

# setup\_pest\_interface

May 8, 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 = "mfnwt"
```

```

# 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)

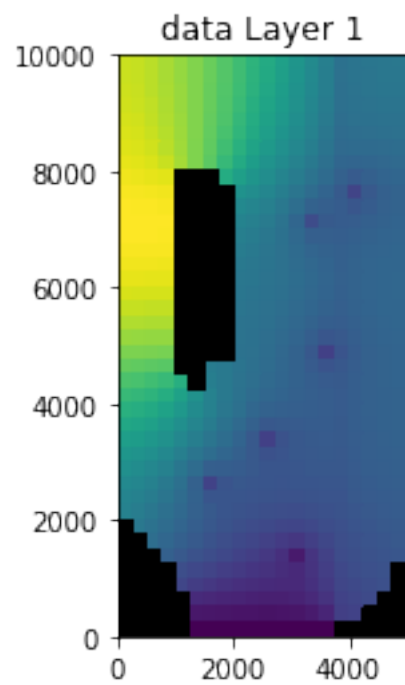
```
In [5]: pyemu.os_utils.run("{0} {1}".format("mfnewt",m.name+".nam"),cwd=m.model_ws)
```

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

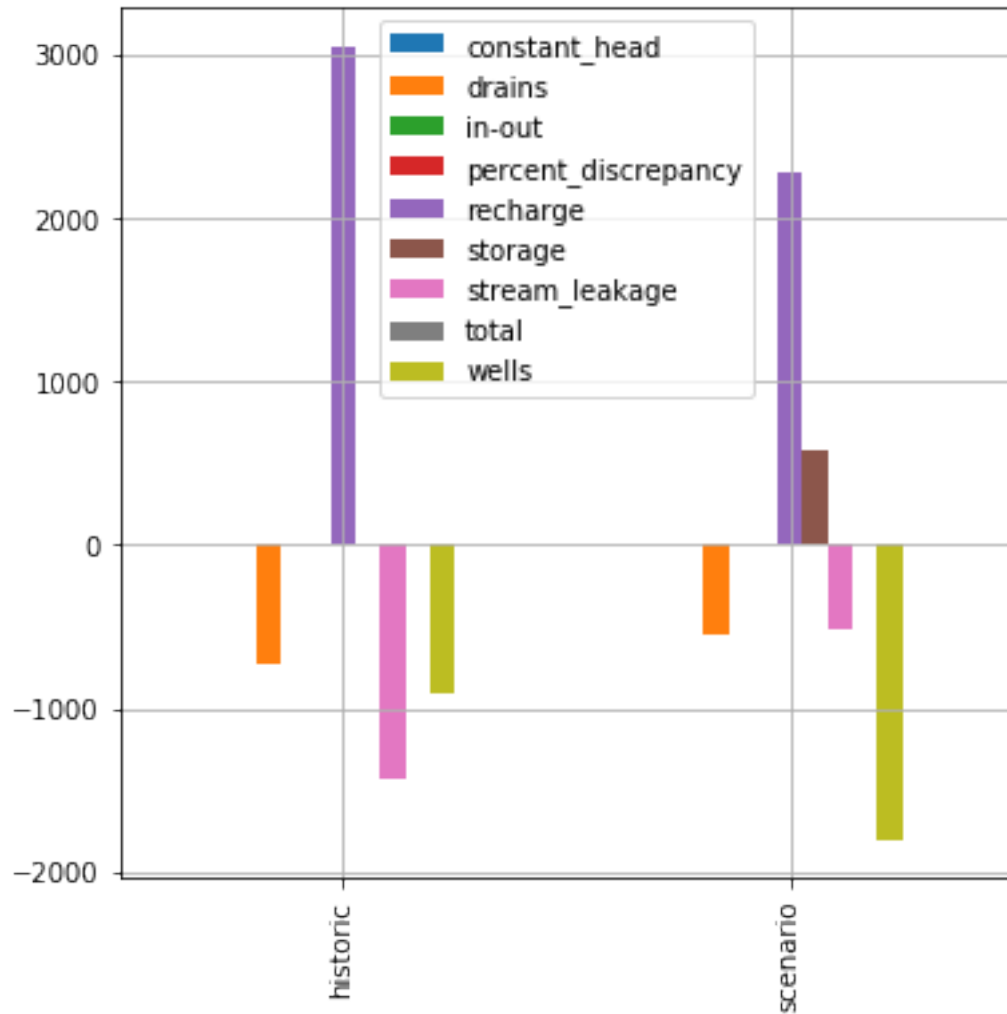
Note that there is a historic period and a scenario with future conditions that differ. For the future scenario, recharge is lower and pumping/abstraction is increased to make up for the presumed deficit in water for agriculture.

```
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()

```



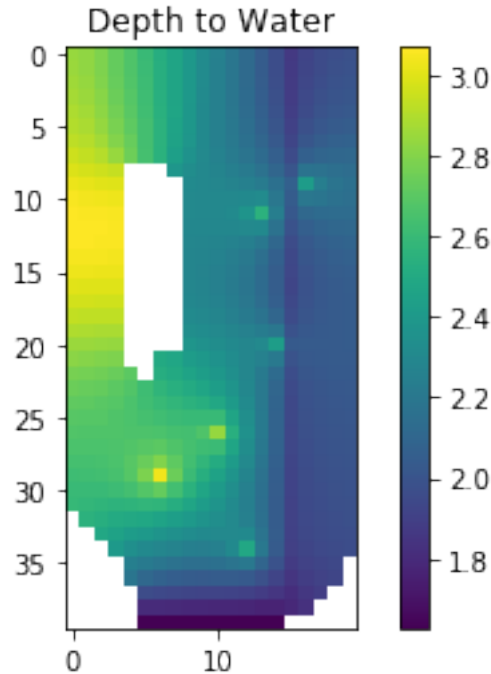
<Figure size 432x288 with 0 Axes>



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()
```

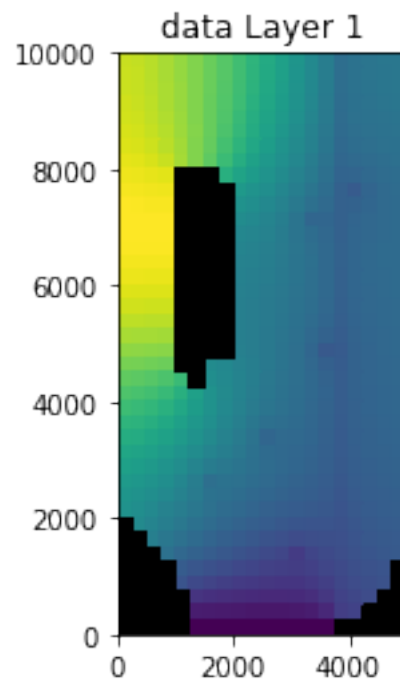


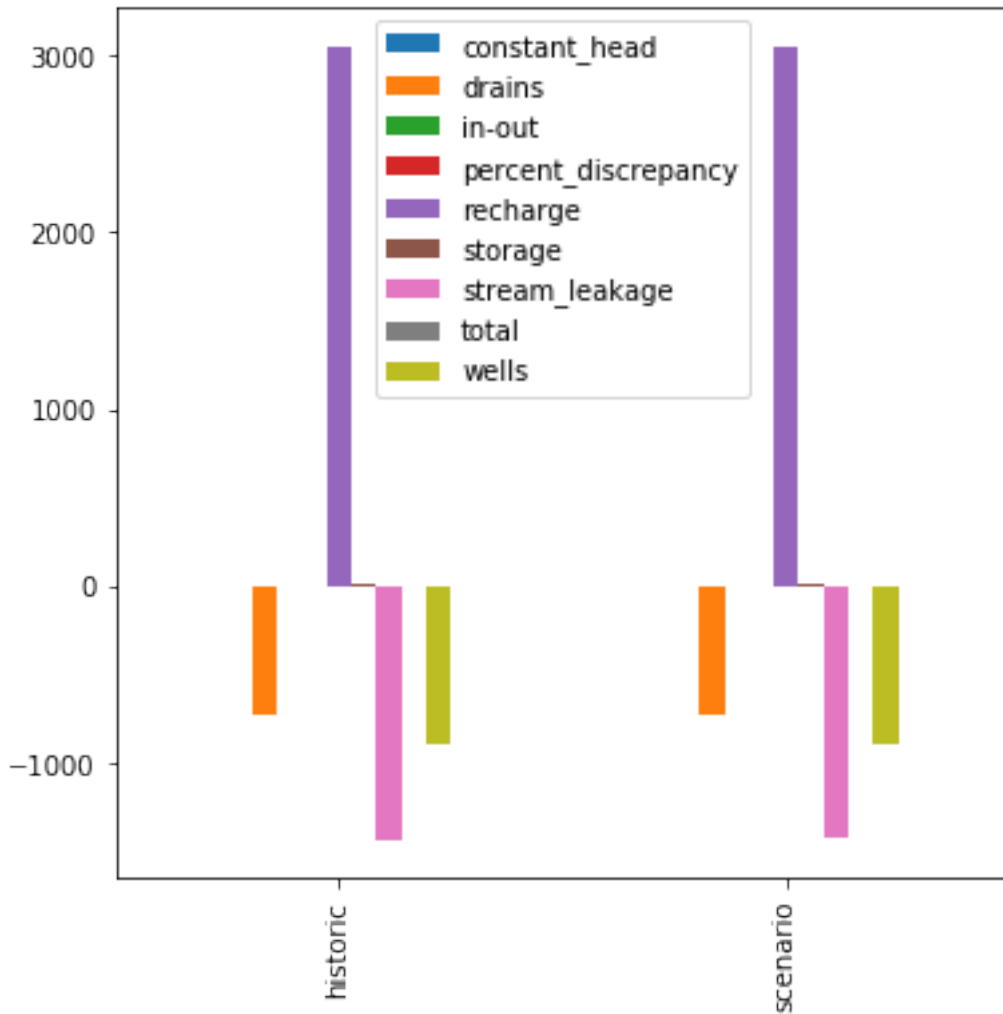
Clearly we can see the river and well locations expressed in the depth to water pattern.

**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(mflag=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 covariance 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_ws="original",
        const_props=props,spatial_list_props=spatial_list_props,temporal_list_props=temporal_list_props,
        grid_props=props,pp_props=props,sfr_pars=sfr_pars,sfr_obs=sfr_obs_dict,build_prior=False,mpp_space=4)
        prep_deps.prep_template(t_d=pst_helper.new_model_ws)
```



2019-05-08 09:00:07.828954 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
2019-05-08 09:00:07.859281 finished: loading flopy model took: 0:00:00.030327
2019-05-08 09:00:07.859402 starting: updating model attributes
2019-05-08 09:00:07.859561 finished: updating model attributes took: 0:00:00.000159
2019-05-08 09:00:07.859713 WARNING: removing existing 'new_model_ws

creating model workspace...
    template

changing model workspace...
    template
2019-05-08 09:00:09.044773 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

2019-05-08 09:00:09.200474 finished: writing new modflow input files took: 0:00:00.155701

2019-05-08 09:00:09.201241 forward\_run line:pyemu.os\_utils.run('mf nwt freyberg.nam 1>freyberg.

2019-05-08 09:00:09.201508 starting: setting up 'template/arr\_org' dir

2019-05-08 09:00:09.202001 finished: setting up 'template/arr\_org' dir took: 0:00:00.000493

2019-05-08 09:00:09.202137 starting: setting up 'template/arr\_mlt' dir

2019-05-08 09:00:09.202988 finished: setting up 'template/arr\_mlt' dir took: 0:00:00.000851

2019-05-08 09:00:09.203255 starting: setting up 'template/list\_org' dir

2019-05-08 09:00:09.203820 finished: setting up 'template/list\_org' dir took: 0:00:00.000565

2019-05-08 09:00:09.203994 starting: setting up 'template/list\_mlt' dir

2019-05-08 09:00:09.204359 finished: setting up 'template/list\_mlt' dir took: 0:00:00.000365

2019-05-08 09:00:09.204662 starting: processing temporal\_list\_props

2019-05-08 09:00:09.242664 finished: processing temporal\_list\_props took: 0:00:00.038002

2019-05-08 09:00:09.243045 starting: processing spatial\_list\_props

2019-05-08 09:00:09.345646 finished: processing spatial\_list\_props took: 0:00:00.102601

2019-05-08 09:00:09.425916 forward\_run line:pyemu.helpers.apply\_list\_pars()

2019-05-08 09:00:09.470053 'extra' pak detected:extra.prsity

2019-05-08 09:00:09.517181 'extra' pak detected:extra.prsity

2019-05-08 09:00:09.578262 'extra' pak detected:extra.prsity

2019-05-08 09:00:09.666427 'extra' pak detected:extra.prsity

2019-05-08 09:00:09.721163 'extra' pak detected:extra.prsity

2019-05-08 09:00:09.765342 'extra' pak detected:extra.prsity

2019-05-08 09:00:09.835896 'extra' pak detected:extra.prsity

2019-05-08 09:00:09.875684 'extra' pak detected:extra.prsity

2019-05-08 09:00:09.913902 'extra' pak detected:extra.prsity

2019-05-08 09:00:10.000753 starting: writing grid tpl:hk3.dat\_gr.tpl

2019-05-08 09:00:10.010060 finished: writing grid tpl:hk3.dat\_gr.tpl took: 0:00:00.009307

2019-05-08 09:00:10.012951 starting: writing grid tpl:vka3.dat\_gr.tpl

2019-05-08 09:00:10.022489 finished: writing grid tpl:vka3.dat\_gr.tpl took: 0:00:00.009538

2019-05-08 09:00:10.025952 starting: writing grid tpl:ss3.dat\_gr.tpl

2019-05-08 09:00:10.036313 finished: writing grid tpl:ss3.dat\_gr.tpl took: 0:00:00.010361

2019-05-08 09:00:10.039682 starting: writing grid tpl:sy3.dat\_gr.tpl

2019-05-08 09:00:10.050258 finished: writing grid tpl:sy3.dat\_gr.tpl took: 0:00:00.010576

2019-05-08 09:00:10.053464 starting: writing grid tpl:str3.dat\_gr.tpl

2019-05-08 09:00:10.064402 finished: writing grid tpl:str3.dat\_gr.tpl took: 0:00:00.010938

2019-05-08 09:00:10.067426 starting: writing grid tpl:prsity3.dat\_gr.tpl

2019-05-08 09:00:10.079651 finished: writing grid tpl:prsity3.dat\_gr.tpl took: 0:00:00.012225

2019-05-08 09:00:10.082780 starting: writing grid tpl:hk4.dat\_gr.tpl

2019-05-08 09:00:10.100673 finished: writing grid tpl:hk4.dat\_gr.tpl took: 0:00:00.017893

2019-05-08 09:00:10.103977 starting: writing grid tpl:vka4.dat\_gr.tpl  
 2019-05-08 09:00:10.114892 finished: writing grid tpl:vka4.dat\_gr.tpl took: 0:00:00.010915  
 2019-05-08 09:00:10.118160 starting: writing grid tpl:ss4.dat\_gr.tpl  
 2019-05-08 09:00:10.128338 finished: writing grid tpl:ss4.dat\_gr.tpl took: 0:00:00.010178  
 2019-05-08 09:00:10.132248 starting: writing grid tpl:sy4.dat\_gr.tpl  
 2019-05-08 09:00:10.141377 finished: writing grid tpl:sy4.dat\_gr.tpl took: 0:00:00.009129  
 2019-05-08 09:00:10.144189 starting: writing grid tpl:strt4.dat\_gr.tpl  
 2019-05-08 09:00:10.154141 finished: writing grid tpl:strt4.dat\_gr.tpl took: 0:00:00.009952  
 2019-05-08 09:00:10.156955 starting: writing grid tpl:prsity4.dat\_gr.tpl  
 2019-05-08 09:00:10.169309 finished: writing grid tpl:prsity4.dat\_gr.tpl took: 0:00:00.012354  
 2019-05-08 09:00:10.172860 starting: writing grid tpl:hk5.dat\_gr.tpl  
 2019-05-08 09:00:10.182297 finished: writing grid tpl:hk5.dat\_gr.tpl took: 0:00:00.009437  
 2019-05-08 09:00:10.185064 starting: writing grid tpl:vka5.dat\_gr.tpl  
 2019-05-08 09:00:10.194329 finished: writing grid tpl:vka5.dat\_gr.tpl took: 0:00:00.009265  
 2019-05-08 09:00:10.196988 starting: writing grid tpl:ss5.dat\_gr.tpl  
 2019-05-08 09:00:10.205949 finished: writing grid tpl:ss5.dat\_gr.tpl took: 0:00:00.008961  
 2019-05-08 09:00:10.208705 starting: writing grid tpl:sy5.dat\_gr.tpl  
 2019-05-08 09:00:10.217476 finished: writing grid tpl:sy5.dat\_gr.tpl took: 0:00:00.008771  
 2019-05-08 09:00:10.220459 starting: writing grid tpl:strt5.dat\_gr.tpl  
 2019-05-08 09:00:10.229903 finished: writing grid tpl:strt5.dat\_gr.tpl took: 0:00:00.009444  
 2019-05-08 09:00:10.232733 starting: writing grid tpl:prsity5.dat\_gr.tpl  
 2019-05-08 09:00:10.244450 finished: writing grid tpl:prsity5.dat\_gr.tpl took: 0:00:00.011717  
 2019-05-08 09:00:10.247114 starting: writing grid tpl:rech2.dat\_gr.tpl  
 2019-05-08 09:00:10.256937 finished: writing grid tpl:rech2.dat\_gr.tpl took: 0:00:00.009823  
 2019-05-08 09:00:10.259641 starting: writing grid tpl:rech3.dat\_gr.tpl  
 2019-05-08 09:00:10.269891 finished: writing grid tpl:rech3.dat\_gr.tpl took: 0:00:00.010250  
 2019-05-08 09:00:10.272953 starting: writing const tpl:hk6.dat\_cn.tpl  
 2019-05-08 09:00:10.279218 finished: writing const tpl:hk6.dat\_cn.tpl took: 0:00:00.006265  
 2019-05-08 09:00:10.281907 starting: writing const tpl:vka6.dat\_cn.tpl  
 2019-05-08 09:00:10.288428 finished: writing const tpl:vka6.dat\_cn.tpl took: 0:00:00.006521  
 2019-05-08 09:00:10.291133 starting: writing const tpl:ss6.dat\_cn.tpl  
 2019-05-08 09:00:10.297275 finished: writing const tpl:ss6.dat\_cn.tpl took: 0:00:00.006142  
 2019-05-08 09:00:10.300432 starting: writing const tpl:sy6.dat\_cn.tpl  
 2019-05-08 09:00:10.306762 finished: writing const tpl:sy6.dat\_cn.tpl took: 0:00:00.006330  
 2019-05-08 09:00:10.309451 starting: writing const tpl:strt6.dat\_cn.tpl  
 2019-05-08 09:00:10.315677 finished: writing const tpl:strt6.dat\_cn.tpl took: 0:00:00.006226  
 2019-05-08 09:00:10.318844 starting: writing const tpl:prsity6.dat\_cn.tpl  
 2019-05-08 09:00:10.326045 finished: writing const tpl:prsity6.dat\_cn.tpl took: 0:00:00.007201  
 2019-05-08 09:00:10.329100 starting: writing const tpl:hk7.dat\_cn.tpl  
 2019-05-08 09:00:10.341363 finished: writing const tpl:hk7.dat\_cn.tpl took: 0:00:00.012263  
 2019-05-08 09:00:10.346249 starting: writing const tpl:vka7.dat\_cn.tpl  
 2019-05-08 09:00:10.354860 finished: writing const tpl:vka7.dat\_cn.tpl took: 0:00:00.008611  
 2019-05-08 09:00:10.357999 starting: writing const tpl:ss7.dat\_cn.tpl  
 2019-05-08 09:00:10.364791 finished: writing const tpl:ss7.dat\_cn.tpl took: 0:00:00.006792  
 2019-05-08 09:00:10.369327 starting: writing const tpl:sy7.dat\_cn.tpl  
 2019-05-08 09:00:10.376299 finished: writing const tpl:sy7.dat\_cn.tpl took: 0:00:00.006972  
 2019-05-08 09:00:10.379360 starting: writing const tpl:strt7.dat\_cn.tpl  
 2019-05-08 09:00:10.385621 finished: writing const tpl:strt7.dat\_cn.tpl took: 0:00:00.006261

```

2019-05-08 09:00:10.388635 starting: writing const tpl:prsity7.dat_cn.tpl
2019-05-08 09:00:10.394679 finished: writing const tpl:prsity7.dat_cn.tpl took: 0:00:00.006044
2019-05-08 09:00:10.397364 starting: writing const tpl:hk8.dat_cn.tpl
2019-05-08 09:00:10.403702 finished: writing const tpl:hk8.dat_cn.tpl took: 0:00:00.006338
2019-05-08 09:00:10.406354 starting: writing const tpl:vka8.dat_cn.tpl
2019-05-08 09:00:10.412223 finished: writing const tpl:vka8.dat_cn.tpl took: 0:00:00.005869
2019-05-08 09:00:10.414963 starting: writing const tpl:ss8.dat_cn.tpl
2019-05-08 09:00:10.421070 finished: writing const tpl:ss8.dat_cn.tpl took: 0:00:00.006107
2019-05-08 09:00:10.423945 starting: writing const tpl:sy8.dat_cn.tpl
2019-05-08 09:00:10.429750 finished: writing const tpl:sy8.dat_cn.tpl took: 0:00:00.005805
2019-05-08 09:00:10.432417 starting: writing const tpl:strt8.dat_cn.tpl
2019-05-08 09:00:10.439022 finished: writing const tpl:strt8.dat_cn.tpl took: 0:00:00.006605
2019-05-08 09:00:10.441944 starting: writing const tpl:prsity8.dat_cn.tpl
2019-05-08 09:00:10.448976 finished: writing const tpl:prsity8.dat_cn.tpl took: 0:00:00.007032
2019-05-08 09:00:10.452089 starting: writing const tpl:rech4.dat_cn.tpl
2019-05-08 09:00:10.458468 finished: writing const tpl:rech4.dat_cn.tpl took: 0:00:00.006379
2019-05-08 09:00:10.461141 starting: writing const tpl:rech5.dat_cn.tpl
2019-05-08 09:00:10.467589 finished: writing const tpl:rech5.dat_cn.tpl took: 0:00:00.006448
2019-05-08 09:00:10.493094 starting: setting up pilot point process
2019-05-08 09:00:10.493496 WARNING: pp_geostrcut is None, using ExpVario with contribution=1 and
2019-05-08 09:00:10.503877 pp_dict: {0: ['hk0', 'vka0', 'ss0', 'sy0', 'strt0', 'prsity0', 'rech
2019-05-08 09:00:10.504336 starting: calling setup_pilot_point_grid()
2019-05-08 09:00:11.255614 640 pilot point parameters created
2019-05-08 09:00:11.256474 pilot point 'pargp':hk0,vka0,ss0,sy0,strt0,prsity0,rech0,rech1,hk1,
2019-05-08 09:00:11.256560 finished: calling setup_pilot_point_grid() took: 0:00:00.752224
2019-05-08 09:00:11.259161 starting: calculating factors for p=hk0, k=0
2019-05-08 09:00:11.260409 saving krige variance file:template/pp_k0_general_zn.fac
2019-05-08 09:00:11.260677 saving krige factors file:template/pp_k0_general_zn.fac
starting interp point loop for 800 points
took 3.111819 seconds
2019-05-08 09:00:14.435976 finished: calculating factors for p=hk0, k=0 took: 0:00:03.176815
2019-05-08 09:00:14.437144 starting: calculating factors for p=vka0, k=0
2019-05-08 09:00:14.438282 finished: calculating factors for p=vka0, k=0 took: 0:00:00.001138
2019-05-08 09:00:14.439166 starting: calculating factors for p=ss0, k=0
2019-05-08 09:00:14.439908 finished: calculating factors for p=ss0, k=0 took: 0:00:00.000742
2019-05-08 09:00:14.440719 starting: calculating factors for p=sy0, k=0
2019-05-08 09:00:14.441421 finished: calculating factors for p=sy0, k=0 took: 0:00:00.000702
2019-05-08 09:00:14.441999 starting: calculating factors for p=strt0, k=0
2019-05-08 09:00:14.443011 finished: calculating factors for p=strt0, k=0 took: 0:00:00.001012
2019-05-08 09:00:14.443595 starting: calculating factors for p=prsity0, k=0
2019-05-08 09:00:14.444341 finished: calculating factors for p=prsity0, k=0 took: 0:00:00.000742
2019-05-08 09:00:14.445284 starting: calculating factors for p=rech0, k=0
2019-05-08 09:00:14.447217 finished: calculating factors for p=rech0, k=0 took: 0:00:00.001933
2019-05-08 09:00:14.448034 starting: calculating factors for p=rech1, k=0
2019-05-08 09:00:14.448945 finished: calculating factors for p=rech1, k=0 took: 0:00:00.000911
2019-05-08 09:00:14.449951 starting: calculating factors for p=hk1, k=1
2019-05-08 09:00:14.450882 saving krige variance file:template/pp_k1_general_zn.fac
2019-05-08 09:00:14.450942 saving krige factors file:template/pp k1 general zn.fac

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starting interp point loop for 800 points
took 2.616637 seconds
2019-05-08 09:00:17.121586 finished: calculating factors for p=hk1, k=1 took: 0:00:02.671635
2019-05-08 09:00:17.122524 starting: calculating factors for p=sy1, k=1
2019-05-08 09:00:17.123315 finished: calculating factors for p=sy1, k=1 took: 0:00:00.000791
2019-05-08 09:00:17.124174 starting: calculating factors for p=ss1, k=1
2019-05-08 09:00:17.125380 finished: calculating factors for p=ss1, k=1 took: 0:00:00.001206
2019-05-08 09:00:17.125982 starting: calculating factors for p=prsity1, k=1
2019-05-08 09:00:17.127026 finished: calculating factors for p=prsity1, k=1 took: 0:00:00.001010
2019-05-08 09:00:17.127842 starting: calculating factors for p=vka1, k=1
2019-05-08 09:00:17.128806 finished: calculating factors for p=vka1, k=1 took: 0:00:00.000964
2019-05-08 09:00:17.129407 starting: calculating factors for p=strt1, k=1
2019-05-08 09:00:17.130103 finished: calculating factors for p=strt1, k=1 took: 0:00:00.000696
2019-05-08 09:00:17.130900 starting: calculating factors for p=hk2, k=2
2019-05-08 09:00:17.131750 saving krige variance file:template/pp_k2_general_zn.fac
2019-05-08 09:00:17.131936 saving krige factors file:template/pp_k2_general_zn.fac
starting interp point loop for 800 points
took 2.7531 seconds
2019-05-08 09:00:19.937425 finished: calculating factors for p=hk2, k=2 took: 0:00:02.806525
2019-05-08 09:00:19.938548 starting: calculating factors for p=strt2, k=2
2019-05-08 09:00:19.939335 finished: calculating factors for p=strt2, k=2 took: 0:00:00.000787
2019-05-08 09:00:19.940054 starting: calculating factors for p=prsity2, k=2
2019-05-08 09:00:19.941240 finished: calculating factors for p=prsity2, k=2 took: 0:00:00.001110
2019-05-08 09:00:19.941911 starting: calculating factors for p=ss2, k=2
2019-05-08 09:00:19.942897 finished: calculating factors for p=ss2, k=2 took: 0:00:00.000986
2019-05-08 09:00:19.943551 starting: calculating factors for p=sy2, k=2
2019-05-08 09:00:19.944533 finished: calculating factors for p=sy2, k=2 took: 0:00:00.000982
2019-05-08 09:00:19.945426 starting: calculating factors for p=vka2, k=2
2019-05-08 09:00:19.946224 finished: calculating factors for p=vka2, k=2 took: 0:00:00.000798
2019-05-08 09:00:19.946363 starting: processing pp_prefix:strt1
2019-05-08 09:00:19.960556 starting: processing pp_prefix:vka2
2019-05-08 09:00:19.970633 starting: processing pp_prefix:vka1
2019-05-08 09:00:19.980097 starting: processing pp_prefix:sy1
2019-05-08 09:00:19.989104 starting: processing pp_prefix:prsity1
2019-05-08 09:00:19.997359 starting: processing pp_prefix:prsity0
2019-05-08 09:00:20.006749 starting: processing pp_prefix:ss2
2019-05-08 09:00:20.015452 starting: processing pp_prefix:sy2
2019-05-08 09:00:20.024200 starting: processing pp_prefix:rech0
2019-05-08 09:00:20.032778 starting: processing pp_prefix:rech1
2019-05-08 09:00:20.041100 starting: processing pp_prefix:prsity2
2019-05-08 09:00:20.050231 starting: processing pp_prefix:ss1
2019-05-08 09:00:20.058571 starting: processing pp_prefix:ss0
2019-05-08 09:00:20.067801 starting: processing pp_prefix:strt2
2019-05-08 09:00:20.076940 starting: processing pp_prefix:hk0
2019-05-08 09:00:20.085339 starting: processing pp_prefix:strt0
2019-05-08 09:00:20.094644 starting: processing pp_prefix:hk1
2019-05-08 09:00:20.102789 starting: processing pp_prefix:vka0
2019-05-08 09:00:20.111712 starting: processing pp_prefix:sy0

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2019-05-08 09:00:20.120657 starting: processing pp_prefix:hk2
2019-05-08 09:00:20.240579 finished: setting up pilot point process took: 0:00:09.747485
2019-05-08 09:00:20.240786 starting: setting up grid process
2019-05-08 09:00:20.240865 WARNING: grid_geostruc is None, using ExpVario with contribution=1
2019-05-08 09:00:20.240993 finished: setting up grid process took: 0:00:00.000207
2019-05-08 09:00:20.244445 starting: save test mlt array arr_mlt/hk0.dat_pp
2019-05-08 09:00:20.246771 finished: save test mlt array arr_mlt/hk0.dat_pp took: 0:00:00.0023
2019-05-08 09:00:20.247634 starting: save test mlt array arr_mlt/vka0.dat_pp
2019-05-08 09:00:20.250137 finished: save test mlt array arr_mlt/vka0.dat_pp took: 0:00:00.002
2019-05-08 09:00:20.251100 starting: save test mlt array arr_mlt/ss0.dat_pp
2019-05-08 09:00:20.257031 finished: save test mlt array arr_mlt/ss0.dat_pp took: 0:00:00.0059
2019-05-08 09:00:20.258076 starting: save test mlt array arr_mlt/sy0.dat_pp
2019-05-08 09:00:20.260224 finished: save test mlt array arr_mlt/sy0.dat_pp took: 0:00:00.0021
2019-05-08 09:00:20.261037 starting: save test mlt array arr_mlt/strt0.dat_pp
2019-05-08 09:00:20.263549 finished: save test mlt array arr_mlt/strt0.dat_pp took: 0:00:00.00
2019-05-08 09:00:20.264362 starting: save test mlt array arr_mlt/prsity0.dat_pp
2019-05-08 09:00:20.267008 finished: save test mlt array arr_mlt/prsity0.dat_pp took: 0:00:00.
2019-05-08 09:00:20.267836 starting: save test mlt array arr_mlt/hk1.dat_pp
2019-05-08 09:00:20.270244 finished: save test mlt array arr_mlt/hk1.dat_pp took: 0:00:00.0024
2019-05-08 09:00:20.271246 starting: save test mlt array arr_mlt/vka1.dat_pp
2019-05-08 09:00:20.273560 finished: save test mlt array arr_mlt/vka1.dat_pp took: 0:00:00.002
2019-05-08 09:00:20.274528 starting: save test mlt array arr_mlt/ss1.dat_pp
2019-05-08 09:00:20.276730 finished: save test mlt array arr_mlt/ss1.dat_pp took: 0:00:00.0022
2019-05-08 09:00:20.277884 starting: save test mlt array arr_mlt/sy1.dat_pp
2019-05-08 09:00:20.280369 finished: save test mlt array arr_mlt/sy1.dat_pp took: 0:00:00.0024
2019-05-08 09:00:20.281304 starting: save test mlt array arr_mlt/strt1.dat_pp
2019-05-08 09:00:20.283624 finished: save test mlt array arr_mlt/strt1.dat_pp took: 0:00:00.00
2019-05-08 09:00:20.284554 starting: save test mlt array arr_mlt/prsity1.dat_pp
2019-05-08 09:00:20.286620 finished: save test mlt array arr_mlt/prsity1.dat_pp took: 0:00:00.
2019-05-08 09:00:20.287524 starting: save test mlt array arr_mlt/hk2.dat_pp
2019-05-08 09:00:20.289684 finished: save test mlt array arr_mlt/hk2.dat_pp took: 0:00:00.0021
2019-05-08 09:00:20.290605 starting: save test mlt array arr_mlt/vka2.dat_pp
2019-05-08 09:00:20.292731 finished: save test mlt array arr_mlt/vka2.dat_pp took: 0:00:00.002
2019-05-08 09:00:20.293540 starting: save test mlt array arr_mlt/ss2.dat_pp
2019-05-08 09:00:20.295708 finished: save test mlt array arr_mlt/ss2.dat_pp took: 0:00:00.0021
2019-05-08 09:00:20.296417 starting: save test mlt array arr_mlt/sy2.dat_pp
2019-05-08 09:00:20.298672 finished: save test mlt array arr_mlt/sy2.dat_pp took: 0:00:00.0022
2019-05-08 09:00:20.299555 starting: save test mlt array arr_mlt/strt2.dat_pp
2019-05-08 09:00:20.302011 finished: save test mlt array arr_mlt/strt2.dat_pp took: 0:00:00.00
2019-05-08 09:00:20.303445 starting: save test mlt array arr_mlt/prsity2.dat_pp
2019-05-08 09:00:20.306376 finished: save test mlt array arr_mlt/prsity2.dat_pp took: 0:00:00.
2019-05-08 09:00:20.307353 starting: save test mlt array arr_mlt/rech0.dat_pp
2019-05-08 09:00:20.309951 finished: save test mlt array arr_mlt/rech0.dat_pp took: 0:00:00.00
2019-05-08 09:00:20.310876 starting: save test mlt array arr_mlt/rech1.dat_pp
2019-05-08 09:00:20.313770 finished: save test mlt array arr_mlt/rech1.dat_pp took: 0:00:00.00
2019-05-08 09:00:20.315224 starting: save test mlt array arr_mlt/hk3.dat_gr
2019-05-08 09:00:20.318519 finished: save test mlt array arr_mlt/hk3.dat_gr took: 0:00:00.0032
2019-05-08 09:00:20.320207 starting: save test mlt array arr_mlt/vka3.dat_gr

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2019-05-08 09:00:20.324052 finished: save test mlt array arr\_mlt/vka3.dat\_gr took: 0:00:00.0033  
 2019-05-08 09:00:20.325500 starting: save test mlt array arr\_mlt/ss3.dat\_gr  
 2019-05-08 09:00:20.328881 finished: save test mlt array arr\_mlt/ss3.dat\_gr took: 0:00:00.0033  
 2019-05-08 09:00:20.330293 starting: save test mlt array arr\_mlt/sy3.dat\_gr  
 2019-05-08 09:00:20.333192 finished: save test mlt array arr\_mlt/sy3.dat\_gr took: 0:00:00.0028  
 2019-05-08 09:00:20.334529 starting: save test mlt array arr\_mlt/strt3.dat\_gr  
 2019-05-08 09:00:20.338186 finished: save test mlt array arr\_mlt/strt3.dat\_gr took: 0:00:00.0033  
 2019-05-08 09:00:20.339591 starting: save test mlt array arr\_mlt/prsity3.dat\_gr  
 2019-05-08 09:00:20.343145 finished: save test mlt array arr\_mlt/prsity3.dat\_gr took: 0:00:00.0033  
 2019-05-08 09:00:20.344426 starting: save test mlt array arr\_mlt/hk4.dat\_gr  
 2019-05-08 09:00:20.348898 finished: save test mlt array arr\_mlt/hk4.dat\_gr took: 0:00:00.0044  
 2019-05-08 09:00:20.350485 starting: save test mlt array arr\_mlt/vka4.dat\_gr  
 2019-05-08 09:00:20.354062 finished: save test mlt array arr\_mlt/vka4.dat\_gr took: 0:00:00.0033  
 2019-05-08 09:00:20.355561 starting: save test mlt array arr\_mlt/ss4.dat\_gr  
 2019-05-08 09:00:20.359039 finished: save test mlt array arr\_mlt/ss4.dat\_gr took: 0:00:00.0034  
 2019-05-08 09:00:20.360446 starting: save test mlt array arr\_mlt/sy4.dat\_gr  
 2019-05-08 09:00:20.363845 finished: save test mlt array arr\_mlt/sy4.dat\_gr took: 0:00:00.0033  
 2019-05-08 09:00:20.365038 starting: save test mlt array arr\_mlt/strt4.dat\_gr  
 2019-05-08 09:00:20.368431 finished: save test mlt array arr\_mlt/strt4.dat\_gr took: 0:00:00.0033  
 2019-05-08 09:00:20.370257 starting: save test mlt array arr\_mlt/prsity4.dat\_gr  
 2019-05-08 09:00:20.373833 finished: save test mlt array arr\_mlt/prsity4.dat\_gr took: 0:00:00.0033  
 2019-05-08 09:00:20.375244 starting: save test mlt array arr\_mlt/hk5.dat\_gr  
 2019-05-08 09:00:20.378799 finished: save test mlt array arr\_mlt/hk5.dat\_gr took: 0:00:00.0035  
 2019-05-08 09:00:20.380297 starting: save test mlt array arr\_mlt/vka5.dat\_gr  
 2019-05-08 09:00:20.383993 finished: save test mlt array arr\_mlt/vka5.dat\_gr took: 0:00:00.0033  
 2019-05-08 09:00:20.385613 starting: save test mlt array arr\_mlt/ss5.dat\_gr  
 2019-05-08 09:00:20.388881 finished: save test mlt array arr\_mlt/ss5.dat\_gr took: 0:00:00.0032  
 2019-05-08 09:00:20.390441 starting: save test mlt array arr\_mlt/sy5.dat\_gr  
 2019-05-08 09:00:20.394018 finished: save test mlt array arr\_mlt/sy5.dat\_gr took: 0:00:00.0035  
 2019-05-08 09:00:20.395569 starting: save test mlt array arr\_mlt/strt5.dat\_gr  
 2019-05-08 09:00:20.399193 finished: save test mlt array arr\_mlt/strt5.dat\_gr took: 0:00:00.0033  
 2019-05-08 09:00:20.400411 starting: save test mlt array arr\_mlt/prsity5.dat\_gr  
 2019-05-08 09:00:20.404060 finished: save test mlt array arr\_mlt/prsity5.dat\_gr took: 0:00:00.0033  
 2019-05-08 09:00:20.405599 starting: save test mlt array arr\_mlt/rech2.dat\_gr  
 2019-05-08 09:00:20.409624 finished: save test mlt array arr\_mlt/rech2.dat\_gr took: 0:00:00.0044  
 2019-05-08 09:00:20.410943 starting: save test mlt array arr\_mlt/rech3.dat\_gr  
 2019-05-08 09:00:20.415054 finished: save test mlt array arr\_mlt/rech3.dat\_gr took: 0:00:00.0044  
 2019-05-08 09:00:20.416867 starting: save test mlt array arr\_mlt/hk6.dat\_cn  
 2019-05-08 09:00:20.421093 finished: save test mlt array arr\_mlt/hk6.dat\_cn took: 0:00:00.0042  
 2019-05-08 09:00:20.423039 starting: save test mlt array arr\_mlt/vka6.dat\_cn  
 2019-05-08 09:00:20.427007 finished: save test mlt array arr\_mlt/vka6.dat\_cn took: 0:00:00.0033  
 2019-05-08 09:00:20.428587 starting: save test mlt array arr\_mlt/ss6.dat\_cn  
 2019-05-08 09:00:20.431804 finished: save test mlt array arr\_mlt/ss6.dat\_cn took: 0:00:00.0032  
 2019-05-08 09:00:20.433235 starting: save test mlt array arr\_mlt/sy6.dat\_cn  
 2019-05-08 09:00:20.436666 finished: save test mlt array arr\_mlt/sy6.dat\_cn took: 0:00:00.0034  
 2019-05-08 09:00:20.438131 starting: save test mlt array arr\_mlt/strt6.dat\_cn  
 2019-05-08 09:00:20.441765 finished: save test mlt array arr\_mlt/strt6.dat\_cn took: 0:00:00.0033  
 2019-05-08 09:00:20.443209 starting: save test mlt array arr\_mlt/prsity6.dat\_cn

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2019-05-08 09:00:20.447514 finished: save test mlt array arr_mlt/prsity6.dat_cn took: 0:00:00.
2019-05-08 09:00:20.449057 starting: save test mlt array arr_mlt/hk7.dat_cn
2019-05-08 09:00:20.452989 finished: save test mlt array arr_mlt/hk7.dat_cn took: 0:00:00.0039
2019-05-08 09:00:20.454610 starting: save test mlt array arr_mlt/vka7.dat_cn
2019-05-08 09:00:20.458439 finished: save test mlt array arr_mlt/vka7.dat_cn took: 0:00:00.003
2019-05-08 09:00:20.459925 starting: save test mlt array arr_mlt/ss7.dat_cn
2019-05-08 09:00:20.463590 finished: save test mlt array arr_mlt/ss7.dat_cn took: 0:00:00.0036
2019-05-08 09:00:20.465089 starting: save test mlt array arr_mlt/sy7.dat_cn
2019-05-08 09:00:20.468906 finished: save test mlt array arr_mlt/sy7.dat_cn took: 0:00:00.0038
2019-05-08 09:00:20.470449 starting: save test mlt array arr_mlt/strt7.dat_cn
2019-05-08 09:00:20.474219 finished: save test mlt array arr_mlt/strt7.dat_cn took: 0:00:00.00
2019-05-08 09:00:20.475786 starting: save test mlt array arr_mlt/prsity7.dat_cn
2019-05-08 09:00:20.479377 finished: save test mlt array arr_mlt/prsity7.dat_cn took: 0:00:00.
2019-05-08 09:00:20.481158 starting: save test mlt array arr_mlt/hk8.dat_cn
2019-05-08 09:00:20.484691 finished: save test mlt array arr_mlt/hk8.dat_cn took: 0:00:00.0035
2019-05-08 09:00:20.486132 starting: save test mlt array arr_mlt/vka8.dat_cn
2019-05-08 09:00:20.489750 finished: save test mlt array arr_mlt/vka8.dat_cn took: 0:00:00.003
2019-05-08 09:00:20.491246 starting: save test mlt array arr_mlt/ss8.dat_cn
2019-05-08 09:00:20.495062 finished: save test mlt array arr_mlt/ss8.dat_cn took: 0:00:00.0038
2019-05-08 09:00:20.496529 starting: save test mlt array arr_mlt/sy8.dat_cn
2019-05-08 09:00:20.499811 finished: save test mlt array arr_mlt/sy8.dat_cn took: 0:00:00.0032
2019-05-08 09:00:20.501661 starting: save test mlt array arr_mlt/strt8.dat_cn
2019-05-08 09:00:20.505475 finished: save test mlt array arr_mlt/strt8.dat_cn took: 0:00:00.00
2019-05-08 09:00:20.506961 starting: save test mlt array arr_mlt/prsity8.dat_cn
2019-05-08 09:00:20.510960 finished: save test mlt array arr_mlt/prsity8.dat_cn took: 0:00:00.
2019-05-08 09:00:20.512414 starting: save test mlt array arr_mlt/rech4.dat_cn
2019-05-08 09:00:20.515836 finished: save test mlt array arr_mlt/rech4.dat_cn took: 0:00:00.00
2019-05-08 09:00:20.517327 starting: save test mlt array arr_mlt/rech5.dat_cn
2019-05-08 09:00:20.521600 finished: save test mlt array arr_mlt/rech5.dat_cn took: 0:00:00.00
2019-05-08 09:00:21.223578 forward_run line:pyemu.helpers.apply_array_pars()

all zeros for runoff...skipping...
all zeros for hcond1...skipping...
all zeros for ppts...skipping...
2019-05-08 09:00:21.372158 starting: processing obs type mflist water budget obs
2019-05-08 09:00:21.471114 forward_run line:pyemu.gw_utils.apply_mflist_budget_obs('freyberg.l
2019-05-08 09:00:21.471670 finished: processing obs type mflist water budget obs took: 0:00:00
2019-05-08 09:00:21.471769 starting: processing obs type hyd file
2019-05-08 09:00:21.472172 finished: processing obs type hyd file took: 0:00:00.000403
2019-05-08 09:00:21.472511 starting: processing obs type external obs-sim smp files
2019-05-08 09:00:21.473084 finished: processing obs type external obs-sim smp files took: 0:00
2019-05-08 09:00:21.474008 starting: processing obs type hob
2019-05-08 09:00:21.474358 finished: processing obs type hob took: 0:00:00.000350
2019-05-08 09:00:21.474799 starting: processing obs type hds
[[0, 0], [0, 1], [0, 2], [1, 0], [1, 1], [1, 2]]
2019-05-08 09:00:21.962440 finished: processing obs type hds took: 0:00:00.487641
2019-05-08 09:00:21.963113 starting: processing obs type sfr
writing 'sfr_obs.config' to template/sfr_obs.config

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2019-05-08 09:00:22.327506 finished: processing obs type sfr took: 0:00:00.364393
2019-05-08 09:00:22.327820 changing dir in to template
2019-05-08 09:00:22.328675 starting: instantiating control file from i/o files
2019-05-08 09:00:22.328941 tpl files: wel.csv.tpl,drn.csv.tpl,hk3.dat_gr.tpl,vka3.dat_gr.tpl,s
2019-05-08 09:00:22.329100 ins files: freyberg.hds.dat.ins,vol.dat.ins,freyberg.sfr.out.proces
2019-05-08 09:00:22.693183 finished: instantiating control file from i/o files took: 0:00:00.3
2019-05-08 09:00:22.976571 starting: writing forward_run.py
2019-05-08 09:00:22.977665 finished: writing forward_run.py took: 0:00:00.001094
2019-05-08 09:00:22.978083 writing pst template/freyberg.pst
noptmax:0, npar_adj:14819, nnz_obs:4434
2019-05-08 09:00:24.883055 starting: running pestchek on freyberg.pst
2019-05-08 09:00:24.973267 pestcheck:PESTCHEK Version 13.0. Watermark Numerical Computing.
2019-05-08 09:00:24.973618 pestcheck:
2019-05-08 09:00:24.973674 pestcheck:Errors ----->
2019-05-08 09:00:24.973817 pestcheck:Line 2403 of file freyberg.pst: parameter name "prsity300
2019-05-08 09:00:24.973873 pestcheck:12 characters long.
2019-05-08 09:00:24.974162 pestcheck:Line 2404 of file freyberg.pst: parameter name "prsity300
2019-05-08 09:00:24.974219 pestcheck:12 characters long.
2019-05-08 09:00:24.974730 pestcheck:Line 2404 of file freyberg.pst: parameter name "prsity300
2019-05-08 09:00:24.974792 pestcheck:once.
2019-05-08 09:00:24.974832 pestcheck:Line 2405 of file freyberg.pst: parameter name "prsity300
2019-05-08 09:00:24.974876 pestcheck:12 characters long.
2019-05-08 09:00:24.974913 pestcheck:Line 2405 of file freyberg.pst: parameter name "prsity300
2019-05-08 09:00:24.974963 pestcheck:once.
2019-05-08 09:00:24.974999 pestcheck:Line 2406 of file freyberg.pst: parameter name "prsity300
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2019-05-08 09:00:24.975156 pestcheck:Line 2406 of file freyberg.pst: parameter name "prsity300
2019-05-08 09:00:24.975219 pestcheck:once.
2019-05-08 09:00:24.975255 pestcheck:Line 2407 of file freyberg.pst: parameter name "prsity300
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2019-05-08 09:00:24.975451 pestcheck:once.
2019-05-08 09:00:24.975483 pestcheck:Line 2408 of file freyberg.pst: parameter name "prsity300
2019-05-08 09:00:24.975524 pestcheck:12 characters long.
2019-05-08 09:00:24.975559 pestcheck:Line 2408 of file freyberg.pst: parameter name "prsity300
2019-05-08 09:00:24.975595 pestcheck:once.
2019-05-08 09:00:24.975624 pestcheck:Line 2409 of file freyberg.pst: parameter name "prsity300
2019-05-08 09:00:24.975745 pestcheck:12 characters long.
2019-05-08 09:00:24.975952 pestcheck:Line 2409 of file freyberg.pst: parameter name "prsity300
2019-05-08 09:00:24.976062 pestcheck:once.
2019-05-08 09:00:24.976111 pestcheck:Line 2410 of file freyberg.pst: parameter name "prsity300
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2019-05-08 09:00:24.976413 pestcheck:Line 2411 of file freyberg.pst: parameter name "prsity300
2019-05-08 09:00:24.976473 pestcheck:12 characters long.
2019-05-08 09:00:24.976510 pestcheck:Line 2411 of file freyberg.pst: parameter name "prsity300
2019-05-08 09:00:24.976644 pestcheck:once.

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2019-05-08 09:00:24.976679 pestcheck:Line 2412 of file freyberg.pst: parameter name "prsity3000  
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2019-05-08 09:00:24.976772 pestcheck:Line 2412 of file freyberg.pst: parameter name "prsity3000  
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2019-05-08 09:00:24.976851 pestcheck:Line 2413 of file freyberg.pst: parameter name "prsity3000  
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2019-05-08 09:00:24.977122 pestcheck:Line 2414 of file freyberg.pst: parameter name "prsity3000  
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2019-05-08 09:00:24.977290 pestcheck:Line 2415 of file freyberg.pst: parameter name "prsity3000  
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2019-05-08 09:00:24.978151 pestcheck:Line 2418 of file freyberg.pst: parameter name "prsity3000  
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2019-05-08 09:00:24.980223 pestcheck:Line 2424 of file freyberg.pst: parameter name "prsity3000  
2019-05-08 09:00:24.980330 pestcheck:once.

2019-05-08 09:00:24.980379 pestcheck:Line 2425 of file freyberg.pst: parameter name "prsity300.  
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 2019-05-08 09:00:24.981405 pestcheck:once.  
 2019-05-08 09:00:24.981524 pestcheck:Line 2428 of file freyberg.pst: parameter name "prsity300.  
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 2019-05-08 09:00:24.981743 pestcheck:Line 2428 of file freyberg.pst: parameter name "prsity300.  
 2019-05-08 09:00:24.981929 pestcheck:once.  
 2019-05-08 09:00:24.982035 pestcheck:Line 2429 of file freyberg.pst: parameter name "prsity300.  
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 2019-05-08 09:00:24.982403 pestcheck:Line 2430 of file freyberg.pst: parameter name "prsity300.  
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2019-05-08 09:00:24.985104 pestcheck:Line 2437 of file freyberg.pst: parameter name "prsity300  
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2019-05-08 09:00:24.985625 pestcheck:Line 2439 of file freyberg.pst: parameter name "prsity300  
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2019-05-08 09:00:24.986403 pestcheck:Line 2441 of file freyberg.pst: parameter name "prsity300  
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2019-05-08 09:00:24.993702 pestcheck:Line 2462 of file freyberg.pst: parameter name "prsity3003  
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2019-05-08 09:00:24.993793 pestcheck:Line 2463 of file freyberg.pst: parameter name "prsity3003  
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2019-05-08 09:00:24.995612 pestcheck:Line 2468 of file freyberg.pst: parameter name "prsity3003  
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2019-05-08 09:00:24.996306 pestcheck:Line 2470 of file freyberg.pst: parameter name "prsity3003  
2019-05-08 09:00:24.996409 pestcheck:12 characters long.  
2019-05-08 09:00:24.996517 pestcheck:Line 2470 of file freyberg.pst: parameter name "prsity3003  
2019-05-08 09:00:24.996565 pestcheck:once.  
2019-05-08 09:00:24.996674 pestcheck:Line 2471 of file freyberg.pst: parameter name "prsity3003  
2019-05-08 09:00:24.996780 pestcheck:12 characters long.  
2019-05-08 09:00:24.996828 pestcheck:Line 2471 of file freyberg.pst: parameter name "prsity3003  
2019-05-08 09:00:24.996937 pestcheck:once.  
2019-05-08 09:00:24.997130 pestcheck:Line 2472 of file freyberg.pst: parameter name "prsity3003  
2019-05-08 09:00:24.997242 pestcheck:12 characters long.  
2019-05-08 09:00:24.997359 pestcheck:Line 2472 of file freyberg.pst: parameter name "prsity3003  
2019-05-08 09:00:24.997465 pestcheck:once.  
2019-05-08 09:00:24.997582 pestcheck:Line 2473 of file freyberg.pst: parameter name "prsity3003  
2019-05-08 09:00:24.997688 pestcheck:12 characters long.  
2019-05-08 09:00:24.997804 pestcheck:Line 2474 of file freyberg.pst: parameter name "prsity3003  
2019-05-08 09:00:24.997910 pestcheck:12 characters long.  
2019-05-08 09:00:24.998033 pestcheck:Line 2474 of file freyberg.pst: parameter name "prsity3003  
2019-05-08 09:00:24.998139 pestcheck:once.  
2019-05-08 09:00:24.998257 pestcheck:Line 2475 of file freyberg.pst: parameter name "prsity3003  
2019-05-08 09:00:24.998363 pestcheck:12 characters long.



2019-05-08 09:00:24.998479 pestcheck:Line 2475 of file freyberg.pst: parameter name "prsity3003  
2019-05-08 09:00:24.998585 pestcheck:once.  
2019-05-08 09:00:24.998700 pestcheck:Line 2476 of file freyberg.pst: parameter name "prsity3003  
2019-05-08 09:00:24.998805 pestcheck:12 characters long.  
2019-05-08 09:00:24.998921 pestcheck:Line 2476 of file freyberg.pst: parameter name "prsity3003  
2019-05-08 09:00:24.999033 pestcheck:once.  
2019-05-08 09:00:24.999081 pestcheck:Line 2477 of file freyberg.pst: parameter name "prsity3003  
2019-05-08 09:00:24.999188 pestcheck:12 characters long.  
2019-05-08 09:00:24.999307 pestcheck:Line 2477 of file freyberg.pst: parameter name "prsity3003  
2019-05-08 09:00:24.999419 pestcheck:once.  
2019-05-08 09:00:24.999521 pestcheck:Line 2478 of file freyberg.pst: parameter name "prsity3003  
2019-05-08 09:00:24.999634 pestcheck:12 characters long.  
2019-05-08 09:00:24.999736 pestcheck:Line 2478 of file freyberg.pst: parameter name "prsity3003  
2019-05-08 09:00:24.999782 pestcheck:once.  
2019-05-08 09:00:24.999820 pestcheck:Line 2479 of file freyberg.pst: parameter name "prsity3003  
2019-05-08 09:00:24.999918 pestcheck:12 characters long.  
2019-05-08 09:00:25.000101 pestcheck:Line 2479 of file freyberg.pst: parameter name "prsity3003  
2019-05-08 09:00:25.000206 pestcheck:once.  
2019-05-08 09:00:25.000319 pestcheck:Line 2480 of file freyberg.pst: parameter name "prsity3003  
2019-05-08 09:00:25.000423 pestcheck:12 characters long.  
2019-05-08 09:00:25.000539 pestcheck:Line 2480 of file freyberg.pst: parameter name "prsity3003  
2019-05-08 09:00:25.000643 pestcheck:once.  
2019-05-08 09:00:25.000692 pestcheck:Line 2481 of file freyberg.pst: parameter name "prsity3003  
2019-05-08 09:00:25.000796 pestcheck:12 characters long.  
2019-05-08 09:00:25.000899 pestcheck:Line 2481 of file freyberg.pst: parameter name "prsity3003  
2019-05-08 09:00:25.001016 pestcheck:once.  
2019-05-08 09:00:25.001119 pestcheck:Line 2482 of file freyberg.pst: parameter name "prsity3003  
2019-05-08 09:00:25.001202 pestcheck:12 characters long.  
2019-05-08 09:00:25.001272 pestcheck:Line 2482 of file freyberg.pst: parameter name "prsity3003  
2019-05-08 09:00:25.001375 pestcheck:once.  
2019-05-08 09:00:25.001421 pestcheck:Line 2483 of file freyberg.pst: parameter name "prsity3004  
2019-05-08 09:00:25.001460 pestcheck:12 characters long.  
2019-05-08 09:00:25.001579 pestcheck:Line 2484 of file freyberg.pst: parameter name "prsity3004  
2019-05-08 09:00:25.001697 pestcheck:12 characters long.  
2019-05-08 09:00:25.001810 pestcheck:Line 2484 of file freyberg.pst: parameter name "prsity3004  
2019-05-08 09:00:25.001914 pestcheck:once.  
2019-05-08 09:00:25.002032 pestcheck:Line 2485 of file freyberg.pst: parameter name "prsity3004  
2019-05-08 09:00:25.002135 pestcheck:12 characters long.  
2019-05-08 09:00:25.002247 pestcheck:Line 2485 of file freyberg.pst: parameter name "prsity3004  
2019-05-08 09:00:25.002350 pestcheck:once.  
2019-05-08 09:00:25.002397 pestcheck:Line 2486 of file freyberg.pst: parameter name "prsity3004  
2019-05-08 09:00:25.002502 pestcheck:12 characters long.  
2019-05-08 09:00:25.002604 pestcheck:Line 2486 of file freyberg.pst: parameter name "prsity3004  
2019-05-08 09:00:25.002651 pestcheck:once.  
2019-05-08 09:00:25.002688 pestcheck:Line 2487 of file freyberg.pst: parameter name "prsity3004  
2019-05-08 09:00:25.002788 pestcheck:12 characters long.  
2019-05-08 09:00:25.002890 pestcheck:Line 2487 of file freyberg.pst: parameter name "prsity3004  
2019-05-08 09:00:25.003008 pestcheck:once.

2019-05-08 09:00:25.003111 pestcheck:Line 2488 of file freyberg.pst: parameter name "prsity3004  
2019-05-08 09:00:25.003157 pestcheck:12 characters long.  
2019-05-08 09:00:25.003259 pestcheck:Line 2488 of file freyberg.pst: parameter name "prsity3004  
2019-05-08 09:00:25.003362 pestcheck:once.  
2019-05-08 09:00:25.003408 pestcheck:Line 2489 of file freyberg.pst: parameter name "prsity3004  
2019-05-08 09:00:25.003514 pestcheck:12 characters long.  
2019-05-08 09:00:25.003617 pestcheck:Line 2489 of file freyberg.pst: parameter name "prsity3004  
2019-05-08 09:00:25.003729 pestcheck:once.  
2019-05-08 09:00:25.003831 pestcheck:Line 2490 of file freyberg.pst: parameter name "prsity3004  
2019-05-08 09:00:25.003942 pestcheck:12 characters long.  
2019-05-08 09:00:25.004125 pestcheck:Line 2490 of file freyberg.pst: parameter name "prsity3004  
2019-05-08 09:00:25.004227 pestcheck:once.  
2019-05-08 09:00:25.004274 pestcheck:Line 2491 of file freyberg.pst: parameter name "prsity3004  
2019-05-08 09:00:25.004314 pestcheck:12 characters long.  
2019-05-08 09:00:25.004413 pestcheck:Line 2491 of file freyberg.pst: parameter name "prsity3004  
2019-05-08 09:00:25.004515 pestcheck:once.  
2019-05-08 09:00:25.004629 pestcheck:Line 2492 of file freyberg.pst: parameter name "prsity3004  
2019-05-08 09:00:25.004731 pestcheck:12 characters long.  
2019-05-08 09:00:25.004843 pestcheck:Line 2492 of file freyberg.pst: parameter name "prsity3004  
2019-05-08 09:00:25.004945 pestcheck:once.  
2019-05-08 09:00:25.005061 pestcheck:Line 2493 of file freyberg.pst: parameter name "prsity3004  
2019-05-08 09:00:25.005189 pestcheck:12 characters long.  
2019-05-08 09:00:25.005291 pestcheck:Line 2494 of file freyberg.pst: parameter name "prsity3004  
2019-05-08 09:00:25.005395 pestcheck:12 characters long.  
2019-05-08 09:00:25.005443 pestcheck:Line 2494 of file freyberg.pst: parameter name "prsity3004  
2019-05-08 09:00:25.005551 pestcheck:once.  
2019-05-08 09:00:25.005653 pestcheck:Line 2495 of file freyberg.pst: parameter name "prsity3004  
2019-05-08 09:00:25.005765 pestcheck:12 characters long.  
2019-05-08 09:00:25.005866 pestcheck:Line 2495 of file freyberg.pst: parameter name "prsity3004  
2019-05-08 09:00:25.005978 pestcheck:once.  
2019-05-08 09:00:25.006096 pestcheck:Line 2496 of file freyberg.pst: parameter name "prsity3004  
2019-05-08 09:00:25.006197 pestcheck:12 characters long.  
2019-05-08 09:00:25.006299 pestcheck:Line 2496 of file freyberg.pst: parameter name "prsity3004  
2019-05-08 09:00:25.006410 pestcheck:once.  
2019-05-08 09:00:25.006564 pestcheck:Line 2497 of file freyberg.pst: parameter name "prsity3004  
2019-05-08 09:00:25.006632 pestcheck:12 characters long.  
2019-05-08 09:00:25.006711 pestcheck:Line 2497 of file freyberg.pst: parameter name "prsity3004  
2019-05-08 09:00:25.006799 pestcheck:once.  
2019-05-08 09:00:25.006948 pestcheck:Line 2498 of file freyberg.pst: parameter name "prsity3004  
2019-05-08 09:00:25.007038 pestcheck:12 characters long.  
2019-05-08 09:00:25.007194 pestcheck:Line 2498 of file freyberg.pst: parameter name "prsity3004  
2019-05-08 09:00:25.007262 pestcheck:once.  
2019-05-08 09:00:25.007327 pestcheck:Line 2499 of file freyberg.pst: parameter name "prsity3004  
2019-05-08 09:00:25.007392 pestcheck:12 characters long.  
2019-05-08 09:00:25.007456 pestcheck:Line 2499 of file freyberg.pst: parameter name "prsity3004  
2019-05-08 09:00:25.007507 pestcheck:once.  
2019-05-08 09:00:25.007586 pestcheck:Line 2500 of file freyberg.pst: parameter name "prsity3004  
2019-05-08 09:00:25.007662 pestcheck:12 characters long.

```

2019-05-08 09:00:25.007800 pestcheck:Line 2500 of file freyberg.pst: parameter name "prsity300
2019-05-08 09:00:25.007851 pestcheck:once.
2019-05-08 09:00:25.007953 pestcheck:Line 2501 of file freyberg.pst: parameter name "prsity300
2019-05-08 09:00:25.008009 pestcheck:12 characters long.
2019-05-08 09:00:25.008116 pestcheck:Line 2501 of file freyberg.pst: parameter name "prsity300
2019-05-08 09:00:25.008224 pestcheck:once.
2019-05-08 09:00:25.008272 pestcheck:Line 2502 of file freyberg.pst: parameter name "prsity300
2019-05-08 09:00:25.008311 pestcheck:12 characters long.
2019-05-08 09:00:25.008415 pestcheck:Line 2502 of file freyberg.pst: parameter name "prsity300
2019-05-08 09:00:25.008522 pestcheck:once.
2019-05-08 09:00:25.008569 pestcheck:Line 2503 of file freyberg.pst: parameter name "prsity300
2019-05-08 09:00:25.008612 pestcheck:12 characters long.
2019-05-08 09:00:25.008715 pestcheck:Line 2504 of file freyberg.pst: parameter name "prsity300
2019-05-08 09:00:25.008821 pestcheck:12 characters long.
2019-05-08 09:00:25.008868 pestcheck:Line 2504 of file freyberg.pst: parameter name "prsity300
2019-05-08 09:00:25.008907 pestcheck:once.
2019-05-08 09:00:25.009010 pestcheck:Line 2505 of file freyberg.pst: parameter name "prsity300
2019-05-08 09:00:25.009131 pestcheck:12 characters long.
2019-05-08 09:00:25.009237 pestcheck:Line 2505 of file freyberg.pst: parameter name "prsity300
2019-05-08 09:00:25.009343 pestcheck:once.
2019-05-08 09:00:25.009389 pestcheck:Line 2506 of file freyberg.pst: parameter name "prsity300
2019-05-08 09:00:25.009429 pestcheck:12 characters long.
2019-05-08 09:00:25.009530 pestcheck:Line 2506 of file freyberg.pst: parameter name "prsity300
2019-05-08 09:00:25.009637 pestcheck:once.
2019-05-08 09:00:25.009753 pestcheck:Line 2507 of file freyberg.pst: parameter name "prsity300
2019-05-08 09:00:25.009859 pestcheck:12 characters long.
2019-05-08 09:00:25.009906 pestcheck:Line 2507 of file freyberg.pst: parameter name "prsity300
2019-05-08 09:00:25.010012 pestcheck:once.
2019-05-08 09:00:25.010136 pestcheck:Line 2508 of file freyberg.pst: parameter name "prsity300
2019-05-08 09:00:25.010176 pestcheck:12 characters long.
2019-05-08 09:00:25.010518 finished: running pestchek on freyberg.pst took: 0:00:00.127463
2019-05-08 09:00:25.010652 starting: saving intermediate _setup_<> dfs into template
2019-05-08 09:00:25.150818 finished: saving intermediate _setup_<> dfs into template took: 0:0
2019-05-08 09:00:25.151739 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()
```

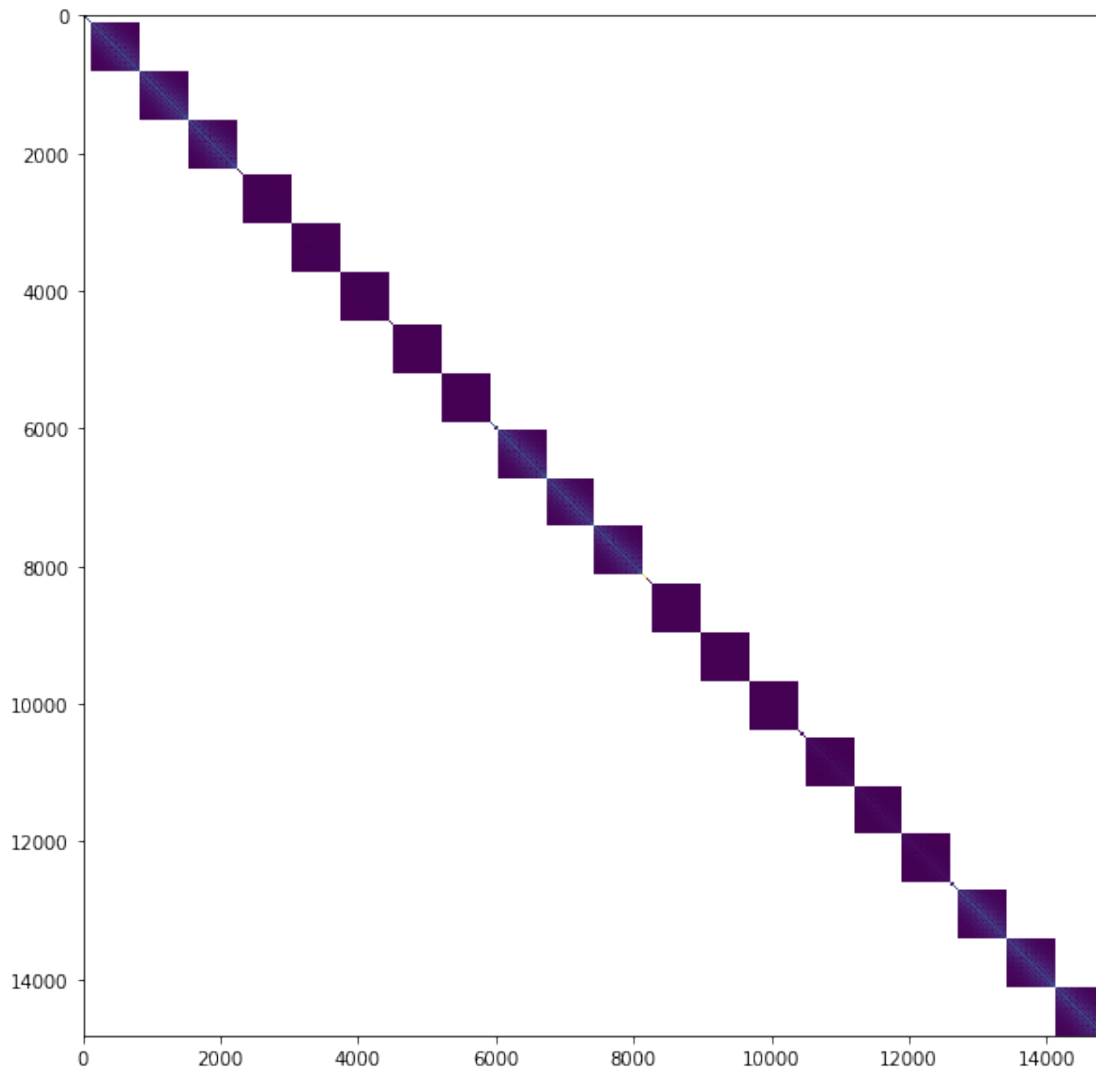
```
2019-05-08 09:00:34.546478 starting: building prior covariance matrix
2019-05-08 09:00:34.656116 WARNING: geospatial prior not implemented for SFR pars
```

```
/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
```

```
2019-05-08 09:00:41.054505 saving prior covariance matrix to file template/prior_cov.jcb
2019-05-08 09:00:45.639259 finished: building prior covariance matrix took: 0:00:11.092781
```



### 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)
```

```
2019-05-08 09:01:00.141001 starting: drawing realizations
```

```
building diagonal cov
```

```
processing name:struct1,nugget:0.0,structures:
```

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

```
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
```

```
working on pargroups ['drncond_k00']
```

```
/Users/jeremyw/miniconda3/lib/python3.5/site-packages/pandas/core/indexing.py:362: SettingWithCopyError:
```

```
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: SettingWithCopyError:
```

```
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
```

```
processing name:struct1,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
processing  name:struct1,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_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_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_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_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_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_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_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
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_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_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
processing name:struct1,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

```



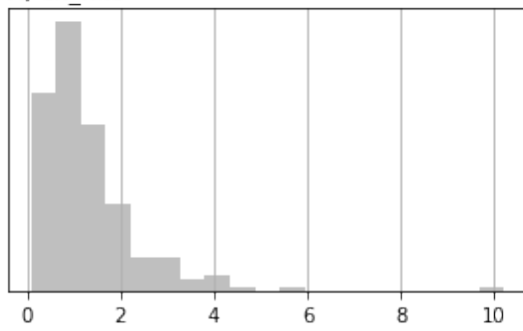
```
making full cov draws with home-grown goodness
working on pargroups ['gr_rech3']
build cov matrix
done
getting diag var cov 705
scaling full cov by diag var cov
making full cov draws with home-grown goodness
adding remaining parameters to diagonal
2019-05-08 09:01:07.559896 finished: drawing realizations took: 0:00:07.418895
```

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

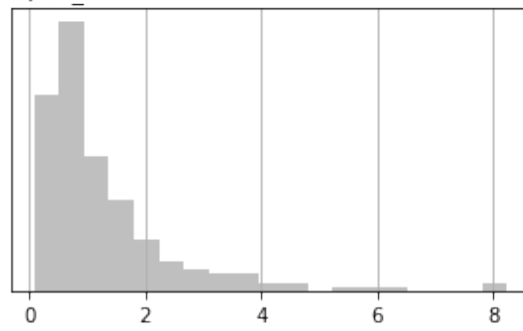
```
In [26]: par = pst_helper.pst.parameter_data
         pyemu.plot_utils.ensemble_helper(pe, plot_cols=par.groupby("pargp").groups, bins=20)
         plt.show()
```

<Figure size 576x756 with 0 Axes>

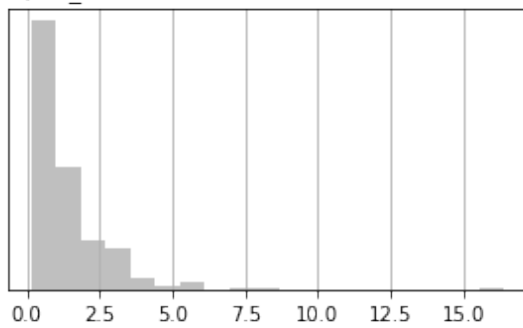
A) cn\_hk6



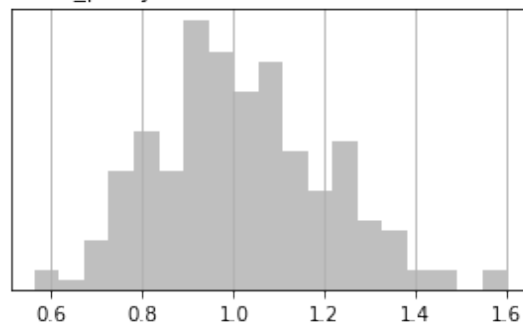
B) cn\_hk7



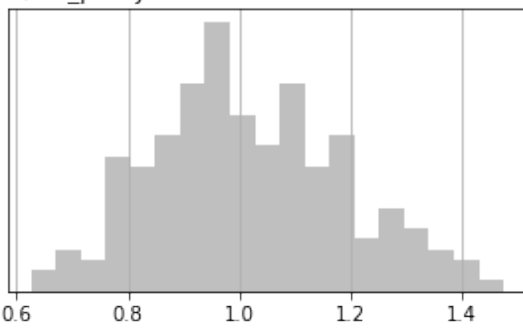
C) cn\_hk8



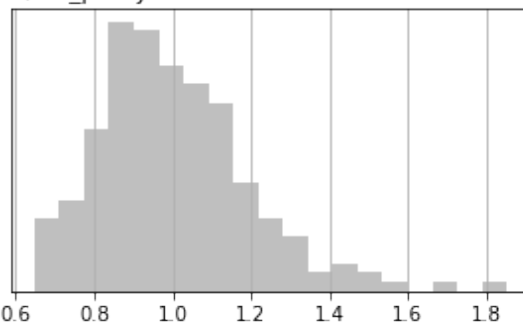
D) cn\_prsity6



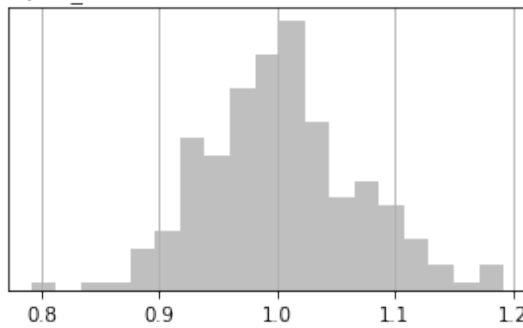
E) cn\_prsity7



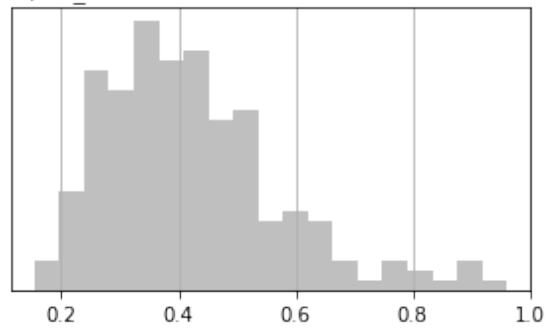
F) cn\_prsity8



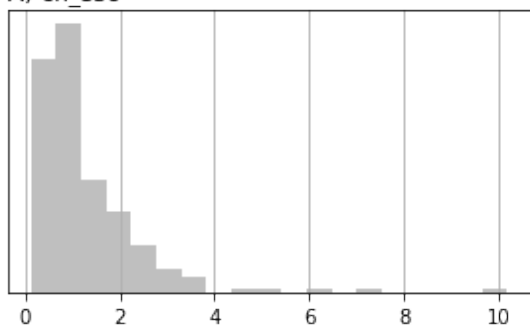
G) cn\_rech4



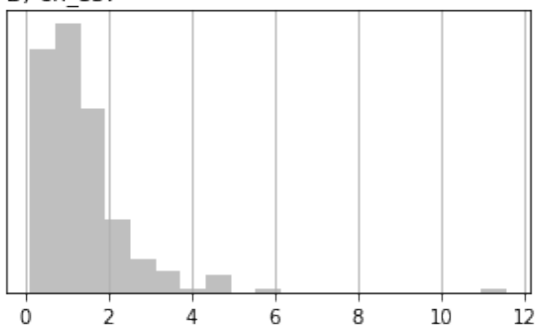
H) cn\_rech5



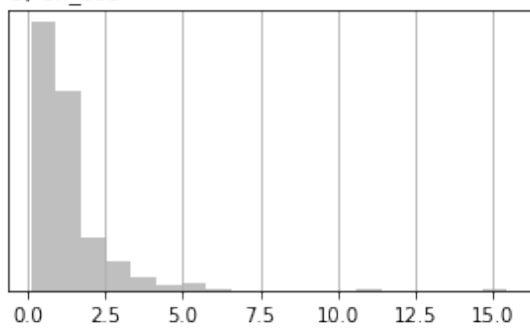
A) cn\_ss6



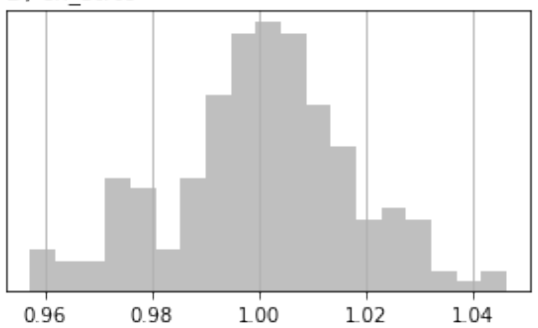
B) cn\_ss7



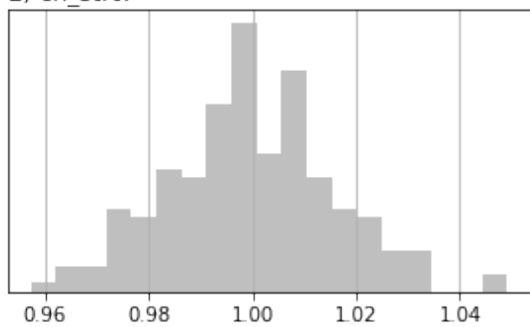
C) cn\_ss8



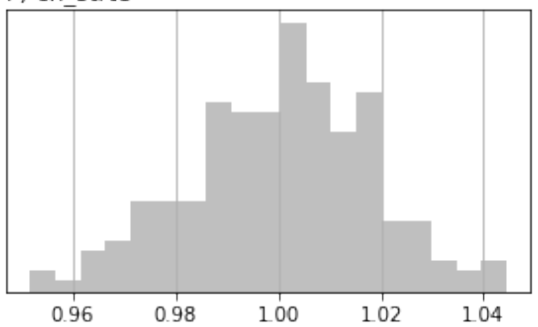
D) cn\_strt6



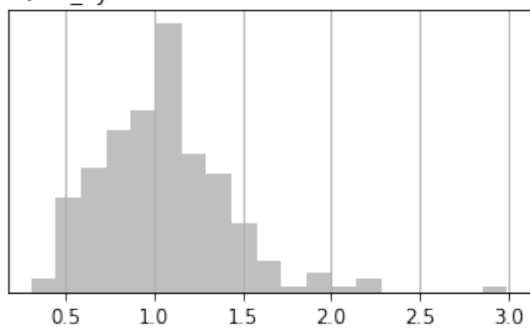
E) cn\_strt7



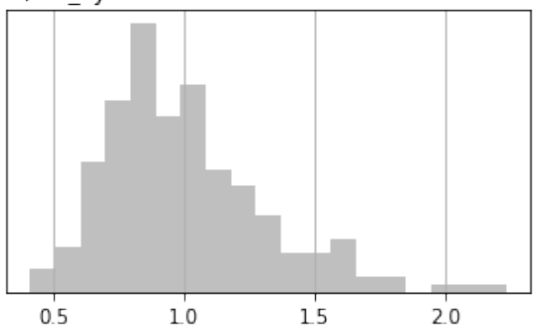
F) cn\_strt8



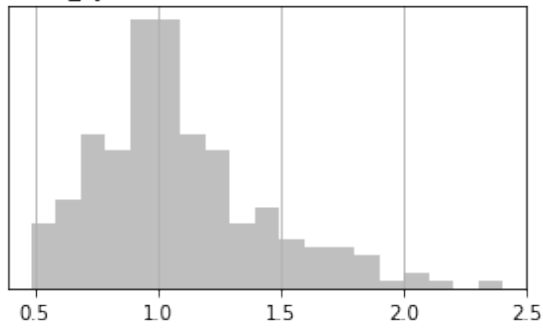
G) cn\_sy6



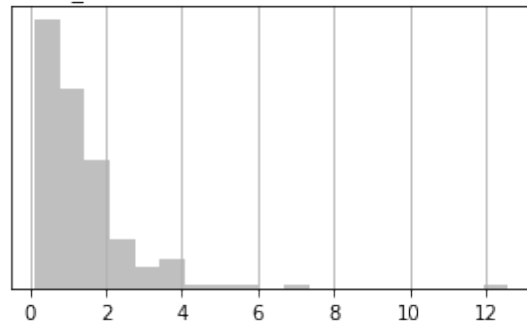
H) cn\_sy7



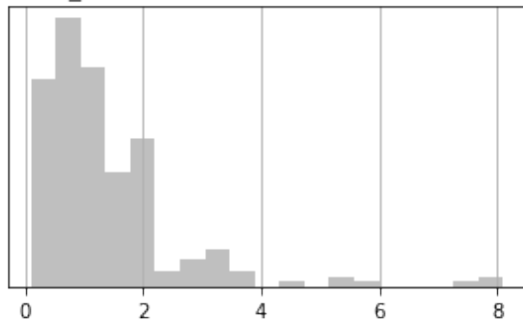
A) cn\_sy8



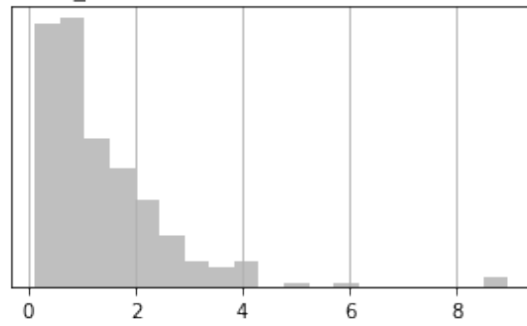
B) cn\_vka6



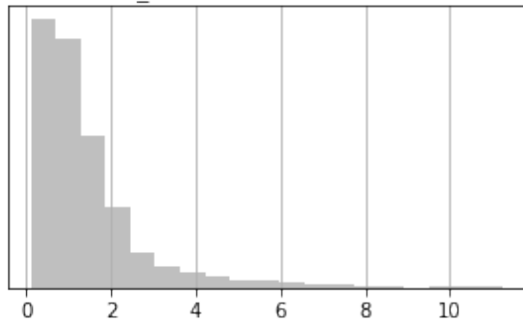
C) cn\_vka7



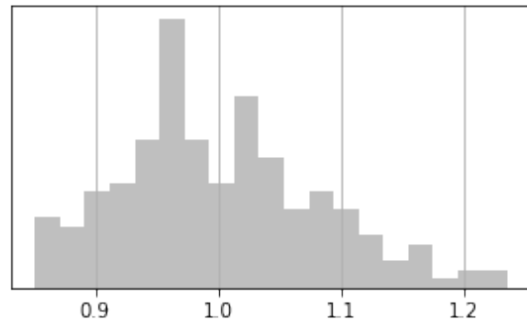
D) cn\_vka8



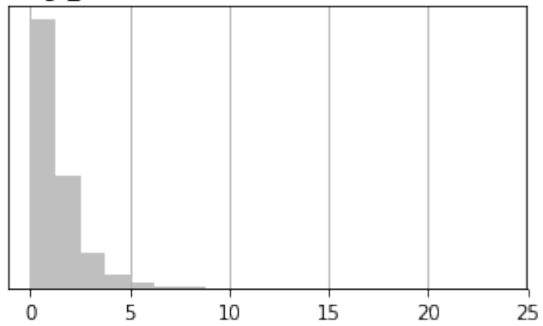
E) drncond\_k00



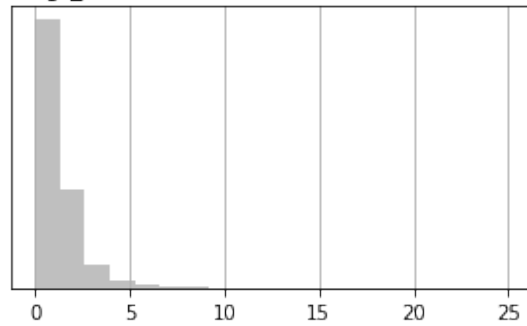
F) flow



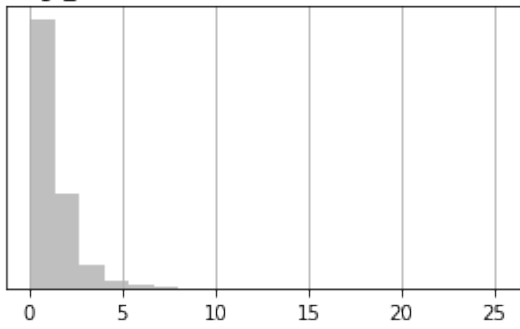
G) gr\_hk3



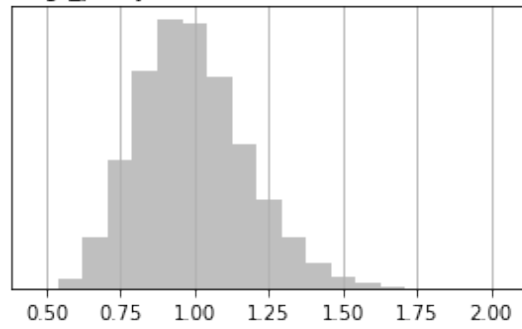
H) gr\_hk4



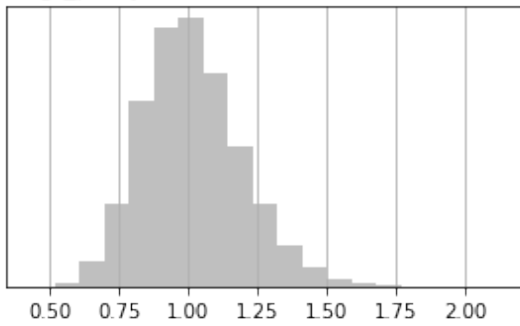
A) gr\_hk5



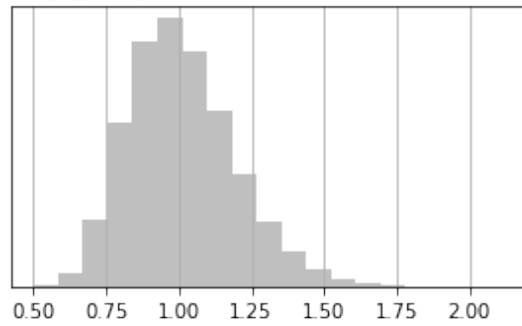
B) gr\_prsity3



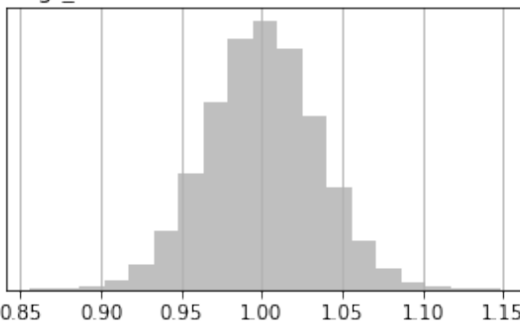
C) gr\_prsity4



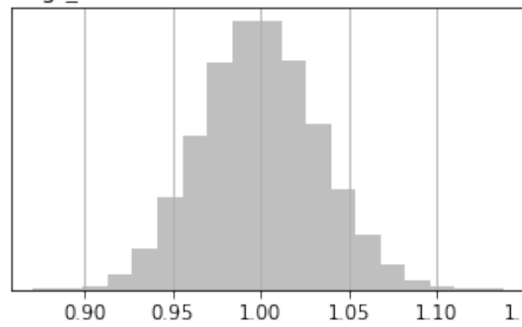
D) gr\_prsity5



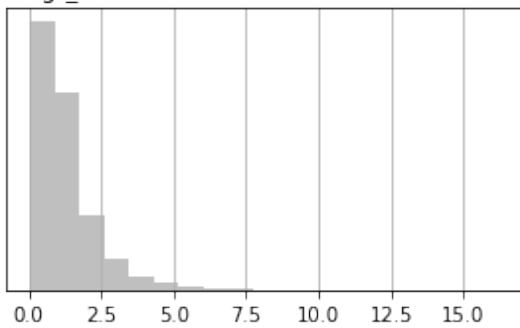
E) gr\_rech2



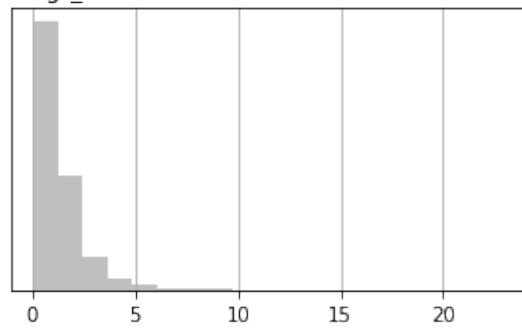
F) gr\_rech3



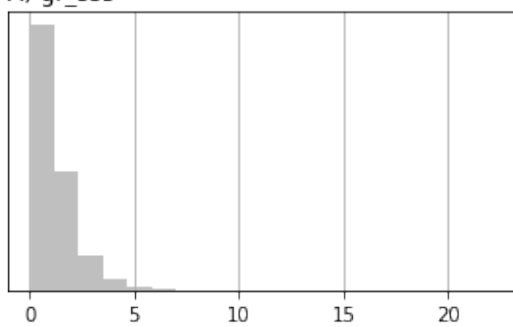
G) gr\_ss3



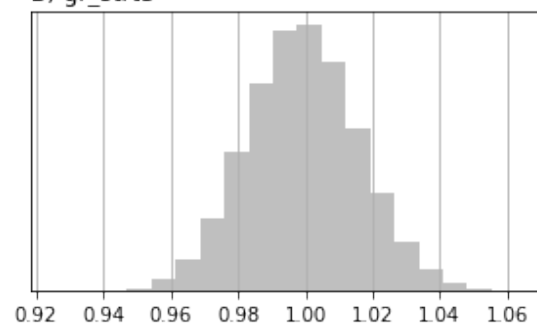
H) gr\_ss4



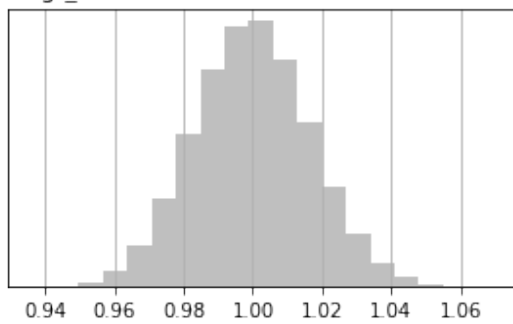
A) gr\_ss5



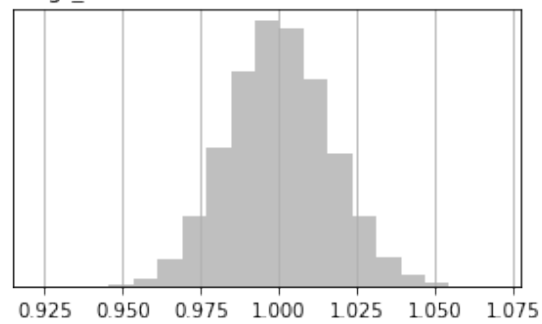
B) gr\_strt3



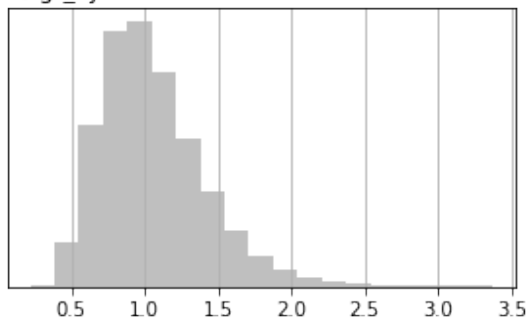
C) gr\_strt4



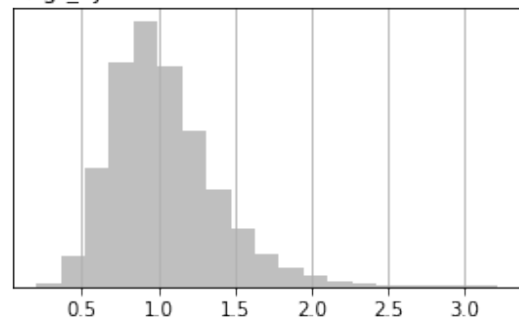
D) gr\_strt5



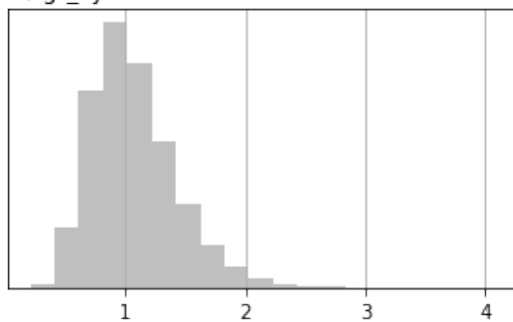
E) gr\_sy3



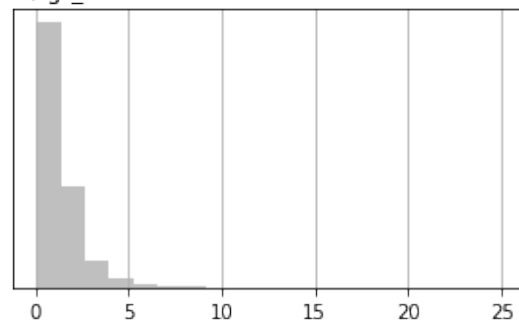
F) gr\_sy4



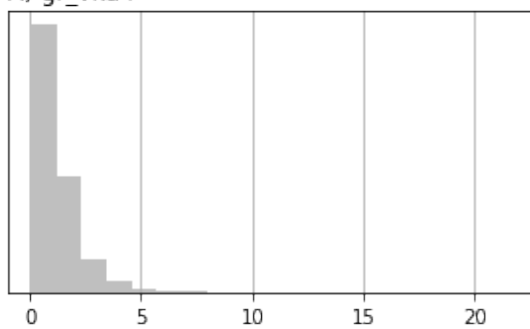
G) gr\_sy5



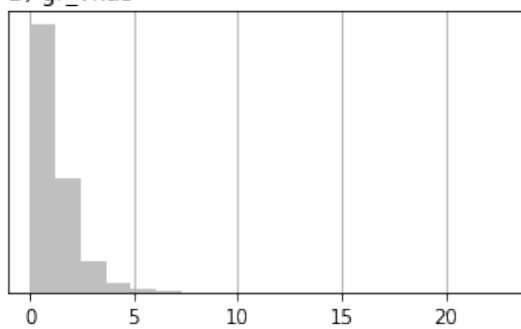
H) gr\_vka3



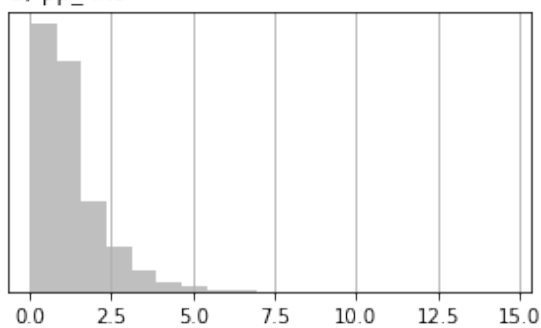
A) gr\_vka4



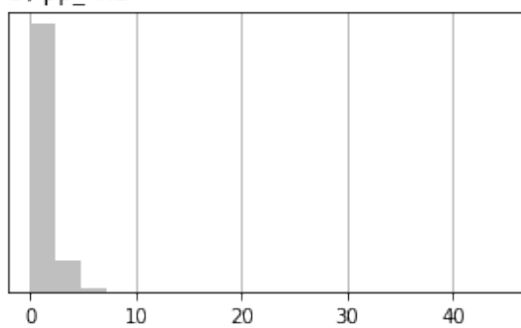
B) gr\_vka5



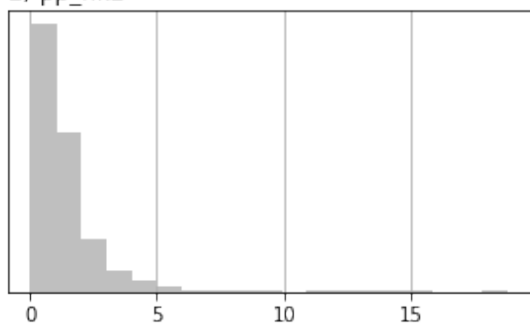
C) pp\_hk0



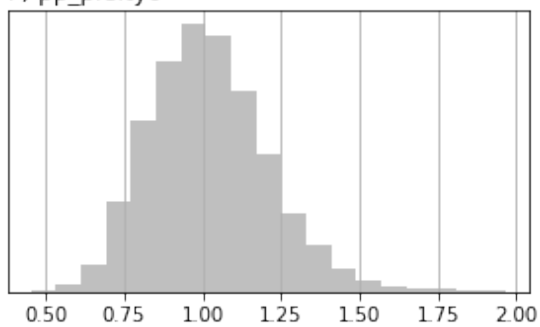
D) pp\_hk1



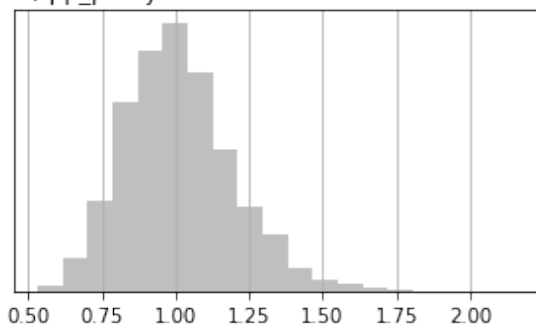
E) pp\_hk2



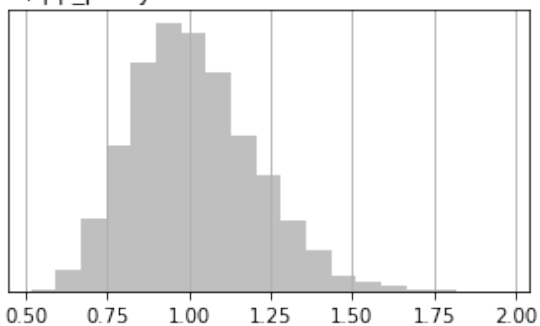
F) pp\_prsity0

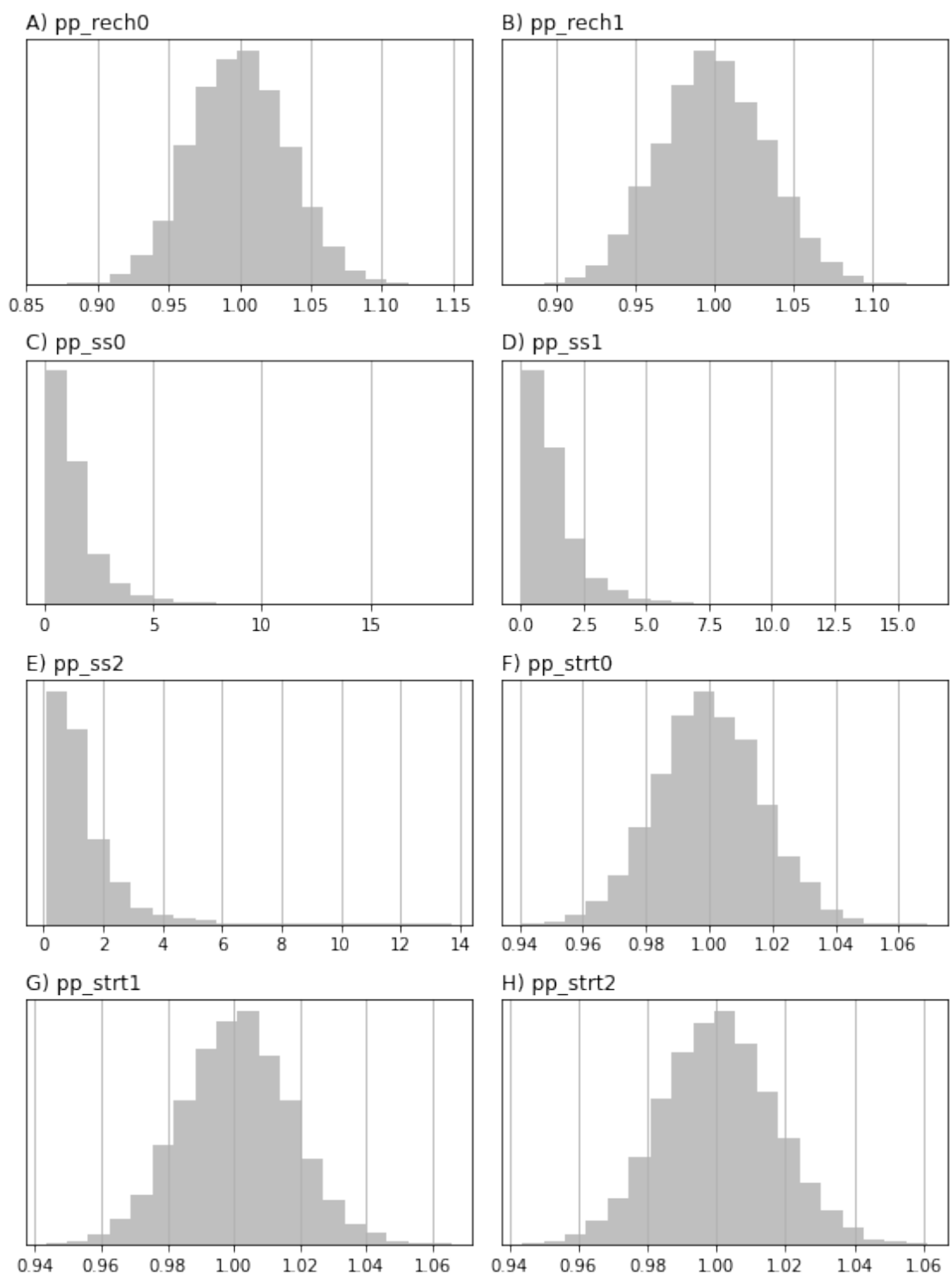


G) pp\_prsity1



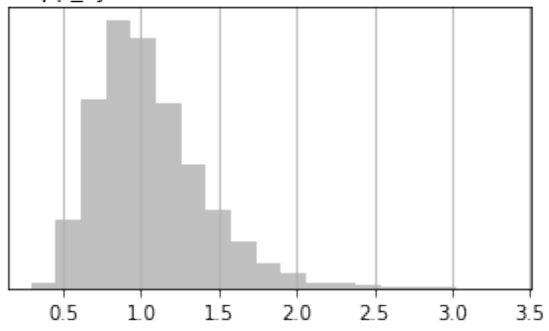
H) pp\_prsity2



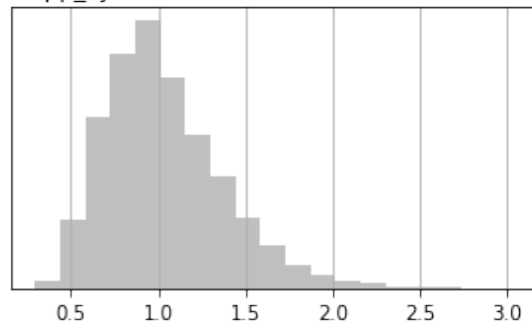




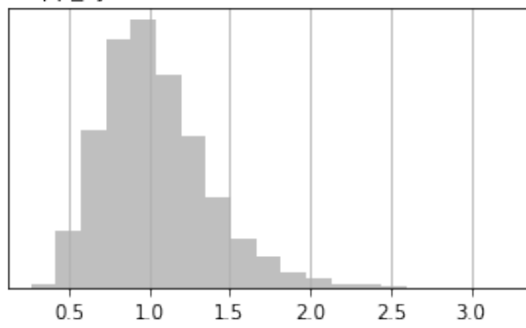
A) pp\_sy0



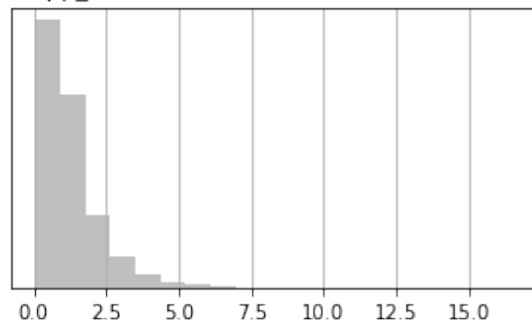
B) pp\_sy1



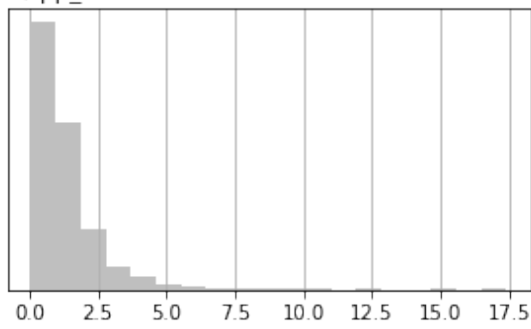
C) pp\_sy2



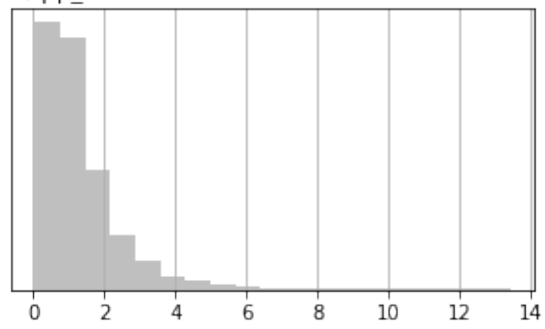
D) pp\_vka0



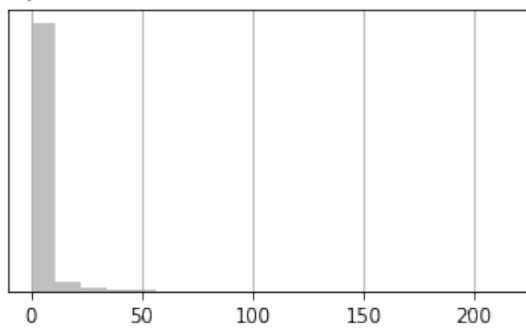
E) pp\_vka1



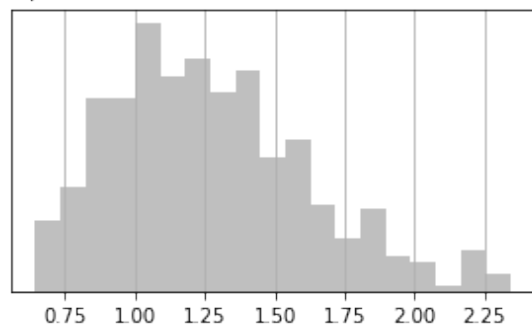
F) pp\_vka2

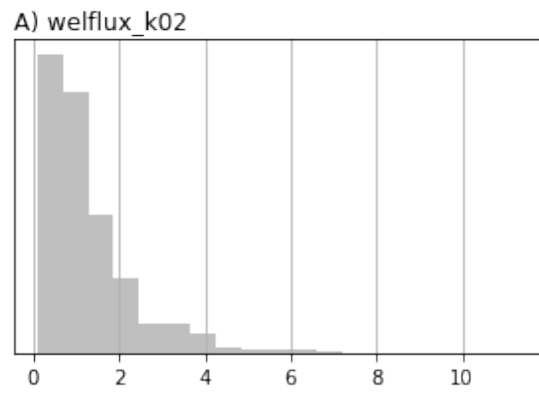


G) strk



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

```

```

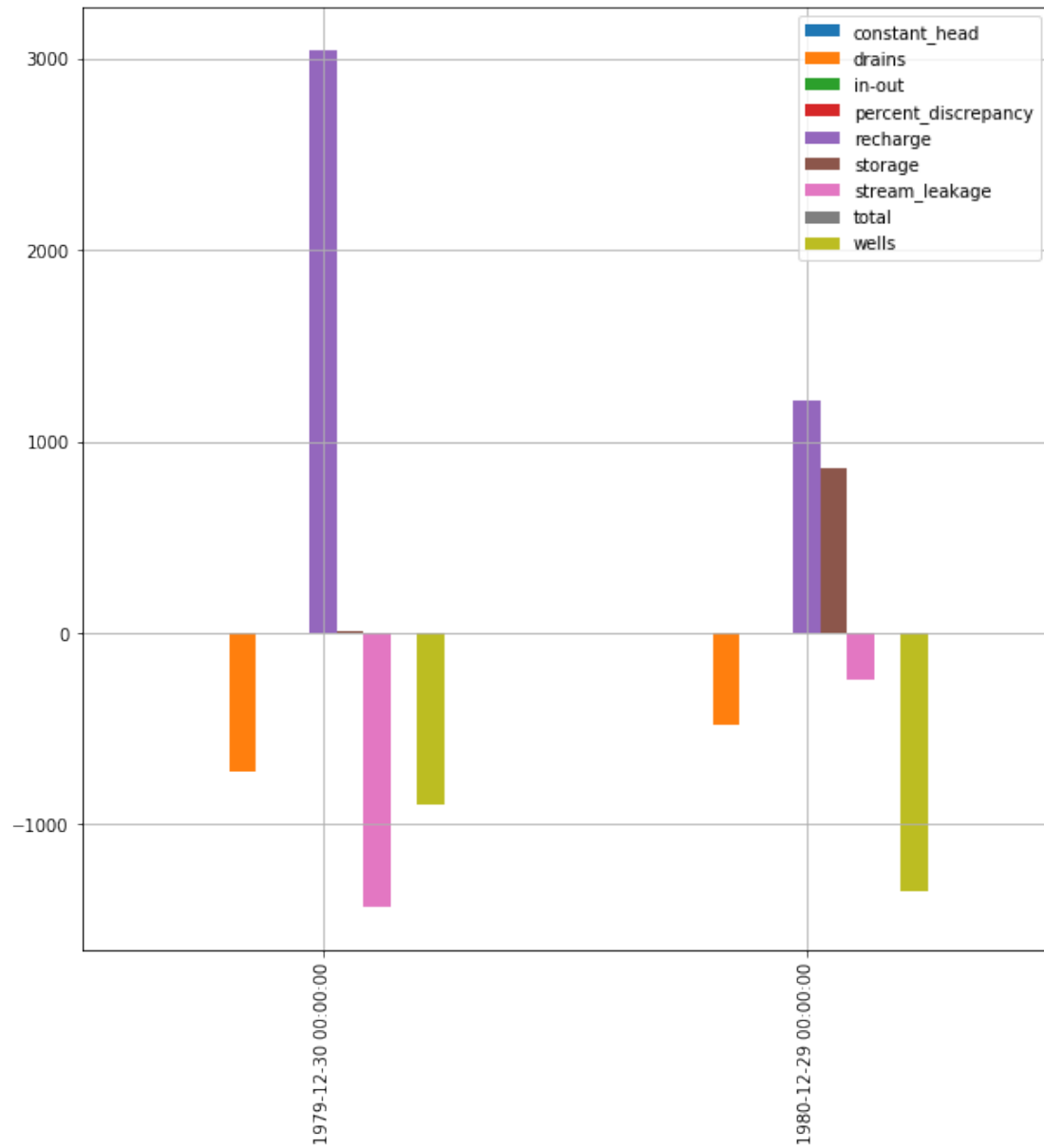
Out[31]: 9.456182577320024e-19

```

```

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.