file handle*) – File to load.
- **model** (*model object*) – The model object (of type *flopy.mt3d.mt.Mt3dms*) to which this package will be added.
- **ext_unit_dict** (*dictionary, optional*) – If the arrays in the file are specified using EXTERNAL, or older style array control records, then *f* should be a file handle. In this case ext_unit_dict is required, which can be constructed using the function *flopy.utils.mfreadnam.parsenamefile*.

Returns

ssm – Mt3dSsm object.

Return type

Mt3dSsm object

Examples

```
>>> import flopy
>>> mt = flopy.mt3d.Mt3dms()
>>> ssm = flopy.mt3d.Mt3dSsm.load('test.ssm', mt)
```

write_file()

Write the package file

Return type
None

class SsmPackage(*label=''*, *instance=None*, *needTFstr=False*)

Bases: object

flopy.mt3d.mttob module

class Mt3dTob(*model*, *outnam='tob_output'*, *CScale=1.0*, *FluxGroups=[]*, *FScale=1.0*, *iOutFlux=0*, *extension='tob'*, *unitnumber=None*, *filenames=None*)

Bases: *Package*

Transport Observation package class

write_file()

Write the package file

Return type
None

flopy.mt3d.mtuzt module

class Mt3dUzt(*model*, *icbcuz=None*, *iet=0*, *iuzfbnd=None*, *cuzinf=None*, *cuzet=None*, *cgwet=None*, *extension='uzt'*, *unitnumber=None*, *filenames=None*, ***kwargs*)

Bases: *Package*

MT3D-USGS Unsaturated-Zone Transport package class

Parameters

- **model** (*model object*) – The model object (of type flopy.mt3dms.mt.Mt3dms) to which this package will be added.
- **icbcuz** (*int*) – Is the unit number to which unsaturated-zone concentration will be written out.
- **iet** (*int*) – Is a flag that indicates whether or not ET is being simulated in the UZF1 flow package (=0 indicates that ET is not being simulated). If ET is not being simulated, IET informs FMI package not to look for UZET and GWET arrays in the flow-transport link file.
- **iuzfbnd** (*array of ints*) – Specifies which row/column indices variably-saturated transport will be simulated in.

  >0 indicates variably-saturated transport will be simulated; =0 indicates variably-saturated transport will not be simulated; <0 Corresponds to IUZFBND < 0 in the UZF1 input package, meaning

    that user-supplied values for FINF are specified recharge and therefore transport through the unsaturated zone is not simulated.

- **incuzinf** (*int*) – (This value is repeated for each stress period as explained next) A flag indicating whether an array containing the concentration of infiltrating water (FINF) for each simulated species (ncomp) will be read for the current stress period.

If INCUZINF >= 0, an array containing the concentration of infiltrating flux for each species will be read. If INCUZINF < 0, the concentration of infiltrating flux will be reused from the previous stress period. If INCUZINF < 0 is specified for the first stress period, then by default the concentration of positive infiltrating flux (source) is set equal to zero. There is no possibility of a negative infiltration flux being specified. If infiltrating water is rejected due to an infiltration rate exceeding the vertical hydraulic conductivity, or because saturation is reached in the unsaturated zone and the water table is therefore at land surface, the concentration of the runoff will be equal to CUZINF specified next. The runoff is routed if IRNBND is specified in the MODFLOW simulation.

- **cuzinf** (*array of floats*) - Is the concentration of the infiltrating flux for a particular species. An array for each species will be read.
- **incuzet** (*int*) - (This value is repeated for each stress period as explained next) A flag indicating whether an array containing the concentration of evapotranspiration flux originating from the unsaturated zone will be read for the current stress period. If INCUZET >= 0, an array containing the concentration of evapotranspiration flux originating from the unsaturated zone for each species will be read. If INCUZET < 0, the concentration of evapotranspiration flux for each species will be reused from the last stress period. If INCUZET < 0 is specified for the first stress period, then by default, the concentration of negative evapotranspiration flux (sink) is set equal to the aquifer concentration, while the concentration of positive evapotranspiration flux (source) is set to zero.
- **cuzet** (*array of floats*) - Is the concentration of ET fluxes originating from the unsaturated zone. As a default, this array is set equal to 0 and only overridden if the user specifies INCUZET > 1. If empirical evidence suggest volatilization of simulated constituents from the unsaturated zone, this may be one mechanism for simulating this process, though it would depend on the amount of simulated ET originating from the unsaturated zone. An array for each species will be read.
- **incgwet** (*int*) - (This value is repeated for each stress period as explained next) Is a flag indicating whether an array containing the concentration of evapotranspiration flux originating from the saturated zone will be read for the current stress period. If INCGWET >= 0, an array containing the concentration of evapotranspiration flux originating from the saturated zone for each species will be read. If INCGWET < 0, the concentration of evapotranspiration flux for each species will be reused from the last stress period. If INCUZET < 0 is specified for the first stress period, then by default, the concentration of negative evapotranspiration flux (sink) is set to the aquifer concentration, while the concentration of positive evapotranspiration flux (source) is set to zero.
- **cgwet** (*array of floats*) - Is the concentration of ET fluxes

originating from the saturated zone. As a default, this array is set equal to 0 and only overridden if the user specifies INCUZET > 1. An array for each species will be read.

- **extension** (*string*) – Filename extension (default is 'uzt')
- **unitnumber** (*int*) – File unit number (default is None).
- **filenames** (*str or list of str*) – Filenames to use for the package and the output files. If filenames=None the package name will be created using the model name and package extension and the uzf output name will be created using the model name and uzf concentration observation extension (for example, modflowtest.cbc and modflowtest.uzcobs.out), if icbcuz is a number greater than zero. If a single string is passed the package will be set to the string and uzf concentration observation output name will be created using the model name and .uzcobs.out extension, if icbcuz is a number greater than zero. To define the names for all package files (input and output) the length of the list of strings should be 2. Default is None.

Notes

Parameters are not supported in FloPy.

Examples

```
>>> import flopy
>>> datadir = 'examples/data/mt3d_test/mfnwt_mt3dusgs/keat_uzf'
>>> mt = flopy.mt3d.Mt3dms.load(
...     'Keat_UZF_mt.nam', exe_name='mt3d-usgs_1.0.00.exe',
...     model_ws=datadir, load_only='btn')
>>> uzt = flopy.mt3d.Mt3dUzt('Keat_UZF.uzt', mt)
```

classmethod load(*f*, *model*, *nlay=None*, *nrow=None*, *ncol=None*, *nper=None*, *ncomp=None*, *ext_unit_dict=None*)

Load an existing package.

Parameters

- **f** (*filename or file handle*) – File to load.
- **model** (*model object*) – The model object (of type *flopy.mt3d.mt.Mt3dms*) to which this package will be added.
- **ext_unit_dict** (*dictionary, optional*) – If the arrays in the file are specified using EXTERNAL, or older style array control records, then *f* should be a file handle. In this case ext_unit_dict is required, which can be constructed using the function *flopy.utils.mfreadnam.parsenamefile*.

Returns

uzt – Mt3dUzt object.

Return type

Mt3dSsm object

Examples

```
>>> import flopy
>>> mt = flopy.mt3d.Mt3dms()
>>> uzt = flopy.mt3d.Mt3dUzt.load('test.uzt', mt)
```

write_file()

Write the package file

Return type
None

12.2.4 SEAWAT Packages

Contents:

flopy.seawat.swt module

class Seawat(*modelname='swttest', namefile_ext='nam', modflowmodel=None, mt3dmodel=None, version='seawat', exe_name='swtv4', structured=True, listunit=2, model_ws='.', external_path=None, verbose=False, load=True, silent=0*)

Bases: *BaseModel*

SEAWAT Model Class.

Parameters

- **modelname** (*str, default "swttest"*) – Name of model. This string will be used to name the SEAWAT input that are created with write_model.
- **namefile_ext** (*str, default "nam"*) – Extension for the namefile.
- **modflowmodel** (Modflow, *default None*) – Instance of a Modflow object.
- **mt3dmodel** (Mt3dms, *default None*) – Instance of a Mt3dms object.
- **version** (*str, default "seawat"*) – Version of SEAWAT to use. Valid versions are "seawat" (default).
- **exe_name** (*str, default "swtv4"*) – The name of the executable to use.
- **structured** (*bool, default True*) – Specify if model grid is structured (default) or unstructured.
- **listunit** (*int, default 2*) – Unit number for the list file.
- **model_ws** (*str, default "."*) – Model workspace. Directory name to create model data sets. Default is the present working directory.
- **external_path** (*str, optional*) – Location for external files.
- **verbose** (*bool, default False*) – Print additional information to the screen.
- **load** (*bool, default True*) – Load model.
- **silent** (*int, default 0*) – Silent option.

Notes

Examples

```
>>> import flopy
>>> m = flopy.seawat.swt.Seawat()
```

change_model_ws(*new_pth=None*, *reset_external=False*)

Change the model work space.

Parameters

new_pth (*str or PathLike*) – Path of the new model workspace. If this path does not exist, it will be created. If no value (None) is given, the default is the present working directory.

Returns

val – Can be used to see what packages are in the model, and can then be used with get_package to pull out individual packages.

Return type

list of strings

get_ifrefm()

get_nrow_ncol_nlay_nper()

classmethod load(*f: str*, *version='seawat'*, *exe_name: str | PathLike = 'swtv4'*, *verbose=False*, *model_ws: str | PathLike = '.'*, *load_only=None*)

Load an existing model.

Parameters

- **f** (*str*) – Name of SEAWAT name file to load.
- **version** (*str, default "seawat"*) – Version of SEAWAT to use. Valid versions are "seawat" (default).
- **exe_name** (*str, default "swtv4"*) – The name of the executable to use.
- **verbose** (*bool, default False*) – Print additional information to the screen.
- **model_ws** (*str or PathLike, default "."*) – Model workspace. Directory to create model data sets. Default is the present working directory.
- **load_only** (*list of str, optional*) – Packages to load (e.g. ["lpf", "adv"]). Default None means that all packages will be loaded.

Return type

flopy.seawat.swt.Seawat

Examples

```
>>> import flopy
>>> m = flopy.seawat.swt.Seawat.load(f)
```

property mcomp

property modelgrid

property modeltime

property ncol

property ncomp

property nlay

property nper

property nrow

property nrow_ncol_nlay_nper

write_name_file()

Write the name file

Return type
None

class SeawatList(*model*, *extension='list'*, *listunit=7*)

Bases: *Package*

List Package class

write_file()

Every Package needs its own write_file function

flopy.seawat.swtvdf module

class SeawatVdf(*model*, *mtdnconc=1*, *mfnadvfd=1*, *nswtcpl=1*, *iwtable=1*, *densemin=0*, *densemax=0*, *dnscrit=0.01*, *denseref=1.0*, *denseslp=0.025*, *crhoref=0*, *firstdt=0.001*, *indense=1*, *dense=1.0*, *nsrhoeos=1*, *drhodprhd=0.00446*, *prhdref=0.0*, *extension='vdf'*, *unitnumber=None*, *filenames=None*, ***kwargs*)

Bases: *Package*

SEAWAT Variable-Density Flow Package Class.

Parameters

- **model** (*model object*) – The model object (of type *flopy.seawat.swt.Seawat*) to which this package will be added.
- **mt3drhoflg)** (*mtdnconc (or)* – is the MT3DMS species number that will be used in the equation of state to compute fluid density. This input variable was formerly referred to as MTDNCONC (Langevin and others, 2003). If MT3DRHOFLG = 0, fluid density is specified using items 6 and 7, and flow will be uncoupled with transport if the IMT Process is active. If MT3DRHOFLG > 0, fluid density is calculated using the MT3DMS species number that corresponds with

MT3DRHOFLG. A value for MT3DRHOFLG greater than zero indicates that flow will be coupled with transport. If MT3DRHOFLG = -1, fluid density is calculated using one or more MT3DMS species. Items 4a, 4b, and 4c will be read instead of item 4. The dependence of fluid density on pressure head can only be activated when MT3DRHOFLG = -1. A value for MT3DRHOFLG of -1 indicates that flow will be coupled with transport.

- **mfnadvfd** (*int*) - is a flag that determines the method for calculating the internodal density values used to conserve fluid mass. If MFNADVFD = 2, internodal conductance values used to conserve fluid mass are calculated using a central-in-space algorithm. If MFNADVFD <> 2, internodal conductance values used to conserve fluid mass are calculated using an upstream-weighted algorithm.
- **nswtcpl** (*int*) - is a flag used to determine the flow and transport coupling procedure. If NSWTCPL = 0 or 1, flow and transport will be explicitly coupled using a one-timestep lag. The explicit coupling option is normally much faster than the iterative option and is recommended for most applications. If NSWTCPL > 1, NSWTCPL is the maximum number of non-linear coupling iterations for the flow and transport solutions. SEAWAT-2000 will stop execution after NSWTCPL iterations if convergence between flow and transport has not occurred. If NSWTCPL = -1, the flow solution will be recalculated only for: The first transport step of the simulation, or The last transport step of the MODFLOW timestep, or The maximum density change at a cell is greater than DNSCRIT.
- **iwtable** (*int*) - is a flag used to activate the variable-density water-table corrections (Guo and Langevin, 2002, eq. 82). If IWTABLE = 0, the water-table correction will not be applied. If IWTABLE > 0, the water-table correction will be applied.
- **densemin** (*float*) - is the minimum fluid density. If the resulting density value calculated with the equation of state is less than DENSEMIN, the density value is set to DENSEMIN. If DENSEMIN = 0, the computed fluid density is not limited by DENSEMIN (this is the option to use for most simulations). If DENSEMIN > 0, a computed fluid density less than DENSEMIN is automatically reset to DENSEMIN.
- **densemax** (*float*) - is the maximum fluid density. If the resulting density value calculated with the equation of state is greater than DENSEMAX, the density value is set to DENSEMAX. If DENSEMAX = 0, the computed fluid density is not limited by DENSEMAX (this is the option to use for most simulations). If DENSEMAX > 0, a computed fluid density larger than DENSEMAX is automatically reset to DENSEMAX.
- **dnscrit** (*float*) - is a user-specified density value. If NSWTCPL is greater than 1, DNSCRIT is the convergence crite- rion, in units of fluid density, for convergence between flow and transport. If the maximum fluid density difference between two consecutive implicit coupling iterations is not less than DNSCRIT, the program will continue to iterate on the flow and transport equations, or will terminate if NSWTCPL is reached. If NSWTCPL

is -1, DNSCRIT is the maximum density threshold, in units of fluid density. If the fluid density change (between the present transport timestep and the last flow solution) at one or more cells is greater than DNSCRIT, then SEAWAT_V4 will update the flow field (by solving the flow equation with the updated density field).

- **denseref** (*float*) - is the fluid density at the reference concentration, temperature, and pressure. For most simulations, DENSEREF is specified as the density of freshwater at 25 degrees C and at a reference pressure of zero.
- **drhodc** (*float*) - formerly referred to as DENSESLP (Langevin and others, 2003), is the slope of the linear equation of state that relates fluid density to solute concentration. In SEAWAT_V4, separate values for DRHODC can be entered for as many MT3DMS species as desired. If DRHODC is not specified for a species, then that species does not affect fluid density. Any measurement unit can be used for solute concentration, provided DENSEREF and DRHODC are set properly. DRHODC can be approximated by the user by dividing the density difference over the range of end- member fluids by the difference in concentration between the end-member fluids.
- **drhodprhd** (*float*) - is the slope of the linear equation of state that relates fluid density to the height of the pressure head (in terms of the reference density). Note that DRHODPRHD can be calculated from the volumetric expansion coefficient for pressure using equation 15. If the simulation is formulated in terms of kilograms and meters, DRHODPRHD has an approximate value of 4.46 x 10-3 kg/m4. A value of zero, which is typically used for most problems, inactivates the dependence of fluid density on pressure.
- **prhdref** (*float*) - is the reference pressure head. This value should normally be set to zero.
- **nsrhoeos** (*int*) - is the number of MT3DMS species to be used in the equation of state for fluid density. This value is read only if MT3DRHOFLG = -1.
- **mtrhospec** (*int*) - is the MT3DMS species number corresponding to the adjacent DRHODC and CRHOREF.
- **crhoref** (*float*) - is the reference concentration (C0) for species, MTRHOSPEC. For most simulations, CRHOREF should be specified as zero. If MT3DRHOFLG > 0, CRHOREF is assumed to equal zero (as was done in previous versions of SEAWAT).
- **firstdt** (*float*) - is the length of the first transport timestep used to start the simulation if both of the following two conditions are met: 1. The IMT Process is active, and 2. transport timesteps are calculated as a function of the user-specified Courant number (the MT3DMS input variable, PERCEL, is greater than zero).
- **indense** (*int*) - is a flag. INDENSE is read only if MT3DRHOFLG is equal to zero. If INDENSE < 0, values for the DENSE array will be reused from the previous stress period. If it is the first stress

period, values for the DENSE array will be set to DENSEREF. If INDENSE = 0, values for the DENSE array will be set to DENSEREF. If INDENSE >= 1, values for the DENSE array will be read from item 7. If INDENSE = 2, values read for the DENSE array are assumed to represent solute concentration, and will be converted to density values using the equation of state.

- **dense** (Transient3d) – A float or array of floats (nlay, nrow, ncol) should be assigned as values to a dictionary related to keys of period number. dense is the fluid density array read for each layer using the MODFLOW-2000 U2DREL array reader. The DENSE array is read only if MT3DRHOFLG is equal to zero. The DENSE array may also be entered in terms of solute concentration, or any other units, if INDENSE is set to 2 and the constants used in the density equation of state are specified appropriately.
- **extension** (*string*) – Filename extension (default is 'vdf')
- **unitnumber** (*int*) – File unit number (default is 37).

Notes

In swt_4 mtdnconc became mt3drhoflg. If the latter one is defined in kwargs, it will overwrite mtdnconc. Same goes for denseslp, which has become drhodc.

When loading an existing SEAWAT model that has DENSE specified as concentrations, the load process will convert those concentrations into density values using the equation of state. This is only relevant when mtdnconc (or mt3drhoflg) is set to zero.

Examples

```
>>> import flopy
>>> m = flopy.seawat.Seawat()
>>> lpf = flopy.seawat.SeawatVdf(m)
```

classmethod load(*f*, *model*, *nper=None*, *ext_unit_dict=None*)

Load an existing package.

Parameters

- **f** (*filename or file handle*) – File to load.
- **model** (*model object*) – The model object (of type *flopy.seawat.swt.Seawat*) to which this package will be added.
- **nper** (*int*) – The number of stress periods. If nper is None, then nper will be obtained from the model object. (default is None).
- **ext_unit_dict** (*dictionary, optional*) – If the arrays in the file are specified using EXTERNAL, or older style array control records, then *f* should be a file handle. In this case ext_unit_dict is required, which can be constructed using the function *flopy.utils.mfreadnam.parsenamefile*.

Returns
vdf – SeawatVdf object.

Return type
SeawatVdf object

Examples

```
>>> import flopy
>>> mf = flopy.modflow.Modflow()
>>> dis = flopy.modflow.ModflowDis(mf)
>>> mt = flopy.mt3d.Mt3dms()
>>> swt = flopy.seawat.Seawat(modflowmodel=mf, mt3dmsmodel=mt)
>>> vdf = flopy.seawat.SeawatVdf.load('test.vdf', m)
```

unitnumber = 37

write_file()
Write the package file

Return type
None

flopy.seawat.swtvsc module

class SeawatVsc(*model*, *mt3dmuflg=-1*, *viscmin=0.0*, *viscmax=0.0*, *viscref=0.0008904*, *nsmueos=0*, *mutempopt=2*, *mtmuspec=1*, *dmudc=1.923e-06*, *cmuref=0.0*, *mtmutempspec=1*, *amucoeff=None*, *invisc=-1*, *visc=-1*, *extension='vsc'*, *unitnumber=None*, *filenames=None*, ***kwargs*)

Bases: *Package*

SEAWAT Viscosity Package Class.

Parameters

- **model** (*model object*) – The model object (of type *flopy.seawat.swt.Seawat*) to which this package will be added.
- **mt3drhoflg)** (*mt3dmuflg (or*) – is the MT3DMS species number that will be used in the equation to compute fluid viscosity. If MT3DMUFLG >= 0, fluid density is calculated using the MT3DMS species number that corresponds with MT3DMUFLG. If MT3DMUFLG = -1, fluid viscosity is calculated using one or more MT3DMS species.
- **viscmin** (*float*) – is the minimum fluid viscosity. If the resulting viscosity value calculated with the equation is less than VISCMIN, the viscosity value is set to VISCMIN. If VISCMIN = 0, the computed fluid viscosity is not limited by VISCMIN (this is the option to use for most simulations). If VISCMIN > 0, a computed fluid viscosity less than VISCMIN is automatically reset to VISCMIN.
- **viscmax** (*float*) – is the maximum fluid viscosity. If the resulting viscosity value calculated with the equation is greater than VISCMAX, the viscosity value is set to VISCMAX. If VISCMAX = 0, the computed fluid viscosity is not limited by VISCMAX (this

is the option to use for most simulations). If VISCMAX > 0, a computed fluid viscosity larger than VISCMAX is automatically reset to VISCMAX.

- **viscref** (*float*) - is the fluid viscosity at the reference concentration and reference temperature. For most simulations, VISCREF is specified as the viscosity of freshwater.
- **dmudc** (*float, or list of floats (of size nsmueos) if nsmueos > 1*) - is the slope of the linear equation that relates fluid viscosity to solute concentration.
- **nmueos** (*int*) - is the number of MT3DMS species to be used in the linear equation for fluid viscosity (this number does not include the temperature species if the nonlinear option is being used). This value is read only if MT3DMUFLG = -1. A value of zero indicates that none of the MT3DMS species have a linear effect on fluid viscosity (the nonlinear temperature dependence may still be activated); nothing should be entered for item 3c in this case.
- **mutempopt** (*int*) - is a flag that specifies the option for including the effect of temperature on fluid viscosity. If MUTEMPOPT = 0, the effect of temperature on fluid viscosity is not included or is a simple linear relation that is specified in item 3c. If MUTEMPOPT = 1, fluid viscosity is calculated using equation 18. The size of the AMUCOEFF array in item 3e is 4 (MUNCOEFF = 4). If MUTEMPOPT = 2, fluid viscosity is calculated using equation 19. The size of the AMUCOEFF array in item 3e is 5 (MUNCOEFF = 5). If MUTEMPOPT = 3, fluid viscosity is calculated using equation 20. The size of the AMUCOEFF array in item 3e is 2 (MUNCOEFF = 2). If NSMUEOS and MUTEMPOPT are both set to zero, all fluid viscosities are set to VISCREF.
- **mtmuspec** (*int, or list of ints (of size nsmueos) if nsmueos > 1*) - is the MT3DMS species number corresponding to the adjacent DMUDC and CMUREF.
- **dmudc** - is the slope of the linear equation that relates fluid viscosity to solute concentration.
- **cmuref** (*float, or list of floats (of size nsmueos) if nsmueos > 1*) - is the reference concentration.
- **mtmuspectemp** (*int*) - is the MT3DMS species number that corresponds to temperature. This value must be between 1 and NCOMP and should not be listed in MTMUSPEC of item 3c.
- **amucoeff** (*float*) - is the coefficient array of size MUNCOEFF. AMUCOEFF is A in equations 18, 19, and 20.
- **muncoeff** (*int*) - is the size of the AMUCOEFF array.
- **invisc** (*int*) - is a flag. INVISC is read only if MT3DMUFLG is equal to zero. If INVISC < 0, values for the VISC array will be reused from the previous stress period. If it is the first stress period, values for the VISC array will be set to VISCREF. If INVISC = 0, values for the VISC array will be set to VISCREF. If INVISC >= 1, values for the VISC array will be read from item 5. If INVISC = 2, values read for the VISC array are assumed to

represent solute concentration, and will be converted to viscosity values.

- **visc** (*float or array of floats (nlay, nrow, ncol)*) – is the fluid viscosity array read for each layer using the MODFLOW-2000 U2DREL array reader. The VISC array is read only if MT3DMUFLG is equal to zero. The VISC array may also be entered in terms of solute concentration (or any other units) if INVISC is set to 2, and the simple linear expression in item 3 can be used to represent the relation to viscosity.
- **extension** (*string*) – Filename extension (default is 'vsc')
- **unitnumber** (*int*) – File unit number (default is 38).

Notes

Examples

```
>>> import flopy
>>> m = flopy.seawat.Seawat()
>>> vsc = flopy.modflow.SeawatVsc(m)
```

classmethod load(*f*, *model*, *nper=None*, *ext_unit_dict=None*)

Load an existing package.

Parameters

- **f** (*filename or file handle*) – File to load.
- **model** (*model object*) – The model object (of type *flopy.seawat.swt.Seawat*) to which this package will be added.
- **nper** (*int*) – The number of stress periods. If nper is None, then nper will be obtained from the model object. (default is None).
- **ext_unit_dict** (*dictionary, optional*) – If the arrays in the file are specified using EXTERNAL, or older style array control records, then *f* should be a file handle. In this case ext_unit_dict is required, which can be constructed using the function *flopy.utils.mfreadnam.parsenamefile*.

Returns

vsc – SeawatVsc object.

Return type

SeawatVsc object

Examples

```
>>> import flopy
>>> mf = flopy.modflow.Modflow()
>>> dis = flopy.modflow.ModflowDis(mf)
>>> mt = flopy.mt3d.Mt3dms()
>>> swt = flopy.seawat.Seawat(modflowmodel=mf, mt3dmsmodel=mt)
>>> vdf = flopy.seawat.SeawatVsc.load('test.vsc', m)
```

unitnumber = 38

write_file()

Write the package file

Return type
None

12.2.5 MODPATH 7 Packages

Contents:

flopy.modpath.mp7 module

mp7 module. Contains the Modpath7List and Modpath7 classes.

class Modpath7(*modelname='modpath7test'*, *simfile_ext='mpsim'*, *namefile_ext='mpnam'*, *version='modpath7'*, *exe_name='mp7'*, *flowmodel=None*, *headfilename=None*, *budgetfilename=None*, *model_ws=None*, *verbose=False*)

Bases: *BaseModel*

Modpath 7 class.

Parameters

- **modelname** (*str*, *default "modpath7test"*) – Basename for MODPATH 7 input and output files.
- **simfile_ext** (*str*, *default "mpsim"*) – Filename extension of the MODPATH 7 simulation file.
- **namefile_ext** (*str*, *default mpnam"*) – Filename extension of the MODPATH 7 namefile.
- **version** (*str*, *default "modpath7"*) – String that defines the MODPATH version. Valid versions are “modpath7” (default).
- **exe_name** (*str*, *default "mp7"*) – The name of the executable to use.
- **flowmodel** (*flopy.modflow.Modflow or flopy.mf6.MFModel object*) – MODFLOW model object.
- **headfilename** (*str*, *optional*) – Filename of the MODFLOW output head file. If headfilename is not provided then it will be set from the flowmodel.
- **budgetfilename** (*str*, *optional*) – Filename of the MODFLOW output cell-by-cell budget file. If budgetfilename is not provided then it will be set from the flowmodel.

- **model_ws** (*str, default "."*) – Model workspace. Directory name to create model data sets. Default is the current working directory.
- **verbose** (*bool, default False*) – Print additional information to the screen.

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow.load('mf2005.nam')
>>> mp = flopy.modpath.Modpath7('mf2005_mp', flowmodel=m)
```

classmethod create_mp7(*modelname='modpath7test', trackdir='forward', flowmodel=None, exe_name='mp7', model_ws='.', verbose=False, columncelldivisions=2, rowcelldivisions=2, layercelldivisions=2, nodes=None*)

Create a default MODPATH 7 model using a passed flowmodel with 8 particles in user-specified node locations or every active model cell.

Parameters

- **modelname** (*str*) – Basename for MODPATH 7 input and output files (default is 'modpath7test').
- **trackdir** (*str*) – Keyword that defines the MODPATH particle tracking direction. Available trackdir's are 'backward' and 'forward'. (default is 'forward')
- **flowmodel** (*flopy.modflow.Modflow or flopy.mf6.MFModel object*) – MODFLOW model
- **exe_name** (*str*) – The name of the executable to use (the default is 'mp7').
- **model_ws** (*str*) – model workspace. Directory name to create model data sets. (default is the current working directory).
- **verbose** (*bool*) – Print additional information to the screen (default is False).
- **columncelldivisions** (*int*) – Number of particles in a cell in the column (x-coordinate) direction (default is 2).
- **rowcelldivisions** (*int*) – Number of particles in a cell in the row (y-coordinate) direction (default is 2).
- **layercelldivisions** (*int*) – Number of particles in a cell in the layer (z-coordinate) direction (default is 2).
- **nodes** (*int, list of ints, tuple of ints, or np.ndarray*) – Nodes (zero-based) with particles. If (default is node 0).

Returns

mp

Return type

Modpath7 object

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow.load('mf2005.nam')
>>> mp = flopy.modpath.Modpath7.create_mp7(flowmodel=m)
```

property hdry

property hnoflo

property laytyp

write_name_file()

Write the name file

Return type
None

class Modpath7List(*model*, *extension='list'*, *unitnumber=None*)

Bases: *Package*

List package class

write_file()

Every Package needs its own write_file function

flopy.modpath.mp7bas module

mp7bas module. Contains the Modpath7Bas class.

class Modpath7Bas(*model*, *porosity=0.3*, *defaultiface=None*, *extension='mpbas'*)

Bases: *Package*

MODPATH 7 Basic Package Class.

Parameters

- **model** (*model object*) – The model object (of type flopy.modpath. Modpath7) to which this package will be added.
- **porosity** (*float or array of floats (nlay, nrow, ncol)*) – The porosity array (the default is 0.30).
- **defaultiface** (*dict*) – Dictionary with keys that are the text string used by MODFLOW in the budget output file to label flow rates for a stress package and the values are the cell face (iface) on which to assign flows (the default is None).
- **extension** (*str, optional*) – File extension (default is 'mpbas').

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow.load('mf2005.nam')
>>> mp = flopy.modpath.Modpath7('mf2005_mp', flowmodel=m)
>>> mpbas = flopy.modpath.Modpath7Bas(mp)
```

write_file(*check=False*)

Write the package file

Parameters
check (*boolean*) – Check package data for common errors. (default False)

Return type
None

flopy.modpath.mp7particledata module

mp7particledata module. Contains the ParticleData, CellDataType,
FaceDataType, and NodeParticleData classes.

class CellDataType(*drape=0*, *columncelldivisions=3*, *rowcelldivisions=3*, *layercelldivisions=3*)

Bases: object

Cell data type class to create a MODPATH 7 particle location template for input style 2, 3, and 4 in cells (templatesubdivisiontype = 2).

Parameters

- **drape** (*int*) – Drape indicates how particles are treated when starting locations are specified for cells that are dry. If drape is 0, Particles are placed in the specified cell. If the cell is dry at the time of release, the status of the particle is set to unreleased and removed from the simulation. If drape is 1, particles are placed in the upper most active grid cell directly beneath the specified layer, row, column or node location (default is 0).
- **columncelldivisions** (*int*) – Number of particles in a cell in the column (x-coordinate) direction (default is 3).
- **rowcelldivisions** (*int*) – Number of particles in a cell in the row (y-coordinate) direction (default is 3).
- **layercelldivisions** (*int*) – Number of particles in a cell in the layer (z-coordinate) direction (default is 3).

Examples

```
>>> import flopy
>>> cd = flopy.modpath.CellDataType()
```

write(*f=None*)

Parameters

f (*fileobject*) – Fileobject that is open with write access

class FaceDataType(*drape=0*, *verticaldivisions1=3*, *horizontaldivisions1=3*, *verticaldivisions2=3*, *horizontaldivisions2=3*, *verticaldivisions3=3*, *horizontaldivisions3=3*, *verticaldivisions4=3*, *horizontaldivisions4=3*, *rowdivisions5=3*, *columndivisions5=3*, *rowdivisions6=3*, *columndivisions6=3*)

Bases: object

Face data type class to create a MODPATH 7 particle location template for input style 2, 3, and 4 on cell faces (templatesubdivisiontype = 2).

Parameters

- **drape** (*int*) – Drape indicates how particles are treated when starting locations are specified for cells that are dry. If drape is 0, Particles are placed in the specified cell. If the cell is dry at the time of release, the status of the particle is set to unreleased and removed from the simulation. If drape is 1, particles are placed in the upper most active grid cell directly beneath the specified layer, row, column or node location (default is 0).
- **verticaldivisions1** (*int*) – The number of vertical subdivisions that define the two-dimensional array of particles on cell face 1 (default is 3).
- **horizontaldivisions1** (*int*) – The number of horizontal subdivisions that define the two-dimensional array of particles on cell face 1 (default is 3).
- **verticaldivisions2** (*int*) – The number of vertical subdivisions that define the two-dimensional array of particles on cell face 2 (default is 3).
- **horizontaldivisions2** (*int*) – The number of horizontal subdivisions that define the two-dimensional array of particles on cell face 2 (default is 3).
- **verticaldivisions3** (*int*) – The number of vertical subdivisions that define the two-dimensional array of particles on cell face 3 (default is 3).
- **horizontaldivisions3** (*int*) – The number of horizontal subdivisions that define the two-dimensional array of particles on cell face 3 (default is 3).
- **verticaldivisions4** (*int*) – The number of vertical subdivisions that define the two-dimensional array of particles on cell face 4 (default is 3).

- **horizontaldivisions4** (*int*) – The number of horizontal subdivisions that define the two-dimensional array of particles on cell face 4 (default is 3).
- **rowdivisions5** (*int*) – The number of row subdivisions that define the two-dimensional array of particles on the bottom cell face (face 5) (default is 3).
- **columndivisions5** (*int*) – The number of column subdivisions that define the two-dimensional array of particles on the bottom cell face (face 5) (default is 3).
- **rowdivisions6** (*int*) – The number of row subdivisions that define the two-dimensional array of particles on the top cell face (face 6) (default is 3).
- **columndivisions6** (*int*) – The number of column subdivisions that define the two-dimensional array of particles on the top cell face (face 6) (default is 3).

Examples

```
>>> import flopy
>>> fd = flopy.modpath.FaceDataType()
```

write(*f=None*)

Parameters
f (*fileobject*) – Fileobject that is open with write access

class LRCParticleData(*subdivisiondata=None*, *lrcregions=None*)

Bases: object

Layer, row, column particle data template class to create MODPATH 7 particle location input style 2 on cell faces (templatesubdivisiontype = 1) and/or in cells (templatesubdivisiontype = 2). Particle locations for this template are specified by layer, row, column regions.

Parameters

- **subdivisiondata** (FaceDataType, CellDataType *or list of* FaceDataType) – and/or CellDataType types FaceDataType, CellDataType, or a list of FaceDataType and/or CellDataTypes that are used to create one or more particle templates in a particle group. If subdivisiondata is None, a default CellDataType with 27 particles per cell will be created (default is None).
- **lrcregions** (*list of lists tuples or np.ndarrays*) – Layer, row, column (zero-based) regions with particles created using the specified template parameters. A region is defined as a list/tuple of minlayer, minrow, mincolumn, maxlayer, maxrow, maxcolumn values. If subdivisiondata is a list, a list/tuple or array of layer, row, column regions with the same length as subdivision data must be provided. If lrcregions is None, particles will be placed in the first model cell (default is None).

Examples

```
>>> import flopy
>>> pg = flopy.modpath.LRCParticleData(lrcregions=[0, 0, 0, 3, 10, 10])
```

write(*f=None*)

Parameters
f (*fileobject*) – Fileobject that is open with write access

class NodeParticleData(*subdivisiondata=None*, *nodes=None*)

Bases: object

Node particle data template class to create MODPATH 7 particle location input style 3 on cell faces (templatesubdivisiontype = 1) and/or in cells (templatesubdivisiontype = 2). Particle locations for this template are specified by nodes.

Parameters

- **subdivisiondata** (FaceDataType, CellDataType *or list of* FaceDataType) – and/or CellDataType types FaceDataType, CellDataType, or a list of FaceDataType and/or CellDataTypes that are used to create one or more particle templates in a particle group. If subdivisiondata is None, a default CellDataType with 27 particles per cell will be created (default is None).
- **nodes** (*int*, *list of ints*, *tuple of ints*, *or np.ndarray*) – Nodes (zero-based) with particles created using the specified template parameters. If subdivisiondata is a list, a list of nodes with the same length as subdivision data must be provided. If nodes is None, particles will be placed in the first model cell (default is None).

Examples

```
>>> import flopy
>>> pg = flopy.modpath.NodeParticleData(nodes=[100, 101])
```

write(*f=None*)

Parameters
f (*fileobject*) – Fileobject that is open with write access

class ParticleData(*partlocs=None*, *structured=False*, *particleids=None*, *localx=None*, *localy=None*, *localz=None*, *timeoffset=None*, *drape=None*)

Bases: object

Class to create the most basic particle data type (starting location input style 1). Input style 1 is the most general input style and provides the most flexibility in customizing starting locations.

Parameters

- **partlocs** (*list/tuple of int*, *list/tuple of list/tuple*, *or np.ndarray*) – Particle locations (zero-based) that are either layer, row, column locations or nodes.

- **structured** (*bool*) - Boolean defining if a structured (True) or unstructured particle recarray will be created (default is False).
- **particleids** (*list*, *tuple*, *or np.ndarray*) - Particle ids for the defined particle locations. If particleids is None, MODPATH 7 will define the particle ids to each particle location. If particleids is provided a particle id must be provided for each partloc (default is None).
- **localx** (*float*, *list*, *tuple*, *or np.ndarray*) - Local x-location of the particle in the cell. If a single value is provided all particles will have the same localx position. If a list, tuple, or np.ndarray is provided a localx position must be provided for each partloc. If localx is None, a value of 0.5 (center of the cell) will be used (default is None).
- **localy** (*float*, *list*, *tuple*, *or np.ndarray*) - Local y-location of the particle in the cell. If a single value is provided all particles will have the same localy position. If a list, tuple, or np.ndarray is provided a localy position must be provided for each partloc. If localy is None, a value of 0.5 (center of the cell) will be used (default is None).
- **localz** (*float*, *list*, *tuple*, *or np.ndarray*) - Local z-location of the particle in the cell. If a single value is provided all particles will have the same localz position. If a list, tuple, or np.ndarray is provided a localz position must be provided for each partloc. If localy is None, a value of 0.5 (center of the cell) will be used (default is None).
- **timeoffset** (*float*, *list*, *tuple*, *or np.ndarray*) - Timeoffset of the particle relative to the release time. If a single value is provided all particles will have the same timeoffset. If a list, tuple, or np.ndarray is provided a timeoffset must be provided for each partloc. If timeoffset is None, a value of 0. (equal to the release time) will be used (default is None).
- **drape** (*int*, *list*, *tuple*, *or np.ndarray*) - Drape indicates how particles are treated when starting locations are specified for cells that are dry. If drape is 0, Particles are placed in the specified cell. If the cell is dry at the time of release, the status of the particle is set to unreleased and removed from the simulation. If drape is 1, particles are placed in the upper most active grid cell directly beneath the specified layer, row, column or node location. If a single value is provided all particles will have the same drape value. If a list, tuple, or np.ndarray is provided a drape value must be provided for each partloc. If drape is None, a value of 0 will be used (default is None).

Examples

```
>>> import flopy
>>> locs = [(0, 0, 0), (1, 0, 0), (2, 0, 0)]
>>> pd = flopy.modpath.ParticleData(locs, structured=True, drape=0,
...                                 localx=0.5, localy=0.5, localz=1)
```

write(*f=None*)

Parameters
f (*fileobject*) – Fileobject that is open with write access

flopy.modpath.mp7particlegroup module

mp7particlegroup module. Contains the ParticleGroup, and
ParticleGroupNodeTemplate classes.

class ParticleGroup(*particlegroupname='PG1'*, *filename=None*, *releasedata=0.0*, *particledata=None*)

Bases: _Modpath7ParticleGroup

ParticleGroup class to create MODPATH 7 particle group data for location input style 1. Location input style 1 is the most general type of particle group that requires the user to define the location of all particles and associated data (relative release time, drape, and optionally particle ids). Particledata locations can be specified by layer, row, column (locationstyle=1) or nodes (locationstyle=2) and are created with the ParticleData class.

Parameters

- **particlegroupname** (*str*) – Name of particle group (default is 'PG1')
- **filename** (*str*) – Name of the external file that will contain the particle data. If filename is '' or None the particle information for the particle group will be written to the MODPATH7 simulation file (default is None).
- **releasedata** (*float, int, list, or tuple*) – If releasedata is a float or an int or a list/tuple with a single float or int, releaseoption is set to 1 and release data is the particle release time (default is 0.0).
- **particledata** (ParticleData) – ParticleData instance with particle data. If particledata is None, a ParticleData instance will be created with a node-based particle in the center of the first node in the model (default is None).

Examples

```
>>> import flopy
>>> p = [(2, 0, 0), (0, 20, 0)]
>>> p = flopy.modpath.ParticleData(p)
>>> pg = flopy.modpath.ParticleGroup(particledata=p)
```

write(*fp=None*, *ws='.'*)

Write MODPATH 7 particle data items 1 through 5

Parameters

- **fp** (*fileobject*) – Fileobject that is open with write access
- **ws** (*str*) – Workspace for particle data

class ParticleGroupLRCTemplate(*particlegroupname='PG1'*, *filename=None*, *releasedata=(0.0,)*, *particledata=None*)

Bases: _ParticleGroupTemplate

Layer, row, column particle template class to create MODPATH 7 particle location input style 2. Particle locations for this template are specified by layer, row, column regions.

Parameters

- **particlegroupname** (*str*) – Name of particle group
- **filename** (*str*) – Name of the external file that will contain the particle data. If filename is ‘’ or None the particle information for the particle group will be written to the MODPATH7 simulation file.
- **releasedata** (*float*, *int*, *list*, *or tuple*) – If releasedata is a float or an int or a list/tuple with a single float or int, releaseoption is set to 1 and release data is the particle release time.
- **particledata** – LRCParticleData object with input style 2 face and/or node particle data. If particledata is None a default LRCParticleData object is created (default is None).

write(*fp=None*, *ws='.'*)

Parameters

- **fp** (*fileobject*) – Fileobject that is open with write access
- **ws** (*str*) – Workspace for particle data

class ParticleGroupNodeTemplate(*particlegroupname='PG1'*, *filename=None*, *releasedata=(0.0,)*, *particledata=None*)

Bases: _ParticleGroupTemplate

Node particle template class to create MODPATH 7 particle location input style 3. Particle locations for this template are specified by nodes.

Parameters

- **particlegroupname** (*str*) – Name of particle group
- **filename** (*str*) – Name of the external file that will contain the particle data. If filename is ‘’ or None the particle information

for the particle group will be written to the MODPATH7 simulation file.

- **releasedata** (*float*, *int*, *list*, *or tuple*) – If releasedata is a float or an int or a list/tuple with a single float or int, releaseoption is set to 1 and release data is the particle release time.
- **particledata** – NodeParticleData object with input style 3 face and/or node particle data. If particledata is None a default NodeParticleData object is created (default is None).

write(*fp=None*, *ws='.'*)

Parameters

- **fp** (*fileobject*) – Fileobject that is open with write access
- **ws** (*str*) – Workspace for particle data

flopy.modpath.mp7sim module

mpsim module. Contains the ModpathSim class. Note that the user can access the ModpathSim class as *flopy.modpath.ModpathSim*.

Additional information for this MODFLOW/MODPATH package can be found at the Online MODFLOW Guide.

class Modpath7Sim(*model*, *mpnamefilename=None*, *listingfilename=None*, *endpointfilename=None*, *pathlinefilename=None*, *timeseriesfilename=None*, *tracefilename=None*, *simulationtype='pathline'*, *trackingdirection='forward'*, *weaksinkoption='stop_at'*, *weaksourceoption='stop_at'*, *budgetoutputoption='no'*, *traceparticledata=None*, *budgetcellnumbers=None*, *referencetime=None*, *stoptimeoption='extend'*, *stoptime=None*, *timepointdata=None*, *zonedataoption='off'*, *stopzone=None*, *zones=0*, *retardationfactoroption='off'*, *retardation=1.0*, *particlegroups=None*, *extension='mpsim'*)

Bases: *Package*

MODPATH Simulation File Package Class.

Parameters

- **model** (*model object*) – The model object (of type flopy.modpath.Modpath7) to which this package will be added.
- **mpnamefilename** (*str*) – Filename of the MODPATH 7 name file. If mpnamefilename is not defined it will be generated from the model name (default is None).
- **listingfilename** (*str*) – Filename of the MODPATH 7 listing file. If listingfilename is not defined it will be generated from the model name (default is None).
- **endpointfilename** (*str*) – Filename of the MODPATH 7 endpoint file. If endpointfilename is not defined it will be generated from the model name (default is None).

- **pathlinefilename** (*str*) - Filename of the MODPATH 7 pathline file. If pathlinefilename is not defined it will be generated from the model name (default is None).
- **timeseriesfilename** (*str*) - Filename of the MODPATH 7 timeseries file. If timeseriesfilename is not defined it will be generated from the model name (default is None).
- **tracefilename** (*str*) - Filename of the MODPATH 7 tracefile file. If tracefilename is not defined it will be generated from the model name (default is None).
- **simulationtype** (*str*) - MODPATH 7 simulation type. Valid simulation types are 'endpoint', 'pathline', 'timeseries', or 'combined' (default is 'pathline').
- **trackingdirection** (*str*) - MODPATH 7 tracking direction. Valid tracking directions are 'forward' or 'backward' (default os 'forward').
- **weaksinkoption** (*str*) - MODPATH 7 weak sink option. Valid weak sink options are 'pass_through' or 'stop_at' (default value is 'stop_at').
- **weaksourceoption** (*str*) - MODPATH 7 weak source option. Valid weak source options are 'pass_through' or 'stop_at' (default value is 'stop_at').
- **budgetoutputoption** (*str*) - MODPATH 7 budget output option. Valid budget output options are 'no' - individual cell water balance errors are not computed and budget record headers are not printed, 'summary' - a summary of individual cell water balance errors for each time step is printed in the listing file without record headers, or 'record_summary' - a summary of individual cell water balance errors for each time step is printed in the listing file with record headers (default is 'summary').
- **traceparticledata** (*list or tuple*) - List or tuple with two ints that define the particle group and particle id (zero-based) of the specified particle that is followed in detail. If traceparticledata is None, trace mode is off (default is None).
- **budgetcellnumbers** (*int, list of ints, tuple of ints, or np. ndarray*) - Cell numbers (zero-based) for which detailed water budgets are computed. If budgetcellnumbers is None, detailed water budgets are not calculated (default is None).
- **referencetime** (*float, list, or tuple*) - Specified reference time if a float or a list/tuple with a single float value is provided (reference time option 1). Otherwise a list or tuple with a zero-based stress period (int) and time step (int) and a float defining the relative time position in the time step is provided (reference time option 2). If referencetime is None, reference time is set to 0 (default is None).
- **stoptimeoption** (*str*) - String indicating how a particle tracking simulation is terminated based on time. If stop time option is 'total', particles will be stopped at the end of the final time step if 'forward' tracking is simulated or at the beginning of

the first time step if backward tracking. If stop time option is 'extend', initial or final steady-state time steps will be extended and all particles will be tracked until they reach a termination location. If stop time option is 'specified', particles will be tracked until they reach a termination location or the specified stop time is reached (default is 'extend').

- **stoptime** (*float*) - User-specified value of tracking time at which to stop a particle tracking simulation. Stop time is only used if the stop time option is 'specified'. If stoptime is None and the stop time option is 'specified' particles will be terminated at the end of the last time step if 'forward' tracking or the beginning of the first time step if 'backward' tracking (default is None).
- **timepointdata** (*list or tuple*) - List or tuple with 2 items that is only used if simulationtype is 'timeseries' or 'combined'. If the second item is a float then the timepoint data corresponds to time point option 1 and the first entry is the number of time points (timepointcount) and the second entry is the time point interval. If the second item is a list, tuple, or np.ndarray then the timepoint data corresponds to time point option 2 and the number of time points entries (timepointcount) in the second item and the second item is an list, tuple, or array of user-defined time points. If Timepointdata is None, time point option 1 is specified and the total simulation time is split into 100 intervals (default is None).
- **zonedataoption** (*str*) - If zonedataoption is 'off', zone array data are not read and a zone value of 1 is applied to all cells. If zonedataoption is 'on', zone array data are read (default is 'off').
- **stopzone** (*int*) - A zero-based specified integer zone value that indicates an automatic stopping location for particles and is only used if zonedataoption is 'on'. A value of -1 indicates no automatic stop zone is used. Stopzone values less than -1 are not allowed. If stopzone is None, stopzone is set to -1 (default is None).
- **zones** (*float or array of floats (nlay, nrow, ncol)*) - Array of zero-based positive integer zones that are only used if zonedataoption is 'on' (default is 0).
- **retardationfactoroption** (*str*) - If retardationfactoroption is 'off', retardation array data are not read and a retardation factor of 1 is applied to all cells. If retardationfactoroption is 'on', retardation factor array data are read (default is 'off').
- **retardation** (*float or array of floats (nlay, nrow, ncol)*) - Array of retardation factors that are only used if retardationfactoroption is 'on' (default is 1).
- **particlegroups** (*ParticleGroup or list of ParticleGroups*) - ParticleGroup or list of ParticlesGroups that contain data for individual particle groups. If None is specified, a particle in the center of node 0 will be created (default is None).

- **extension** (*string*) – Filename extension (default is 'mpsim')

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow.load('mf2005.nam')
>>> mp = flopy.modpath.Modpath7('mf2005_mp', flowmodel=m)
>>> mpsim = flopy.modpath.Modpath7Sim(mp)
```

write_file(*check=False*)

Write the package file

Parameters
check (*boolean*) – Check package data for common errors. (default False)

Return type
None

class **budgetOpt**(*value*, *names=None*, ***, *module=None*, *qualname=None*, *type=None*, *start=1*, *boundary=None*)

Bases: Enum

Enumeration of different budget output options

no = 0

record_summary = 2

summary = 1

class **onoffOpt**(*value*, *names=None*, ***, *module=None*, *qualname=None*, *type=None*, *start=1*, *boundary=None*)

Bases: Enum

Enumeration of on-off options

off = 1

on = 2

class **simType**(*value*, *names=None*, ***, *module=None*, *qualname=None*, *type=None*, *start=1*, *boundary=None*)

Bases: Enum

Enumeration of different simulation types

combined = 4

endpoint = 1

pathline = 2

timeseries = 3

sim_enum_error(*v*, *s*, *e*)

Standard enumeration error format error :param v: Enumeration value :type v: str :param s: User-defined value :type s: str :param e: Enumeration class :type e: Enum class

class stopOpt(*value*, *names=None*, ***, *module=None*, *qualname=None*, *type=None*, *start=1*, *boundary=None*)

Bases: Enum

Enumeration of different stop time options

extend = 2

specified = 3

total = 1

class trackDir(*value*, *names=None*, ***, *module=None*, *qualname=None*, *type=None*, *start=1*, *boundary=None*)

Bases: Enum

Enumeration of different tracking directions

backward = 2

forward = 1

class weakOpt(*value*, *names=None*, ***, *module=None*, *qualname=None*, *type=None*, *start=1*, *boundary=None*)

Bases: Enum

Enumeration of different weak sink and source options

pass_through = 1

stop_at = 2

12.2.6 MODPATH 6 Packages

Contents:

flopy.modpath.mp6 module

class Modpath6(*modelname='modpathtest'*, *simfile_ext='mpsim'*, *namefile_ext='mpnam'*, *version='modpath'*, *exe_name: str | PathLike = 'mp6'*, *modflowmodel=None*, *dis_file: str | PathLike | None = None*, *dis_unit=87*, *head_file: str | PathLike | None = None*, *budget_file: str | PathLike | None = None*, *model_ws: str | PathLike | None = None*, *external_path: str | PathLike | None = None*, *verbose=False*, *load=True*, *listunit=7*)

Bases: *BaseModel*

Modpath6 class.

Parameters

- **modelname** (*str, default "modpathtest"*) – Basename for MODPATH 6 input and output files.
- **simfile_ext** (*str, default "mpsim"*) – Filename extension of the MODPATH 6 simulation file.
- **namefile_ext** (*str, default mpnam"*) – Filename extension of the MODPATH 6 namefile.

- **version** (*str, default "modpath"*) – String that defines the MODPATH version. Valid versions are "modpath" (default).
- **exe_name** (*str or PathLike, default "mp6"*) – The name of the executable to use.
- **modflowmodel** (*flopy.modflow.Modflow*) – MODFLOW model object with one of LPF, BCF6, or UPW packages.
- **dis_file** (*str or PathLike*) – Required dis file name.
- **dis_unit** (*int, default 87*) – Optional dis file unit number.
- **head_file** (*str or PathLike*) – Required filename of the MODFLOW output head file.
- **budget_file** (*str or PathLike*) – Required filename of the MODFLOW output cell-by-cell budget file.
- **model_ws** (*str or PathLike, optional*) – Model workspace. Directory name to create model data sets. Default is the current working directory.
- **external_path** (*str or PathLike, optional*) – Location for external files.
- **verbose** (*bool, default False*) – Print additional information to the screen.
- **load** (*bool, default True*) – Load model.
- **listunit** (*int, default 7*) – LIST file unit number.

create_mpsim(*simtype='pathline', trackdir='forward', packages='WEL', start_time=0, default_ifaces=None, ParticleColumnCount=4, ParticleRowCount=4, MinRow=0, MinColumn=0, MaxRow=None, MaxColumn=None*)

Create a MODPATH simulation file using available MODFLOW boundary package data.

Parameters

- **simtype** (*str*) –

  Keyword defining the MODPATH simulation type. Available simtype's
  are 'endpoint', 'pathline', and 'timeseries'. (default is 'PATHLINE')

- **trackdir** (*str*) – Keyword that defines the MODPATH particle tracking direction. Available trackdir's are 'backward' and 'forward'. (default is 'forward')
- **packages** (*None, str or list of strings*) – Keyword defining the modflow packages used to create initial particle locations. Supported packages are 'WEL', 'MNW2' and 'RCH'. (default is 'WEL').
- **start_time** (*float or tuple*) – Sets the value of MODPATH reference time relative to MODFLOW time. float : value of MODFLOW simulation time at which to start the particle tracking simulation.

  Sets the value of MODPATH ReferenceTimeOption to 1.

  tuple
  [(period, step, time fraction) MODFLOW stress period, time

step and fraction] between 0 and 1 at which to start the particle tracking simulation. Sets the value of MODPATH ReferenceTimeOption to 2.

- **default_ifaces** (*list*) – List of cell faces (1-6; see MODPATH6 manual, fig. 7) on which to start particles. (default is None, meaning ifaces will vary depending on packages argument above)
- **ParticleRowCount** (*int*) – Rows of particles to start on each cell index face (iface).
- **ParticleColumnCount** (*int*) – Columns of particles to start on each cell index face (iface).

Returns
mpsim

Return type
ModpathSim object

getmf()

getsim()

property mf

next_ext_unit()

Function to encapsulate next_ext_unit attribute

property sim

write_name_file()

Write the name file

Return type
None

class Modpath6List(*model*, *extension='list'*, *listunit=7*)

Bases: *Package*

List package class

write_file()

Every Package needs its own write_file function

flopy.modpath.mp6bas module

mpbas module. Contains the ModpathBas class. Note that the user can access the ModpathBas class as *flopy.modflow.ModpathBas*.

Additional information for this MODFLOW/MODPATH package can be found at the Online MODFLOW Guide.

class Modpath6Bas(*model*, *hnoflo=-9999.0*, *hdry=-8888.0*, *def_face_ct=0*, *bud_label=None*, *def_iface=None*, *laytyp=None*, *ibound=None*, *prsity=0.3*, *prsityCB=0.3*, *extension='mpbas'*, *unitnumber=86*)

Bases: *Package*

MODPATH Basic Package Class.

Parameters

- **model** (*model object*) – The model object (of type flopy.modpath.mp.Modpath) to which this package will be added.
- **hnoflo** (*float*) – Head value assigned to inactive cells (default is -9999.).
- **hdry** (*float*) – Head value assigned to dry cells (default is -8888.).
- **def_face_ct** (*int*) – Number fo default iface codes to read (default is 0).
- **bud_label** (*str or list of strs*) – MODFLOW budget item to which a default iface is assigned.
- **def_iface** (*int or list of ints*) – Cell face (iface) on which to assign flows from MODFLOW budget file.
- **laytyp** (*None, int or list of ints*) – MODFLOW layer type (0 is convertible, 1 is confined). If None, read from modflow model
- **ibound** (*None or array of ints, optional*) – The ibound array (the default is 1). If None, pull from parent modflow model
- **prsity** (*array of ints, optional*) – The porosity array (the default is 0.30).
- **prsityCB** (*array of ints, optional*) – The porosity array for confining beds (the default is 0.30).
- **extension** (*str, optional*) – File extension (default is 'mpbas').

heading

Text string written to top of package input file.

Type

str

Notes

Examples

```
>>> import flopy
>>> m = flopy.modpath.Modpath6()
>>> mpbas = flopy.modpath.Modpath6Bas(m)
```

write_file()

Write the package file

Return type

None

flopy.modpath.mp6sim module

mpsim module. Contains the ModpathSim class. Note that the user can access the ModpathSim class as *flopy.modpath.ModpathSim*.

Additional information for this MODFLOW/MODPATH package can be found at the Online MODFLOW Guide.

class Modpath6Sim(*model*, *mp_name_file='mp.nam'*, *mp_list_file='mp.list'*, *option_flags=[1, 2, 1, 1, 1, 2, 2, 1, 2, 1, 1, 1]*, *ref_time=0*, *ref_time_per_stp=[0, 0, 1.0]*, *stop_time=None*, *group_name=['group_1']*, *group_placement=[[1, 1, 1, 0, 1, 1]]*, *release_times=[[1, 1]]*, *group_region=[[1, 1, 1, 1, 1, 1]]*, *mask_nlay=[1]*, *mask_layer=[1]*, *mask_1lay=[1]*, *face_ct=[1]*, *ifaces=[[6, 1, 1]]*, *part_ct=[[1, 1, 1]]*, *time_ct=1*, *release_time_incr=1*, *time_pts=[1]*, *particle_cell_cnt=[[2, 2, 2]]*, *cell_bd_ct=1*, *bud_loc=[[1, 1, 1, 1]]*, *trace_id=1*, *stop_zone=1*, *zone=1*, *retard_fac=1.0*, *retard_fcCB=1.0*, *strt_file=None*, *extension='mpsim'*)

Bases: *Package*

MODPATH Simulation File Package Class.

Parameters

- **model** (*model object*) – The model object (of type flopy.modpath.mp.Modpath) to which this package will be added.
- **extension** (*string*) – Filename extension (default is 'mpsim')

heading

Text string written to top of package input file.

Type

str

Notes

Examples

```
>>> import flopy
>>> m = flopy.modpath.Modpath6()
>>> dis = flopy.modpath.Modpath6Sim(m)
```

check(*f=None*, *verbose=True*, *level=1*, *checktype=None*)

Check package data for common errors.

Parameters

- **f** (*str or file handle*) – String defining file name or file handle for summary file of check method output. If a sting is passed a file handle is created. If f is None, check method does not write results to a summary file. (default is None)
- **verbose** (*bool*) – Boolean flag used to determine if check method results are written to the screen
- **level** (*int*) – Check method analysis level. If level=0, summary checks are performed. If level=1, full checks are performed.

Return type
None

Examples

write_file()
Write the package file

Return type
None

class **StartingLocationsFile**(*model*, *inputstyle=1*, *extension='loc'*, *verbose=False*, *use_pandas=True*)

Bases: *Package*

Class for working with MODPATH Starting Locations file for particles.

Parameters

- **model** (*Modpath object*) – The model object (of type flopy.modpath.mp.Modpath) to which this package will be added.
- **inputstyle** (*1*) – Input style described in MODPATH6 manual (currently only input style 1 is supported)
- **extension** (*string*) – Filename extension (default is 'loc')
- **use_pandas** (*bool*, *default True*) – If True use pandas to write the particle locations >2x speed

static **get_dtypes**()
Build numpy dtype for the MODPATH 6 starting locations file.

static **get_empty_starting_locations_data**(*npt=0*, *default_xloc0=0.5*, *default_yloc0=0.5*, *default_zloc0=0.0*)

get an empty recarray for particle starting location info.

Parameters
npt (*int*) – Number of particles. Particles in array will be numbered consecutively from 1 to npt.

write_file(*data=None*, *float_format='{:.8f}'*)
Every Package needs its own write_file function

12.3 Flopy Utilities

12.3.1 Model Utilities (including binary file readers)

Contents:

flopy.utils.binaryfile module

Module to read MODFLOW binary output files. The module contains four important classes that can be accessed by the user.

- HeadFile (Binary head file. Can also be used for drawdown)
- HeadUFile (Binary MODFLOW-USG unstructured head file)
- UcnFile (Binary concentration file from MT3DMS)
- CellBudgetFile (Binary cell-by-cell flow file)

class BinaryHeader(*bintype=None*, *precision='single'*)

Bases: *Header*

Represents data headers for binary output files.

Parameters

- **bintype** (*str*) – Type of file being opened. Accepted values are 'head' and 'ucn'.
- **precision** (*str*) – Precision of floating point data in the file.

static create(*bintype=None*, *precision='single'*, ***kwargs*)

Create a binary header

static set_dtype(*bintype=None*, *precision='single'*)

Set the dtype

set_values(***kwargs*)

Set values using kwargs

class BinaryLayerFile(*filename: str | PathLike*, *precision*, *verbose*, *kwargs*)

Bases: *LayerFile*

The BinaryLayerFile class is a parent class from which concrete classes inherit. This class should not be instantiated directly.

Notes

The BinaryLayerFile class is built on a record array consisting of headers, which are record arrays of the modflow header information (kstp, kper, pertim, totim, text, nrow, ncol, ilay), and long ints pointing to the 1st byte of data for the corresponding data arrays.

get_databytes(*header*)

Parameters

header (datafile.Header) – header object

Returns

databytes – size of the data array, in bytes, following the header

Return type

int

get_ts(*idx*)

Get a time series from the binary file.

Parameters
idx (*tuple of ints, or a list of a tuple of ints*) – idx can be (layer, row, column) or it can be a list in the form [(layer, row, column), (layer, row, column), ...]. The layer, row, and column values must be zero based.

Returns
out – Array has size (ntimes, ncells + 1). The first column in the data array will contain time (totim).

Return type
numpy array

Notes

The layer, row, and column values must be zero-based, and must be within the following ranges: 0 <= k < nlay; 0 <= i < nrow; 0 <= j < ncol

Examples

exception BudgetIndexError

Bases: Exception

class CellBudgetFile(*filename: str | PathLike*, *precision='auto'*, *verbose=False*, ***kwargs*)

Bases: object

The CellBudgetFile class provides convenient ways to retrieve and manipulate budget data from a binary cell budget file. A utility method is also provided to reverse the budget records for particle tracking simulations in which particles are tracked backwards from terminating to release locations (e.g., to compute capture zones).

Parameters

- **filename** (*str or PathLike*) – Path of the cell budget file.
- **precision** (*string*) – Precision of floating point budget data in the file. Accepted values are 'single' or 'double'. Default is 'single'.
- **verbose** (*bool*) – Toggle logging output. Default is False.

Examples

```
>>> import flopy.utils.binaryfile as bf
>>> cbb = bf.CellBudgetFile('mymodel.cbb')
>>> cbb.list_records()
>>> rec = cbb.get_data(kstpkper=(0,0), text='RIVER LEAKAGE')
```

close()

Close the file handle

get_data(*idx=None*, *kstpkper=None*, *totim=None*, *text=None*, *paknam=None*, *full3D=False*)

Get data from the binary budget file.

Parameters

- **idx** (*int or list*) – The zero-based record number. The first record is record 0.
- **kstpkper** (*tuple of ints*) – A tuple containing the time step and stress period (kstp, kper). The kstp and kper values are zero based.
- **totim** (*float*) – The simulation time.
- **text** (*str*) – The text identifier for the record. Examples include 'RIVER LEAKAGE', 'STORAGE', 'FLOW RIGHT FACE', etc.
- **full3D** (*boolean*) – If true, then return the record as a three dimensional numpy array, even for those list-style records written as part of a 'COMPACT BUDGET' MODFLOW budget file. (Default is False.)

Returns

recordlist – A list of budget objects. The structure of the returned object depends on the structure of the data in the cbb file.

If full3D is True, then this method will return a numpy masked array of size (nlay, nrow, ncol) for those list-style 'COMPACT BUDGET' records written by MODFLOW.

Return type
list of records

Notes

Examples

get_indices(*text=None*)

Get a list of indices for a selected record name

Parameters
text (*str*) – The text identifier for the record. Examples include 'RIVER LEAKAGE', 'STORAGE', 'FLOW RIGHT FACE', etc.

Returns
out – indices of selected record name in budget file.

Return type
tuple

get_kstpkper()

Get a list of unique tuples (stress period, time step) in the file. Indices are 0-based, use the *kstpkper* attribute for 1-based.

Returns
List of unique combinations of stress period & time step indices (0-based) in the binary file

Return type
list of (kstp, kper) tuples

get_nrecords()

Return the number of records in the file

Returns
out - Number of records in the file.

Return type
int

get_position(*idx*, *header=False*)

Get the starting position of the data or header for a specified record number in the binary budget file.

Parameters

- **idx** (*int*) - The zero-based record number. The first record is record 0.
- **header** (*bool*) - If True, the position of the start of the header data is returned. If False, the position of the start of the data is returned (default is False).

Returns
ipos - The position of the start of the data in the cell budget file or the start of the header.

Return type
int64

get_record(*idx*, *full3D=False*)

Get a single data record from the budget file.

Parameters

- **idx** (*int*) - The zero-based record number. The first record is record 0.
- **full3D** (*boolean*) - If true, then return the record as a three dimensional numpy array, even for those list-style records written as part of a 'COMPACT BUDGET' MODFLOW budget file. (Default is False.)

Returns

record - The structure of the returned object depends on the structure of the data in the cbb file. Compact list data are returned as

If full3D is True, then this method will return a numpy masked array of size (nlay, nrow, ncol) for those list-style 'COMPACT BUDGET' records written by MODFLOW.

Return type
a single data record

Notes

Examples

get_residual(*totim*, *scaled=False*)

Return an array the size of the model grid containing the flow residual calculated from the budget terms. Residual will not be correct unless all flow terms are written to the budget file.

Parameters

- **totim** (*float*) – Simulation time for which to calculate the residual. This value must be precise, so it is best to get it from the get_times method.
- **scaled** (*bool*) – If True, then divide the residual by the total cell inflow

Returns

residual – The flow residual for the cell of shape (nlay, nrow, ncol)

Return type

np.ndarray

get_times()

Get a list of unique times in the file

Returns

out – List contains unique simulation times (totim) in binary file.

Return type

list of floats

get_ts(*idx*, *text=None*, *times=None*)

Get a time series from the binary budget file.

Parameters

- **idx** (*tuple of ints, or a list of a tuple of ints*) – idx can be (layer, row, column) or it can be a list in the form [(layer, row, column), (layer, row, column), ...]. The layer, row, and column values must be zero based.
- **text** (*str*) – The text identifier for the record. Examples include 'RIVER LEAKAGE', 'STORAGE', 'FLOW RIGHT FACE', etc.
- **times** (*iterable of floats*) – List of times to from which to get time series.

Returns

out – Array has size (ntimes, ncells + 1). The first column in the data array will contain time (totim).

Return type

numpy array

Notes

The layer, row, and column values must be zero-based, and must be within the following ranges: 0 <= k < nlay; 0 <= i < nrow; 0 <= j < ncol

Examples

get_unique_package_names(*decode=False*)

Get a list of unique package names in the file

Parameters
decode (*bool*) – Optional boolean used to decode byte strings (default is False).

Returns
names – List of unique package names in the binary file.

Return type
list of strings

get_unique_record_names(*decode=False*)

Get a list of unique record names in the file

Parameters
decode (*bool*) – Optional boolean used to decode byte strings (default is False).

Returns
names – List of unique text names in the binary file.

Return type
list of strings

list_records()

Print a list of all of the records in the file

list_unique_packages()

Print a list of unique package names

list_unique_records()

Print a list of unique record names

reverse(*filename: PathLike | None = None*)

Write a binary cell budget file with the records in reverse order. If a new filename is not provided, or if the filename is the same as the existing filename, the file will be overwritten and data reloaded from the rewritten/reversed file.

Parameters
filename (*str or PathLike, optional*) – Path of the new reversed binary cell budget file to create.

class HeadFile(*filename: str | PathLike*, *text='head'*, *precision='auto'*, *verbose=False*, ***kwargs*)

Bases: *BinaryLayerFile*

The HeadFile class provides simple ways to retrieve and manipulate 2D or 3D head arrays, or time series arrays for one or more cells, from a binary head output file.

A utility method is also provided to reverse the order of head data, for use with particle tracking simulations in which particles are tracked backwards in time from terminating to release locations (e.g., to compute capture zones).

Parameters

- **filename** (*str or PathLike*) – Path of the head file.
- **text** (*string*) – Name of the text string in the head file. Default is 'head'.
- **precision** (*string*) – Precision of floating point head data in the value. Accepted values are 'auto', 'single' or 'double'. Default is 'auto', which enables automatic detection of precision.
- **verbose** (*bool*) – Toggle logging output. Default is False.

Examples

```
>>> import flopy.utils.binaryfile as bf
>>> hdobj = bf.HeadFile('model.hds', precision='single')
>>> hdobj.list_records()
>>> rec = hdobj.get_data(kstpkper=(0, 49))
```

```
>>> ddnobj = bf.HeadFile('model.ddn', text='drawdown', precision='single')
>>> ddnobj.list_records()
>>> rec = ddnobj.get_data(totim=100.)
```

reverse(*filename: PathLike | None = None*)

Write a new binary head file with the records in reverse order. If a new filename is not provided, or if the filename is the same as the existing filename, the file will be overwritten and data reloaded from the rewritten/reversed file.

Parameters

filename (*str or PathLike*) – Path of the new reversed binary file to create.

class HeadUFile(*filename: str | PathLike, text='headu', precision='auto', verbose=False, **kwargs*)

Bases: *BinaryLayerFile*

The HeadUFile class provides simple ways to retrieve a list of head arrays from a MODFLOW-USG binary head file and time series arrays for one or more cells.

Parameters

- **filename** (*str or PathLike*) – Path of the head file
- **text** (*string*) – Name of the text string in the head file. Default is 'headu'.
- **precision** (*string*) – Precision of the floating point head data in the file. Accepted values are 'auto', 'single' or 'double'. Default is 'auto', which enables precision to be automatically detected.
- **verbose** (*bool*) – Toggle logging output. Default is False.

Notes

The BinaryLayerFile class is built on a record array consisting of headers, which are record arrays of the modflow header information (kstp, kper, pertim, totim, text, nrow, ncol, ilay), and long ints pointing to the 1st byte of data for the corresponding data arrays. This class overrides methods in the parent class so that the proper sized arrays are created: for unstructured grids, nrow and ncol are the starting and ending node numbers for layer, ilay.

When the get_data method is called for this class, a list of one-dimensional arrays will be returned, where each array is the head array for a layer. If the heads for a layer were not saved, then None will be returned for that layer.

Examples

```
>>> import flopy.utils.binaryfile as bf
>>> hdobj = bf.HeadUFile('model.hds')
>>> hdobj.list_records()
>>> usgheads = hdobj.get_data(kstpkper=(0, 49))
```

get_databytes(*header*)

Parameters
header (datafile.Header) – header object

Returns
databytes – size of the data array, in bytes, following the header

Return type
int

get_ts(*idx*)

Get a time series from the binary HeadUFile

Parameters
idx (*int or list of ints*) – idx can be nodenumber or it can be a list in the form [nodenumber, nodenumber, ...]. The nodenumber, values must be zero based.

Returns
out – Array has size (ntimes, ncells + 1). The first column in the data array will contain time (totim).

Return type
numpy array

class UcnFile(*filename*, *text='concentration'*, *precision='auto'*, *verbose=False*, ***kwargs*)

Bases: *BinaryLayerFile*

UcnFile Class.

Parameters

- **filename** (*string*) – Name of the concentration file
- **text** (*string*) – Name of the text string in the ucn file. Default is 'CONCENTRATION'
- **precision** (*string*) – 'auto', 'single' or 'double'. Default is 'auto'.

- **verbose** (*bool*) – Write information to the screen. Default is False.

Notes

The UcnFile class provides simple ways to retrieve 2d and 3d concentration arrays from a MT3D binary head file and time series arrays for one or more cells.

The BinaryLayerFile class is built on a record array consisting of headers, which are record arrays of the modflow header information (kstp, kper, pertim, totim, text, nrow, ncol, ilay) and long integers, which are pointers to first bytes of data for the corresponding data array.

Examples

```
>>> import flopy.utils.binaryfile as bf
>>> ucnobj = bf.UcnFile('MT3D001.UCN', precision='single')
>>> ucnobj.list_records()
>>> rec = ucnobj.get_data(kstpkper=(0, 0))
```

binaryread(*file*, *vartype*, *shape=(1,)*, *charlen=16*)

Uses numpy to read from binary file. This was found to be faster than the
struct approach and is used as the default.

binaryread_struct(*file*, *vartype*, *shape=(1,)*, *charlen=16*)

Read text, a scalar value, or an array of values from a binary file.

file
[file object] is an open file object

vartype
[type] is the return variable type: str, numpy.int32, numpy.float32, or numpy.float64

shape
[tuple] is the shape of the returned array (shape(1,) returns a single value) for example, shape = (nlay, nrow, ncol)

charlen
[int] is the length of the text string. Note that string arrays cannot be returned, only multi-character strings. Shape has no affect on strings.

get_headfile_precision(*filename: str | PathLike*)

Determine precision of a MODFLOW head file.

Parameters

- **filename** (*str or PathLike*) –
- **precision.** (*Path of binary MODFLOW file to determine*) –

Returns

- **result** (*str*)
- *Result will be unknown, single, or double*

join_struct_arrays(*arrays*)

Simple function that can join two numpy structured arrays.

write_budget(*fbin*, *data*, *kstp=1*, *kper=1*, *text=' FLOW-JA-FACE'*, *imeth=1*, *delt=1.0*, *pertim=1.0*, *totim=1.0*, *text1id1=' GWF-1'*, *text2id1=' GWF-1'*, *text1id2=' GWF-1'*, *text2id2=' NPF'*)

write_head(*fbin*, *data*, *kstp=1*, *kper=1*, *pertim=1.0*, *totim=1.0*, *text=' HEAD'*, *ilay=1*)

flopy.utils.check module

class check(*package*, *f: str | PathLike | None = None*, *verbose=True*, *level=1*, *property_threshold_values={}*)

Bases: object

Check package for common errors

Parameters

- **package** (*object*) – Instance of Package class.
- **f** (*str or PathLike, optional*) – Path to the summary file. If no path is provided, a summary file is not created and results are only written to stdout.
- **verbose** (*bool*) – Boolean flag used to determine if check method results are written to the screen
- **level** (*int*) – Check method analysis level. If level=0, summary checks are performed. If level=1, full checks are performed.
- **property_threshold_values** (*dict*) –

  hk

  [tuple] Reasonable minimum/maximum hydraulic conductivity value; values below this will be flagged. Default is (1e-11, 1e5), after Bear, 1972 (see https://en.wikipedia.org/wiki/Hydraulic_conductivity) and Schwartz and Zhang (2003, Table 4.4).

  vka

  [tuple] Reasonable minimum/maximum hydraulic conductivity value; Default is (1e-11, 1e5), after Bear, 1972 (see https://en.wikipedia.org/wiki/Hydraulic_conductivity) and Schwartz and Zhang (2003, Table 4.4).

  vkcb

  [tuple] Reasonable minimum/maximum hydraulic conductivity value for quasi-3D confining bed; Default is (1e-11, 1e5), after Bear, 1972 (see https://en.wikipedia.org/wiki/Hydraulic_conductivity) and Schwartz and Zhang (2003, Table 4.4).

  sy

  [tuple] Reasonable minimum/maximum specific yield values; Default is (0.01,0.5) after Anderson, Woessner and Hunt (2015, Table 5.2).

  sy

  [tuple] Reasonable minimum/maximum specific storage values;

Default is (3.3e-6, 2e-2) after Anderson, Woessner and Hunt (2015, Table 5.2).

Notes

Anderson, M.P, Woessner, W.W. and Hunt, R.J., 2015. Applied Groundwater
Modeling: Simulation of Flow and Advective Transport, Elsevier, 564p.

Bear, J., 1972. Dynamics of Fluids in Porous Media. Dover Publications. Schwartz, F.W. and Zhang, H., 2003. Fundamentals of Groundwater, Wiley,
583 p.

append_passed(*message*)

Add a check to the passed list if it isn't already in there.

bc_stage_names = {'DRN': 'elev', 'GHB': 'bhead'}

get_active(*include_cbd=False*)

Returns a boolean array of active cells for the model.

Parameters
include_cbd (*boolean*) – If True, active is of same dimension as the thickness array in the DIS module (includes quasi 3-D confining beds). Default False.

Returns
active – True where active.

Return type
3-D boolean array

get_neighbors(*a*)

For a structured grid, this returns the 6 neighboring values for each value in a. For an unstructured grid, this returns the n_max neighboring values, where n_max is the maximum number of nodal connections for any node within the model; nodes with less than n_max connections are assigned np.nan for indices above the number of connections for that node.

Parameters

- **a** (*3-D Model array in layer, row, column order array, even for an*) –
- **instance** (*unstructured grid; for*) –
- **array** (*a Util3d*) –
- **flopy.modflow.ModflowBas.ibound).** (*(e.g.*) –

Returns
neighbors – Array of neighbors, where axis 0 contains the n neighboring values for each value in a, and subsequent axes are in layer, row, column order. "n" is 6 for a structured grid, and "n" is n_max for an unstructured grid, as described above. Nan is returned for values at edges.

Return type
4-D array

isvalid(*inds*)

Check that indices are valid for model grid

Parameters

inds (*tuple or lists or arrays; or a 1-D array*) – (k, i, j) for structured grids; (node) for unstructured.

Returns

isvalid – True for each index in inds that is valid for the model grid.

Return type

1-D boolean array

package_check_levels = {'sfr': 1}

print_summary(*cols=None*, *delimiter=','*, *float_format='{:.6f}'*)

property_threshold_values = {'hani': None, 'hk': (1e-11, 100000.0), 'k': (1e-11, 100000.0), 'k22': (1e-11, 100000.0), 'k33': (1e-11, 100000.0), 'ss': (1e-06, 0.01), 'sy': (0.01, 0.5), 'vka': (1e-11, 100000.0), 'vkcb': (1e-11, 100000.0)}

remove_passed(*message*)

Remove a check to the passed list if it failed in any stress period.

solver_packages = {'mf2005': ['DE4', 'SIP', 'GMG', 'PCG', 'PCGN'], 'mf2k': ['DE4', 'SIP', 'SOR', 'GMG', 'PCG', 'PCGN'], 'mfnwt': ['DE4', 'SIP', 'PCG', 'NWT'], 'mfusg': ['SMS']}

stress_period_data_values(*stress_period_data*, *criteria*, *col=None*, *error_name=''*, *error_type='Warning'*)

If criteria contains any true values, return the error_type, package name, k,i,j indices, values, and description of error for each row in stress_period_data where criteria=True.

summarize(*scrub: bool = False*)

thin_cell_threshold = 1.0

values(*a*, *criteria*, *error_name=''*, *error_type='Warning'*)

If criteria contains any true values, return the error_type, package name, indices, array values, and description of error for each True value in criteria.

view_summary_array_fields(*fields*)

fields_view(*arr*, *fields*)

creates view of array that only contains the fields in fields. https://stackoverflow.com/q/15182381/

class mf6check(*package*, *f=None*, *verbose=True*, *level=1*, *property_threshold_values={}*)

Bases: check

get_active(*include_cbd=False*)

Returns a boolean array of active cells for the model.

Parameters

include_cbd (*boolean*) – Does not apply to MF6 models, always false.

Returns
active - True where active.

Return type
3-D boolean array

flopy.utils.compare module

compare(*namefile1: str | PathLike = None*, *namefile2: str | PathLike = None*, *precision='auto'*, *max_cumpd=0.01*, *max_incpd=0.01*, *htol=0.001*, *outfile1: str | PathLike | None = None*, *outfile2: str | PathLike | None = None*, *files1: str | PathLike | List[str | PathLike] | None = None*, *files2: str | PathLike | List[str | PathLike] | None = None*)

Compare the budget and head results for two MODFLOW-based model simulations.

Parameters

- **namefile1** (*str or PathLike, optional*) - namefile path for base model
- **namefile2** (*str or PathLike, optional*) - namefile path for comparison model
- **precision** (*str*) - precision for binary head file ("auto", "single", or "double") default is "auto"
- **max_cumpd** (*float*) - maximum percent discrepancy allowed for cumulative budget terms (default is 0.01)
- **max_incpd** (*float*) - maximum percent discrepancy allowed for incremental budget terms (default is 0.01)
- **htol** (*float*) - maximum allowed head difference (default is 0.001)
- **outfile1** (*str or PathLike, optional*) - budget comparison output file name. If outfile1 is None, no budget comparison output is saved. (default is None)
- **outfile2** (*str or PathLike, optional*) - head comparison output file name. If outfile2 is None, no head comparison output is saved. (default is None)
- **files1** (*str, PathLike, or list, optional*) - base model output file. If files1 is not None, results will be extracted from files1 and namefile1 will not be used. (default is None)
- **files2** (*str, PathLike, or list, optional*) - comparison model output file. If files2 is not None, results will be extracted from files2 and namefile2 will not be used. (default is None)

Returns
success - boolean indicating if the budget and head differences are less than max_cumpd, max_incpd, and htol.

Return type
bool

compare_budget(*namefile1: str | PathLike | None*, *namefile2: str | PathLike | None*, *max_cumpd=0.01*, *max_incpd=0.01*, *outfile: str | PathLike | None = None*, *files1: str | PathLike | List[str | PathLike] | None = None*, *files2: str | PathLike | List[str | PathLike] | None = None*)

Compare the budget results from two simulations.

Parameters

- **namefile1** (*str or PathLike, optional*) – namefile path for base model
- **namefile2** (*str or PathLike, optional*) – namefile path for comparison model
- **max_cumpd** (*float*) – maximum percent discrepancy allowed for cumulative budget terms (default is 0.01)
- **max_incpd** (*float*) – maximum percent discrepancy allowed for incremental budget terms (default is 0.01)
- **outfile** (*str or PathLike, optional*) – budget comparison output file name. If outfile is None, no comparison output is saved. (default is None)
- **files1** (*str, PathLike, or list, optional*) – base model output file. If files1 is not None, results will be extracted from files1 and namefile1 will not be used. (default is None)
- **files2** (*str, PathLike, or list, optional*) – comparison model output file. If files2 is not None, results will be extracted from files2 and namefile2 will not be used. (default is None)

Returns

success – boolean indicating if the difference between budgets are less than max_cumpd and max_incpd

Return type

bool

compare_concentrations(*namefile1: str | PathLike, namefile2: str | PathLike, precision='auto', ctol=0.001, outfile: str | PathLike | None = None, files1: str | PathLike | List[str | PathLike] | None = None, files2: str | PathLike | List[str | PathLike] | None = None, difftol=False, verbose=False*)

Compare the mt3dms and mt3dusgs concentration results from two simulations.

Parameters

- **namefile1** (*str or PathLike*) – namefile path for base model
- **namefile2** (*str or PathLike*) – namefile path for comparison model
- **precision** (*str*) – precision for binary head file ("auto", "single", or "double") default is "auto"
- **ctol** (*float*) – maximum allowed concentration difference (default is 0.001)
- **outfile** (*str or PathLike, optional*) – concentration comparison output file name. If outfile is None, no comparison output is saved. (default is None)
- **files1** (*str, PathLike, or list, optional*) – base model output file. If files1 is not None, results will be extracted from files1 and namefile1 will not be used. (default is None)

- **files2** (*str, PathLike, or list, optional*) – comparison model output file. If files2 is not None, results will be extracted from files2 and namefile2 will not be used. (default is None)
- **difftol** (*bool*) – boolean determining if the absolute value of the concentration difference greater than ctol should be evaluated (default is False)
- **verbose** (*bool*) – boolean indicating if verbose output should be written to the terminal (default is False)

Returns
success - boolean indicating if the concentration differences are less than ctol.

Return type
bool

compare_heads(*namefile1: str | PathLike | None, namefile2: str | PathLike | None, precision='auto', text='head', text2=None, htol=0.001, outfile: str | PathLike | None = None, files1: str | PathLike | List[str | PathLike] | None = None, files2: str | PathLike | List[str | PathLike] | None = None, difftol=False, verbose=False, exfile: str | PathLike | None = None, exarr=None, maxerr=None*)

Compare the head results from two simulations.

Parameters

- **namefile1** (*str or PathLike*) – namefile path for base model
- **namefile2** (*str or PathLike*) – namefile path for comparison model
- **precision** (*str*) – precision for binary head file ("auto", "single", or "double") default is "auto"
- **htol** (*float*) – maximum allowed head difference (default is 0.001)
- **outfile** (*str or PathLike*) – head comparison output file name. If outfile is None, no comparison output is saved. (default is None)
- **files1** (*str or PathLike, or List of str or PathLike*) – base model output files. If files1 is not None, results will be extracted from files1 and namefile1 will not be used. (default is None)
- **files2** (*str or PathLike, or List of str or PathLike*) – comparison model output files. If files2 is not None, results will be extracted from files2 and namefile2 will not be used. (default is None)
- **difftol** (*bool*) – boolean determining if the absolute value of the head difference greater than htol should be evaluated (default is False)
- **verbose** (*bool*) – boolean indicating if verbose output should be written to the terminal (default is False)
- **exfile** (*str or PathLike, optional*) – path to a file with exclusion array data. Head differences will not be evaluated where exclusion array values are greater than zero. (default is None)

- **exarr** (*numpy.ndarry*) – exclusion array. Head differences will not be evaluated where exclusion array values are greater than zero. (default is None).
- **maxerr** (*int*) – maximum number of head difference greater than htol that should be reported. If maxerr is None, all head difference greater than htol will be reported. (default is None)

Returns
success – boolean indicating if the head differences are less than htol.

Return type
bool

compare_stages(*namefile1: str | PathLike = None, namefile2: str | PathLike = None, files1: str | PathLike | List[str | PathLike] | None = None, files2: str | PathLike | List[str | PathLike] | None = None, htol=0.001, outfile: str | PathLike | None = None, difftol=False, verbose=False*)

Compare SWR process stage results from two simulations.

Parameters

- **namefile1** (*str or PathLike*) – namefile path for base model
- **namefile2** (*str or PathLike*) – namefile path for comparison model
- **precision** (*str*) – precision for binary head file ("auto", "single", or "double") default is "auto"
- **htol** (*float*) – maximum allowed stage difference (default is 0.001)
- **outfile** (*str or PathLike, optional*) – head comparison output file name. If outfile is None, no comparison output is saved. (default is None)
- **files1** (*str, PathLike, or list, optional*) – base model output file. If files1 is not None, results will be extracted from files1 and namefile1 will not be used. (default is None)
- **files2** (*str, PathLike, or list, optional*) – comparison model output file. If files2 is not None, results will be extracted from files2 and namefile2 will not be used. (default is None)
- **difftol** (*bool*) – boolean determining if the absolute value of the stage difference greater than htol should be evaluated (default is False)
- **verbose** (*bool*) – boolean indicating if verbose output should be written to the terminal (default is False)

Returns
success – boolean indicating if the stage differences are less than htol.

Return type
bool

compare_swrbudget(*namefile1: str | PathLike | None, namefile2: str | PathLike | None, max_cumpd=0.01, max_incpd=0.01, outfile: str | PathLike | None = None, files1: str | PathLike | List[str | PathLike] | None = None, files2: str | PathLike | List[str | PathLike] | None = None*)

Compare the SWR budget results from two simulations.

Parameters

- **namefile1** (*str or PathLike, optional*) – namefile path for base model
- **namefile2** (*str or PathLike, optional*) – namefile path for comparison model
- **max_cumpd** (*float*) – maximum percent discrepancy allowed for cumulative budget terms (default is 0.01)
- **max_incpd** (*float*) – maximum percent discrepancy allowed for incremental budget terms (default is 0.01)
- **outfile** (*str or PathLike, optional*) – budget comparison output file name. If outfile is None, no comparison output is saved. (default is None)
- **files1** (*str, PathLike, or list, optional*) – base model output file. If files1 is not None, results will be extracted from files1 and namefile1 will not be used. (default is None)
- **files2** (*str, PathLike, or list, optional*) – comparison model output file. If files2 is not None, results will be extracted from files2 and namefile2 will not be used. (default is None)

Returns

success – boolean indicating if the difference between budgets are less than max_cumpd and max_incpd

Return type

bool

eval_bud_diff(*fpth: str | PathLike, b0, b1, ia=None, dtol=1e-06*)

flopy.utils.crs module

Utilities related to coordinate reference system handling.

get_authority_crs(*crs*)

Try to get the authority representation for a coordinate reference system (CRS), for more robust comparison with other CRS objects.

Parameters

crs (*pyproj.CRS, int, str*) – Coordinate reference system (CRS) for the model grid (must be projected; geographic CRS are not supported). The value can be anything accepted by pyproj.CRS.from_user_input(), such as an authority string (eg "EPSG:26916") or a WKT string.

Returns

CRS instance initiallized with the name and authority code (e.g. "epsg:5070") produced by pyproj.crs.CRS.to_authority()

Return type

pyproj.CRS instance

Notes

pyproj.crs.CRS.to_authority() will return None if a matching authority name and code can't be found. In this case, the input crs instance will be returned.

References

http://pyproj4.github.io/pyproj/stable/api/crs/crs.html

get_crs(*prjfile=None*, *crs=None*, ***kwargs*)

Helper function to produce a pyproj.CRS object from various input.

Notes

Longer-term, this would just handle the crs and prjfile arguments, but in the near term, we need to warn users about deprecating the prj, epsg, proj4 and wkt_string inputs.

Parameters

- **prjfile** (*str or pathlike*, *optional*) – ESRI-style projection file with well-known text defining the CRS for the model grid (must be projected; geographic CRS are not supported).
- **crs** (pyproj.CRS, int, str, optional if *prjfile* is specified) – Coordinate reference system (CRS) for the model grid (must be projected; geographic CRS are not supported). The value can be anything accepted by pyproj.CRS.from_user_input(), such as an authority string (eg "EPSG:26916") or a WKT string.
- ****kwargs** (*dict*, *optional*) – Support deprecated keyword options.

  Deprecated since version 3.4: The following keyword options will be removed for FloPy 3.6:

  – prj (str or pathlike): use prjfile instead.

  – epsg (int): use crs instead.

  – proj4 (str): use crs instead.

  – wkt_string (str): use crs instead.

Return type

pyproj.CRS instance

get_shapefile_crs(*shapefile*)

Get the coordinate reference system for a shapefile.

Parameters

shapefile (*str or pathlike*) – Path to a shapefile or an associated projection (.prj) file.

Return type

pyproj.CRS instance

flopy.utils.cvfdutil module

class Point(*x*, *y*)

Bases: object

area_of_polygon(*x*, *y*)

Calculates the signed area of an arbitrary polygon given its vertices https://stackoverflow.com/a/4682656/ (Joe Kington) http://softsurfer.com/Archive/algorithm_0101/algorithm_0101.htm#2D%20Polygons

centroid_of_polygon(*points*)

https://stackoverflow.com/a/14115494/ (mgamba)

get_disv_gridprops(*verts*, *iverts*, *xcyc=None*)

Calculate disv grid properties from verts and iverts

Parameters

- **verts** (*ndarray*) – 2d array of x, y vertices
- **iverts** (*list*) – list of size ncpl, with a list of vertex numbers for each cell

Returns

gridprops – Dictionary containing entries that can be passed directly into the modflow6 disv package.

Return type

dict

gridlist_to_disv_gridprops(*gridlist*)

Take a list of flopy structured model grids and convert them into a dictionary that can be passed into the modflow6 disv package. Cells from a child grid will patched in to make a single set of vertices. Cells will be numbered according to consecutive numbering of active cells in the grid list.

Parameters

gridlist (*list*) – List of flopy.discretization.modelgrid. Must be of type structured grids

Returns

gridprops – Dictionary containing entries that can be passed directly into the modflow6 disv package.

Return type

dict

gridlist_to_verts(*gridlist*)

Take a list of flopy structured model grids and convert them into vertices. The idomain can be set to remove cells in a parent grid. Cells from a child grid will patched in to make a single set of vertices. Cells will be numbered according to consecutive numbering of active cells in the grid list.

Parameters

gridlist (*list*) – List of flopy.discretization.modelgrid. Must be of type structured grids

Returns

verts, iverts – vertices and list of cells and which vertices comprise the cells

Return type
np.ndarray, list

isBetween(*a*, *b*, *c*, *epsilon=0.001*)

segment_face(*ivert*, *ivlist1*, *ivlist2*, *vertices*)

Check the vertex lists for cell 1 and cell 2. Add a new vertex to cell 1 if necessary.

Parameters

- **ivert** (*int*) – vertex number to check
- **ivlist1** (*list*) – list of vertices for cell 1. Add a new vertex to this cell if needed.
- **ivlist2** (*list*) – list of vertices for cell2.
- **vertices** (*ndarray*) – array of x, y vertices

Returns
segmented – Return True if a face in cell 1 was split up by adding a new vertex

Return type
bool

shapefile_to_cvfd(*shp*, ***kwargs*)

shapefile_to_xcyc(*shp*)

Get cell centroid coordinates

Parameters
shp (*string*) – Name of shape file

Returns
xcyc – x, y coordinates of all polygons in shp

Return type
ndarray

shared_face(*ivlist1*, *ivlist2*)

to_cvfd(*vertdict*, *nodestart=None*, *nodestop=None*, *skip_hanging_node_check=False*, *verbose=False*)

Convert a vertex dictionary into verts and iverts

Parameters

- **vertdict** – vertdict is a dictionary {icell: [(x1, y1), (x2, y2), (x3, y3), ...]}
- **nodestart** (*int*) – starting node number. (default is zero)
- **nodestop** (*int*) – ending node number up to but not including. (default is len(vertdict))
- **skip_hanging_node_check** (*bool*) – skip the hanging node check. this may only be necessary for quad-based grid refinement. (default is False)
- **verbose** (*bool*) – print messages to the screen. (default is False)

Returns

- **verts** (*ndarray*) – array of x, y vertices

- **iverts** (*list*) – list containing a list for each cell

flopy.utils.datafile module

Module to read MODFLOW output files. The module contains shared abstract classes that should not be directly accessed.

class Header(*filetype=None*, *precision='single'*)

Bases: object

The header class is an abstract base class to create headers for MODFLOW files

get_dtype()

Return the dtype

get_names()

Return the dtype names

get_values()

Return the header values

class LayerFile(*filename: str | PathLike*, *precision*, *verbose*, *kwargs*)

Bases: object

Base class for layered output files. Do not instantiate directly.

close()

Close the file handle.

get_alldata(*mflay=None*, *nodata=-9999*)

Get all of the data from the file.

Parameters

- **mflay** (*integer*) – MODFLOW zero-based layer number to return. If None, then all all layers will be included. (Default is None.)
- **nodata** (*float*) – The nodata value in the data array. All array values that have the nodata value will be assigned np.nan.

Returns

data – Array has size (ntimes, nlay, nrow, ncol) if mflay is None or it has size (ntimes, nrow, ncol) if mlay is specified.

Return type

numpy array

Notes

Examples

get_data(*kstpkper=None*, *idx=None*, *totim=None*, *mflay=None*)

Get data from the file for the specified conditions.

Parameters

- **idx** (*int*) – The zero-based record number. The first record is record 0.
- **kstpkper** (*tuple of ints*) – A tuple (kstep, kper) of zero-based time step and stress period.
- **totim** (*float*) – The simulation time.
- **mflay** (*integer*) – MODFLOW zero-based layer number to return. If None, then all all layers will be included. (Default is None.)

Returns

data – Array has size (nlay, nrow, ncol) if mflay is None or it has size (nrow, ncol) if mlay is specified.

Return type

numpy array

Notes

If both kstpkper and totim are None, the last entry will be returned.

get_kstpkper()

Get a list of unique tuples (stress period, time step) in the file. Indices are 0-based, use the *kstpkper* attribute for 1-based.

Returns

List of unique combinations of stress period & time step indices (0-based) in the binary file

Return type

list of (kstp, kper) tuples

get_nrecords()

get_times()

Get a list of unique times in the file

Returns

out – List contains unique simulation times (totim) in binary file.

Return type

list of floats

list_records()

Print a list of all of the records in the file obj.list_records()

plot(*axes=None*, *kstpkper=None*, *totim=None*, *mflay=None*, *filename_base=None*, ***kwargs*)

Plot 3-D model output data in a specific location in LayerFile instance

Parameters

- **axes** (*list of matplotlib.pyplot.axis*) – List of matplotlib.pyplot.axis that will be used to plot data for each layer. If axes=None axes will be generated. (default is None)
- **kstpkper** (*tuple of ints*) – A tuple containing the time step and stress period (kstp, kper). These are zero-based kstp and kper values.
- **totim** (*float*) – The simulation time.
- **mflay** (*int*) – MODFLOW zero-based layer number to return. If None, then all all layers will be included. (default is None)
- **filename_base** (*str*) – Base file name that will be used to automatically generate file names for output image files. Plots will be exported as image files if file_name_base is not None. (default is None)
- ****kwargs** (*dict*) –

  pcolor
  [bool] Boolean used to determine if matplotlib.pyplot.pcolormesh plot will be plotted. (default is True)

  colorbar
  [bool] Boolean used to determine if a color bar will be added to the matplotlib.pyplot.pcolormesh. Only used if pcolor=True. (default is False)

  contour
  [bool] Boolean used to determine if matplotlib.pyplot.contour plot will be plotted. (default is False)

  clabel
  [bool] Boolean used to determine if matplotlib.pyplot.clabel will be plotted. Only used if contour=True. (default is False)

  grid
  [bool] Boolean used to determine if the model grid will be plotted on the figure. (default is False)

  masked_values
  [list] List of unique values to be excluded from the plot.

  file_extension
  [str] Valid matplotlib.pyplot file extension for savefig(). Only used if filename_base is not None. (default is 'png')

Return type

None

Notes

Examples

```
>>> import flopy
>>> hdobj = flopy.utils.HeadFile('test.hds')
>>> times = hdobj.get_times()
>>> hdobj.plot(totim=times[-1])
```

to_shapefile(*filename: str | PathLike*, *kstpkper=None*, *totim=None*, *mflay=None*, *attrib_name='lf_data'*, *verbose=False*)

Export model output data to a shapefile at a specific location
in LayerFile instance.

Parameters

- **filename** (*str or PathLike*) – Shapefile path to write
- **kstpkper** (*tuple of ints*) – A tuple containing the time step and stress period (kstp, kper). These are zero-based kstp and kper values.
- **totim** (*float*) – The simulation time.
- **mflay** (*integer*) – MODFLOW zero-based layer number to return. If None, then layer 1 will be written
- **attrib_name** (*str*) – Base name of attribute columns. (default is 'lf_data')
- **verbose** (*bool*) – Whether to print verbose output

Return type
None

Notes

Examples

```
>>> import flopy
>>> hdobj = flopy.utils.HeadFile('test.hds')
>>> times = hdobj.get_times()
>>> hdobj.to_shapefile('test_heads_sp6.shp', totim=times[-1])
```

flopy.utils.datautil module

class ArrayIndexIter(*array_shape*, *index_as_tuple=False*)

Bases: object

class ConstIter(*value*)

Bases: object

class DatumUtil

Bases: object

static cellid_model_num(*data_item_name*, *model_data*, *model_dim*)

static is_basic_type(*obj*)

static is_float(*str*)

static is_int(*str*)

class FileIter(*file_path*)

Bases: object

close()

class MultiList(*mdlist=None*, *shape=None*, *callback=None*)

Bases: object

Class for storing objects in an n-dimensional list which can be iterated through as a single list.

Parameters

- **mdlist** (*list*) – multi-dimensional list to initialize the multi-list. either mdlist or both shape and callback must be specified
- **shape** (*tuple*) – shape of the multi-list
- **callback** (*method*) – callback method that takes a location in the multi-list (tuple) and returns an object to be stored at that location in the multi-list

increment_dimension : (dimension, callback)

increments the size of one of the two dimensions of the multi-list

build_list : (callback)

builds a multi-list of shape self.list_shape, constructing objects for the list using the supplied callback method

first_item : () : object

gets the first entry in the multi-list

get_total_size : () : int

returns the total number of entries in the multi-list

in_shape : (indexes) : boolean

returns whether a tuple of indexes are valid indexes for the shape of the multi-list

inc_shape_idx : (indexes) : tuple

given a tuple of indexes pointing to an entry in the multi-list, returns a tuple of indexes pointing to the next entry in the multi-list

first_index : () : tuple

returns a tuple of indexes pointing to the first entry in the multi-list

indexes : (start_indexes=None, end_indexes=None) : iter(tuple)

returns an iterator that iterates from the location in the multi-list defined by start_indexes to the location in the multi-list defined by end_indexes

elements : () : iter(object)
returns an iterator that iterates over each object stored in the multi-list

build_list(*callback*)

elements()

first_index()

first_item()

get_total_size()

in_shape(*indexes*)

inc_shape_idx(*indexes*)

increment_dimension(*dimension*, *callback*)

indexes(*start_indexes=None*, *end_indexes=None*)

nth_index(*n*)

class **MultiListIter**(*multi_list*, *detailed_info=False*, *iter_leaf_lists=False*)
Bases: object

class **NameIter**(*name*, *first_not_numbered=True*)
Bases: object

class **PathIter**(*path*, *first_not_numbered=True*)
Bases: object

class **PyListUtil**(*path=None*, *max_error=0.01*)
Bases: object

Class contains miscellaneous methods to work with and compare python lists

Parameters

- **path** (*string*) – file path to read/write to
- **max_error** (*float*) – maximum acceptable error when doing a compare of floating point numbers

is_iterable : (obj : unknown) : boolean
determines if obj is iterable

is_empty_list : (current_list : list) : boolean
determines if an n-dimensional list is empty

con_convert : (data : string, data_type : type that has conversion

operation) : boolean

returns true if data can be converted into data_type

max_multi_dim_list_size : (current_list : list) : boolean
determines the max number of items in a multi-dimensional list 'current_list'

first_item : (current_list : list) : variable
returns the first item in the list 'current_list'

next_item : (current_list : list) : variable
: returns the next item in the list 'current_list'

array_comp : (first_array : list, second_array : list) : boolean
: compares two lists, returns true if they are identical (with max_error)

spilt_data_line : (line : string) : list
: splits a string apart (using split) and then cleans up the results dealing with various MODFLOW input file releated delimiters. returns the delimiter type used.

clean_numeric : (text : string) : string
: returns a cleaned up version of 'text' with only numeric characters

save_array_diff : (first_array : list, second_array : list,

first_array_name : string, second_array_name : string)

saves lists 'first_array' and 'second_array' to files first_array_name and second_array_name and then saves the difference of the two arrays to 'debug_array_diff.txt'

save_array(*filename: string*, *multi_array: list*)
: saves 'multi_array' to the file 'filename'

array_comp(*first_array*, *second_array*)

static **clean_numeric**(*text*)

consistent_delim = False

delimiter_list = {',': 1}

delimiter_used = None

static **first_item**(*current_list*)

static **has_one_item**(*current_list*)

static **is_empty_list**(*current_list*)

static **is_iterable**(*obj*)

line_num = 0

static **max_multi_dim_list_size**(*current_list*)

static **next_item**(*current_list*, *new_list=True*, *nesting_change=0*, *end_of_list=True*)

static **next_list**(*current_list*)

numeric_chars = {'-': 0, '.': 0, '0': 0, '1': 0, '2': 0, '3': 0, '4': 0, '5': 0, '6': 0, '7': 0, '8': 0, '9': 0}

quote_list = {'"', "'"}

static **reset_delimiter_used**()

riv_array_comp(*first_array*, *second_array*)

save_array(*filename*, *multi_array*)

save_array_diff(*first_array*, *second_array*, *first_array_name*, *second_array_name*)

static split_data_line(*line*, *external_file=False*, *delimiter_conf_length=15*)

clean_filename(*file_name*)

clean_name(*name*)

find_keyword(*arr_line*, *keyword_dict*)

max_tuple_abs_size(*some_tuple*)

flopy.utils.flopy_io module

Module for input/output utilities

flux_to_wel(*cbc_file*, *text*, *precision='single'*, *model=None*, *verbose=False*)

Convert flux in a binary cell budget file to a wel instance

Parameters

- **cbc_file** (*(str) cell budget file name*) –
- **text** (*(str) text string of the desired flux type (e.g. "drains")*) –
- **precision** (*(optional str) precision of the cell budget file*) –
- **model** (*(optional) BaseModel instance. If passed, a new ModflowWel*) – instance will be added to model
- **verbose** (*bool flag passed to CellBudgetFile*) –

Return type

flopy.modflow.ModflowWel instance

get_next_line(*f*)

Get the next line from a file that is not a blank line

Parameters

f (*filehandle*) – filehandle to a open file

Returns

line – next non-empty line in a open file

Return type

string

get_ts_sp(*line*)

Reader method to get time step and stress period numbers from list files and Modflow other output files

Parameters

line (*str*) – line containing information about the stress period and time step. The line must contain "STRESS PERIOD <x> TIME STEP <y>"

Return type

tuple of stress period and time step numbers

get_url_text(*url*, *error_msg=None*)

Get text from a url.

line_parse(*line*)

Convert a line of text into to a list of values. This handles the case where a free formatted MODFLOW input file may have commas in it.

line_strip(*line*)

Remove comments and replace commas from input text for a free formatted modflow input file

Parameters
line (*str*) – a line of text from a modflow input file

Returns
str

Return type
line with comments removed and commas replaced

loadtxt(*file*, *delimiter=' '*, *dtype=None*, *skiprows=0*, *use_pandas=True*, ***kwargs*)

Use pandas to load a text file (significantly faster than n.loadtxt or genfromtxt see https://stackoverflow.com/q/18259393/)

Parameters

- **file** (*file or str*) – File, filename, or generator to read.
- **delimiter** (*str, optional*) – The string used to separate values. By default, this is any whitespace.
- **dtype** (*data-type, optional*) – Data-type of the resulting array
- **skiprows** (*int, optional*) – Skip the first skiprows lines; default: 0.
- **use_pandas** (*bool*) – If true, the much faster pandas.read_csv method is used.
- **kwargs** (*dict*) – Keyword arguments passed to numpy.loadtxt or pandas.read_csv.

Returns
ra – Numpy record array of file contents.

Return type
np.recarray

multi_line_strip(*fobj*)

Get next line that is not blank or is not a comment line from a free formatted modflow input file

Parameters
fobj (*open file object*) – a line of text from an input file

Returns
str

Return type
line with comments removed and commas replaced

pop_item(*line*, *dtype=<class 'str'>*)

read_fixed_var(*line*, *ncol=1*, *length=10*, *ipos=None*, *free=False*)

Parse a fixed format line using user provided data

Parameters

- **line** (*str*) – text string to parse.

- **ncol** (*int*) – number of columns to parse from line. (default is 1)
- **length** (*int*) – length of each column for fixed column widths. (default is 10)
- **ipos** (*list, int, or numpy array*) – user-provided column widths. (default is None)
- **free** (*bool*) – boolean indicating if sting is free format. ncol, length, and ipos are not used if free is True. (default is False)

Returns
out – padded list containing data parsed from the passed text string

Return type
list

relpath_safe(*path: str | PathLike, start: str | PathLike = '.', scrub: bool = False*) → str

Return a relative version of the path starting at the given start path. This is impossible on Windows if the paths are on different drives, in which case the absolute path is returned. The builtin os.path.relpath raises a ValueError, this method is a workaround to avoid interrupting normal control flow (background at https://bugs.python.org/issue7195).

This method also truncates/obfuscates absolute paths with usernames.

Parameters

- **path** (*str or PathLike*) – the path to truncate relative to the start path
- **start** (*str or PathLike, default "."*) – the starting path, defaults to the current working directory
- **scrub** (*bool, default False*) – whether to remove the current login name from paths

Returns

- **str** (the relative path, unless the platform is Windows and the *path*)
- is not on the same drive as *start*, in which case the absolute path,
- *with elements before and including usernames removed and obfuscated*

scrub_login(*s: str*) → str

Remove the current login name from the given string, replacing any occurences with "***".

Parameters
s (*str*) – the input string

Return type
the string with login name obfuscated

ulstrd(*f, nlist, ra, model, sfac_columns, ext_unit_dict*)

Read a list and allow for open/close, binary, external, sfac, etc.

Parameters

- **f** (*file handle*) – file handle for where the list is being read from
- **nlist** (*int*) – size of the list (number of rows) to read
- **ra** (*np.recarray*) – A record array of the correct size that will be filled with the list
- **model** (*model object*) – The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.
- **sfac_columns** (*list*) – A list of strings containing the column names to scale by sfac
- **ext_unit_dict** (*dictionary, optional*) – If the list in the file is specified using EXTERNAL, then in this case ext_unit_dict is required, which can be constructed using the function *flopy.utils.mfreadnam.parsenamefile*.

write_fixed_var(*v*, *length=10*, *ipos=None*, *free=False*, *comment=None*)

Parameters

- **v** (*list, int, float, bool, or numpy array*) – list, int, float, bool, or numpy array containing the data to be written to a string.
- **length** (*int*) – length of each column for fixed column widths. (default is 10)
- **ipos** (*list, int, or numpy array*) – user-provided column widths. (default is None)
- **free** (*bool*) – boolean indicating if a free format string should be generated. length and ipos are not used if free is True. (default is False)
- **comment** (*str*) – comment string to add to the end of the string

Returns

out – fixed or free format string generated using user-provided data

Return type

str

flopy.utils.formattedfile module

Module to read MODFLOW formatted output files. The module contains one important classes that can be accessed by the user.

- FormattedHeadFile (Formatted head file. Can also be used for drawdown)

class FormattedHeadFile(*filename*, *text='head'*, *precision='single'*, *verbose=False*, ***kwargs*)

Bases: *FormattedLayerFile*

FormattedHeadFile Class.

Parameters

- **filename** (*string*) – Name of the formatted head file
- **text** (*string*) – Name of the text string in the formatted head file. Default is 'head'

- **precision** (*string*) – 'single' or 'double'. Default is 'single'.
- **verbose** (*bool*) – Write information to the screen. Default is False.

Notes

The FormattedHeadFile class provides simple ways to retrieve 2d and 3d head arrays from a MODFLOW formatted head file and time series arrays for one or more cells.

The FormattedHeadFile class is built on a record array consisting of headers, which are record arrays of the modflow header information (kstp, kper, pertim, totim, text, nrow, ncol, ilay) and long integers, which are pointers to first bytes of data for the corresponding data array.

FormattedHeadFile can only read formatted head files containing headers. Use the LABEL option in the output control file to generate head files with headers.

Examples

```
>>> import flopy.utils.formattedfile as ff
>>> hdobj = ff.FormattedHeadFile('model.fhd', precision='single')
>>> hdobj.list_records()
>>> rec = hdobj.get_data(kstpkper=(0, 49))
>>> rec2 = ddnobj.get_data(totim=100.)
```

class FormattedHeader(*text_ident*, *precision='single'*)

Bases: *Header*

The TextHeader class is a class to read in headers from MODFLOW formatted files.

Parameters

- **type** (*text_ident is the text string in the header that identifies the*) –
- **point** (*of data (eg. 'head') precision is the precision of the floating*) –
- **file** (*data in the*) –

read_header(*text_file*)

Read header information from a formatted file

Parameters

- **of** (*text_file is an open file object currently at the beginning*) –
- **header** (*the*) –

Returns

- **out** (*numpy array of header information*)
- *also stores the header's format string as self.format_string*

class FormattedLayerFile(*filename*, *precision*, *verbose*, *kwargs*)

Bases: *LayerFile*

The FormattedLayerFile class is the super class from which specific derived classes are formed. This class should not be instantiated directly

close()

Close the file handle.

get_ts(*idx*)

Get a time series from the formatted file.

Parameters

idx (*tuple of ints, or a list of a tuple of ints*) – idx can be (layer, row, column) or it can be a list in the form [(layer, row, column), (layer, row, column), ...]. The layer, row, and column values must be zero based.

Returns

out – Array has size (ntimes, ncells + 1). The first column in the data array will contain time (totim).

Return type

numpy array

Notes

The layer, row, and column values must be zero-based, and must be within the following ranges: 0 <= k < nlay; 0 <= i < nrow; 0 <= j < ncol

Examples

is_float(*s*)

is_int(*s*)

flopy.utils.geometry module

Container objects for working with geometric information

class Collection(*geometries=()*)

Bases: list

The collection object is container for a group of flopy geometries

This class acts as a base class for MultiPoint, MultiLineString, and MultiPolygon classes. This class can also accept a mix of geometries and act as a stand alone container.

Parameters

geometries (*list*) – list of flopy.util.geometry objects

property bounds

Method to calculate the bounding box of the collection

Return type

tuple (xmin, ymin, xmax, ymax)

plot(*ax=None*, ***kwargs*)
Plotting method for collection

Parameters

- **ax** (*matplotlib.axes object*) –
- **kwargs** (*keyword arguments*) – matplotlib keyword arguments

Return type
matplotlib.axes object

class **MultiLineString**(*linestrings=()*)
Bases: *Collection*

property bounds

has_z = False

plot(*ax=None*, ***kwargs*)

property pyshp_parts

shapeType = 3

type = 'LineString'

property x

property y

property z

class **MultiLineString**(*linestrings=()*)
Bases: *Collection*

Container for housing and describing multilinestring geometries (e.g. to be
read or written to shapefiles or other geographic data formats)

Parameters:

polygons
[list] list of flopy.utils.geometry.LineString objects

class **MultiPoint**(*points=()*)
Bases: *Collection*

Container for housing and describing multipoint geometries (e.g. to be
read or written to shapefiles or other geographic data formats)

Parameters:

polygons
[list] list of flopy.utils.geometry.Point objects

class **MultiPolygon**(*polygons=()*)
Bases: *Collection*

Container for housing and describing multipolygon geometries (e.g. to be
read or written to shapefiles or other geographic data formats)

Parameters:

polygons
[list] list of flopy.utils.geometry.Polygon objects

class Point(**coordinates*)

Bases: *Shape*

property bounds

has_z = False

plot(*ax=None*, ***kwargs*)

property pyshp_parts

shapeType = 1

type = 'Point'

property x

property y

property z

class Polygon(*exterior*, *interiors=None*)

Bases: *Shape*

property bounds

get_patch(***kwargs*)

property patch

plot(*ax=None*, ***kwargs*)

Plot the feature. :param ax: :type ax: matplotlib.pyplot axes instance :param Accepts keyword arguments to descartes.PolygonPatch. Requires the: :param descartes package (pip install descartes).:

property pyshp_parts

shapeType = 5

type = 'Polygon'

class Shape(*shapetype*, *coordinates=None*, *exterior=None*, *interiors=None*)

Bases: object

Parent class for handling geo interfacing, do not instantiate directly

Parameters:

type
[str] shapetype string

coordinates
[list or tuple] list of tuple of point or linestring coordinates

exterior
[list or tuple] 2d list of polygon coordinates

interiors
[list or tuple] 2d or 3d list of polygon interiors

static **from_geojson**(*geo_interface*)

Method to load from geojson

Parameters
geo_interface (*geojson, dict*) – geojson compliant representation of a linestring

Return type
Polygon, *LineString*, or *Point*

property **geojson**

get_polygon_area(*geom*)

Calculate the area of a closed polygon

Parameters
geom (*geospatial representation of polygon*) – accepted types:

vertices np.array([(x, y),....]) geojson.Polygon shapely.Polygon shapefile.Shape

Returns
area – area of polygon centroid

Return type
float

get_polygon_centroid(*geom*)

Calculate the centroid of a closed polygon

Parameters
geom (*geospatial representation of polygon*) – accepted types:

vertices np.array([(x, y),....]) geojson.Polygon shapely.Polygon shapefile.Shape

Returns
centroid – (x, y) of polygon centroid

Return type
tuple

is_clockwise(**geom*)

Determine if a ring is defined clockwise

Parameters
***geom** (*geospatial representation of polygon*) – accepted types:

vertices [(x, y),....] geojson.Polygon shapely.Polygon shapefile.Shape x and y vertices: [x1, x2, x3], [y1, y2, y3]

Returns
: **clockwise** – True when the ring is defined clockwise, False otherwise

Return type
: bool

point_in_polygon(*xc*, *yc*, *polygon*)
: Use the ray casting algorithm to determine if a point is within a polygon. Enables very fast intersection calculations!

  Parameters
  - **xc** (*np.ndarray*) – 2d array of xpoints
  - **yc** (*np.ndarray*) – 2d array of ypoints
  - **polygon** (*iterable (list)*) – polygon vertices [(x0, y0),....(xn, yn)] note: polygon can be open or closed

  Returns
  : **mask** – True value means point is in polygon!

  Return type
  : np.array

project_point_onto_xc_line(*line*, *pts*, *d0=0*, *direction='x'*)
: Method to project points onto a cross sectional line that is defined by distance. Used for plotting MODPATH results on to a cross section!

  line
  : [list or np.ndarray] numpy array of [(x0, y0), (x1, y1)] that defines the line to project on to

  pts
  : [list or np.ndarray] numpy array of [(x, y),] points to be projected

  d0 : distance offset along line of min(xl) direction : string
  : projection direction "x" or "y"

  Returns
  : np.ndarray of projected [(x, y),] points

rotate(*x*, *y*, *xoff*, *yoff*, *angrot_radians*)
: Given x and y array-like values calculate the rotation about an arbitrary origin and then return the rotated coordinates.

transform(*x*, *y*, *xoff*, *yoff*, *angrot_radians*, *length_multiplier=1.0*, *inverse=False*)
: Given x and y array-like values calculate the translation about an arbitrary origin and then return the rotated coordinates.

flopy.utils.geospatial_utils module

class GeoSpatialCollection(*obj*, *shapetype=None*)
: Bases: object

  The GeoSpatialCollection class allows a user to convert between Collection objects from common geospatial libraries.

  Parameters
  - **obj** (*collection object*) – obj can accept the following types

    str : shapefile path PathLike : shapefile path shapefile.Reader object list of [shapefile.Shape, shapefile.Shape,] shapefile.Shapes object flopy.utils.geometry.Collection object list of [flopy.utils.geometry, ...] objects geojson.GeometryCollection object geojson.FeatureCollection object shapely.GeometryCollection object list of [[vertices], ...]

- **shapetype** (*list*) – optional list of shapetypes that is required when vertices are supplied to the class as the obj parameter

property flopy_geometry

Property that returns a flopy.util.geometry.Collection object

Return type
flopy.util.geometry.Collectionnos object

property geojson

Property that returns a geojson.GeometryCollection object to the user

Return type
geojson.GeometryCollection

property points

Property returns a multidimensional list of vertices

Return type
list of vertices

property shape

Property that returns a shapefile.Shapes object

Return type
shapefile.Shapes object

property shapely

Property that returns a shapely.geometry.collection.GeometryCollection object to the user

Return type
shapely.geometry.collection.GeometryCollection object

property shapetype

Returns a list of shapetypes to the user

Return type
list of str

class GeoSpatialUtil(*obj*, *shapetype=None*)

Bases: object

Geospatial utils are a unifying method to provide conversion between commonly used geospatial input types

Parameters

- **obj** (*geospatial object*) –

  obj can accept any of the following objects:
  shapefile.Shape object flopy.utils.geometry objects list of vertices geojson geometry objects shapely.geometry objects

- **shapetype** (*str*) – shapetype is required when a list of vertices is supplied for obj

property flopy_geometry

Returns a flopy geometry object to the user

Return type
flopy.utils.geometry.<Shape>

property geojson

Returns a geojson object to the user

Return type
geojson.<shape>

property points

Returns a list of vertices to the user

Return type
list

property shape

Returns a shapefile.Shape object to the user

Return type
shapefile.shape

property shapely

Returns a shapely.geometry object to the user

Return type
shapely.geometry.<shape>

property shapetype

Shapetype string for a geometry

Return type
str

flopy.utils.get_modflow module

Download and install USGS MODFLOW and related programs.

This script originates from FloPy: https://github.com/modflowpy/flopy This file can be downloaded and run independently outside FloPy. It requires Python 3.6 or later, and has no dependencies.

See https://developer.github.com/v3/repos/releases/ for GitHub Releases API.

run_main(*bindir*, *owner='MODFLOW-USGS'*, *repo='executables'*, *release_id='latest'*, *ostag=None*, *subset=None*, *downloads_dir=None*, *force=False*, *quiet=False*, *_is_cli=False*)

Run main method to get MODFLOW and related programs.

Parameters

- **bindir** (*str or Path*) – Writable path to extract executables. Auto-select options start with a colon character. See error message or other documentation for further information on auto-select options.
- **owner** (*str, default "MODFLOW-USGS"*) – Name of GitHub repository owner (user or organization).

- **repo** (*str, default "executables"*) – Name of GitHub repository. Choose one of "executables" (default), "modflow6", or "modflow6-nightly-build".
- **release_id** (*str, default "latest"*) – GitHub release ID.
- **ostag** (*str, optional*) – Operating system tag; default is to automatically choose.
- **subset** (*list, set or str, optional*) – Optional subset of executables to extract, specified as a list (e.g.) ["mfnwt", "mp6"] or a comma-separated string "mfnwt,mp6".
- **downloads_dir** (*str or Path, optional*) – Manually specify directory to download archives. Default is to use home Downloads, if available, otherwise a temporary directory.
- **force** (*bool, default False*) – If True, always download archive. Default False will use archive if previously downloaded in downloads_dir.
- **quiet** (*bool, default False*) – If True, show fewer messages.
- **_is_cli** (*bool, default False*) – Control behavior of method if this is run as a command-line interface or as a Python function.

flopy.utils.gridgen module

class Gridgen(*modelgrid, model_ws: str | PathLike = '.', exe_name: str | PathLike = 'gridgen', surface_interpolation='replicate', vertical_pass_through=False, **kwargs*)

Bases: object

Class to work with the gridgen program to create layered quadtree grids.

Parameters

- **modelgrid** (*flopy.discretization.StructuredGrid*) – Flopy StructuredGrid object. Note this also accepts ModflowDis and ModflowGwfdis objects, however it is deprecated and support will be removed in version 3.3.7
- **model_ws** (*str or PathLike*) – workspace location for creating gridgen files (default is '.')
- **exe_name** (*str*) – path and name of the gridgen program. (default is gridgen)
- **surface_interpolation** (*str*) – Default gridgen method for interpolating elevations. Valid options include 'replicate' (default) and 'interpolate'
- **vertical_pass_through** (*bool*) – If true, Gridgen's GRID_TO_USGDATA command will connect layers where intermediate layers are inactive. (default is False)
- ****kwargs** –

  verical_smoothing_level

  [int] maximum level difference between two vertically

adjacent cells. Adjust with caution, as adjustments can cause unexpected results to simulated flows

horizontal_smoothing_level
[int] maximum level difference between two horizontally adjacent cells. Adjust with caution, as adjustments can cause unexpected results to simulated flows

Notes

For the surface elevations, the top of a layer uses the same surface as the bottom of the overlying layer.

add_active_domain(*feature*, *layers*)

Parameters

- **feature** (*str or list*) –

  feature can be:
  a string containing the name of a polygon a list of polygons flopy.utils.geometry.Collection object of Polygons shapely.geometry.Collection object of Polygons geojson.GeometryCollection object of Polygons list of shapefile.Shape objects shapefile.Shapes object

- **layers** (*list*) – A list of layers (zero based) for which this active domain applies.

Return type
None

add_refinement_features(*features*, *featuretype*, *level*, *layers*)

Parameters

- **features** (*str, list, or collection object*) –

  features can be
  a string containing the name of a shapefile a list of points, lines, or polygons flopy.utils.geometry.Collection object a list of flopy.utils.geometry objects shapely.geometry.Collection object geojson.GeometryCollection object a list of shapefile.Shape objects shapefile.Shapes object

- **featuretype** (*str*) – Must be either 'point', 'line', or 'polygon'
- **level** (*int*) – The level of refinement for this features
- **layers** (*list*) – A list of layers (zero based) for which this refinement features applies.

Return type
None

build(*verbose=False*)
Build the quadtree grid

Parameters
verbose (*bool*) – If true, print the results of the gridgen command to the terminal (default is False)

Return type
None

export(*verbose=False*)

Export the quadtree grid to shapefiles, usgdata, and vtk

Parameters
verbose (*bool*) – If true, print the results of the gridgen command to the terminal (default is False)

Return type
None

get_angldegx(*fldr=None*)

Get the angldegx array

Parameters
fldr (*ndarray*) – Flow direction indicator array. If None, then it is read from gridgen output.

Returns
angldegx – A 1D vector indicating the angle (in degrees) between the x axis and an outward normal to the face.

Return type
ndarray

get_area()

Get the area array

Returns
area – A 1D vector of cell areas of size nodes

Return type
ndarray

get_bot()

Get the bot array

Returns
bot – A 1D vector of cell bottom elevations of size nodes

Return type
ndarray

get_cellxy(*ncells*)

Parameters
ncells (*int*) – Number of cells for which to create the list of cell centers

Returns
cellxy – x and y cell centers. Shape is (ncells, 2)

Return type
ndarray

get_center(*nodenumber*)

Return the cell center x and y coordinates

Parameters
nodenumber –

Returns
(x, y)

Return type
tuple

get_cl12()

Get the cl12 array

Returns
cl12 – A 1D vector of the cell connection distances, which are from the center of cell n to its shared face will cell m

Return type
ndarray

get_disu(*model*, *nper=1*, *perlen=1*, *nstp=1*, *tsmult=1*, *steady=True*, *itmuni=4*, *lenuni=2*)

Create a MODFLOW-USG DISU flopy object.

Parameters

- **model** (*Flopy model object*) – The Flopy model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.
- **nper** (*int*) – Number of model stress periods (default is 1).
- **perlen** (*float or array of floats (nper)*) – A single value or array of the stress period lengths (default is 1).
- **nstp** (*int or array of ints (nper)*) – Number of time steps in each stress period (default is 1).
- **tsmult** (*float or array of floats (nper)*) – Time step multiplier (default is 1.0).
- **steady** (*boolean or array of boolean (nper)*) – True or False indicating whether or not stress period is steady state (default is True).
- **itmuni** (*int*) – Time units, default is days (4)
- **lenuni** (*int*) – Length units, default is meters (2)

Returns
disu

Return type
Flopy ModflowDisU object.

get_fahl()

Get the fahl array

Returns
fahl – A 1D vector of the cell connection information, which is flow area for a vertical connection and horizontal length for a horizontal connection

Return type
ndarray

get_fldr()

Get the fldr array

Returns
fldr - A 1D vector indicating the direction of the connection 1, 2, and 3 are plus x, y, and z directions. -1, -2, and -3 are negative x, y, and z directions.

Return type
ndarray

get_gridprops_disu5()

Get a dictionary of information needed to create a MODFLOW-USG DISU Package. The returned dictionary can be unpacked directly into the ModflowDisU constructor. The ja dictionary entry will be returned as zero-based.

Returns
gridprops

Return type
dict

get_gridprops_disu6(*repair_asymmetry=True*)

Get a dictionary of information needed to create a MODFLOW 6 DISU Package. The returned dictionary can be unpacked directly into the ModflowGwfdisu constructor.

Parameters
repair_asymmetry (*bool*) - MODFLOW 6 checks for symmetry in the hwva array, and round off errors in the floating point calculations can result in small errors. If this flag is true, then symmetry will be forced by setting the symmetric counterparts to the same value (the first one encountered).

Returns
gridprops

Return type
dict

get_gridprops_disv()

Get a dictionary of information needed to create a MODFLOW 6 DISV Package. The returned dictionary can be unpacked directly into the ModflowGwfdisv constructor.

Returns
gridprops

Return type
dict

get_gridprops_unstructuredgrid()

Get a dictionary of information needed to create a flopy UnstructuredGrid. The returned dictionary can be unpacked directly into the flopy.discretization.UnstructuredGrid() constructor.

Returns
: **gridprops**

Return type
: dict

get_gridprops_vertexgrid()

Get a dictionary of information needed to create a flopy VertexGrid. The returned dictionary can be unpacked directly into the flopy.discretization.VertexGrid() constructor.

Returns
: **gridprops**

Return type
: dict

get_hwva(*ja=None*, *ihc=None*, *fahl=None*, *top=None*, *bot=None*)

Get the hwva array

Parameters

- **ja** (*ndarray*) – Cell connectivity. If None, it will be read from gridgen output.
- **ihc** (*ndarray*) – Connection horizontal indicator array. If None it will be read and calculated from gridgen output.
- **fahl** (*ndarray*) – Flow area, horizontal width array required by MODFLOW-USG. If none then it will be read from the gridgen output. Default is None.
- **top** (*ndarray*) – Cell top elevation. If None, it will be read from gridgen output.
- **bot** (*ndarray*) – Cell bottom elevation. If None, it will be read from gridgen output.

Returns
: **fahl** – A 1D vector of the cell connection information, which is flow area for a vertical connection and horizontal length for a horizontal connection

Return type
: ndarray

get_iac()

Get the iac array

Returns
: **iac** – A 1D vector of the number of connections (plus 1) for each cell

Return type
: ndarray

get_ihc(*nodelay=None*, *ia=None*, *fldr=None*)

Get the ihc array

Parameters
: **fldr** (*ndarray*) – Flow direction indicator array. If None, then it is read from gridgen output.

Returns
ihc – A 1D vector indicating the direction of the connection where 0 is vertical, 1 is a regular horizontal connection and 2 is a vertically staggered horizontal connection.

Return type
ndarray

get_ivc(*fldr=None*)
Get the MODFLOW-USG ivc array

Parameters
fldr (*ndarray*) – Flow direction indicator array. If None, then it is read from gridgen output.

Returns
ivc – A 1D vector indicating the direction of the connection where 1 is vertical and 0 is horizontal.

Return type
ndarray

get_ja(*nja=None*)
Get the zero-based ja array

Parameters
nja (*int*) – Number of connections. If None, then it is read from gridgen output.

Returns
ja – A 1D vector of the cell connectivity (one-based)

Return type
ndarray

get_nlay()
Get the number of layers

Returns
nlay

Return type
int

get_nod_recarray()
Load the qtg.nod file and return as a numpy recarray

Returns
node_ra – Recarray representation of the node file with zero-based indexing

Return type
ndarray

get_nodelay()
Return the nodelay array, which is an array of size nlay containing the number of nodes in each layer.

Returns
nodelay – Number of nodes in each layer

Return type
ndarray

get_nodes()
Get the number of nodes

Returns
nodes

Return type
int

get_top()
Get the top array

Returns
top – A 1D vector of cell top elevations of size nodes

Return type
ndarray

get_vertices(*nodenumber*)
Return a list of 5 vertices for the cell. The first vertex should be the same as the last vertex.

Parameters
nodenumber –

Returns
list of vertices

Return type
list

get_verts_iverts(*ncells*, *verbose=False*)
Return a 2d array of x and y vertices and a list of size ncells that has the list of vertices for each cell.

Parameters

- **ncells** (*int*) – The number of entries in iverts. This should be ncpl for a layered model and nodes for a disu model.
- **verbose** (*bool*) – Print information as its working

Returns
verts, iverts – verts is a 2d array of x and y vertex pairs (nvert, 2) and iverts is a list of vertices that comprise each cell

Return type
tuple

static **gridarray_to_flopyusg_gridarray**(*nodelay*, *a*)

intersect(*features*, *featuretype*, *layer*)

Parameters

- **features** (*str or list*) – features can be either a string containing the name of a shapefile or it can be a list of points, lines, or polygons

- **featuretype** (*str*) – Must be either 'point', 'line', or 'polygon'
- **layer** (*int*) – Layer (zero based) to intersect with. Zero based.

Returns
result – Recarray of the intersection properties.

Return type
np.recarray

plot(*ax=None*, *layer=0*, *edgecolor='k'*, *facecolor='none'*, *cmap='Dark2'*, *a=None*, *masked_values=None*, ***kwargs*)

Plot the grid. This method will plot the grid using the shapefile that was created as part of the build method.

Note that the layer option is not working yet.

Parameters

- **ax** (*matplotlib.pyplot axis*) – The plot axis. If not provided it, plt.gca() will be used. If there is not a current axis then a new one will be created.
- **layer** (*int*) – Layer number to plot
- **cmap** (*string*) – Name of colormap to use for polygon shading (default is 'Dark2')
- **edgecolor** (*string*) – Color name. (Default is 'scaled' to scale the edge colors.)
- **facecolor** (*string*) – Color name. (Default is 'scaled' to scale the face colors.)
- **a** (*numpy.ndarray*) – Array to plot.
- **masked_values** (*iterable of floats, ints*) – Values to mask.
- **kwargs** (*dictionary*) – Keyword arguments that are passed to PatchCollection.set(**kwargs). Some common kwargs would be 'linewidths', 'linestyles', 'alpha', etc.

Returns
pc

Return type
matplotlib.collections.PatchCollection

set_surface_interpolation(*isurf*, *type*, *elev=None*, *elev_extent=None*)

Parameters

- **isurf** (*int*) – surface number where 0 is top and nlay + 1 is bottom
- **type** (*str*) – Must be 'INTERPOLATE', 'REPLICATE' or 'ASCIIGRID'.
- **elev** (*numpy.ndarray of shape (nr, nc) or str*) – Array that is used as an asciigrid. If elev is a string, then it is assumed to be the name of the asciigrid.

- **elev_extent** (*list-like*) – List of xmin, xmax, ymin, ymax extents of the elev grid. Must be specified for ASCIIGRID; optional otherwise.

Return type
None

features_to_shapefile(*features*, *featuretype*, *filename: str | PathLike*)

Write a shapefile for the features of type featuretype.

Parameters

- **features** (*list*) – point, line, or polygon features. Method accepts feature can be:

  a list of geometries flopy.utils.geometry.Collection object shapely.geometry.Collection object geojson.GeometryCollection object list of shapefile.Shape objects shapefile.Shapes object

- **featuretype** (*str*) – Must be 'point', 'line', 'linestring', or 'polygon'
- **filename** (*str or PathLike*) – Path of the shapefile to write

Return type
None

get_ia_from_iac(*iac*)

get_isym(*ia*, *ja*)

is_symmetrical(*isym*, *a*, *atol=0*)

ndarray_to_asciigrid(*fname: str | PathLike*, *a*, *extent*, *nodata=1e+30*)

read1d(*f*, *a*)

Quick file to array reader for reading gridgen output. Much faster than the read1d function in util_array

repair_array_asymmetry(*isym*, *a*, *atol=0*)

flopy.utils.gridintersect module

class GridIntersect(*mfgrid*, *method=None*, *rtree=True*)

Bases: object

Class for intersecting shapely geometries (Point, Linestring, Polygon, or their Multi variants) with MODFLOW grids. Contains optimized search routines for structured grids.

Notes

- The STR-tree query is based on the bounding box of the shape or collection, if the bounding box of the shape covers nearly the entire grid, the query won't be able to limit the search space much, resulting in slower performance. Therefore, it can sometimes be faster to intersect each individual shape in a collection than it is to intersect with the whole collection at once.
- Building the STR-tree can take a while for large grids. Once built the intersect routines (for individual shapes) should be pretty fast.
- The optimized routines for structured grids can outperform the shapely routines for point and linestring intersections because of the reduced overhead of building and parsing the STR-tree. However, for polygons the STR-tree implementation is often faster than the optimized structured routines, especially for larger grids.

filter_query_result(*cellids*, *shp*)

Filter array of geometries to obtain grid cells that intersect with shape.

Used to (further) reduce query result to cells that intersect with shape.

Parameters

- **cellids** (*iterable*) – iterable of cellids, query result
- **shp** (*shapely.geometry*) – shapely geometry that is prepared and used to filter query result

Returns
filter or generator containing polygons that intersect with shape

Return type
array_like

intersect(*shp*, *shapetype=None*, *sort_by_cellid=True*, *keepzerolengths=False*, *return_all_intersections=False*, *contains_centroid=False*, *min_area_fraction=None*, *shapely2=True*)

Method to intersect a shape with a model grid.

Parameters

- **shp** (*shapely.geometry, geojson object, shapefile.Shape,*) – or flopy geometry object
- **shapetype** (*str, optional*) – type of shape (i.e. "point", "linestring", "polygon" or their multi-variants), used by GeoSpatialUtil if shp is passed as a list of vertices, default is None
- **sort_by_cellid** (*bool*) – sort results by cellid, ensures cell with lowest cellid is returned for boundary cases when using vertex methods, default is True
- **keepzerolengths** (*bool*) – boolean method to keep zero length intersections for linestring intersection, only used if shape type is "linestring"
- **return_all_intersections** (*bool, optional*) – if True, return multiple intersection results for points or linestrings on grid cell boundaries (e.g. returns 2 intersection results if a point lies on the boundary between two grid cells). The

default is False. Only used if shape type is "point" or "linestring".

- **contains_centroid** (*bool*, *optional*) – if True, only store intersection result if cell centroid is contained within intersection shape, only used if shape type is "polygon"
- **min_area_fraction** (*float*, *optional*) – float defining minimum intersection area threshold, if intersection area is smaller than min_frac_area * cell_area, do not store intersection result, only used if shape type is "polygon"
- **shapely2** (*bool*, *optional*) – temporary flag to determine whether to use methods optimized for shapely 2.0. Useful for comparison performance between the old (shapely 1.8) and new (shapely 2.0) implementations.

Returns
a record array containing information about the intersection

Return type
numpy.recarray

intersects(*shp*, *shapetype=None*)

Return cellids for grid cells that intersect with shape.

Parameters

- **shp** (*shapely.geometry*, *geojson geometry*, *shapefile.shape*,) – or flopy geometry object shape to intersect with the grid
- **shapetype** (*str*, *optional*) – type of shape (i.e. "point", "linestring", "polygon" or their multi-variants), used by GeoSpatialUtil if shp is passed as a list of vertices, default is None

Returns
a record array containing cell IDs of the gridcells the shape intersects with

Return type
numpy.recarray

static **plot_linestring**(*rec*, *ax=None*, *cmap=None*, ***kwargs*)

method to plot the linestring intersection results from the resulting numpy.recarray.

Note: only works when recarray has 'intersects' column!

Parameters

- **rec** (*numpy.recarray*) – record array containing intersection results (the resulting shapes)
- **ax** (*matplotlib.pyplot.axes*, *optional*) – axes to plot onto, if not provided, creates a new figure
- **cmap** (*str*) – matplotlib colormap
- ****kwargs** – passed to the plot function

Returns
returns the axes handle

Return type
matplotlib.pyplot.axes

static plot_point(*rec*, *ax=None*, ***kwargs*)

method to plot the point intersection results from the resulting numpy.recarray.

Note: only works when recarray has 'intersects' column!

Parameters

- **rec** (*numpy.recarray*) – record array containing intersection results
- **ax** (*matplotlib.pyplot.axes*, *optional*) – axes to plot onto, if not provided, creates a new figure
- ****kwargs** – passed to the scatter function

Returns
returns the axes handle

Return type
matplotlib.pyplot.axes

static plot_polygon(*rec*, *ax=None*, ***kwargs*)

method to plot the polygon intersection results from the resulting numpy.recarray.

Note: only works when recarray has 'intersects' column!

Parameters

- **rec** (*numpy.recarray*) – record array containing intersection results (the resulting shapes)
- **ax** (*matplotlib.pyplot.axes*, *optional*) – axes to plot onto, if not provided, creates a new figure
- ****kwargs** – passed to the plot function

Returns
returns the axes handle

Return type
matplotlib.pyplot.axes

query_grid(*shp*)

Perform spatial query on grid with shapely geometry. If no spatial query is possible returns all grid cells.

Parameters
shp (*shapely.geometry*) – shapely geometry

Returns
array containing cellids of grid cells in query result

Return type
array_like

static sort_gridshapes(*geoms*, *cellids*)

Sort geometries (from i.e. query result) by cell id.

Deprecated since version 3.3.6: sorting is now performed on cellids.

Parameters
geoms (*iterable*) – list or iterable of geometries

Returns
sorted list of gridcells

Return type
list

class ModflowGridIndices

Bases: object

Collection of methods that can be used to find cell indices for a structured, but irregularly spaced MODFLOW grid.

static **find_position_in_array**(*arr*, *x*)

If arr has x positions for the left edge of a cell, then return the cell index containing x.

Parameters

- **arr** (*A one dimensional array (such as Xe) that contains*) – coordinates for the left cell edge.
- **x** (*float*) – The x position to find in arr.

static **kij_from_nn0**(*n*, *nlay*, *nrow*, *ncol*)

Convert the node number to a zero-based layer, row and column format. Return (k0, i0, j0).

Parameters

- **nodenumber** (*int*) – The cell nodenumber, ranging from 0 to number of nodes - 1.
- **nlay** (*int*) – The number of layers.
- **nrow** (*int*) – The number of rows.
- **ncol** (*int*) – The number of columns.

static **kij_from_nodenumber**(*nodenumber*, *nlay*, *nrow*, *ncol*)

Convert the modflow node number to a zero-based layer, row and column format. Return (k0, i0, j0).

Parameters

- **nodenumber** (*int*) – The cell nodenumber, ranging from 1 to number of nodes.
- **nlay** (*int*) – The number of layers.
- **nrow** (*int*) – The number of rows.
- **ncol** (*int*) – The number of columns.

static **nn0_from_kij**(*k*, *i*, *j*, *nrow*, *ncol*)

Calculate the zero-based nodenumber using the zero-based layer, row, and column values. The first node has a value of 0.

Parameters

- **k** (*int*) – The model layer number as a zero-based value.
- **i** (*int*) – The model row number as a zero-based value.

- **j** (*int*) – The model column number as a zero-based value.
- **nrow** (*int*) – The number of model rows.
- **ncol** (*int*) – The number of model columns.

static nodenumber_from_kij(*k*, *i*, *j*, *nrow*, *ncol*)

Calculate the nodenumber using the zero-based layer, row, and column values. The first node has a value of 1.

Parameters

- **k** (*int*) – The model layer number as a zero-based value.
- **i** (*int*) – The model row number as a zero-based value.
- **j** (*int*) – The model column number as a zero-based value.
- **nrow** (*int*) – The number of model rows.
- **ncol** (*int*) – The number of model columns.

ignore_shapely2_strtree_warning()

ignore_shapely_warnings_for_object_array()

parse_shapely_ix_result(*collection*, *ix_result*, *shptyps=None*)

Recursive function for parsing shapely intersection results. Returns a list of shapely shapes matching shptyps.

Parameters

- **collection** (*list*) – state variable for storing result, generally an empty list
- **ix_result** (*shapely.geometry type*) – any shapely intersection result
- **shptyps** (*str*, *list of str*, *or None*, *optional*) – if None (default), return all types of shapes. if str, return shapes of that type, if list of str, return all types in list

Returns

list containing shapely geometries of type shptyps

Return type

list

flopy.utils.gridutil module

Grid utilities

get_disu_kwargs(*nlay*, *nrow*, *ncol*, *delr*, *delc*, *tp*, *botm*, *return_vertices=False*)

Create args needed to construct a DISU package for a regular MODFLOW grid.

Parameters

- **nlay** (*int*) – Number of layers
- **nrow** (*int*) – Number of rows
- **ncol** (*int*) – Number of columns
- **delr** (*numpy.ndarray*) – Column spacing along a row
- **delc** (*numpy.ndarray*) – Row spacing along a column

- **tp** (*int or numpy.ndarray*) - Top elevation(s) of cells in the model's top layer
- **botm** (*numpy.ndarray*) - Bottom elevation(s) for each layer
- **return_vertices** (*bool*) - If true, then include vertices and cell2d in kwargs

get_disv_kwargs(*nlay*, *nrow*, *ncol*, *delr*, *delc*, *tp*, *botm*, *xoff=0.0*, *yoff=0.0*)

Create args needed to construct a DISV package.

Parameters

- **nlay** (*int*) - Number of layers
- **nrow** (*int*) - Number of rows
- **ncol** (*int*) - Number of columns
- **delr** (*float or numpy.ndarray*) - Column spacing along a row with shape (ncol)
- **delc** (*float or numpy.ndarray*) - Row spacing along a column with shape (nrow)
- **tp** (*float or numpy.ndarray*) - Top elevation(s) of cells in the model's top layer with shape (nrow, ncol)
- **botm** (*list of floats or numpy.ndarray*) - Bottom elevation(s) of all cells in the model with shape (nlay, nrow, ncol)
- **xoff** (*float*) - Value to add to all x coordinates. Optional (default = 0.)
- **yoff** (*float*) - Value to add to all y coordinates. Optional (default = 0.)

get_lni(*ncpl*, *nodes*) → List[Tuple[int, int]]

Get layer index and within-layer node index (both 0-based).

Node count per layer may be an int or array-like of integers. An integer ncpl indicates all layers have the same node count. If an integer ncpl is less than any specified node numbers, the grid is understood to have at least enough layers to contain them.

If ncpl is array-like it is understood to describe node count per zero-indexed layer.

Parameters

- **ncpl** (*node count per layer (int or array-like of ints)*) -
- **nodes** (*node numbers (array-like of nodes)*) -

Return type

A list of tuples (layer index, node index)

uniform_flow_field(*qx*, *qy*, *qz*, *shape*, *delr=None*, *delc=None*, *delv=None*)

flopy.utils.lgrutil module

class Lgr(*nlayp*, *nrowp*, *ncolp*, *delrp*, *delcp*, *topp*, *botmp*, *idomainp*, *ncpp=3*, *ncppl=1*, *xllp=0.0*, *yllp=0.0*)

Bases: object

property child

Return a SimpleRegularGrid object for the child model

Returns
simple_regular_grid - simple grid object containing grid information for the child

Return type
SimpleRegularGrid

get_delr_delc()

get_exchange_data(*angldegx=False*, *cdist=False*)

Get the list of parent/child connections

<cellidm1> <cellidm2> <ihc> <cl1> <cl2> <hwva> <angledegx>

Returns
exglist - list of connections between parent and child

Return type
list

get_idomain()

Return the idomain array for the child model. This will normally be all ones unless the idomain array for the parent model is non-rectangular and irregularly shaped. Then, parts of the child model will have idomain zero cells.

Returns
idomain - idomain array for the child model

Return type
ndarray

get_lower_left()

Return the lower left corner of the child grid

Returns
(xll, yll) - location of lower left corner of the child grid

Return type
tuple

get_parent_connections(*kc*, *ic*, *jc*)

Return a list of parent cell indices that are connected to child cell kc, ic, jc.

get_parent_indices(*kc*, *ic*, *jc*)

Method returns the parent cell indices for this child. The returned indices are in zero-based indexing.

get_replicated_parent_array(*parent_array*)

Get a two-dimensional array the size of the child grid that has values replicated from the provided parent array.

Parameters

parent_array (*ndarray*) – A two-dimensional array that is the size of the parent model rows and columns.

Returns

child_array – A two-dimensional array that is the size of the child model rows and columns

Return type

ndarray

get_shape()

Return the shape of the child grid

Returns

(nlay, nrow, ncol) – shape of the child grid

Return type

tuple

get_top_botm()

property parent

Return a SimpleRegularGrid object for the parent model

Returns

simple_regular_grid – simple grid object containing grid information for the parent

Return type

SimpleRegularGrid

class SimpleRegularGrid(*nlay*, *nrow*, *ncol*, *delr*, *delc*, *top*, *botm*, *idomain*, *xorigin*, *yorigin*)

Bases: object

Simple object for representing regular MODFLOW grid information.

Parameters

- **nlay** (*int*) – number of layers
- **nrow** (*int*) – number of rows
- **ncol** (*int*) – number of columns
- **delr** (*ndarray*) – delr array
- **delc** (*ndarray*) – delc array
- **top** (*ndarray*) – top array (nrow, ncol)
- **botm** (*ndarray*) – botm array (nlay, nrow, ncol)
- **idomain** (*ndarray*) – idomain array (nlay, nrow, ncol)
- **xorigin** (*float*) – x location of grid lower left corner
- **yorigin** (*float*) – y location of grid lower left corner

get_gridprops_dis6()

property modelgrid

flopy.utils.mflistfile module

This is a set of classes for reading budget information out of MODFLOW-style listing files. Cumulative and incremental budgets are returned as numpy recarrays, which can then be easily plotted.

class ListBudget(*file_name*, *budgetkey=None*, *timeunit='days'*)

Bases: object

MODFLOW family list file handling

Parameters

- **file_name** (*str*) – the list file name
- **budgetkey** (*str*) – the text string identifying the budget table. (default is None)
- **timeunit** (*str*) – the time unit to return in the recarray. (default is 'days')

Notes

The ListBudget class should not be instantiated directly. Access is through derived classes: MfListBudget (MODFLOW), SwtListBudget (SEAWAT) and SwrListBudget (MODFLOW with the SWR process)

Examples

```
>>> mf_list = MfListBudget("my_model.list")
>>> incremental, cumulative = mf_list.get_budget()
>>> df_inc, df_cumul = mf_list.get_dataframes(start_datetime="10-21-2015")
```

get_budget(*names=None*)

Get the recarrays with the incremental and cumulative water budget items in the list file.

Parameters

names (*str or list of strings*) – Selection of column names to return. If names is not None then totim, time_step, stress_period, and selection(s) will be returned. (default is None).

Returns

out – Numpy recarrays with the water budget items in list file. The recarray also includes totim, time_step, and stress_period. A separate recarray is returned for the incremental and cumulative water budget entries.

Return type

recarrays

Examples

```
>>> mf_list = MfListBudget("my_model.list")
>>> budget = mf_list.get_budget()
```

get_cumulative(*names=None*)

Get a recarray with the cumulative water budget items in the list file.

Parameters

names (*str or list of strings*) – Selection of column names to return. If names is not None then totim, time_step, stress_period, and selection(s) will be returned. (default is None).

Returns

out – Numpy recarray with the water budget items in list file. The recarray also includes totim, time_step, and stress_period.

Return type

recarray

Examples

```
>>> mf_list = MfListBudget("my_model.list")
>>> cumulative = mf_list.get_cumulative()
```

get_data(*kstpkper=None*, *idx=None*, *totim=None*, *incremental=False*)

Get water budget data from the list file for the specified conditions.

Parameters

- **idx** (*int*) – The zero-based record number. The first record is record 0. (default is None).
- **kstpkper** (*tuple of ints*) – A tuple containing the time step and stress period (kstp, kper). These are zero-based kstp and kper values. (default is None).
- **totim** (*float*) – The simulation time. (default is None).
- **incremental** (*bool*) – Boolean flag used to determine if incremental or cumulative water budget data for the specified conditions will be returned. If incremental=True, incremental water budget data will be returned. If incremental=False, cumulative water budget data will be returned. (default is False).

Returns

data – Array has size (number of budget items, 3). Recarray names are 'index', 'value', 'name'.

Return type

numpy recarray

Notes

if both kstpkper and totim are None, will return the last entry

Examples

```
>>> import matplotlib.pyplot as plt
>>> import flopy
>>> mf_list = flopy.utils.MfListBudget("my_model.list")
>>> data = mf_list.get_data(kstpkper=(0,0))
>>> plt.bar(data['index'], data['value'])
>>> plt.xticks(data['index'], data['name'], rotation=45, size=6)
>>> plt.show()
```

get_dataframes(*start_datetime='1-1-1970'*, *diff=False*)

Get pandas dataframes with the incremental and cumulative water budget items in the list file.

Parameters
start_datetime (*str*) – If start_datetime is passed as None, the rows are indexed on totim. Otherwise, a DatetimeIndex is set. (default is 1-1-1970).

Returns
out – Pandas dataframes with the incremental and cumulative water budget items in list file. A separate pandas dataframe is returned for the incremental and cumulative water budget entries.

Return type
pandas dataframes

Examples

```
>>> mf_list = MfListBudget("my_model.list")
>>> incrementaldf, cumulativedf = mf_list.get_dataframes()
```

get_incremental(*names=None*)

Get a recarray with the incremental water budget items in the list file.

Parameters
names (*str or list of strings*) – Selection of column names to return. If names is not None then totim, time_step, stress_period, and selection(s) will be returned. (default is None).

Returns
out – Numpy recarray with the water budget items in list file. The recarray also includes totim, time_step, and stress_period.

Return type
recarray

Examples

```
>>> mf_list = MfListBudget("my_model.list")
>>> incremental = mf_list.get_incremental()
```

get_kstpkper()

Get a list of unique stress periods and time steps in the list file water budgets.

Returns
out – List of unique kstp, kper combinations in list file. kstp and kper values are zero-based.

Return type
list of (kstp, kper) tuples

Examples

```
>>> mf_list = MfListBudget("my_model.list")
>>> kstpkper = mf_list.get_kstpkper()
```

get_model_runtime(*units='seconds'*)

Get the elapsed runtime of the model from the list file.

Parameters
units (*str*) – Units in which to return the runtime. Acceptable values are 'seconds', 'minutes', 'hours' (default is 'seconds')

Returns
out – Floating point value with the runtime in requested units. Returns NaN if runtime not found in list file

Return type
float

Examples

```
>>> mf_list = MfListBudget("my_model.list")
>>> budget = mf_list.get_model_runtime(units='hours')
```

get_record_names()

Get a list of water budget record names in the file.

Returns
out – List of unique text names in the binary file.

Return type
list of strings

Examples

```
>>> mf_list = MfListBudget('my_model.list')
>>> names = mf_list.get_record_names()
```

get_reduced_pumping()

Get numpy recarray of reduced pumping data from a list file. Reduced pumping data most have been written to the list file during the model run. Works with MfListBudget and MfusgListBudget.

Returns
A numpy recarray with the reduced pumping data from the list file.

Return type
numpy recarray

Example

```
>>> objLST = MfListBudget("my_model.lst")
>>> raryReducedPpg = objLST.get_reduced_pumping()
>>> dfReducedPpg = pd.DataFrame.from_records(raryReducedPpg)
```

get_times()

Get a list of unique water budget times in the list file.

Returns
out – List contains unique water budget simulation times (totim) in list file.

Return type
list of floats

Examples

```
>>> mf_list = MfListBudget('my_model.list')
>>> times = mf_list.get_times()
```

get_tslens()

Get a list of unique water budget time step lengths in the list file.

Returns
out – List contains unique water budget simulation time step lengths (tslen) in list file.

Return type
list of floats

Examples

```
>>> mf_list = MfListBudget('my_model.list')
>>> ts_lengths = mf_list.get_tslens()
```

isvalid()

Get a boolean indicating if budget data are available in the file.

Returns
out – Boolean indicating if budget data are available in the file.

Return type
boolean

Examples

```
>>> mf_list = MfListBudget('my_model.list')
>>> valid = mf_list.isvalid()
```

set_budget_key()

class **Mf6ListBudget**(*file_name*, *budgetkey=None*, *timeunit='days'*)

Bases: *ListBudget*

set_budget_key()

class **MfListBudget**(*file_name*, *budgetkey=None*, *timeunit='days'*)

Bases: *ListBudget*

set_budget_key()

class **MfusgListBudget**(*file_name*, *budgetkey=None*, *timeunit='days'*)

Bases: *ListBudget*

set_budget_key()

class **SwrListBudget**(*file_name*, *budgetkey=None*, *timeunit='days'*)

Bases: *ListBudget*

set_budget_key()

class **SwtListBudget**(*file_name*, *budgetkey=None*, *timeunit='days'*)

Bases: *ListBudget*

set_budget_key()

flopy.utils.mfreadnam module

mfreadnam module. Contains the NamData class. Note that the user can access the NamData class as *flopy.modflow.NamData*.

Additional information about the MODFLOW name file can be found at the Online MODFLOW Guide.

class NamData(*pkgtype*, *name*, *handle*, *packages*)

Bases: object

MODFLOW Namefile Class.

Parameters

- **pkgtype** (*string*) – String identifying the type of MODFLOW package. See the mfnam_packages dictionary keys in the model object for a list of supported packages. This dictionary is also passed in as packages.
- **name** (*string*) – Filename of the package file identified in the name file
- **handle** (*file handle*) – File handle referring to the file identified by *name*
- **packages** (*dictionary*) – Dictionary of package objects as defined in the *mfnam_packages* attribute of *flopy.modflow.mf.Modflow*.

filehandle

File handle to the package file. Read from *handle*.

Type

file handle

filename

Filename of the package file identified in the name file. Read from *name*.

Type

string

filetype

String identifying the type of MODFLOW package. Read from *pkgtype*.

Type

string

package

Package type. Only assigned if *pkgtype* is found in the keys of *packages*

Type

string

Notes

Examples

attribs_from_namfile_header(*namefile*)

Return spatial and temporal reference info from the nam header.

Parameters

namefile (*str*, *PathLike or None*) – Path to NAM file to read.

Return type

dict

get_entries_from_namefile(*path: str | PathLike*, *ftype: str = None*, *unit: int = None*, *extension: str = None*) → List[Tuple]

Get entries from an MF6 namefile. Can select using FTYPE, UNIT, or file extension. This function only supports MF6 namefiles.

Parameters

- **path** (*str or PathLike*) – path to a MODFLOW-based model name file
- **ftype** (*str*) – package type
- **unit** (*int*) – file unit number
- **extension** (*str*) – file extension

Returns

entries – list of tuples containing FTYPE, UNIT, FNAME, STATUS for each namefile entry that meets a user-specified value.

Return type

list of tuples

get_input_files(*namefile*)

Return a list of all the input files in this model. :param namefile: path to a MODFLOW-based model name file :type namefile: str

Returns

filelist – list of MODFLOW-based model input files

Return type

list

get_mf6_blockdata(*f*, *blockstr*)

Return list with all non comments between start and end of block specified by blockstr. :param f: open file object :type f: file object :param blockstr: name of block to search :type blockstr: str

Returns

data – list of data in specified block

Return type

list

get_mf6_files(*mfnamefile*)

Return a list of all the MODFLOW 6 input and output files in this model. :param mfnamefile: path to the MODFLOW 6 simulation name file :type mfnamefile: str

Returns

- **filelist** (*list*) – list of MODFLOW 6 input files in a simulation
- **outplist** (*list*) – list of MODFLOW 6 output files in a simulation

get_mf6_ftypes(*namefile*, *ftypekeys*)

Return a list of FTYPES that are in the name file and in ftypekeys. :param namefile: path to a MODFLOW 6 name file :type namefile: str :param ftypekeys: list of desired FTYPEs :type ftypekeys: list

Returns
ftypes – list of FTYPES that match ftypekeys in namefile

Return type
list

get_mf6_mshape(*disfile*)

Return the shape of the MODFLOW 6 model. :param disfile: path to a MODFLOW 6 discretization file :type disfile: str

Returns
mshape – tuple with the shape of the MODFLOW 6 model.

Return type
tuple

get_mf6_nper(*tdisfile*)

Return the number of stress periods in the MODFLOW 6 model. :param tdisfile: path to the TDIS file :type tdisfile: str

Returns
nper – number of stress periods in the simulation

Return type
int

get_sim_name(*namefiles*, *rootpth=None*)

Get simulation name. :param namefiles: path(s) to MODFLOW-based model name files :type namefiles: str or list of strings :param rootpth: optional root directory path (default is None) :type rootpth: str

Returns
simname – list of namefiles without the file extension

Return type
list

getfiletypeunit(*nf*, *filetype*)

Method to return unit number of a package from a NamData instance

Parameters

- **nf** (*NamData instance*) –
- **filetype** (*string, name of package seeking information for*) –

Returns
cunit

Return type
int, unit number corresponding to the package type

parsenamefile(*namfilename*, *packages*, *verbose=True*)

Returns dict from the nam file with NamData keyed by unit number

Parameters

- **namefilename** (*str or Path*) – Name of the MODFLOW namefile to parse.

- **packages** (*dict*) – Dictionary of package objects as defined in the *mfnam_packages* attribute of *flopy.modflow.mf.Modflow*.
- **verbose** (*bool*) – Print messages to screen. Default is True.

Returns
For each file listed in the name file, a *flopy.utils.mfreadnam.NamData* instance is stored in the returned dict keyed by unit number.

Return type
dict

Raises

- **FileNotFoundError** – If namfilename does not exist in the directory.
- **ValueError** – For lines that cannot be parsed.

flopy.utils.modpathfile module

Module to read MODPATH output files. The module contains two important classes that can be accessed by the user.

- EndpointFile (ascii endpoint file)
- PathlineFile (ascii pathline file)

class EndpointFile(*filename*, *verbose=False*)

Bases: object

EndpointFile Class.

Parameters

- **filename** (*string*) – Name of the endpoint file
- **verbose** (*bool*) – Write information to the screen. Default is False.

Examples

```
>>> import flopy
>>> endobj = flopy.utils.EndpointFile('model.mpend')
>>> e1 = endobj.get_data(partid=1)
```

get_alldata()

Get endpoint data from the endpoint file for all endpoints.

Returns
ra – A numpy recarray with the endpoint particle data

Return type
numpy record array

Notes

Examples

```
>>> import flopy
>>> endobj = flopy.utils.EndpointFile('model.mpend')
>>> e = endobj.get_alldata()
```

get_data(*partid=0*)

Get endpoint data from the endpoint file for a single particle.

Parameters
partid (*int*) – The zero-based particle id. The first record is record 0. (default is 0)

Returns
ra – A numpy recarray with the endpoint particle data for endpoint partid.

Return type
numpy record array

Notes

Examples

```
>>> import flopy
>>> endobj = flopy.utils.EndpointFile('model.mpend')
>>> e1 = endobj.get_data(partid=1)
```

get_destination_endpoint_data(*dest_cells*, *source=False*)

Get endpoint data that terminate in a set of destination cells.

Parameters

- **dest_cells** (*list or array of tuples*) – (k, i, j) of each destination cell for MODPATH versions less than MODPATH 7 or node number of each destination cell. (zero based)
- **source** (*bool*) – Boolean to specify is dest_cells applies to source or destination cells (default is False).

Returns
epdest – Slice of endpoint data array (e.g. EndpointFile.get_alldata) containing only endpoint data with final locations in (k,i,j) or (node) dest_cells.

Return type
np.recarray

Examples

```
>>> import flopy
>>> e = flopy.utils.EndpointFile('modpath.endpoint')
>>> e0 = e.get_destination_endpoint_data([(0, 0, 0),
...                                       (1, 0, 0)])
```

get_maxid()

Get the maximum endpoint particle id in the file endpoint file

Returns
out - Maximum endpoint particle id.

Return type
int

get_maxtime()

Get the maximum time in the endpoint file

Returns
out - Maximum endpoint time.

Return type
float

get_maxtraveltime()

Get the maximum travel time in the endpoint file

Returns
out - Maximum endpoint travel time.

Return type
float

kijnames = ['k0', 'i0', 'j0', 'node0', 'k', 'i', 'j', 'node', 'particleid', 'particlegroup', 'particleidloc', 'zone0', 'zone']

write_shapefile(*endpoint_data=None*, *shpname='endpoints.shp'*, *direction='ending'*, *mg=None*, *crs=None*, ***kwargs*)

Write particle starting / ending locations to shapefile.

endpoint_data
[np.recarray] Record array of same form as that returned by EndpointFile.get_alldata. (if none, EndpointFile.get_alldata() is exported).

shpname
[str] File path for shapefile

direction
[str] String defining if starting or ending particle locations should be considered. (default is 'ending')

mg
[flopy.discretization.grid instance] Used to scale and rotate Global x,y,z values in MODPATH Endpoint file.

crs
[pyproj.CRS, int, str, optional] Coordinate reference system (CRS) for the model grid (must be projected; geographic CRS are not supported). The

value can be anything accepted by pyproj.CRS.from_user_input(), such as an authority string (eg "EPSG:26916") or a WKT string.

kwargs : keyword arguments to flopy.export.shapefile_utils.recarray2shp

Deprecated since version 3.5: The following keyword options will be removed for FloPy 3.6:

- epsg (int): use crs instead.

class PathlineFile(*filename: str | PathLike*, *verbose=False*)

Bases: _ModpathSeries

PathlineFile Class.

Parameters

- **filename** (*str or PathLike*) – Path of the pathline file
- **verbose** (*bool*) – Write information to the screen. Default is False.

Examples

```
>>> import flopy
>>> pthobj = flopy.utils.PathlineFile('model.mppth')
>>> p1 = pthobj.get_data(partid=1)
```

get_alldata(*totim=None*, *ge=True*)

get pathline data from the pathline file for all pathlines and all times.

Parameters

- **totim** (*float*) – The simulation time. All pathline points for particle partid that are greater than or equal to (ge=True) or less than or equal to (ge=False) totim will be returned. Default is None
- **ge** (*bool*) – Boolean that determines if pathline times greater than or equal to or less than or equal to totim is used to create a subset of pathlines. Default is True.

Returns

plist – A list of numpy recarrays with the x, y, z, time, k, and particleid for all pathlines.

Return type

a list of numpy record array

Examples

```
>>> import flopy.utils.modpathfile as mpf
>>> pthobj = flopy.utils.PathlineFile('model.mppth')
>>> p = pthobj.get_alldata()
```

get_data(*partid=0*, *totim=None*, *ge=True*)

get pathline data from the pathline file for a single pathline.

Parameters

- **partid** (*int*) – The zero-based particle id. The first record is record 0.
- **totim** (*float*) – The simulation time. All pathline points for particle partid that are greater than or equal to (ge=True) or less than or equal to (ge=False) totim will be returned. Default is None
- **ge** (*bool*) – Boolean that determines if pathline times greater than or equal to or less than or equal to totim is used to create a subset of pathlines. Default is True.

Returns
ra – A numpy recarray with the x, y, z, time, k, and particleid for pathline partid.

Return type
numpy record array

Notes

Examples

```
>>> import flopy.utils.modpathfile as mpf
>>> pthobj = flopy.utils.PathlineFile('model.mppth')
>>> p1 = pthobj.get_data(partid=1)
```

get_destination_pathline_data(*dest_cells*, *to_recarray=False*)

Get pathline data that pass through a set of destination cells.

Parameters

- **dest_cells** (*list or array of tuples*) – (k, i, j) of each destination cell for MODPATH versions less than MODPATH 7 or node number of each destination cell. (zero based)
- **to_recarray** (*bool*) – Boolean that controls returned pthldest. If to_recarray is True, a single recarray with all of the pathlines that intersect dest_cells are returned. If to_recarray is False, a list of recarrays (the same form as returned by get_alldata method) that intersect dest_cells are returned (default is False).

Returns
pthldest – Slice of pathline data array (e.g. PathlineFile._data) containing only pathlines that pass through (k,i,j) or (node) dest_cells.

Return type
np.recarray

Examples

```
>>> import flopy
>>> p = flopy.utils.PathlineFile('modpath.pathline')
>>> p0 = p.get_destination_pathline_data([(0, 0, 0),
...                                        (1, 0, 0)])
```

get_maxid()

Get the maximum pathline number in the file pathline file

Returns
out - Maximum pathline number.

Return type
int

get_maxtime()

Get the maximum time in pathline file

Returns
out - Maximum pathline time.

Return type
float

kijnames = ['k', 'i', 'j', 'node', 'particleid', 'particlegroup', 'linesegmentindex', 'particleidloc', 'sequencenumber']

write_shapefile(*pathline_data=None*, *one_per_particle=True*, *direction='ending'*, *shpname='pathlines.shp'*, *mg=None*, *crs=None*, ***kwargs*)

Write pathlines to a shapefile

pathline_data
[np.recarray] Record array of same form as that returned by PathlineFile.get_alldata(). (if none, PathlineFile.get_alldata() is exported).

one_per_particle
[boolean (default True)] True writes a single LineString with a single set of attribute data for each particle. False writes a record/geometry for each pathline segment (each row in the PathLine file). This option can be used to visualize attribute information (time, model layer, etc.) across a pathline in a GIS.

direction
[str] String defining if starting or ending particle locations should be included in shapefile attribute information. Only used if one_per_particle=False. (default is 'ending')

shpname
[str] File path for shapefile

mg
[flopy.discretization.grid instance] Used to scale and rotate Global x,y,z values in MODPATH Pathline file.

crs
[pyproj.CRS, int, str, optional] Coordinate reference system (CRS) for the model grid (must be projected; geographic CRS are not supported). The

value can be anything accepted by pyproj.CRS.from_user_input(), such as an authority string (eg "EPSG:26916") or a WKT string.

kwargs : keyword arguments to flopy.export.shapefile_utils.recarray2shp

Deprecated since version 3.5: The following keyword options will be removed for FloPy 3.6:

- epsg (int): use crs instead.

class TimeseriesFile(*filename*, *verbose=False*)

Bases: _ModpathSeries

TimeseriesFile Class.

Parameters

- **filename** (*string*) – Name of the timeseries file
- **verbose** (*bool*) – Write information to the screen. Default is False.

Examples

```
>>> import flopy
>>> tsobj = flopy.utils.TimeseriesFile('model.timeseries')
>>> ts1 = tsobj.get_data(partid=1)
```

get_alldata(*totim=None*, *ge=True*)

get timeseries data from the timeseries file for all timeseries and all times.

Parameters

- **totim** (*float*) – The simulation time. All timeseries points for timeseries partid that are greater than or equal to (ge=True) or less than or equal to (ge=False) totim will be returned. Default is None
- **ge** (*bool*) – Boolean that determines if timeseries times greater than or equal to or less than or equal to totim is used to create a subset of timeseries. Default is True.

Returns

tlist – A list of numpy recarrays with the x, y, z, time, k, and particleid for all timeseries.

Return type

a list of numpy record array

Examples

```
>>> import flopy
>>> tsobj = flopy.utils.TimeseriesFile('model.timeseries')
>>> ts = tsobj.get_alldata()
```

get_data(*partid=0*, *totim=None*, *ge=True*)

get timeseries data from the timeseries file for a single timeseries particleid.

Parameters

- **partid** (*int*) – The zero-based particle id. The first record is record 0.
- **totim** (*float*) – The simulation time. All timeseries points for particle partid that are greater than or equal to (ge=True) or less than or equal to (ge=False) totim will be returned. Default is None
- **ge** (*bool*) – Boolean that determines if timeseries times greater than or equal to or less than or equal to totim is used to create a subset of timeseries. Default is True.

Returns

ra – A numpy recarray with the x, y, z, time, k, and particleid for timeseries partid.

Return type

numpy record array

Notes

Examples

```
>>> import flopy
>>> tsobj = flopy.utils.TimeseriesFile('model.timeseries')
>>> ts1 = tsobj.get_data(partid=1)
```

get_destination_timeseries_data(*dest_cells*)

Get timeseries data that pass through a set of destination cells.

Parameters

dest_cells (*list or array of tuples*) – (k, i, j) of each destination cell for MODPATH versions less than MODPATH 7 or node number of each destination cell. (zero based)

Returns

tsdest – Slice of timeseries data array (e.g. TmeseriesFile._data) containing only timeseries that pass through (k,i,j) or (node) dest_cells.

Return type

np.recarray

Examples

```
>>> import flopy
>>> ts = flopy.utils.TimeseriesFile('modpath.timeseries')
>>> tss = ts.get_destination_timeseries_data([(0, 0, 0),
...                                           (1, 0, 0)])
```

get_maxid()

Get the maximum timeseries number in the file timeseries file

Returns
out - Maximum pathline number.

Return type
int

get_maxtime()
Get the maximum time in timeseries file

Returns
out - Maximum pathline time.

Return type
float

kijnames = ['k', 'i', 'j', 'node', 'particleid', 'particlegroup', 'particleidloc', 'timestep', 'timestepindex', 'timepointindex']

write_shapefile(*timeseries_data=None*, *one_per_particle=True*, *direction='ending'*, *shpname='pathlines.shp'*, *mg=None*, *crs=None*, ***kwargs*)
Write pathlines to a shapefile

timeseries_data
[np.recarray] Record array of same form as that returned by Timeseries.get_alldata(). (if none, Timeseries.get_alldata() is exported).

one_per_particle
[boolean (default True)] True writes a single LineString with a single set of attribute data for each particle. False writes a record/geometry for each pathline segment (each row in the Timeseries file). This option can be used to visualize attribute information (time, model layer, etc.) across a pathline in a GIS.

direction
[str] String defining if starting or ending particle locations should be included in shapefile attribute information. Only used if one_per_particle=False. (default is 'ending')

shpname
[str] File path for shapefile

mg
[flopy.discretization.grid instance] Used to scale and rotate Global x,y,z values in MODPATH Timeseries file.

crs
[pyproj.CRS, int, str, optional] Coordinate reference system (CRS) for the model grid (must be projected; geographic CRS are not supported). The value can be anything accepted by pyproj.CRS.from_user_input(), such as an authority string (eg "EPSG:26916") or a WKT string.

kwargs : keyword arguments to flopy.export.shapefile_utils.recarray2shp

Deprecated since version 3.5: The following keyword options will be removed for FloPy 3.6:

- epsg (int): use crs instead.

flopy.utils.mtlistfile module

This is a class for reading the mass budget from a (multi-component) mt3d(usgs) run. Also includes support for SFT budget.

class MtListBudget(*file_name*)

Bases: object

MT3D mass budget reader

Parameters

file_name (*str*) – the list file name

Examples

```
>>> mt_list = MtListBudget("my_mt3d.list")
>>> gw_df, sw_df = mt_list.parse(start_datetime="10-21-2015")
```

parse(*forgive=True*, *diff=True*, *start_datetime=None*, *time_unit='d'*)

Main entry point for parsing the list file.

Parameters

- **forgive** (*bool*) – flag to raise exceptions when fail-to-read occurs. Default is True
- **diff** (*bool*) – flag to return dataframes with 'in minus out' columns. Default is True
- **start_datetime** (*str*) – str that can be parsed by pandas.to_datetime. Example: '1-1-1970'. Default is None.
- **time_unit** (*str*) – str to pass to pandas.to_timedelta. Default is 'd' (days)

Returns

df_gw,df_sw – a dataframe for the groundwater mass and (optionally) surface-water mass budget. If the SFT process is not used, df_sw is None.

Return type

pandas.DataFrame

flopy.utils.observationfile module

class CsvFile(*csvfile*, *delimiter=','*, *deletechars=''*, *replace_space=''*)

Bases: object

Class for reading csv based output files

Parameters

- **csvfile** (*str*) – csv file name
- **delimiter** (*str*) – optional delimiter for the csv or formatted text file, defaults to ","
- **deletechars** (*str*) – optional string containing characters that should be deleted from the column names, defaults to ""

- **replace_space** (*str*) – optional string containing the character that will be used to replace the space with in any column names, defaults to ""

property nobs

Method to get the number of observations

Return type
int

property obsnames

Method to get the observation names

Return type
list

static read_csv(*fobj*, *dtype*, *delimiter=','*, *deletechars=''*, *replace_space=''*)

Parameters

- **fobj** (*file object*) – open text file object to read
- **dtype** (*np.dtype*) –
- **delimiter** (*str*) – optional delimiter for the csv or formatted text file, defaults to ","
- **deletechars** (*str*) – optional string containing characters that should be deleted from the column names, defaults to ""
- **replace_space** (*str*) – optional string containing the character that will be used to replace the space with in any column names, defaults to ""

Return type
np.recarray

class HydmodObs(*filename*, *verbose=False*, *hydlbl_len=20*)

Bases: *ObsFiles*

HydmodObs Class - used to read binary MODFLOW HYDMOD package output

Parameters

- **filename** (*str*) – Name of the hydmod output file
- **verbose** (*boolean*) – If true, print additional information to to the screen during the extraction. (default is False)
- **hydlbl_len** (*int*) – Length of hydmod labels. (default is 20)

Return type
None

class Mf6Obs(*filename*, *verbose=False*, *isBinary='auto'*)

Bases: *ObsFiles*

Mf6Obs Class - used to read ascii and binary MODFLOW6 observation output

Parameters

- **filename** (*str*) – Name of the hydmod output file
- **verbose** (*boolean*) – If true, print additional information to to the screen during the extraction. (default is False)

- **isBinary** (*str, bool*) – default is "auto", code will attempt to automatically check if file is binary. User can change this to True or False if the auto check fails to work

Return type
None

class ObsFiles

Bases: *FlopyBinaryData*

get_data(*idx=None, obsname=None, totim=None*)

Get data from the observation file.

Parameters

- **idx** (*int*) – The zero-based record number. The first record is record 0. If idx is None and totim are None, data for all simulation times are returned. (default is None)
- **obsname** (*string*) – The name of the observation to return. If obsname is None, all observation data are returned. (default is None)
- **totim** (*float*) – The simulation time to return. If idx is None and totim are None, data for all simulation times are returned. (default is None)

Returns
data – Array has size (ntimes, nitems). totim is always returned. nitems is 2 if idx or obsname is not None or nobs+1.

Return type
numpy record array

Notes

If both idx and obsname are None, will return all of the observation data.

Examples

```
>>> hyd = HydmodObs("my_model.hyd")
>>> ts = hyd.get_data()
```

get_dataframe(*start_datetime='1-1-1970', idx=None, obsname=None, totim=None, timeunit='D'*)

Get pandas dataframe with the incremental and cumulative water budget items in the hydmod file.

Parameters

- **start_datetime** (*str*) – If start_datetime is passed as None, the rows are indexed on totim. Otherwise, a DatetimeIndex is set. (default is 1-1-1970).
- **idx** (*int*) – The zero-based record number. The first record is record 0. If idx is None and totim are None, a dataframe with all simulation times is returned. (default is None)

- **obsname** (*string*) – The name of the observation to return. If obsname is None, all observation data are returned. (default is None)
- **totim** (*float*) – The simulation time to return. If idx is None and totim are None, a dataframe with all simulation times is returned. (default is None)
- **timeunit** (*string*) – time unit of the simulation time. Valid values are 'S'econds, 'M'inutes, 'H'ours, 'D'ays, 'Y'ears. (default is 'D').

Returns
out – Pandas dataframe of selected data.

Return type
pandas dataframe

Notes

If both idx and obsname are None, will return all of the observation data as a dataframe.

Examples

```
>>> hyd = HydmodObs("my_model.hyd")
>>> df = hyd.get_dataframes()
```

get_nobs()

Get the number of observations in the file

Returns
out – A tupe with the number of records and number of flow items in the file. The number of flow items is non-zero only if swrtype='flow'.

Return type
tuple of int

get_ntimes()

Get the number of times in the file

Returns
out – The number of simulation times (totim) in binary file.

Return type
int

get_obsnames()

Get a list of observation names in the file

Returns
out – List of observation names in the binary file. totim is not included in the list of observation names.

Return type
list of strings

get_times()

Get a list of unique times in the file

Returns
out – List contains unique simulation times (totim) in binary file.

Return type
list of floats

class SwrObs(*filename*, *precision='double'*, *verbose=False*)

Bases: *ObsFiles*

Read binary SWR observations output from MODFLOW SWR Process observation files

Parameters

- **filename** (*string*) – Name of the cell budget file
- **precision** (*string*) – 'single' or 'double'. Default is 'double'.
- **verbose** (*bool*) – Write information to the screen. Default is False.

Notes

Examples

```
>>> import flopy
>>> so = flopy.utils.SwrObs('mymodel.swr.obs')
```

get_reduced_pumping(*f*, *structured=True*)

Method to read reduced pumping from a list file or an external reduced pumping observation file

Parameters

- **f** (*str*) – file name
- **structured** (*bool*) – boolean flag to indicate if model is Structured or USG model. Defaults to True (structured grid).

Returns
np.recarray

Return type
recarray of reduced pumping records.

get_selection(*data*, *names*)

Parameters

- **data** (*numpy recarray*) – recarray of data to make a selection from
- **names** (*string or list of strings*) – column names to return

Returns
out – recarray with selection

Return type
numpy recarray

flopy.utils.optionblock module

class OptionBlock(*options_line*, *package*, *block=True*)

Bases: object

Parent class to for option blocks within Modflow-nwt models. This class contains base information and routines that can be shared throughout all option block classes.

Parameters

- **options_line** (*str*) – single line based options string
- **package** (*flopy.pakbase.Package instance*) – valid packages include ModflowWel, ModflowSfr2, ModflowUzf1
- **block** (*bool*) – flag to write as single line or block type

dtype = 'dtype'

classmethod load_options(*options*, *package*)

Loader for the options class. Reads in an options block and uses context from option util dictionaries to check the validity of the data

Parameters

- **options** (*str or file*) – string path to a file or file object
- **package** (*flopy.package type*) – valid packages include flopy.modflow.ModflowWel, flopy.modflow.ModflowUzf1, flopy.modflow.ModflowSfr2

Return type

OptionBlock object

n_nested = 'nvars'

nested = 'nested'

optional = 'optional'

simple_flag = {'dtype': <class 'numpy.bool_'>, 'nested': False, 'optional': False}

simple_float = {'dtype': <class 'float'>, 'nested': False, 'optional': False}

simple_int = {'dtype': <class 'int'>, 'nested': False, 'optional': False}

simple_str = {'dtype': <class 'str'>, 'nested': False, 'optional': False}

simple_tabfile = {'dtype': <class 'numpy.bool_'>, 'nested': True, 'nvars': 2, 'vars': {'maxval': {'dtype': <class 'int'>, 'nested': False, 'optional': False}, 'numtab': {'dtype': <class 'int'>, 'nested': False, 'optional': False}}}

property single_line_options

Method to get the single line representation of the Options Block

Returns

t

Return type

(str) single line representation of Options

update_from_package(*pak*)

Updater method to check the package and update OptionBlock attribute values based on package values.

Parameters

pak (*flopy.package*) – valid packages include ModflowWel, ModflowSfr2, and ModflowUzf1 instances

vars = 'vars'

write_options(*f*)

Method to write the options block or options line to an open file object.

Parameters

f

[file, str] open file object, or path to file

class OptionUtil

Bases: object

static isfloat(*s*)

Simple method to check that a string is a valid floating point variable

Parameters

s (*str*) –

Return type

bool

static isint(*s*)

Simple data check method to check that a string is a valid integer

Parameters

s (*str*) –

Return type

bool

static isvalid(*dtype*, *val*)

Check to see if a dtype is valid before setting as an attribute

Parameters

- **dtype** (*type*) – int, float, str, bool, etc...
- **val** (*string*) –

Return type

bool

flopy.utils.parse_version module

exception InvalidVersion

Bases: ValueError

An invalid version was found, users should refer to PEP 440.

class LegacyVersion(*version: str*)

Bases: _BaseVersion

property base_version: str

property dev: None

property epoch: int

property is_devrelease: bool

property is_postrelease: bool

property is_prerelease: bool

property local: None

property post: None

property pre: None

property public: str

property release: None

class Version(*version: str*)

Bases: _BaseVersion

property base_version: str

property dev: int | None

property epoch: int

property is_devrelease: bool

property is_postrelease: bool

property is_prerelease: bool

property local: str | None

property major: int

property micro: int

property minor: int

property post: int | None

property pre: tuple[str, int] | None

property public: str

property release: tuple[int, ...]

parse(*version: str*) → *LegacyVersion* | *Version*

Parse the given version string and return either a *Version* object or a *LegacyVersion* object depending on if the given version is a valid PEP 440 version or a legacy version.

flopy.utils.postprocessing module

get_extended_budget(*cbcfile*, *precision='single'*, *idx=None*, *kstpkper=None*, *totim=None*, *boundary_ifaces=None*, *hdsfile=None*, *model=None*)

Get the flow rate across cell faces including potential stresses applied along boundaries at a given time. Only implemented for "classical" MODFLOW versions where the budget is recorded as FLOW RIGHT FACE, FLOW FRONT FACE and FLOW LOWER FACE arrays.

Parameters

- **cbcfile** (*str*) – Cell by cell file produced by Modflow.
- **precision** (*str*) – Binary file precision, default is 'single'.
- **idx** (*int or list*) – The zero-based record number.
- **kstpkper** (*tuple of ints*) – A tuple containing the time step and stress period (kstp, kper). The kstp and kper values are zero based.
- **totim** (*float*) – The simulation time.
- **boundary_ifaces** (*dictionary {str: int or list}*) – A dictionary defining how to treat stress flows at boundary cells. The keys are budget terms corresponding to stress packages (same term as in the overall volumetric budget printed in the listing file). The values are either a single iface number to be applied to all cells for the stress package, or a list of lists describing individual boundary cells in the same way as in the package input plus the iface number appended. The iface number indicates the face to which the stress flow is assigned, following the MODPATH convention (see MODPATH user guide). Example: boundary_ifaces = { 'RECHARGE': 6, 'RIVER LEAKAGE': 6, 'CONSTANT HEAD': [[lay, row, col, iface], ...], 'WELLS': [[lay, row, col, flux, iface], ...], 'HEAD DEP BOUNDS': [[lay, row, col, head, cond, iface], ...]}. Note: stresses that are not informed in boundary_ifaces are implicitly treated as internally-distributed sinks/sources.
- **hdsfile** (*str*) – Head file produced by MODFLOW (only required if boundary_ifaces is used).
- **model** (*flopy.modflow.Modflow object*) – Modflow model instance (only required if boundary_ifaces is used).

Returns

(Qx_ext, Qy_ext, Qz_ext) – Flow rates across cell faces. Qx_ext is a ndarray of size (nlay, nrow, ncol + 1). Qy_ext is a ndarray of size (nlay, nrow + 1, ncol). The sign is such that the y axis is considered to increase in the north direction. Qz_ext is a ndarray of size (nlay + 1, nrow, ncol). The sign is such that the z axis is considered to increase in the upward direction.

Return type
tuple

get_gradients(*heads*, *m*, *nodata*, *per_idx=None*)

Calculates the hydraulic gradients from the heads array for each stress period.

Parameters

- **heads** (*3 or 4-D np.ndarray*) – Heads array.
- **m** (*flopy.modflow.Modflow object*) – Must have a flopy.modflow.ModflowDis object attached.
- **nodata** (*real*) – HDRY value indicating dry cells.
- **per_idx** (*int or sequence of ints*) – stress periods to return. If None, returns all stress periods (default).

Returns
grad – Array of hydraulic gradients

Return type
3 or 4-D np.ndarray

get_specific_discharge(*vectors*, *model*, *head=None*, *position='centers'*)

Get the discharge vector at cell centers at a given time. For "classical" MODFLOW versions, we calculate it from the flow rate across cell faces. For MODFLOW 6, we directly take it from MODFLOW output (this requires setting the option "save_specific_discharge" in the NPF package).

Parameters

- **vectors** (*tuple*, *np.recarray*) – either a tuple of (flow right face, flow front face, flow lower face) numpy arrays from a MODFLOW-2005 compatible Cell Budget File or a specific discharge recarray from a MODFLOW 6 Cell Budget File
- **model** (*object*) – flopy model object
- **head** (*np.ndarray*) – numpy array of head values for a specific model position : str

  Position at which the specific discharge will be calculated. Possible values are "centers" (default), "faces" and "vertices".

Returns
(qx, qy, qz) – Discharge vector. qx, qy, qz are ndarrays of size (nlay, nrow, ncol) for a structured grid or size (nlay, ncpl) for an unstructured grid. The sign of qy is such that the y axis is considered to increase in the north direction. The sign of qz is such that the z axis is considered to increase in the upward direction. Note: if a head array is provided, inactive and dry cells are set to NaN.

Return type
tuple

get_transmissivities(*heads*, *m*, *r=None*, *c=None*, *x=None*, *y=None*, *sctop=None*, *scbot=None*, *nodata=-999*)

Computes transmissivity in each model layer at specified locations and open intervals. A saturated thickness is determined for each row, column or x, y location supplied, based on the open interval (sctop, scbot), if supplied, otherwise the layer tops and bottoms and the water table are used.

Parameters

- **heads** (*2D array OR 3D array*) – numpy array of shape nlay by n locations (2D) OR complete heads array of the model for one time (3D)
- **m** (*flopy.modflow.Modflow object*) – Must have dis and lpf or upw packages.
- **r** (*1D array-like of ints, of length n locations*) – row indices (optional; alternately specify x, y)
- **c** (*1D array-like of ints, of length n locations*) – column indices (optional; alternately specify x, y)
- **x** (*1D array-like of floats, of length n locations*) – x locations in real world coordinates (optional)
- **y** (*1D array-like of floats, of length n locations*) – y locations in real world coordinates (optional)
- **sctop** (*1D array-like of floats, of length n locations*) – open interval tops (optional; default is model top)
- **scbot** (*1D array-like of floats, of length n locations*) – open interval bottoms (optional; default is model bottom)
- **nodata** (*numeric*) – optional; locations where heads=nodata will be assigned T=0

Returns

T – Transmissivities in each layer at each location

Return type

2D array of same shape as heads (nlay x n locations)

get_water_table(*heads*, *hdry=-1e+30*, *hnoflo=1e+30*, *masked_values=None*)

Get a 2D array representing the water table elevation for each stress period in heads array.

Parameters

- **heads** (*3 or 4-D np.ndarray*) – Heads array.
- **hdry** (*real*) – The head that is assigned to cells that are converted to dry during a simulation. By default, -1e30.
- **hnoflo** (*real*) – The value of head assigned to all inactive (no flow) cells throughout the simulation, including vertical pass-through cells in MODFLOW 6. By default, 1e30.
- **masked_values** (*list*) – List of any values (in addition to hdry and hnoflo) that should be masked in the water table calculation.

Returns

wt – for each stress period.

Return type

2 or 3-D np.ndarray of water table elevations

flopy.utils.rasters module

class Raster(*array*, *bands*, *crs*, *transform*, *nodataval*, *driver='GTiff'*, *rio_ds=None*)

Bases: object

The Raster object is used for cropping, sampling raster values, and re-sampling raster values to grids, and provides methods to plot rasters and histograms of raster digital numbers for visualization and analysis purposes.

Parameters

- **array** (*np.ndarray*) – a three dimensional array of raster values with dimensions defined by (raster band, nrow, ncol)
- **bands** (*tuple*) – a tuple of raster bands
- **crs** (*int, string, rasterio.crs.CRS object*) – either a epsg code, a proj4 string, or a CRS object
- **transform** (*affine.Affine object*) – affine object, which is used to define geometry
- **nodataval** (*float*) – raster no data value
- **rio_ds** (*DatasetReader object*) – rasterIO dataset Reader object

Notes

Examples

```
>>> from flopy.utils import Raster
>>>
>>> rio = Raster.load("myraster.tif")
```

FLOAT32 = (<class 'float'>, <class 'numpy.float32'>, <class 'numpy.float64'>)

FLOAT64 = (<class 'numpy.float64'>,)

INT16 = (<class 'numpy.int16'>, <class 'numpy.uint16'>)

INT32 = (<class 'int'>, <class 'numpy.int32'>, <class 'numpy.uint32'>, <class 'numpy.uint64'>, <class 'numpy.uint32'>, <class 'numpy.uint32'>)

INT64 = (<class 'numpy.int64'>, <class 'numpy.uint64'>)

INT8 = (<class 'numpy.int8'>, <class 'numpy.uint8'>)

property bands

Returns a tuple of raster bands

property bounds

Returns a tuple of xmin, xmax, ymin, ymax boundaries

crop(*polygon*, *invert=False*)

Method to crop a new raster object from the current raster object

Parameters

- **polygon** (*list, geojson, shapely.geometry, shapefile.Shape*) – crop method accepts any of these geometries:

  a list of (x, y) points, ex. [(x1, y1), ...] geojson Polygon object shapely Polygon object shapefile Polygon shape flopy Polygon shape

- **invert** (*bool*) – Default value is False. If invert is True then the area inside the shapes will be masked out

get_array(*band, masked=True*)

Method to get a numpy array corresponding to the provided raster band. Nodata vals are set to np.NaN

Parameters

- **band** (*int*) – band number from the raster
- **masked** (*bool*) – determines if nodatavals will be returned as np.nan to the user

Return type

np.ndarray

histogram(*ax=None, **kwargs*)

Method to plot a histogram of digital numbers

Parameters

- **ax** (*matplotlib.pyplot.axes*) – optional matplotlib axes for plotting
- ****kwargs** – matplotlib keyword arguments see matplotlib documentation for valid arguments for histogram

Returns

ax

Return type

matplotlib.pyplot.axes

static load(*raster: str | PathLike*)

Static method to load a raster file into the raster object

Parameters

raster (*str or PathLike*) – The path to the raster file

Return type

A Raster object

property nodatavals

Returns a Tuple of values used to define no data

plot(*ax=None, contour=False, **kwargs*)

Method to plot raster layers or contours.

Parameters

- **ax** (*matplotlib.pyplot.axes*) – optional matplotlib axes for plotting
- **contour** (*bool*) – flag to indicate creation of contour plot

- ****kwargs** – matplotlib keyword arguments see matplotlib documentation for valid arguments for plot and contour.

Returns
ax

Return type
matplotlib.pyplot.axes

resample_to_grid(*modelgrid*, *band*, *method='nearest'*, *multithread=False*, *thread_pool=2*, *extrapolate_edges=False*)

Method to resample the raster data to a user supplied grid of x, y coordinates.

x, y coordinate arrays should correspond to grid vertices

Parameters

- **modelgrid** (*flopy.Grid object*) – model grid to sample data from
- **band** (*int*) – raster band to re-sample
- **method** (*str*) – resampling methods

  linear for bi-linear interpolation

  nearest for nearest neighbor

  cubic for bi-cubic interpolation

  mean for mean sampling

  median for median sampling

  min for minimum sampling

  max for maximum sampling

  'mode' for majority sampling
- **multithread** (*bool*) – DEPRECATED boolean flag indicating if multithreading should be used with the mean and median sampling methods
- **thread_pool** (*int*) – DEPRECATED number of threads to use for mean and median sampling
- **extrapolate_edges** (*bool*) – boolean flag indicating if areas without data should be filled using the nearest interpolation method. This option has no effect when using the nearest interpolation method.

Return type
np.array

sample_point(**point*, *band=1*)

Method to get nearest raster value at a user provided point

Parameters

- ***point** (*point geometry representation*) – accepted data types: x, y values : ex. sample_point(1, 3, band=1) tuple of x, y: ex sample_point((1, 3), band=1) shapely.geometry.Point geojson.Point flopy.geometry.Point
- **band** (*int*) – raster band to re-sample

Returns
value

Return type
float

sample_polygon(*polygon*, *band*, *invert=False*, ***kwargs*)

Method to get an unordered list of raster values that are located within a arbitrary polygon

Parameters

- **polygon** (*list*, *geojson*, *shapely.geometry*, *shapefile.Shape*) – sample_polygon method accepts any of these geometries:

  a list of (x, y) points, ex. [(x1, y1), ...] geojson Polygon object shapely Polygon object shapefile Polygon shape flopy Polygon shape

- **band** (*int*) – raster band to re-sample
- **invert** (*bool*) – Default value is False. If invert is True then the area inside the shapes will be masked out

Return type
np.ndarray of unordered raster values

write(*name*)

Method to write raster data to a .tif file

Parameters
name (*str*) – output raster .tif file name

property xcenters

Returns a np.ndarray of raster x cell centers

property ycenters

Returns a np.ndarray of raster y cell centers

flopy.utils.recarray_utils module

create_empty_recarray(*length*, *dtype*, *default_value=0*)

Create a empty recarray with a defined default value for floats.

Parameters

- **length** (*int*) – Shape of the empty recarray.
- **dtype** (*np.dtype*) – dtype of the empty recarray.
- **default_value** (*float*) – default value to use for floats in recarray.

Returns
r – Recarray of type dtype with shape length.

Return type
np.recarray

Examples

```
>>> import numpy as np
>>> from flopy.utils import create_empty_recarray
>>> dt = np.dtype([('x', np.float32), ('y', np.float32)])
>>> create_empty_recarray(1, dt)
rec.array([(0., 0.)],
          dtype=[('x', '<f4'), ('y', '<f4')])
```

ra_slice(*ra*, *cols*)

Create a slice of a recarray

Deprecated since version 3.5: Use numpy.lib.recfunctions.repack_fields instead

Parameters

- **ra** (*np.recarray*) – recarray to extract a limited number of columns from.
- **cols** (*list of str*) – List of key names to extract from ra.

Returns

ra_slice – Slice of ra

Return type

np.recarray

Examples

```
>>> import numpy as np
>>> from flopy.utils import ra_slice
>>> a = np.core.records.fromrecords([("a", 1, 1.1), ("b", 2, 2.1)])
>>> ra_slice(a, ['f0', 'f1'])
rec.array([('a', 1), ('b', 2)],
          dtype=[('f0', '<U1'), ('f1', '<i4')])
```

recarray(*array*, *dtype*)

Convert a list of lists or tuples to a recarray.

Deprecated since version 3.5: Use numpy.core.records.fromrecords instead

Parameters

- **array** (*list of lists*) – list of lists containing data to convert to a recarray. The number of entries in each list in the list must be the same.
- **dtype** (*np.dtype*) – dtype of the array data

Returns

r – Recarray of type dtype with shape equal to the length of array.

Return type

np.recarray

Examples

```
>>> import numpy as np
>>> import flopy
>>> dt = np.dtype([('x', np.float32), ('y', np.float32)])
>>> a = [(1., 2.), (10., 20.), (100., 200.)]
>>> flopy.utils.recarray(a, dt)
rec.array([(  1.,   2.), ( 10.,  20.), (100., 200.)],
          dtype=[('x', '<f4'), ('y', '<f4')])
```

flopy.utils.reference module

Temporal referencing for flopy model objects.

class TemporalReference(*itmuni=4*, *start_datetime=None*)

Bases: object

For now, just a container to hold start time and time units files outside of DIS package.

defaults = {'itmuni': 4, 'start_datetime': '01-01-1970'}

itmuni_text = {0: 'undefined', 1: 'seconds', 2: 'minutes', 3: 'hours', 4: 'days', 5: 'years'}

itmuni_values = {'days': 4, 'hours': 3, 'minutes': 2, 'seconds': 1, 'undefined': 0, 'years': 5}

property model_time_units

flopy.utils.sfroutputfile module

class SfrFile(*filename*, *geometries=None*, *verbose=False*)

Bases: object

Read SFR package results from text file (ISTCB2 > 0)

Parameters

- **filename** (*str*) – Name of the sfr output file
- **geometries** (*any*) – Ignored
- **verbose** (*any*) – Ignored

Notes

Indexing starts at one for: layer, row, column, segment, reach. Indexing starts at zero for: i, j, k, and kstpkper.

Examples

```
>>> import flopy
>>> sfq = flopy.utils.SfrFile('mymodel.sfq')
```

property df

dtypes = {'column': <class 'int'>, 'layer': <class 'int'>, 'reach': <class 'int'>, 'row': <class 'int'>, 'segment': <class 'int'>}

get_dataframe()

Read the whole text file into a pandas dataframe.

Returns
df – SFR output as a pandas dataframe

Return type
pandas dataframe

static get_nstrm(*df*)

Get the number of SFR cells from the results dataframe.

Returns
nrch – Number of SFR cells

Return type
int

get_results(*segment*, *reach*)

Get results for a single reach or sequence of segments and reaches.

Parameters

- **segment** (*int or sequence of ints*) – Segment number for each location.
- **reach** (*int or sequence of ints*) – Reach number for each location

Returns
results – Dataframe of same format as SfrFile.df, but subset to input locations.

Return type
dataframe

get_times()

Parse the stress period/timestep headers.

Returns
kstpkper – list of kstp, kper tuples

Return type
tuple

flopy.utils.swroutputfile module

class SwrBudget(*filename*, *precision='double'*, *verbose=False*)

Bases: *SwrFile*

Read binary SWR budget output from MODFLOW SWR Process binary output files

Parameters

- **filename** (*string*) – Name of the swr budget output file
- **precision** (*string*) – 'single' or 'double'. Default is 'double'.
- **verbose** (*bool*) – Write information to the screen. Default is False.

Notes

Examples

```
>>> import flopy
>>> stageobj = flopy.utils.SwrStage('mymodel.swr.bud')
```

class SwrExchange(*filename*, *precision='double'*, *verbose=False*)

Bases: *SwrFile*

Read binary SWR surface-water groundwater exchange output from MODFLOW SWR Process binary output files

Parameters

- **filename** (*string*) – Name of the swr surface-water groundwater exchange output file
- **precision** (*string*) – 'single' or 'double'. Default is 'double'.
- **verbose** (*bool*) – Write information to the screen. Default is False.

Notes

Examples

```
>>> import flopy
>>> stageobj = flopy.utils.SwrStage('mymodel.swr.qaq')
```

class SwrFile(*filename*, *swrtype='stage'*, *precision='double'*, *verbose=False*)

Bases: *FlopyBinaryData*

Read binary SWR output from MODFLOW SWR Process binary output files The SwrFile class is the super class from which specific derived classes are formed. This class should not be instantiated directly

Parameters

- **filename** (*string*) – Name of the swr output file
- **swrtype** (*str*) – swr data type. Valid data types are 'stage', 'budget', 'flow', 'exchange', or 'structure'. (default is 'stage')

- **precision** (*string*) – 'single' or 'double'. Default is 'double'.
- **verbose** (*bool*) – Write information to the screen. Default is False.

Notes

Examples

```
>>> import flopy
>>> so = flopy.utils.SwrFile('mymodel.swr.stage.bin')
```

get_connectivity()

Get connectivity data from the file.

Returns
data – Array has size (nrecord, 3). None is returned if swrtype is not 'flow'

Return type
numpy array

Notes

Examples

get_data(*idx=None*, *kswrkstpkper=None*, *totim=None*)

Get data from the file for the specified conditions.

Parameters

- **idx** (*int*) – The zero-based record number. The first record is record 0. (default is None)
- **kswrkstpkper** (*tuple of ints*) – A tuple containing the swr time step, time step, and stress period (kswr, kstp, kper). These are zero-based kswr, kstp, and kper values. (default is None)
- **totim** (*float*) – The simulation time. (default is None)

Returns
data – Array has size (nitems).

Return type
numpy record array

Notes

if both kswrkstpkper and totim are None, will return the last entry

Examples

get_kswrkstpkper()

Get a list of unique stress periods, time steps, and swr time steps in the file

Returns
out - List of unique kswr, kstp, kper combinations in binary file. kswr, kstp, and kper values are zero-based.

Return type
list of (kswr, kstp, kper) tuples

get_nrecords()

Get the number of records in the file

Returns
out - A tupe with the number of records and number of flow items in the file. The number of flow items is non-zero only if swrtype='flow'.

Return type
tuple of int

get_ntimes()

Get the number of times in the file

Returns
out - The number of simulation times (totim) in binary file.

Return type
int

get_record_names()

Get a list of unique record names in the file

Returns
out - List of unique text names in the binary file.

Return type
list of strings

get_times()

Get a list of unique times in the file

Returns
out - List contains unique simulation times (totim) in binary file.

Return type
list of floats

get_ts(*irec=0*, *iconn=0*, *klay=0*, *istr=0*)

Get a time series from a swr binary file.

Parameters

- **irec** (*int*) – is the zero-based reach (stage, qm, qaq) or reach group number (budget) to retrieve. (default is 0)
- **iconn** (*int*) – is the zero-based connection number for reach (irch) to retrieve qm data. iconn is only used if qm data is being read. (default is 0)
- **klay** (*int*) – is the zero-based layer number for reach (irch) to retrieve qaq data . klay is only used if qaq data is being read. (default is 0)
- **klay** – is the zero-based structure number for reach (irch) to retrieve structure data . isrt is only used if structure data is being read. (default is 0)

Returns
out – Array has size (ntimes, nitems). The first column in the data array will contain time (totim). nitems is 2 for stage data, 15 for budget data, 3 for qm data, and 11 for qaq data.

Return type
numpy recarray

Notes

The irec, iconn, and klay values must be zero-based.

Examples

class SwrFlow(*filename*, *precision='double'*, *verbose=False*)

Bases: *SwrFile*

Read binary SWR flow output from MODFLOW SWR Process binary output files

Parameters

- **filename** (*string*) – Name of the swr flow output file
- **precision** (*string*) – 'single' or 'double'. Default is 'double'.
- **verbose** (*bool*) – Write information to the screen. Default is False.

Notes

Examples

```
>>> import flopy
>>> stageobj = flopy.utils.SwrStage('mymodel.swr.flow')
```

class SwrStage(*filename*, *precision='double'*, *verbose=False*)

Bases: *SwrFile*

Read binary SWR stage output from MODFLOW SWR Process binary output files

Parameters

- **filename** (*string*) – Name of the swr stage output file

- **precision** (*string*) – 'single' or 'double'. Default is 'double'.
- **verbose** (*bool*) – Write information to the screen. Default is False.

Notes

Examples

```
>>> import flopy
>>> stageobj = flopy.utils.SwrStage('mymodel.swr.stg')
```

class SwrStructure(*filename*, *precision='double'*, *verbose=False*)

Bases: *SwrFile*

Read binary SWR structure output from MODFLOW SWR Process binary output files

Parameters

- **filename** (*string*) – Name of the swr structure output file
- **precision** (*string*) – 'single' or 'double'. Default is 'double'.
- **verbose** (*bool*) – Write information to the screen. Default is False.

Notes

Examples

```
>>> import flopy
>>> stageobj = flopy.utils.SwrStage('mymodel.swr.str')
```

flopy.utils.triangle module

class Triangle(*model_ws='.'*, *exe_name='triangle'*, *maximum_area=None*, *angle=20.0*, *nodes=None*, *additional_args=None*)

Bases: object

Class to work with the triangle program to unstructured triangular grids. Information on the triangle program can be found at https://www.cs.cmu.edu/~quake/triangle.html

Parameters

- **model_ws** (*str*) – workspace location for creating triangle files (default is '.')
- **exe_name** (*str*) – path and name of the triangle program. (default is triangle, which means that the triangle program must be in your path)
- **maximum_area** (*float*) – the maximum area for any triangle. The default value is None, which means that the user must specify maximum areas for each region.

- **angle** (*float*) – Triangle will continue to add vertices until no angle is less than this specified value. (default is 20 degrees)
- **nodes** (*ndarray*) – Two dimensional array of shape (npoints, 2) with x and y positions of fixed node locations to include in the resulting triangular mesh. (default is None)
- **additional_args** (*list*) – list of additional command line switches to pass to triangle

Return type
None

add_hole(*hole*)

Add a point that will turn enclosing polygon into a hole

Parameters
hole (*tuple*) – (x, y)

Return type
None

add_polygon(*polygon*)

Add a polygon

Parameters
polygon (*list, geojson, shapely.geometry, shapefile.Shape*) – add polygon method accepts any of these geometries:

a list of (x, y) points geojson Polygon object shapely Polygon object shapefile Polygon shape flopy.utils.geometry.Polygon object

Return type
None

add_region(*point, attribute=0, maximum_area=None*)

Add a point that will become a region with a maximum area, if specified.

Parameters

- **point** (*tuple*) – (x, y)
- **attribute** (*integer or float*) – integer value assigned to output elements
- **maximum_area** (*float*) – maximum area of elements in region

Return type
None

build(*verbose=False*)

Build the triangular mesh

Parameters
verbose (*bool*) – If true, print the results of the triangle command to the terminal (default is False)

Return type
None

clean()

Remove the input and output files created by this class and by the Triangle program

Return type
None

get_attribute_array()

Return an array containing the attribute value for each cell. These are the attribute values that are passed into the add_region() method.

Returns
attribute_array

Return type
ndarray

get_boundary_marker_array()

Get an integer array that has boundary markers

Returns
iedge – integer array of size ncpl containing a boundary ids. The array contains zeros for cells that do not touch a boundary. The boundary ids are the segment numbers for each segment in each polygon that is added with the add_polygon method.

Return type
ndarray

get_cell2d()

Get a list of the information needed for the MODFLOW DISV Package.

Returns
cell2d – innermost list contains cell number, x, y, number of vertices, and then the vertex numbers comprising the cell.

Return type
list (of lists)

get_cell_edge_length(*n*, *ibm*)

Get the length of the edge for cell n that corresponds to boundary marker ibm

Parameters

- **n** (*int*) – cell number. 0 <= n < self.ncpl
- **ibm** (*integer*) – boundary marker number

Returns
length – Length of the edge along that boundary marker. Will return None if cell n does not touch boundary marker.

Return type
float

get_edge_cells(*ibm*)

Get a list of cell numbers that correspond to the specified boundary marker.

Parameters
ibm (*integer*) – boundary marker value

Returns
cell_list – list of zero-based cell numbers

Return type
list

get_vertices()

Get a list of vertices in the form needed for the MODFLOW DISV Package.

Returns
vertices – innermost list contains vertex number, x, and y

Return type
list (of lists)

get_xcyc()

Get a 2-dimensional array of x and y cell center coordinates.

Returns
xcyc – column 0 contains the x coordinates and column 1 contains the y coordinates

Return type
ndarray

label_cells(*ax=None*, *onebased=True*, ***kwargs*)

Label the cells with their cell numbers

Parameters

- **ax** (*matplotlib.pyplot.Axes*) – axis to add the plot to. (default is plt.gca())
- **onebased** (*bool*) – Make the labels one-based if True so that they correspond to what would be written to MODFLOW.
- **kwargs** (*dictionary*) – dictionary of arguments to pass to ax.text()

Return type
None

label_vertices(*ax=None*, *onebased=True*, ***kwargs*)

Label the mesh vertices with their vertex numbers

Parameters

- **ax** (*matplotlib.pyplot.Axes*) – axis to add the plot to. (default is plt.gca())
- **onebased** (*bool*) – Make the labels one-based if True so that they correspond to what would be written to MODFLOW.
- **kwargs** (*dictionary*) – dictionary of arguments to pass to ax.text()

Return type
None

plot(*ax=None*, *layer=0*, *edgecolor='k'*, *facecolor='none'*, *cmap='Dark2'*, *a=None*, *masked_values=None*, ***kwargs*)

Plot the grid. This method will plot the grid using the shapefile that was created as part of the build method.

Note that the layer option is not working yet.

Parameters

- **ax** (*matplotlib.pyplot axis*) – The plot axis. If not provided it, plt.gca() will be used. If there is not a current axis then a new one will be created.
- **layer** (*int*) – Layer number to plot
- **cmap** (*string*) – Name of colormap to use for polygon shading (default is 'Dark2')
- **edgecolor** (*string*) – Color name. (Default is 'scaled' to scale the edge colors.)
- **facecolor** (*string*) – Color name. (Default is 'scaled' to scale the face colors.)
- **a** (*numpy.ndarray*) – Array to plot.
- **masked_values** (*iterable of floats, ints*) – Values to mask.
- **kwargs** (*dictionary*) – Keyword arguments that are passed to PatchCollection.set(**kwargs). Some common kwargs would be 'linewidths', 'linestyles', 'alpha', etc.

Return type
None

plot_boundary(*ibm*, *ax=None*, ***kwargs*)

Plot a line and vertices for the specified boundary marker

Parameters

- **ibm** (*integer*) – plot the boundary for this boundary marker
- **ax** (*matplotlib.pyplot.Axes*) – axis to add the plot to. (default is plt.gca())
- **kwargs** (*dictionary*) – dictionary of arguments to pass to ax.plot()

Return type
None

plot_centroids(*ax=None*, ***kwargs*)

Plot the cell centroids

Parameters

- **ax** (*matplotlib.pyplot.Axes*) – axis to add the plot to. (default is plt.gca())
- **kwargs** (*dictionary*) – dictionary of arguments to pass to ax.plot()

Return type
None

plot_vertices(*ax=None*, ***kwargs*)

Plot the mesh vertices

Parameters

- **ax** (*matplotlib.pyplot.Axes*) – axis to add the plot to. (default is plt.gca())

- **kwargs** (*dictionary*) – dictionary of arguments to pass to ax.plot()

Return type
None

flopy.utils.util_array module

util_array module. Contains the util_2d, util_3d and transient_2d classes.
These classes encapsulate modflow-style array inputs away from the individual packages. The end-user should not need to instantiate these classes directly.

class ArrayFormat(*u2d*, *python=None*, *fortran=None*, *array_free_format=None*)
Bases: object

ArrayFormat class for handling various output format types for both MODFLOW and flopy

Parameters

- **u2d** (*Util2d instance*) –
- **python** (*str (optional)*) – python-style output format descriptor e.g. {0:15.6e}
- **fortran** (*str (optional)*) – fortran style output format descriptor e.g. (2E15.6)

fortran
fortran format output descriptor (e.g. (100G15.6)

Type
str

py
python format output descriptor (e.g. "{0:15.6E}")

Type
str

numpy
numpy format output descriptor (e.g. "%15.6e")

Type
str

npl
number if items per line of output

Type
int

width
the width of the formatted numeric output

Type
int

decimal
the number of decimal digits in the numeric output

Type
int

format
the output format type e.g. I, G, E, etc

Type
str

free
free format flag

Type
bool

binary
binary format flag

Type
bool

get_default_numpy_fmt : (dtype : [np.int32, np.float32])
a static method to get a default numpy dtype - used for loading

decode_fortran_descriptor : (fd : str)
a static method to decode fortran descriptors into npl, format, width, decimal.

Notes

Examples

property array_free_format

property binary

property decimal

static decode_fortran_descriptor(*fd*)
Decode fortran descriptor

Parameters
fd (*str*) –

Returns
npl, fmt, width, decimal

Return type
int, str, int, int

classmethod float()

property format

property fortran

property free

static get_default_numpy_fmt(*dtype*)

classmethod integer()

property npl

property numpy

property py

property width

class Transient2d(*model*, *shape*, *dtype*, *value*, *name*, *fmtin=None*, *cnstnt=1.0*, *iprn=-1*, *ext_filename=None*, *locat=None*, *bin=False*, *array_free_format=None*)

Bases: DataInterface

Transient2d class for handling time-dependent 2-D model arrays. just a thin wrapper around Util2d

Parameters

- **model** (*model object*) – The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.
- **shape** (*length 2 tuple*) – shape of the 2-D transient arrays, typically (nrow,ncol)
- **dtype** (*[np.int32, np.float32, bool]*) – the type of the data
- **value** (*variable*) – the data to be assigned to the 2-D arrays. Typically a dict of {kper:value}, where kper is the zero-based stress period to assign a value to. Value should be cast-able to Util2d instance can be a scalar, list, or ndarray is the array value is constant in time.
- **name** (*string*) – name of the property, used for writing comments to input files and for forming external files names (if needed)
- **fmtin** (*string*) – modflow fmtin variable (optional). (the default is None)
- **cnstnt** (*string*) – modflow cnstnt variable (optional) (the default is 1.0)
- **iprn** (*int*) – modflow iprn variable (optional) (the default is -1)
- **locat** (*int*) – modflow locat variable (optional) (the default is None). If the model instance does not support free format and the external flag is not set and the value is a simple scalar, then locat must be explicitly passed as it is the unit number

  to read the array from
- **ext_filename** (*string*) – the external filename to write the array representation to (optional) (the default is None) . If type(value) is a string and is an accessible filename, the ext_filename is reset to value.
- **bin** (*bool*) – flag to control writing external arrays as binary (optional) (the default is False)

transient_2ds

the transient sequence of Util2d objects

Type

dict{kper:Util2d}

get_kper_entry : (itmp,string)
: get the itmp value and the Util2d file entry of the value in transient_2ds in bin kper. if kper < min(Transient2d.keys()), return (1,zero_entry<Util2d>). If kper > < min(Transient2d.keys()), but is not found in Transient2d.keys(), return (-1,")

Notes

Examples

property array

build_transient_sequence()
: parse self.__value into a dict{kper:Util2d}

property data_type

property dtype

export(*f*, ***kwargs*)

classmethod from_4d(*model*, *pak_name*, *m4ds*)
: construct a Transient2d instance from a dict(name: (masked) 4d numpy.ndarray :param model: :type model: flopy.mbase derived type :param pak_name: :type pak_name: str package name (e.g. RCH) :param m4ds: each ndarray must have shape (nper,1,nrow,ncol).

    if an entire (nrow,ncol) slice is np.NaN, then that kper is skipped.

    Return type
    Transient2d instance

get_kper_entry(*kper*)
: Get the file entry info for a given kper returns (itmp,file entry string from Util2d)

get_zero_2d(*kper*)

static masked4d_array_to_kper_dict(*m4d*)

property model

property name

plot(*filename_base=None*, *file_extension=None*, *kper=0*, *fignum=None*, ***kwargs*)
: Plot transient 2-D model input data

    Parameters

    - **filename_base** (*str*) – Base file name that will be used to automatically generate file names for output image files. Plots will be exported as image files if file_name_base is not None. (default is None)
    - **file_extension** (*str*) – Valid matplotlib.pyplot file extension for savefig(). Only used if filename_base is not None. (default is 'png')

- **kper** (*int or str*) – model stress period. if 'all' is provided, all stress periods will be plotted
- **fignum** (*list or int*) – Figure numbers for plot title
- ****kwargs** (*dict*) –

  axes
  : [list of matplotlib.pyplot.axis] List of matplotlib.pyplot.axis that will be used to plot data for each layer. If axes=None axes will be generated. (default is None)

  pcolor
  : [bool] Boolean used to determine if matplotlib.pyplot.pcolormesh plot will be plotted. (default is True)

  colorbar
  : [bool] Boolean used to determine if a color bar will be added to the matplotlib.pyplot.pcolormesh. Only used if pcolor=True. (default is False)

  inactive
  : [bool] Boolean used to determine if a black overlay in inactive cells in a layer will be displayed. (default is True)

  contour
  : [bool] Boolean used to determine if matplotlib.pyplot.contour plot will be plotted. (default is False)

  clabel
  : [bool] Boolean used to determine if matplotlib.pyplot.clabel will be plotted. Only used if contour=True. (default is False)

  grid
  : [bool] Boolean used to determine if the model grid will be plotted on the figure. (default is False)

  masked_values
  : [list] List of unique values to be excluded from the plot.

  kper
  : [str] MODFLOW zero-based stress period number to return. If kper='all' then data for all stress period will be extracted. (default is zero).

Returns
: **out** – Empty list is returned if filename_base is not None. Otherwise a list of matplotlib.pyplot.axis is returned.

Return type
: list

Notes

Examples

```
>>> import flopy
>>> ml = flopy.modflow.Modflow.load('test.nam')
>>> ml.rch.rech.plot()
```

property plottable

class Transient3d(*model*, *shape*, *dtype*, *value*, *name*, *fmtin=None*, *cnstnt=1.0*, *iprn=-1*, *ext_filename=None*, *locat=None*, *bin=False*, *array_free_format=None*)

Bases: DataInterface

Transient3d class for handling time-dependent 3-D model arrays. just a thin wrapper around Util3d

Parameters

- **model** (*model object*) – The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.
- **shape** (*length 3 tuple*) – shape of the 3-D transient arrays, typically (nlay,nrow,ncol)
- **dtype** (*[np.int32, np.float32, bool]*) – the type of the data
- **value** (*variable*) – the data to be assigned to the 3-D arrays. Typically a dict of {kper:value}, where kper is the zero-based stress period to assign a value to. Value should be cast-able to Util2d instance can be a scalar, list, or ndarray is the array value is constant in time.
- **name** (*string*) – name of the property, used for writing comments to input files and for forming external files names (if needed)
- **fmtin** (*string*) – modflow fmtin variable (optional). (the default is None)
- **cnstnt** (*string*) – modflow cnstnt variable (optional) (the default is 1.0)
- **iprn** (*int*) – modflow iprn variable (optional) (the default is -1)
- **locat** (*int*) – modflow locat variable (optional) (the default is None). If the model instance does not support free format and the external flag is not set and the value is a simple scalar, then locat must be explicitly passed as it is the unit number

  to read the array from
- **ext_filename** (*string*) – the external filename to write the array representation to (optional) (the default is None) . If type(value) is a string and is an accessible filename, the ext_filename is reset to value.
- **bin** (*bool*) – flag to control writing external arrays as binary (optional) (the default is False)

transient_3ds

the transient sequence of Util3d objects

Type
dict{kper:Util3d}

get_kper_entry : (itmp,string)

get the itmp value and the Util2d file entry of the value in transient_2ds in bin kper. if kper < min(Transient2d.keys()), return (1,zero_entry<Util2d>). If kper > < min(Transient2d.keys()), but is not found in Transient2d.keys(), return (-1,”)

Notes

Examples

property array

build_transient_sequence()

parse self.__value into a dict{kper:Util3d}

property data_type

property dtype

get_kper_entry(*kper*)

get the file entry info for a given kper returns (itmp,file entry string from Util3d)

get_zero_3d(*kper*)

property model

property name

property plottable

class Util2d(*model*, *shape*, *dtype*, *value*, *name*, *fmtin=None*, *cnstnt=1.0*, *iprn=-1*, *ext_filename=None*, *locat=None*, *bin=False*, *how=None*, *array_free_format=None*)

Bases: DataInterface

Util2d class for handling 1- or 2-D model arrays

Parameters

- **model** (*model object*) – The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.
- **shape** (*tuple*) – Shape of the 1- or 2-D array
- **dtype** (*[np.int32, np.float32, bool]*) – the type of the data
- **value** (*variable*) – the data to be assigned to the 1- or 2-D array. can be a scalar, list, ndarray, or filename
- **name** (*string*) – name of the property (optional). (the default is None
- **fmtin** (*string*) – modflow fmtin variable (optional). (the default is None)
- **cnstnt** (*string*) – modflow cnstnt variable (optional) (the default is 1.0)

- **iprn** (*int*) - modflow iprn variable (optional) (the default is -1)
- **locat** (*int*) - modflow locat variable (optional) (the default is None). If the model instance does not support free format and the external flag is not set and the value is a simple scalar, then locat must be explicitly passed as it is the unit number

    to read the array from)

- **ext_filename** (*string*) - the external filename to write the array representation to (optional) (the default is None) . If type(value) is a string and is an accessible filename, the ext_filename is reset to value.
- **bin** (*bool*) - flag to control writing external arrays as binary (optional) (the default is False)

array

the array representation of the 2-D object

Type
np.ndarray

how

the str flag to control how the array is written to the model input files e.g. "constant","internal","external","openclose"

Type
str

format

controls the ASCII representation of the numeric array

Type
ArrayFormat object

get_file_entry : string

get the model input file string including the control record

Notes

If value is a valid filename and model.external_path is None, then a copy of the file is made and placed in model.model_ws directory.

If value is a valid filename and model.external_path is not None, then a copy of the file is made a placed in the external_path directory.

If value is a scalar, it is always written as a constant, regardless of the model.external_path setting.

If value is an array and model.external_path is not None, then the array is written out in the external_path directory. The name of the file that holds the array is created from the name attribute. If the model supports "free format", then the array is accessed via the "open/close" approach. Otherwise, a unit number and filename is added to the name file.

If value is an array and model.external_path is None, then the array is written internally to the model input file.

Examples

all()

property array

Get the COPY of array representation of value attribute with the effects of the control record multiplier applied.

Returns
array – Copy of the array with the multiplier applied.

Return type
numpy.ndarray

Note: .array is a COPY of the array representation as seen by the model - with the effects of the control record multiplier applied.

static array2string(*shape*, *data*, *fortran_format='(FREE)'*, *python_format=None*)

return a string representation of a (possibly wrapped format) array from a file (self.__value) and casts to the proper type (self._dtype) made static to support the load functionality this routine now supports fixed format arrays where the numbers may touch.

property cnstnt_str

property data_type

property dtype

export(*f*, ***kwargs*)

property filename

property format

get_constant_cr(*value*)

get_external_cr()

get_file_entry(*how=None*)

get_internal_cr()

get_openclose_cr()

get_value()

property how

classmethod load(*f_handle*, *model*, *shape*, *dtype*, *name*, *ext_unit_dict=None*, *array_free_format=None*, *array_format='modflow'*)

functionality to load Util2d instance from an existing model input file. external and internal record types must be fully loaded if you are using fixed format record types,make sure ext_unit_dict has been initialized from the NAM file

static load_bin(*shape*, *file_in*, *dtype*, *bintype=None*)

Load unformatted file to a 2-D array

Parameters

- **shape** (*tuple of int*) – One or two array dimensions
- **file_in** (*file or str*) – Filename or file handle
- **dtype** (*np.int32 or np.float32*) – Data type of unformatted file and Numpy array; use np.int32 for Fortran's INTEGER, and np.float32 for Fortran's REAL data types.
- **bintype** (*str*) – Normally 'Head'

Notes

This method is similar to MODFLOW's U2DREL and U2DINT subroutines, but only for unformatted files.

Return type

2-D array

static load_block(*shape*, *file_in*, *dtype*)

Load block format from a MT3D file to a 2-D array

Parameters

- **shape** (*tuple of int*) – Array dimensions (nrow, ncol)
- **file_in** (*file or str*) – Filename or file handle
- **dtype** (*np.int32 or np.float32*) –

Return type

2-D array

static load_txt(*shape*, *file_in*, *dtype*, *fmtin*)

Load formatted file to a 1-D or 2-D array

Parameters

- **shape** (*tuple of int*) – One or two array dimensions
- **file_in** (*file or str*) – Filename or file handle
- **dtype** (*np.int32 or np.float32*) –
- **fmtin** (*str*) – Fortran array format descriptor, '(FREE)' or e.g. '(10G11.4)'

Notes

This method is similar to MODFLOW's U1DREL, U1DINT, U2DREL and U2DINT subroutines, but only for formatted files.

Return type

1-D or 2-D array

property model

property model_file_path

where the model expects the file to be

Returns
file_path (str)

Return type
path relative to the name file

property name

static parse_control_record(*line*, *current_unit=None*, *dtype=<class 'numpy.float32'>*, *ext_unit_dict=None*, *array_format=None*)

parses a control record when reading an existing file rectifies fixed to free format current_unit (optional) indicates the unit number of the file being parsed

parse_value(*value*)

parses and casts the raw value into an acceptable format for __value lot of defense here, so we can make assumptions later

plot(*title=None*, *filename_base=None*, *file_extension=None*, *fignum=None*, ***kwargs*)

Plot 2-D model input data

Parameters

- **title** (*str*) – Plot title. If a plot title is not provide one will be created based on data name (self._name). (default is None)
- **filename_base** (*str*) – Base file name that will be used to automatically generate file names for output image files. Plots will be exported as image files if file_name_base is not None. (default is None)
- **file_extension** (*str*) – Valid matplotlib.pyplot file extension for savefig(). Only used if filename_base is not None. (default is 'png')
- ****kwargs** (*dict*) –

  axes
  [list of matplotlib.pyplot.axis] List of matplotlib.pyplot.axis that will be used to plot data for each layer. If axes=None axes will be generated. (default is None)

  pcolor
  [bool] Boolean used to determine if matplotlib.pyplot.pcolormesh plot will be plotted. (default is True)

  colorbar
  [bool] Boolean used to determine if a color bar will be added to the matplotlib.pyplot.pcolormesh. Only used if pcolor=True. (default is False)

  inactive
  [bool] Boolean used to determine if a black overlay in

inactive cells in a layer will be displayed. (default is True)

contour
[bool] Boolean used to determine if matplotlib.pyplot.contour plot will be plotted. (default is False)

clabel
[bool] Boolean used to determine if matplotlib.pyplot.clabel will be plotted. Only used if contour=True. (default is False)

grid
[bool] Boolean used to determine if the model grid will be plotted on the figure. (default is False)

masked_values
[list] List of unique values to be excluded from the plot.

Returns
out – Empty list is returned if filename_base is not None. Otherwise a list of matplotlib.pyplot.axis is returned.

Return type
list

Notes

Examples

```
>>> import flopy
>>> ml = flopy.modflow.Modflow.load('test.nam')
>>> ml.dis.top.plot()
```

property plottable

property python_file_path

where python is going to write the file :returns: **file_path (str)** :rtype: path relative to python: includes model_ws

set_fmtin(*fmtin*)

property string

get the string representation of value attribute

Note: the string representation DOES NOT include the effects of the control record multiplier - this method is used primarily for writing model input files

sum()

unique()

property vtype

static write_bin(*shape*, *file_out*, *data*, *bintype=None*, *header_data=None*)

static write_txt(*shape*, *file_out*, *data*, *fortran_format='(FREE)'*, *python_format=None*)

class Util3d(*model*, *shape*, *dtype*, *value*, *name*, *fmtin=None*, *cnstnt=1.0*, *iprn=-1*, *locat=None*, *ext_unit_dict=None*, *array_free_format=None*)

Bases: `DataInterface`

Util3d class for handling 3-D model arrays. just a thin wrapper around
Util2d

Parameters

- **model** (*model object*) – The model object (of type *flopy.modflow.mf.Modflow*) to which this package will be added.
- **shape** (*length 3 tuple*) – shape of the 3-D array, typically (nlay,nrow,ncol)
- **dtype** (*[np.int32, np.float32, bool]*) – the type of the data
- **value** (*variable*) – the data to be assigned to the 3-D array. can be a scalar, list, or ndarray
- **name** (*string*) – name of the property, used for writing comments to input files
- **fmtin** (*string*) – modflow fmtin variable (optional). (the default is None)
- **cnstnt** (*string*) – modflow cnstnt variable (optional) (the default is 1.0)
- **iprn** (*int*) – modflow iprn variable (optional) (the default is -1)
- **locat** (*int*) – modflow locat variable (optional) (the default is None). If the model instance does not support free format and the external flag is not set and the value is a simple scalar, then locat must be explicitly passed as it is the unit number to read the array from
- **ext_filename** (*string*) – the external filename to write the array representation to (optional) (the default is None) . If type(value) is a string and is an accessible filename, the ext_filename is reset to value.
- **bin** (*bool*) – flag to control writing external arrays as binary (optional) (the defaut is False)

array

the array representation of the 3-D object

Type

np.ndarray

get_file_entry : string

get the model input file string including the control record for the entire 3-D property

Notes

Examples

property array

Return a numpy array of the 3D shape. If an unstructured model, then return an array of size nodes.

build_2d_instances()

property data_type

property dtype

export(*f*, ***kwargs*)

get_file_entry()

get_value()

classmethod load(*f_handle*, *model*, *shape*, *dtype*, *name*, *ext_unit_dict=None*, *array_format=None*)

property model

property name

plot(*filename_base=None*, *file_extension=None*, *mflay=None*, *fignum=None*, ***kwargs*)

Plot 3-D model input data

Parameters

- **filename_base** (*str*) – Base file name that will be used to automatically generate file names for output image files. Plots will be exported as image files if file_name_base is not None. (default is None)
- **file_extension** (*str*) – Valid matplotlib.pyplot file extension for savefig(). Only used if filename_base is not None. (default is 'png')
- **mflay** (*int*) – MODFLOW zero-based layer number to return. If None, then all all layers will be included. (default is None)
- ****kwargs** (*dict*) –

  axes
  [list of matplotlib.pyplot.axis] List of matplotlib.pyplot.axis that will be used to plot data for each layer. If axes=None axes will be generated. (default is None)

  pcolor
  [bool] Boolean used to determine if matplotlib.pyplot.pcolormesh plot will be plotted. (default is True)

  colorbar
  [bool] Boolean used to determine if a color bar will be added to the matplotlib.pyplot.pcolormesh. Only used if pcolor=True. (default is False)

inactive
[bool] Boolean used to determine if a black overlay in inactive cells in a layer will be displayed. (default is True)

contour
[bool] Boolean used to determine if matplotlib.pyplot.contour plot will be plotted. (default is False)

clabel
[bool] Boolean used to determine if matplotlib.pyplot.clabel will be plotted. Only used if contour=True. (default is False)

grid
[bool] Boolean used to determine if the model grid will be plotted on the figure. (default is False)

masked_values
[list] List of unique values to be excluded from the plot.

Returns
out – Empty list is returned if filename_base is not None. Otherwise a list of matplotlib.pyplot.axis is returned.

Return type
list

Notes

Examples

```
>>> import flopy
>>> ml = flopy.modflow.Modflow.load('test.nam')
>>> ml.lpf.hk.plot()
```

property plottable

new_u2d(*old_util2d*, *value*)

read1d(*f*, *a*)

Fill the 1d array, a, with the correct number of values. Required in case lpf 1d arrays (chani, layvka, etc) extend over more than one line

flopy.utils.util_list module

util_list module. Contains the mflist class.
This classes encapsulates modflow-style list inputs away from the individual packages. The end-user should not need to instantiate this class directly.

some more info

class MfList(*package*, *data=None*, *dtype=None*, *model=None*, *list_free_format=None*, *binary=False*)

Bases: DataInterface, DataListInterface

a generic object for handling transient boundary condition lists

Parameters

- **package** (*package object*) – The package object (of type *flopy.pakbase.Package*) to which this MfList will be added.
- **data** (*varies*) – the data of the transient list (optional). (the default is None)

mxact

the max number of active bc for any stress period

Type

int

add_record(kper,index,value) : None

add a record to stress period kper at index location

write_transient(f) : None

write the transient sequence to the model input file f

check_kij() : None

checks for boundaries outside of model domain - issues warnings only

Notes

Examples

add_record(*kper*, *index*, *values*)

append(*other*)

append the recarrays from one MfList to another :param other: that corresponds with self :type other: variable: an item that can be cast in to an MfList

Returns

dict of {kper

Return type

recarray}

property array

attribute_by_kper(*attr*, *function=<function mean>*, *idx_val=None*)

property binary

check_kij()

property data

property data_type

property df

drop(*fields*)

drop fields from an MfList

Parameters
: **fields** (*list or set of field names to drop*) –

Returns
: **dropped**

Return type
: MfList without the dropped fields

property dtype

export(*f*, ***kwargs*)

property fmt_string

Returns a C-style fmt string for numpy savetxt that corresponds to the dtype

classmethod from_4d(*model*, *pak_name*, *m4ds*)

construct an MfList instance from a dict of (attribute_name,masked 4D ndarray :param model: :type model: mbase derived type :param pak_name: :type pak_name: str package name (e.g GHB) :param m4ds: :type m4ds: {attribute name:4d masked numpy.ndarray}

Return type
: MfList instance

get_dataframe(*squeeze=False*)

Cast recarrays for stress periods into single dataframe containing all stress periods.

Parameters
: **squeeze** (*bool*) – Reduce number of rows in dataframe to only include stress periods where a variable changes.

Returns
: **df** – Dataframe of shape nrow = nper x ncells, ncol = nvar. If the squeeze option is chosen, nper is the number of stress periods where at least one cells is different, otherwise it is equal to the number of keys in MfList.data.

Return type
: dataframe

get_empty(*ncell=0*)

get_filename(*kper*)

get_filenames()

get_indices()

a helper function for plotting - get all unique indices

get_itmp(*kper*)

static masked4D_arrays_to_stress_period_data(*dtype*, *m4ds*)

convert a dictionary of 4-dim masked arrays to
: a stress_period_data style dict of recarray

Parameters

- **dtype** (*numpy dtype*) –
- **m4ds** (*dict {name:masked numpy 4-dim ndarray}*) –

Returns
dict {kper

Return type
recarray}

property masked_4D_arrays

masked_4D_arrays_itr()

property mg

property model

property mxact

property name

property package

plot(*key=None*, *names=None*, *kper=0*, *filename_base=None*, *file_extension=None*, *mflay=None*, ***kwargs*)

Plot stress period boundary condition (MfList) data for a specified stress period

Parameters

- **key** (*str*) – MfList dictionary key. (default is None)
- **names** (*list*) – List of names for figure titles. (default is None)
- **kper** (*int*) – MODFLOW zero-based stress period number to return. (default is zero)
- **filename_base** (*str*) – Base file name that will be used to automatically generate file names for output image files. Plots will be exported as image files if file_name_base is not None. (default is None)
- **file_extension** (*str*) – Valid matplotlib.pyplot file extension for savefig(). Only used if filename_base is not None. (default is 'png')
- **mflay** (*int*) – MODFLOW zero-based layer number to return. If None, then all all layers will be included. (default is None)
- ****kwargs** (*dict*) –

  axes
  [list of matplotlib.pyplot.axis] List of matplotlib.pyplot.axis that will be used to plot data for each layer. If axes=None axes will be generated. (default is None)

pcolor
[bool] Boolean used to determine if matplotlib.pyplot.pcolormesh plot will be plotted. (default is True)

colorbar
[bool] Boolean used to determine if a color bar will be added to the matplotlib.pyplot.pcolormesh. Only used if pcolor=True. (default is False)

inactive
[bool] Boolean used to determine if a black overlay in inactive cells in a layer will be displayed. (default is True)

contour
[bool] Boolean used to determine if matplotlib.pyplot.contour plot will be plotted. (default is False)

clabel
[bool] Boolean used to determine if matplotlib.pyplot.clabel will be plotted. Only used if contour=True. (default is False)

grid
[bool] Boolean used to determine if the model grid will be plotted on the figure. (default is False)

masked_values
[list] List of unique values to be excluded from the plot.

Returns
out - Empty list is returned if filename_base is not None. Otherwise a list of matplotlib.pyplot.axis is returned.

Return type
list

Notes

Examples

```
>>> import flopy
>>> ml = flopy.modflow.Modflow.load('test.nam')
>>> ml.wel.stress_period_data.plot(ml.wel, kper=1)
```

property plottable

to_array(*kper=0*, *mask=False*)
Convert stress period boundary condition (MfList) data for a specified stress period to a 3-D numpy array

Parameters

- **kper** (*int*) – MODFLOW zero-based stress period number to return. (default is zero)

- **mask** (*boolean*) – return array with np.NaN instead of zero

Returns
out – Dictionary of 3-D numpy arrays containing the stress period data for a selected stress period. The dictionary keys are the MfList dtype names for the stress period data ('cond', 'flux', 'bhead', etc.).

Return type
dict of numpy.ndarrays

Notes

Examples

```
>>> import flopy
>>> ml = flopy.modflow.Modflow.load('test.nam')
>>> v = ml.wel.stress_period_data.to_array(kper=1)
```

to_shapefile(*filename*, *kper=None*)
Export stress period boundary condition (MfList) data for a specified stress period

Parameters
- **filename** (*str*) – Shapefile name to write
- **kper** (*int*) – MODFLOW zero-based stress period number to return. (default is None)

Return type
None

Notes

Examples

```
>>> import flopy
>>> ml = flopy.modflow.Modflow.load('test.nam')
>>> ml.wel.to_shapefile('test_hk.shp', kper=1)
```

property vtype

write_transient(*f*, *single_per=None*, *forceInternal=False*, *write_header=True*, *cln_data=None*)

flopy.utils.utils_def module

Generic classes and utility functions

class FlopyBinaryData

Bases: object

The FlopyBinaryData class is a class to that defines the data types for integer, floating point, and character data in MODFLOW binary files. The FlopyBinaryData class is the super class from which the specific derived classes are formed. This class should not be instantiated directly.

read_integer()

read_real()

read_record(*count*, *dtype=None*)

read_text(*nchar=20*)

set_float(*precision*)

get_dis(*model*)

Returns dis or disu object from a given model object.

get_open_file_object(*fname_or_fobj*, *read_write='rw'*)

Returns an open file object for either a file name or open file object.

get_pak_vals_shape(*model*, *vals*)

Function to define shape of package input data for Util2d.

Parameters

- **model** (*flopy model object*) –
- **vals** (*Package input values (dict of arrays or scalars, or ndarray, or*) – single scalar).

Returns
shape – shape of input data for Util2d

Return type
tuple

get_unitnumber_from_ext_unit_dict(*model*, *pak_class*, *ext_unit_dict=None*, *ipakcb=0*)

For a given modflow package, defines input file unit number, plus package input and (optionally) output (budget) save file names.

Parameters

- **model** (*model object*) – model for which the unit number is sought.
- **pak_class** (*modflow package class for which the unit number is sought.*) –
- **ext_unit_dict** (*external unit dictionary, optional.*) – If not provided, unitnumber and filenames will be returned as None.
- **ipakcb** (*int, optional*) – Modflow package unit number on which budget is saved. Default is 0, in which case the returned output file is None.

Returns

- **unitnumber** (*int*) – file unit number for the given modflow package (or None)
- **filenames** (*list*) – list of [package input file name, budget file name],

get_util2d_shape_for_layer(*model*, *layer=0*)

Define nrow and ncol for array (Util2d) shape of a given layer in structured and/or unstructured models.

Parameters

- **model** (*model object*) – model for which Util2d shape is sought.
- **layer** (*int*) – layer (base 0) for which Util2d shape is sought.

Returns
(nrow,ncol) – util2d shape for the given layer

Return type
tuple of ints

totim_to_datetime(*totim*, *start='1-1-1970'*, *timeunit='D'*)

Parameters

- **totim** (*list or numpy array*) –
- **start** (*str*) – Starting date for simulation. (default is 1-1-1970).
- **timeunit** (*string*) – time unit of the simulation time. Valid values are 'S'econds, 'M'inutes, 'H'ours, 'D'ays, 'Y'ears. (default is 'D').

Returns
out – datetime object calculated from start and totim values

Return type
list

type_from_iterable(*_iter*, *index=0*, *_type=<class 'int'>*, *default_val=0*)

Returns value of specified type from iterable.

Parameters

- **_iter** (*iterable*) –
- **index** (*int*) – Iterable index to try to convert
- **_type** (*Python type*) –
- **default_val** (*default value (0)*) –

Returns
val

Return type
value of type _type, or default_val

flopy.utils.utl_import module

get_version(*module: module*) → str

import_optional_dependency(*name: str*, *error_message: str = ''*, *errors: str = 'raise'*, *min_version: str | None = None*)

Import an optional dependency.

By default, if a dependency is missing an ImportError with a nice message will be raised. If a dependency is present, but too old, we raise.

Parameters

- **name** (*str*) – The module name.
- **error_message** (*str*) – Additional text to include in the ImportError message.
- **errors** (*str {'raise', 'warn', 'ignore'}*) – What to do when a dependency is not found or its version is too old.
  - raise : Raise an ImportError
  - warn : Only applicable when a module's version is to old. Warns that the version is too old and returns None
  - ignore: If the module is not installed, return None, otherwise, return the module, even if the version is too old. It's expected that users validate the version locally when using errors="ignore" (see. io/html.py)
  - silent: Same as "ignore" except warning message is not written to the screen.
- **min_version** (*str, default None*) – Specify a minimum version that is different from the global FloPy minimum version required.

Returns

maybe_module – The imported module, when found and the version is correct. None is returned when the package is not found and *errors* is False, or when the package's version is too old and *errors* is 'warn'.

Return type

Optional[ModuleType]

flopy.utils.voronoi module

class VoronoiGrid(*tri*, ***kwargs*)

Bases: object

FloPy VoronoiGrid helper class for creating a voronoi model grid from an array of input points that define cell centers. The class handles boundary cells by closing polygons along the edge, something that cannot be done directly with the scipy.spatial.Voronoi class.

Parameters

- **input** (*flopy.utils.Triangle*) – Constructred and built flopy Triangle object.

- **kwargs** (*dict*) – List of additional keyword arguments that will be passed through to scipy.spatial.Voronoi. For circular shaped model grids, the qhull_options='Qz' option has been found to work well.

Notes

When using VoronoiGrid, the construction order used for the Triangle grid matters. The first add_polygon() call must be to add the model domain. Then add_polygon() must be used to add any holes. Lastly, add_polygon() can be used to add regions. This VoronoiGrid class uses this order to find model edges that require further work for defining and closing edge model cells.

get_disu5_gridprops()

get_disu6_gridprops()

get_disv_gridprops()

Get a dictionary of arguments that can be passed in to the flopy.mf6.ModflowGwfdisv class.

Returns
disv_gridprops – Dictionary of arguments than can be unpacked into the flopy.mf6.ModflowGwfdisv constructor

Return type
dict

get_gridprops_unstructuredgrid()

Get a dictionary of information needed to create a flopy UnstructuredGrid. The returned dictionary can be unpacked directly into the flopy.discretization.UnstructuredGrid() constructor.

Returns
gridprops

Return type
dict

get_gridprops_vertexgrid()

Get a dictionary of information needed to create a flopy VertexGrid. The returned dictionary can be unpacked directly into the flopy.discretization.VertexGrid() constructor.

Returns
gridprops

Return type
dict

get_patch_collection(*ax=None*, ***kwargs*)

Get a matplotlib patch collection representation of the voronoi grid

Parameters

- **ax** (*matplotlib.pyplot.Axes*) – axes to plot the patch collection

- **kwargs** (*dict*) – Additional keyward arguments to pass to the flopy.plot.plot_cvfd function that returns a patch collection from verts and iverts

Returns
pc – patch collection of model

Return type
matplotlib.collections.PatchCollection

plot(*ax=None*, *plot_title=True*, ***kwargs*)
Plot the voronoi model grid

Parameters

- **ax** (*matplotlib.pyplot.Axes*) – axes to plot the voronoi grid
- **plot_title** (*bool*) – Add the number of cells and number of vertices as a plot title
- **kwargs** (*dict*) – Additional keyword arguments to pass to self.get_patch_collection

Returns
ax – axes that contains the voronoi model grid

Return type
matplotlib.pyplot.Axes

get_sorted_vertices(*icell_vertices*, *vertices*)

get_valid_faces(*vor*)

point_in_cell(*point*, *vertices*)

sort_vertices(*vlist*)

tri2vor(*tri*, ***kwargs*)
This is the workhorse for the VoronoiGrid class for creating a voronoi grid from a constructed and built flopy Triangle grid.

Parameters

- **tri** (*flopy.utils.Triangle*) –
- **voronoi** (*Flopy triangle object is used to construct the complementary*) –
- **diagram.** –

Returns
verts, iverts

Return type
ndarray, list of lists

flopy.utils.zonbud module

class ZBNetOutput(*zones*, *time*, *arrays*, *zone_array*, *flux=True*)

Bases: object

Class that holds zonebudget netcdf output and allows export utilities to recognize the output data type.

Parameters

- **zones** (*np.ndarray*) – array of zone numbers
- **time** (*np.ndarray*) – array of totim
- **arrays** (*dict*) – dictionary of budget term arrays. axis 0 is totim, axis 1 is zones
- **flux** (*bool*) – boolean flag to indicate if budget data is a flux "L^3/T"(True, default) or if the data have been processed to volumetric values "L^3" (False)

class ZoneBudget(*cbc_file*, *z*, *kstpkper=None*, *totim=None*, *aliases=None*, *verbose=False*, ***kwargs*)

Bases: object

ZoneBudget class

Parameters

- **cbc_file** (*str or CellBudgetFile object*) – The file name or CellBudgetFile object for which budgets will be computed.
- **z** (*ndarray*) – The array containing to zones to be used.
- **kstpkper** (*tuple of ints*) – A tuple containing the time step and stress period (kstp, kper). The kstp and kper values are zero based.
- **totim** (*float*) – The simulation time.
- **aliases** (*dict*) – A dictionary with key, value pairs of zones and aliases. Replaces the corresponding record and field names with the aliases provided. When using this option in conjunction with a list of zones, the zone(s) passed may either be all strings (aliases), all integers, or mixed.

Return type

None

Examples

```
>>> from flopy.utils.zonbud import ZoneBudget
>>> zon = ZoneBudget.read_zone_file('zone_input_file')
>>> zb = ZoneBudget('zonebudtest.cbc', zon, kstpkper=(0, 0))
>>> zb.to_csv('zonebudtest.csv')
>>> zb_mgd = zb * 7.48052 / 1000000
```

copy()

Return a deepcopy of the object.

export(*f*, *ml*, ***kwargs*)

Method to export a netcdf file, or add zonebudget output to an open netcdf file instance

Parameters

- **f** (*str or flopy.export.netcdf.NetCdf object*) –
- **ml** (*flopy.modflow.Modflow or flopy.mf6.ModflowGwf object*) –
- ****kwargs** – logger : flopy.export.netcdf.Logger instance masked_vals : list

  list of values to mask

Return type

flopy.export.netcdf.NetCdf object

get_budget(*names=None*, *zones=None*, *net=False*, *pivot=False*)

Get a list of zonebudget record arrays.

Parameters

- **names** (*list of strings*) – A list of strings containing the names of the records desired.
- **zones** (*list of ints or strings*) – A list of integer zone numbers or zone names desired.
- **net** (*boolean*) – If True, returns net IN-OUT for each record.
- **pivot** (*boolean*) – If True, returns data in a more user friendly format

Returns

budget_list – A list of the zonebudget record arrays.

Return type

list of record arrays

Examples

```
>>> names = ['FROM_CONSTANT_HEAD', 'RIVER_LEAKAGE_OUT']
>>> zones = ['ZONE_1', 'ZONE_2']
>>> zb = ZoneBudget('zonebudtest.cbc', zon, kstpkper=(0, 0))
>>> bud = zb.get_budget(names=names, zones=zones)
```

get_dataframes(*start_datetime=None*, *timeunit='D'*, *index_key='totim'*, *names=None*, *zones=None*, *net=False*, *pivot=False*)

Get pandas dataframes.

Parameters

- **start_datetime** (*str*) – Datetime string indicating the time at which the simulation starts.
- **timeunit** (*str*) – String that indicates the time units used in the model.
- **index_key** (*str*) – Indicates the fields to be used (in addition to "record") in the resulting DataFrame multi-index.

- **names** (*list of strings*) – A list of strings containing the names of the records desired.
- **zones** (*list of ints or strings*) – A list of integer zone numbers or zone names desired.
- **net** (*boolean*) – If True, returns net IN-OUT for each record.
- **pivot** (*bool*) – If True, returns dataframe in a more user friendly format

Returns
df – Pandas DataFrame with the budget information.

Return type
Pandas DataFrame

Examples

```
>>> from flopy.utils.zonbud import ZoneBudget
>>> zon = ZoneBudget.read_zone_file('zone_input_file')
>>> zb = ZoneBudget('zonebudtest.cbc', zon, kstpkper=(0, 0))
>>> df = zb.get_dataframes()
```

get_model_shape()

Get model shape

Returns

- **nlay** (*int*) – Number of layers
- **nrow** (*int*) – Number of rows
- **ncol** (*int*) – Number of columns

get_record_names(*stripped=False*)

Get a list of water budget record names in the file.

Returns
out – List of unique text names in the binary file.

Return type
list of strings

Examples

```
>>> zb = ZoneBudget('zonebudtest.cbc', zon, kstpkper=(0, 0))
>>> recnames = zb.get_record_names()
```

get_volumetric_budget(*modeltime*, *recarray=None*, *extrapolate_kper=False*)

Method to generate a volumetric budget table based on flux information

Parameters

- **modeltime** (*flopy.discretization.ModelTime object*) – ModelTime object for calculating volumes

- **recarray** (*np.recarray*) – optional, user can pass in a numpy recarray to calculate volumetric budget. recarray must be pivoted before passing to get_volumetric_budget
- **extrapolate_kper** (*bool*) – flag to determine if we fill in data gaps with other timestep information from the same stress period. if True, we assume that flux is constant throughout a stress period and the pandas dataframe returned contains a volumetric budget per stress period

  if False, calculates volumes from available flux data

Return type
pd.DataFrame

classmethod read_output(*fname*, *net=False*, *dataframe=False*, ***kwargs*)

Method to read a zonebudget output file into a recarray or pandas dataframe

Parameters

- **fname** (*str*) – zonebudget output file name
- **net** (*bool*) – boolean flag for net budget
- **dataframe** (*bool*) – boolean flag to return a pandas dataframe
- ****kwargs** – pivot : bool

  start_datetime
  [str] Datetime string indicating the time at which the simulation starts. Can be used when pandas dataframe is requested

  timeunit
  [str] String that indicates the time units used in the model.

Return type
np.recarray

classmethod read_zone_file(*fname*)

Method to read a zonebudget zone file into memory

Parameters
fname (*str*) – zone file name

Returns
zones

Return type
np.array

to_csv(*fname*)

Saves the budget record arrays to a formatted comma-separated values file.

Parameters
fname (*str*) – The name of the output comma-separated values file.

Return type
None

classmethod **write_zone_file**(*fname*, *array*, *fmtin=None*, *iprn=None*)

Saves a numpy array in a format readable by the zonebudget program executable.

File format: line 1: nlay, nrow, ncol line 2: INTERNAL (format) line 3: begin data . . .

example from NACP: 19 250 500 INTERNAL (10I7) 199 199 199 199 199 199 199 199 199 199 199 199 199 199 199 199 199 199 ... INTERNAL (10I7) 199 199 199 199 199 199 199 199 199 199 199 199 199 199 199 199 199 199 ...

Parameters

- **array** (*array*) – The array of zones to be written.
- **fname** (*str*) – The path and name of the file to be written.
- **fmtin** (*int*) – The number of values to write to each line.
- **iprn** (*int*) – Padding space to add between each value.

class **ZoneBudget6**(*name='zonebud'*, *model_ws='.'*, *exe_name='zbud6'*, *extension='.zbnam'*)

Bases: object

Model class for building, editing and running MODFLOW 6 zonebuget

Parameters

- **name** (*str*) – model name for zonebudget
- **model_ws** (*str*) – path to model
- **exe_name** (*str*) – excutable name
- **extension** (*str*) – name file extension

add_package(*pkg_name*, *pkg*)

Method to add a package to the ZoneBudget6 object

Parameters

- **pkg_name** (*str*) – three letter package abbreviation
- **pkg** (*str or object*) – either a package file name or package object

change_model_name(*name*)

Method to change the model name for writing a zonebudget model.

Parameters

name (*str*) – new model name

change_model_ws(*model_ws*)

Method to change the model ws for writing a zonebudget model.

Parameters

model_ws (*str*) – new model directory

export(*f*, *ml*, ***kwargs*)

Method to export a netcdf file, or add zonebudget output to an open netcdf file instance

Parameters

- **f** (*str, PathLike, or flopy.export.netcdf.NetCdf object*) – The file to export to
- **ml** (*flopy.modflow.Modflow or flopy.mf6.ModflowGwf object*) –

- ****kwargs** – logger : flopy.export.netcdf.Logger instance masked_vals : list

  list of values to mask

Return type
flopy.export.netcdf.NetCdf object

get_budget(*f=None*, *names=None*, *zones=None*, *net=False*, *pivot=False*)

Method to read and get zonebudget output

Parameters

- **f** (*str*) – zonebudget output file name
- **names** (*list of strings*) – A list of strings containing the names of the records desired.
- **zones** (*list of ints or strings*) – A list of integer zone numbers or zone names desired.
- **net** (*boolean*) – If True, returns net IN-OUT for each record.
- **pivot** (*bool*) – Method to pivot recordarray into a more user friendly method for working with data

Return type
np.recarray

get_dataframes(*start_datetime=None*, *timeunit='D'*, *index_key='totim'*, *names=None*, *zones=None*, *net=False*, *pivot=False*)

Get pandas dataframes.

Parameters

- **start_datetime** (*str*) – Datetime string indicating the time at which the simulation starts.
- **timeunit** (*str*) – String that indicates the time units used in the model.
- **index_key** (*str*) – Indicates the fields to be used (in addition to "record") in the resulting DataFrame multi-index.
- **names** (*list of strings*) – A list of strings containing the names of the records desired.
- **zones** (*list of ints or strings*) – A list of integer zone numbers or zone names desired.
- **net** (*boolean*) – If True, returns net IN-OUT for each record.
- **pivot** (*bool*) – If True, returns data in a more user friendly fashion

Returns
df – Pandas DataFrame with the budget information.

Return type
Pandas DataFrame

Examples

```
>>> from flopy.utils.zonbud import ZoneBudget6
>>> zb6 = ZoneBudget6.load("my_nam_file", model_ws="my_model_ws")
>>> zb6.run_model()
>>> df = zb6.get_dataframes()
```

get_volumetric_budget(*modeltime*, *recarray=None*, *extrapolate_kper=False*)

Method to generate a volumetric budget table based on flux information

Parameters

- **modeltime** (*flopy.discretization.ModelTime object*) – ModelTime object for calculating volumes
- **recarray** (*np.recarray*) – optional, user can pass in a numpy recarray to calculate volumetric budget. recarray must be pivoted before passing to get_volumetric_budget
- **extrapolate_kper** (*bool*) – flag to determine if we fill in data gaps with other timestep information from the same stress period. if True, we assume that flux is constant throughout a stress period and the pandas dataframe returned contains a volumetric budget per stress period

  if False, calculates volumes from available flux data

Return type

pd.DataFrame

static load(*nam_file*, *model_ws: str | PathLike = '.'*)

Method to load a zonebudget model from namefile

Parameters

- **nam_file** (*str*) – zonebudget name file
- **model_ws** (*str or PathLike, default "."*) – model workspace path

Return type

ZoneBudget6 object

run_model(*exe_name=None*, *nam_file=None*, *silent=False*)

Method to run a zonebudget model

Parameters

- **exe_name** (*str*) – optional zonebudget executable name
- **nam_file** (*str*) – optional zonebudget name file name
- **silent** (*bool*) – optional flag to silence output

Return type

tuple

write_input(*line_length=20*)

Method to write a ZoneBudget 6 model to file

Parameters

line_length (*int*) – length of line for izone array

class ZoneFile6(*model*, *izone*, *extension='.zon'*, *aliases=None*)

Bases: object

Class to build, read, write and edit MODFLOW 6 zonebudget zone files

Parameters

- **model** (*ZoneBudget6 object*) – model object
- **izone** (*np.array*) – numpy array of zone numbers
- **extension** (*str*) – zone file extension name, defaults to ".zon"
- **aliases** (*dict*) – optional dictionary of zone aliases. ex. {1 : "nw_model"}

static load(*f: str | PathLike*, *model*)

Method to load a Zone file for zonebudget 6.

Parameter

f

[str or PathLike] zone file path

model

[ZoneBudget6 object] zonebudget 6 model object

rtype

ZoneFile6 object

property ncells

Method to get number of model cells

write_input(*f=None*, *line_length=20*)

Method to write the zonebudget 6 file

Parameters

- **f** (*str*) – zone file name
- **line_length** (*int*) – maximum length of line to write in izone array

dataframe_to_netcdf_fmt(*df*, *zone_array*, *flux=True*)

Method to transform a volumetric zonebudget dataframe into array format for netcdf.

time is on axis 0 zone is on axis 1

Parameters

- **df** (*pd.DataFrame*) –
- **zone_array** (*np.ndarray*) – zonebudget zones array
- **flux** (*bool*) – boolean flag to indicate if budget data is a flux "L^3/T" (True, default) or if the data have been processed to volumetric values "L^3" (False)

Return type

ZBNetOutput object

sort_tuple(*tup*, *n=2*)

Sort a tuple by the first n values

tup: tuple
input tuple

n
[int] values to sort tuple by (default is 2)

Returns
tup – tuple sorted by the first n values

Return type
tuple

sum_flux_tuples(*fromzones*, *tozones*, *fluxes*)

12.3.2 Plotting Utilities

Contents:

flopy.plot.crosssection module

class PlotCrossSection(*model=None*, *modelgrid=None*, *ax=None*, *line=None*, *extent=None*, *geographic_coords=False*)

Bases: object

Class to create a cross sectional plot of a model.

Parameters

- **ax** (*matplotlib.pyplot axis*) – The plot axis. If not provided it, plt.gca() will be used.
- **model** (*flopy.modflow object*) – flopy model object. (Default is None)
- **modelgrid** (*flopy.discretization.Grid object*) – can be a StructuredGrid, VertexGrid, or UnstructuredGrid object
- **line** (*dict*) – Dictionary with either "row", "column", or "line" key. If key is "row" or "column" key value should be the zero-based row or column index for cross-section. If key is "line" value should be an array of (x, y) tuples with vertices of cross-section. Vertices should be in map coordinates consistent with xul, yul, and rotation.
- **extent** (*tuple of floats*) – (xmin, xmax, ymin, ymax) will be used to specify axes limits. If None then these will be calculated based on grid, coordinates, and rotation.
- **geographic_coords** (*bool*) – boolean flag to allow the user to plot cross section lines in geographic coordinates. If False (default), cross section is plotted as the distance along the cross section line.

contour_array(*a*, *masked_values=None*, *head=None*, ***kwargs*)

Contour a two-dimensional array.

Parameters

- **a** (*numpy.ndarray*) – Three-dimensional array to plot.
- **masked_values** (*iterable of floats, ints*) – Values to mask.
- **head** (*numpy.ndarray*) – Three-dimensional array to set top of patches to the minimum of the top of a layer or the head value. Used to create patches that conform to water-level elevations.
- ****kwargs** (*dictionary*) – keyword arguments passed to matplotlib.pyplot.contour

Returns
contour_set

Return type
matplotlib.pyplot.contour

get_extent()

Get the extent of the rotated and offset grid

Returns
tuple

Return type
(xmin, xmax, ymin, ymax)

get_grid_line_collection(***kwargs*)

Get a PatchCollection of the grid

Parameters
****kwargs** (*dictionary*) – keyword arguments passed to matplotlib.collections.LineCollection

Returns
PatchCollection

Return type
matplotlib.collections.LineCollection

get_grid_patch_collection(*plotarray, projpts=None, fill_between=False, **kwargs*)

Get a PatchCollection of plotarray in unmasked cells

Parameters

- **plotarray** (*numpy.ndarray*) – One-dimensional array to attach to the Patch Collection.
- **projpts** (*dict*) – dictionary defined by node number which contains model patch vertices.
- **fill_between** (*bool*) – flag to create polygons that mimick the matplotlib fill between method. Only used by the plot_fill_between method.
- ****kwargs** (*dictionary*) – keyword arguments passed to matplotlib.collections.PatchCollection

Returns
patches

Return type
matplotlib.collections.PatchCollection

plot_array(*a*, *masked_values=None*, *head=None*, ***kwargs*)

Plot a three-dimensional array as a patch collection.

Parameters

- **a** (*numpy.ndarray*) – Three-dimensional array to plot.
- **masked_values** (*iterable of floats, ints*) – Values to mask.
- **head** (*numpy.ndarray*) – Three-dimensional array to set top of patches to the minimum of the top of a layer or the head value. Used to create patches that conform to water-level elevations.
- ****kwargs** (*dictionary*) – keyword arguments passed to matplotlib.collections.PatchCollection

Returns
patches

Return type
matplotlib.collections.PatchCollection

plot_bc(*name=None*, *package=None*, *kper=0*, *color=None*, *head=None*, ***kwargs*)

Plot boundary conditions locations for a specific boundary type from a flopy model

Parameters

- **name** (*string*) – Package name string ('WEL', 'GHB', etc.). (Default is None)
- **package** (*flopy.modflow.Modflow package class instance*) – flopy package class instance. (Default is None)
- **kper** (*int*) – Stress period to plot
- **color** (*string*) – matplotlib color string. (Default is None)
- **head** (*numpy.ndarray*) – Three-dimensional array (structured grid) or Two-dimensional array (vertex grid) to set top of patches to the minimum of the top of a layer or the head value. Used to create patches that conform to water-level elevations.
- ****kwargs** (*dictionary*) – keyword arguments passed to matplotlib.collections.PatchCollection

Returns
patches

Return type
matplotlib.collections.PatchCollection

plot_endpoint(*ep*, *direction='ending'*, *selection=None*, *selection_direction=None*, *method='cell'*, *head=None*, ***kwargs*)

plot_fill_between(*a*, *colors=('blue', 'red')*, *masked_values=None*, *head=None*, ***kwargs*)

Plot a three-dimensional array as lines.

Parameters

- **a** (*numpy.ndarray*) – Three-dimensional array to plot.

- **colors** (*list*) – matplotlib fill colors, two required
- **masked_values** (*iterable of floats, ints*) – Values to mask.
- **head** (*numpy.ndarray*) – Three-dimensional array to set top of patches to the minimum of the top of a layer or the head value. Used to create patches that conform to water-level elevations.
- ****kwargs** (*dictionary*) – keyword arguments passed to matplotlib.pyplot.plot

Returns
plot

Return type
list containing matplotlib.fillbetween objects

plot_grid(***kwargs*)

Plot the grid lines.

Parameters
kwargs (*ax, colors. The remaining kwargs are passed into the*) – the LineCollection constructor.

Returns
lc

Return type
matplotlib.collections.LineCollection

plot_ibound(*ibound=None*, *color_noflow='black'*, *color_ch='blue'*, *color_vpt='red'*, *head=None*, ***kwargs*)

Make a plot of ibound. If not specified, then pull ibound from the self.model

Parameters

- **ibound** (*numpy.ndarray*) – ibound array to plot. (Default is ibound in 'BAS6' package.)
- **color_noflow** (*string*) – (Default is 'black')
- **color_ch** (*string*) – Color for constant heads (Default is 'blue'.)
- **head** (*numpy.ndarray*) – Three-dimensional array to set top of patches to the minimum of the top of a layer or the head value. Used to create patches that conform to water-level elevations.
- ****kwargs** (*dictionary*) – keyword arguments passed to matplotlib.collections.PatchCollection

Returns
patches

Return type
matplotlib.collections.PatchCollection

plot_inactive(*ibound=None*, *color_noflow='black'*, ***kwargs*)

Make a plot of inactive cells. If not specified, then pull ibound from the self.ml

Parameters

- **ibound** (*numpy.ndarray*) – ibound array to plot. (Default is ibound in 'BAS6' package.)
- **color_noflow** (*string*) – (Default is 'black')

Returns
quadmesh

Return type
matplotlib.collections.QuadMesh

plot_pathline(*pl*, *travel_time=None*, *method='cell'*, *head=None*, ***kwargs*)

Plot the MODPATH pathlines

Parameters

- **pl** (*list of rec arrays or a single rec array*) – rec array or list of rec arrays is data returned from modpathfile PathlineFile get_data() or get_alldata() methods. Data in rec array is 'x', 'y', 'z', 'time', 'k', and 'particleid'.
- **travel_time** (*float or str*) – travel_time is a travel time selection for the displayed pathlines. If a float is passed then pathlines with times less than or equal to the passed time are plotted. If a string is passed a variety logical constraints can be added in front of a time value to select pathlines for a select period of time. Valid logical constraints are <=, <, ==, >=, and >. For example, to select all pathlines less than 10000 days travel_time='< 10000' would be passed to plot_pathline. (default is None)
- **method** (*str*) –

  "cell" shows only pathlines that intersect with a cell

  "all" projects all pathlines onto the cross section regardless
  of whether they intersect with a given cell
- **head** (*np.ndarray*) – optional adjustment to only show pathlines that are <= to the top of the water table given a user supplied head array
- **kwargs** (*layer, ax, colors. The remaining kwargs are passed*) – into the LineCollection constructor.

Returns
lc

Return type
matplotlib.collections.LineCollection

plot_surface(*a*, *masked_values=None*, ***kwargs*)

Plot a two- or three-dimensional array as line(s).

Parameters

- **a** (*numpy.ndarray*) – Two- or three-dimensional array to plot.
- **masked_values** (*iterable of floats, ints*) – Values to mask.

- ****kwargs** (*dictionary*) – keyword arguments passed to matplotlib.pyplot.plot

Returns
plot

Return type
list containing matplotlib.plot objects

plot_timeseries(*ts*, *travel_time=None*, *method='cell'*, *head=None*, ***kwargs*)
Plot the MODPATH timeseries.

Parameters

- **ts** (*list of rec arrays or a single rec array*) – rec array or list of rec arrays is data returned from modpathfile TimeseriesFile get_data() or get_alldata() methods. Data in rec array is 'x', 'y', 'z', 'time', 'k', and 'particleid'.
- **travel_time** (*float or str*) – travel_time is a travel time selection for the displayed pathlines. If a float is passed then pathlines with times less than or equal to the passed time are plotted. If a string is passed a variety logical constraints can be added in front of a time value to select pathlines for a select period of time. Valid logical constraints are <=, <, ==, >=, and >. For example, to select all pathlines less than 10000 days travel_time='< 10000' would be passed to plot_pathline. (default is None)
- **kwargs** (*layer, ax, colors. The remaining kwargs are passed*) – into the LineCollection constructor. If layer='all', pathlines are output for all layers

Returns
lo

Return type
list of Line2D objects

plot_vector(*vx*, *vy*, *vz*, *head=None*, *kstep=1*, *hstep=1*, *normalize=False*, *masked_values=None*, ***kwargs*)
Plot a vector.

Parameters

- **vx** (*np.ndarray*) – x component of the vector to be plotted (non-rotated) array shape must be (nlay, nrow, ncol) for a structured grid array shape must be (nlay, ncpl) for a unstructured grid
- **vy** (*np.ndarray*) – y component of the vector to be plotted (non-rotated) array shape must be (nlay, nrow, ncol) for a structured grid array shape must be (nlay, ncpl) for a unstructured grid
- **vz** (*np.ndarray*) – y component of the vector to be plotted (non-rotated) array shape must be (nlay, nrow, ncol) for a structured grid array shape must be (nlay, ncpl) for a unstructured grid

- **head** (*numpy.ndarray*) – MODFLOW's head array. If not provided, then the quivers will be plotted in the cell center.
- **kstep** (*int*) – layer frequency to plot (default is 1)
- **hstep** (*int*) – horizontal frequency to plot (default is 1)
- **normalize** (*bool*) – boolean flag used to determine if vectors should be normalized using the vector magnitude in each cell (default is False)
- **masked_values** (*iterable of floats*) – values to mask
- **kwargs** (*matplotlib.pyplot keyword arguments for the*) – plt.quiver method

Returns
quiver – result of the quiver function

Return type
matplotlib.pyplot.quiver

property polygons

Method to return cached matplotlib polygons for a cross section

Returns
dict

Return type
[matplotlib.patches.Polygon]

set_zcentergrid(*vs*, *kstep=1*)

Get an array of z elevations at the center of a cell that is based on minimum of cell top elevation (self.elev) or passed vs numpy.ndarray

Parameters

- **vs** (*numpy.ndarray*) – Three-dimensional array to plot.
- **kstep** (*int*) – plotting layer interval

Returns
zcentergrid

Return type
numpy.ndarray

set_zpts(*vs*)

Get an array of projected vertices corrected with corrected elevations based on minimum of cell elevation (self.elev) or passed vs numpy.ndarray

Parameters
vs (*numpy.ndarray*) – Two-dimensional array to plot.

Returns
zpts

Return type
dict

flopy.plot.map module

class PlotMapView(*model=None*, *modelgrid=None*, *ax=None*, *layer=0*, *extent=None*)

Bases: object

Class to create a map of the model. Delegates plotting functionality based on model grid type.

Parameters

- **modelgrid** (*flopy.discretization.Grid*) – The modelgrid class can be StructuredGrid, VertexGrid, or UnstructuredGrid (Default is None)
- **ax** (*matplotlib.pyplot axis*) – The plot axis. If not provided it, plt.gca() will be used. If there is not a current axis then a new one will be created.
- **model** (*flopy.modflow object*) – flopy model object. (Default is None)
- **layer** (*int*) – Layer to plot. Default is 0. Must be between 0 and nlay - 1.
- **extent** (*tuple of floats*) – (xmin, xmax, ymin, ymax) will be used to specify axes limits. If None then these will be calculated based on grid, coordinates, and rotation.

Notes

contour_array(*a*, *masked_values=None*, ***kwargs*)

Contour an array on the grid. By default the top layer is contoured. To select a different layer, specify the layer in the class constructor.

For structured and vertex grids, the array may be 1D, 2D or 3D. For unstructured grids, the array must be 1D or 2D.

Parameters

- **a** (*1D, 2D or 3D array-like*) – Array to plot.
- **masked_values** (*iterable of floats, ints*) – Values to mask.
- ****kwargs** (*dictionary*) – keyword arguments passed to matplotlib.pyplot.pcolormesh

Returns

contour_set

Return type

matplotlib.pyplot.contour

property extent

plot_array(*a*, *masked_values=None*, ***kwargs*)

Plot an array. If the array is three-dimensional, then the method will plot the layer tied to this class (self.layer).

Parameters

- **a** (*numpy.ndarray*) – Array to plot.
- **masked_values** (*iterable of floats, ints*) – Values to mask.

- ****kwargs** (*dictionary*) – keyword arguments passed to matplotlib.pyplot.pcolormesh

Returns
quadmesh – matplotlib.collections.PatchCollection

Return type
matplotlib.collections.QuadMesh or

plot_bc(*name=None*, *package=None*, *kper=0*, *color=None*, *plotAll=False*, ***kwargs*)

Plot boundary conditions locations for a specific boundary type from a flopy model

Parameters

- **name** (*string*) – Package name string ('WEL', 'GHB', etc.). (Default is None)
- **package** (*flopy.modflow.Modflow package class instance*) – flopy package class instance. (Default is None)
- **kper** (*int*) – Stress period to plot
- **color** (*string*) – matplotlib color string. (Default is None)
- **plotAll** (*bool*) – Boolean used to specify that boundary condition locations for all layers will be plotted on the current ModelMap layer. (Default is False)
- ****kwargs** (*dictionary*) – keyword arguments passed to matplotlib.collections.PatchCollection

Returns
quadmesh

Return type
matplotlib.collections.QuadMesh

plot_endpoint(*ep*, *direction='ending'*, *selection=None*, *selection_direction=None*, ***kwargs*)

Plot MODPATH endpoints.

Parameters

- **ep** (*recarray or dataframe*) – A numpy recarray with the endpoint particle data from the MODPATH endpoint file
- **direction** (*str*) – String defining if starting or ending particle locations should be considered. (default is 'ending')
- **selection** (*tuple*) – tuple that defines the zero-base layer, row, column location (l, r, c) to use to make a selection of particle endpoints. The selection could be a well location to determine capture zone for the well. If selection is None, all particle endpoints for the user-sepcified direction will be plotted. (default is None)
- **selection_direction** (*str*) – String defining is a selection should be made on starting or ending particle locations. If selection is not None and selection_direction is None, the

selection direction will be set to the opposite of direction. (default is None)

- **kwargs** (*ax, c, s or size, colorbar, colorbar_label, shrink. The*) – remaining kwargs are passed into the matplotlib scatter method. If colorbar is True a colorbar will be added to the plot. If colorbar_label is passed in and colorbar is True then colorbar_label will be passed to the colorbar set_label() method. If shrink is passed in and colorbar is True then the colorbar size will be set using shrink.

Returns
sp – The PathCollection added to the plot.

Return type
matplotlib.collections.PathCollection

plot_grid(***kwargs*)

Plot the grid lines.

Parameters
kwargs (*ax, colors. The remaining kwargs are passed into the*) – the LineCollection constructor.

Returns
lc

Return type
matplotlib.collections.LineCollection

plot_ibound(*ibound=None, color_noflow='black', color_ch='blue', color_vpt='red', **kwargs*)

Make a plot of ibound. If not specified, then pull ibound from the self.ml

Parameters

- **ibound** (*numpy.ndarray*) – ibound array to plot. (Default is ibound in the modelgrid)
- **color_noflow** (*string*) – (Default is 'black')
- **color_ch** (*string*) – Color for constant heads (Default is 'blue'.)
- **color_vpt** (*string*) – Color for vertical pass through cells (Default is 'red')

Returns
quadmesh

Return type
matplotlib.collections.QuadMesh

plot_inactive(*ibound=None, color_noflow='black', **kwargs*)

Make a plot of inactive cells. If not specified, then pull ibound from the self.ml

Parameters

- **ibound** (*numpy.ndarray*) – ibound array to plot. (Default is ibound in 'BAS6' package.)
- **color_noflow** (*string*) – (Default is 'black')

Returns
: **quadmesh**

Return type
: matplotlib.collections.QuadMesh

plot_pathline(*pl*, *travel_time=None*, ***kwargs*)
: Plot MODPATH pathlines.

Parameters

- **pl** (*list of recarrays or dataframes, or a single recarray or dataframe*) – Particle pathline data. If a list of recarrays or dataframes, each must contain the path of only a single particle. If just one recarray or dataframe, it should contain the paths of all particles. Pathline data returned from PathlineFile.get_data() or get_alldata() can be passed directly as this argument. Data columns should be 'x', 'y', 'z', 'time', 'k', and 'particleid' at minimum. Additional columns are ignored. The 'particleid' column must be unique to each particle path.
- **travel_time** (*float or str*) – Travel time selection. If a float, then pathlines with total time less than or equal to the given value are plotted. If a string, the value must be a comparison operator, then a time value. Valid operators are <=, <, ==, >=, and >. For example, to filter pathlines with less than 10000 units of total time traveled, use '< 10000'. (Default is None.)
- **kwargs** (*dict*) – Explicitly supported kwargs are layer, ax, colors. Any remaining kwargs are passed into the LineCollection constructor. If layer='all', pathlines are shown for all layers.

Returns
: **lc** – The pathlines added to the plot.

Return type
: matplotlib.collections.LineCollection

plot_shapefile(*shp*, ***kwargs*)
: Plot a shapefile. The shapefile must be in the same coordinates as the rotated and offset grid.

Parameters

- **shp** (*str, os.PathLike or pyshp shapefile object*) – Path of the shapefile to plot
- **kwargs** (*dictionary*) – Keyword arguments passed to plotutil.plot_shapefile()

plot_shapes(*obj*, ***kwargs*)
: Plot shapes is a method that facilitates plotting a collection of geospatial objects

Parameters

- **obj** (*collection object*) – obj can accept the following types str : shapefile path PathLike : shapefile path shapefile.Reader object list of [shapefile.Shape, shapefile.Shape,] shapefile.Shapes object flopy.utils.geometry.Collection object list of [flopy.utils.geometry, ...] objects geojson.GeometryCollection object geojson.FeatureCollection object shapely.GeometryCollection object list of [[vertices], ...]

- **kwargs** (*dictionary*) – keyword arguments passed to plotutil.plot_shapefile()

Return type
matplotlib.Collection object

plot_timeseries(*ts*, *travel_time=None*, ***kwargs*)

Plot MODPATH timeseries.

Parameters

- **ts** (*list of recarrays or dataframes, or a single recarray or dataframe*) – Particle timeseries data. If a list of recarrays or dataframes, each must contain the path of only a single particle. If just one recarray or dataframe, it should contain the paths of all particles. Timeseries data returned from TimeseriesFile.get_data() or get_alldata() can be passed directly as this argument. Data columns should be 'x', 'y', 'z', 'time', 'k', and 'particleid' at minimum. Additional columns are ignored. The 'particleid' column must be unique to each particle path.
- **travel_time** (*float or str*) – Travel time selection. If a float, then pathlines with total time less than or equal to the given value are plotted. If a string, the value must be a comparison operator, then a time value. Valid operators are <=, <, ==, >=, and >. For example, to filter pathlines with less than 10000 units of total time traveled, use '< 10000'. (Default is None.)
- **kwargs** (*dict*) – Explicitly supported kwargs are layer, ax, colors. Any remaining kwargs are passed into the LineCollection constructor. If layer='all', pathlines are shown for all layers.

Returns
lc – The pathlines added to the plot.

Return type
matplotlib.collections.LineCollection

plot_vector(*vx*, *vy*, *istep=1*, *jstep=1*, *normalize=False*, *masked_values=None*, ***kwargs*)

Plot a vector.

Parameters

- **vx** (*np.ndarray*) – x component of the vector to be plotted (non-rotated) array shape must be (nlay, nrow, ncol) for a structured grid array shape must be (nlay, ncpl) for a unstructured grid

- **vy** (*np.ndarray*) – y component of the vector to be plotted (non-rotated) array shape must be (nlay, nrow, ncol) for a structured grid array shape must be (nlay, ncpl) for a unstructured grid
- **istep** (*int*) – row frequency to plot (default is 1)
- **jstep** (*int*) – column frequency to plot (default is 1)
- **normalize** (*bool*) – boolean flag used to determine if vectors should be normalized using the vector magnitude in each cell (default is False)
- **masked_values** (*iterable of floats*) – values to mask
- **kwargs** (*matplotlib.pyplot keyword arguments for the*) – plt.quiver method

Returns
quiver – result of the quiver function

Return type
matplotlib.pyplot.quiver

flopy.plot.plotutil module

Module containing helper functions for plotting model data using ModelMap and ModelCrossSection. Functions for plotting shapefiles are also included.

class PlotUtilities

Bases: object

Class which groups a collection of plotting utilities which Flopy and Flopy6 can use to generate map based plots

static saturated_thickness(*head*, *top*, *botm*, *laytyp*, *mask_values=None*)

Calculate the saturated thickness.

Parameters

- **head** (*numpy.ndarray*) – head array
- **top** (*numpy.ndarray*) – top array of shape (nrow, ncol)
- **botm** (*numpy.ndarray*) – botm array of shape (nlay, nrow, ncol)
- **laytyp** (*numpy.ndarray*) – confined (0) or convertible (1) of shape (nlay)
- **mask_values** (*list of floats*) – If head is one of these values, then set sat to top - bot

Returns
sat_thk – Saturated thickness of shape (nlay, nrow, ncol).

Return type
numpy.ndarray

class SwiConcentration(*model=None*, *botm=None*, *istrat=1*, *nu=None*)

Bases: object

The binary_header class is a class to create headers for MODFLOW binary files

calc_conc(*zeta*, *layer=None*)

Calculate concentrations for a given time step using passed zeta.

Parameters

- **zeta** (*dictionary of numpy arrays*) – Dictionary of zeta results. zeta keys are zero-based zeta surfaces.
- **layer** (*int*) – Concentration will be calculated for the specified layer. If layer is None, then the concentration will be calculated for all layers. (default is None).

Returns

conc – Calculated concentration.

Return type

numpy array

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow.load('test')
>>> c = flopy.plot.SwiConcentration(model=m)
>>> conc = c.calc_conc(z, layer=0)
```

class UnstructuredPlotUtilities

Bases: object

Collection of unstructured grid and vertex grid compatible plotting helper functions

static arctan2(*verts*, *reverse=False*)

Reads 2 dimensional set of verts and orders them using the arctan 2 method

Parameters

verts (*np.array of floats*) – Nx2 array of verts

Returns

verts – Nx2 array of verts

Return type

np.array of float

static irregular_shape_patch(*xverts*, *yverts=None*)

Patch for vertex cross-section plotting when we have an irregular shape type throughout the model grid or multiple shape types. This method is also used by the model splitter as a helper function for remapping the cell2d array.

Parameters

- **xverts** (*list*) – xvertices
- **yverts** (*list or None*) – yvertices

Return type

xverts, yverts as np.ndarray

static line_intersect_grid(*ptsin*, *xgrid*, *ygrid*)

Uses cross product method to find which cells intersect with the line and then uses the parameterized line equation to caluculate intersection x, y vertex points. Should be quite fast for large model grids!

Parameters

- **pts** (*list*) – list of tuple line vertex pairs (ex. [(1, 0), (10, 0)]
- **xgrid** (*np.array*) – model grid x vertices
- **ygrid** (*np.array*) – model grid y vertices

Returns
vdict

Return type
dict of cell vertices

advanced_package_bc_helper(*pkg*, *modelgrid*, *kper*)

Helper function for plotting boundary conditions from "advanced" packages

Parameters

- **pkg** (*flopy Package objects*) –
- **modelgrid** (*flopy.discretization.Grid object*) –

filter_modpath_by_travel_time(*recarray*, *travel_time*)

Helper method for filtering particles by travel time. Used in modpath plotting routines

Parameters

- **recarray** (*np.recarray*) – recarray of modpath particle information
- **travel_time** (*str*, *float*) – travel time logical argument to filter modpath output

Return type
np.recarray

intersect_modpath_with_crosssection(*recarrays*, *projpts*, *xvertices*, *yvertices*, *projection*, *ncpl*, *method='cell'*, *starting=False*)

Method to intersect modpath output with a cross-section

Parameters

- **recarrays** (*list*) – list of numpy recarrays
- **projpts** (*dict*) – dict of crossectional cell vertices
- **xvertices** (*np.array*) – array of modelgrid xvertices
- **yvertices** (*np.array*) – array of modelgrid yvertices
- **projection** (*str*) – projection direction (x or y)
- **ncpl** (*int*) – number of cells per layer (cross sectional version)
- **method** (*str*) – intersection method ('cell' or 'all')
- **starting** (*bool*) – modpath starting location flag

Returns
dict

Return type
dictionary of intersecting recarrays

parse_modpath_selection_options(*ep*, *direction*, *selection*, *selection_direction*)

Returns

plot_shapefile(*shp*, *ax=None*, *radius=500.0*, *cmap='Dark2'*, *edgecolor='scaled'*, *facecolor='scaled'*, *a=None*, *masked_values=None*, *idx=None*, ***kwargs*)

Generic function for plotting a shapefile.

Parameters

- **shp** (*string or os.PathLike*) – Path of the shapefile to plot.
- **ax** (*matplolib.pyplot.axes object*) –
- **radius** (*float*) – Radius of circle for points. (Default is 500.)
- **cmap** (*string*) – Name of colormap to use for polygon shading (default is 'Dark2')
- **edgecolor** (*string*) – Color name. (Default is 'scaled' to scale the edge colors.)
- **facecolor** (*string*) – Color name. (Default is 'scaled' to scale the face colors.)
- **a** (*numpy.ndarray*) – Array to plot.
- **masked_values** (*iterable of floats, ints*) – Values to mask.
- **idx** (*iterable int*) – A list or array that contains shape numbers to include in the patch collection. Return all shapes if not specified.
- **kwargs** (*dictionary*) – Keyword arguments that are passed to PatchCollection.set(**kwargs). Some common kwargs would be 'linewidths', 'linestyles', 'alpha', etc.

Returns
pc

Return type
matplotlib.collections.PatchCollection

Examples

reproject_modpath_to_crosssection(*idict*, *projpts*, *xypts*, *projection*, *modelgrid*, *ncpl*, *geographic_coords*, *starting=False*)

Method to reproject modpath points onto cross sectional line

Parameters

- **idict** (*dict*) – dictionary of intersecting points
- **projpts** (*dict*) – dictionary of cross sectional cells
- **xypts** (*dict*) – dictionary of cross sectional line
- **projection** (*str*) – projection direction (x or y)
- **modelgrid** (*Grid object*) – flopy modelgrid object
- **ncpl** (*int*) – number of cells per layer (cross sectional version)

- **geographic_coords** (*bool*) – flag for plotting in geographic coordinates
- **starting** (*bool*) – flag for modpath position

Return type
dictionary of projected modpath lines or points

shapefile_extents(*shp*)

Determine the extents of a shapefile

Parameters
shp (*string*) – Name of the shapefile to convert to a PatchCollection.

Returns
extents – tuple with xmin, xmax, ymin, ymax from shapefile.

Return type
tuple

Examples

```
>>> import flopy
>>> fshp = 'myshapefile'
>>> extent = flopy.plot.plotutil.shapefile_extents(fshp)
```

shapefile_get_vertices(*shp*)

Get vertices for the features in a shapefile

Parameters
shp (*string*) – Name of the shapefile to extract shapefile feature vertices.

Returns
vertices – Vertices is a list with vertices for each feature in the shapefile. Individual feature vertices are x, y tuples and contained in a list. A list with a single x, y tuple is returned for point shapefiles. A list with multiple x, y tuples is returned for polyline and polygon shapefiles.

Return type
list

Examples

```
>>> import flopy
>>> fshp = 'myshapefile'
>>> lines = flopy.plot.plotutil.shapefile_get_vertices(fshp)
```

shapefile_to_patch_collection(*shp: str | PathLike*, *radius=500.0*, *idx=None*)

Create a patch collection from the shapes in a shapefile

Parameters

- **shp** (*str or PathLike*) – Name of the shapefile to convert to a PatchCollection.
- **radius** (*float*) – Radius of circle for points in the shapefile. (Default is 500.)

- **idx** (*iterable int*) – A list or array that contains shape numbers to include in the patch collection. Return all shapes if not specified.

Returns
pc – Patch collection of shapes in the shapefile

Return type
matplotlib.collections.PatchCollection

flopy.plot.styles module

class styles

Bases: object

Styles class for custom matplotlib styling

The class contains both custom styles and plotting methods for custom formatting using a specific matplotlib style

Additional styles can be easily added to the mplstyle folder and accessed using the plt.style.context() method.

classmethod USGSMap()

classmethod USGSPlot()

classmethod add_annotation(*ax=None*, *text=''*, *xy=None*, *xytext=None*, *bold=True*, *italic=True*, *fontsize=9*, *ha='left'*, *va='bottom'*, ***kwargs*)

Add an annotation to a axis object

Parameters

- **ax** (*axis object*) – matplotlib axis object (default is None)
- **text** (*str*) – text string
- **xy** (*tuple*) – tuple with the location of the annotation (default is None)
- **xytext** (*tuple*) – tuple with the location of the text
- **bold** (*bool*) – boolean indicating if bold font (default is True)
- **italic** (*bool*) – boolean indicating if italic font (default is True)
- **fontsize** (*int*) – font size (default is 9 points)
- **ha** (*str*) – matplotlib horizontal alignment keyword (default is left)
- **va** (*str*) – matplotlib vertical alignment keyword (default is bottom)
- **kwargs** (*dict*) – dictionary with valid matplotlib annotation object keywords

Returns
ann_obj – matplotlib annotation object

Return type
object

classmethod add_text(*ax=None*, *text=''*, *x=0.0*, *y=0.0*, *transform=True*, *bold=True*, *italic=True*, *fontsize=9*, *ha='left'*, *va='bottom'*, ***kwargs*)

Add USGS-style text to a axis object

Parameters

- **ax** (*axis object*) – matplotlib axis object (default is None)
- **text** (*str*) – text string
- **x** (*float*) – x-location of text string (default is 0.)
- **y** (*float*) – y-location of text string (default is 0.)
- **transform** (*bool*) – boolean that determines if a transformed (True) or data (False) coordinate system is used to define the (x, y) location of the text string (default is True)
- **bold** (*bool*) – boolean indicating if bold font (default is True)
- **italic** (*bool*) – boolean indicating if italic font (default is True)
- **fontsize** (*int*) – font size (default is 9 points)
- **ha** (*str*) – matplotlib horizontal alignment keyword (default is left)
- **va** (*str*) – matplotlib vertical alignment keyword (default is bottom)
- **kwargs** (*dict*) – dictionary with valid matplotlib text object keywords

Returns
text_obj – matplotlib text object

Return type
object

classmethod graph_legend(*ax=None*, *handles=None*, *labels=None*, ***kwargs*)

Add a USGS-style legend to a matplotlib axis object

Parameters

- **ax** (*axis object*) – matplotlib axis object (default is None)
- **handles** (*list*) – list of legend handles
- **labels** (*list*) – list of labels for legend handles
- **kwargs** (*kwargs*) – matplotlib legend kwargs

Returns
leg – matplotlib legend object

Return type
object

classmethod graph_legend_title(*leg*, *title=None*, *fontsize=9*)

Set the legend title for a matplotlib legend object

Parameters

- **leg** (*legend object*) – matplotlib legend object
- **title** (*str*) – title for legend
- **fontsize** (*int*) – fontsize for legend

Returns
leg – matplotlib legend object

Return type
object

classmethod heading(*ax=None*, *letter=None*, *heading=None*, *x=0.0*, *y=1.01*, *idx=None*, *fontsize=9*)

Add a USGS-style heading to a matplotlib axis object

Parameters

- **ax** (*axis object*) – matplotlib axis object (default is None)
- **letter** (*str*) – string that defines the subplot (A, B, C, etc.)
- **heading** (*str*) – text string
- **x** (*float*) – location of the heading in the x-direction in normalized plot dimensions ranging from 0 to 1 (default is 0.00)
- **y** (*float*) – location of the heading in the y-direction in normalized plot dimensions ranging from 0 to 1 (default is 1.01)
- **idx** (*int*) – index for programatically generating the heading letter when letter is None and idx is not None. idx = 0 will generate A (default is None)

Returns
text – matplotlib text object

Return type
object

classmethod remove_edge_ticks(*ax=None*)

Remove unnecessary ticks on the edges of the plot

Parameters
ax (*axis object*) – matplotlib axis object (default is None)

Returns
ax – matplotlib axis object

Return type
axis object

classmethod set_font_type(*family*, *fontname*)

Method to set the matplotlib font type for the current style

Note: this method only works when adding text using the styles methods.

Parameters

- **family** (*str*) – matplotlib.rcparams font.family
- **font** (*str*) – matplotlib.rcparams font.fontname

Return type
None

classmethod xlabel(*ax=None*, *label=''*, *bold=False*, *italic=False*, ***kwargs*)
Method to set the xlabel using the styled fontdict

Parameters

- **ax** (*axis object*) – matplotlib axis object (default is None)
- **label** (*str*) – axis label for the chart
- **bold** (*bool*) – flag to switch to boldface test
- **italic** (*bool*) – flag to use italic text
- **kwargs** (*dict*) – keyword arguments for the matplotlib set_xlabel method

Return type
None

classmethod ylabel(*ax=None*, *label=''*, *bold=False*, *italic=False*, ***kwargs*)
Method to set the ylabel using the styled fontdict

Parameters

- **ax** (*axis object*) – matplotlib axis object (default is None)
- **label** (*str*) – axis label for the chart
- **bold** (*bool*) – flag to switch to boldface test
- **italic** (*bool*) – flag to use italic text
- **kwargs** (*dict*) – keyword arguments for the matplotlib set_xlabel method

Return type
None

12.3.3 Export Utilities

Contents:

flopy.export.longnames module

Human readable long names for netCDF variables.

flopy.export.metadata module

class acdd(*sciencebase_id*, *model*)

Bases: object

Translate ScienceBase global metadata attributes to CF and ACDD global attributes.

Parameters

- **sciencebase_id** (*str*) – Unique identifier for ScienceBase record (e.g. 582da7efe4b04d580bd37be8)
- **model** (*flopy model object*) – Model object

References

https://www.sciencebase.gov/catalog/ https://cfconventions.org/cf-conventions/v1.6.0/cf-conventions.html#description-of-file-contents https://wiki.esipfed.org/Attribute_Convention_for_Data_Discovery

property bounds

property creator

property creator_url

property geospatial_bounds

Describes the data's 2D or 3D geospatial extent in OGC's Well-Known Text (WKT) Geometry format

property geospatial_bounds_vertical_crs

The vertical coordinate reference system (CRS) for the Z axis of the point coordinates in the geospatial_bounds attribute.

get_sciencebase_metadata(*id*)

Gets metadata json text for given ID from sciencebase.gov; loads into python dictionary. Fetches the reference text using the url: https://www.sciencebase.gov/catalog/item/<ID>?format=json

Parameters

ID (*str*) – ScienceBase ID string; e.g. 582da7efe4b04d580bd37be8 for Dane County Model

Returns

metadata – Dictionary of metadata

Return type

dict

get_sciencebase_xml_metadata()

Gets xml from sciencebase.gov, using XML url obtained from json using get_sciencebase_metadata().

Parameters

ID (*str*) – ScienceBase ID string; e.g. 582da7efe4b04d580bd37be8 for Dane County Model

Returns

metadata – Dictionary of metadata

Return type
dict

property references

property time_coverage

property vertical_datum
Try to parse the vertical datum from the xml info

property xmlfile

property xmlroot
ElementTree root element object for xml metadata

flopy.export.netcdf module

class Logger(*filename*, *echo=False*)

Bases: object

Basic class for logging events during the linear analysis calculations if filename is passed, then an file handle is opened

Parameters
filename (*bool or string*) – if string, it is the log file to write. If a bool, then log is written to the screen. echo (bool): a flag to force screen output

items
tracks when something is started. If a log entry is not in items, then it is treated as a new entry with the string being the key and the datetime as the value. If a log entry is in items, then the end time and delta time are written and the item is popped from the keys

Type
dict

log(*phrase*)
log something that happened

Parameters
phrase (*str*) – the thing that happened

warn(*message*)
Write a warning to the log file

Parameters
message (*str*) – the warning text

class NetCdf(*output_filename: str | PathLike*, *model*, *time_values=None*, *z_positive='up'*, *verbose=None*, *prj=None*, *logger=None*, *forgive=False*, ***kwargs*)

Bases: object

Support for writing a netCDF4 compliant file from a flopy model

Parameters

- **output_filename** (*str or PathLike*) – Path of the .nc file to write
- **model** (*flopy model instance*) –

- **time_values** (*the entries for the time dimension*) – if not None, the constructor will initialize the file. If None, the perlen array of ModflowDis will be used
- **z_positive** (*str ('up' or 'down')*) – Positive direction of vertical coordinates written to NetCDF file. (default 'down')
- **verbose** (*if True, stdout is verbose. If str, then a log file*) – is written to the verbose file
- **prj** (*str, optional, default None*) – PROJ4 string
- **logger** (Logger, *optional, default None*) – Logging object for custom logging configuration
- **forgive** (*what to do if a duplicate variable name is being created. If*) – True, then the newly requested var is skipped. If False, then an exception is raised.
- ****kwargs** (*keyword arguments*) –

  modelgrid
  [flopy.discretization.Grid instance] user supplied model grid which will be used in lieu of the model object modelgrid for netcdf production

Notes

This class relies heavily on the grid and modeltime objects, including these attributes: lenuni, itmuni, start_datetime, and proj4. Make sure these attributes have meaningful values.

add_global_attributes(*attr_dict*)

add global attribute to an initialized file

Parameters
attr_dict (*dict(attribute name, attribute value)*) –

Return type
None

Raises

- **Exception of self.nc is None (initialize_file()** –
- **has not been called)** –

add_sciencebase_metadata(*id*, *check=True*)

Add metadata from ScienceBase using the flopy.export.metadata.acdd class.

Returns
metadata

Return type
flopy.export.metadata.acdd object

append(*other*, *suffix='_1'*)

copy(*output_filename*)

create_group_variable(*group*, *name*, *attributes*, *precision_str*, *dimensions=('time',)*)

Create a new group variable in the netcdf object

Parameters

- **name** (*str*) – the name of the variable
- **attributes** (*dict*) – attributes to add to the new variable
- **precision_str** (*str*) – netcdf-compliant string. e.g. f4
- **dimensions** (*tuple*) – which dimensions the variable applies to default : ("time","layer","x","y")
- **group** (*str*) – which netcdf group the variable goes in default : None which creates the variable in root

Return type
nc variable

Raises

- **AssertionError if precision_str not right** –
- **AssertionError if variable name already in netcdf object** –
- **AssertionError if one of more dimensions do not exist** –

create_variable(*name*, *attributes*, *precision_str='f4'*, *dimensions=('time', 'layer')*, *group=None*)

Create a new variable in the netcdf object

Parameters

- **name** (*str*) – the name of the variable
- **attributes** (*dict*) – attributes to add to the new variable
- **precision_str** (*str*) – netcdf-compliant string. e.g. f4
- **dimensions** (*tuple*) – which dimensions the variable applies to default : ("time","layer","x","y")
- **group** (*str*) – which netcdf group the variable goes in default : None which creates the variable in root

Return type
nc variable

Raises

- **AssertionError if precision_str not right** –
- **AssertionError if variable name already in netcdf object** –
- **AssertionError if one of more dimensions do not exist** –

difference(*other*, *minuend='self'*, *mask_zero_diff=True*, *onlydiff=True*)

make a new NetCDF instance that is the difference with another netcdf file

Parameters

- **other** (*either an str filename of a netcdf file or*) – a netCDF4 instance

- **minuend** (*(optional) the order of the difference operation.*) – Default is self (e.g. self - other). Can be "self" or "other"
- **mask_zero_diff** (*bool flag to mask differences that are zero. If*) – True, positions in the difference array that are zero will be set to self.fillvalue
- **only_diff** (*bool flag to only add non-zero diffs to output file*) –

Return type
net NetCDF instance

Notes

assumes the current NetCDF instance has been populated. The variable names and dimensions between the two files must match exactly. The name of the new .nc file is <self.output_filename>.diff.nc. The masks from both self and other are carried through to the new instance

classmethod empty_like(*other*, *output_filename=None*, *verbose=None*, *logger=None*)

get_longnames_from_docstrings(*outfile='longnames.py'*)

This is experimental.

Scrape Flopy module docstrings and return docstrings for parameters included in the list of variables added to NetCdf object. Create a dictionary of longnames keyed by the NetCdf variable names; make each longname from the first sentence of the docstring for that parameter.

One major limitation is that variables from mflists often aren't described in the docstrings.

initialize_file(*time_values=None*)

initialize the netcdf instance, including global attributes, dimensions, and grid information

Parameters
time_values (*list of times to use as time dimension*) – entries. If none, then use the times in self.model.dis.perlen and self.start_datetime

initialize_geometry()

initialize the geometric information needed for the netcdf file

initialize_group(*group='timeseries'*, *dimensions=('time',)*, *attributes=None*, *dimension_data=None*)

Method to initialize a new group within a netcdf file. This group can have independent dimensions from the global dimensions

Parameters:

name
[str] name of the netcdf group

dimensions
[tuple] data dimension names for group

dimension_shape
[tuple] tuple of data dimension lengths

attributes
[dict] nested dictionary of {dimension : {attributes}} for each netcdf group dimension

dimension_data
[dict] dictionary of {dimension : [data]} for each netcdf group dimension

property nc_crs

static normalize_name(*name*)

write()

write the nc object to disk

classmethod zeros_like(*other*, *output_filename=None*, *verbose=None*, *logger=None*)

flopy.export.shapefile_utils module

Module for exporting and importing flopy model attributes

enforce_10ch_limit(*names: List[str]*, *warnings: bool = True*) → List[str]

Enforce 10 character limit for fieldnames. Add suffix for duplicate names starting at 0.

Parameters

- **names** (*list of strings*) –
- **warnings** (*whether to warn if names are truncated*) –

Returns
list of unique strings of len <= 10.

Return type
list

get_pyshp_field_dtypes(*code*)

Returns a numpy dtype for a pyshp field type.

get_pyshp_field_info(*dtypename*)

Get pyshp dtype information for a given numpy dtype.

model_attributes_to_shapefile(*path: str | PathLike*, *ml*, *package_names=None*, *array_dict=None*, *verbose=False*, ***kwargs*)

Wrapper function for writing a shapefile of model data. If package_names is not None, then search through the requested packages looking for arrays that can be added to the shapefile as attributes

Parameters

- **path** (*str or PathLike*) – path to write the shapefile to
- **ml** (*flopy.mbase*) – model instance
- **package_names** (*list of package names (e.g. ["dis","lpf"])*) – Packages to export data arrays to shapefile. (default is None)
- **array_dict** (*dict of {name:2D array} pairs*) – Additional 2D arrays to add as attributes to the shapefile. (default is None)
- **verbose** (*bool, optional, default False*) – whether to print verbose output
- ****kwargs** (*keyword arguments*) –

  modelgrid
  [fp.modflow.Grid object] if modelgrid is supplied, user supplied modelgrid is used in lieu of the modelgrid attached to the modflow model object

  crs
  [pyproj.CRS, int, str, optional if *prjfile* is specified] Coordinate reference system (CRS) for the model grid (must be projected; geographic CRS are not supported). The value can be anything accepted by pyproj.CRS.from_user_input(), such as an authority string (eg "EPSG:26916") or a WKT string.

  prjfile
  [str or pathlike, optional if *crs* is specified] ESRI-style projection file with well-known text defining the CRS for the model grid (must be projected; geographic CRS are not supported).

Return type
None

Examples

```
>>> import flopy
>>> m = flopy.modflow.Modflow()
>>> flopy.utils.model_attributes_to_shapefile('model.shp', m)
```

recarray2shp(*recarray*, *geoms*, *shpname: str | PathLike = 'recarray.shp'*, *mg=None*, *crs=None*, *prjfile: str | PathLike | None = None*, *verbose=False*, ***kwargs*)

Write a numpy record array to a shapefile, using a corresponding list of geometries. Method supports list of flopy geometry objects, flopy Collection object, shapely Collection object, and geojson Geometry Collection objects

Parameters

- **recarray** (*np.recarray*) – Numpy record array with attribute information that will go in the shapefile
- **geoms** (*list of flopy.utils.geometry, shapely geometry collection,*) –

  flopy geometry collection, shapefile.Shapes,
  list of shapefile.Shape objects, or geojson geometry collection

The number of geometries in geoms must equal the number of records in recarray.

- **shpname** (*str or PathLike, default "recarray.shp"*) – Path for the output shapefile
- **mg** (*flopy.discretization.Grid object*) – flopy model grid
- **crs** (pyproj.CRS, int, str, optional if *prjfile* is specified) – Coordinate reference system (CRS) for the model grid (must be projected; geographic CRS are not supported). The value can be anything accepted by pyproj.CRS.from_user_input(), such as an authority string (eg "EPSG:26916") or a WKT string.
- **prjfile** (str or pathlike, optional if *crs* is specified) – ESRI-style projection file with well-known text defining the CRS for the model grid (must be projected; geographic CRS are not supported).
- ****kwargs** (*dict, optional*) – Support deprecated keyword options.

  Deprecated since version 3.5: The following keyword options will be removed for FloPy 3.6:

  – epsg (int): use crs instead.

  – prj (str or PathLike): use prjfile instead.

Notes

Uses pyshp and optionally pyproj.

shape_attr_name(*name*, *length=6*, *keep_layer=False*)

Function for to format an array name to a maximum of 10 characters to conform with ESRI shapefile maximum attribute name length

Parameters

- **name** (*str*) – data array name
- **length** (*int*) – maximum length of string to return. Value passed to function is overridden and set to 10 if keep_layer=True. (default is 6)
- **keep_layer** (*bool*) – Boolean that determines if layer number in name should be retained. (default is False)

Return type

str

Examples

```
>>> import flopy
>>> name = flopy.utils.shape_attr_name('averylongstring')
>>> name
>>> 'averyl'
```

shp2recarray(*shpname: str | PathLike*)

Read a shapefile into a numpy recarray.

Parameters

shpname (*str or PathLike*) – ESRI Shapefile path

Return type

np.recarray

write_grid_shapefile(*path: str | PathLike*, *mg*, *array_dict*, *nan_val=nan*, *crs=None*, *prjfile: str | PathLike | None = None*, *verbose=False*, ***kwargs*)

Method to write a shapefile of gridded input data

Parameters

- **path** (*str or PathLike*) – shapefile file path
- **mg** (*flopy.discretization.grid.Grid object*) – flopy model grid
- **array_dict** (*dict*) – dictionary of model input arrays
- **nan_val** (*float*) – value to fill nans
- **crs** (pyproj.CRS, int, str, optional if *prjfile* is specified) – Coordinate reference system (CRS) for the model grid (must be projected; geographic CRS are not supported). The value can be anything accepted by pyproj.CRS.from_user_input(), such as an authority string (eg "EPSG:26916") or a WKT string.
- **prjfile** (str or pathlike, optional if *crs* is specified) – ESRI-style projection file with well-known text defining the CRS for the model grid (must be projected; geographic CRS are not supported).
- ****kwargs** (*dict, optional*) – Support deprecated keyword options.

  Deprecated since version 3.5: The following keyword options will be removed for FloPy 3.6:

  – epsg (int): use crs instead.

  – prj (str or PathLike): use prjfile instead.

Return type

None

write_gridlines_shapefile(*filename: str | PathLike*, *mg*)

Write a polyline shapefile of the grid lines - a lightweight alternative to polygons.

Parameters

- **filename** (*str or PathLike*) – path of the shapefile to write
- **mg** (*flopy.discretization.grid.Grid object*) – flopy model grid

Return type

None

write_prj(*shpname*, *modelgrid=None*, *crs=None*, *prjfile=None*, ***kwargs*)

flopy.export.unitsformat module

unit format strings for netCDF variables.

flopy.export.utils module

array2d_export(*f: str | PathLike*, *u2d*, *fmt=None*, *verbose=False*, ***kwargs*)

export helper for Util2d instances

Parameters

- **f** (*str or PathLike*) – filename or existing export instance type (NetCdf only for now)
- **u2d** (*Util2d instance*) –
- **fmt** (*str*) – output format flag. 'vtk' will export to vtk
- **verbose** (*bool*) – whether to print verbose output
- ****kwargs** (*keyword arguments*) – min_valid : minimum valid value max_valid : maximum valid value modelgrid : flopy.discretization.Grid

  model grid instance which will supercede the flopy.model.modelgrid

  if fmt is set to 'vtk', parameters of Vtk initializer

array3d_export(*f: str | PathLike*, *u3d*, *fmt=None*, ***kwargs*)

export helper for Transient2d instances

Parameters

- **f** (*str or PathLike*) – filename or existing export instance type (NetCdf only for now)
- **u3d** (*Util3d instance*) –
- **fmt** (*str*) – output format flag. 'vtk' will export to vtk
- ****kwargs** (*keyword arguments*) – min_valid : minimum valid value max_valid : maximum valid value modelgrid : flopy.discretization.Grid

  model grid instance which will supercede the flopy.model.modelgrid

  if fmt is set to 'vtk', parameters of Vtk initializer

contour_array(*modelgrid*, *ax*, *a*, *layer=0*, ***kwargs*)

Create a QuadMesh plot of the specified array using pcolormesh

Parameters

- **modelgrid** (*flopy.discretization.Grid object*) – modelgrid object
- **ax** (*matplotlib.axes.Axes*) – ax to add the contours
- **a** (*np.ndarray*) – array to contour
- **layer** (*int, optional*) – layer to contour

Returns

contour_set

Return type
ContourSet

ensemble_helper(*inputs_filename: str | PathLike*, *outputs_filename: str | PathLike*, *models*, *add_reals=True*, ***kwargs*)

Helper to export an ensemble of model instances. Assumes all models have same dis and reference information, only difference is properties and boundary conditions. Assumes model.nam.split('_')[-1] is the realization suffix to use in the netcdf variable names

export_array(*modelgrid*, *filename: str | PathLike*, *a*, *nodata=-9999*, *fieldname='value'*, *verbose=False*, ***kwargs*)

Write a numpy array to Arc Ascii grid or shapefile with the model reference.

Parameters

- **modelgrid** (*flopy.discretization.StructuredGrid object*) – model grid
- **filename** (*str or PathLike*) – Path of output file. Export format is determined by file extention. '.asc' Arc Ascii grid '.tif' GeoTIFF (requries rasterio package) '.shp' Shapefile
- **a** (*2D numpy.ndarray*) – Array to export
- **nodata** (*scalar*) – Value to assign to np.nan entries (default -9999)
- **fieldname** (*str*) – Attribute field name for array values (shapefile export only). (default 'values')
- **verbose** (*bool, optional, default False*) – whether to show verbose output
- **kwargs** – keyword arguments to np.savetxt (ascii) rasterio.open (GeoTIFF) or flopy.export.shapefile_utils.write_grid_shapefile

Notes

Rotated grids will be either be unrotated prior to export, using scipy.ndimage.rotate (Arc Ascii format) or rotation will be included in their transform property (GeoTiff format). In either case the pixels will be displayed in the (unrotated) projected geographic coordinate system, so the pixels will no longer align exactly with the model grid (as displayed from a shapefile, for example). A key difference between Arc Ascii and GeoTiff (besides disk usage) is that the unrotated Arc Ascii will have a different grid size, whereas the GeoTiff will have the same number of rows and pixels as the original.

export_array_contours(*modelgrid*, *filename: str | PathLike*, *a*, *fieldname='level'*, *interval=None*, *levels=None*, *maxlevels=1000*, ***kwargs*)

Contour an array using matplotlib; write shapefile of contours.

Parameters

- **modelgrid** (*flopy.discretization.Grid object*) – model grid object
- **filename** (*str or PathLike*) – Path of output file with '.shp' extention.
- **a** (*2D numpy array*) – Array to contour

- **fieldname** (*str*) – gis field name
- **interval** (*float*) – interval to calculate levels from
- **levels** (*list*) – list of contour levels
- **maxlevels** (*int*) – maximum number of contour levels
- ****kwargs** (*keyword arguments to flopy.export.shapefile_utils. recarray2shp*) –

export_contourf(*filename*, *contours*, *fieldname='level'*, *verbose=False*, ***kwargs*)

Write matplotlib filled contours to shapefile.

Parameters

- **filename** (*str or PathLike*) – name of output shapefile (e.g. myshp.shp)
- **contours** (*matplotlib.contour.QuadContourSet or list of them*) – (object returned by matplotlib.pyplot.contourf)
- **fieldname** (*str*) – Name of shapefile attribute field to contain the contour level. The fieldname column in the attribute table will contain the lower end of the range represented by the polygon. Default is 'level'.
- **verbose** (*bool, optional, default False*) – whether to show verbose output
- ****kwargs** (*keyword arguments to flopy.export.shapefile_utils. recarray2shp*) –

Return type

None

Examples

```
>>> import flopy
>>> import matplotlib.pyplot as plt
>>> from flopy.export.utils import export_contourf
>>> a = np.random.random((10, 10))
>>> cs = plt.contourf(a)
>>> export_contourf('myfilledcontours.shp', cs)
```

export_contours(*filename: str | PathLike*, *contours*, *fieldname='level'*, *verbose=False*, ***kwargs*)

Convert matplotlib contour plot object to shapefile.

Parameters

- **filename** (*str or PathLike*) – path of output shapefile
- **contours** (*matplotlib.contour.QuadContourSet or list of them*) – (object returned by matplotlib.pyplot.contour)
- **fieldname** (*str*) – gis attribute table field name
- **verbose** (*bool, optional, default False*) – whether to show verbose output

- ****kwargs** (*key-word arguments to flopy.export.shapefile_utils.recarray2shp*) –

Returns
: **df**

Return type
: dataframe of shapefile contents

generic_array_export(*f: str | PathLike, array, var_name='generic_array', dimensions=('time', 'layer', 'y', 'x'), precision_str='f4', units='unitless', **kwargs*)

Method to export a generic array to NetCdf

Parameters

- **f** (*str or PathLike*) – filename or existing export instance type (NetCdf only for now)
- **array** (*np.ndarray*) –
- **var_name** (*str*) – variable name
- **dimensions** (*tuple*) – netcdf dimensions
- **precision_str** (*str*) – binary precision string, default "f4"
- **units** (*string*) – units of array data
- ****kwargs** (*keyword arguments*) –

  model
  : [flopy.modflow.mbase] flopy model object

mflist_export(*f: str | PathLike | NetCdf, mfl, **kwargs*)

export helper for MfList instances

Parameters

- **f** (*str or PathLike or NetCdf*) – file path or existing export instance type (NetCdf only for now)
- **mfl** (*MfList instance*) –
- ****kwargs** (*keyword arguments*) –

  modelgrid
  : [flopy.discretization.Grid] model grid instance which will supercede the flopy.model.modelgrid

  crs
  : [pyproj.CRS, int, str, optional if *prjfile* is specified] Coordinate reference system (CRS) for the model grid (must be projected; geographic CRS are not supported). The value can be anything accepted by pyproj.CRS.from_user_input(), such as an authority string (eg "EPSG:26916") or a WKT string.

  prjfile
  : [str or pathlike, optional if *crs* is specified] ESRI-style projection file with well-known text defining the CRS for the model grid (must be projected; geographic CRS are not supported).

model_export(*f: str | PathLike | NetCdf | dict*, *ml*, *fmt=None*, ***kwargs*)

Method to export a model to a shapefile or netcdf file

Parameters

- **f** (*str or PathLike or NetCdf or dict*) – file path (".nc" for netcdf or ".shp" for shapefile) or NetCDF object or dictionary
- **ml** (*flopy.modflow.mbase.ModelInterface object*) – flopy model object
- **fmt** (*str*) – output format flag. 'vtk' will export to vtk
- ****kwargs** (*keyword arguments*) –

  modelgrid: flopy.discretization.Grid
  user supplied modelgrid object which will supercede the built in modelgrid object

  crs
  [pyproj.CRS, int, str, optional if *prjfile* is specified] Coordinate reference system (CRS) for the model grid (must be projected; geographic CRS are not supported). The value can be anything accepted by pyproj.CRS.from_user_input(), such as an authority string (eg "EPSG:26916") or a WKT string.

  prjfile
  [str or pathlike, optional if *crs* is specified] ESRI-style projection file with well-known text defining the CRS for the model grid (must be projected; geographic CRS are not supported).

  if fmt is set to 'vtk', parameters of Vtk initializer

output_helper(*f: str | PathLike | NetCdf | dict*, *ml*, *oudic*, *verbose=False*, ***kwargs*)

Export model outputs using the model spatial reference info.

Parameters

- **f** (*str or PathLike or NetCdf or dict*) – filepath to write output to (must have .shp or .nc extension), NetCDF object, or dictionary
- **ml** (*flopy.mbase.ModelInterface derived type*) –
- **oudic** (*dict*) – output_filename,flopy datafile/cellbudgetfile instance
- **verbose** (*bool*) – whether to show verbose output
- ****kwargs** (*keyword arguments*) –

  modelgrid
  [flopy.discretizaiton.Grid] user supplied model grid instance that will be used for export in lieu of the models model grid instance

  mflay
  [int] zero based model layer which can be used in shapefile exporting

  kper
  [int] zero based stress period which can be used for shapefile exporting

Return type
None

Note:

casts down double precision to single precision for netCDF files

package_export(*f: str | PathLike | NetCdf | dict*, *pak*, *fmt=None*, *verbose=False*, ***kwargs*)

Method to export a package to shapefile or netcdf

Parameters

- **f** (*str or PathLike or NetCdf or dict*) – output file path (extension .shp for shapefile or .nc for netcdf) or NetCDF object or dictionary
- **pak** (*flopy.pakbase.Package object*) – package to export
- **fmt** (*str*) – output format flag. 'vtk' will export to vtk
- **kwargs** (****) –

  modelgrid: flopy.discretization.Grid
  user supplied modelgrid object which will supercede the built in modelgrid object

  crs
  [pyproj.CRS, int, str, optional if *prjfile* is specified] Coordinate reference system (CRS) for the model grid (must be projected; geographic CRS are not supported). The value can be anything accepted by pyproj.CRS.from_user_input(), such as an authority string (eg "EPSG:26916") or a WKT string.

  prjfile
  [str or pathlike, optional if *crs* is specified] ESRI-style projection file with well-known text defining the CRS for the model grid (must be projected; geographic CRS are not supported).

  if fmt is set to 'vtk', parameters of Vtk initializer

Returns
f

Return type
NetCdf object or None

transient2d_export(*f: str | PathLike*, *t2d*, *fmt=None*, ***kwargs*)

export helper for Transient2d instances

Parameters

- **f** (*str or PathLike*) – filename or existing export instance type (NetCdf only for now)
- **t2d** (*Transient2d instance*) –
- **fmt** (*str*) – output format flag. 'vtk' will export to vtk
- ****kwargs** (*keyword arguments*) – min_valid : minimum valid value max_valid : maximum valid value modelgrid : flopy.discretization.Grid

model grid instance which will supercede the flopy.model.modelgrid

if fmt is set to 'vtk', parameters of Vtk initializer

flopy.export.vtk module

The vtk module provides functionality for exporting model inputs and outputs to VTK.

class Pvd

Bases: object

Simple class to build a Paraview Data File (PVD)

add_timevalue(*file*, *timevalue*)

Method to add a Dataset record to the pvd file

Parameters

- **file** (*os.PathLike or str*) – vtu file name
- **timevalue** (*float*) – time step value in model time

write(*f*)

Method to write a pvd file from the PVD object.

Parameters

f (*os.PathLike or str*) – PVD file name

class Vtk(*model=None*, *modelgrid=None*, *vertical_exageration=1*, *binary=True*, *xml=False*, *pvd=False*, *shared_points=False*, *smooth=False*, *point_scalars=False*)

Bases: object

Class that builds VTK objects and exports models to VTK files

Parameters

- **model** (*flopy.ModelInterface object*) – any flopy model object, example flopy.modflow.Modflow() object
- **modelgrid** (*flopy.discretization.Grid object*) – any flopy modelgrid object, example. VertexGrid
- **vertical_exageration** (*float*) – floating point value to scale vertical exageration of the vtk points default is 1.
- **binary** (*bool*) – flag that indicates if Vtk will write a binary or text file. Binary is prefered as paraview has a bug (8/4/2021) where is cannot represent NaN values from ASCII (non xml) files. In this case no-data values are set to 1e+30.
- **xml** (*bool*) – flag to write xml based VTK files
- **pvd** (*bool*) – boolean flag to write a paraview pvd file for transient data. This file maps vtk files to a model time.
- **shared_points** (*bool*) – boolean flag to share points in grid polyhedron construction. Default is False, as paraview has a bug (8/4/2021) where some polyhedrons will not properly close when using shared points. If shared_points is True file size will be slightly smaller.

- **smooth** (*bool*) - boolean flag to interpolate vertex elevations based on shared cell elevations. Default is False.
- **point_scalars** (*bool*) - boolen flag to write interpolated data at each point based "shared vertices".

add_array(*array*, *name*, *masked_values=None*, *dtype=None*)

Method to set an array to the vtk grid

Parameters

- **array** (*np.ndarray*, *list*) - list of array values to set to the vtk_array
- **name** (*str*) - array name for vtk
- **masked_values** (*list*, *None*) - list of values to set equal to nan
- **dtype** (*vtk datatype object*) - method to supply and force a vtk datatype

add_cell_budget(*cbc*, *text=None*, *kstpkper=None*, *masked_values=None*)

Method to add cell budget data to vtk

Parameters

- **cbc** (*flopy.utils.CellBudget object*) - flopy binary CellBudget object
- **text** (*str or None*) - The text identifier for the record. Examples include 'RIVER LEAKAGE', 'STORAGE', 'FLOW RIGHT FACE', etc. If text=None all compatible records are exported
- **kstpkper** (*tuple*, *list of tuples*, *None*) - tuple or list of tuples of kstpkper, if kstpkper=None all records are selected
- **masked_values** (*list*, *None*) - list of values to set equal to nan

add_heads(*hds*, *kstpkper=None*, *masked_values=None*)

Method to add head data to a vtk file

Parameters

- **hds** (*flopy.utils.LayerFile object*) - Binary or Formatted HeadFile type object
- **kstpkper** (*tuple*, *list of tuples*, *None*) - tuple or list of tuples of kstpkper, if kstpkper=None all records are selected
- **masked_values** (*list*, *None*) - list of values to set equal to nan

add_model(*model*, *selpaklist=None*, *masked_values=None*)

Method to add all array and transient list data from a modflow model to a timeseries of vtk files

Parameters

- **model** (*fp.modflow.ModelInterface*) - any flopy model object
- **selpaklist** (*list*, *None*) - optional parameter where the user can supply a list of packages to export.

- **masked_values** (*list, None*) – list of values to set equal to nan

add_package(*pkg, masked_values=None*)

Method to set all arrays within a package to VTK arrays

Parameters

- **pkg** (*flopy.pakbase.Package object*) – flopy package object, example ModflowWel
- **masked_values** (*list, None*) – list of values to set equal to nan

add_pathline_points(*pathlines, timeseries=False*)

Method to add Modpath output from a pathline or timeseries file to the grid. Colors will be representative of totim.

Parameters

- **pathlines** (*np.recarray or list*) – pathlines accepts a numpy recarray of a particle pathline or a list of numpy reccarrays associated with pathlines
- **timeseries** (*bool*) – method to plot data as a series of vtk timeseries files for animation or as a single static vtk file. Default is false

add_transient_array(*d, name=None, masked_values=None*)

Method to add transient array data to the vtk object

Parameters

- **d** (*dict*) – dictionary of array2d, arry3d data or numpy array data
- **name** (*str, None*) – parameter name, required when user provides a dictionary of numpy arrays
- **masked_values** (*list, None*) – list of values to set equal to nan

Return type

None

add_transient_list(*mflist, masked_values=None*)

Method to add transient list data to a vtk object

Parameters

- **mflist** (*flopy.utils.MfList object*) –
- **masked_values** (*list, None*) – list of values to set equal to nan

add_transient_vector(*d, name, masked_values=None*)

Method to add transient vector data to vtk

Parameters

- **d** (*dict*) – dictionary of vectors
- **name** (*str*) – name of vector to be displayed in vtk

- **masked_values** (*list, None*) – list of values to set equal to nan

add_vector(*vector, name, masked_values=None*)

Method to add vector data to vtk

Parameters

- **vector** (*array*) – array of dimension (3, nnodes)
- **name** (*str*) – name of the vector to be displayed in vtk
- **masked_values** (*list, None*) – list of values to set equal to nan

to_pyvista()

Convert VTK object to PyVista meshes. If the VTK object contains 0 or multiple meshes a list of meshes is returned. Otherwise the one mesh is returned alone. PyVista must be installed for this method.

Returns
PyVista mesh or list of meshes

Return type
pyvista.DataSet or list of pyvista.DataSet

write(*f: str | PathLike, kper=None*)

Method to write a vtk file from the VTK object

Parameters

- **f** (*str or PathLike*) – vtk file name
- **kpers** (*int, list, tuple*) – stress period or list of stress periods to write to vtk. This parameter only applies to transient package data.

12.3.4 PEST Utilities

Contents:

flopy.pest.params module

class Params(*mfpackage, partype, parname, startvalue, lbound, ubound, span, transform='log'*)

Bases: object

Class to define parameters that will be estimated using PEST.

Parameters

- **mfpackage** (*str*) – The Modflow package type to associated with this parameter. 'LPF' is one package that is working now.
- **partype** (*str*) – The parameter type, such as 'hk'. This must be a valid attribute in the mfpackage.
- **parname** (*str*) – The parameter name, such as 'HK_1'.
- **startvalue** (*float*) – The starting value for the parameter.

- **lbound** (*float*) – The lower bound for the parameter.
- **ubound** (*float*) – The upper bound for the parameter.
- **span** (*dict*) – The span over which the parameter applies. The span depends on the type of array that the parameter applies to. For 3d arrays, span should have either 'idx' or 'layers' keys. span['layers'] should be a list of layer to for which parname will be applied as a multiplier. idx is a tuple, which contains the indices to which this parameter applies. For example, if the parameter applies to a part of a 3D MODFLOW array, then idx can be a tuple of layer, row, and column indices (e.g. (karray, iarray, jarray). This idx variable could also be a 3D bool array. It is ultimately used to assign parameter to the array using arr[idx] = parname. For transient 2d arrays, span must include a 'kpers' key such that span['kpers'] is a list of stress period to which parname will be applied as a multiplier.
- **transform** (*Parameter transformation type.*) –

zonearray2params(*mfpackage*, *partype*, *parzones*, *lbound*, *ubound*, *parvals*, *transform*, *zonearray*)

Helper function to create a list of flopy parameters from a zone array and list of parameter zone numbers.

The parameter name is set equal to the parameter type and the parameter zone value, separated by an underscore.

flopy.pest.templatewriter module

class TemplateWriter(*model*, *plist*)

Bases: object

Class for writing PEST template files.

Parameters

- **model** (*flopy.modflow object*) – flopy model object.
- **plist** (*list*) – list of parameter objects of type flopy.pest.params.Params.

write_template()

Write the template files for all model files that have arrays that have been parameterized.

flopy.pest.tplarray module

class Transient2dTpl(*transient2d*)

Bases: object

add_parameter(*p*)

Store the parameters in a list for later substitution

get_kper_entry(*kper*)

class Util2dTpl(*chararray*, *name*, *multiplier*, *indexed_param*)

Bases: object

Class to define a two-dimensional template array for use with parameter estimation.

Parameters

- **chararray** (*A Numpy ndarray of dtype 'str'.*) –
- **name** (*The parameter type. This will be written to the control record*) – as a comment.
- **indexed_param** (*bool*) – A flag to indicated whether or not the array contains parameter names within the array itself.

get_file_entry()

Convert the array into a string.

Returns
file_entry

Return type
str

class Util3dTpl(*u3d*)

Bases: object

Class to define a three-dimensional template array for use with parameter estimation.

Parameters
u3d (*Util3d object*) –

add_parameter(*p*)

Fill the chararray with the parameter name.

Parameters
p (flopy.pest.params.Params) – Parameter. Must have .idx and .name attributes

get_template_array(*pakarray*)

Convert the package array into the appropriate template array

12.3.5 Discretization Utilities

Contents:

flopy.discretization.grid module

class CachedData(*data*)

Bases: object

property data

property data_nocopy

update_data(*data*)

class Grid(*grid_type=None*, *top=None*, *botm=None*, *idomain=None*, *lenuni=None*, *crs=None*, *prjfile=None*, *xoff=0.0*, *yoff=0.0*, *angrot=0.0*, ***kwargs*)

Bases: object

Base class for a structured or unstructured model grid

Parameters

- **grid_type** (*enumeration*) – type of model grid ('structured', 'vertex', 'unstructured')
- **top** (*float or ndarray*) – top elevations of cells in topmost layer
- **botm** (*float or ndarray*) – bottom elevations of all cells
- **idomain** (*int or ndarray*) – ibound/idomain value for each cell
- **lenuni** (*int or ndarray*) – model length units
- **crs** (pyproj.CRS, int, str, optional if *prjfile* is specified) – Coordinate reference system (CRS) for the model grid (must be projected; geographic CRS are not supported). The value can be anything accepted by pyproj.CRS.from_user_input(), such as an authority string (eg "EPSG:26916") or a WKT string.
- **prjfile** (str or pathlike, optional if *crs* is specified) – ESRI-style projection file with well-known text defining the CRS for the model grid (must be projected; geographic CRS are not supported).
- **xoff** (*float*) – x coordinate of the origin point (lower left corner of model grid) in the spatial reference coordinate system
- **yoff** (*float*) – y coordinate of the origin point (lower left corner of model grid) in the spatial reference coordinate system
- **angrot** (*float*) – rotation angle of model grid, as it is rotated around the origin point
- ****kwargs** (*dict, optional*) – Support deprecated keyword options.

  Deprecated since version 3.5: The following keyword options will be removed for FloPy 3.6:

  – prj (str or pathlike): use prjfile instead.

  – epsg (int): use crs instead.

  – proj4 (str): use crs instead.

grid_type

type of model grid ('structured', 'vertex', 'unstructured')

Type

enumeration

top

top elevations of cells in topmost layer

Type

float or ndarray

botm

bottom elevations of all cells

Type
float or ndarray

idomain
ibound/idomain value for each cell

Type
int or ndarray

lenuni
modflow lenuni parameter

Type
int

xoffset
x coordinate of the origin point in the spatial reference coordinate system

Type
float

yoffset
y coordinate of the origin point in the spatial reference coordinate system

Type
float

angrot
rotation angle of model grid, as it is rotated around the origin point

Type
float

angrot_radians
rotation angle of model grid, in radians

Type
float

xgrid
returns numpy meshgrid of x edges in reference frame defined by point_type

Type
ndarray

ygrid
returns numpy meshgrid of y edges in reference frame defined by point_type

Type
ndarray

zgrid
returns numpy meshgrid of z edges in reference frame defined by point_type

Type
ndarray

xcenters
returns x coordinate of cell centers

Type
ndarray

ycenters

returns y coordinate of cell centers

Type
ndarray

ycenters

returns z coordinate of cell centers

Type
ndarray

xyzgrid

returns the location of grid edges of all model cells. if the model grid contains spatial reference information, the grid edges are in the coordinate system provided by the spatial reference information. returns a list of three ndarrays for the x, y, and z coordinates

Type
[ndarray, ndarray, ndarray]

xyzcellcenters

returns the cell centers of all model cells in the model grid. if the model grid contains spatial reference information, the cell centers are in the coordinate system provided by the spatial reference information. otherwise the cell centers are based on a 0,0 location for the upper left corner of the model grid. returns a list of three ndarrays for the x, y, and z coordinates

Type
[ndarray, ndarray, ndarray]

get_coords(*x*, *y*)

transform point or array of points x, y from model coordinates to spatial coordinates

grid_lines : (point_type=PointType.spatialxyz) : list

returns the model grid lines in a list. each line is returned as a list containing two tuples in the format [(x1,y1), (x2,y2)] where x1,y1 and x2,y2 are the endpoints of the line.

xyvertices : (point_type) : ndarray

1D array of x and y coordinates of cell vertices for whole grid (single layer) in C-style (row-major) order (same as np.ravel())

Notes

Examples

property angrot

property angrot_radians

attribs_from_namfile_header(*namefile*)

property botm

property cell_thickness

Get the cell thickness for a structured, vertex, or unstructured grid.

Returns
thick

Return type
calculated thickness

cross_section_adjust_indicies(*k*, *cbcnt*)

Method to get adjusted indicies by layer and confining bed for PlotCrossSection plotting

Parameters

- **k** (*int*) – zero based layer number
- **cbcnt** (*int*) – confining bed counter

Returns

- **tuple** (*(int, int, int) (adjusted layer, nodeskip layer, node*)
- *adjustment value based on number of confining beds and the layer)*

cross_section_lay_ncpl_ncb(*ncb*)

Get PlotCrossSection compatible layers, ncpl, and ncb variables

Parameters
ncb (*int*) – number of confining beds

Returns
tuple

Return type
(int, int, int) layers, ncpl, ncb

cross_section_nodeskip(*nlay*, *xypts*)

Get a nodeskip list for PlotCrossSection. This is a correction for UnstructuredGridPlotting

Parameters

- **nlay** (*int*) – nlay is nlay + ncb
- **xypts** (*dict*) – dictionary of node number and xyvertices of a cross-section

Returns
list

Return type
n-dimensional list of nodes to not plot for each layer

cross_section_set_contour_arrays(*plotarray*, *xcenters*, *head*, *elev*, *projpts*)

Method to set countour array centers for rare instances where matplotlib contouring is prefered over trimesh plotting

Parameters

- **plotarray** (*np.ndarray*) – array of data for contouring
- **xcenters** (*np.ndarray*) – xcenters array

- **zcenters** (*np.ndarray*) – zcenters array
- **head** (*np.ndarray*) – head array to adjust cell centers location
- **elev** (*np.ndarray*) – cell elevation array
- **projpts** (*dict*) – dictionary of projected cross sectional vertices

Returns

- **tuple** (*(np.ndarray, np.ndarray, np.ndarray, bool)*)
- *plotarray, xcenter array, ycenter array, and a boolean flag*
- *for contouring*

property cross_section_vertices

property crs

Coordinate reference system (CRS) for the model grid.

If pyproj is not installed this property is always None; see *epsg* for an alternative CRS definition.

property epsg

EPSG integer code registered to a coordinate reference system.

This property is derived from *crs* if pyproj is installed, otherwise it preserved from the constructor.

property extent

classmethod from_binary_grid_file(*file_path*, *verbose=False*)

get_coords(*x*, *y*)

Given x and y array-like values, apply rotation, scale and offset, to convert them from model coordinates to real-world coordinates.

get_lni(*nodes*)

Get the layer index and within-layer node index (both 0-based) for the given nodes

Parameters
nodes (*node numbers (array-like)*) –

Return type
list of tuples (layer index, node index)

get_local_coords(*x*, *y*)

Given x and y array-like values, apply rotation, scale and offset, to convert them from real-world coordinates to model coordinates.

get_number_plottable_layers(*a*)

get_plottable_layer_array(*plotarray*, *layer*)

get_plottable_layer_shape(*layer=None*)

Determine the shape that is required in order to plot a 2d array for this grid. For a regular MODFLOW grid, this is (nrow, ncol). For a vertex grid, this is (ncpl,) and for an unstructured grid this is (ncpl[layer],).

Parameters
layer (*int*) – Has no effect unless grid changes by layer

Returns
shape – required shape of array to plot for a layer

Return type
tuple

get_xcellcenters_for_layer(*layer*)

get_xvertices_for_layer(*layer*)

get_ycellcenters_for_layer(*layer*)

get_yvertices_for_layer(*layer*)

property grid_lines

property grid_type

property idomain

intersect(*x*, *y*, *local=False*, *forgive=False*)

property is_complete

property is_valid

property iverts

property laycbd

property lenuni

load_coord_info(*namefile=None*, *reffile='usgs.model.reference'*)
Attempts to load spatial reference information from the following files (in order): 1) usgs.model.reference 2) NAM file (header comment) 3) defaults

property map_polygons

property ncpl

neighbors(*node=None*, ***kwargs*)
Method to get nearest neighbors of a cell

Parameters

- **node** (*int*) – model grid node number
- **kwargs** (****) –

method
[str] "rook" for shared edge neighbors and "queen" for shared vertex neighbors

reset
[bool] flag to reset the neighbor calculation

Returns
list or dict – neighbors

Return type
list of cell node numbers or dict of all cells and

property nlay

property nnodes

property nvert

property prj

property prjfile

Path to a .prj file containing WKT for a coordinate reference system.

property proj4

PROJ string for a coordinate reference system.

This property is derived from *crs* if pyproj is installed, otherwise it preserved from the constructor.

read_usgs_model_reference_file(*reffile='usgs.model.reference'*)

read spatial reference info from the usgs.model.reference file https://water.usgs.gov/ogw/policy/gw-model/modelers-setup.html

remove_confining_beds(*array*)

Method to remove confining bed layers from an array

Parameters
array (*np.ndarray*) – array to remove quasi3d confining bed data from. Shape of axis 0 should be (self.lay + ncb) to remove beds

Return type
np.ndarray

saturated_thick(*array*, *mask=None*)

Raises AttributeError, use *saturated_thickness()*.

saturated_thickness(*array*, *mask=None*)

Get the saturated thickness for a structured, vertex, or unstructured grid. If the optional array is passed then thickness is returned relative to array values (saturated thickness). Returned values ranges from zero to cell thickness if optional array is passed.

Parameters

- **array** (*ndarray*) – array of elevations that will be used to adjust the cell thickness
- **mask** (*float*, *list*, *tuple*, *ndarray*) – array values to replace with a nan value.

Returns
thickness

Return type
calculated saturated thickness

set_coord_info(*xoff=None*, *yoff=None*, *angrot=None*, *crs=None*, *prjfile=None*, *merge_coord_info=True*, ***kwargs*)

Set coordinate information for a grid.

Parameters

- **xoff** (*float*, *optional*) – X and Y coordinate of the origin point in the spatial reference coordinate system.
- **yoff** (*float*, *optional*) – X and Y coordinate of the origin point in the spatial reference coordinate system.
- **angrot** (*float*, *optional*) – Rotation angle of model grid, as it is rotated around the origin point.
- **crs** (*pyproj.CRS*, *int*, *str*, *optional*) – Coordinate reference system (CRS) for the model grid (must be projected; geographic CRS are not supported). The value can be anything accepted by pyproj.CRS.from_user_input(), such as an authority string (eg "EPSG:26916") or a WKT string.
- **prjfile** (*str or pathlike*, *optional*) – ESRI-style projection file with well-known text defining the CRS for the model grid (must be projected; geographic CRS are not supported).
- **merge_coord_info** (*bool*, *default True*) – If True, retaining previous properties. If False, overwrite properties with defaults, unless specified.
- ****kwargs** (*dict*, *optional*) – Support deprecated keyword options.

  Deprecated since version 3.5: The following keyword options will be removed for FloPy 3.6:

  - epsg (int): use crs instead.
  - proj4 (str): use crs instead.

property shape

property size

property thick

Raises AttributeError, use *cell_thickness()*.

property top

property top_botm

property units

property verts

write_shapefile(*filename='grid.shp'*, *crs=None*, *prjfile=None*, ***kwargs*)

Write a shapefile of the grid with just the row and column attributes.

property xcellcenters

property xoffset

property xvertices

property xyzcellcenters

property xyzextent

property xyzvertices

property ycellcenters

property yoffset

property yvertices

property zcellcenters

property zvertices

flopy.discretization.modeltime module

class ModelTime(*period_data=None*, *time_units='days'*, *start_datetime=None*, *steady_state=None*)

Bases: object

Class for MODFLOW simulation time

Parameters

- **stress_periods** (*pandas dataframe*) – headings are: perlen, nstp, tsmult
- **temporal_reference** (TemporalReference) – contains start time and time units information

property nper

property nstp

property perlen

property start_datetime

property steady_state

property time_units

property totim

property tslen

property tsmult

flopy.discretization.structuredgrid module

class StructuredGrid(*delc=None*, *delr=None*, *top=None*, *botm=None*, *idomain=None*, *lenuni=None*, *crs=None*, *prjfile=None*, *xoff=0.0*, *yoff=0.0*, *angrot=0.0*, *nlay=None*, *nrow=None*, *ncol=None*, *laycbd=None*, ***kwargs*)

Bases: *Grid*

class for a structured model grid

Parameters

- **delr** (*float or ndarray*) – column spacing along a row.
- **delc** (*float or ndarray*) – row spacing along a column.

- **top** (*float or ndarray*) - top elevations of cells in topmost layer
- **botm** (*float or ndarray*) - bottom elevations of all cells
- **idomain** (*int or ndarray*) - ibound/idomain value for each cell
- **lenuni** (*int or ndarray*) - model length units
- **crs** (pyproj.CRS, int, str, optional if *prjfile* is specified) - Coordinate reference system (CRS) for the model grid (must be projected; geographic CRS are not supported). The value can be anything accepted by pyproj.CRS.from_user_input(), such as an authority string (eg "EPSG:26916") or a WKT string.
- **prjfile** (str or pathlike, optional if *crs* is specified) - ESRI-style projection file with well-known text defining the CRS for the model grid (must be projected; geographic CRS are not supported).
- **xoff** (*float*) - x coordinate of the origin point (lower left corner of model grid) in the spatial reference coordinate system
- **yoff** (*float*) - y coordinate of the origin point (lower left corner of model grid) in the spatial reference coordinate system
- **angrot** (*float*) - rotation angle of model grid, as it is rotated around the origin point
- ****kwargs** (*dict, optional*) - Support deprecated keyword options.

  Deprecated since version 3.5: The following keyword options will be removed for FloPy 3.6:

  - prj (str or pathlike): use prjfile instead.
  - epsg (int): use crs instead.
  - proj4 (str): use crs instead.
- **Properties** -
- **----------** -
- **nlay** - returns the number of model layers
- **nrow** - returns the number of model rows
- **ncol** - returns the number of model columns
- **delc** - returns the delc array
- **delr** - returns the delr array
- **xyedges** - returns x-location points for the edges of the model grid and y-location points for the edges of the model grid

get_cell_vertices(*i*, *j*)

returns vertices for a single cell at row, column i, j.

array_at_faces(*a*, *direction*, *withnan=True*)

Computes values at the center of cell faces using linear interpolation.

Parameters

- **a** (*ndarray*) - Values at cell centers, shape (nlay, row, ncol).

- **direction** (*str, possible values are 'x', 'y' and 'z'*) – Direction in which values will be interpolated at cell faces.
- **withnan** (*bool*) – If True (default), the result value will be set to NaN where the cell face sits between inactive cells. If False, not.

Returns
afaces – Array values interpolated at cell vertices, shape as input extended by 1 along the specified direction.

Return type
ndarray

array_at_verts(*a*)

Interpolate array values at cell vertices.

Parameters
a (*ndarray*) – Array values. Allowed shapes are: (nlay, nrow, ncol), (nlay, nrow, ncol+1), (nlay, nrow+1, ncol) and (nlay+1, nrow, ncol). * When the shape is (nlay, nrow, ncol), input values are considered at cell centers, and output values are computed by trilinear interpolation. * When the shape is extended in one direction, input values are considered at the center of cell faces in this direction, and output values are computed by bilinear interpolation in planes defined by these cell faces.

Returns
averts – Array values interpolated at cell vertices, shape (nlay+1, nrow+1, ncol+1).

Return type
ndarray

Notes

- Output values are smooth (continuous) even if top elevations or

bottom elevations are not constant across layers (i.e., in this case, vertices of neighboring cells are implicitly merged). * NaN values are assigned in accordance with inactive cells defined by idomain.

array_at_verts_basic(*a*)

Computes values at cell vertices using neighbor averaging.

Parameters
a (*ndarray*) – Array values at cell centers.

Returns
averts – Array values at cell vertices, shape (a.shape[0]+1, a.shape[1]+1, a.shape[2]+1). NaN values are assigned in accordance with inactive cells defined by idomain.

Return type
ndarray

property cross_section_vertices

Get a set of xvertices and yvertices ordered by node for plotting cross sections

Returns
: **xverts, yverts**

Return type
: (np.ndarray, np.ndarray)

property delc

property delr

property delz

property extent

classmethod from_binary_grid_file(*file_path*, *verbose=False*)

Instantiate a StructuredGrid model grid from a MODFLOW 6 binary grid (*.grb) file.

Parameters

- **file_path** (*str*) – file path for the MODFLOW 6 binary grid file
- **verbose** (*bool*) – Write information to standard output. Default is False.

Returns
: **return**

Return type
: *StructuredGrid*

classmethod from_gridspec(*file_path: str | PathLike*, *lenuni=0*)

Instantiate a StructuredGrid from grid specification file.

Parameters

- **file_path** (*str or PathLike*) – Path to the grid specification file
- **lenuni** (*int*) – Length unit code

Return type
: A StructuredGrid

get_cell_vertices(**args*, ***kwargs*)

Method to get a set of cell vertices for a single cell
: used in the Shapefile export utilities and plotting code

Parameters

- **node** – (int) node number
- **i** – (int) cell row number
- **j** – (int) cell column number

Returns --- list of x,y cell vertices

get_lrc(*nodes*)

Get layer, row, column from a list of zero-based MODFLOW node numbers.

Parameters
: **nodes** (*int, list or array_like*) – Zero-based node number

Returns
list of tuples containing the layer (k), row (i), and column (j) for each node in the input list

Return type
list

Examples

```
>>> import flopy
>>> sg = flopy.discretization.StructuredGrid(nlay=20, nrow=30, ncol=40)
>>> sg.get_lrc(100)
[(0, 2, 20)]
>>> sg.get_lrc([100, 1000, 10_000])
[(0, 2, 20), (0, 25, 0), (8, 10, 0)]
```

get_node(*lrc_list*)

Get node number from a list of zero-based MODFLOW layer, row, column tuples.

Parameters
lrc_list (*tuple of int or list of tuple of int*) – Zero-based layer, row, column tuples

Returns
list of MODFLOW nodes for each layer (k), row (i), and column (j) tuple in the input list

Return type
list

Examples

```
>>> import flopy
>>> sg = flopy.discretization.StructuredGrid(nlay=20, nrow=30, ncol=40)
>>> sg.get_node((0, 2, 20))
[100]
>>> sg.get_node([(0, 2, 20), (0, 25, 0), (8, 10, 0)])
[100, 1000, 10000]
```

get_number_plottable_layers(*a*)

Calculate and return the number of 2d plottable arrays that can be obtained from the array passed (a)

Parameters
a (*ndarray*) – array to check for plottable layers

Returns
nplottable – number of plottable layers

Return type
int

get_plottable_layer_array(*a, layer*)

property grid_lines

Get the grid lines as a list

intersect(*x*, *y*, *z=None*, *local=False*, *forgive=False*)

Get the row and column of a point with coordinates x and y

When the point is on the edge of two cells, the cell with the lowest row or column is returned.

Parameters

- **x** (*float*) – The x-coordinate of the requested point
- **y** (*float*) – The y-coordinate of the requested point
- **z** (*float*) – Optional z-coordinate of the requested point (will return layer, row, column) if supplied
- **local** (*bool (optional)*) – If True, x and y are in local coordinates (defaults to False)
- **forgive** (*bool (optional)*) – Forgive x,y arguments that fall outside the model grid and return NaNs instead (defaults to False - will throw exception)

Returns

- **row** (*int*) – The row number
- **col** (*int*) – The column number

property is_complete

property is_rectilinear

Test whether the grid is rectilinear (it is always so in the x and y directions, but not necessarily in the z direction).

property is_regular

Test if the grid spacing is regular and equal in x, y and z directions.

property is_regular_x

Test whether the grid spacing is regular in the x direction.

property is_regular_xy

Test if the grid spacing is regular and equal in x and y directions.

property is_regular_xz

Test if the grid spacing is regular and equal in x and z directions.

property is_regular_y

Test whether the grid spacing is regular in the y direction.

property is_regular_yz

Test if the grid spacing is regular and equal in y and z directions.

property is_regular_z

Test if the grid spacing is regular in z direction.

property is_valid

property iverts

property map_polygons

Get a list of matplotlib Polygon patches for plotting

Return type

list of Polygon objects

property ncol

property ncpl

neighbors(**args*, ***kwargs*)

Method to get nearest neighbors for a cell

Parameters

- ***args** – lay (int), row (int), column (int) or node (int)
- ****kwargs** –

k
[int] layer number

i
[int] row number

j
[int] column number

as_node
[bool] flag to return neighbors as node numbers

method
[str] "rook" for shared edge neighbors (default) "queen" for shared vertex neighbors (for flow accumulation calculations)

reset
[bool] flag to re-calculate neighbors, default is False

Return type

list of neighboring cells

property nlay

property nnodes

property nrow

property nvert

plot(***kwargs*)

Plot the grid lines.

Parameters

kwargs (*ax, colors. The remaining kwargs are passed into the*) – the LineCollection constructor.

Returns

lc

Return type

matplotlib.collections.LineCollection

property shape

property top_botm

property top_botm_withnan

Same as top_botm array but with NaN where idomain==0 both above and below a cell.

property verts

property xycenters

Return a list of two numpy one-dimensional float arrays for center x and y coordinates in model space - not offset or rotated.

property xyedges

one with the cell edge x coordinate (size = ncol+1) and the other with the cell edge y coordinate (size = nrow+1) in model space - not offset or rotated.

Type
Return a list of two 1D numpy arrays

property xyzcellcenters

two two-dimensional arrays for center x and y coordinates, and one three-dimensional array for center z coordinates. Coordinates are given in real-world coordinates.

Type
Return a list of three numpy float arrays

property xyzvertices

Method to get all grid vertices in a layer

Returns
[] 2D array

property zedges

Return zedges for (column, row)==(0, 0).

property zverts_smooth

Get a unique z of cell vertices using bilinear interpolation of top and bottom elevation layers.

Returns
zverts - z of cell vertices. NaN values are assigned in accordance with inactive cells defined by idomain.

Return type
ndarray, shape (nlay+1, nrow+1, ncol+1)

array_at_faces_1d(*a*, *delta*)

Interpolate array at cell faces of a 1d grid using linear interpolation.

Parameters

- **a** (*1d ndarray*) - Values at cell centers.
- **delta** (*1d ndarray*) - Grid steps.

Returns
afaces - Array values interpolated at cell faces, shape as input extended by 1.

Return type
1d ndarray

array_at_verts_basic2d(*a*)

Computes values at cell vertices on 2d array using neighbor averaging.

Parameters
a (*ndarray*) – Array values at cell centers, could be a slice in any orientation.

Returns
averts – Array values at cell vertices, shape (a.shape[0]+1, a.shape[1]+1).

Return type
ndarray

flopy.discretization.unstructuredgrid module

class UnstructuredGrid(*vertices=None, iverts=None, xcenters=None, ycenters=None, top=None, botm=None, idomain=None, lenuni=None, ncpl=None, crs=None, prjfile=None, xoff=0.0, yoff=0.0, angrot=0.0, iac=None, ja=None, **kwargs*)

Bases: *Grid*

Class for an unstructured model grid

Parameters

- **vertices** (*list*) – list of vertices that make up the grid. Each vertex consists of three entries [iv, xv, yv] which are the vertex number, which should be zero-based, and the x and y vertex coordinates.
- **iverts** (*list*) – list of vertex numbers that comprise each cell. This list must be of size nodes, if the grid_varies_by_nodes argument is true, or it must be of size ncpl[0] if the same 2d spatial grid is used for each layer.
- **xcenters** (*list or ndarray*) – list of x center coordinates for all cells in the grid if the grid varies by layer or for all cells in a layer if the same grid is used for all layers
- **ycenters** (*list or ndarray*) – list of y center coordinates for all cells in the grid if the grid varies by layer or for all cells in a layer if the same grid is used for all layers
- **top** (*list or ndarray*) – top elevations for all cells in the grid.
- **botm** (*list or ndarray*) – bottom elevations for all cells in the grid.
- **idomain** (*int or ndarray*) – ibound/idomain value for each cell
- **lenuni** (*int or ndarray*) – model length units
- **ncpl** (*ndarray*) – one dimensional array of size nlay with the number of cells in each layer. This can also be passed in as a tuple or list as long as it can be set using ncpl = np.array(ncpl, dtype=int). The sum of ncpl must be equal to the number of cells in the grid. ncpl is optional and if it is not passed in, then

it is is set using ncpl = np.array([len(iverts)], dtype=int), which means that all cells in the grid are contained in a single plottable layer. If the model grid defined in verts and iverts applies for all model layers, then the length of iverts can be equal to ncpl[0] and there is no need to repeat all of the vertex information for cells in layers

- **crs** (pyproj.CRS, int, str, optional if *prjfile* is specified) – Coordinate reference system (CRS) for the model grid (must be projected; geographic CRS are not supported). The value can be anything accepted by pyproj.CRS.from_user_input(), such as an authority string (eg "EPSG:26916") or a WKT string.
- **prjfile** (str or pathlike, optional if *crs* is specified) – ESRI-style projection file with well-known text defining the CRS for the model grid (must be projected; geographic CRS are not supported). beneath the top layer.
- **xoff** (*float*) – x coordinate of the origin point (lower left corner of model grid) in the spatial reference coordinate system
- **yoff** (*float*) – y coordinate of the origin point (lower left corner of model grid) in the spatial reference coordinate system
- **angrot** (*float*) – rotation angle of model grid, as it is rotated around the origin point
- **iac** (*list or ndarray*) – optional number of connections per node array
- **ja** (*list or ndarray*) – optional jagged connection array
- ****kwargs** (*dict, optional*) – Support deprecated keyword options.

  Deprecated since version 3.5: The following keyword options will be removed for FloPy 3.6:

  - prj (str or pathlike): use prjfile instead.
  - epsg (int): use crs instead.
  - proj4 (str): use crs instead.
- **Properties** –
- **----------** –
- **vertices** – returns list of vertices that make up the grid
- **cell2d** – returns list of cells and their vertices

get_cell_vertices(*cellid*)

returns vertices for a single cell at cellid.

Notes

This class handles spatial representation of unstructured grids. It is based on the concept of being able to support multiple model layers that may have a different number of cells in each layer. The array ncpl is of size nlay and and its sum must equal nodes. If the length of iverts is equal to ncpl[0] and the number of cells per layer is the same for each layer, then it is assumed that the grid does not vary by layer. In this case, the xcenters and ycenters arrays must also be of size ncpl[0]. This makes it possible to efficiently store spatial grid information for multiple layers.

If the spatial grid is different for each model layer, then the grid_varies_by_layer flag will automatically be set to false, and iverts must be of size nodes. The arrays for xcenters and ycenters must also be of size nodes.

cross_section_adjust_indicies(*k*, *cbcnt*)

Method to get adjusted indicies by layer and confining bed for PlotCrossSection plotting

Parameters

- **k** (*int*) – zero based model layer
- **cbcnt** (*int*) – confining bed counter

Returns

- **tuple** (*(int, int, int) (adjusted layer, nodeskip layer, node)*)
- *adjustment value based on number of confining beds and the layer)*

cross_section_lay_ncpl_ncb(*ncb*)

Get PlotCrossSection compatible layers, ncpl, and ncb variables

Parameters
ncb (*int*) – number of confining beds

Returns
tuple

Return type
(int, int, int) layers, ncpl, ncb

cross_section_nodeskip(*nlay*, *xypts*)

Get a nodeskip list for PlotCrossSection. This is a correction for UnstructuredGridPlotting

Parameters

- **nlay** (*int*) – nlay is nlay + ncb
- **xypts** (*dict*) – dictionary of node number and xyvertices of a cross-section

Returns
list

Return type
n-dimensional list of nodes to not plot for each layer

cross_section_set_contour_arrays(*plotarray*, *xcenters*, *head*, *elev*, *projpts*)

Method to set countour array centers for rare instances where matplotlib contouring is prefered over trimesh plotting

Parameters

- **plotarray** (*np.ndarray*) – array of data for contouring
- **xcenters** (*np.ndarray*) – xcenters array
- **head** (*np.ndarray*) – head array to adjust cell centers location
- **elev** (*np.ndarray*) – cell elevation array
- **projpts** (*dict*) – dictionary of projected cross sectional vertices

Returns

- **tuple** (*(np.ndarray, np.ndarray, np.ndarray, bool)*)
- *plotarray, xcenter array, ycenter array, and a boolean flag*
- *for contouring*

property cross_section_vertices

Method to get vertices for cross-sectional plotting

Return type

xvertices, yvertices

property extent

classmethod from_argus_export(*file_path*, *nlay=1*)

Create a new UnstructuredGrid from an Argus One Trimesh file

Parameters

- **file_path** (*Path-like*) – Path to trimesh file
- **nlay** (*int*) – Number of layers to create

Return type

An UnstructuredGrid

classmethod from_binary_grid_file(*file_path*, *verbose=False*)

Instantiate a UnstructuredGrid model grid from a MODFLOW 6 binary grid (*.grb) file.

Parameters

- **file_path** (*str*) – file path for the MODFLOW 6 binary grid file
- **verbose** (*bool*) – Write information to standard output. Default is False.

Returns

return

Return type

UnstructuredGrid

classmethod from_gridspec(*file_path: str | PathLike*)

Create an UnstructuredGrid from a grid specification file.

Parameters
file_path (*str or PathLike*) – Path to the grid specification file

Return type
An UnstructuredGrid

get_cell_vertices(*cellid*)

Method to get a set of cell vertices for a single cell
used in the Shapefile export utilities

Parameters
cellid – (int) cellid number

Returns --- list of x,y cell vertices

get_layer_node_range(*layer*)

get_number_plottable_layers(*a*)

Calculate and return the number of 2d plottable arrays that can be obtained from the array passed (a)

Parameters
a (*ndarray*) – array to check for plottable layers

Returns
nplottable – number of plottable layers

Return type
int

get_plottable_layer_array(*a, layer*)

get_plottable_layer_shape(*layer=None*)

Determine the shape that is required in order to plot in 2d for this grid.

Parameters
layer (*int*) – Has no effect unless grid changes by layer

Returns
shape – required shape of array to plot for a layer

Return type
tuple

get_xcellcenters_for_layer(*layer*)

get_xvertices_for_layer(*layer*)

get_ycellcenters_for_layer(*layer*)

get_yvertices_for_layer(*layer*)

property grid_lines

Creates a series of grid line vertices for drawing a model grid line collection. If the grid varies by layer, then return a dictionary with keys equal to layers and values equal to grid lines. Otherwise, just return the grid lines

Returns
grid lines or dictionary of lines by layer

Return type
dict

property grid_varies_by_layer

property iac

intersect(*x*, *y*, *z=None*, *local=False*, *forgive=False*)

Get the CELL2D number of a point with coordinates x and y

When the point is on the edge of two cells, the cell with the lowest CELL2D number is returned.

Parameters

- **x** (*float*) – The x-coordinate of the requested point
- **y** (*float*) – The y-coordinate of the requested point
- **z** (*float*, *None*) – optional, z-coordiante of the requested point
- **local** (*bool (optional)*) – If True, x and y are in local coordinates (defaults to False)
- **forgive** (*bool (optional)*) – Forgive x,y arguments that fall outside the model grid and return NaNs instead (defaults to False - will throw exception)

Returns
icell2d – The CELL2D number

Return type
int

property is_complete

property is_valid

property iverts

property ja

property map_polygons

Property to get Matplotlib polygon objects for the modelgrid

Return type
list or dict of matplotlib.collections.Polygon

property ncpl

static ncpl_from_ihc(*ihc*, *iac*)

Use the ihc and iac arrays to calculate the number of cells per layer array (ncpl) assuming that the plottable layer number is stored in the diagonal position of the ihc array.

Parameters

- **ihc** (*ndarray*) – horizontal indicator array. If the plottable layer number is stored in the diagonal position, then this will be used to create the returned ncpl array. plottable layer numbers must increase monotonically and be consecutive with node number
- **iac** (*ndarray*) – array of size nodes that has the number of connections for a cell, plus one for the cell itself

Returns
ncpl – number of cells per plottable layer

Return type
ndarray

property nlay

property nnodes

property nvert

plot(***kwargs*)

Plot the grid lines.

Parameters
kwargs (*ax, colors. The remaining kwargs are passed into the*) – the LineCollection constructor.

Returns
lc

Return type
matplotlib.collections.LineCollection

set_ncpl(*ncpl*)

property shape

property top_botm

property verts

property xyzcellcenters

Method to get cell centers and set to grid

property xyzvertices

Method to get model grid verticies

Returns
list of dimension ncpl by nvertices

flopy.discretization.vertexgrid module

class VertexGrid(*vertices=None*, *cell2d=None*, *top=None*, *botm=None*, *idomain=None*, *lenuni=None*, *crs=None*, *prjfile=None*, *xoff=0.0*, *yoff=0.0*, *angrot=0.0*, *nlay=None*, *ncpl=None*, *cell1d=None*, ***kwargs*)

Bases: *Grid*

class for a vertex model grid

Parameters

- **vertices** - list of vertices that make up the grid
- **cell2d** - list of cells and their vertices
- **top** (*list or ndarray*) - top elevations for all cells in the grid.
- **botm** (*list or ndarray*) - bottom elevations for all cells in the grid.
- **idomain** (*int or ndarray*) - ibound/idomain value for each cell
- **lenuni** (*int or ndarray*) - model length units
- **crs** (pyproj.CRS, int, str, optional if *prjfile* is specified) - Coordinate reference system (CRS) for the model grid (must be projected; geographic CRS are not supported). The value can be anything accepted by pyproj.CRS.from_user_input(), such as an authority string (eg "EPSG:26916") or a WKT string.
- **prjfile** (str or pathlike, optional if *crs* is specified) - ESRI-style projection file with well-known text defining the CRS for the model grid (must be projected; geographic CRS are not supported).
- **xoff** (*float*) - x coordinate of the origin point (lower left corner of model grid) in the spatial reference coordinate system
- **yoff** (*float*) - y coordinate of the origin point (lower left corner of model grid) in the spatial reference coordinate system
- **angrot** (*float*) - rotation angle of model grid, as it is rotated around the origin point
- ****kwargs** (*dict, optional*) - Support deprecated keyword options.

  Deprecated since version 3.5: The following keyword options will be removed for FloPy 3.6:

  – prj (str or pathlike): use prjfile instead.

  – epsg (int): use crs instead.

  – proj4 (str): use crs instead.
- **Properties** -
- **----------** -
- **vertices** - returns list of vertices that make up the grid
- **cell2d** - returns list of cells and their vertices

get_cell_vertices(*cellid*)

returns vertices for a single cell at cellid.

property cell1d

property cell2d

property extent

classmethod from_binary_grid_file(*file_path*, *verbose=False*)

Instantiate a VertexGrid model grid from a MODFLOW 6 binary grid (*.grb) file.

Parameters

- **file_path** (*str*) – file path for the MODFLOW 6 binary grid file
- **verbose** (*bool*) – Write information to standard output. Default is False.

Returns
return

Return type
VertexGrid

get_cell_vertices(*cellid*)

Method to get a set of cell vertices for a single cell
used in the Shapefile export utilities

Parameters
cellid – (int) cellid number

Returns --- list of x,y cell vertices

get_number_plottable_layers(*a*)

Calculate and return the number of 2d plottable arrays that can be obtained from the array passed (a)

Parameters
a (*ndarray*) – array to check for plottable layers

Returns
nplottable – number of plottable layers

Return type
int

get_plottable_layer_array(*a*, *layer*)

get_xcellcenters_for_layer(*layer*)

get_xvertices_for_layer(*layer*)

get_ycellcenters_for_layer(*layer*)

get_yvertices_for_layer(*layer*)

property grid_lines

Creates a series of grid line vertices for drawing a model grid line collection

Returns
grid line vertices

Return type
list

intersect(*x*, *y*, *z=None*, *local=False*, *forgive=False*)

Get the CELL2D number of a point with coordinates x and y

When the point is on the edge of two cells, the cell with the lowest CELL2D number is returned.

Parameters

- **x** (*float*) – The x-coordinate of the requested point
- **y** (*float*) – The y-coordinate of the requested point
- **z** (*float*, *None*) – optional, z-coordiante of the requested point will return (lay, icell2d)
- **local** (*bool (optional)*) – If True, x and y are in local coordinates (defaults to False)
- **forgive** (*bool (optional)*) – Forgive x,y arguments that fall outside the model grid and return NaNs instead (defaults to False - will throw exception)

Returns
icell2d – The CELL2D number

Return type
int

property is_complete

property is_valid

property iverts

property map_polygons

Get a list of matplotlib Polygon patches for plotting

Return type
list of Polygon objects

property ncpl

property nlay

property nnodes

property nvert

plot(***kwargs*)

Plot the grid lines.

Parameters
kwargs (*ax, colors. The remaining kwargs are passed into the*) – the LineCollection constructor.

Returns
lc

Return type
matplotlib.collections.LineCollection

property shape

property top_botm

property verts

property xyzcellcenters

Method to get cell centers and set to grid

property xyzvertices

Method to get all grid vertices in a layer, arranged per cell

Returns

list of size sum(nvertices per cell)

CHAPTER

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PYTHON MODULE INDEX

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