flopy3_Modpath7_structured_example

May 22, 2019

0.1 Problem 2A (exercise 8)

This notebook demonstrates how to create and run problem 2a (exercise 8) using python and FloPy. The notebook also shows how to create a modpath simulation to determine the recharge area for model layer 3. An analysis of simulated travel times is also included. MODPATH results are plotted using `matplotlib` and FloPy PlotMapView objects.

```
In [1]: import sys
        import os
        import numpy as np
        import matplotlib as mpl
        import matplotlib.pyplot as plt

        import flopy

        if not os.path.exists("data"):
            os.mkdir("data")
```

```
flopy is installed in /Users/jdhughes/Documents/Development/flopy_git/flopy_fork/flopy
```

0.1.1 Flow model data

```
In [2]: nper, nstp, perlen, tsmult = 1, 1, 1., 1.
        nlay, nrow, ncol = 3, 21, 20
        delr = delc = 500.
        top = 400.
        botm = [220., 200., 0.]
        laytyp = [1, 0, 0]
        kh = [50., 0.01, 200.]
        kv = [10., 0.01, 20.]
        wel_loc = (2, 10, 9)
        wel_q = 0 #-150000.
        rch = 0.005
        riv_h = 320.
        riv_z = 317.
        riv_c = 1.e5
```

0.1.2 MODPATH 7 using MODFLOW 6

Create and run MODFLOW 6

In [3]:
```python
ws = os.path.join('data', 'mp7_ex1', 'mf6')
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 = '{}.nam'.format(nm)
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, 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)
```

```python
    # 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 = '{}.hds'.format(nm)
    head_record = [headfile]
    budgetfile = '{}.cbb'.format(nm)
    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(silent=True)

    # Run the simulation
    success, buff = sim.run_simulation()
```

```
FloPy is using the following  executable to run the model: /Users/jdhughes/.local/bin/mf6
                                   MODFLOW 6
                U.S. GEOLOGICAL SURVEY MODULAR HYDROLOGIC MODEL
                            VERSION 6.0.4 03/13/2019

   MODFLOW 6 compiled Mar 19 2019 16:46:21 with IFORT compiler (ver. 19.0.0)

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```

```
Run start date and time (yyyy/mm/dd hh:mm:ss): 2019/05/22 10:28:22

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): 2019/05/22 10:28:22
Elapsed run time:  0.028 Seconds

Normal termination of simulation.
```

Create and run MODPATH 7 Create a list of node in model layer 3

In [4]:
```
n = ncol * nrow * 2
nodes = []
for i in range(nrow):
    for j in range(ncol):
        nodes.append(n)
        n += 1
```

Build and run the MODPATH files

In [5]:
```
# create modpath files
mpnam = modelname=nm + '_mp'
mp = flopy.modpath.Modpath7.create_mp7(modelname=mpnam,
                                       trackdir='backward',
                                       flowmodel=gwf,
                                       model_ws=ws,
                                       columncelldivisions=3,
                                       rowcelldivisions=2,
                                       layercelldivisions=8,
                                       nodes=nodes)


# write modpath datasets
mp.write_input()

# run modpath
mp.run_model()
```

```
FloPy is using the following  executable to run the model: /Users/jdhughes/.local/bin/mp7

MODPATH Version 7.2.001
Program compiled Mar 19 2019 16:49:28 with IFORT compiler (ver. 19.0.0)


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.
     20160 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.
```

```
Out[5]: (True, [])
```

Load MODPATH 7 endpoint output Get the endpoint data for particles started in model layer 3.

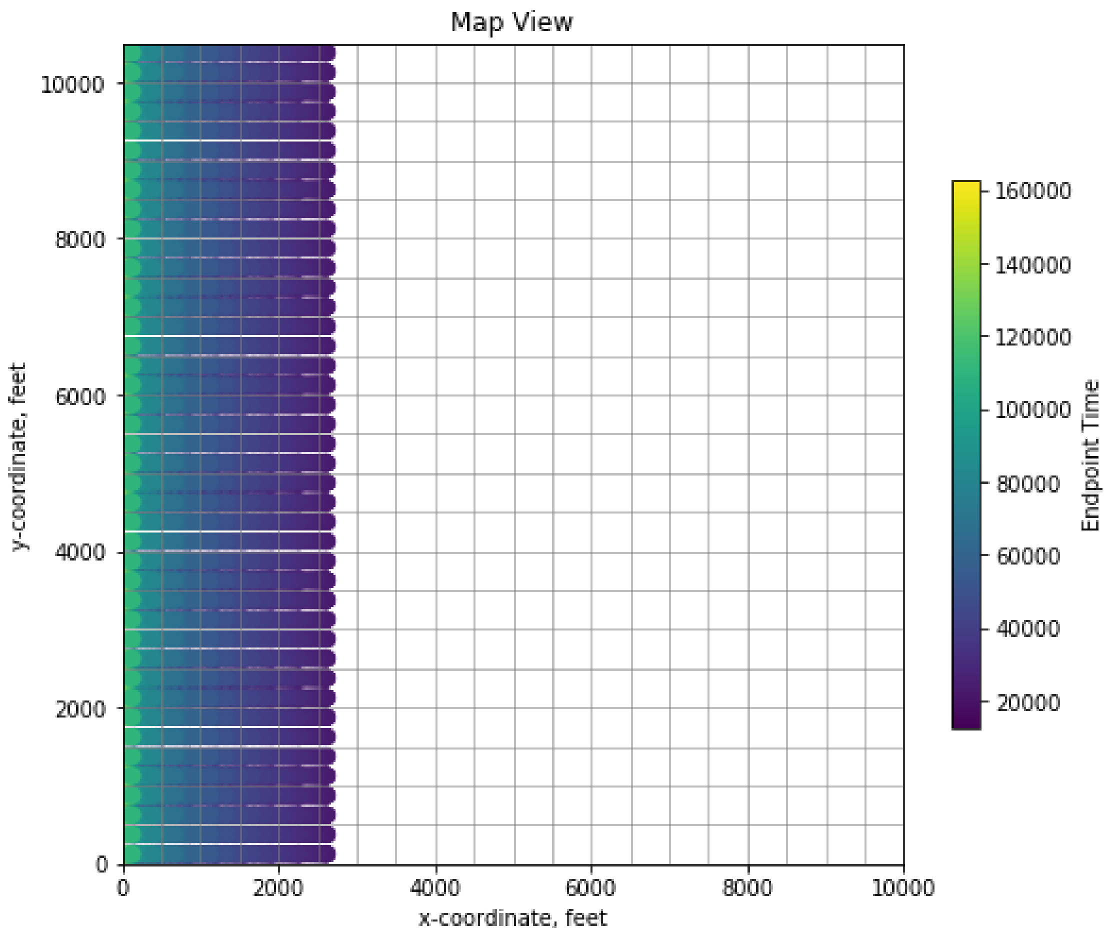
```
In [6]: fpth = os.path.join(ws, nm + '_mp.mpend')
        e = flopy.utils.EndpointFile(fpth)

        epd = e.get_alldata()
```

0.1.3 Plot MODPATH 7 output

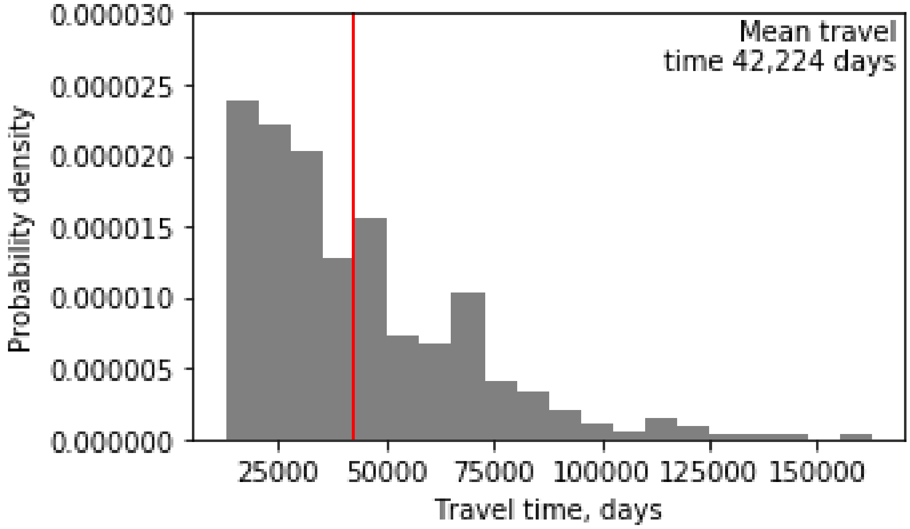
Plot the recharge area for the lower aquifer.

```
In [7]: f, ax = plt.subplots(ncols=1, nrows=1, figsize=(7.5, 7.5))
        ax.set_aspect('equal')
        mm = flopy.plot.PlotMapView(model=gwf, ax=ax)
        mm.plot_grid(lw=0.5)
        mm.plot_endpoint(epd, direction='ending', colorbar=True, shrink=0.5)
        ax.set_title('Map View')
        ax.set_ylabel('y-coordinate, feet')
        ax.set_xlabel('x-coordinate, feet')
        plt.tight_layout();
```



Plot the distribution of particle travel times

```
In [8]: f, ax = plt.subplots(ncols=1, nrows=1, figsize=(5, 3))
        ax.hist(epd.time, 20, density=True, color='0.5');
        ax.set_ylim(0, 0.00003)
        ax.plot([epd.time.mean(), epd.time.mean()], [0,0.00003], lw=1, color='red')
        mtxt = 'Mean travel\ntime {:,d} days'.format(int(epd.time.mean()))
        ax.text(0.99, 0.99, mtxt, ha='right', va='top', transform=ax.transAxes)
        ax.set_ylabel('Probability density')
        ax.set_xlabel('Travel time, days')
        plt.tight_layout();
```


Mean travel
time 42,224 days
Probability density
0.000030
0.000025
0.000020
0.000015
0.000010
0.000005
0.000000
25000
50000
75000
100000
125000
150000
Travel time, days