setup_pest_interface

July 1, 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]: %matplotlib inline
        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
        %matplotlib inline
```

```
flopy is installed in /Users/jeremyw/Dev/gw1876/activities_csiro/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 pat
        # 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 dependecies (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("mfnwt",m.name+".nam"),cwd=m.model_ws)
```

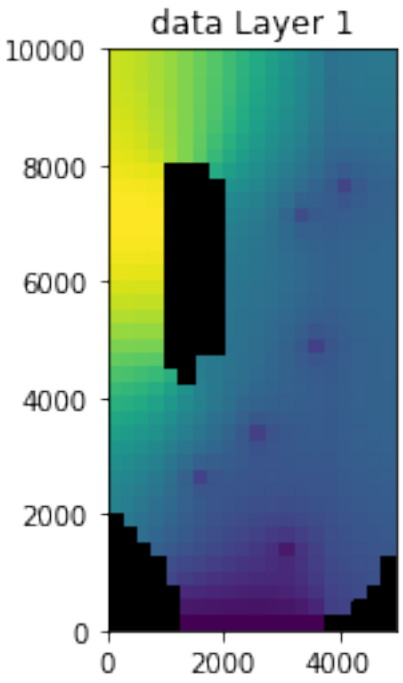
1.0.4 read in the heads and plot them up along with the budget components

Note that there is a historic period and a scenario with future conditions that differ.

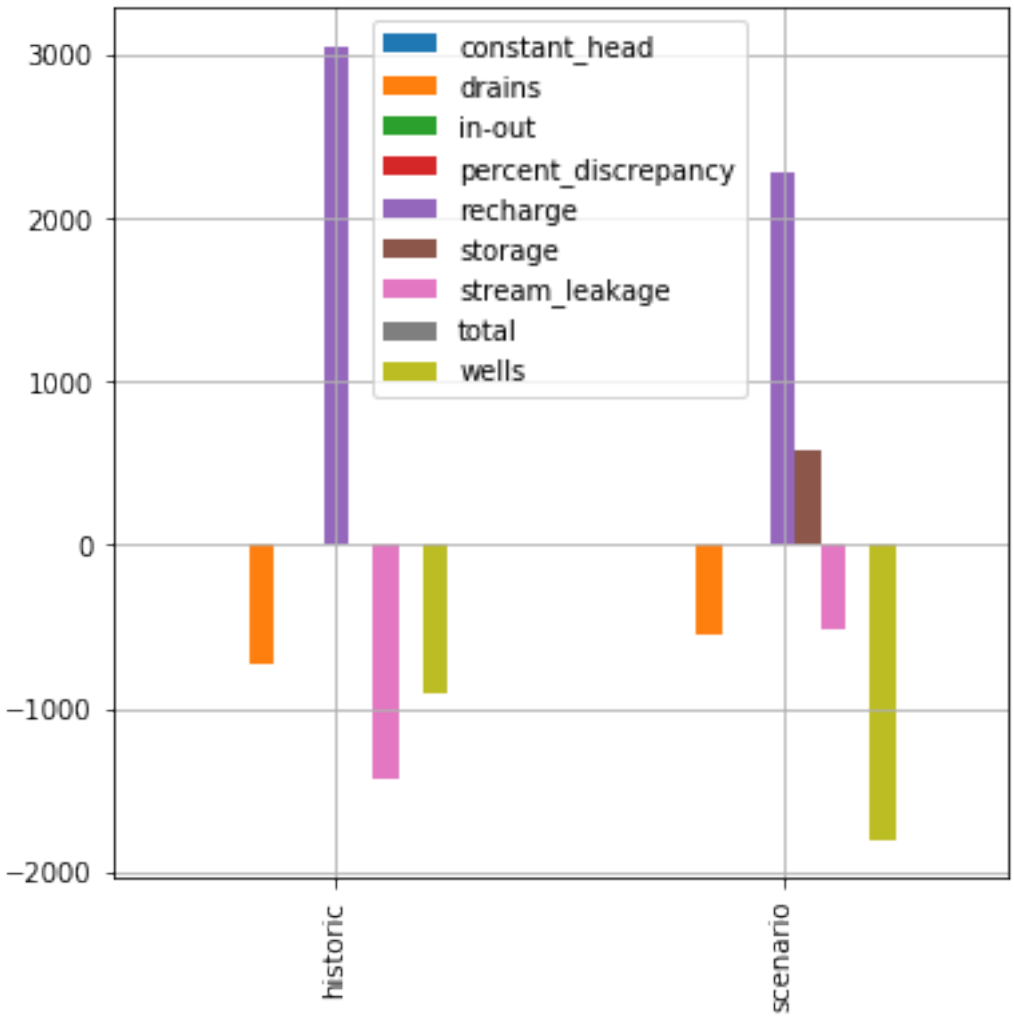
For the future scenario, a serious drought, recharge is lower and pumping/abstraction is increased to make up for the presumed deficite in water for agriculture.

```
In [6]: plt.figure()
        hds = flopy.utils.HeadFile(os.path.join(m.model_ws,m.name+".hds"),model=m)
        hds.plot(mflay=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"])

Out[6]: [Text(0, 0, 'historic'), Text(0, 0, 'scenario')]
```




```
<Figure size 432x288 with 0 Axes>
```

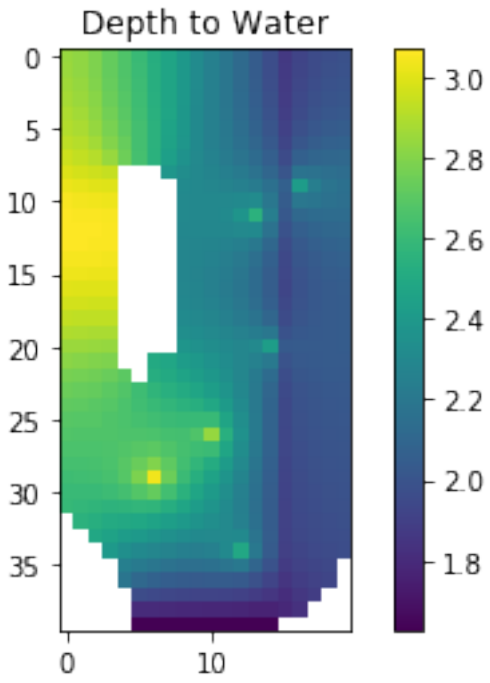


We can see the effect of the "scenario" in the second stress period with less recharge and more abstraction.

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)

Out[7]: <matplotlib.colorbar.Colorbar at 0x111b38978>
```



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

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 [8]: 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 [9]: 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 [10]: 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 [11]: sfr_obs_dict = {"hw":np.arange(1,int(m.nrow/2))}
         sfr_obs_dict["tw"] = np.arange(int(m.nrow/2),m.nrow)
         for i in range(m.nrow):
             sfr_obs_dict[i] = i+1
```

1.1.5 here we go...

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

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

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

```
In [12]: pst_helper = pyemu.helpers.PstFromFlopyModel(nam_file,new_model_ws="template",org_mode
                                                      const_props=props,spatial_list_props=spati
                                                       temporal_list_props=temporal_list_props,
                                                      grid_props=props,pp_props=props,sfr_pars='
                                                       sfr_obs=sfr_obs_dict,build_prior=False,m
                                                      pp_space=4)
         prep_deps.prep_template(t_d=pst_helper.new_model_ws)
```

```
2019-07-01 12:09:08.762486 starting: loading flopy 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 'flopy.modflow.mfwel.ModflowWel'> for kper     1
   loading <class 'flopy.modflow.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 'flopy.modflow.mfdrn.ModflowDrn'> for kper     1
   loading <class 'flopy.modflow.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
2019-07-01 12:09:08.794815 finished: loading flopy model took: 0:00:00.032329
2019-07-01 12:09:08.795029 starting: updating model attributes
```

```
2019-07-01 12:09:08.795124 finished: updating model attributes took: 0:00:00.000095
2019-07-01 12:09:08.795268 WARNING: removing existing 'new_model_ws

creating model workspace...
   template

changing model workspace...
   template
2019-07-01 12:09:10.062010 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
```

```
2019-07-01 12:09:10.150628 finished: writing new modflow input files took: 0:00:00.088618
2019-07-01 12:09:10.151328 forward_run line:pyemu.os_utils.run('mfnwt freyberg.nam 1>freyberg.r
2019-07-01 12:09:10.151483 starting: setting up 'template/arr_org' dir
2019-07-01 12:09:10.152238 finished: setting up 'template/arr_org' dir took: 0:00:00.000755
2019-07-01 12:09:10.152453 starting: setting up 'template/arr_mlt' dir
2019-07-01 12:09:10.152908 finished: setting up 'template/arr_mlt' dir took: 0:00:00.000455
2019-07-01 12:09:10.153132 starting: setting up 'template/list_org' dir
2019-07-01 12:09:10.153664 finished: setting up 'template/list_org' dir took: 0:00:00.000532
2019-07-01 12:09:10.153827 starting: setting up 'template/list_mlt' dir
2019-07-01 12:09:10.154089 finished: setting up 'template/list_mlt' dir took: 0:00:00.000262
2019-07-01 12:09:10.154340 starting: processing temporal_list_props
2019-07-01 12:09:10.183614 finished: processing temporal_list_props took: 0:00:00.029274
2019-07-01 12:09:10.184002 starting: processing spatial_list_props
2019-07-01 12:09:10.353995 finished: processing spatial_list_props took: 0:00:00.169993
2019-07-01 12:09:10.413936 forward_run line:pyemu.helpers.apply_list_pars()

2019-07-01 12:09:10.442672 'extra' pak detected:extra.prsity
2019-07-01 12:09:10.475766 'extra' pak detected:extra.prsity
2019-07-01 12:09:10.508793 'extra' pak detected:extra.prsity
2019-07-01 12:09:10.554543 'extra' pak detected:extra.prsity
2019-07-01 12:09:10.589537 'extra' pak detected:extra.prsity
2019-07-01 12:09:10.629334 'extra' pak detected:extra.prsity
2019-07-01 12:09:10.680331 'extra' pak detected:extra.prsity
2019-07-01 12:09:10.714640 'extra' pak detected:extra.prsity
2019-07-01 12:09:10.755390 'extra' pak detected:extra.prsity
2019-07-01 12:09:10.843667 starting: writing grid tpl:hk3.dat_gr.tpl
2019-07-01 12:09:10.853054 finished: writing grid tpl:hk3.dat_gr.tpl took: 0:00:00.009387
2019-07-01 12:09:10.855847 starting: writing grid tpl:vka3.dat_gr.tpl
2019-07-01 12:09:10.865128 finished: writing grid tpl:vka3.dat_gr.tpl took: 0:00:00.009281
2019-07-01 12:09:10.868123 starting: writing grid tpl:ss3.dat_gr.tpl
2019-07-01 12:09:10.877572 finished: writing grid tpl:ss3.dat_gr.tpl took: 0:00:00.009449
2019-07-01 12:09:10.880559 starting: writing grid tpl:sy3.dat_gr.tpl
2019-07-01 12:09:10.889714 finished: writing grid tpl:sy3.dat_gr.tpl took: 0:00:00.009155
2019-07-01 12:09:10.892553 starting: writing grid tpl:strt3.dat_gr.tpl
2019-07-01 12:09:10.901587 finished: writing grid tpl:strt3.dat_gr.tpl took: 0:00:00.009034
2019-07-01 12:09:10.904422 starting: writing grid tpl:prsity3.dat_gr.tpl
2019-07-01 12:09:10.915870 finished: writing grid tpl:prsity3.dat_gr.tpl took: 0:00:00.011448
2019-07-01 12:09:10.919467 starting: writing grid tpl:hk4.dat_gr.tpl
2019-07-01 12:09:10.930012 finished: writing grid tpl:hk4.dat_gr.tpl took: 0:00:00.010545
2019-07-01 12:09:10.933282 starting: writing grid tpl:vka4.dat_gr.tpl
2019-07-01 12:09:10.943264 finished: writing grid tpl:vka4.dat_gr.tpl took: 0:00:00.009982
2019-07-01 12:09:10.946050 starting: writing grid tpl:ss4.dat_gr.tpl
2019-07-01 12:09:10.955581 finished: writing grid tpl:ss4.dat_gr.tpl took: 0:00:00.009531
2019-07-01 12:09:10.958369 starting: writing grid tpl:sy4.dat_gr.tpl
2019-07-01 12:09:10.967784 finished: writing grid tpl:sy4.dat_gr.tpl took: 0:00:00.009415
2019-07-01 12:09:10.970790 starting: writing grid tpl:strt4.dat_gr.tpl
2019-07-01 12:09:10.980109 finished: writing grid tpl:strt4.dat_gr.tpl took: 0:00:00.009319
2019-07-01 12:09:10.982962 starting: writing grid tpl:prsity4.dat_gr.tpl
```

```
2019-07-01 12:09:10.994514 finished: writing grid tpl:prsity4.dat_gr.tpl took: 0:00:00.011552
2019-07-01 12:09:10.997229 starting: writing grid tpl:hk5.dat_gr.tpl
2019-07-01 12:09:11.006742 finished: writing grid tpl:hk5.dat_gr.tpl took: 0:00:00.009513
2019-07-01 12:09:11.009655 starting: writing grid tpl:vka5.dat_gr.tpl
2019-07-01 12:09:11.019833 finished: writing grid tpl:vka5.dat_gr.tpl took: 0:00:00.010178
2019-07-01 12:09:11.023109 starting: writing grid tpl:ss5.dat_gr.tpl
2019-07-01 12:09:11.032626 finished: writing grid tpl:ss5.dat_gr.tpl took: 0:00:00.009517
2019-07-01 12:09:11.035724 starting: writing grid tpl:sy5.dat_gr.tpl
2019-07-01 12:09:11.045299 finished: writing grid tpl:sy5.dat_gr.tpl took: 0:00:00.009575
2019-07-01 12:09:11.048139 starting: writing grid tpl:strt5.dat_gr.tpl
2019-07-01 12:09:11.057899 finished: writing grid tpl:strt5.dat_gr.tpl took: 0:00:00.009760
2019-07-01 12:09:11.060817 starting: writing grid tpl:prsity5.dat_gr.tpl
2019-07-01 12:09:11.073525 finished: writing grid tpl:prsity5.dat_gr.tpl took: 0:00:00.012708
2019-07-01 12:09:11.076408 starting: writing grid tpl:rech2.dat_gr.tpl
2019-07-01 12:09:11.085686 finished: writing grid tpl:rech2.dat_gr.tpl took: 0:00:00.009278
2019-07-01 12:09:11.088490 starting: writing grid tpl:rech3.dat_gr.tpl
2019-07-01 12:09:11.097894 finished: writing grid tpl:rech3.dat_gr.tpl took: 0:00:00.009404
2019-07-01 12:09:11.100785 starting: writing const tpl:hk6.dat_cn.tpl
2019-07-01 12:09:11.106354 finished: writing const tpl:hk6.dat_cn.tpl took: 0:00:00.005569
2019-07-01 12:09:11.109024 starting: writing const tpl:vka6.dat_cn.tpl
2019-07-01 12:09:11.117520 finished: writing const tpl:vka6.dat_cn.tpl took: 0:00:00.008496
2019-07-01 12:09:11.122012 starting: writing const tpl:ss6.dat_cn.tpl
2019-07-01 12:09:11.131101 finished: writing const tpl:ss6.dat_cn.tpl took: 0:00:00.009089
2019-07-01 12:09:11.134296 starting: writing const tpl:sy6.dat_cn.tpl
2019-07-01 12:09:11.140532 finished: writing const tpl:sy6.dat_cn.tpl took: 0:00:00.006236
2019-07-01 12:09:11.143206 starting: writing const tpl:strt6.dat_cn.tpl
2019-07-01 12:09:11.149229 finished: writing const tpl:strt6.dat_cn.tpl took: 0:00:00.006023
2019-07-01 12:09:11.151974 starting: writing const tpl:prsity6.dat_cn.tpl
2019-07-01 12:09:11.158082 finished: writing const tpl:prsity6.dat_cn.tpl took: 0:00:00.006108
2019-07-01 12:09:11.161028 starting: writing const tpl:hk7.dat_cn.tpl
2019-07-01 12:09:11.168244 finished: writing const tpl:hk7.dat_cn.tpl took: 0:00:00.007216
2019-07-01 12:09:11.172069 starting: writing const tpl:vka7.dat_cn.tpl
2019-07-01 12:09:11.178571 finished: writing const tpl:vka7.dat_cn.tpl took: 0:00:00.006502
2019-07-01 12:09:11.182060 starting: writing const tpl:ss7.dat_cn.tpl
2019-07-01 12:09:11.188474 finished: writing const tpl:ss7.dat_cn.tpl took: 0:00:00.006414
2019-07-01 12:09:11.191124 starting: writing const tpl:sy7.dat_cn.tpl
2019-07-01 12:09:11.197812 finished: writing const tpl:sy7.dat_cn.tpl took: 0:00:00.006688
2019-07-01 12:09:11.200579 starting: writing const tpl:strt7.dat_cn.tpl
2019-07-01 12:09:11.206251 finished: writing const tpl:strt7.dat_cn.tpl took: 0:00:00.005672
2019-07-01 12:09:11.208888 starting: writing const tpl:prsity7.dat_cn.tpl
2019-07-01 12:09:11.214708 finished: writing const tpl:prsity7.dat_cn.tpl took: 0:00:00.005820
2019-07-01 12:09:11.218792 starting: writing const tpl:hk8.dat_cn.tpl
2019-07-01 12:09:11.225248 finished: writing const tpl:hk8.dat_cn.tpl took: 0:00:00.006456
2019-07-01 12:09:11.228124 starting: writing const tpl:vka8.dat_cn.tpl
2019-07-01 12:09:11.234458 finished: writing const tpl:vka8.dat_cn.tpl took: 0:00:00.006334
2019-07-01 12:09:11.237041 starting: writing const tpl:ss8.dat_cn.tpl
2019-07-01 12:09:11.243253 finished: writing const tpl:ss8.dat_cn.tpl took: 0:00:00.006212
2019-07-01 12:09:11.245985 starting: writing const tpl:sy8.dat_cn.tpl
```

```
2019-07-01 12:09:11.252467 finished: writing const tpl:sy8.dat_cn.tpl took: 0:00:00.006482
2019-07-01 12:09:11.255243 starting: writing const tpl:strt8.dat_cn.tpl
2019-07-01 12:09:11.261056 finished: writing const tpl:strt8.dat_cn.tpl took: 0:00:00.005813
2019-07-01 12:09:11.264434 starting: writing const tpl:prsity8.dat_cn.tpl
2019-07-01 12:09:11.270560 finished: writing const tpl:prsity8.dat_cn.tpl took: 0:00:00.006126
2019-07-01 12:09:11.273554 starting: writing const tpl:rech4.dat_cn.tpl
2019-07-01 12:09:11.279809 finished: writing const tpl:rech4.dat_cn.tpl took: 0:00:00.006255
2019-07-01 12:09:11.282748 starting: writing const tpl:rech5.dat_cn.tpl
2019-07-01 12:09:11.289160 finished: writing const tpl:rech5.dat_cn.tpl took: 0:00:00.006412
2019-07-01 12:09:11.312834 starting: setting up pilot point process
2019-07-01 12:09:11.313200 WARNING: pp_geostruct is None, using ExpVario with contribution=1 ar
2019-07-01 12:09:11.316081 pp_dict: {0: ['hk0', 'prsity0', 'rech0', 'rech1', 'ss0', 'strt0', 's
2019-07-01 12:09:11.316152 starting: calling setup_pilot_point_grid()
2019-07-01 12:09:11.939714 640 pilot point parameters created
2019-07-01 12:09:11.940468 pilot point 'pargp':hk0,prsity0,rech0,rech1,ss0,strt0,sy0,vka0,hk1,p
2019-07-01 12:09:11.940527 finished: calling setup_pilot_point_grid() took: 0:00:00.624375
2019-07-01 12:09:11.942585 starting: calculating factors for p=hk0, k=0
2019-07-01 12:09:11.943303 saving krige variance file:template/pp_k0_general_zn.fac
2019-07-01 12:09:11.943355 saving krige factors file:template/pp_k0_general_zn.fac
starting interp point loop for 800 points
took 2.851104 seconds
2019-07-01 12:09:14.849860 finished: calculating factors for p=hk0, k=0 took: 0:00:02.907275
2019-07-01 12:09:14.851120 starting: calculating factors for p=prsity0, k=0
2019-07-01 12:09:14.852346 finished: calculating factors for p=prsity0, k=0 took: 0:00:00.0012
2019-07-01 12:09:14.853679 starting: calculating factors for p=rech0, k=0
2019-07-01 12:09:14.855288 finished: calculating factors for p=rech0, k=0 took: 0:00:00.001609
2019-07-01 12:09:14.856247 starting: calculating factors for p=rech1, k=0
2019-07-01 12:09:14.857110 finished: calculating factors for p=rech1, k=0 took: 0:00:00.000863
2019-07-01 12:09:14.858116 starting: calculating factors for p=ss0, k=0
2019-07-01 12:09:14.859003 finished: calculating factors for p=ss0, k=0 took: 0:00:00.000887
2019-07-01 12:09:14.859602 starting: calculating factors for p=strt0, k=0
2019-07-01 12:09:14.860536 finished: calculating factors for p=strt0, k=0 took: 0:00:00.000934
2019-07-01 12:09:14.861353 starting: calculating factors for p=sy0, k=0
2019-07-01 12:09:14.862698 finished: calculating factors for p=sy0, k=0 took: 0:00:00.001345
2019-07-01 12:09:14.863237 starting: calculating factors for p=vka0, k=0
2019-07-01 12:09:14.864033 finished: calculating factors for p=vka0, k=0 took: 0:00:00.000796
2019-07-01 12:09:14.864979 starting: calculating factors for p=hk1, k=1
2019-07-01 12:09:14.865736 saving krige variance file:template/pp_k1_general_zn.fac
2019-07-01 12:09:14.865871 saving krige factors file:template/pp_k1_general_zn.fac
starting interp point loop for 800 points
took 2.790778 seconds
2019-07-01 12:09:17.710110 finished: calculating factors for p=hk1, k=1 took: 0:00:02.845131
2019-07-01 12:09:17.711705 starting: calculating factors for p=prsity1, k=1
2019-07-01 12:09:17.712921 finished: calculating factors for p=prsity1, k=1 took: 0:00:00.0012
2019-07-01 12:09:17.713684 starting: calculating factors for p=ss1, k=1
2019-07-01 12:09:17.715065 finished: calculating factors for p=ss1, k=1 took: 0:00:00.001381
2019-07-01 12:09:17.715990 starting: calculating factors for p=strt1, k=1
2019-07-01 12:09:17.717249 finished: calculating factors for p=strt1, k=1 took: 0:00:00.001259
```

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2019-07-01 12:09:17.718122 starting: calculating factors for p=sy1, k=1
2019-07-01 12:09:17.719099 finished: calculating factors for p=sy1, k=1 took: 0:00:00.000977
2019-07-01 12:09:17.720035 starting: calculating factors for p=vka1, k=1
2019-07-01 12:09:17.721200 finished: calculating factors for p=vka1, k=1 took: 0:00:00.001165
2019-07-01 12:09:17.722061 starting: calculating factors for p=hk2, k=2
2019-07-01 12:09:17.723166 saving krige variance file:template/pp_k2_general_zn.fac
2019-07-01 12:09:17.723278 saving krige factors file:template/pp_k2_general_zn.fac
starting interp point loop for 800 points
took 2.813795 seconds
2019-07-01 12:09:20.595614 finished: calculating factors for p=hk2, k=2 took: 0:00:02.873553
2019-07-01 12:09:20.596565 starting: calculating factors for p=prsity2, k=2
2019-07-01 12:09:20.597564 finished: calculating factors for p=prsity2, k=2 took: 0:00:00.0009
2019-07-01 12:09:20.598939 starting: calculating factors for p=ss2, k=2
2019-07-01 12:09:20.599875 finished: calculating factors for p=ss2, k=2 took: 0:00:00.000936
2019-07-01 12:09:20.600617 starting: calculating factors for p=strt2, k=2
2019-07-01 12:09:20.601665 finished: calculating factors for p=strt2, k=2 took: 0:00:00.001048
2019-07-01 12:09:20.602597 starting: calculating factors for p=sy2, k=2
2019-07-01 12:09:20.603279 finished: calculating factors for p=sy2, k=2 took: 0:00:00.000682
2019-07-01 12:09:20.603869 starting: calculating factors for p=vka2, k=2
2019-07-01 12:09:20.604584 finished: calculating factors for p=vka2, k=2 took: 0:00:00.000715
2019-07-01 12:09:20.604993 starting: processing pp_prefix:hk0
2019-07-01 12:09:20.618015 starting: processing pp_prefix:vka0
2019-07-01 12:09:20.627649 starting: processing pp_prefix:rech1
2019-07-01 12:09:20.636921 starting: processing pp_prefix:ss1
2019-07-01 12:09:20.645212 starting: processing pp_prefix:vka1
2019-07-01 12:09:20.654139 starting: processing pp_prefix:sy0
2019-07-01 12:09:20.664933 starting: processing pp_prefix:strt1
2019-07-01 12:09:20.674943 starting: processing pp_prefix:prsity2
2019-07-01 12:09:20.684395 starting: processing pp_prefix:vka2
2019-07-01 12:09:20.694030 starting: processing pp_prefix:prsity1
2019-07-01 12:09:20.702777 starting: processing pp_prefix:prsity0
2019-07-01 12:09:20.710987 starting: processing pp_prefix:hk1
2019-07-01 12:09:20.719326 starting: processing pp_prefix:ss2
2019-07-01 12:09:20.728132 starting: processing pp_prefix:hk2
2019-07-01 12:09:20.737665 starting: processing pp_prefix:ss0
2019-07-01 12:09:20.747584 starting: processing pp_prefix:strt0
2019-07-01 12:09:20.757153 starting: processing pp_prefix:rech0
2019-07-01 12:09:20.766549 starting: processing pp_prefix:strt2
2019-07-01 12:09:20.775629 starting: processing pp_prefix:sy2
2019-07-01 12:09:20.785036 starting: processing pp_prefix:sy1
2019-07-01 12:09:20.898154 finished: setting up pilot point process took: 0:00:09.585320
2019-07-01 12:09:20.898585 starting: setting up grid process
2019-07-01 12:09:20.898668 WARNING: grid_geostruct is None, using ExpVario with contribution=1
2019-07-01 12:09:20.898790 finished: setting up grid process took: 0:00:00.000205
2019-07-01 12:09:20.908839 starting: save test mlt array arr_mlt/hk0.dat_pp
2019-07-01 12:09:20.910714 finished: save test mlt array arr_mlt/hk0.dat_pp took: 0:00:00.0018
2019-07-01 12:09:20.911729 starting: save test mlt array arr_mlt/vka0.dat_pp
2019-07-01 12:09:20.913271 finished: save test mlt array arr_mlt/vka0.dat_pp took: 0:00:00.001
```

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2019-07-01 12:09:20.914228 starting: save test mlt array arr_mlt/ss0.dat_pp
2019-07-01 12:09:20.915444 finished: save test mlt array arr_mlt/ss0.dat_pp took: 0:00:00.0012
2019-07-01 12:09:20.916427 starting: save test mlt array arr_mlt/sy0.dat_pp
2019-07-01 12:09:20.917600 finished: save test mlt array arr_mlt/sy0.dat_pp took: 0:00:00.0011
2019-07-01 12:09:20.918502 starting: save test mlt array arr_mlt/strt0.dat_pp
2019-07-01 12:09:20.919498 finished: save test mlt array arr_mlt/strt0.dat_pp took: 0:00:00.000
2019-07-01 12:09:20.920473 starting: save test mlt array arr_mlt/prsity0.dat_pp
2019-07-01 12:09:20.921681 finished: save test mlt array arr_mlt/prsity0.dat_pp took: 0:00:00.0
2019-07-01 12:09:20.922404 starting: save test mlt array arr_mlt/hk1.dat_pp
2019-07-01 12:09:20.923767 finished: save test mlt array arr_mlt/hk1.dat_pp took: 0:00:00.0013
2019-07-01 12:09:20.924676 starting: save test mlt array arr_mlt/vka1.dat_pp
2019-07-01 12:09:20.926004 finished: save test mlt array arr_mlt/vka1.dat_pp took: 0:00:00.001
2019-07-01 12:09:20.926904 starting: save test mlt array arr_mlt/ss1.dat_pp
2019-07-01 12:09:20.928085 finished: save test mlt array arr_mlt/ss1.dat_pp took: 0:00:00.0011
2019-07-01 12:09:20.928973 starting: save test mlt array arr_mlt/sy1.dat_pp
2019-07-01 12:09:20.930130 finished: save test mlt array arr_mlt/sy1.dat_pp took: 0:00:00.0011
2019-07-01 12:09:20.931008 starting: save test mlt array arr_mlt/strt1.dat_pp
2019-07-01 12:09:20.932168 finished: save test mlt array arr_mlt/strt1.dat_pp took: 0:00:00.001
2019-07-01 12:09:20.932866 starting: save test mlt array arr_mlt/prsity1.dat_pp
2019-07-01 12:09:20.934345 finished: save test mlt array arr_mlt/prsity1.dat_pp took: 0:00:00.0
2019-07-01 12:09:20.935224 starting: save test mlt array arr_mlt/hk2.dat_pp
2019-07-01 12:09:20.936816 finished: save test mlt array arr_mlt/hk2.dat_pp took: 0:00:00.0015
2019-07-01 12:09:20.937688 starting: save test mlt array arr_mlt/vka2.dat_pp
2019-07-01 12:09:20.938910 finished: save test mlt array arr_mlt/vka2.dat_pp took: 0:00:00.001
2019-07-01 12:09:20.939787 starting: save test mlt array arr_mlt/ss2.dat_pp
2019-07-01 12:09:20.941140 finished: save test mlt array arr_mlt/ss2.dat_pp took: 0:00:00.0013
2019-07-01 12:09:20.942110 starting: save test mlt array arr_mlt/sy2.dat_pp
2019-07-01 12:09:20.943380 finished: save test mlt array arr_mlt/sy2.dat_pp took: 0:00:00.0012
2019-07-01 12:09:20.944280 starting: save test mlt array arr_mlt/strt2.dat_pp
2019-07-01 12:09:20.945635 finished: save test mlt array arr_mlt/strt2.dat_pp took: 0:00:00.001
2019-07-01 12:09:20.946891 starting: save test mlt array arr_mlt/prsity2.dat_pp
2019-07-01 12:09:20.948364 finished: save test mlt array arr_mlt/prsity2.dat_pp took: 0:00:00.0
2019-07-01 12:09:20.949321 starting: save test mlt array arr_mlt/rech0.dat_pp
2019-07-01 12:09:20.950466 finished: save test mlt array arr_mlt/rech0.dat_pp took: 0:00:00.001
2019-07-01 12:09:20.951174 starting: save test mlt array arr_mlt/rech1.dat_pp
2019-07-01 12:09:20.952454 finished: save test mlt array arr_mlt/rech1.dat_pp took: 0:00:00.001
2019-07-01 12:09:20.953282 starting: save test mlt array arr_mlt/hk3.dat_gr
2019-07-01 12:09:20.954344 finished: save test mlt array arr_mlt/hk3.dat_gr took: 0:00:00.0010
2019-07-01 12:09:20.954998 starting: save test mlt array arr_mlt/vka3.dat_gr
2019-07-01 12:09:20.956344 finished: save test mlt array arr_mlt/vka3.dat_gr took: 0:00:00.0013
2019-07-01 12:09:20.957296 starting: save test mlt array arr_mlt/ss3.dat_gr
2019-07-01 12:09:20.958424 finished: save test mlt array arr_mlt/ss3.dat_gr took: 0:00:00.0011
2019-07-01 12:09:20.959401 starting: save test mlt array arr_mlt/sy3.dat_gr
2019-07-01 12:09:20.960544 finished: save test mlt array arr_mlt/sy3.dat_gr took: 0:00:00.0011
2019-07-01 12:09:20.961401 starting: save test mlt array arr_mlt/strt3.dat_gr
2019-07-01 12:09:20.962620 finished: save test mlt array arr_mlt/strt3.dat_gr took: 0:00:00.001
2019-07-01 12:09:20.963559 starting: save test mlt array arr_mlt/prsity3.dat_gr
2019-07-01 12:09:20.965061 finished: save test mlt array arr_mlt/prsity3.dat_gr took: 0:00:00.0
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2019-07-01 12:09:20.966598 starting: save test mlt array arr_mlt/hk4.dat_gr
2019-07-01 12:09:20.968555 finished: save test mlt array arr_mlt/hk4.dat_gr took: 0:00:00.0019
2019-07-01 12:09:20.969979 starting: save test mlt array arr_mlt/vka4.dat_gr
2019-07-01 12:09:20.971904 finished: save test mlt array arr_mlt/vka4.dat_gr took: 0:00:00.001
2019-07-01 12:09:20.973417 starting: save test mlt array arr_mlt/ss4.dat_gr
2019-07-01 12:09:20.975296 finished: save test mlt array arr_mlt/ss4.dat_gr took: 0:00:00.0018
2019-07-01 12:09:20.976571 starting: save test mlt array arr_mlt/sy4.dat_gr
2019-07-01 12:09:20.978453 finished: save test mlt array arr_mlt/sy4.dat_gr took: 0:00:00.0018
2019-07-01 12:09:20.979803 starting: save test mlt array arr_mlt/strt4.dat_gr
2019-07-01 12:09:20.981732 finished: save test mlt array arr_mlt/strt4.dat_gr took: 0:00:00.00
2019-07-01 12:09:20.983122 starting: save test mlt array arr_mlt/prsity4.dat_gr
2019-07-01 12:09:20.985168 finished: save test mlt array arr_mlt/prsity4.dat_gr took: 0:00:00.0
2019-07-01 12:09:20.986814 starting: save test mlt array arr_mlt/hk5.dat_gr
2019-07-01 12:09:20.988756 finished: save test mlt array arr_mlt/hk5.dat_gr took: 0:00:00.0019
2019-07-01 12:09:20.990228 starting: save test mlt array arr_mlt/vka5.dat_gr
2019-07-01 12:09:20.992418 finished: save test mlt array arr_mlt/vka5.dat_gr took: 0:00:00.002
2019-07-01 12:09:20.993875 starting: save test mlt array arr_mlt/ss5.dat_gr
2019-07-01 12:09:20.995719 finished: save test mlt array arr_mlt/ss5.dat_gr took: 0:00:00.0018
2019-07-01 12:09:20.997117 starting: save test mlt array arr_mlt/sy5.dat_gr
2019-07-01 12:09:20.998513 finished: save test mlt array arr_mlt/sy5.dat_gr took: 0:00:00.0013
2019-07-01 12:09:20.999451 starting: save test mlt array arr_mlt/strt5.dat_gr
2019-07-01 12:09:21.001339 finished: save test mlt array arr_mlt/strt5.dat_gr took: 0:00:00.00
2019-07-01 12:09:21.002530 starting: save test mlt array arr_mlt/prsity5.dat_gr
2019-07-01 12:09:21.003863 finished: save test mlt array arr_mlt/prsity5.dat_gr took: 0:00:00.0
2019-07-01 12:09:21.004793 starting: save test mlt array arr_mlt/rech2.dat_gr
2019-07-01 12:09:21.006246 finished: save test mlt array arr_mlt/rech2.dat_gr took: 0:00:00.00
2019-07-01 12:09:21.007202 starting: save test mlt array arr_mlt/rech3.dat_gr
2019-07-01 12:09:21.008890 finished: save test mlt array arr_mlt/rech3.dat_gr took: 0:00:00.00
2019-07-01 12:09:21.010234 starting: save test mlt array arr_mlt/hk6.dat_cn
2019-07-01 12:09:21.012020 finished: save test mlt array arr_mlt/hk6.dat_cn took: 0:00:00.0017
2019-07-01 12:09:21.013440 starting: save test mlt array arr_mlt/vka6.dat_cn
2019-07-01 12:09:21.015502 finished: save test mlt array arr_mlt/vka6.dat_cn took: 0:00:00.002
2019-07-01 12:09:21.016954 starting: save test mlt array arr_mlt/ss6.dat_cn
2019-07-01 12:09:21.018930 finished: save test mlt array arr_mlt/ss6.dat_cn took: 0:00:00.0019
2019-07-01 12:09:21.020144 starting: save test mlt array arr_mlt/sy6.dat_cn
2019-07-01 12:09:21.022321 finished: save test mlt array arr_mlt/sy6.dat_cn took: 0:00:00.0021
2019-07-01 12:09:21.023838 starting: save test mlt array arr_mlt/strt6.dat_cn
2019-07-01 12:09:21.025847 finished: save test mlt array arr_mlt/strt6.dat_cn took: 0:00:00.002
2019-07-01 12:09:21.027337 starting: save test mlt array arr_mlt/prsity6.dat_cn
2019-07-01 12:09:21.029517 finished: save test mlt array arr_mlt/prsity6.dat_cn took: 0:00:00.0
2019-07-01 12:09:21.030988 starting: save test mlt array arr_mlt/hk7.dat_cn
2019-07-01 12:09:21.033067 finished: save test mlt array arr_mlt/hk7.dat_cn took: 0:00:00.0020
2019-07-01 12:09:21.034620 starting: save test mlt array arr_mlt/vka7.dat_cn
2019-07-01 12:09:21.036744 finished: save test mlt array arr_mlt/vka7.dat_cn took: 0:00:00.002
2019-07-01 12:09:21.038283 starting: save test mlt array arr_mlt/ss7.dat_cn
2019-07-01 12:09:21.040148 finished: save test mlt array arr_mlt/ss7.dat_cn took: 0:00:00.0018
2019-07-01 12:09:21.041688 starting: save test mlt array arr_mlt/sy7.dat_cn
2019-07-01 12:09:21.043668 finished: save test mlt array arr_mlt/sy7.dat_cn took: 0:00:00.0019
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2019-07-01 12:09:21.044999 starting: save test mlt array arr_mlt/strt7.dat_cn
2019-07-01 12:09:21.047170 finished: save test mlt array arr_mlt/strt7.dat_cn took: 0:00:00.002
2019-07-01 12:09:21.048214 starting: save test mlt array arr_mlt/prsity7.dat_cn
2019-07-01 12:09:21.049823 finished: save test mlt array arr_mlt/prsity7.dat_cn took: 0:00:00.0
2019-07-01 12:09:21.051004 starting: save test mlt array arr_mlt/hk8.dat_cn
2019-07-01 12:09:21.052367 finished: save test mlt array arr_mlt/hk8.dat_cn took: 0:00:00.0013
2019-07-01 12:09:21.053391 starting: save test mlt array arr_mlt/vka8.dat_cn
2019-07-01 12:09:21.054475 finished: save test mlt array arr_mlt/vka8.dat_cn took: 0:00:00.001
2019-07-01 12:09:21.055488 starting: save test mlt array arr_mlt/ss8.dat_cn
2019-07-01 12:09:21.056593 finished: save test mlt array arr_mlt/ss8.dat_cn took: 0:00:00.0011
2019-07-01 12:09:21.057560 starting: save test mlt array arr_mlt/sy8.dat_cn
2019-07-01 12:09:21.058651 finished: save test mlt array arr_mlt/sy8.dat_cn took: 0:00:00.0010
2019-07-01 12:09:21.059504 starting: save test mlt array arr_mlt/strt8.dat_cn
2019-07-01 12:09:21.060769 finished: save test mlt array arr_mlt/strt8.dat_cn took: 0:00:00.001
2019-07-01 12:09:21.061878 starting: save test mlt array arr_mlt/prsity8.dat_cn
2019-07-01 12:09:21.063228 finished: save test mlt array arr_mlt/prsity8.dat_cn took: 0:00:00.0
2019-07-01 12:09:21.064147 starting: save test mlt array arr_mlt/rech4.dat_cn
2019-07-01 12:09:21.066013 finished: save test mlt array arr_mlt/rech4.dat_cn took: 0:00:00.001
2019-07-01 12:09:21.067348 starting: save test mlt array arr_mlt/rech5.dat_cn
2019-07-01 12:09:21.069291 finished: save test mlt array arr_mlt/rech5.dat_cn took: 0:00:00.001
2019-07-01 12:09:21.740795 forward_run line:pyemu.helpers.apply_array_pars()

all zeros for runoff...skipping...
all zeros for hcond1...skipping...
all zeros for pptsw...skipping...
2019-07-01 12:09:21.874492 starting: processing obs type mflist water budget obs
2019-07-01 12:09:21.995112 forward_run line:pyemu.gw_utils.apply_mflist_budget_obs('freyberg.li
2019-07-01 12:09:21.995621 finished: processing obs type mflist water budget obs took: 0:00:00
2019-07-01 12:09:21.995738 starting: processing obs type hyd file
2019-07-01 12:09:21.996153 finished: processing obs type hyd file took: 0:00:00.000415
2019-07-01 12:09:21.996254 starting: processing obs type external obs-sim smp files
2019-07-01 12:09:21.996375 finished: processing obs type external obs-sim smp files took: 0:00
2019-07-01 12:09:21.996929 starting: processing obs type hob
2019-07-01 12:09:21.997184 finished: processing obs type hob took: 0:00:00.000255
2019-07-01 12:09:21.997245 starting: processing obs type hds
[[0, 0], [0, 1], [0, 2], [1, 0], [1, 1], [1, 2]]
2019-07-01 12:09:22.446249 finished: processing obs type hds took: 0:00:00.449004
2019-07-01 12:09:22.446880 starting: processing obs type sfr
writing 'sfr_obs.config' to template/sfr_obs.config
2019-07-01 12:09:22.842490 finished: processing obs type sfr took: 0:00:00.395610
2019-07-01 12:09:22.842869 changing dir in to template
2019-07-01 12:09:22.843633 starting: instantiating control file from i/o files
2019-07-01 12:09:22.843723 tpl files: drn.csv.tpl,wel.csv.tpl,hk3.dat_gr.tpl,vka3.dat_gr.tpl,ss
2019-07-01 12:09:22.843770 ins files: freyberg.hds.dat.ins,vol.dat.ins,freyberg.sfr.out.process
2019-07-01 12:09:23.211851 finished: instantiating control file from i/o files took: 0:00:00.36
2019-07-01 12:09:23.460557 starting: writing forward_run.py
2019-07-01 12:09:23.461356 finished: writing forward_run.py took: 0:00:00.000799
2019-07-01 12:09:23.461536 writing pst template/freyberg.pst
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noptmax:0, npar_adj:14819, nnz_obs:4434
2019-07-01 12:09:25.372248 starting: running pestchek on freyberg.pst
2019-07-01 12:09:25.484040 pestcheck:PESTCHEK Version 13.0. Watermark Numerical Computing.
2019-07-01 12:09:25.484604 pestcheck:
2019-07-01 12:09:25.484940 pestcheck:Errors ----->
2019-07-01 12:09:25.485057 pestcheck:Line 2403 of file freyberg.pst: parameter name "prsity3000
2019-07-01 12:09:25.485129 pestcheck:12 characters long.
2019-07-01 12:09:25.485183 pestcheck:Line 2404 of file freyberg.pst: parameter name "prsity3000
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2019-07-01 12:09:25.511954 pestcheck:Line 2475 of file freyberg.pst: parameter name "prsity3003
2019-07-01 12:09:25.512060 pestcheck:once.
2019-07-01 12:09:25.512109 pestcheck:Line 2476 of file freyberg.pst: parameter name "prsity3003
2019-07-01 12:09:25.512149 pestcheck:12 characters long.
2019-07-01 12:09:25.512251 pestcheck:Line 2476 of file freyberg.pst: parameter name "prsity3003
2019-07-01 12:09:25.512358 pestcheck:once.
2019-07-01 12:09:25.512414 pestcheck:Line 2477 of file freyberg.pst: parameter name "prsity3003
2019-07-01 12:09:25.512515 pestcheck:12 characters long.
2019-07-01 12:09:25.512621 pestcheck:Line 2477 of file freyberg.pst: parameter name "prsity3003
```

```
2019-07-01 12:09:25.512672 pestcheck:once.
2019-07-01 12:09:25.512712 pestcheck:Line 2478 of file freyberg.pst: parameter name "prsity3003
2019-07-01 12:09:25.512815 pestcheck:12 characters long.
2019-07-01 12:09:25.512922 pestcheck:Line 2478 of file freyberg.pst: parameter name "prsity3003
2019-07-01 12:09:25.512970 pestcheck:once.
2019-07-01 12:09:25.513010 pestcheck:Line 2479 of file freyberg.pst: parameter name "prsity3003
2019-07-01 12:09:25.513111 pestcheck:12 characters long.
2019-07-01 12:09:25.513218 pestcheck:Line 2479 of file freyberg.pst: parameter name "prsity3003
2019-07-01 12:09:25.513335 pestcheck:once.
2019-07-01 12:09:25.513461 pestcheck:Line 2480 of file freyberg.pst: parameter name "prsity3003
2019-07-01 12:09:25.513501 pestcheck:12 characters long.
2019-07-01 12:09:25.513603 pestcheck:Line 2480 of file freyberg.pst: parameter name "prsity3003
2019-07-01 12:09:25.513710 pestcheck:once.
2019-07-01 12:09:25.513758 pestcheck:Line 2481 of file freyberg.pst: parameter name "prsity3003
2019-07-01 12:09:25.513798 pestcheck:12 characters long.
2019-07-01 12:09:25.513900 pestcheck:Line 2481 of file freyberg.pst: parameter name "prsity3003
2019-07-01 12:09:25.514006 pestcheck:once.
2019-07-01 12:09:25.514119 pestcheck:Line 2482 of file freyberg.pst: parameter name "prsity3003
2019-07-01 12:09:25.514227 pestcheck:12 characters long.
2019-07-01 12:09:25.514275 pestcheck:Line 2482 of file freyberg.pst: parameter name "prsity3003
2019-07-01 12:09:25.514315 pestcheck:once.
2019-07-01 12:09:25.514490 pestcheck:Line 2483 of file freyberg.pst: parameter name "prsity3004
2019-07-01 12:09:25.514538 pestcheck:12 characters long.
2019-07-01 12:09:25.514578 pestcheck:Line 2484 of file freyberg.pst: parameter name "prsity3004
2019-07-01 12:09:25.514682 pestcheck:12 characters long.
2019-07-01 12:09:25.514788 pestcheck:Line 2484 of file freyberg.pst: parameter name "prsity3004
2019-07-01 12:09:25.514837 pestcheck:once.
2019-07-01 12:09:25.514877 pestcheck:Line 2485 of file freyberg.pst: parameter name "prsity3004
2019-07-01 12:09:25.514979 pestcheck:12 characters long.
2019-07-01 12:09:25.515086 pestcheck:Line 2485 of file freyberg.pst: parameter name "prsity3004
2019-07-01 12:09:25.515135 pestcheck:once.
2019-07-01 12:09:25.515175 pestcheck:Line 2486 of file freyberg.pst: parameter name "prsity3004
2019-07-01 12:09:25.515277 pestcheck:12 characters long.
2019-07-01 12:09:25.515401 pestcheck:Line 2486 of file freyberg.pst: parameter name "prsity3004
2019-07-01 12:09:25.515442 pestcheck:once.
2019-07-01 12:09:25.515546 pestcheck:Line 2487 of file freyberg.pst: parameter name "prsity3004
2019-07-01 12:09:25.515667 pestcheck:12 characters long.
2019-07-01 12:09:25.515795 pestcheck:Line 2487 of file freyberg.pst: parameter name "prsity3004
2019-07-01 12:09:25.515905 pestcheck:once.
2019-07-01 12:09:25.515954 pestcheck:Line 2488 of file freyberg.pst: parameter name "prsity3004
2019-07-01 12:09:25.515995 pestcheck:12 characters long.
2019-07-01 12:09:25.516099 pestcheck:Line 2488 of file freyberg.pst: parameter name "prsity3004
2019-07-01 12:09:25.516206 pestcheck:once.
2019-07-01 12:09:25.516254 pestcheck:Line 2489 of file freyberg.pst: parameter name "prsity3004
2019-07-01 12:09:25.516389 pestcheck:12 characters long.
2019-07-01 12:09:25.516486 pestcheck:Line 2489 of file freyberg.pst: parameter name "prsity3004
2019-07-01 12:09:25.516535 pestcheck:once.
2019-07-01 12:09:25.516575 pestcheck:Line 2490 of file freyberg.pst: parameter name "prsity3004
```

```
2019-07-01 12:09:25.516678 pestcheck:12 characters long.
2019-07-01 12:09:25.516785 pestcheck:Line 2490 of file freyberg.pst: parameter name "prsity300
2019-07-01 12:09:25.516833 pestcheck:once.
2019-07-01 12:09:25.516873 pestcheck:Line 2491 of file freyberg.pst: parameter name "prsity300
2019-07-01 12:09:25.516977 pestcheck:12 characters long.
2019-07-01 12:09:25.517084 pestcheck:Line 2491 of file freyberg.pst: parameter name "prsity300
2019-07-01 12:09:25.517133 pestcheck:once.
2019-07-01 12:09:25.517173 pestcheck:Line 2492 of file freyberg.pst: parameter name "prsity300
2019-07-01 12:09:25.517276 pestcheck:12 characters long.
2019-07-01 12:09:25.517392 pestcheck:Line 2492 of file freyberg.pst: parameter name "prsity300
2019-07-01 12:09:25.517441 pestcheck:once.
2019-07-01 12:09:25.517481 pestcheck:Line 2493 of file freyberg.pst: parameter name "prsity300
2019-07-01 12:09:25.517673 pestcheck:12 characters long.
2019-07-01 12:09:25.517723 pestcheck:Line 2494 of file freyberg.pst: parameter name "prsity300
2019-07-01 12:09:25.517764 pestcheck:12 characters long.
2019-07-01 12:09:25.517868 pestcheck:Line 2494 of file freyberg.pst: parameter name "prsity300
2019-07-01 12:09:25.517978 pestcheck:once.
2019-07-01 12:09:25.518028 pestcheck:Line 2495 of file freyberg.pst: parameter name "prsity300
2019-07-01 12:09:25.518068 pestcheck:12 characters long.
2019-07-01 12:09:25.518169 pestcheck:Line 2495 of file freyberg.pst: parameter name "prsity300
2019-07-01 12:09:25.518278 pestcheck:once.
2019-07-01 12:09:25.518335 pestcheck:Line 2496 of file freyberg.pst: parameter name "prsity300
2019-07-01 12:09:25.518438 pestcheck:12 characters long.
2019-07-01 12:09:25.518545 pestcheck:Line 2496 of file freyberg.pst: parameter name "prsity300
2019-07-01 12:09:25.518593 pestcheck:once.
2019-07-01 12:09:25.518634 pestcheck:Line 2497 of file freyberg.pst: parameter name "prsity300
2019-07-01 12:09:25.518736 pestcheck:12 characters long.
2019-07-01 12:09:25.518848 pestcheck:Line 2497 of file freyberg.pst: parameter name "prsity300
2019-07-01 12:09:25.518999 pestcheck:once.
2019-07-01 12:09:25.519107 pestcheck:Line 2498 of file freyberg.pst: parameter name "prsity300
2019-07-01 12:09:25.519156 pestcheck:12 characters long.
2019-07-01 12:09:25.519196 pestcheck:Line 2498 of file freyberg.pst: parameter name "prsity300
2019-07-01 12:09:25.519312 pestcheck:once.
2019-07-01 12:09:25.519436 pestcheck:Line 2499 of file freyberg.pst: parameter name "prsity300
2019-07-01 12:09:25.519476 pestcheck:12 characters long.
2019-07-01 12:09:25.519608 pestcheck:Line 2499 of file freyberg.pst: parameter name "prsity300
2019-07-01 12:09:25.519712 pestcheck:once.
2019-07-01 12:09:25.519760 pestcheck:Line 2500 of file freyberg.pst: parameter name "prsity300
2019-07-01 12:09:25.519799 pestcheck:12 characters long.
2019-07-01 12:09:25.519898 pestcheck:Line 2500 of file freyberg.pst: parameter name "prsity300
2019-07-01 12:09:25.520003 pestcheck:once.
2019-07-01 12:09:25.520050 pestcheck:Line 2501 of file freyberg.pst: parameter name "prsity300
2019-07-01 12:09:25.520088 pestcheck:12 characters long.
2019-07-01 12:09:25.520187 pestcheck:Line 2501 of file freyberg.pst: parameter name "prsity300
2019-07-01 12:09:25.520324 pestcheck:once.
2019-07-01 12:09:25.520378 pestcheck:Line 2502 of file freyberg.pst: parameter name "prsity300
2019-07-01 12:09:25.520478 pestcheck:12 characters long.
2019-07-01 12:09:25.520531 pestcheck:Line 2502 of file freyberg.pst: parameter name "prsity300
```

```
2019-07-01 12:09:25.520625 pestcheck:once.
2019-07-01 12:09:25.520673 pestcheck:Line 2503 of file freyberg.pst: parameter name "prsity3005
2019-07-01 12:09:25.520711 pestcheck:12 characters long.
2019-07-01 12:09:25.520811 pestcheck:Line 2504 of file freyberg.pst: parameter name "prsity3005
2019-07-01 12:09:25.520918 pestcheck:12 characters long.
2019-07-01 12:09:25.520966 pestcheck:Line 2504 of file freyberg.pst: parameter name "prsity3005
2019-07-01 12:09:25.521005 pestcheck:once.
2019-07-01 12:09:25.521104 pestcheck:Line 2505 of file freyberg.pst: parameter name "prsity3005
2019-07-01 12:09:25.521208 pestcheck:12 characters long.
2019-07-01 12:09:25.521255 pestcheck:Line 2505 of file freyberg.pst: parameter name "prsity3005
2019-07-01 12:09:25.521294 pestcheck:once.
2019-07-01 12:09:25.521448 pestcheck:Line 2506 of file freyberg.pst: parameter name "prsity3005
2019-07-01 12:09:25.522323 pestcheck:12 characters long.
2019-07-01 12:09:25.522592 pestcheck:Line 2506 of file freyberg.pst: parameter name "prsity3005
2019-07-01 12:09:25.522681 pestcheck:once.
2019-07-01 12:09:25.522833 pestcheck:Line 2507 of file freyberg.pst: parameter name "prsity3005
2019-07-01 12:09:25.522901 pestcheck:12 characters long.
2019-07-01 12:09:25.522966 pestcheck:Line 2507 of file freyberg.pst: parameter name "prsity3005
2019-07-01 12:09:25.523046 pestcheck:once.
2019-07-01 12:09:25.523260 pestcheck:Line 2508 of file freyberg.pst: parameter name "prsity3005
2019-07-01 12:09:25.523398 pestcheck:12 characters long.
2019-07-01 12:09:25.523804 finished: running pestchek on freyberg.pst took: 0:00:00.151556
2019-07-01 12:09:25.524008 starting: saving intermediate _setup_<> dfs into template
2019-07-01 12:09:25.659184 finished: saving intermediate _setup_<> dfs into template took: 0:0
2019-07-01 12:09:25.659484 all done
```

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

```
In [13]: # 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[13]: (14819, 4434)
```

Oh snap!

1.1.6 Add modpath input files, instruction files and calls

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

```
In [14]: 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
```

```
Out[14]: ['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 [15]: #pst_helper.frun_post_lines.append("os.system('mp6 freyberg.mpsim >mp6.stdout')")
         pst_helper.frun_post_lines.append("pyemu.os_utils.run('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 [16]: 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 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.mpenp
observations in this instruction file will havegeneric values.
```

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

```
In [17]: for k in range(m.nlay):
             np.savetxt(os.path.join(pst_helper.new_model_ws,"arr_org","prsity_layer_{0}.ref".
```

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 [18]: 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
```

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

```
In [19]: 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 [20]: # table can also be written to a .tex file
         pst.write_par_summary_table(filename="none").sort_index()
```

Out[20]:

	type	transform	count	initial value	upper bound	\
cn_hk6	cn_hk6	log	1	0	1	
cn_hk7	cn_hk7	log	1	0	1	
cn_hk8	cn_hk8	log	1	0	1	
cn_prsity6	cn_prsity6	log	1	0	0.176091	
cn_prsity7	cn_prsity7	log	1	0	0.176091	
cn_prsity8	cn_prsity8	log	1	0	0.176091	
cn_rech4	cn_rech4	log	1	0	0.0413927	
cn_rech5	cn_rech5	log	1	0	0.0413927	
cn_ss6	cn_ss6	log	1	0	1	
cn_ss7	cn_ss7	log	1	0	1	
cn_ss8	cn_ss8	log	1	0	1	
cn_strt6	cn_strt6	log	1	0	0.0211893	
cn_strt7	cn_strt7	log	1	0	0.0211893	
cn_strt8	cn_strt8	log	1	0	0.0211893	
cn_sy6	cn_sy6	log	1	0	0.243038	
cn_sy7	cn_sy7	log	1	0	0.243038	
cn_sy8	cn_sy8	log	1	0	0.243038	
cn_vka6	cn_vka6	log	1	0	1	
cn_vka7	cn_vka7	log	1	0	1	
cn_vka8	cn_vka8	log	1	0	1	
drncond_k00	drncond_k00	log	10	0	1	
flow	flow	log	1	0	0.09691	
gr_hk3	gr_hk3	log	705	0	1	
gr_hk4	gr_hk4	log	705	0	1	
gr_hk5	gr_hk5	log	705	0	1	
gr_prsity3	gr_prsity3	log	705	0	0.176091	
gr_prsity4	gr_prsity4	log	705	0	0.176091	
gr_prsity5	gr_prsity5	log	705	0	0.176091	
gr_rech2	gr_rech2	log	705	0	0.0413927	
gr_rech3	gr_rech3	log	705	0	0.0413927	
...	...	...	...	...	...	
gr_strt5	gr_strt5	log	705	0	0.0211893	
gr_sy3	gr_sy3	log	705	0	0.243038	
gr_sy4	gr_sy4	log	705	0	0.243038	

gr_sy5	gr_sy5	log	705	0	0.243038
gr_vka3	gr_vka3	log	705	0	1
gr_vka4	gr_vka4	log	705	0	1
gr_vka5	gr_vka5	log	705	0	1
pp_hk0	pp_hk0	log	32	0	1
pp_hk1	pp_hk1	log	32	0	1
pp_hk2	pp_hk2	log	32	0	1
pp_prsity0	pp_prsity0	log	32	0	0.176091
pp_prsity1	pp_prsity1	log	32	0	0.176091
pp_prsity2	pp_prsity2	log	32	0	0.176091
pp_rech0	pp_rech0	log	32	0	0.0413927
pp_rech1	pp_rech1	log	32	0	0.0413927
pp_ss0	pp_ss0	log	32	0	1
pp_ss1	pp_ss1	log	32	0	1
pp_ss2	pp_ss2	log	32	0	1
pp_strt0	pp_strt0	log	32	0	0.0211893
pp_strt1	pp_strt1	log	32	0	0.0211893
pp_strt2	pp_strt2	log	32	0	0.0211893
pp_sy0	pp_sy0	log	32	0	0.243038
pp_sy1	pp_sy1	log	32	0	0.243038
pp_sy2	pp_sy2	log	32	0	0.243038
pp_vka0	pp_vka0	log	32	0	1
pp_vka1	pp_vka1	log	32	0	1
pp_vka2	pp_vka2	log	32	0	1
strk	strk	log	40	0	2
welflux	welflux	log	2	0	1
welflux_k02	welflux_k02	log	6	0	1

	lower bound	standard deviation
cn_hk6	-1	0.5
cn_hk7	-1	0.5
cn_hk8	-1	0.5
cn_prsity6	-0.30103	0.11928
cn_prsity7	-0.30103	0.11928
cn_prsity8	-0.30103	0.11928
cn_rech4	-0.0457575	0.0217875
cn_rech5	-0.0457575	0.0217875
cn_ss6	-1	0.5
cn_ss7	-1	0.5
cn_ss8	-1	0.5
cn_strt6	-0.0222764	0.0108664
cn_strt7	-0.0222764	0.0108664
cn_strt8	-0.0222764	0.0108664
cn_sy6	-0.60206	0.211275
cn_sy7	-0.60206	0.211275
cn_sy8	-0.60206	0.211275
cn_vka6	-1	0.5
cn_vka7	-1	0.5

```
cn_vka8              -1                0.5
drncond_k00          -1                0.5
flow          -0.124939         0.0554622
gr_hk3               -1                0.5
gr_hk4               -1                0.5
gr_hk5               -1                0.5
gr_prsity3     -0.30103           0.11928
gr_prsity4     -0.30103           0.11928
gr_prsity5     -0.30103           0.11928
gr_rech2     -0.0457575         0.0217875
gr_rech3     -0.0457575         0.0217875
...                 ...               ...
gr_strt5     -0.0222764         0.0108664
gr_sy3         -0.60206          0.211275
gr_sy4         -0.60206          0.211275
gr_sy5         -0.60206          0.211275
gr_vka3              -1                0.5
gr_vka4              -1                0.5
gr_vka5              -1                0.5
pp_hk0               -1                0.5
pp_hk1               -1                0.5
pp_hk2               -1                0.5
pp_prsity0     -0.30103           0.11928
pp_prsity1     -0.30103           0.11928
pp_prsity2     -0.30103           0.11928
pp_rech0     -0.0457575         0.0217875
pp_rech1     -0.0457575         0.0217875
pp_ss0               -1                0.5
pp_ss1               -1                0.5
pp_ss2               -1                0.5
pp_strt0     -0.0222764         0.0108664
pp_strt1     -0.0222764         0.0108664
pp_strt2     -0.0222764         0.0108664
pp_sy0         -0.60206          0.211275
pp_sy1         -0.60206          0.211275
pp_sy2         -0.60206          0.211275
pp_vka0              -1                0.5
pp_vka1              -1                0.5
pp_vka2              -1                0.5
strk                 -2                  1
welflux              -1                0.5
welflux_k02          -1                0.5

[65 rows x 7 columns]
```

In [21]:
```
pst.write_obs_summary_table(filename="none")
```

Out[21]:
```
                    group                         value  non-zero weight  \
flaqx               flaqx           -977.239 to 40.562               84
```

flout	flout	10054 to 226396	84
flx_constan	flx_constan	0	2
flx_drains	flx_drains	-723.325 to -548.613	2
flx_in-out	flx_in-out	0.012695 to 0.467	2
flx_percent	flx_percent	0 to 0.02	2
flx_recharg	flx_recharg	2284.2 to 3045.6	2
flx_storage	flx_storage	8.01049 to 576.618	2
flx_stream_	flx_stream_	-1430.27 to -511.738	2
flx_total	flx_total	0.0126953 to 0.467041	2
flx_wells	flx_wells	-1800 to -900	2
hds	hds	32.5047 to 39.6612	4230
obgnme	obgnme	1E+10	2
vol_constan	vol_constan	0	2
vol_drains	vol_drains	-2.84038E+06 to -2.64014E+06	2
vol_in-out	vol_in-out	45 to 216	2
vol_percent	vol_percent	0	2
vol_recharg	vol_recharg	1.11164E+07 to 1.19502E+07	2
vol_storage	vol_storage	29238.3 to 239704	2
vol_stream_	vol_stream_	-5.40728E+06 to -5.22049E+06	2
vol_total	vol_total	45 to 216	2
vol_wells	vol_wells	-3.942E+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 0.00994629
flx_constan	0	1	1	NA
flx_drains	0	1	1	0.13825 to 0.182278
flx_in-out	0	1	1	214.133 to 7877.12
flx_percent	0	1	1	5000
flx_recharg	0	1	1	0.0328343 to 0.043779
flx_storage	0	1	1	0.173425 to 12.4836
flx_stream_	0	1	1	0.0699167 to 0.195413
flx_total	0	1	1	214.114 to 7876.92
flx_wells	0	1	1	0.0555556 to 0.111111
hds	0	1	1	2.52136 to 3.07648
obgnme	0	1	1	1E-08
vol_constan	0	1	1	NA
vol_drains	0	1	1	3.52066E-05 to 3.78768E-05
vol_in-out	0	1	1	0.462963 to 2.22222
vol_percent	0	1	1	NA
vol_recharg	0	1	1	8.36808E-06 to 8.99569E-06
vol_storage	0	1	1	0.000417182 to 0.00342017
vol_stream_	0	1	1	1.84936E-05 to 1.91553E-05
vol_total	0	1	1	0.462963 to 2.22222
vol_wells	0	1	1	2.53678E-05 to 3.04414E-05

Let's run the process once (`noptmax=0`) to make sure its all plumbed up. Pro-tip: you can use any of the `pestpp-###` binaries/executables to run `noptmax=0`

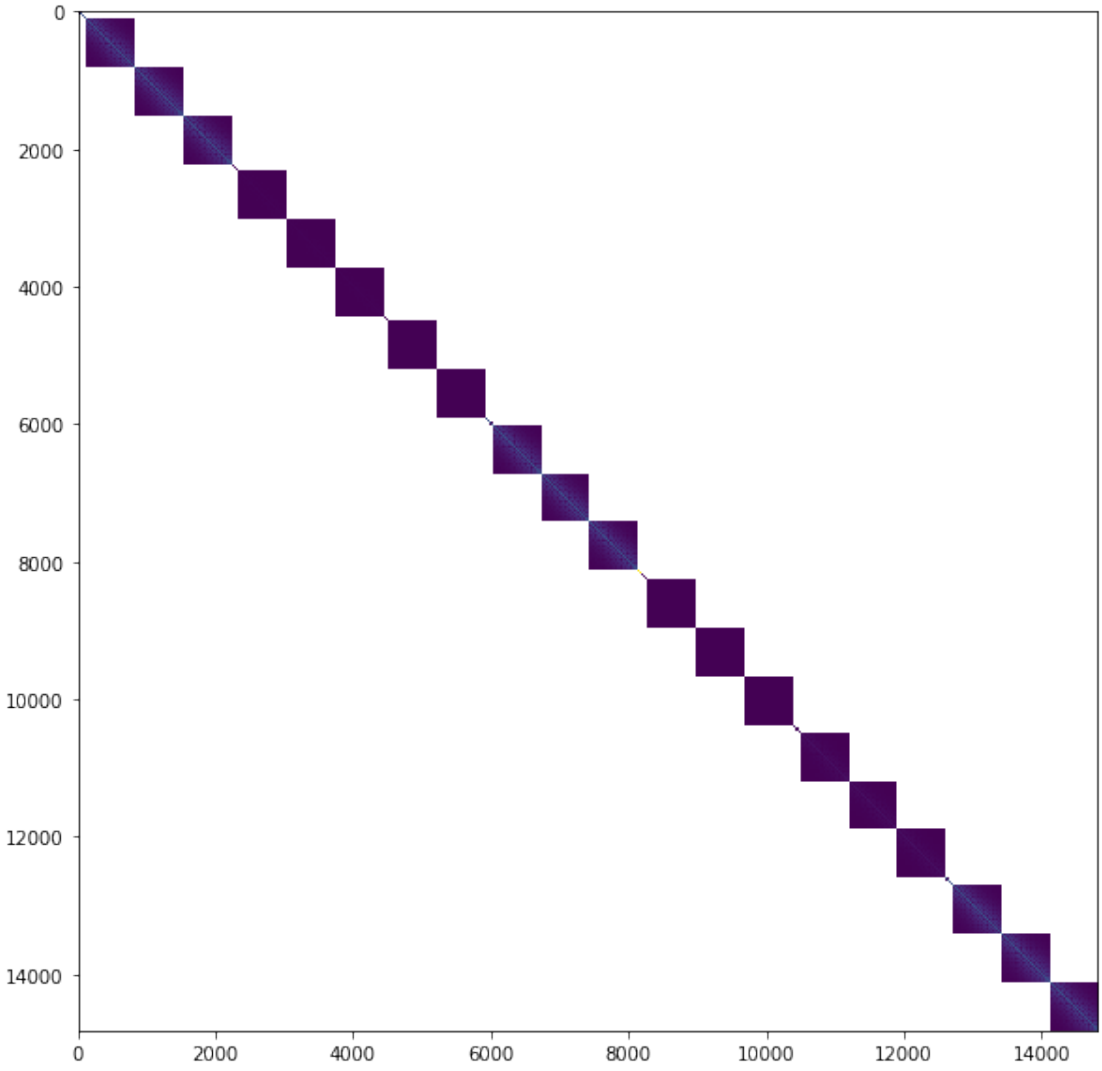
```
In [22]: pst.control_data.noptmax = 0
         pst.write(os.path.join(pst_helper.new_model_ws,"freyberg.pst"))
         pyemu.os_utils.run("pestpp-ies freyberg.pst",cwd=pst_helper.new_model_ws)
```

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

```
2019-07-01 12:09:34.917287 starting: building prior covariance matrix
2019-07-01 12:09:35.038040 WARNING: geospatial prior not implemented for SFR pars


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


2019-07-01 12:09:42.239003 saving prior covariance matrix to file template/prior_cov.jcb
2019-07-01 12:09:46.792368 finished: building prior covariance matrix took: 0:00:11.875081
```



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

```
In [24]: pe = pst_helper.draw(500)

2019-07-01 12:10:01.350703 starting: drawing realizations
building diagonal cov
processing  name:grid_geostruct,nugget:0.0,structures:
name:var1,contribution:1.0,a:2500.0,anisotropy:1.0,bearing:0.0

working on pargroups ['gr_hk3']
build cov matrix
done
getting diag var cov 705
```

```
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['gr_vka3']
build cov matrix
done
getting diag var cov 705
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['gr_ss3']
build cov matrix
done
getting diag var cov 705
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['gr_sy3']
build cov matrix
done
getting diag var cov 705
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['gr_strt3']
build cov matrix
done
getting diag var cov 705
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['gr_prsity3']
build cov matrix
done
getting diag var cov 705
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['gr_hk4']
build cov matrix
done
getting diag var cov 705
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['gr_vka4']
build cov matrix
done
getting diag var cov 705
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['gr_ss4']
build cov matrix
done
getting diag var cov 705
```

```
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['gr_sy4']
build cov matrix
done
getting diag var cov 705
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['gr_strt4']
build cov matrix
done
getting diag var cov 705
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['gr_prsity4']
build cov matrix
done
getting diag var cov 705
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['gr_hk5']
build cov matrix
done
getting diag var cov 705
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['gr_vka5']
build cov matrix
done
getting diag var cov 705
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['gr_ss5']
build cov matrix
done
getting diag var cov 705
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['gr_sy5']
build cov matrix
done
getting diag var cov 705
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['gr_strt5']
build cov matrix
done
getting diag var cov 705
```

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

working on pargroups ['pp_hk0']
build cov matrix
done
getting diag var cov 32
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['pp_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_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_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_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_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_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_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_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_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_sy1']
```

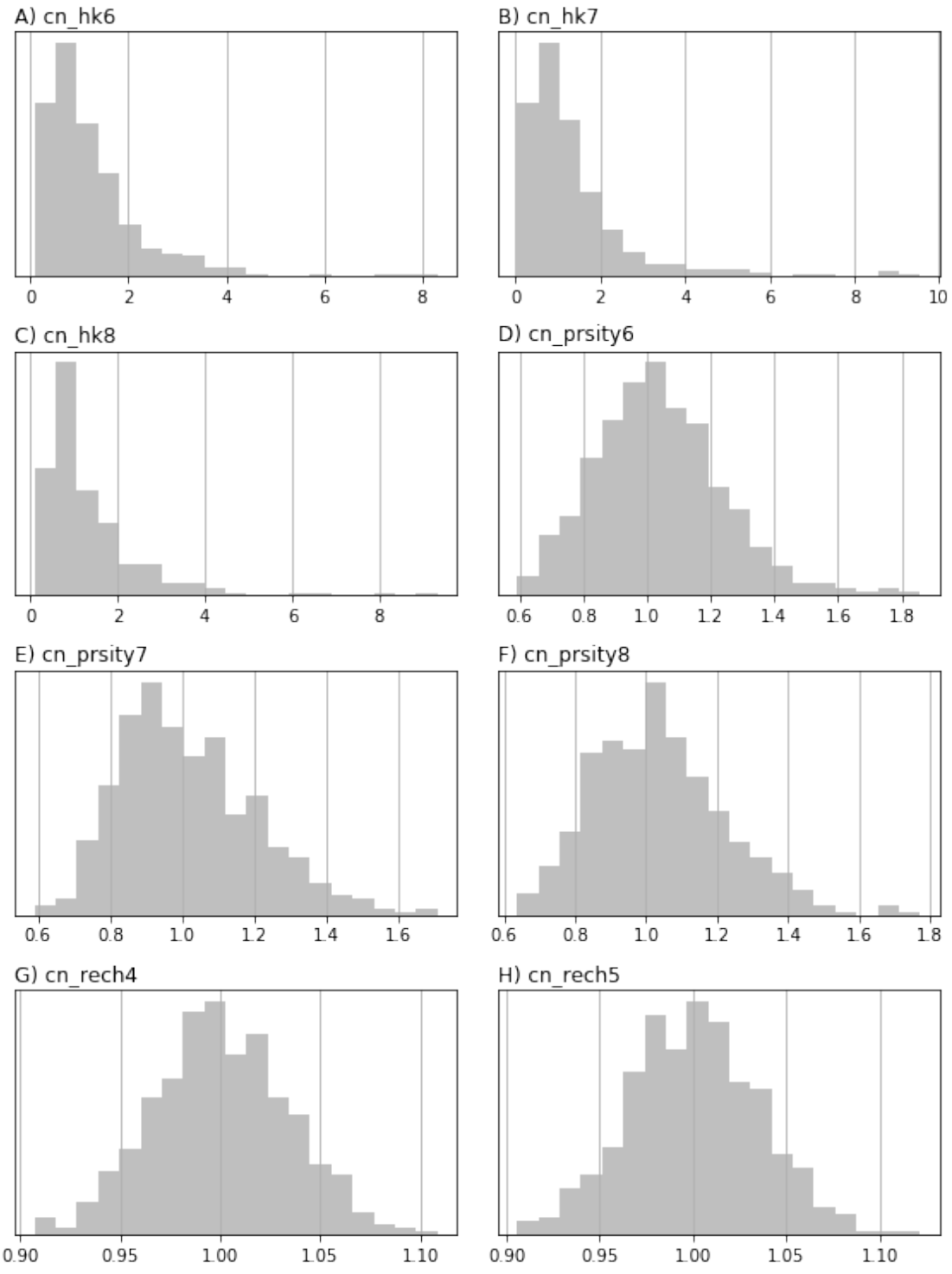
```
build cov matrix
done
getting diag var cov 32
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['pp_vka1']
build cov matrix
done
getting diag var cov 32
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['pp_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_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_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_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:spatial_list_geostruct,nugget:0.0,structures:
```

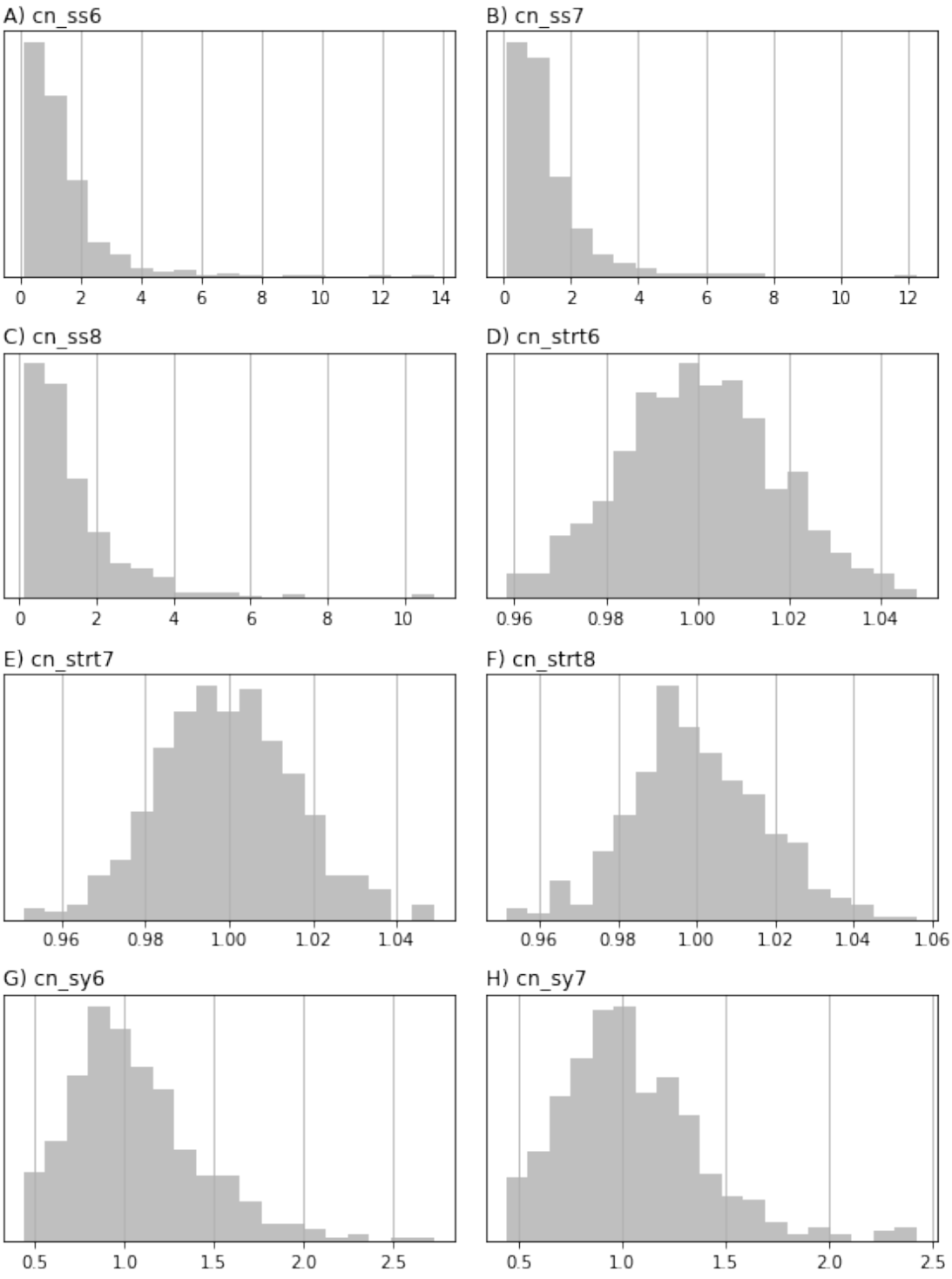
```
name:var1,contribution:1.0,a:2500.0,anisotropy:1.0,bearing:0.0

working on pargroups ['drncond_k00']
build cov matrix
done
getting diag var cov 10
scaling full cov by diag var cov
making full cov draws with home-grown goodness


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


working on pargroups ['welflux_k02']
build cov matrix
done
getting diag var cov 6
scaling full cov by diag var cov
making full cov draws with home-grown goodness
processing  name:temporal_list_geostruct,nugget:0.0,structures:
name:var1,contribution:1.0,a:180.0,anisotropy:1.0,bearing:0.0

working on pargroups ['welflux']
build cov matrix
done
getting diag var cov 2
scaling full cov by diag var cov
making full cov draws with home-grown goodness
adding remaining parameters to diagonal
2019-07-01 12:10:12.739350 finished: drawing realizations took: 0:00:11.388647
```

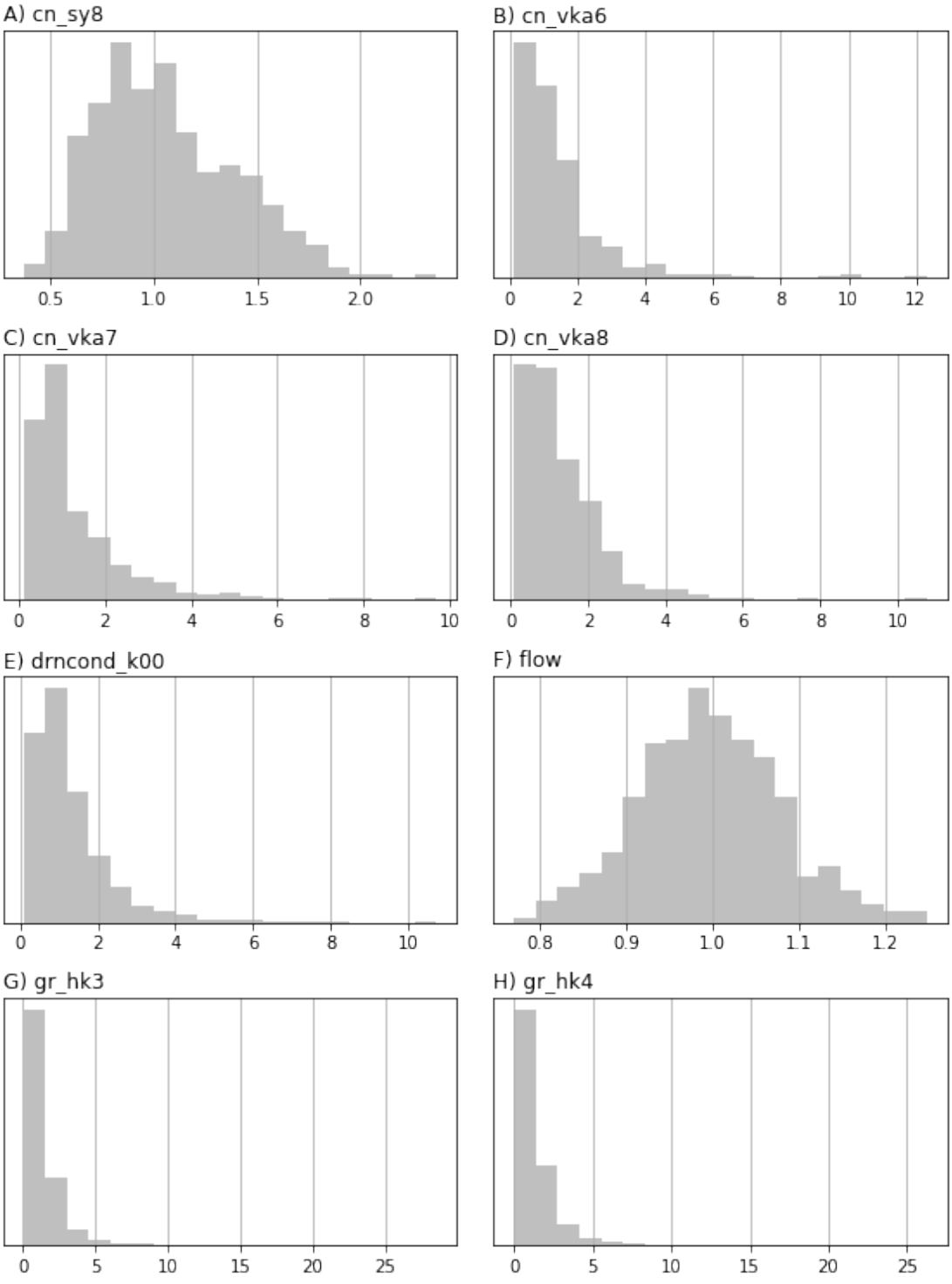
You can see that parameters are treated in parameter group (pargp) blocks for this ensemble generation. Let's plot one parameter:

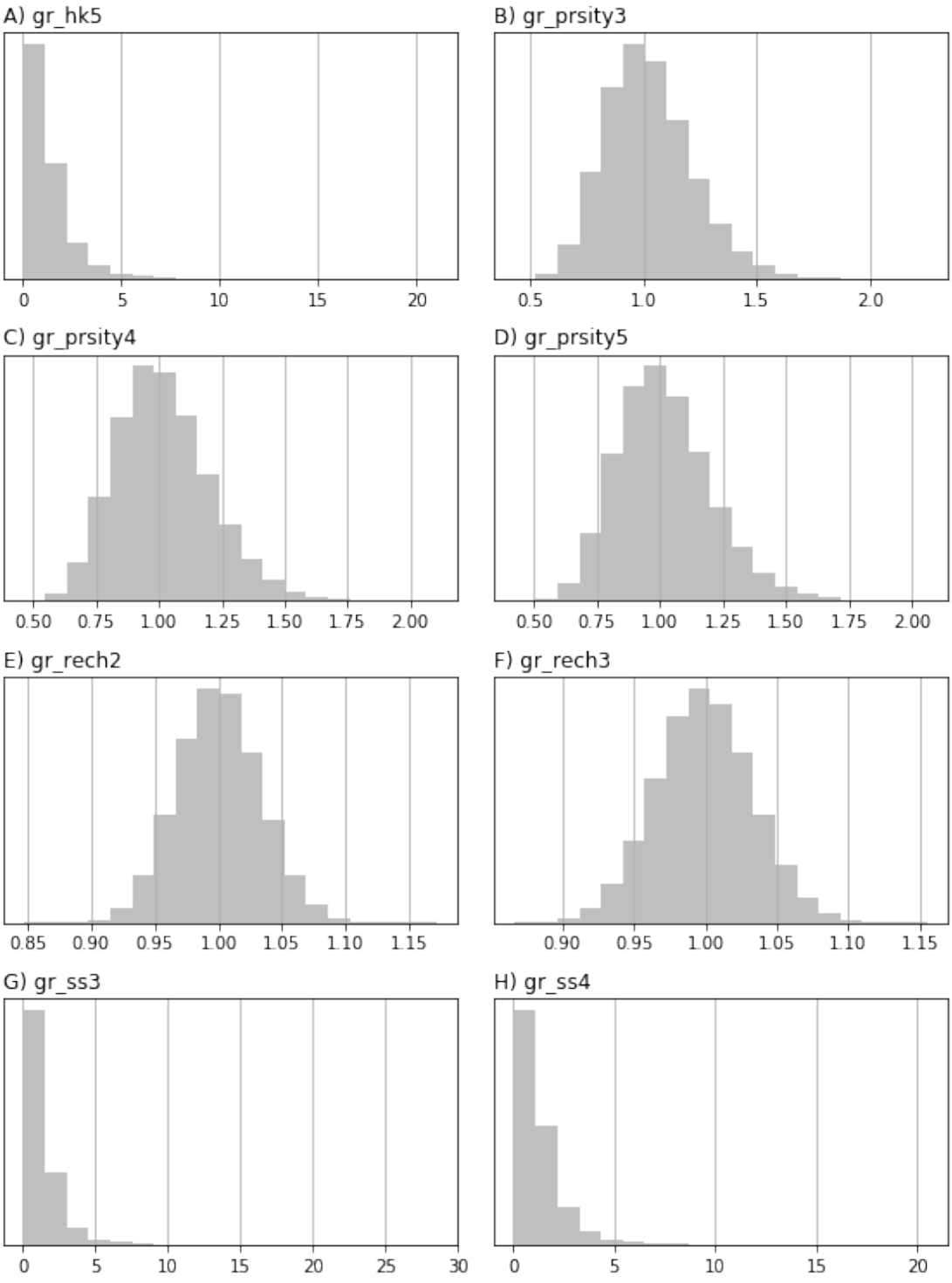
```
In [25]: par = pst_helper.pst.parameter_data
         pyemu.plot_utils.ensemble_helper(pe,plot_cols=par.groupby("pargp").groups,bins=20)
         plt.show()
```

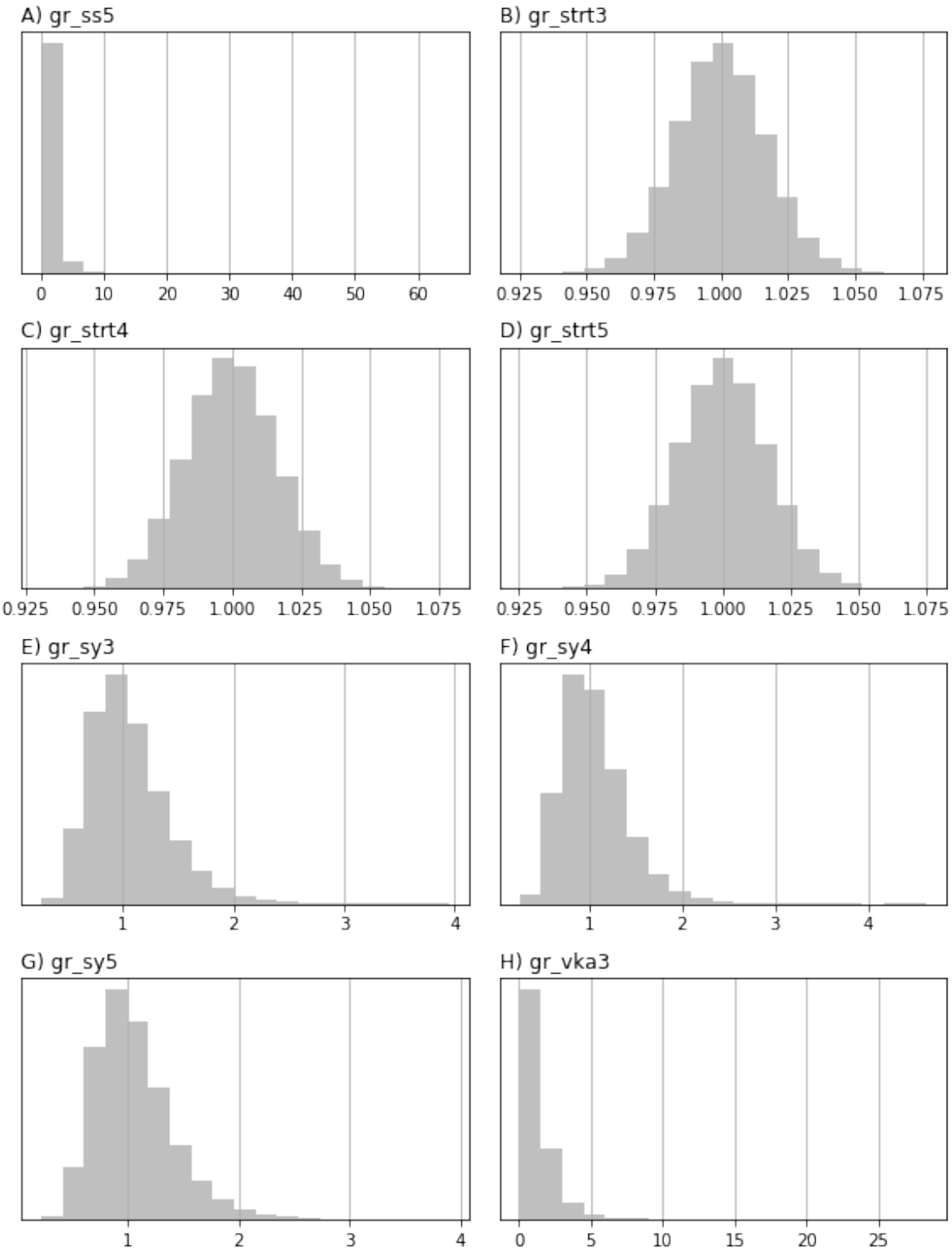
<Figure size 576x756 with 0 Axes>

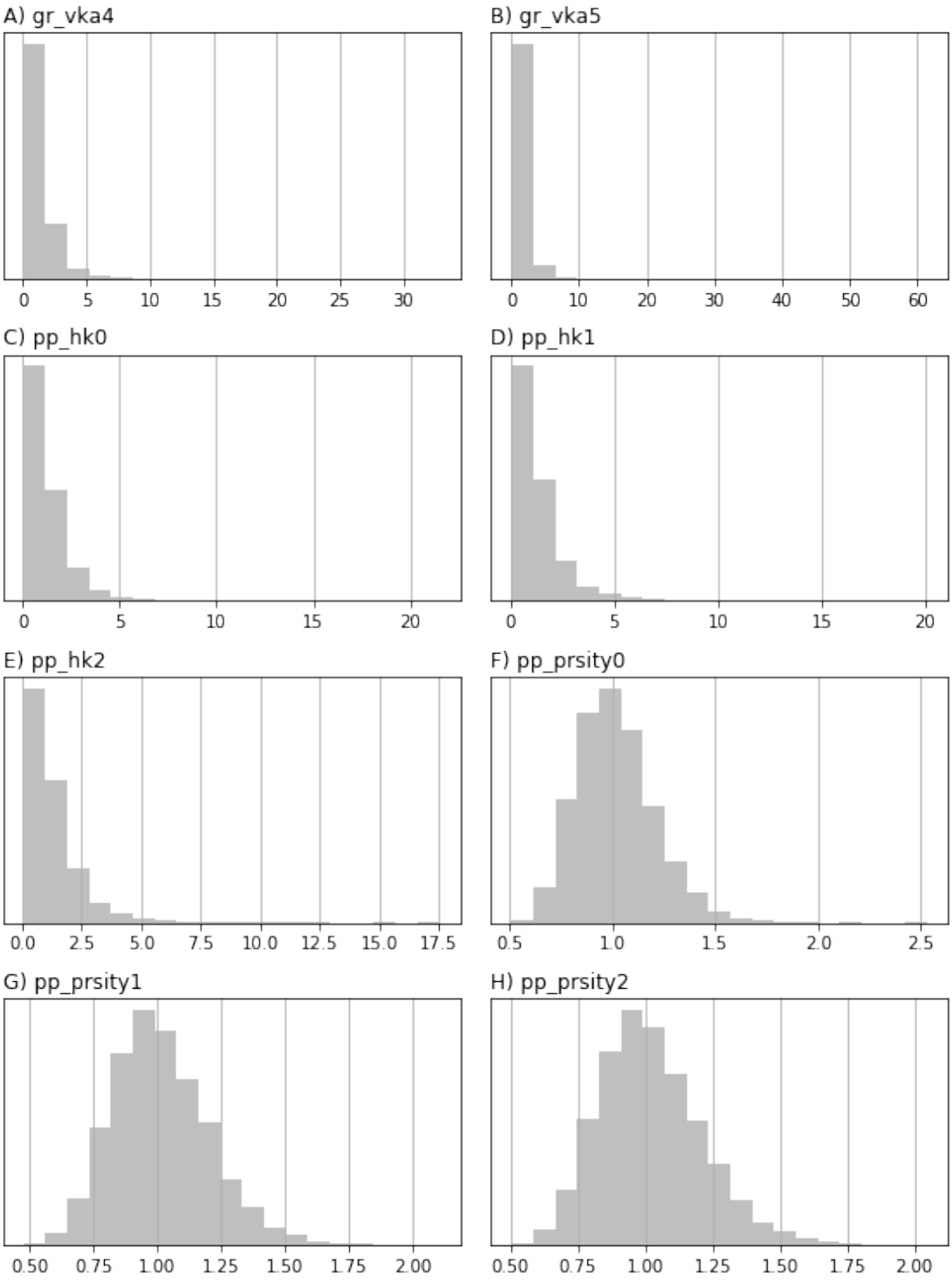


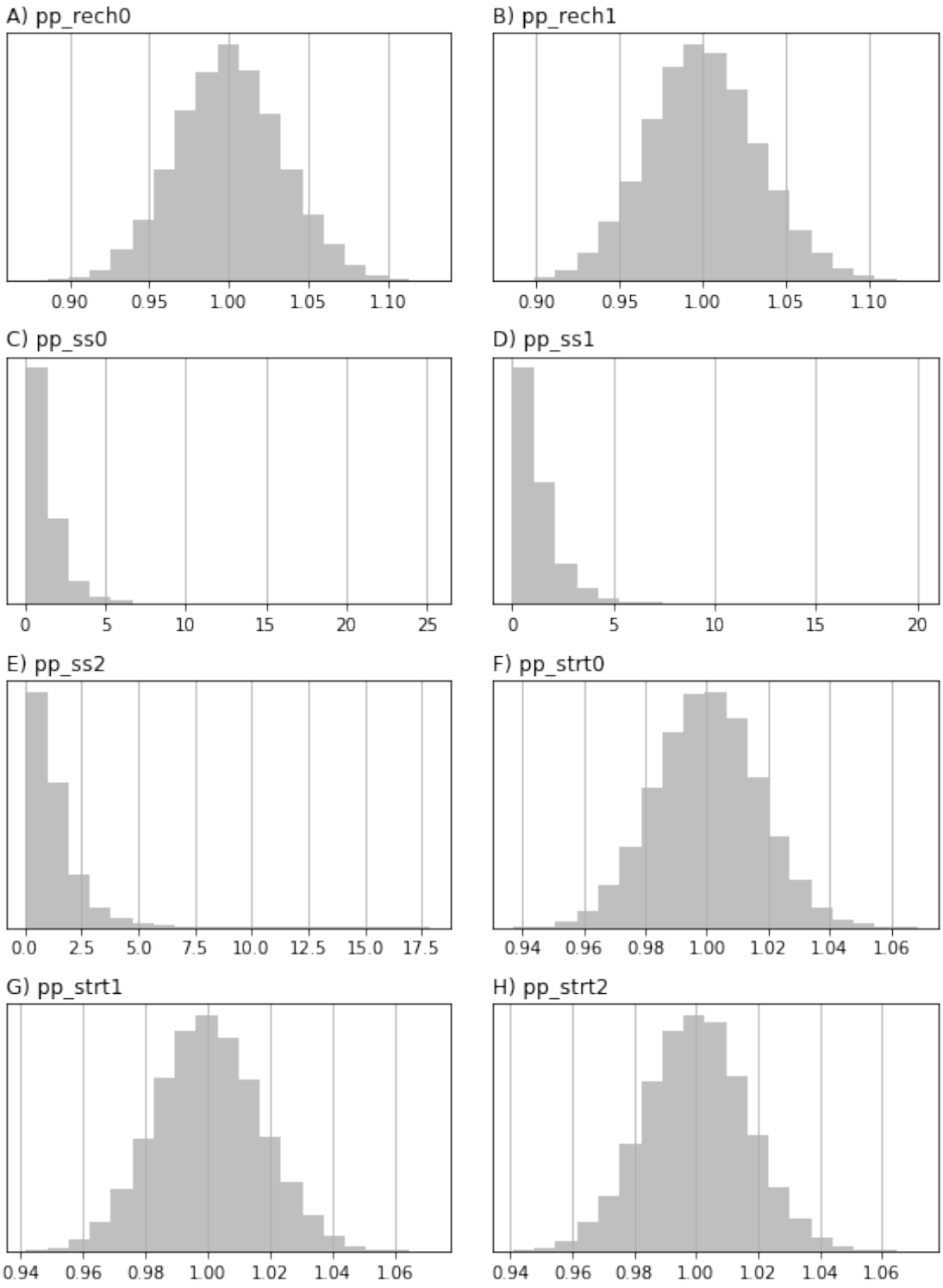

A) cn_ss6
0
2
4
6
8
10
12
14
B) cn_ss7
0
2
4
6
8
10
12
C) cn_ss8
0
2
4
6
8
10
D) cn_strt6
0.96
0.98
1.00
1.02
1.04
E) cn_strt7
0.96
0.98
1.00
1.02
1.04
F) cn_strt8
0.96
0.98
1.00
1.02
1.04
1.06
G) cn_sy6
0.5
1.0
1.5
2.0
2.5
H) cn_sy7
0.5
1.0
1.5
2.0
2.5

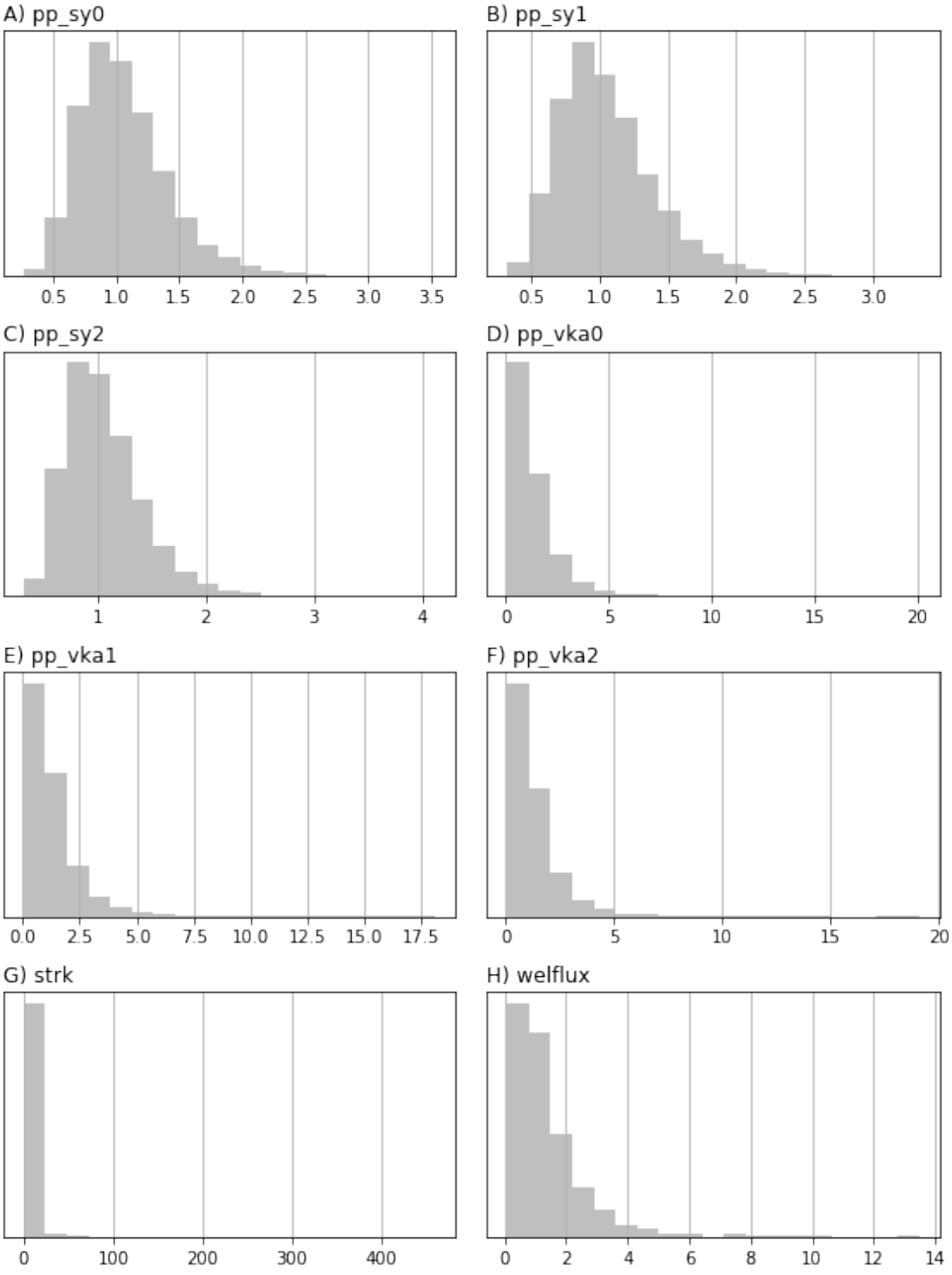

A) cn_sy8
0.5
1.0
1.5
2.0
B) cn_vka6
0
2
4
6
8
10
12
C) cn_vka7
0
2
4
6
8
10
D) cn_vka8
0
2
4
6
8
10
E) drncond_k00
0
2
4
6
8
10
F) flow
0.8
0.9
1.0
1.1
1.2
G) gr_hk3
0
5
10
15
20
25
H) gr_hk4
0
5
10
15
20
25

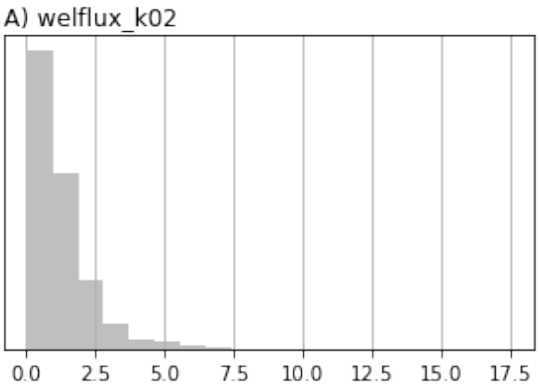

A) gr_hk5
0
5
10
15
20
B) gr_prsity3
0.5
1.0
1.5
2.0
C) gr_prsity4
0.50
0.75
1.00
1.25
1.50
1.75
2.00
D) gr_prsity5
0.50
0.75
1.00
1.25
1.50
1.75
2.00
E) gr_rech2
0.85
0.90
0.95
1.00
1.05
1.10
1.15
F) gr_rech3
0.90
0.95
1.00
1.05
1.10
1.15
G) gr_ss3
0
5
10
15
20
25
30
H) gr_ss4
0
5
10
15
20


A) gr_ss5
0
10
20
30
40
50
60
B) gr_strt3
0.925
0.950
0.975
1.000
1.025
1.050
1.075
C) gr_strt4
0.925
0.950
0.975
1.000
1.025
1.050
1.075
D) gr_strt5
0.925
0.950
0.975
1.000
1.025
1.050
1.075
E) gr_sy3
1
2
3
4
F) gr_sy4
1
2
3
4
G) gr_sy5
1
2
3
4
H) gr_vka3
0
5
10
15
20
25


A) gr_vka4
0 5 10 15 20 25 30
B) gr_vka5
0 10 20 30 40 50 60
C) pp_hk0
0 5 10 15 20
D) pp_hk1
0 5 10 15 20
E) pp_hk2
0.0 2.5 5.0 7.5 10.0 12.5 15.0 17.5
F) pp_prsity0
0.5 1.0 1.5 2.0 2.5
G) pp_prsity1
0.50 0.75 1.00 1.25 1.50 1.75 2.00
H) pp_prsity2
0.50 0.75 1.00 1.25 1.50 1.75 2.00


A) pp_rech0
0.90 0.95 1.00 1.05 1.10
B) pp_rech1
0.90 0.95 1.00 1.05 1.10
C) pp_ss0
0 5 10 15 20 25
D) pp_ss1
0 5 10 15 20
E) pp_ss2
0.0 2.5 5.0 7.5 10.0 12.5 15.0 17.5
F) pp_strt0
0.94 0.96 0.98 1.00 1.02 1.04 1.06
G) pp_strt1
0.94 0.96 0.98 1.00 1.02 1.04 1.06
H) pp_strt2
0.94 0.96 0.98 1.00 1.02 1.04 1.06


A) pp_sy0
0.5 1.0 1.5 2.0 2.5 3.0 3.5
B) pp_sy1
0.5 1.0 1.5 2.0 2.5 3.0
C) pp_sy2
1 2 3 4
D) pp_vka0
0 5 10 15 20
E) pp_vka1
0.0 2.5 5.0 7.5 10.0 12.5 15.0 17.5
F) pp_vka2
0 5 10 15 20
G) strk
0 100 200 300 400
H) welflux
0 2 4 6 8 10 12 14



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

```
In [26]: 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 [27]: 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".forma
         obs_locs
```

Out[27]:

	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 excercise

```
In [28]: 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[28]: ['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',
```

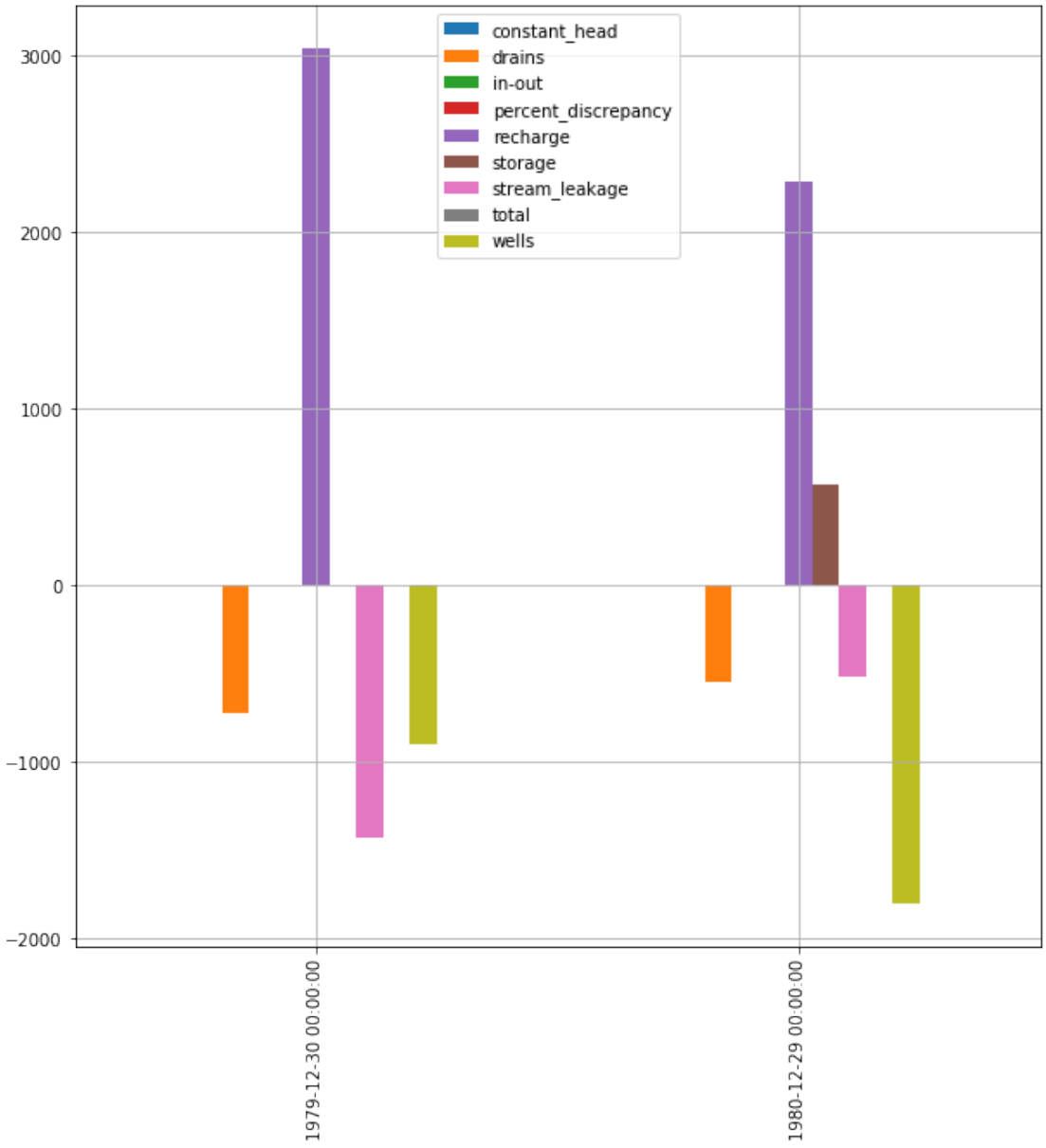
```
 'hds_00_021_010_000',
 'hds_00_022_015_000',
 'hds_00_024_004_000',
 'hds_00_026_006_000',
 'hds_00_029_015_000',
 'hds_00_033_007_000',
 'hds_00_034_010_000']
```

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

```
In [29]: swgw_forecasts = obs.loc[obs.obsnme.apply(lambda x: "fa" in x and ("hw" in x or "tw" i

         hds_fore_name = "hds_00_{0:03d}_{1:03d}".format(int(pst_helper.m.nrow/3),int(pst_helpe
         hds_forecasts = obs.loc[obs.obsnme.apply(lambda x: hds_fore_name in x),"obsnme"].tolis
         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"))
         forecasts

noptmax:0, npar_adj:14819, nnz_obs:14


Out[29]: ['fa_hw_19791230',
          'fa_hw_19801229',
          'fa_tw_19791230',
          'fa_tw_19801229',
          'hds_00_013_002_000',
          'hds_00_013_002_001',
          'part_time',
          'part_status']
```

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 [30]: 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[30]: 9.456182577320024e-19

In [31]: 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()
```


constant_head
drains
in-out
percent_discrepancy
recharge
storage
stream_leakage
total
wells
3000
2000
1000
0
−1000
−2000
1979-12-30 00:00:00
1980-12-29 00:00:00