

# setup\_pest\_interface

May 11, 2019

## 1 Setup the PEST(++) interface around the enhanced Freyberg model

In this notebook, we will construct a complex model independent (non-intrusive) interface around an existing MODFLOW-NWT model using the python/flopy/pyemu stack.

```
In [1]: import os
import shutil
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import flopy
import pyemu
import prep_deps
import redis
import matplotlib as mpl
plt.rcParams['font.size']=12
```

flopy is installed in /Users/jeremyw/Dev/gw1876/activities\_2day\_mfm/notebooks/flopy

First we define a base directory `b_d` from which we will read in a model already created `freyberg.nam`. This will form the basis of the remainder of the exercise

```
In [2]: b_d = os.path.join(".", "base_model_files")
nam_file = "freyberg.nam"
```

### 1.0.1 load the existing Freyberg model. This version should run but is not yet connected with PEST++

```
In [3]: # note that to load a model in a different folder, you supply the namefile without path
# to it in the model_ws variable
m = flopy.modflow.Modflow.load(nam_file, model_ws=b_d, check=False, forgive=False)
```

### 1.0.2 we can do a couple flopy things to move where the new model will be written

```
In [4]: # assign the executable name for the model
m.exe_name = "mfwt"
```

```

# now let's run this in a new folder called temp so we don't overwrite the original da
m.change_model_ws("temp",reset_external=True)

# this writes all the MODFLOW files in the new location
m.write_input()

# the following helps get the dependencies (both python and executables) in the right p
prep_deps.prep_template(t_d="temp")

```

```

changing model workspace...
temp

```

### 1.0.3 now we can run the model once using a pyemu helper

This helper is particularly useful if you run on more than one platform (e.g. Mac and Windows)

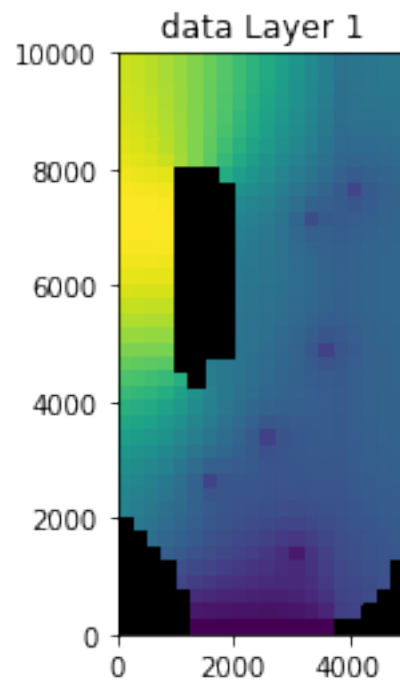
```
In [5]: pyemu.os_utils.run("{0} {1}".format("mfnewt",m.name+".nam"),cwd=m.model_ws)
```

### 1.0.4 read in the heads and plot them up along with the budget components

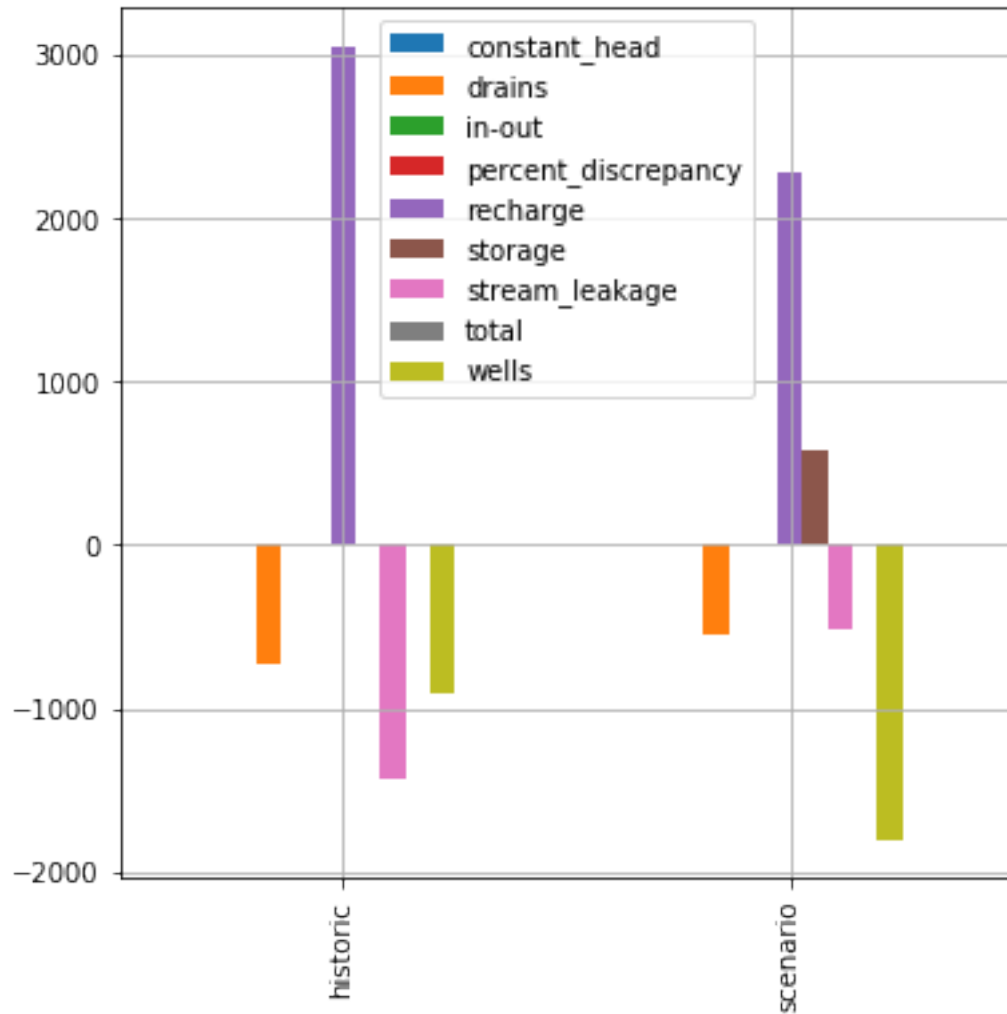
Note that there is a historic period and a scenario with future conditions that differ. For the future scenario, recharge is lower and pumping/abstraction is increased to make up for the presumed deficit in water for agriculture.

```
In [6]: plt.figure()
        hds = flopy.utils.HeadFile(os.path.join(m.model_ws,m.name+".hds"),model=m)
        hds.plot(mfay=0)
        lst = flopy.utils.MfListBudget(os.path.join(m.model_ws,m.name+".list"))
        df = lst.get_dataframes(diff=True)[0]
        plt.figure()
        ax = df.plot(kind="bar",figsize=(6,6), grid=True)
        ax.set_xticklabels(["historic","scenario"])
        plt.show()

```



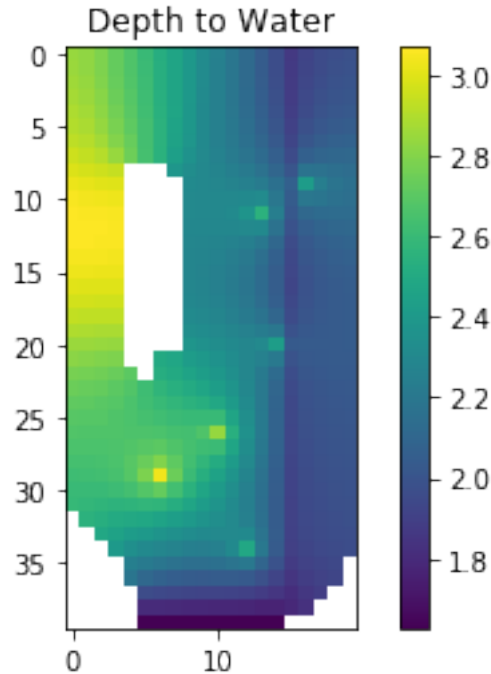
<Figure size 432x288 with 0 Axes>



We can see the effect of the “scenario” in the second stress period with less recharge and more abstraction.

### 1.0.5 Plot depth to water

```
In [7]: dtw = m.dis.top.array - hds.get_data()[0,:,:]
dtw = np.ma.masked_where(m.bas6.ibound[0].array==0,dtw)
c = plt.imshow(dtw)
plt.title('Depth to Water')
plt.colorbar(c)
plt.show()
```

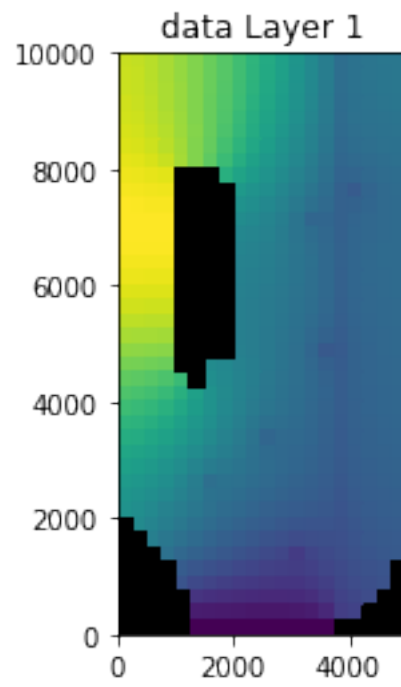


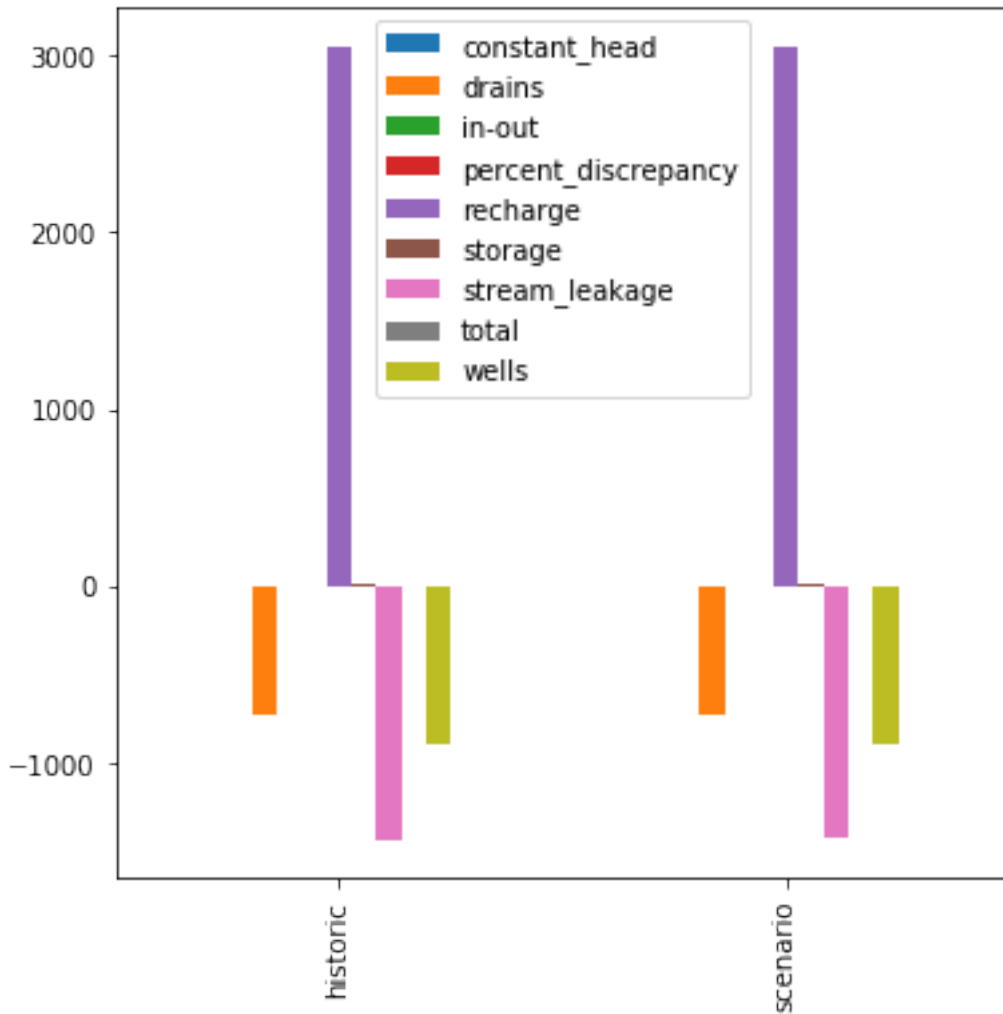
Clearly we can see the river and well locations expressed in the depth to water pattern.

**1.0.6 What we are going to do is implement the scenario with parameters so we can more easily account for the stochastic nature of the forcing conditions during the scenario stress period and also make implementation of future scenarios work in this stochastic framework:**

```
In [8]: # reset scenario period recharge
m.rch.rech[1] = m.rch.rech[0]
# reset scenario period abstraction
m.wel.stress_period_data[1] = m.wel.stress_period_data[0]
m.write_input()
pyemu.os_utils.run("{0} {1}".format("mfntw", m.name+".nam"), cwd=m.model_ws)
hds = flopy.utils.HeadFile(os.path.join(m.model_ws, m.name+".hds"), model=m)
axes = hds.plot(mflay=0)

lst = flopy.utils.MfListBudget(os.path.join(m.model_ws, m.name+".list"))
df = lst.get_dataframes(diff=True)[0]
ax = df.plot(kind="bar", figsize=(6,6))
ax.set_xticklabels(["historic", "scenario"])
plt.show()
```





Now we see that the scenario and historic periods have the same water balance

## 1.1 Setup data structures related to what we want to parameterize and what we want to observe

### 1.1.1 first the parameterization of model inputs

```
In [9]: props = []
        # here we specify which packages we wish to parameterize,
        # starting with those that do not change over time
        paks = ["upw.hk", "upw.vka", "upw.ss", "upw.sy", "bas6.strt", "extra.prsity"]
        for k in range(m.nlay):
            props.extend([[p,k] for p in paks])
        # next we specify that we want to make parameters for recharge
        # for both stress periods (zero-based! Python style)
        props.append(["rch.rech", 0])
        props.append(["rch.rech", 1])
```

### 1.1.2 we want to handle list-type parameters in two ways

for `spatial_list_props` this will apply a multiplier distributed spatially that applied in all stress periods throughout the model

for `temporal_list_props` this will apply a multiplier for each stress period applied to all the spatial locations

```
In [10]: spatial_list_props = [{"wel.flux",2}, {"drn.cond",0}]
        temporal_list_props = [{"wel.flux",0}, {"wel.flux",1}]
```

### 1.1.3 next we want to set up extracting observations. First, we will setup a post-processor that will read the heads for all active cells in both stress periods - why not?

```
In [11]: hds_kperk = [[0,k] for k in range(m.nlay)]
        hds_kperk.extend([[1,k] for k in range(m.nlay)])
```

### 1.1.4 then we setup monitoring of the SFR ASCII outputs.

we will accumulate the first 20 reaches and last 20 reaches together to form forecasts of sw-gw exchange in the headwaters (hw) and tailwaters (tw). Then we will also add each reach individually for monitoring as well

```
In [12]: sfr_obs_dict = {"hw":np.arange(1,int(m.nrow/2))}
        sfr_obs_dict["tw"] = np.arange(int(m.nrow/2),m.nrow)
        for i in range(m.nrow):
            sfr_obs_dict[i] = i+1
```

### 1.1.5 here we go...

This `pyemu` class has grown into a monster... it does (among other things): - sets up combinations of multiplier parameters for array inputs, including uniform, zones, pilot points, grids, and KL expansion types - sets up combinations of multiplier parameters for list inputs - handles several of the shitty modflow exceptions to the array and list style inputs - sets up large numbers of observations based on arrays or time series - writes `.tpl`, `.ins`, `.pst`, etc - writes a python forward run script (WAT?!) - writes a prior parameter covaraince matrix using geostatistical correlations - draws from the prior parameter covariance matrix to generate a prior parameter ensemble

This will be slow because the pure python kriging... but, hey, its free!

For our purposes, we will setup combinations of constant (by layer), pilot points and grid-scale parameters for each of the array-based properties we defined earlier. This lets us explore options for parameterization and also start to understand how information flows in the history matching problem

```
In [13]: pst_helper = pyemu.helpers.PstFromFlopyModel(nam_file,new_model_ws="template",org_model=
                                                    const_props=props,spatial_list_props=spat.
                                                    temporal_list_props=temporal_list_props,
                                                    grid_props=props,pp_props=props,sfr_pars=
                                                    sfr_obs=sfr_obs_dict,build_prior=False,m
                                                    pp_space=4)
        prep_deps.prep_template(t_d=pst_helper.new_model_ws)
```



2019-05-11 16:58:30.753019 starting: loading floppy model

Creating new model with name: freyberg

Parsing the namefile --> temp/freyberg.nam

External unit dictionary:

OrderedDict([(2, filename:temp/freyberg.list, filetype:LIST), (11, filename:temp/freyberg.dis,

ModflowBas6 free format:True

loading dis package file...

Loading dis package with:

3 layers, 40 rows, 20 columns, and 2 stress periods

loading laycbd...

loading delr...

loading delc...

loading top...

loading botm...

for 3 layers and 0 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 upw package file...

loading ipakcb, HDRY, NPUPW, IPHDRY...

loading LAYTYP...

loading LAYAVG...

loading CHANI...

loading LAYVKA...

loading LAYWET...

loading hk layer 1...

loading vka layer 1...

loading ss layer 1...

loading sy layer 1...

loading hk layer 2...

loading vka layer 2...

loading ss layer 2...

loading sy layer 2...

loading hk layer 3...

loading vka layer 3...

```

    loading ss layer    3...
    loading sy layer    3...
Adding freyberg.cbc (unit=50) to the output list.
adding Package:  UPW
    UPW  package load...success
loading rch package file...
    loading rech stress period    1...
    loading rech stress period    2...
adding Package:  RCH
    RCH  package load...success
loading nwt package file...
adding Package:  NWT
    NWT  package load...success
loading oc package file...
Adding freyberg.hds (unit=51) to the output list.
adding Package:  OC
    OC   package load...success
loading lmt package file...
adding Package:  LMT6
    LMT6 package load...success
loading wel package file...
    loading <class 'flopymodflow.mfwel.ModflowWel'> for kper    1
    loading <class 'flopymodflow.mfwel.ModflowWel'> for kper    2
adding Package:  WEL
    WEL  package load...success
loading sfr2 package file...
Adding freyberg.sfr.out (unit=60) to the output list.
adding Package:  SFR
    SFR  package load...success
loading drn package file...
    loading <class 'flopymodflow.mfdrn.ModflowDrn'> for kper    1
    loading <class 'flopymodflow.mfdrn.ModflowDrn'> for kper    2
adding Package:  DRN
    DRN  package load...success
    DATA(BINARY) file load...skipped
        freyberg.cbc
    DATA(BINARY) file load...skipped
        freyberg.hds
    DATA file load...skipped
        freyberg.sfr.out
Warning: external file unit 0 does not exist in ext_unit_dict.

```

The following 10 packages were successfully loaded.

```

    freyberg.dis
    freyberg.bas
    freyberg.upw
    freyberg.rch
    freyberg.nwt

```

```

    freyberg.oc
    freyberg.lmt6
    freyberg.wel
    freyberg.sfr
    freyberg.drn
The following 1 packages were not loaded.
    freyberg.list
2019-05-11 16:58:30.786335 finished: loading floppy model took: 0:00:00.033316
2019-05-11 16:58:30.789321 starting: updating model attributes
2019-05-11 16:58:30.789633 finished: updating model attributes took: 0:00:00.000312
2019-05-11 16:58:30.789697 WARNING: removing existing 'new_model_ws

creating model workspace...
    template

changing model workspace...
    template
2019-05-11 16:58:32.062224 starting: writing new modflow input files

Writing packages:
    Package:  DIS
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
Util2d:botm_layer_1: resetting 'how' to external
Util2d:botm_layer_2: resetting 'how' to external
    Package:  BAS6
Util2d:ibound_layer_0: resetting 'how' to external
Util2d:ibound_layer_1: resetting 'how' to external
Util2d:ibound_layer_2: resetting 'how' to external
Util2d:strt_layer_0: resetting 'how' to external
Util2d:strt_layer_1: resetting 'how' to external
Util2d:strt_layer_2: resetting 'how' to external
    Package:  UPW
Util2d:hk: resetting 'how' to external
Util2d:vka: resetting 'how' to external
Util2d:ss: resetting 'how' to external
Util2d:sy: resetting 'how' to external
Util2d:hk: resetting 'how' to external
Util2d:vka: resetting 'how' to external
Util2d:ss: resetting 'how' to external
Util2d:sy: resetting 'how' to external
Util2d:hk: resetting 'how' to external
Util2d:vka: resetting 'how' to external
Util2d:ss: resetting 'how' to external
Util2d:sy: resetting 'how' to external
    Package:  RCH

```

Util2d:rech\_1: resetting 'how' to external

Util2d:rech\_2: resetting 'how' to external

Package: NWT

Package: OC

Package: LMT6

Package: WEL

Package: SFR

Package: DRN

2019-05-11 16:58:32.180059 finished: writing new modflow input files took: 0:00:00.117835

2019-05-11 16:58:32.180670 forward\_run line:pyemu.os\_utils.run('mf nwt freyberg.nam 1>freyberg.

2019-05-11 16:58:32.180788 starting: setting up 'template/arr\_org' dir

2019-05-11 16:58:32.181277 finished: setting up 'template/arr\_org' dir took: 0:00:00.000489

2019-05-11 16:58:32.181613 starting: setting up 'template/arr\_mlt' dir

2019-05-11 16:58:32.182076 finished: setting up 'template/arr\_mlt' dir took: 0:00:00.000463

2019-05-11 16:58:32.182178 starting: setting up 'template/list\_org' dir

2019-05-11 16:58:32.182608 finished: setting up 'template/list\_org' dir took: 0:00:00.000430

2019-05-11 16:58:32.182776 starting: setting up 'template/list\_mlt' dir

2019-05-11 16:58:32.183416 finished: setting up 'template/list\_mlt' dir took: 0:00:00.000640

2019-05-11 16:58:32.183640 starting: processing temporal\_list\_props

2019-05-11 16:58:32.206110 finished: processing temporal\_list\_props took: 0:00:00.022470

2019-05-11 16:58:32.206454 starting: processing spatial\_list\_props

2019-05-11 16:58:32.288990 finished: processing spatial\_list\_props took: 0:00:00.082536

2019-05-11 16:58:32.357655 forward\_run line:pyemu.helpers.apply\_list\_pars()

2019-05-11 16:58:32.397817 'extra' pak detected:extra.prsity

2019-05-11 16:58:32.450489 'extra' pak detected:extra.prsity

2019-05-11 16:58:32.501479 'extra' pak detected:extra.prsity

2019-05-11 16:58:32.562476 'extra' pak detected:extra.prsity

2019-05-11 16:58:32.602904 'extra' pak detected:extra.prsity

2019-05-11 16:58:32.643770 'extra' pak detected:extra.prsity

2019-05-11 16:58:32.694861 'extra' pak detected:extra.prsity

2019-05-11 16:58:32.735288 'extra' pak detected:extra.prsity

2019-05-11 16:58:32.772616 'extra' pak detected:extra.prsity

2019-05-11 16:58:32.856625 starting: writing grid tpl:hk3.dat\_gr.tpl

2019-05-11 16:58:32.866326 finished: writing grid tpl:hk3.dat\_gr.tpl took: 0:00:00.009701

2019-05-11 16:58:32.869347 starting: writing grid tpl:vka3.dat\_gr.tpl

2019-05-11 16:58:32.878196 finished: writing grid tpl:vka3.dat\_gr.tpl took: 0:00:00.008849

2019-05-11 16:58:32.881103 starting: writing grid tpl:ss3.dat\_gr.tpl

2019-05-11 16:58:32.890365 finished: writing grid tpl:ss3.dat\_gr.tpl took: 0:00:00.009262

2019-05-11 16:58:32.893239 starting: writing grid tpl:sy3.dat\_gr.tpl

2019-05-11 16:58:32.902663 finished: writing grid tpl:sy3.dat\_gr.tpl took: 0:00:00.009424

2019-05-11 16:58:32.905253 starting: writing grid tpl:str3.dat\_gr.tpl

2019-05-11 16:58:32.914721 finished: writing grid tpl:str3.dat\_gr.tpl took: 0:00:00.009468

2019-05-11 16:58:32.917537 starting: writing grid tpl:prsity3.dat\_gr.tpl

2019-05-11 16:58:32.931687 finished: writing grid tpl:prsity3.dat\_gr.tpl took: 0:00:00.014150

2019-05-11 16:58:32.935164 starting: writing grid tpl:hk4.dat\_gr.tpl

2019-05-11 16:58:32.945214 finished: writing grid tpl:hk4.dat\_gr.tpl took: 0:00:00.010050

2019-05-11 16:58:32.948084 starting: writing grid tpl:vka4.dat\_gr.tpl  
 2019-05-11 16:58:32.958050 finished: writing grid tpl:vka4.dat\_gr.tpl took: 0:00:00.009966  
 2019-05-11 16:58:32.960842 starting: writing grid tpl:ss4.dat\_gr.tpl  
 2019-05-11 16:58:32.970499 finished: writing grid tpl:ss4.dat\_gr.tpl took: 0:00:00.009657  
 2019-05-11 16:58:32.973541 starting: writing grid tpl:sy4.dat\_gr.tpl  
 2019-05-11 16:58:32.983382 finished: writing grid tpl:sy4.dat\_gr.tpl took: 0:00:00.009841  
 2019-05-11 16:58:32.986392 starting: writing grid tpl:strt4.dat\_gr.tpl  
 2019-05-11 16:58:32.996050 finished: writing grid tpl:strt4.dat\_gr.tpl took: 0:00:00.009658  
 2019-05-11 16:58:32.999221 starting: writing grid tpl:prsity4.dat\_gr.tpl  
 2019-05-11 16:58:33.011707 finished: writing grid tpl:prsity4.dat\_gr.tpl took: 0:00:00.012486  
 2019-05-11 16:58:33.015427 starting: writing grid tpl:hk5.dat\_gr.tpl  
 2019-05-11 16:58:33.025384 finished: writing grid tpl:hk5.dat\_gr.tpl took: 0:00:00.009957  
 2019-05-11 16:58:33.028510 starting: writing grid tpl:vka5.dat\_gr.tpl  
 2019-05-11 16:58:33.039767 finished: writing grid tpl:vka5.dat\_gr.tpl took: 0:00:00.011257  
 2019-05-11 16:58:33.042888 starting: writing grid tpl:ss5.dat\_gr.tpl  
 2019-05-11 16:58:33.053154 finished: writing grid tpl:ss5.dat\_gr.tpl took: 0:00:00.010266  
 2019-05-11 16:58:33.056431 starting: writing grid tpl:sy5.dat\_gr.tpl  
 2019-05-11 16:58:33.066752 finished: writing grid tpl:sy5.dat\_gr.tpl took: 0:00:00.010321  
 2019-05-11 16:58:33.069766 starting: writing grid tpl:strt5.dat\_gr.tpl  
 2019-05-11 16:58:33.079890 finished: writing grid tpl:strt5.dat\_gr.tpl took: 0:00:00.010124  
 2019-05-11 16:58:33.083216 starting: writing grid tpl:prsity5.dat\_gr.tpl  
 2019-05-11 16:58:33.096241 finished: writing grid tpl:prsity5.dat\_gr.tpl took: 0:00:00.013025  
 2019-05-11 16:58:33.099774 starting: writing grid tpl:rech2.dat\_gr.tpl  
 2019-05-11 16:58:33.109890 finished: writing grid tpl:rech2.dat\_gr.tpl took: 0:00:00.010116  
 2019-05-11 16:58:33.114026 starting: writing grid tpl:rech3.dat\_gr.tpl  
 2019-05-11 16:58:33.124783 finished: writing grid tpl:rech3.dat\_gr.tpl took: 0:00:00.010757  
 2019-05-11 16:58:33.127848 starting: writing const tpl:hk6.dat\_cn.tpl  
 2019-05-11 16:58:33.134630 finished: writing const tpl:hk6.dat\_cn.tpl took: 0:00:00.006782  
 2019-05-11 16:58:33.137646 starting: writing const tpl:vka6.dat\_cn.tpl  
 2019-05-11 16:58:33.145124 finished: writing const tpl:vka6.dat\_cn.tpl took: 0:00:00.007478  
 2019-05-11 16:58:33.148933 starting: writing const tpl:ss6.dat\_cn.tpl  
 2019-05-11 16:58:33.157072 finished: writing const tpl:ss6.dat\_cn.tpl took: 0:00:00.008139  
 2019-05-11 16:58:33.159768 starting: writing const tpl:sy6.dat\_cn.tpl  
 2019-05-11 16:58:33.167421 finished: writing const tpl:sy6.dat\_cn.tpl took: 0:00:00.007653  
 2019-05-11 16:58:33.170466 starting: writing const tpl:strt6.dat\_cn.tpl  
 2019-05-11 16:58:33.177077 finished: writing const tpl:strt6.dat\_cn.tpl took: 0:00:00.006611  
 2019-05-11 16:58:33.180249 starting: writing const tpl:prsity6.dat\_cn.tpl  
 2019-05-11 16:58:33.187065 finished: writing const tpl:prsity6.dat\_cn.tpl took: 0:00:00.006816  
 2019-05-11 16:58:33.190826 starting: writing const tpl:hk7.dat\_cn.tpl  
 2019-05-11 16:58:33.197587 finished: writing const tpl:hk7.dat\_cn.tpl took: 0:00:00.006761  
 2019-05-11 16:58:33.200881 starting: writing const tpl:vka7.dat\_cn.tpl  
 2019-05-11 16:58:33.207303 finished: writing const tpl:vka7.dat\_cn.tpl took: 0:00:00.006422  
 2019-05-11 16:58:33.210347 starting: writing const tpl:ss7.dat\_cn.tpl  
 2019-05-11 16:58:33.216803 finished: writing const tpl:ss7.dat\_cn.tpl took: 0:00:00.006456  
 2019-05-11 16:58:33.219715 starting: writing const tpl:sy7.dat\_cn.tpl  
 2019-05-11 16:58:33.226694 finished: writing const tpl:sy7.dat\_cn.tpl took: 0:00:00.006979  
 2019-05-11 16:58:33.229939 starting: writing const tpl:strt7.dat\_cn.tpl  
 2019-05-11 16:58:33.236944 finished: writing const tpl:strt7.dat\_cn.tpl took: 0:00:00.007005

```

2019-05-11 16:58:33.240118 starting: writing const tpl:prsity7.dat_cn.tpl
2019-05-11 16:58:33.246354 finished: writing const tpl:prsity7.dat_cn.tpl took: 0:00:00.006236
2019-05-11 16:58:33.249207 starting: writing const tpl:hk8.dat_cn.tpl
2019-05-11 16:58:33.255456 finished: writing const tpl:hk8.dat_cn.tpl took: 0:00:00.006249
2019-05-11 16:58:33.258943 starting: writing const tpl:vka8.dat_cn.tpl
2019-05-11 16:58:33.265614 finished: writing const tpl:vka8.dat_cn.tpl took: 0:00:00.006671
2019-05-11 16:58:33.268493 starting: writing const tpl:ss8.dat_cn.tpl
2019-05-11 16:58:33.274817 finished: writing const tpl:ss8.dat_cn.tpl took: 0:00:00.006324
2019-05-11 16:58:33.277638 starting: writing const tpl:sy8.dat_cn.tpl
2019-05-11 16:58:33.284236 finished: writing const tpl:sy8.dat_cn.tpl took: 0:00:00.006598
2019-05-11 16:58:33.287543 starting: writing const tpl:strt8.dat_cn.tpl
2019-05-11 16:58:33.294172 finished: writing const tpl:strt8.dat_cn.tpl took: 0:00:00.006629
2019-05-11 16:58:33.296976 starting: writing const tpl:prsity8.dat_cn.tpl
2019-05-11 16:58:33.303325 finished: writing const tpl:prsity8.dat_cn.tpl took: 0:00:00.006349
2019-05-11 16:58:33.306158 starting: writing const tpl:rech4.dat_cn.tpl
2019-05-11 16:58:33.312361 finished: writing const tpl:rech4.dat_cn.tpl took: 0:00:00.006203
2019-05-11 16:58:33.315297 starting: writing const tpl:rech5.dat_cn.tpl
2019-05-11 16:58:33.321563 finished: writing const tpl:rech5.dat_cn.tpl took: 0:00:00.006266
2019-05-11 16:58:33.348294 starting: setting up pilot point process
2019-05-11 16:58:33.348473 WARNING: pp_geostruc is None, using ExpVario with contribution=1 and
2019-05-11 16:58:33.352292 pp_dict: {0: ['hk0', 'vka0', 'ss0', 'sy0', 'strt0', 'prsity0', 'rech
2019-05-11 16:58:33.352627 starting: calling setup_pilot_point_grid()
2019-05-11 16:58:34.006446 640 pilot point parameters created
2019-05-11 16:58:34.007178 pilot point 'pargp':hk0,vka0,ss0,sy0,strt0,prsity0,rech0,rech1,sy1,l
2019-05-11 16:58:34.007233 finished: calling setup_pilot_point_grid() took: 0:00:00.654606
2019-05-11 16:58:34.009510 starting: calculating factors for p=hk0, k=0
2019-05-11 16:58:34.010272 saving krige variance file:template/pp_k0_general_zn.fac
2019-05-11 16:58:34.010325 saving krige factors file:template/pp_k0_general_zn.fac
starting interp point loop for 800 points
took 2.659873 seconds
2019-05-11 16:58:36.724609 finished: calculating factors for p=hk0, k=0 took: 0:00:02.715099
2019-05-11 16:58:36.725756 starting: calculating factors for p=vka0, k=0
2019-05-11 16:58:36.726552 finished: calculating factors for p=vka0, k=0 took: 0:00:00.000796
2019-05-11 16:58:36.727163 starting: calculating factors for p=ss0, k=0
2019-05-11 16:58:36.728434 finished: calculating factors for p=ss0, k=0 took: 0:00:00.001271
2019-05-11 16:58:36.729340 starting: calculating factors for p=sy0, k=0
2019-05-11 16:58:36.730294 finished: calculating factors for p=sy0, k=0 took: 0:00:00.000954
2019-05-11 16:58:36.730891 starting: calculating factors for p=strt0, k=0
2019-05-11 16:58:36.731827 finished: calculating factors for p=strt0, k=0 took: 0:00:00.000936
2019-05-11 16:58:36.732418 starting: calculating factors for p=prsity0, k=0
2019-05-11 16:58:36.733670 finished: calculating factors for p=prsity0, k=0 took: 0:00:00.001271
2019-05-11 16:58:36.734563 starting: calculating factors for p=rech0, k=0
2019-05-11 16:58:36.735574 finished: calculating factors for p=rech0, k=0 took: 0:00:00.001011
2019-05-11 16:58:36.736179 starting: calculating factors for p=rech1, k=0
2019-05-11 16:58:36.736843 finished: calculating factors for p=rech1, k=0 took: 0:00:00.000664
2019-05-11 16:58:36.737857 starting: calculating factors for p=sy1, k=1
2019-05-11 16:58:36.738699 saving krige variance file:template/pp_k1_general_zn.fac
2019-05-11 16:58:36.738966 saving krige factors file:template/pp_k1_general_zn.fac

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starting interp point loop for 800 points
took 2.603323 seconds
2019-05-11 16:58:39.398384 finished: calculating factors for p=sy1, k=1 took: 0:00:02.660527
2019-05-11 16:58:39.399799 starting: calculating factors for p=hk1, k=1
2019-05-11 16:58:39.401213 finished: calculating factors for p=hk1, k=1 took: 0:00:00.001414
2019-05-11 16:58:39.402315 starting: calculating factors for p=vka1, k=1
2019-05-11 16:58:39.403286 finished: calculating factors for p=vka1, k=1 took: 0:00:00.000971
2019-05-11 16:58:39.403902 starting: calculating factors for p=ss1, k=1
2019-05-11 16:58:39.405121 finished: calculating factors for p=ss1, k=1 took: 0:00:00.001219
2019-05-11 16:58:39.405730 starting: calculating factors for p=prsity1, k=1
2019-05-11 16:58:39.406449 finished: calculating factors for p=prsity1, k=1 took: 0:00:00.0007
2019-05-11 16:58:39.407513 starting: calculating factors for p=strt1, k=1
2019-05-11 16:58:39.408350 finished: calculating factors for p=strt1, k=1 took: 0:00:00.000837
2019-05-11 16:58:39.409086 starting: calculating factors for p=prsity2, k=2
2019-05-11 16:58:39.409927 saving krige variance file:template/pp_k2_general_zn.fac
2019-05-11 16:58:39.410061 saving krige factors file:template/pp_k2_general_zn.fac
starting interp point loop for 800 points
took 2.62104 seconds
2019-05-11 16:58:42.086791 finished: calculating factors for p=prsity2, k=2 took: 0:00:02.6777
2019-05-11 16:58:42.087701 starting: calculating factors for p=ss2, k=2
2019-05-11 16:58:42.088486 finished: calculating factors for p=ss2, k=2 took: 0:00:00.000785
2019-05-11 16:58:42.089598 starting: calculating factors for p=hk2, k=2
2019-05-11 16:58:42.090321 finished: calculating factors for p=hk2, k=2 took: 0:00:00.000723
2019-05-11 16:58:42.091235 starting: calculating factors for p=vka2, k=2
2019-05-11 16:58:42.092161 finished: calculating factors for p=vka2, k=2 took: 0:00:00.000926
2019-05-11 16:58:42.092877 starting: calculating factors for p=sy2, k=2
2019-05-11 16:58:42.093828 finished: calculating factors for p=sy2, k=2 took: 0:00:00.000951
2019-05-11 16:58:42.094605 starting: calculating factors for p=strt2, k=2
2019-05-11 16:58:42.095308 finished: calculating factors for p=strt2, k=2 took: 0:00:00.000703
2019-05-11 16:58:42.096010 starting: processing pp_prefix:hk0
2019-05-11 16:58:42.107973 starting: processing pp_prefix:ss0
2019-05-11 16:58:42.116854 starting: processing pp_prefix:prsity2
2019-05-11 16:58:42.125038 starting: processing pp_prefix:strt2
2019-05-11 16:58:42.133265 starting: processing pp_prefix:prsity1
2019-05-11 16:58:42.141724 starting: processing pp_prefix:vka0
2019-05-11 16:58:42.149978 starting: processing pp_prefix:sy2
2019-05-11 16:58:42.158545 starting: processing pp_prefix:sy1
2019-05-11 16:58:42.167130 starting: processing pp_prefix:rech0
2019-05-11 16:58:42.175465 starting: processing pp_prefix:vka1
2019-05-11 16:58:42.183950 starting: processing pp_prefix:sy0
2019-05-11 16:58:42.193416 starting: processing pp_prefix:strt1
2019-05-11 16:58:42.202395 starting: processing pp_prefix:prsity0
2019-05-11 16:58:42.210616 starting: processing pp_prefix:rech1
2019-05-11 16:58:42.218699 starting: processing pp_prefix:ss1
2019-05-11 16:58:42.227387 starting: processing pp_prefix:vka2
2019-05-11 16:58:42.235771 starting: processing pp_prefix:ss2
2019-05-11 16:58:42.244059 starting: processing pp_prefix:strt0
2019-05-11 16:58:42.252187 starting: processing pp_prefix:hk2

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2019-05-11 16:58:42.260579 starting: processing pp_prefix:hk1
2019-05-11 16:58:42.369850 finished: setting up pilot point process took: 0:00:09.021556
2019-05-11 16:58:42.370841 starting: setting up grid process
2019-05-11 16:58:42.371369 WARNING: grid_geostruc is None, using ExpVario with contribution=1
2019-05-11 16:58:42.371512 finished: setting up grid process took: 0:00:00.000671
2019-05-11 16:58:42.374136 starting: save test mlt array arr_mlt/hk0.dat_pp
2019-05-11 16:58:42.376369 finished: save test mlt array arr_mlt/hk0.dat_pp took: 0:00:00.00223
2019-05-11 16:58:42.377263 starting: save test mlt array arr_mlt/vka0.dat_pp
2019-05-11 16:58:42.379323 finished: save test mlt array arr_mlt/vka0.dat_pp took: 0:00:00.0020
2019-05-11 16:58:42.380173 starting: save test mlt array arr_mlt/ss0.dat_pp
2019-05-11 16:58:42.386669 finished: save test mlt array arr_mlt/ss0.dat_pp took: 0:00:00.0064
2019-05-11 16:58:42.387664 starting: save test mlt array arr_mlt/sy0.dat_pp
2019-05-11 16:58:42.389886 finished: save test mlt array arr_mlt/sy0.dat_pp took: 0:00:00.0022
2019-05-11 16:58:42.390838 starting: save test mlt array arr_mlt/strt0.dat_pp
2019-05-11 16:58:42.392936 finished: save test mlt array arr_mlt/strt0.dat_pp took: 0:00:00.00
2019-05-11 16:58:42.394105 starting: save test mlt array arr_mlt/prsity0.dat_pp
2019-05-11 16:58:42.396653 finished: save test mlt array arr_mlt/prsity0.dat_pp took: 0:00:00.
2019-05-11 16:58:42.397810 starting: save test mlt array arr_mlt/hk1.dat_pp
2019-05-11 16:58:42.399996 finished: save test mlt array arr_mlt/hk1.dat_pp took: 0:00:00.0021
2019-05-11 16:58:42.400895 starting: save test mlt array arr_mlt/vka1.dat_pp
2019-05-11 16:58:42.402962 finished: save test mlt array arr_mlt/vka1.dat_pp took: 0:00:00.002
2019-05-11 16:58:42.403789 starting: save test mlt array arr_mlt/ss1.dat_pp
2019-05-11 16:58:42.405965 finished: save test mlt array arr_mlt/ss1.dat_pp took: 0:00:00.0021
2019-05-11 16:58:42.406918 starting: save test mlt array arr_mlt/sy1.dat_pp
2019-05-11 16:58:42.409158 finished: save test mlt array arr_mlt/sy1.dat_pp took: 0:00:00.0022
2019-05-11 16:58:42.410106 starting: save test mlt array arr_mlt/strt1.dat_pp
2019-05-11 16:58:42.412287 finished: save test mlt array arr_mlt/strt1.dat_pp took: 0:00:00.00
2019-05-11 16:58:42.413313 starting: save test mlt array arr_mlt/prsity1.dat_pp
2019-05-11 16:58:42.415648 finished: save test mlt array arr_mlt/prsity1.dat_pp took: 0:00:00.
2019-05-11 16:58:42.416649 starting: save test mlt array arr_mlt/hk2.dat_pp
2019-05-11 16:58:42.418979 finished: save test mlt array arr_mlt/hk2.dat_pp took: 0:00:00.0023
2019-05-11 16:58:42.419761 starting: save test mlt array arr_mlt/vka2.dat_pp
2019-05-11 16:58:42.422123 finished: save test mlt array arr_mlt/vka2.dat_pp took: 0:00:00.002
2019-05-11 16:58:42.422859 starting: save test mlt array arr_mlt/ss2.dat_pp
2019-05-11 16:58:42.425094 finished: save test mlt array arr_mlt/ss2.dat_pp took: 0:00:00.0022
2019-05-11 16:58:42.425923 starting: save test mlt array arr_mlt/sy2.dat_pp
2019-05-11 16:58:42.428194 finished: save test mlt array arr_mlt/sy2.dat_pp took: 0:00:00.0022
2019-05-11 16:58:42.429160 starting: save test mlt array arr_mlt/strt2.dat_pp
2019-05-11 16:58:42.431769 finished: save test mlt array arr_mlt/strt2.dat_pp took: 0:00:00.00
2019-05-11 16:58:42.432828 starting: save test mlt array arr_mlt/prsity2.dat_pp
2019-05-11 16:58:42.435273 finished: save test mlt array arr_mlt/prsity2.dat_pp took: 0:00:00.
2019-05-11 16:58:42.436186 starting: save test mlt array arr_mlt/rech0.dat_pp
2019-05-11 16:58:42.438376 finished: save test mlt array arr_mlt/rech0.dat_pp took: 0:00:00.00
2019-05-11 16:58:42.439247 starting: save test mlt array arr_mlt/rech1.dat_pp
2019-05-11 16:58:42.441723 finished: save test mlt array arr_mlt/rech1.dat_pp took: 0:00:00.00
2019-05-11 16:58:42.443554 starting: save test mlt array arr_mlt/hk3.dat_gr
2019-05-11 16:58:42.447099 finished: save test mlt array arr_mlt/hk3.dat_gr took: 0:00:00.0035
2019-05-11 16:58:42.448584 starting: save test mlt array arr_mlt/vka3.dat_gr

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2019-05-11 16:58:42.452230 finished: save test mlt array arr\_mlt/vka3.dat\_gr took: 0:00:00.0030  
 2019-05-11 16:58:42.453774 starting: save test mlt array arr\_mlt/ss3.dat\_gr  
 2019-05-11 16:58:42.457187 finished: save test mlt array arr\_mlt/ss3.dat\_gr took: 0:00:00.0034  
 2019-05-11 16:58:42.458697 starting: save test mlt array arr\_mlt/sy3.dat\_gr  
 2019-05-11 16:58:42.462184 finished: save test mlt array arr\_mlt/sy3.dat\_gr took: 0:00:00.0034  
 2019-05-11 16:58:42.463900 starting: save test mlt array arr\_mlt/strt3.dat\_gr  
 2019-05-11 16:58:42.467502 finished: save test mlt array arr\_mlt/strt3.dat\_gr took: 0:00:00.0030  
 2019-05-11 16:58:42.468900 starting: save test mlt array arr\_mlt/prsity3.dat\_gr  
 2019-05-11 16:58:42.472602 finished: save test mlt array arr\_mlt/prsity3.dat\_gr took: 0:00:00.0030  
 2019-05-11 16:58:42.474059 starting: save test mlt array arr\_mlt/hk4.dat\_gr  
 2019-05-11 16:58:42.477696 finished: save test mlt array arr\_mlt/hk4.dat\_gr took: 0:00:00.0036  
 2019-05-11 16:58:42.479294 starting: save test mlt array arr\_mlt/vka4.dat\_gr  
 2019-05-11 16:58:42.482874 finished: save test mlt array arr\_mlt/vka4.dat\_gr took: 0:00:00.0030  
 2019-05-11 16:58:42.484310 starting: save test mlt array arr\_mlt/ss4.dat\_gr  
 2019-05-11 16:58:42.487804 finished: save test mlt array arr\_mlt/ss4.dat\_gr took: 0:00:00.0034  
 2019-05-11 16:58:42.489517 starting: save test mlt array arr\_mlt/sy4.dat\_gr  
 2019-05-11 16:58:42.492802 finished: save test mlt array arr\_mlt/sy4.dat\_gr took: 0:00:00.0032  
 2019-05-11 16:58:42.493874 starting: save test mlt array arr\_mlt/strt4.dat\_gr  
 2019-05-11 16:58:42.496481 finished: save test mlt array arr\_mlt/strt4.dat\_gr took: 0:00:00.0030  
 2019-05-11 16:58:42.497407 starting: save test mlt array arr\_mlt/prsity4.dat\_gr  
 2019-05-11 16:58:42.500537 finished: save test mlt array arr\_mlt/prsity4.dat\_gr took: 0:00:00.0030  
 2019-05-11 16:58:42.501921 starting: save test mlt array arr\_mlt/hk5.dat\_gr  
 2019-05-11 16:58:42.505264 finished: save test mlt array arr\_mlt/hk5.dat\_gr took: 0:00:00.0033  
 2019-05-11 16:58:42.506485 starting: save test mlt array arr\_mlt/vka5.dat\_gr  
 2019-05-11 16:58:42.509533 finished: save test mlt array arr\_mlt/vka5.dat\_gr took: 0:00:00.0030  
 2019-05-11 16:58:42.510915 starting: save test mlt array arr\_mlt/ss5.dat\_gr  
 2019-05-11 16:58:42.514364 finished: save test mlt array arr\_mlt/ss5.dat\_gr took: 0:00:00.0034  
 2019-05-11 16:58:42.515491 starting: save test mlt array arr\_mlt/sy5.dat\_gr  
 2019-05-11 16:58:42.518595 finished: save test mlt array arr\_mlt/sy5.dat\_gr took: 0:00:00.0031  
 2019-05-11 16:58:42.519888 starting: save test mlt array arr\_mlt/strt5.dat\_gr  
 2019-05-11 16:58:42.522952 finished: save test mlt array arr\_mlt/strt5.dat\_gr took: 0:00:00.0030  
 2019-05-11 16:58:42.524581 starting: save test mlt array arr\_mlt/prsity5.dat\_gr  
 2019-05-11 16:58:42.527477 finished: save test mlt array arr\_mlt/prsity5.dat\_gr took: 0:00:00.0030  
 2019-05-11 16:58:42.528729 starting: save test mlt array arr\_mlt/rech2.dat\_gr  
 2019-05-11 16:58:42.532178 finished: save test mlt array arr\_mlt/rech2.dat\_gr took: 0:00:00.0030  
 2019-05-11 16:58:42.533719 starting: save test mlt array arr\_mlt/rech3.dat\_gr  
 2019-05-11 16:58:42.537274 finished: save test mlt array arr\_mlt/rech3.dat\_gr took: 0:00:00.0030  
 2019-05-11 16:58:42.538934 starting: save test mlt array arr\_mlt/hk6.dat\_cn  
 2019-05-11 16:58:42.541970 finished: save test mlt array arr\_mlt/hk6.dat\_cn took: 0:00:00.0030  
 2019-05-11 16:58:42.543348 starting: save test mlt array arr\_mlt/vka6.dat\_cn  
 2019-05-11 16:58:42.547742 finished: save test mlt array arr\_mlt/vka6.dat\_cn took: 0:00:00.0040  
 2019-05-11 16:58:42.549270 starting: save test mlt array arr\_mlt/ss6.dat\_cn  
 2019-05-11 16:58:42.552658 finished: save test mlt array arr\_mlt/ss6.dat\_cn took: 0:00:00.0033  
 2019-05-11 16:58:42.553807 starting: save test mlt array arr\_mlt/sy6.dat\_cn  
 2019-05-11 16:58:42.556306 finished: save test mlt array arr\_mlt/sy6.dat\_cn took: 0:00:00.0024  
 2019-05-11 16:58:42.557717 starting: save test mlt array arr\_mlt/strt6.dat\_cn  
 2019-05-11 16:58:42.561069 finished: save test mlt array arr\_mlt/strt6.dat\_cn took: 0:00:00.0030  
 2019-05-11 16:58:42.562517 starting: save test mlt array arr\_mlt/prsity6.dat\_cn

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2019-05-11 16:58:42.565540 finished: save test mlt array arr_mlt/prsity6.dat_cn took: 0:00:00.
2019-05-11 16:58:42.566876 starting: save test mlt array arr_mlt/hk7.dat_cn
2019-05-11 16:58:42.569517 finished: save test mlt array arr_mlt/hk7.dat_cn took: 0:00:00.0026
2019-05-11 16:58:42.570974 starting: save test mlt array arr_mlt/vka7.dat_cn
2019-05-11 16:58:42.574579 finished: save test mlt array arr_mlt/vka7.dat_cn took: 0:00:00.003
2019-05-11 16:58:42.576036 starting: save test mlt array arr_mlt/ss7.dat_cn
2019-05-11 16:58:42.579724 finished: save test mlt array arr_mlt/ss7.dat_cn took: 0:00:00.0036
2019-05-11 16:58:42.581275 starting: save test mlt array arr_mlt/sy7.dat_cn
2019-05-11 16:58:42.584891 finished: save test mlt array arr_mlt/sy7.dat_cn took: 0:00:00.0036
2019-05-11 16:58:42.586402 starting: save test mlt array arr_mlt/strt7.dat_cn
2019-05-11 16:58:42.589789 finished: save test mlt array arr_mlt/strt7.dat_cn took: 0:00:00.003
2019-05-11 16:58:42.591000 starting: save test mlt array arr_mlt/prsity7.dat_cn
2019-05-11 16:58:42.594466 finished: save test mlt array arr_mlt/prsity7.dat_cn took: 0:00:00.
2019-05-11 16:58:42.595990 starting: save test mlt array arr_mlt/hk8.dat_cn
2019-05-11 16:58:42.598910 finished: save test mlt array arr_mlt/hk8.dat_cn took: 0:00:00.0029
2019-05-11 16:58:42.599921 starting: save test mlt array arr_mlt/vka8.dat_cn
2019-05-11 16:58:42.602716 finished: save test mlt array arr_mlt/vka8.dat_cn took: 0:00:00.002
2019-05-11 16:58:42.604188 starting: save test mlt array arr_mlt/ss8.dat_cn
2019-05-11 16:58:42.607381 finished: save test mlt array arr_mlt/ss8.dat_cn took: 0:00:00.0031
2019-05-11 16:58:42.608568 starting: save test mlt array arr_mlt/sy8.dat_cn
2019-05-11 16:58:42.611451 finished: save test mlt array arr_mlt/sy8.dat_cn took: 0:00:00.0028
2019-05-11 16:58:42.612634 starting: save test mlt array arr_mlt/strt8.dat_cn
2019-05-11 16:58:42.616100 finished: save test mlt array arr_mlt/strt8.dat_cn took: 0:00:00.003
2019-05-11 16:58:42.617644 starting: save test mlt array arr_mlt/prsity8.dat_cn
2019-05-11 16:58:42.620383 finished: save test mlt array arr_mlt/prsity8.dat_cn took: 0:00:00.
2019-05-11 16:58:42.621631 starting: save test mlt array arr_mlt/rech4.dat_cn
2019-05-11 16:58:42.624686 finished: save test mlt array arr_mlt/rech4.dat_cn took: 0:00:00.003
2019-05-11 16:58:42.626334 starting: save test mlt array arr_mlt/rech5.dat_cn
2019-05-11 16:58:42.629659 finished: save test mlt array arr_mlt/rech5.dat_cn took: 0:00:00.003
2019-05-11 16:58:43.244516 forward_run line:pyemu.helpers.apply_array_pars()

all zeros for runoff...skipping...
all zeros for hcond1...skipping...
all zeros for ppts...skipping...
2019-05-11 16:58:43.378135 starting: processing obs type mflist water budget obs
2019-05-11 16:58:43.469682 forward_run line:pyemu.gw_utils.apply_mflist_budget_obs('freyberg.l
2019-05-11 16:58:43.470109 finished: processing obs type mflist water budget obs took: 0:00:00
2019-05-11 16:58:43.470365 starting: processing obs type hyd file
2019-05-11 16:58:43.470572 finished: processing obs type hyd file took: 0:00:00.000207
2019-05-11 16:58:43.470839 starting: processing obs type external obs-sim smp files
2019-05-11 16:58:43.470993 finished: processing obs type external obs-sim smp files took: 0:00
2019-05-11 16:58:43.471955 starting: processing obs type hob
2019-05-11 16:58:43.472454 finished: processing obs type hob took: 0:00:00.000499
2019-05-11 16:58:43.472513 starting: processing obs type hds
[[0, 0], [0, 1], [0, 2], [1, 0], [1, 1], [1, 2]]
2019-05-11 16:58:43.903938 finished: processing obs type hds took: 0:00:00.431425
2019-05-11 16:58:43.904394 starting: processing obs type sfr
writing 'sfr_obs.config' to template/sfr_obs.config

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2019-05-11 16:58:44.241271 finished: processing obs type sfr took: 0:00:00.336877
2019-05-11 16:58:44.241775 changing dir in to template
2019-05-11 16:58:44.242490 starting: instantiating control file from i/o files
2019-05-11 16:58:44.242578 tpl files: drn.csv.tpl,wel.csv.tpl,hk3.dat_gr.tpl,vka3.dat_gr.tpl,s
2019-05-11 16:58:44.242621 ins files: freyberg.hds.dat.ins,vol.dat.ins,freyberg.sfr.out.proces
2019-05-11 16:58:44.585111 finished: instantiating control file from i/o files took: 0:00:00.3
2019-05-11 16:58:44.829554 starting: writing forward_run.py
2019-05-11 16:58:44.830561 finished: writing forward_run.py took: 0:00:00.001007
2019-05-11 16:58:44.830636 writing pst template/freyberg.pst
noptmax:0, npar_adj:14819, nnz_obs:4434
2019-05-11 16:58:46.725288 starting: running pestchek on freyberg.pst
2019-05-11 16:58:46.812525 pestcheck:PESTCHEK Version 13.0. Watermark Numerical Computing.
2019-05-11 16:58:46.812866 pestcheck:
2019-05-11 16:58:46.812917 pestcheck:Errors ----->
2019-05-11 16:58:46.812972 pestcheck:Line 2403 of file freyberg.pst: parameter name "prsity300
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2019-05-11 16:58:46.813036 pestcheck:Line 2404 of file freyberg.pst: parameter name "prsity300
2019-05-11 16:58:46.813103 pestcheck:12 characters long.
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2019-05-11 16:58:46.841785 pestcheck:Line 2470 of file freyberg.pst: parameter name "prsity3003  
2019-05-11 16:58:46.841884 pestcheck:once.  
2019-05-11 16:58:46.841940 pestcheck:Line 2471 of file freyberg.pst: parameter name "prsity3003  
2019-05-11 16:58:46.842045 pestcheck:12 characters long.  
2019-05-11 16:58:46.842153 pestcheck:Line 2471 of file freyberg.pst: parameter name "prsity3003  
2019-05-11 16:58:46.842270 pestcheck:once.  
2019-05-11 16:58:46.842376 pestcheck:Line 2472 of file freyberg.pst: parameter name "prsity3003  
2019-05-11 16:58:46.842423 pestcheck:12 characters long.  
2019-05-11 16:58:46.842528 pestcheck:Line 2472 of file freyberg.pst: parameter name "prsity3003  
2019-05-11 16:58:46.842820 pestcheck:once.  
2019-05-11 16:58:46.842929 pestcheck:Line 2473 of file freyberg.pst: parameter name "prsity3003  
2019-05-11 16:58:46.843066 pestcheck:12 characters long.  
2019-05-11 16:58:46.845805 pestcheck:Line 2474 of file freyberg.pst: parameter name "prsity3003  
2019-05-11 16:58:46.845893 pestcheck:12 characters long.  
2019-05-11 16:58:46.845933 pestcheck:Line 2474 of file freyberg.pst: parameter name "prsity3003  
2019-05-11 16:58:46.846055 pestcheck:once.  
2019-05-11 16:58:46.846085 pestcheck:Line 2475 of file freyberg.pst: parameter name "prsity3003  
2019-05-11 16:58:46.846118 pestcheck:12 characters long.



2019-05-11 16:58:46.846169 pestcheck:Line 2475 of file freyberg.pst: parameter name "prsity3003  
2019-05-11 16:58:46.846204 pestcheck:once.  
2019-05-11 16:58:46.846322 pestcheck:Line 2476 of file freyberg.pst: parameter name "prsity3003  
2019-05-11 16:58:46.846356 pestcheck:12 characters long.  
2019-05-11 16:58:46.846413 pestcheck:Line 2476 of file freyberg.pst: parameter name "prsity3003  
2019-05-11 16:58:46.846480 pestcheck:once.  
2019-05-11 16:58:46.846596 pestcheck:Line 2477 of file freyberg.pst: parameter name "prsity3003  
2019-05-11 16:58:46.846631 pestcheck:12 characters long.  
2019-05-11 16:58:46.846668 pestcheck:Line 2477 of file freyberg.pst: parameter name "prsity3003  
2019-05-11 16:58:46.846702 pestcheck:once.  
2019-05-11 16:58:46.846754 pestcheck:Line 2478 of file freyberg.pst: parameter name "prsity3003  
2019-05-11 16:58:46.846788 pestcheck:12 characters long.  
2019-05-11 16:58:46.846926 pestcheck:Line 2478 of file freyberg.pst: parameter name "prsity3003  
2019-05-11 16:58:46.846991 pestcheck:once.  
2019-05-11 16:58:46.847091 pestcheck:Line 2479 of file freyberg.pst: parameter name "prsity3003  
2019-05-11 16:58:46.847142 pestcheck:12 characters long.  
2019-05-11 16:58:46.847242 pestcheck:Line 2479 of file freyberg.pst: parameter name "prsity3003  
2019-05-11 16:58:46.847290 pestcheck:once.  
2019-05-11 16:58:46.847329 pestcheck:Line 2480 of file freyberg.pst: parameter name "prsity3003  
2019-05-11 16:58:46.847434 pestcheck:12 characters long.  
2019-05-11 16:58:46.847485 pestcheck:Line 2480 of file freyberg.pst: parameter name "prsity3003  
2019-05-11 16:58:46.847582 pestcheck:once.  
2019-05-11 16:58:46.847631 pestcheck:Line 2481 of file freyberg.pst: parameter name "prsity3003  
2019-05-11 16:58:46.847670 pestcheck:12 characters long.  
2019-05-11 16:58:46.847773 pestcheck:Line 2481 of file freyberg.pst: parameter name "prsity3003  
2019-05-11 16:58:46.847896 pestcheck:once.  
2019-05-11 16:58:46.848000 pestcheck:Line 2482 of file freyberg.pst: parameter name "prsity3003  
2019-05-11 16:58:46.848108 pestcheck:12 characters long.  
2019-05-11 16:58:46.848144 pestcheck:Line 2482 of file freyberg.pst: parameter name "prsity3003  
2019-05-11 16:58:46.848173 pestcheck:once.  
2019-05-11 16:58:46.848201 pestcheck:Line 2483 of file freyberg.pst: parameter name "prsity3004  
2019-05-11 16:58:46.848248 pestcheck:12 characters long.  
2019-05-11 16:58:46.848380 pestcheck:Line 2484 of file freyberg.pst: parameter name "prsity3004  
2019-05-11 16:58:46.848476 pestcheck:12 characters long.  
2019-05-11 16:58:46.848524 pestcheck:Line 2484 of file freyberg.pst: parameter name "prsity3004  
2019-05-11 16:58:46.848563 pestcheck:once.  
2019-05-11 16:58:46.848664 pestcheck:Line 2485 of file freyberg.pst: parameter name "prsity3004  
2019-05-11 16:58:46.848714 pestcheck:12 characters long.  
2019-05-11 16:58:46.848809 pestcheck:Line 2485 of file freyberg.pst: parameter name "prsity3004  
2019-05-11 16:58:46.848868 pestcheck:once.  
2019-05-11 16:58:46.848968 pestcheck:Line 2486 of file freyberg.pst: parameter name "prsity3004  
2019-05-11 16:58:46.849019 pestcheck:12 characters long.  
2019-05-11 16:58:46.849114 pestcheck:Line 2486 of file freyberg.pst: parameter name "prsity3004  
2019-05-11 16:58:46.849160 pestcheck:once.  
2019-05-11 16:58:46.849198 pestcheck:Line 2487 of file freyberg.pst: parameter name "prsity3004  
2019-05-11 16:58:46.849302 pestcheck:12 characters long.  
2019-05-11 16:58:46.849407 pestcheck:Line 2487 of file freyberg.pst: parameter name "prsity3004  
2019-05-11 16:58:46.849522 pestcheck:once.

2019-05-11 16:58:46.849627 pestcheck:Line 2488 of file freyberg.pst: parameter name "prsity3004  
2019-05-11 16:58:46.849674 pestcheck:12 characters long.  
2019-05-11 16:58:46.849784 pestcheck:Line 2488 of file freyberg.pst: parameter name "prsity3004  
2019-05-11 16:58:46.849973 pestcheck:once.  
2019-05-11 16:58:46.850079 pestcheck:Line 2489 of file freyberg.pst: parameter name "prsity3004  
2019-05-11 16:58:46.850193 pestcheck:12 characters long.  
2019-05-11 16:58:46.850298 pestcheck:Line 2489 of file freyberg.pst: parameter name "prsity3004  
2019-05-11 16:58:46.850350 pestcheck:once.  
2019-05-11 16:58:46.850388 pestcheck:Line 2490 of file freyberg.pst: parameter name "prsity3004  
2019-05-11 16:58:46.850489 pestcheck:12 characters long.  
2019-05-11 16:58:46.850594 pestcheck:Line 2490 of file freyberg.pst: parameter name "prsity3004  
2019-05-11 16:58:46.850644 pestcheck:once.  
2019-05-11 16:58:46.850685 pestcheck:Line 2491 of file freyberg.pst: parameter name "prsity3004  
2019-05-11 16:58:46.850787 pestcheck:12 characters long.  
2019-05-11 16:58:46.850908 pestcheck:Line 2491 of file freyberg.pst: parameter name "prsity3004  
2019-05-11 16:58:46.850947 pestcheck:once.  
2019-05-11 16:58:46.851047 pestcheck:Line 2492 of file freyberg.pst: parameter name "prsity3004  
2019-05-11 16:58:46.851152 pestcheck:12 characters long.  
2019-05-11 16:58:46.851199 pestcheck:Line 2492 of file freyberg.pst: parameter name "prsity3004  
2019-05-11 16:58:46.851238 pestcheck:once.  
2019-05-11 16:58:46.851339 pestcheck:Line 2493 of file freyberg.pst: parameter name "prsity3004  
2019-05-11 16:58:46.851470 pestcheck:12 characters long.  
2019-05-11 16:58:46.851518 pestcheck:Line 2494 of file freyberg.pst: parameter name "prsity3004  
2019-05-11 16:58:46.851625 pestcheck:12 characters long.  
2019-05-11 16:58:46.851675 pestcheck:Line 2494 of file freyberg.pst: parameter name "prsity3004  
2019-05-11 16:58:46.851770 pestcheck:once.  
2019-05-11 16:58:46.851892 pestcheck:Line 2495 of file freyberg.pst: parameter name "prsity3004  
2019-05-11 16:58:46.851941 pestcheck:12 characters long.  
2019-05-11 16:58:46.852036 pestcheck:Line 2495 of file freyberg.pst: parameter name "prsity3004  
2019-05-11 16:58:46.852153 pestcheck:once.  
2019-05-11 16:58:46.852228 pestcheck:Line 2496 of file freyberg.pst: parameter name "prsity3004  
2019-05-11 16:58:46.852393 pestcheck:12 characters long.  
2019-05-11 16:58:46.852456 pestcheck:Line 2496 of file freyberg.pst: parameter name "prsity3004  
2019-05-11 16:58:46.852500 pestcheck:once.  
2019-05-11 16:58:46.852612 pestcheck:Line 2497 of file freyberg.pst: parameter name "prsity3004  
2019-05-11 16:58:46.853334 pestcheck:12 characters long.  
2019-05-11 16:58:46.853534 pestcheck:Line 2497 of file freyberg.pst: parameter name "prsity3004  
2019-05-11 16:58:46.853644 pestcheck:once.  
2019-05-11 16:58:46.853693 pestcheck:Line 2498 of file freyberg.pst: parameter name "prsity3004  
2019-05-11 16:58:46.853744 pestcheck:12 characters long.  
2019-05-11 16:58:46.853798 pestcheck:Line 2498 of file freyberg.pst: parameter name "prsity3004  
2019-05-11 16:58:46.853912 pestcheck:once.  
2019-05-11 16:58:46.854029 pestcheck:Line 2499 of file freyberg.pst: parameter name "prsity3004  
2019-05-11 16:58:46.854078 pestcheck:12 characters long.  
2019-05-11 16:58:46.854118 pestcheck:Line 2499 of file freyberg.pst: parameter name "prsity3004  
2019-05-11 16:58:46.854190 pestcheck:once.  
2019-05-11 16:58:46.854267 pestcheck:Line 2500 of file freyberg.pst: parameter name "prsity3004  
2019-05-11 16:58:46.854376 pestcheck:12 characters long.

```

2019-05-11 16:58:46.854498 pestcheck:Line 2500 of file freyberg.pst: parameter name "prsity300
2019-05-11 16:58:46.854605 pestcheck:once.
2019-05-11 16:58:46.854652 pestcheck:Line 2501 of file freyberg.pst: parameter name "prsity300
2019-05-11 16:58:46.854758 pestcheck:12 characters long.
2019-05-11 16:58:46.854863 pestcheck:Line 2501 of file freyberg.pst: parameter name "prsity300
2019-05-11 16:58:46.854978 pestcheck:once.
2019-05-11 16:58:46.855084 pestcheck:Line 2502 of file freyberg.pst: parameter name "prsity300
2019-05-11 16:58:46.855199 pestcheck:12 characters long.
2019-05-11 16:58:46.855304 pestcheck:Line 2502 of file freyberg.pst: parameter name "prsity300
2019-05-11 16:58:46.855419 pestcheck:once.
2019-05-11 16:58:46.855539 pestcheck:Line 2503 of file freyberg.pst: parameter name "prsity300
2019-05-11 16:58:46.855644 pestcheck:12 characters long.
2019-05-11 16:58:46.855749 pestcheck:Line 2504 of file freyberg.pst: parameter name "prsity300
2019-05-11 16:58:46.855863 pestcheck:12 characters long.
2019-05-11 16:58:46.855968 pestcheck:Line 2504 of file freyberg.pst: parameter name "prsity300
2019-05-11 16:58:46.856082 pestcheck:once.
2019-05-11 16:58:46.856188 pestcheck:Line 2505 of file freyberg.pst: parameter name "prsity300
2019-05-11 16:58:46.856302 pestcheck:12 characters long.
2019-05-11 16:58:46.856407 pestcheck:Line 2505 of file freyberg.pst: parameter name "prsity300
2019-05-11 16:58:46.856526 pestcheck:once.
2019-05-11 16:58:46.856631 pestcheck:Line 2506 of file freyberg.pst: parameter name "prsity300
2019-05-11 16:58:46.856746 pestcheck:12 characters long.
2019-05-11 16:58:46.856851 pestcheck:Line 2506 of file freyberg.pst: parameter name "prsity300
2019-05-11 16:58:46.856965 pestcheck:once.
2019-05-11 16:58:46.857080 pestcheck:Line 2507 of file freyberg.pst: parameter name "prsity300
2019-05-11 16:58:46.857139 pestcheck:12 characters long.
2019-05-11 16:58:46.857182 pestcheck:Line 2507 of file freyberg.pst: parameter name "prsity300
2019-05-11 16:58:46.857306 pestcheck:once.
2019-05-11 16:58:46.857447 pestcheck:Line 2508 of file freyberg.pst: parameter name "prsity300
2019-05-11 16:58:46.857585 pestcheck:12 characters long.
2019-05-11 16:58:46.858384 finished: running pestchek on freyberg.pst took: 0:00:00.133096
2019-05-11 16:58:46.858477 starting: saving intermediate _setup_<> dfs into template
2019-05-11 16:58:47.006131 finished: saving intermediate _setup_<> dfs into template took: 0:0
2019-05-11 16:58:47.006269 all done

```

The `pst_helper` instance contains the `pyemu.Pst` instance:

```

In [14]: # so, pull out the `pyemu.Pst` instance which
          #contains all the input that ultimately goes in the PEST control %%file
          pst = pst_helper.pst
          pst.npar,pst.nobs

```

```

Out[14]: (14819, 4434)

```

Oh snap!

### 1.1.6 Add modpath input files, instruction files and calls

First copy over all the MODPATH-related files from the base directory identified in the `b_d` variable. We will track a single particle for forecast purposes

```
In [15]: mp_files = [f for f in os.listdir(b_d) if "mp" in f or "location" in f]
          [shutil.copy2(os.path.join(b_d,f),os.path.join(pst_helper.new_model_ws,f)) for f in mp_files]

Out[15]: ['template/mp_ibound_1.ref',
          'template/mp_ibound_2.ref',
          'template/mp_ibound_3.ref',
          'template/freyberg.locations',
          'template/freyberg.mpsim',
          'template/freyberg.mpbas',
          'template/freyberg.mpnam']
```

The following `frun_post_lines` property adds statements at the end of the `forward_run.py` script. In this case, it runs MODPATH using `mp6`. We will also identify any additional temporary files that the forward run script should attempt to remove at the start of a run.

```
In [16]: pst_helper.frun_post_lines.append("os.system('mp6 freyberg.mpsim >mp6.stdout')")
          pst_helper.tmp_files.append("freyberg.mpenpt")
          pst_helper.write_forward_run()
```

Create and add instruction files and related observations for MODPATH

```
In [17]: out_file = "freyberg.mpenpt"
          ins_file = out_file + ".ins"
          with open(os.path.join(pst_helper.new_model_ws,ins_file),'w') as f:
              f.write("pif ~\n")
              f.write("l7 w w !part_status! w w !part_time!\n")
          df = pst_helper.pst.add_observations(os.path.join(pst_helper.new_model_ws,ins_file),
                                              os.path.join(pst_helper.new_model_ws,out_file),
                                              pst_path=".")
```

error using inschek for instruction file ./freyberg.mpenpt.ins:File b'template/./freyberg.mpenpt.ins' observations in this instruction file will have generic values.

Finally we need to copy the original `prsim` arrays to the `arr_org` dir for use in the multiplier parameterization scheme

```
In [18]: for k in range(m.nlay):
          np.savetxt(os.path.join(pst_helper.new_model_ws,"arr_org","prsim_layer_{0}.ref".format(k)),
```

### 1.1.7 Final bits and bobs

We need to set some realistic parameter bounds and account for expected (but stochastic) scenario conditions:

`pyemu` uses pandas data frame format for the parameter and observation data sections. This exposes plenty of querying and bulk editing options.

```

In [19]: par = pst.parameter_data
# properties
tag_dict = {"hk": [0.1, 10.0], "vka": [0.1, 10], "strt": [0.95, 1.05], "prsity": [0.5, 1.5]}
for t, [l, u] in tag_dict.items():
    t_pars = par.loc[par.parnme.apply(lambda x: t in x), "parnme"]
    par.loc[t_pars, "parubnd"] = u
    par.loc[t_pars, "parlbnd"] = l

# recharge - just change the constant recharge mult
# for the historic and scenario stress periods
scen_rch = ["cn_rech5"]
hist_rch = ["cn_rech4"]
par.loc[par.pargp.apply(lambda x: x in scen_rch), "parubnd"] = 0.8
par.loc[par.pargp.apply(lambda x: x in scen_rch), "parlbnd"] = 0.1
par.loc[par.pargp.apply(lambda x: x in scen_rch), "parval1"] = 0.4
par.loc[par.pargp.apply(lambda x: x in hist_rch), "parubnd"] = 1.2
par.loc[par.pargp.apply(lambda x: x in hist_rch), "parlbnd"] = 0.8
par.loc[par.pargp.apply(lambda x: x in hist_rch), "parval1"] = 1.0

# well abstraction - same idea here: change the historic and scenario pars
par.loc["welflux_001", "parval1"] = 1.5
par.loc["welflux_001", "parlbnd"] = 1.0
par.loc["welflux_001", "parubnd"] = 2.0
par.loc["welflux_000", "parval1"] = 1.0
par.loc["welflux_000", "parlbnd"] = 0.5
par.loc["welflux_000", "parubnd"] = 1.5

```

given the combinations of multipliers, we need to set a hard upper bound on porosity and sy since those have physical upper limits

```

In [20]: arr_csv = os.path.join(pst_helper.new_model_ws, "arr_pars.csv")
df = pd.read_csv(arr_csv, index_col=0)
pr_sy = df.model_file.apply(lambda x: "prsity" in x or "sy" in x)
df.loc[:, "upper_bound"] = np.NaN
df.loc[pr_sy, "upper_bound"] = 0.4
df.to_csv(arr_csv)

```

```

In [21]: # table can also be written to a .tex file
pst.write_par_summary_table(filename="none").sort_index()

```

```

Out[21]:

```

	type	transform	count	initial value	\
cn_hk6	cn_hk6	log	1	0	
cn_hk7	cn_hk7	log	1	0	
cn_hk8	cn_hk8	log	1	0	
cn_prsity6	cn_prsity6	log	1	0	
cn_prsity7	cn_prsity7	log	1	0	
cn_prsity8	cn_prsity8	log	1	0	
cn_rech4	cn_rech4	log	1	0	
cn_rech5	cn_rech5	log	1	-0.39794	

cn_ss6	cn_ss6	log	1	0
cn_ss7	cn_ss7	log	1	0
cn_ss8	cn_ss8	log	1	0
cn_strt6	cn_strt6	log	1	0
cn_strt7	cn_strt7	log	1	0
cn_strt8	cn_strt8	log	1	0
cn_sy6	cn_sy6	log	1	0
cn_sy7	cn_sy7	log	1	0
cn_sy8	cn_sy8	log	1	0
cn_vka6	cn_vka6	log	1	0
cn_vka7	cn_vka7	log	1	0
cn_vka8	cn_vka8	log	1	0
drncond_k00	drncond_k00	log	10	0
flow	flow	log	1	0
gr_hk3	gr_hk3	log	705	0
gr_hk4	gr_hk4	log	705	0
gr_hk5	gr_hk5	log	705	0
gr_prsity3	gr_prsity3	log	705	0
gr_prsity4	gr_prsity4	log	705	0
gr_prsity5	gr_prsity5	log	705	0
gr_rech2	gr_rech2	log	705	0
gr_rech3	gr_rech3	log	705	0
...	...	...	...	...
gr_strt5	gr_strt5	log	705	0
gr_sy3	gr_sy3	log	705	0
gr_sy4	gr_sy4	log	705	0
gr_sy5	gr_sy5	log	705	0
gr_vka3	gr_vka3	log	705	0
gr_vka4	gr_vka4	log	705	0
gr_vka5	gr_vka5	log	705	0
pp_hk0	pp_hk0	log	32	0
pp_hk1	pp_hk1	log	32	0
pp_hk2	pp_hk2	log	32	0
pp_prsity0	pp_prsity0	log	32	0
pp_prsity1	pp_prsity1	log	32	0
pp_prsity2	pp_prsity2	log	32	0
pp_rech0	pp_rech0	log	32	0
pp_rech1	pp_rech1	log	32	0
pp_ss0	pp_ss0	log	32	0
pp_ss1	pp_ss1	log	32	0
pp_ss2	pp_ss2	log	32	0
pp_strt0	pp_strt0	log	32	0
pp_strt1	pp_strt1	log	32	0
pp_strt2	pp_strt2	log	32	0
pp_sy0	pp_sy0	log	32	0
pp_sy1	pp_sy1	log	32	0
pp_sy2	pp_sy2	log	32	0
pp_vka0	pp_vka0	log	32	0

pp_vka1	pp_vka1	log	32	0
pp_vka2	pp_vka2	log	32	0
strk	strk	log	40	0
welflux	welflux	log	2	0 to 0.176091
welflux_k02	welflux_k02	log	6	0

	upper bound	lower bound	standard deviation
cn_hk6	1	-1	0.5
cn_hk7	1	-1	0.5
cn_hk8	1	-1	0.5
cn_prsity6	0.176091	-0.30103	0.11928
cn_prsity7	0.176091	-0.30103	0.11928
cn_prsity8	0.176091	-0.30103	0.11928
cn_rech4	0.0791812	-0.09691	0.0440228
cn_rech5	-0.09691	-1	0.225772
cn_ss6	1	-1	0.5
cn_ss7	1	-1	0.5
cn_ss8	1	-1	0.5
cn_strt6	0.0211893	-0.0222764	0.0108664
cn_strt7	0.0211893	-0.0222764	0.0108664
cn_strt8	0.0211893	-0.0222764	0.0108664
cn_sy6	0.243038	-0.60206	0.211275
cn_sy7	0.243038	-0.60206	0.211275
cn_sy8	0.243038	-0.60206	0.211275
cn_vka6	1	-1	0.5
cn_vka7	1	-1	0.5
cn_vka8	1	-1	0.5
drncond_k00	1	-1	0.5
flow	0.09691	-0.124939	0.0554622
gr_hk3	1	-1	0.5
gr_hk4	1	-1	0.5
gr_hk5	1	-1	0.5
gr_prsity3	0.176091	-0.30103	0.11928
gr_prsity4	0.176091	-0.30103	0.11928
gr_prsity5	0.176091	-0.30103	0.11928
gr_rech2	0.0413927	-0.0457575	0.0217875
gr_rech3	0.0413927	-0.0457575	0.0217875
...	...	...	...
gr_strt5	0.0211893	-0.0222764	0.0108664
gr_sy3	0.243038	-0.60206	0.211275
gr_sy4	0.243038	-0.60206	0.211275
gr_sy5	0.243038	-0.60206	0.211275
gr_vka3	1	-1	0.5
gr_vka4	1	-1	0.5
gr_vka5	1	-1	0.5
pp_hk0	1	-1	0.5
pp_hk1	1	-1	0.5
pp_hk2	1	-1	0.5

pp_prsity0	0.176091	-0.30103	0.11928
pp_prsity1	0.176091	-0.30103	0.11928
pp_prsity2	0.176091	-0.30103	0.11928
pp_rech0	0.0413927	-0.0457575	0.0217875
pp_rech1	0.0413927	-0.0457575	0.0217875
pp_ss0	1	-1	0.5
pp_ss1	1	-1	0.5
pp_ss2	1	-1	0.5
pp_strt0	0.0211893	-0.0222764	0.0108664
pp_strt1	0.0211893	-0.0222764	0.0108664
pp_strt2	0.0211893	-0.0222764	0.0108664
pp_sy0	0.243038	-0.60206	0.211275
pp_sy1	0.243038	-0.60206	0.211275
pp_sy2	0.243038	-0.60206	0.211275
pp_vka0	1	-1	0.5
pp_vka1	1	-1	0.5
pp_vka2	1	-1	0.5
strk	2	-2	1
welflux	0.176091 to 0.30103	-0.30103 to 0	0.0752575 to 0.11928
welflux_k02	1	-1	0.5

[65 rows x 7 columns]

In [22]: `pst.write_obs_summary_table(filename="none")`

Out [22]:

	group	value	non-zero weight \
flaqx	flaqx	-977.239 to 32.171	84
flout	flout	10069 to 226396	84
flx_constan	flx_constan	0	2
flx_drains	flx_drains	-723.325 to -723.028	2
flx_in-out	flx_in-out	0.012695 to 0.046143	2
flx_percent	flx_percent	0	2
flx_recharg	flx_recharg	3045.6	2
flx_storage	flx_storage	5.7734 to 8.01049	2
flx_stream_	flx_stream_	-1430.27 to -1428.3	2
flx_total	flx_total	0.0126953 to 0.0461426	2
flx_wells	flx_wells	-900	2
hds	hds	32.5065 to 39.6612	4230
obgnme	obgnme	1E+10	2
vol_constan	vol_constan	0	2
vol_drains	vol_drains	-2.90404E+06 to -2.64014E+06	2
vol_in-out	vol_in-out	45 to 63	2
vol_percent	vol_percent	0	2
vol_recharg	vol_recharg	1.11164E+07 to 1.22281E+07	2
vol_storage	vol_storage	29238.3 to 31345.6	2
vol_stream_	vol_stream_	-5.74182E+06 to -5.22049E+06	2
vol_total	vol_total	45 to 63	2
vol_wells	vol_wells	-3.6135E+06 to -3.285E+06	2



	zero weight	weight	standard deviation	percent error
flaqx	0	1	1	0.102329 to 833.333
flout	0	1	1	0.000441704 to 0.00993147
flx_constan	0	1	1	NA
flx_drains	0	1	1	0.13825 to 0.138307
flx_in-out	0	1	1	2167.18 to 7877.12
flx_percent	0	1	1	NA
flx_recharg	0	1	1	0.0328343
flx_storage	0	1	1	12.4836 to 17.3208
flx_stream_	0	1	1	0.0699167 to 0.0700133
flx_total	0	1	1	2167.2 to 7876.92
flx_wells	0	1	1	0.111111
hds	0	1	1	2.52136 to 3.07631
obgnme	0	1	1	1E-08
vol_constan	0	1	1	NA
vol_drains	0	1	1	3.44348E-05 to 3.78768E-05
vol_in-out	0	1	1	1.5873 to 2.22222
vol_percent	0	1	1	NA
vol_recharg	0	1	1	8.1779E-06 to 8.99569E-06
vol_storage	0	1	1	0.00319024 to 0.00342017
vol_stream_	0	1	1	1.74161E-05 to 1.91553E-05
vol_total	0	1	1	1.5873 to 2.22222
vol_wells	0	1	1	2.7674E-05 to 3.04414E-05

Lets run the process once (noptmax=0) to make sure its all plumbed up

```
In [23]: pst.control_data.noptmax = 0
          pst.write(os.path.join(pst_helper.new_model_ws,"freyberg.pst"))
          pyemu.os_utils.run("pestpp-ies freyberg.pst",cwd=pst_helper.new_model_ws)

noptmax:0, npar_adj:14819, nnz_obs:4436
```

Now we need to generate the prior parameter covariance matrix and stochastic realizations. We will use the geostatistical covariance information in the pst\_helper instance for this:

```
In [24]: if pst_helper.pst.npar < 15000:
          cov = pst_helper.build_prior(fmt="coo",filename=os.path.join(pst_helper.new_model_ws,"cov.pst"))
          cov = np.ma.masked_where(cov.x==0,cov.x)
          fig = plt.figure(figsize=(10,10))
          ax = plt.subplot(111)
          ax.imshow(cov)
          plt.show()
```

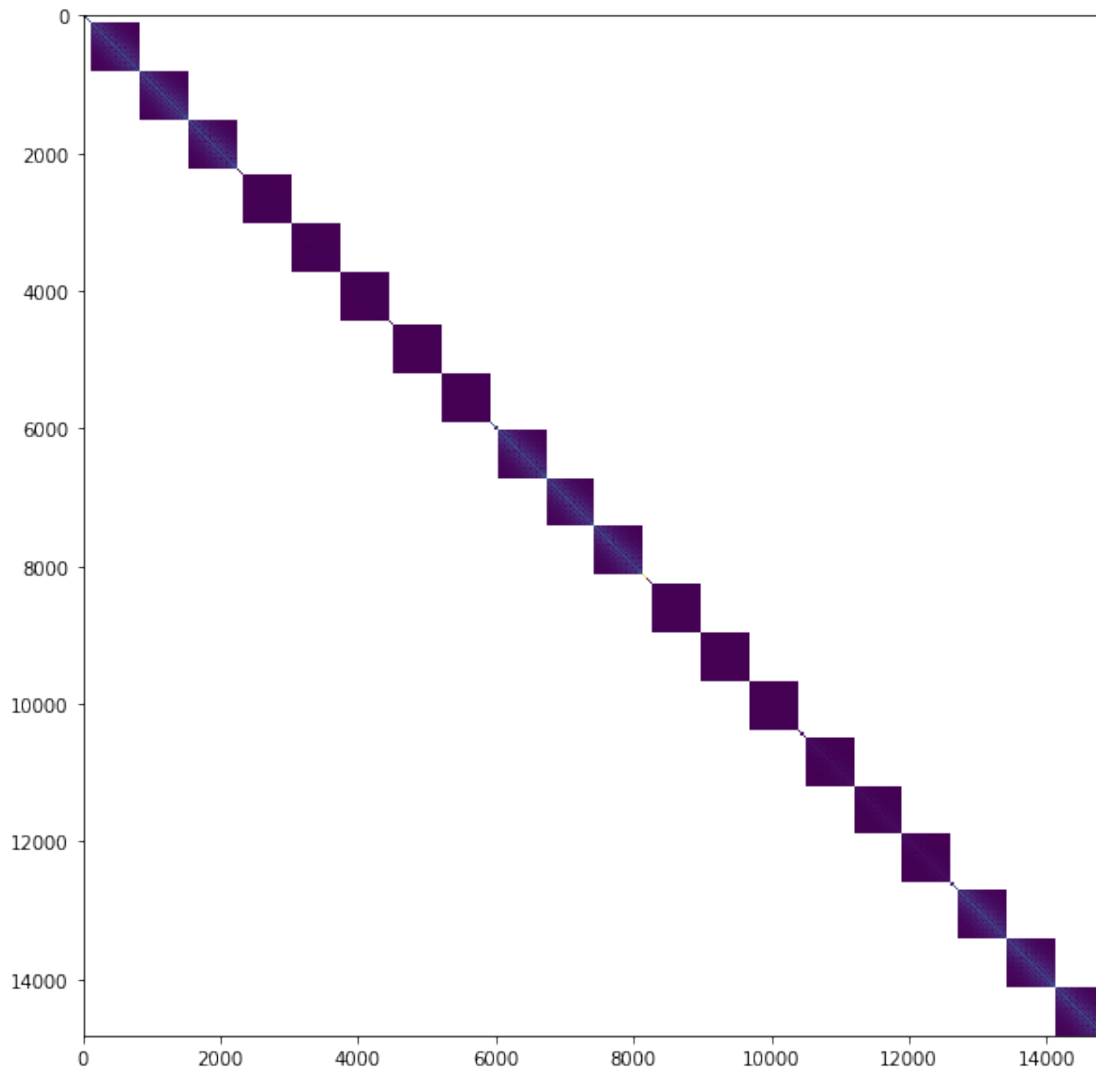
```
2019-05-11 16:58:56.528218 starting: building prior covariance matrix
2019-05-11 16:58:56.640263 WARNING: geospatial prior not implemented for SFR pars
```

```
/Users/jeremyw/miniconda3/lib/python3.5/site-packages/pandas/core/indexing.py:362: SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame.
Try using .loc[row_indexer,col_indexer] = value instead
```

```
See the caveats in the documentation: http://pandas.pydata.org/pandas-docs/stable/indexing.html
  self.obj[key] = _infer_fill_value(value)
/Users/jeremyw/miniconda3/lib/python3.5/site-packages/pandas/core/indexing.py:543: SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame.
Try using .loc[row_indexer,col_indexer] = value instead
```

```
See the caveats in the documentation: http://pandas.pydata.org/pandas-docs/stable/indexing.html
  self.obj[item] = s
```

```
2019-05-11 16:59:02.987584 saving prior covariance matrix to file template/prior_cov.jcb
2019-05-11 16:59:07.463718 finished: building prior covariance matrix took: 0:00:10.935500
```



### 1.1.8 now we can make a draw of 200 from the prior parameter covariance matrix to form a prior parameter ensemble

```
In [25]: pe = pst_helper.draw(200)
```

```
2019-05-11 16:59:22.789041 starting: drawing realizations
```

```
building diagonal cov
```

```
processing name:grid_geostruct,nugget:0.0,structures:
```

```
name:var1,contribution:1.0,a:2500.0,anisotropy:1.0,bearing:0.0
```

```
working on pargroups ['gr_hk3']
```

```
build cov matrix
```

```
done
```

```
getting diag var cov 705
```

```
scaling full cov by diag var cov
```

```
making full cov draws with home-grown goodness
```

```
working on pargroups ['gr_vka3']
```

```
build cov matrix
```

```
done
```

```
getting diag var cov 705
```

```
scaling full cov by diag var cov
```

```
making full cov draws with home-grown goodness
```

```
working on pargroups ['gr_ss3']
```

```
build cov matrix
```

```
done
```

```
getting diag var cov 705
```

```
scaling full cov by diag var cov
```

```
making full cov draws with home-grown goodness
```

```
working on pargroups ['gr_sy3']
```

```
build cov matrix
```

```
done
```

```
getting diag var cov 705
```

```
scaling full cov by diag var cov
```

```
making full cov draws with home-grown goodness
```

```
working on pargroups ['gr_strt3']
```

```
build cov matrix
```

```
done
```

```
getting diag var cov 705
```

```
scaling full cov by diag var cov
```

```
making full cov draws with home-grown goodness
```

```
working on pargroups ['gr_prsity3']
```

```
build cov matrix
```

```
done
```

```
getting diag var cov 705
```

```
scaling full cov by diag var cov
```

```

making full cov draws with home-grown goodness
working on pargroups ['gr_hk4']
build cov matrix
done
getting diag var cov 705
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['gr_vka4']
build cov matrix
done
getting diag var cov 705
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['gr_ss4']
build cov matrix
done
getting diag var cov 705
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['gr_sy4']
build cov matrix
done
getting diag var cov 705
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['gr_strt4']
build cov matrix
done
getting diag var cov 705
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['gr_prsity4']
build cov matrix
done
getting diag var cov 705
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['gr_hk5']
build cov matrix
done
getting diag var cov 705
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['gr_vka5']
build cov matrix
done
getting diag var cov 705
scaling full cov by diag var cov

```

```

making full cov draws with home-grown goodness
working on pargroups ['gr_ss5']
build cov matrix
done
getting diag var cov 705
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['gr_sy5']
build cov matrix
done
getting diag var cov 705
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['gr_strt5']
build cov matrix
done
getting diag var cov 705
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['gr_prsity5']
build cov matrix
done
getting diag var cov 705
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['gr_rech2']
build cov matrix
done
getting diag var cov 705
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['gr_rech3']
build cov matrix
done
getting diag var cov 705
scaling full cov by diag var cov
making full cov draws with home-grown goodness
processing name:pp_geostruct,nugget:0.0,structures:
name:var1,contribution:1.0,a:1000.0,anisotropy:1.0,bearing:0.0

working on pargroups ['pp_hk0']
build cov matrix
done
getting diag var cov 32
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['pp_vka0']
build cov matrix

```

```

done
getting diag var cov 32
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['pp_ss0']
build cov matrix
done
getting diag var cov 32
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['pp_sy0']
build cov matrix
done
getting diag var cov 32
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['pp_strt0']
build cov matrix
done
getting diag var cov 32
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['pp_prsity0']
build cov matrix
done
getting diag var cov 32
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['pp_rech0']
build cov matrix
done
getting diag var cov 32
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['pp_rech1']
build cov matrix
done
getting diag var cov 32
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['pp_sy1']
build cov matrix
done
getting diag var cov 32
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['pp_hk1']
build cov matrix

```

```

done
getting diag var cov 32
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['pp_vka1']
build cov matrix
done
getting diag var cov 32
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['pp_ss1']
build cov matrix
done
getting diag var cov 32
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['pp_prsity1']
build cov matrix
done
getting diag var cov 32
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['pp_strt1']
build cov matrix
done
getting diag var cov 32
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['pp_prsity2']
build cov matrix
done
getting diag var cov 32
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['pp_ss2']
build cov matrix
done
getting diag var cov 32
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['pp_hk2']
build cov matrix
done
getting diag var cov 32
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['pp_vka2']
build cov matrix

```

```

done
getting diag var cov 32
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['pp_sy2']
build cov matrix
done
getting diag var cov 32
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['pp_strt2']
build cov matrix
done
getting diag var cov 32
scaling full cov by diag var cov
making full cov draws with home-grown goodness
processing name:spatial_list_geostruc,nugget:0.0,structures:
name:var1,contribution:1.0,a:2500.0,anisotropy:1.0,bearing:0.0

working on pargroups ['drncond_k00']

```

```

/Users/jeremyw/miniconda3/lib/python3.5/site-packages/pandas/core/indexing.py:362: SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame.
Try using .loc[row_indexer,col_indexer] = value instead

```

```

See the caveats in the documentation: http://pandas.pydata.org/pandas-docs/stable/indexing.html
    self.obj[key] = _infer_fill_value(value)
/Users/jeremyw/miniconda3/lib/python3.5/site-packages/pandas/core/indexing.py:543: SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame.
Try using .loc[row_indexer,col_indexer] = value instead

```

```

See the caveats in the documentation: http://pandas.pydata.org/pandas-docs/stable/indexing.html
    self.obj[item] = s

```

```

build cov matrix
done
getting diag var cov 10
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['welflux_k02']
build cov matrix
done
getting diag var cov 6
scaling full cov by diag var cov
making full cov draws with home-grown goodness
processing name:temporal_list_geostruc,nugget:0.0,structures:

```



```
name:var1,contribution:1.0,a:180.0,anisotropy:1.0,bearing:0.0

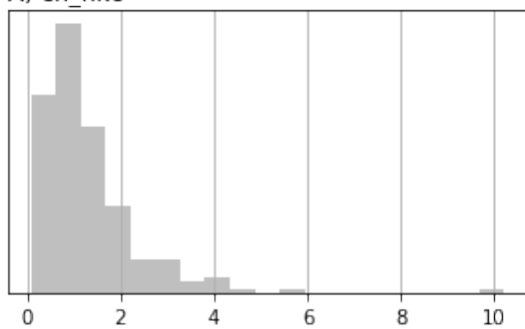
working on pargroups ['welflux']
build cov matrix
done
getting diag var cov 2
scaling full cov by diag var cov
making full cov draws with home-grown goodness
adding remaining parameters to diagonal
2019-05-11 16:59:30.400590 finished: drawing realizations took: 0:00:07.611549
```

You can see that parameters are treated in parameter group (pargp) blocks for this ensemble generation. Let's plot one parameter:

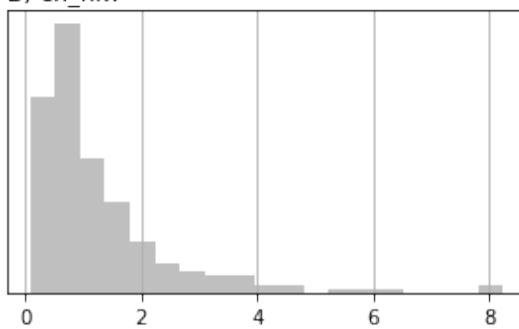
```
In [26]: par = pst_helper.pst.parameter_data
         pyemu.plot_utils.ensemble_helper(pe,plot_cols=par.groupby("pargp").groups,bins=20)
         plt.show()
```

<Figure size 576x756 with 0 Axes>

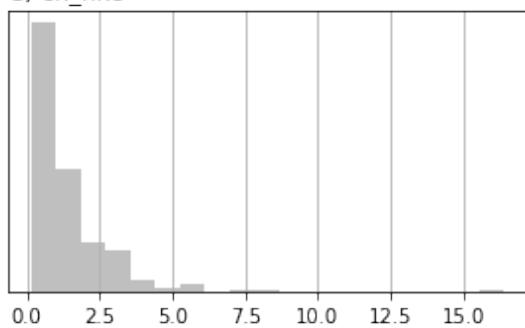
A) cn\_hk6



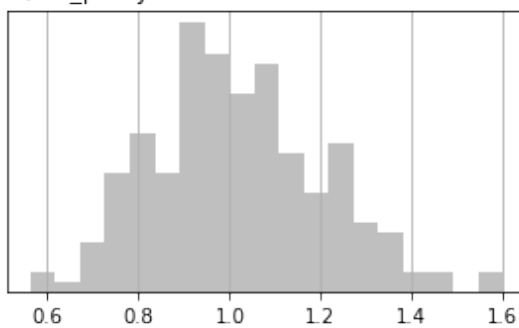
B) cn\_hk7



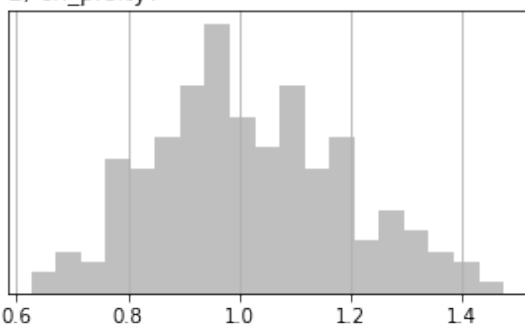
C) cn\_hk8



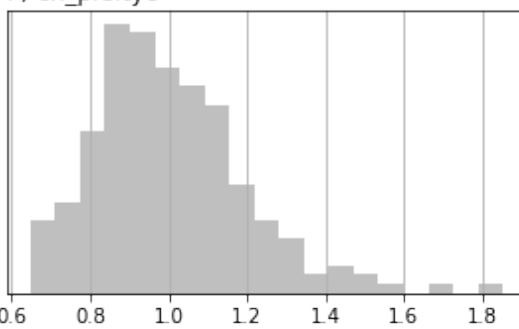
D) cn\_prsity6



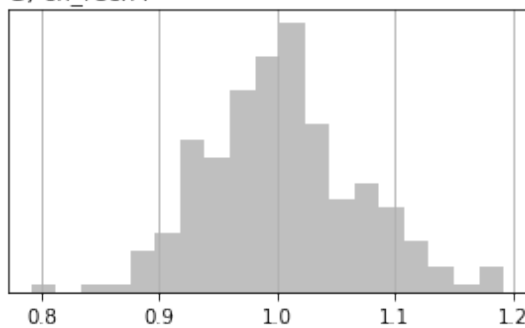
E) cn\_prsity7



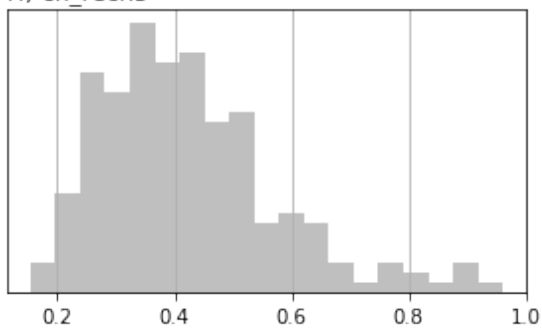
F) cn\_prsity8



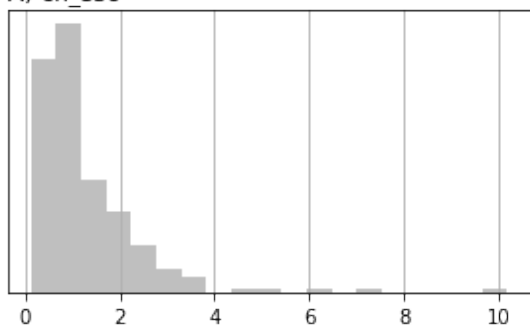
G) cn\_rech4



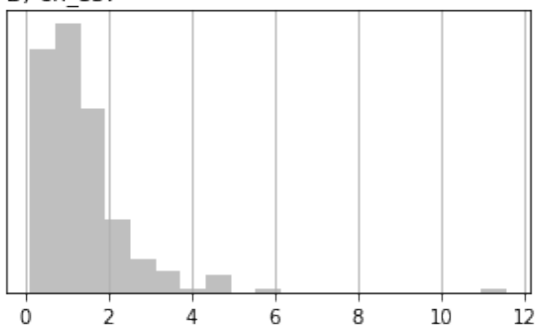
H) cn\_rech5



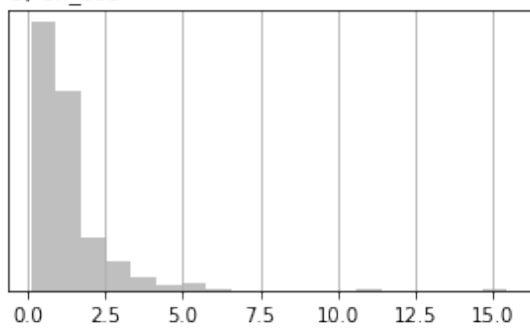
A) cn\_ss6



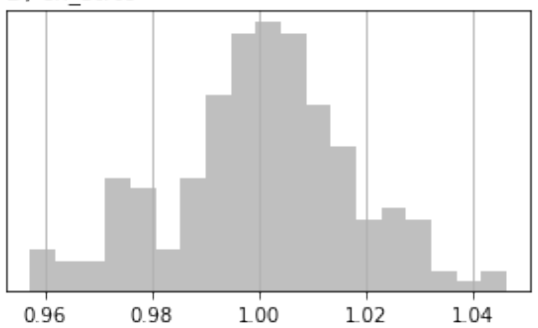
B) cn\_ss7



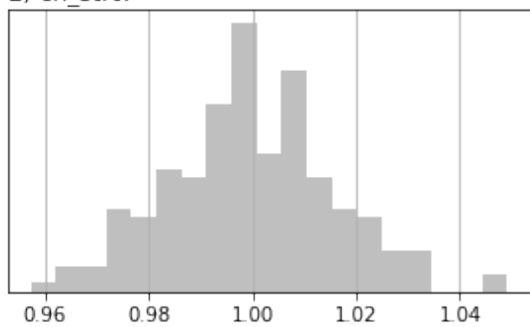
C) cn\_ss8



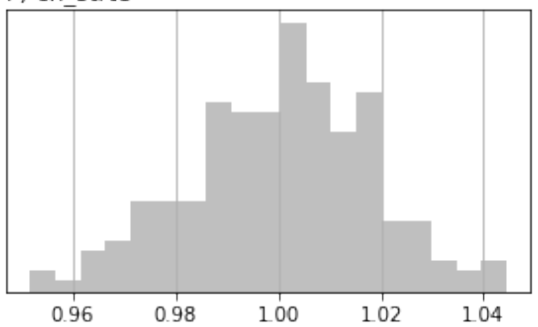
D) cn\_strt6



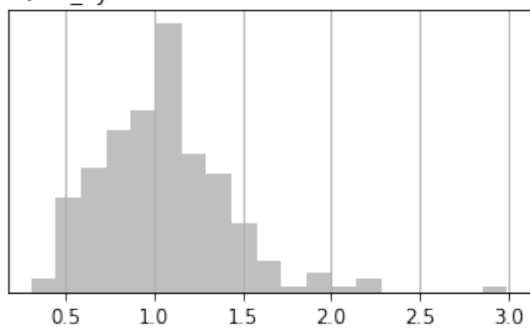
E) cn\_strt7



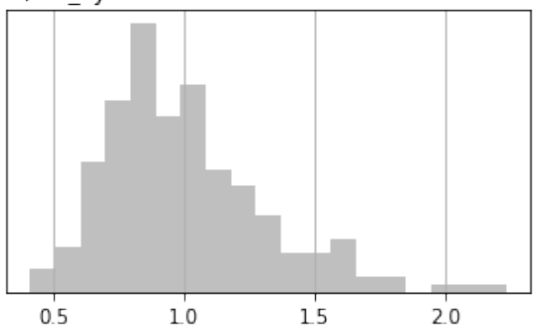
F) cn\_strt8



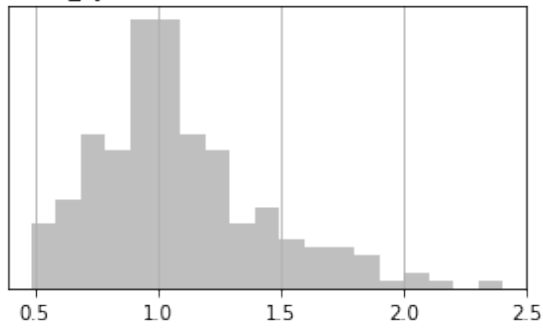
G) cn\_sy6



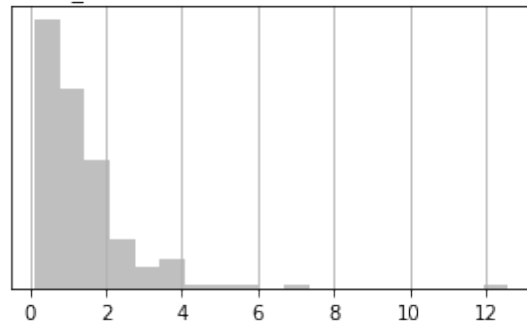
H) cn\_sy7



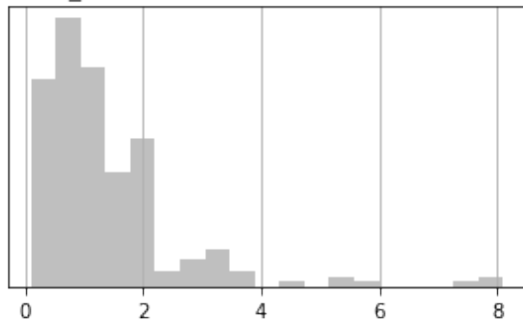
A) cn\_sy8



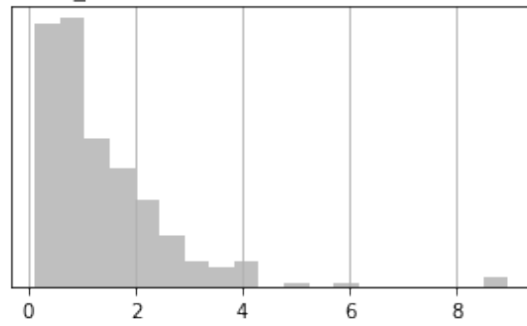
B) cn\_vka6



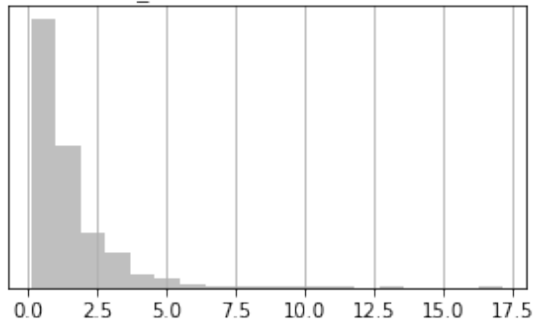
C) cn\_vka7



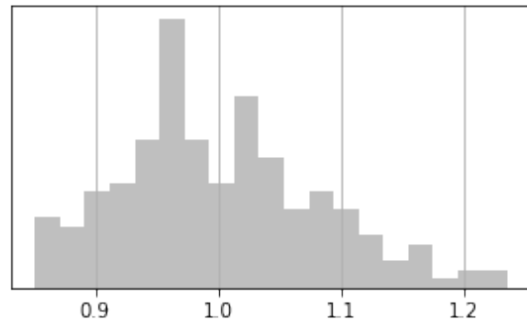
D) cn\_vka8



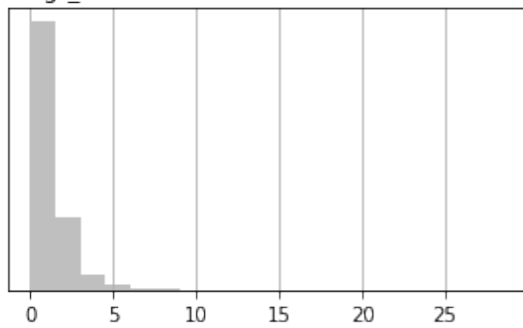
E) drncond\_k00



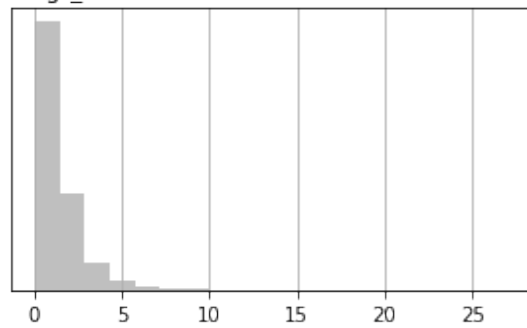
F) flow



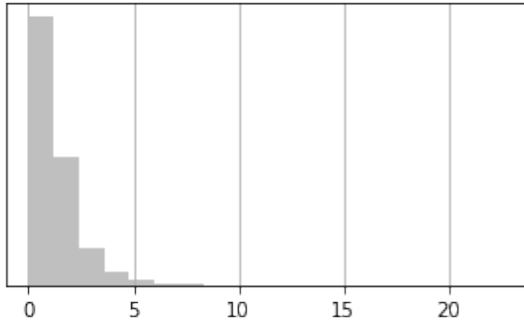
G) gr\_hk3



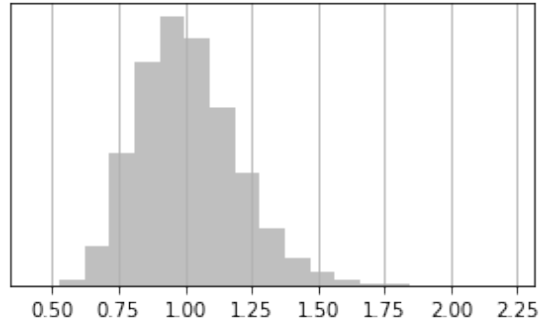
H) gr\_hk4



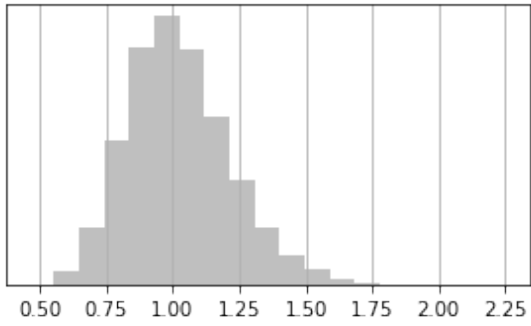
A) gr\_hk5



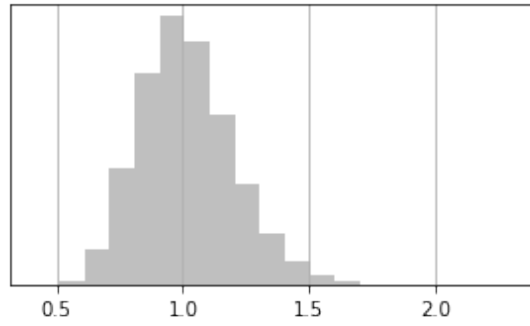
B) gr\_prsity3



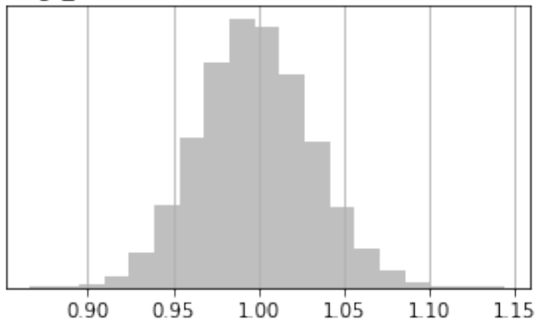
C) gr\_prsity4



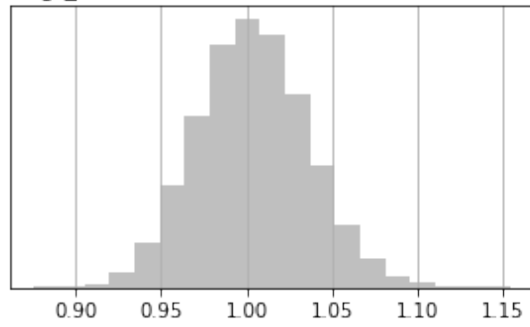
D) gr\_prsity5



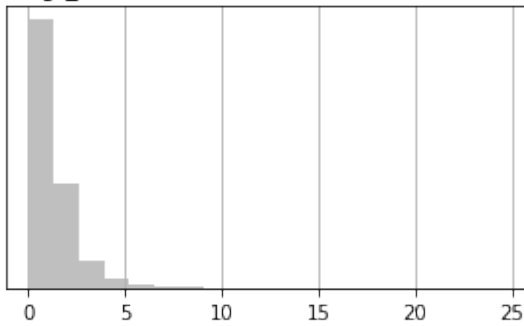
E) gr\_rech2



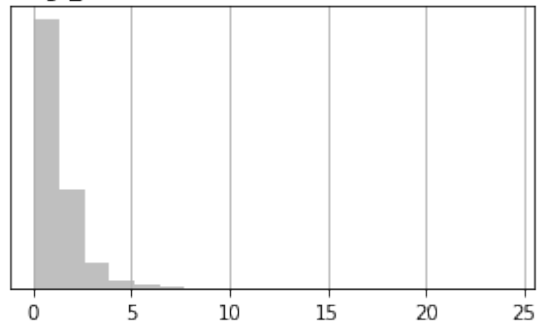
F) gr\_rech3



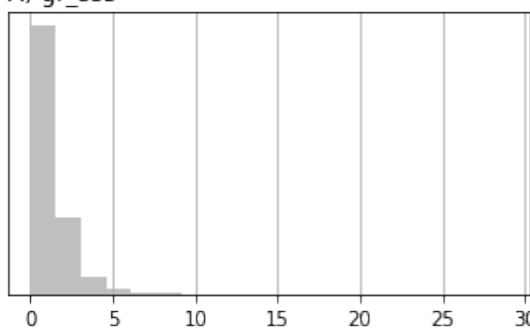
G) gr\_ss3



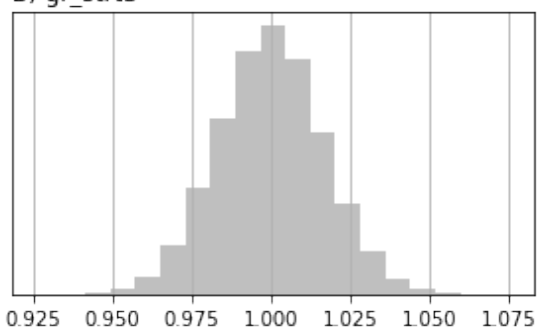
H) gr\_ss4



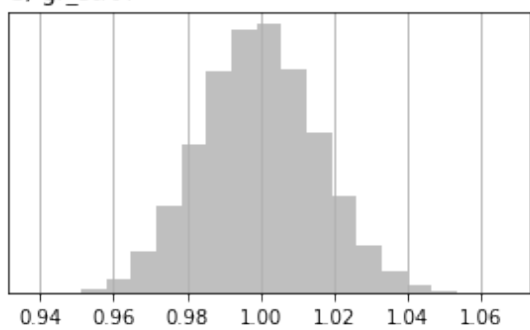
A) gr\_ss5



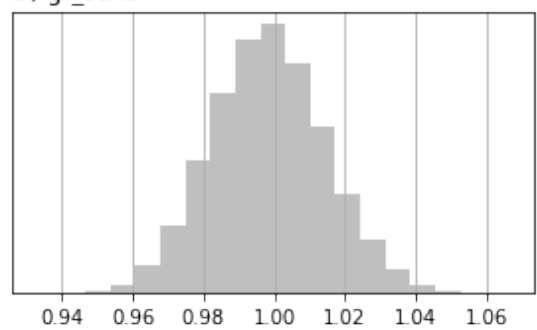
B) gr\_strt3



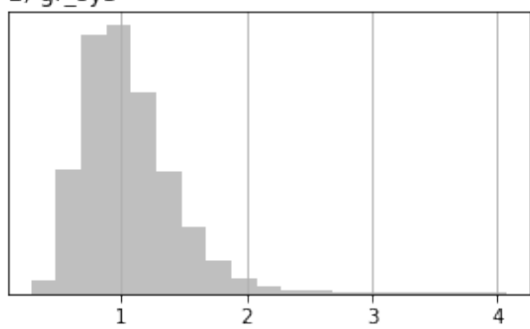
C) gr\_strt4



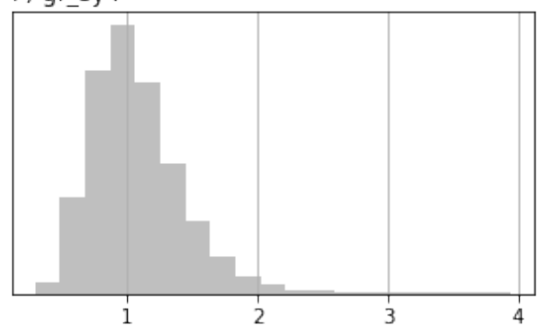
D) gr\_strt5



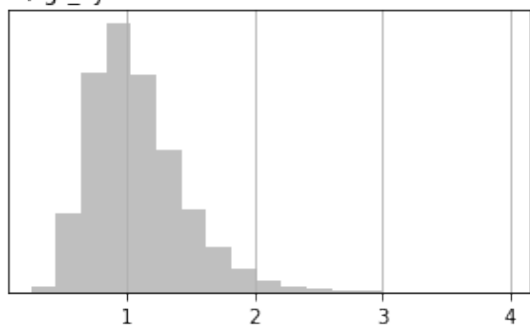
E) gr\_sy3



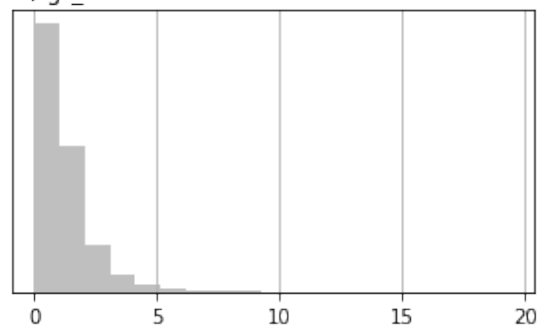
F) gr\_sy4



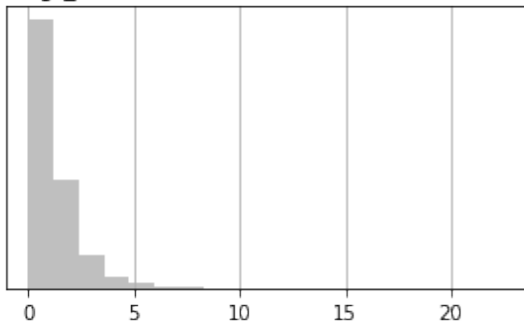
G) gr\_sy5



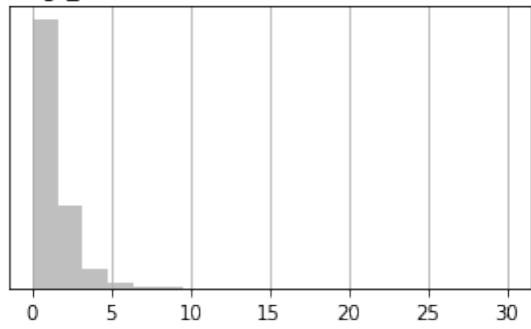
H) gr\_vka3



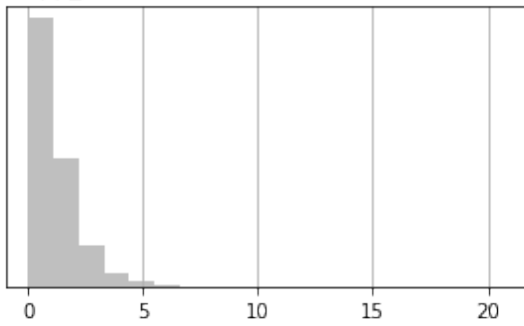
A) gr\_vka4



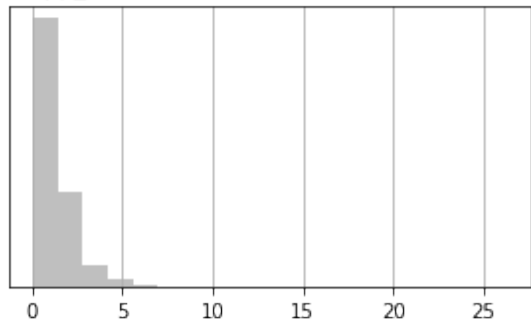
B) gr\_vka5



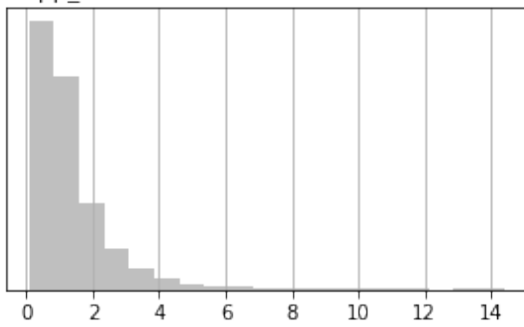
C) pp\_hk0



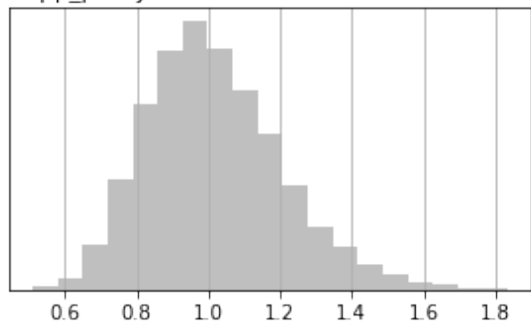
D) pp\_hk1



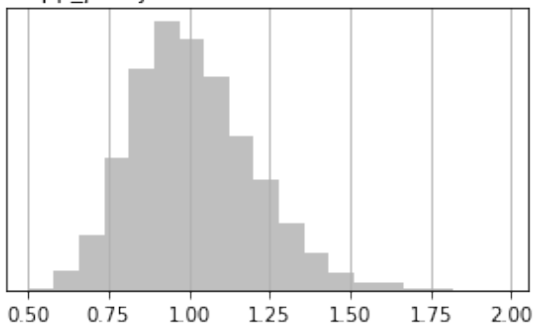
E) pp\_hk2



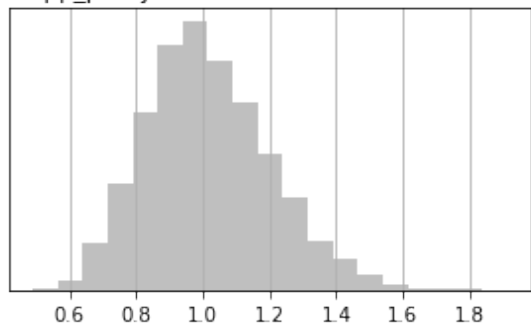
F) pp\_prsity0



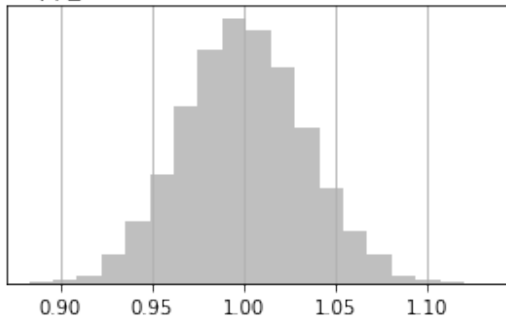
G) pp\_prsity1



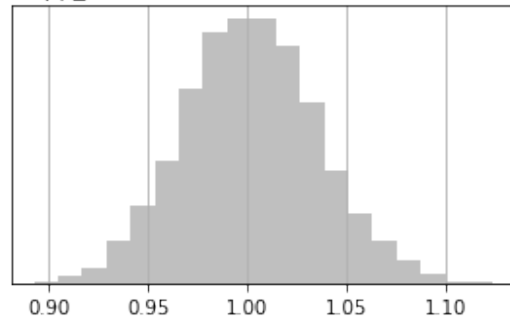
H) pp\_prsity2



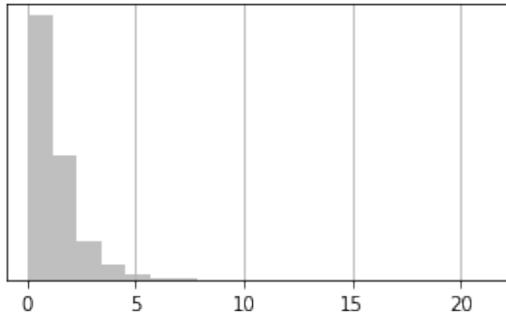
A) pp\_rech0



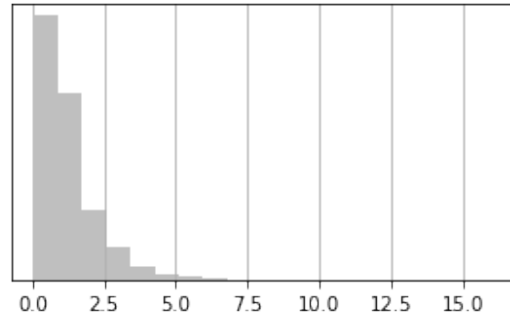
B) pp\_rech1



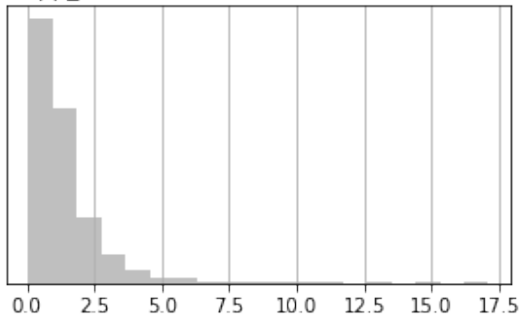
C) pp\_ss0



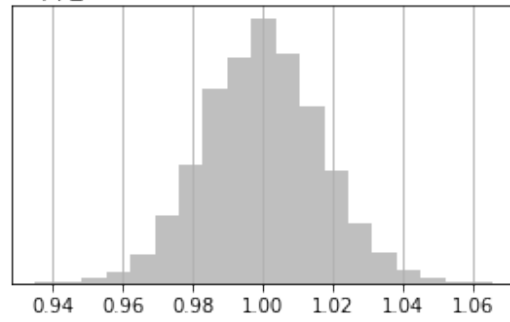
D) pp\_ss1



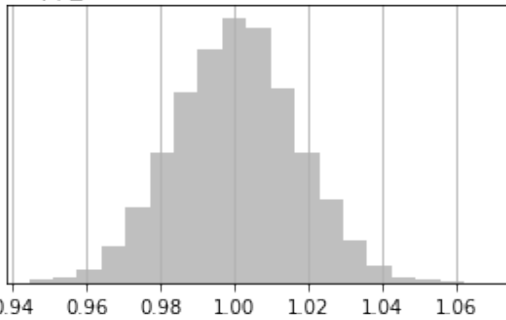
E) pp\_ss2



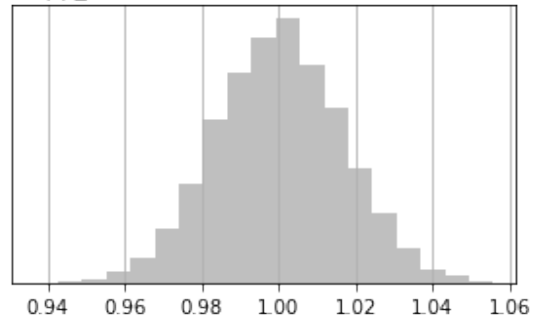
F) pp\_strt0



G) pp\_strt1

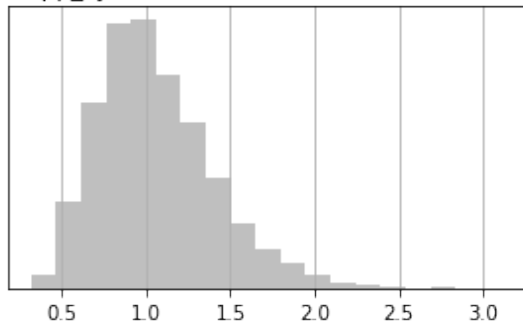


H) pp\_strt2

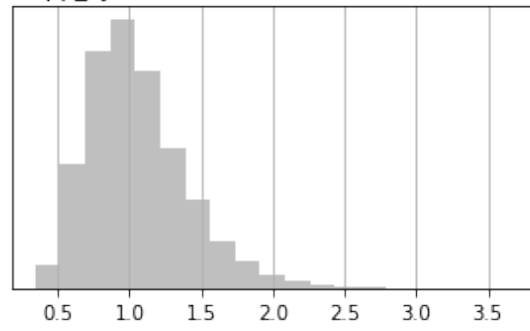




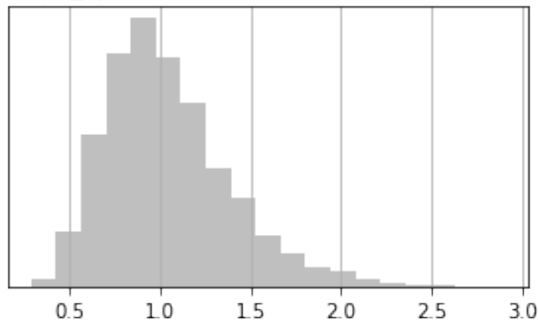
A) pp\_sy0



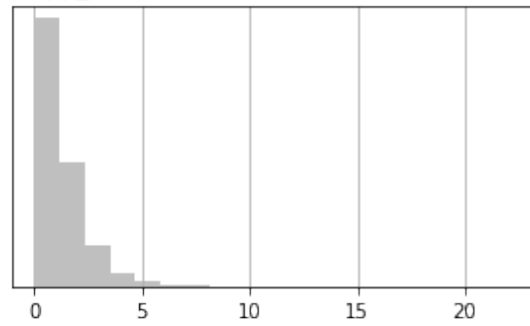
B) pp\_sy1



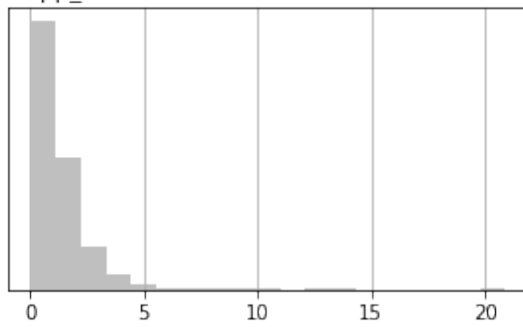
C) pp\_sy2



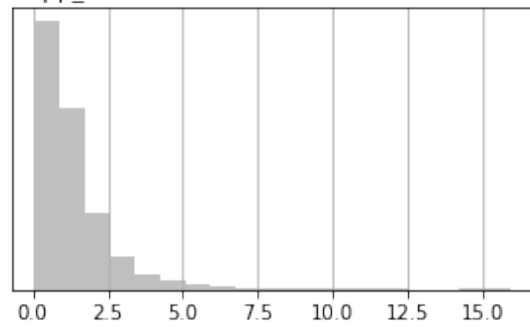
D) pp\_vka0



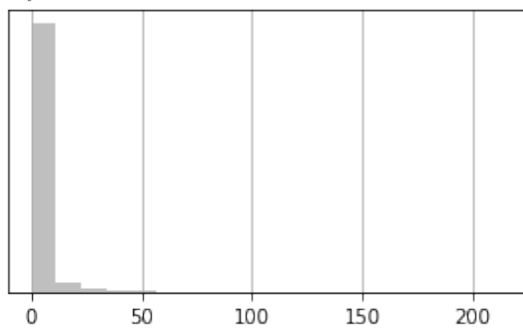
E) pp\_vka1



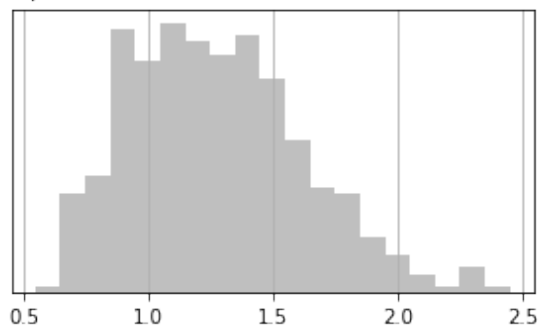
F) pp\_vka2

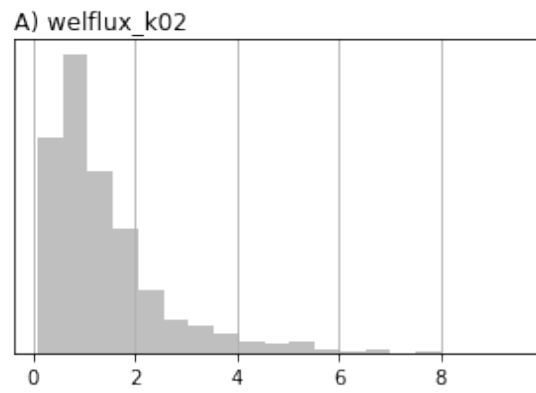


G) strk



H) welflux





Now we need to enforce parameter bounds and save this ensemble for later

```
In [27]: pe.enforce()  
         pe.to_binary(os.path.join(pst_helper.new_model_ws, "prior.jcb"))
```

### 1.1.9 set weights for “observations” and identify forecasts

The next major task is to set the weights on the observations. So far, in the `pst_helper` process, we simply identified what outputs from the model we want to observe. We now use a pre-cooked csv file to set nonzero weights only for GW level observation locations used in the original Freyberg model. We will also use the SFR flow out of the last reach (`fo` in the last row in 19791230)

```
In [28]: obs_locs = pd.read_csv(os.path.join("../", "base_model_files", "obs_loc.csv"))
        if pst_helper.m.nrow != 40:
            obs_locs.loc[:, "row"] = (obs_locs.row * redis_fac) + int(redis_fac / 2.0)
            obs_locs.loc[:, "col"] = (obs_locs.col * redis_fac) + int(redis_fac / 2.0)
            #build obs names that correspond to the obsnme values in the control file
            obs_locs.loc[:, "obsnme"] = obs_locs.apply(lambda x: "hds_00_{0:03d}_{1:03d}_000".format(x["row"], x["col"]), axis=1)
        obs_locs
```

```
Out[28]:
```

	row	col	obsnme
0	3	16	hds_00_002_015_000
1	3	10	hds_00_002_009_000
2	4	9	hds_00_003_008_000
3	10	2	hds_00_009_001_000
4	14	11	hds_00_013_010_000
5	16	17	hds_00_015_016_000
6	22	11	hds_00_021_010_000
7	23	16	hds_00_022_015_000
8	25	5	hds_00_024_004_000
9	27	7	hds_00_026_006_000
10	30	16	hds_00_029_015_000
11	34	8	hds_00_033_007_000
12	35	11	hds_00_034_010_000

Set all weights to zero first, then turn on the weights at only a few locations. These nonzero obs will be given meaningful weights in the prior monte carlo exercise

```
In [29]: obs = pst.observation_data
        obs.loc[:, "weight"] = 0.0
        obs.loc[obs_locs.obsnme, "weight"] = 1.0
        obs.loc[obs_locs.obsnme, "obgnme"] = "calhead"
        fo_obs = "fo_{0}_19791230".format(pst_helper.m.nrow-1)
        obs.loc[fo_obs, "weight"] = 1.0
        obs.loc[fo_obs, "obgnme"] = "calflux"
        pst.nnz_obs_names
```

```
Out[29]: ['fo_39_19791230',
          'hds_00_002_009_000',
          'hds_00_002_015_000',
          'hds_00_003_008_000',
          'hds_00_009_001_000',
          'hds_00_013_010_000',
          'hds_00_015_016_000',
```

```

'hds_00_021_010_000',
'hds_00_022_015_000',
'hds_00_024_004_000',
'hds_00_026_006_000',
'hds_00_029_015_000',
'hds_00_033_007_000',
'hds_00_034_010_000']

```

Now we will define which model outputs are going to be treated as “forecasts” and save the control file

```

In [30]: swgw_forecasts = obs.loc[obs.obsnme.apply(lambda x: "fa" in x and ("hw" in x or "tw" in x))]
print(swgw_forecasts)
hds_fore_name = "hds_00_{0:03d}_{1:03d}".format(int(pst_helper.m.nrow/3),int(pst_helper.m.nrow/3))
hds_forecasts = obs.loc[obs.obsnme.apply(lambda x: hds_fore_name in x), "obsnme"].tolist()
forecasts = swgw_forecasts
forecasts.extend(hds_forecasts)
forecasts.append("part_time")
forecasts.append("part_status")
pst_helper.pst.pestpp_options["forecasts"] = forecasts
pst.write(os.path.join(pst_helper.new_model_ws, "freyberg.pst"))

['fa_hw_19791230', 'fa_hw_19801229', 'fa_tw_19791230', 'fa_tw_19801229']
noptmax:0, npar_adj:14819, nnz_obs:14

```

Run one last time. phi should be near zero since we haven’t change the parval1 values for historic stress period and only the 13 gw level obs have nonzero weights

```

In [31]: pyemu.os_utils.run("pestpp-ies.exe freyberg.pst", cwd=pst_helper.new_model_ws)
pst = pyemu.Pst(os.path.join(pst_helper.new_model_ws, "freyberg.pst"))
pst.phi

```

```

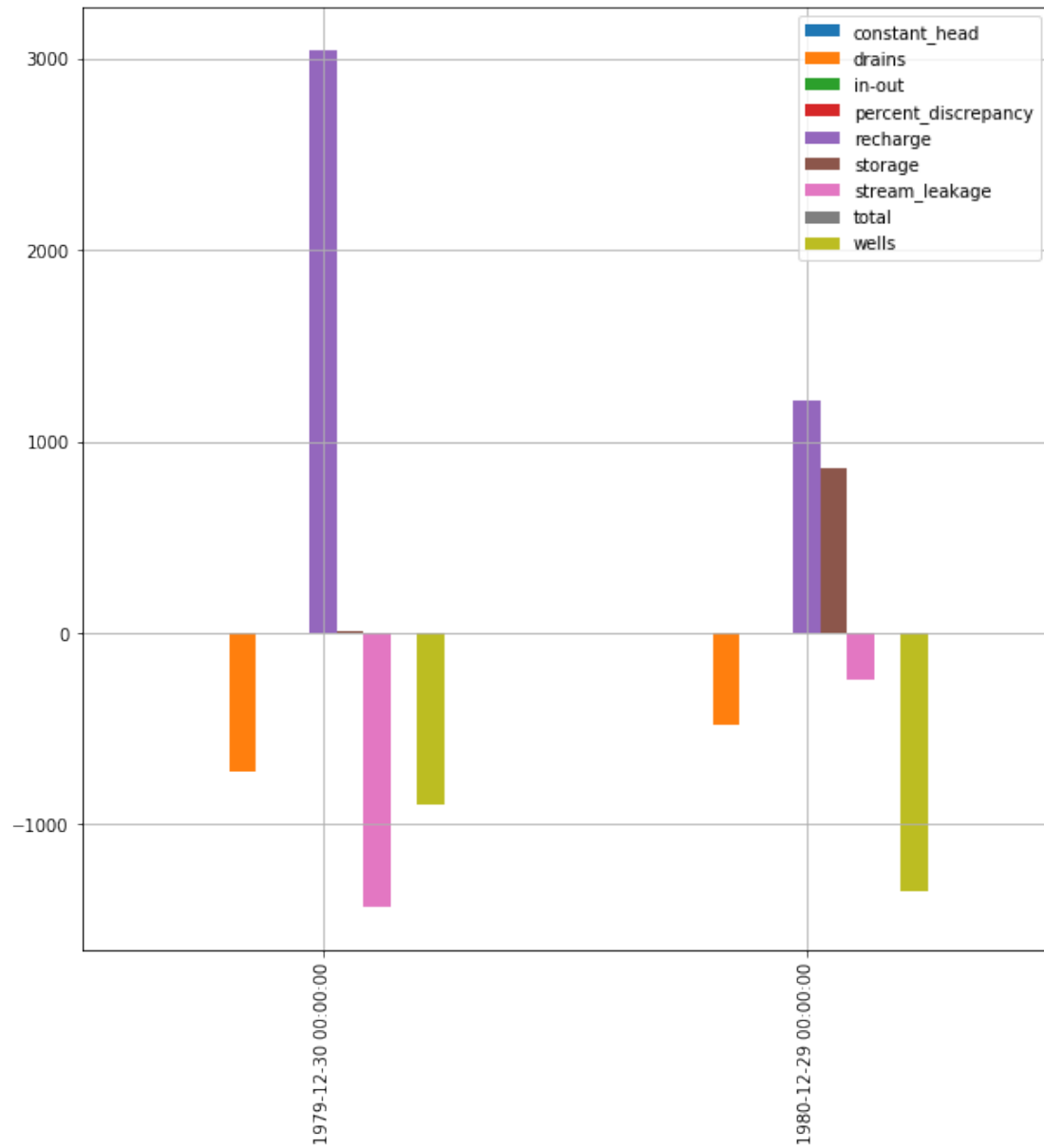
Out[31]: 9.456182577320024e-19

```

```

In [32]: lst = flopy.utils.MfListBudget(os.path.join("template", "freyberg.list"))
df = lst.get_dataframes(diff=True)[0]
df.plot(kind="bar", figsize=(10,10), grid=True)
plt.show()

```



We see the effect of our parameterized scenario - a large drop in recharge and more abstraction.