setup_pest_interface

May 18, 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 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)

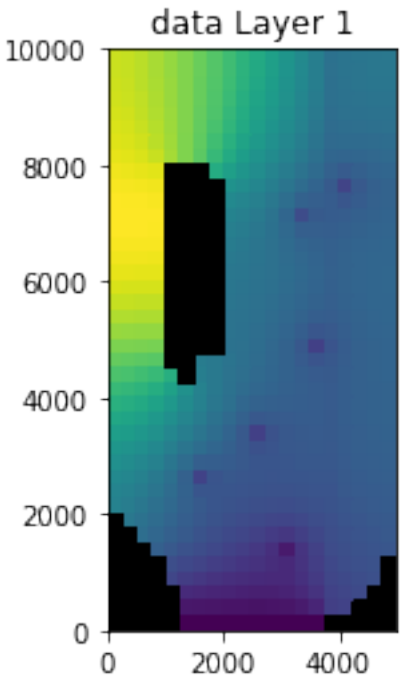
```
In [5]: pyemu.os_utils.run("{0} {1}".format("mfnwt",m.name+".nam"),cwd=m.model_ws)
```

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

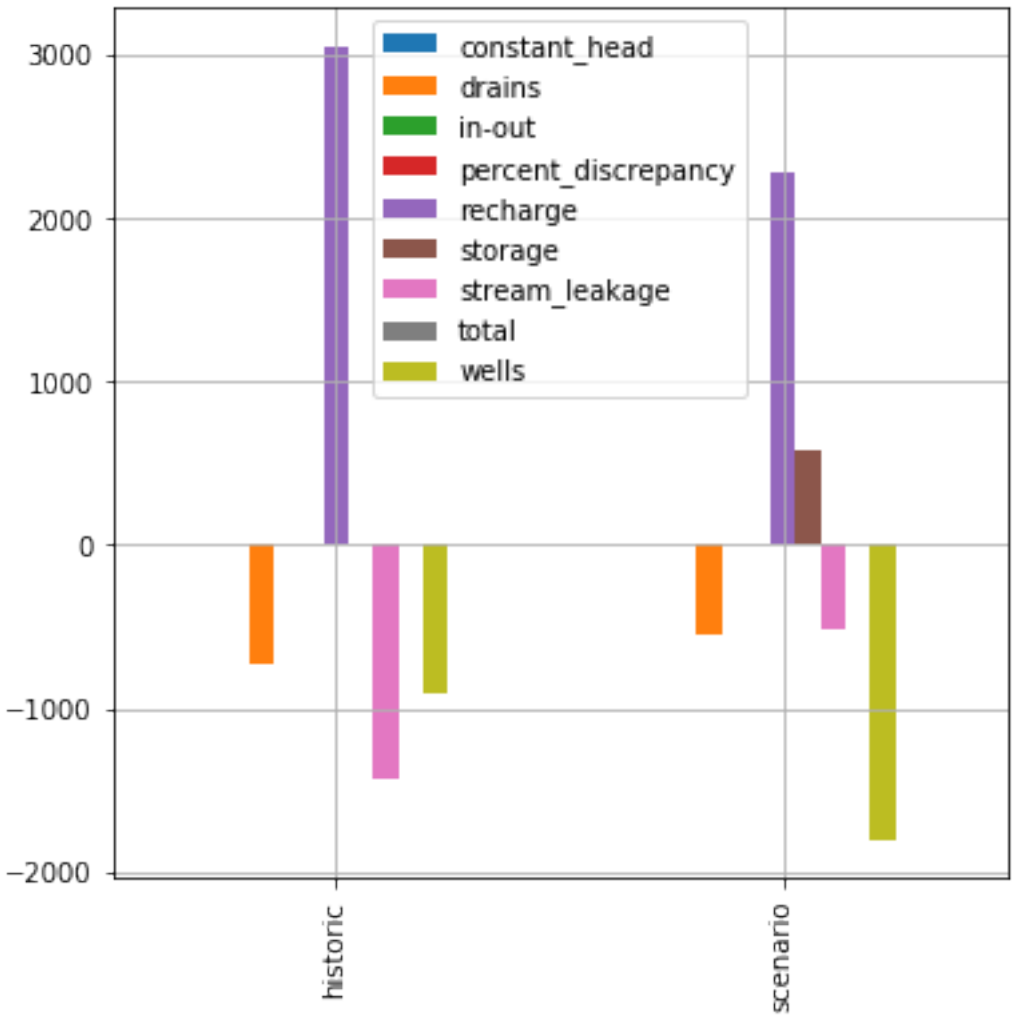
Note that there is a historic period and a scenario with future conditions that differ.

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"])
        plt.show()
```



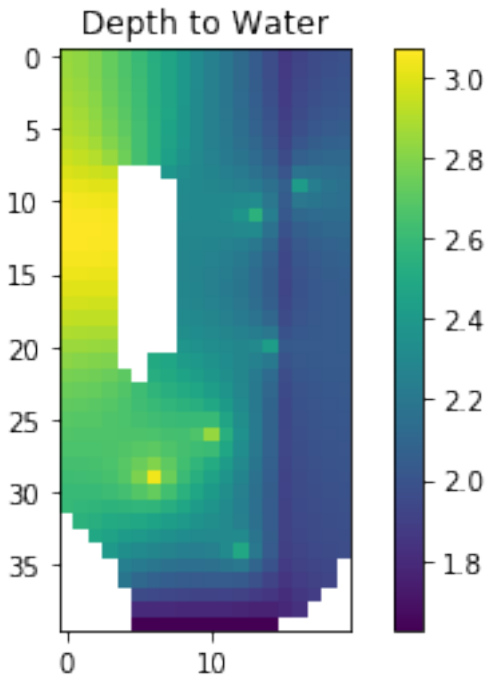

```
<Figure size 432x288 with 0 Axes>
```



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()
```

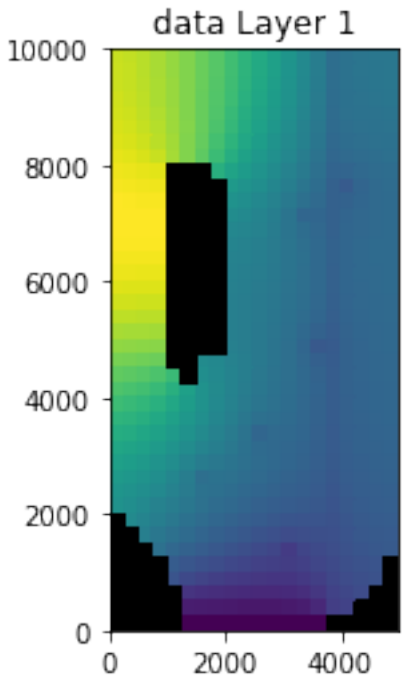


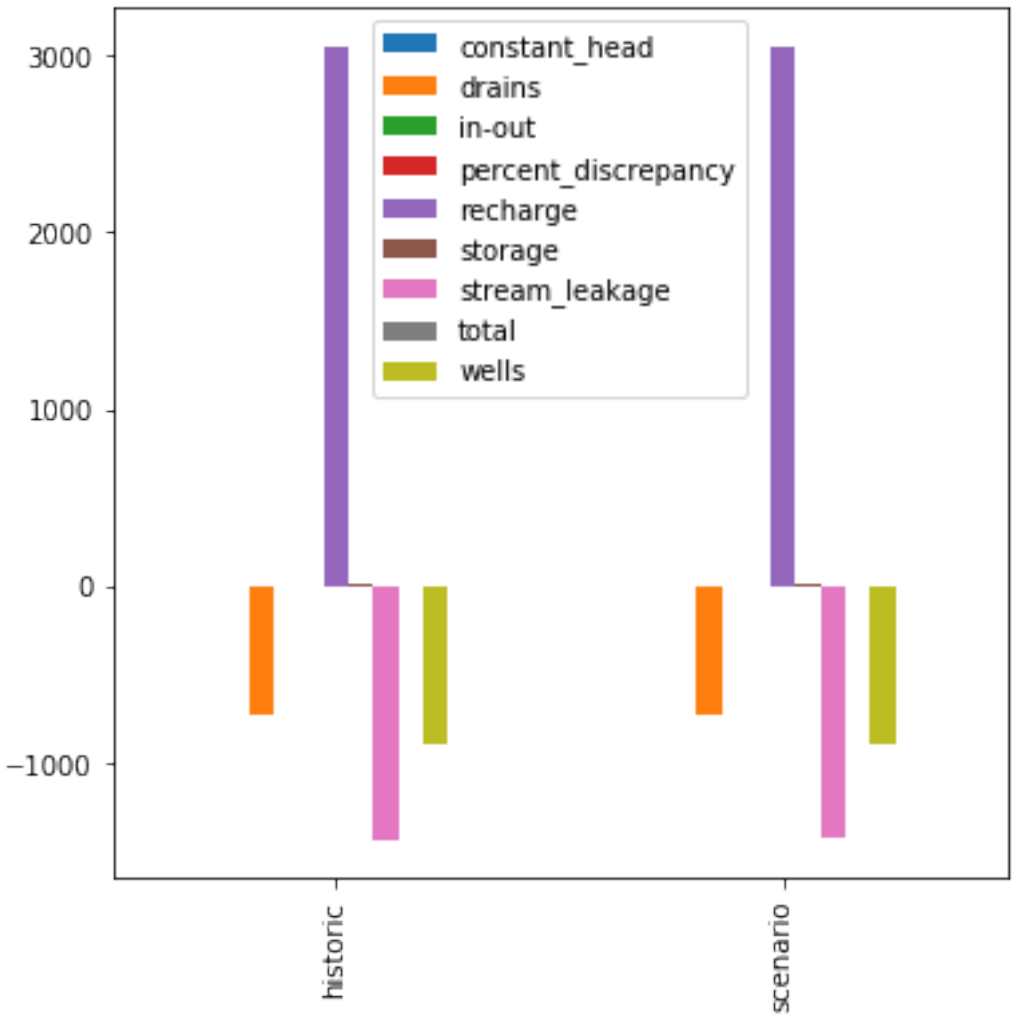
Clearly we can see the river and well locations expressed in the depth to water pattern.

1.0.6 What we are going to do is implement the scenario with parameters so we can more easy account for the stochastic nature of the forcing conditions during the scenario stress period and also make implemention 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("mfnwt",m.name+".nam"),cwd=m.model_ws)
hds = flopy.utils.HeadFile(os.path.join(m.model_ws,m.name+".hds"),model=m)
axes = hds.plot(mflay=0)

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


data Layer 1
10000
8000
6000
4000
2000
0
0
2000
4000



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

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

1.1.1 first the parameterization of model inputs

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

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

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

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

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

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

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

1.1.4 then we setup monitoring of the SFR ASCII outputs.

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

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

1.1.5 here we go...

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

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

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

```
In [13]: pst_helper = pyemu.helpers.PstFromFlopyModel(nam_file,new_model_ws="template",org_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)
```

```
2019-05-18 16:30:49.143597 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
2019-05-18 16:30:49.179421 finished: loading flopy model took: 0:00:00.035824
2019-05-18 16:30:49.179614 starting: updating model attributes
2019-05-18 16:30:49.179696 finished: updating model attributes took: 0:00:00.000082
2019-05-18 16:30:49.179888 WARNING: removing existing 'new_model_ws

creating model workspace...
   template

changing model workspace...
   template
2019-05-18 16:30:50.487511 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

2019-05-18 16:30:50.629389 finished: writing new modflow input files took: 0:00:00.141878
2019-05-18 16:30:50.630044 forward_run line:pyemu.os_utils.run('mfnwt freyberg.nam 1>freyberg.r
2019-05-18 16:30:50.630165 starting: setting up 'template/arr_org' dir
2019-05-18 16:30:50.630544 finished: setting up 'template/arr_org' dir took: 0:00:00.000379
2019-05-18 16:30:50.630788 starting: setting up 'template/arr_mlt' dir
2019-05-18 16:30:50.631137 finished: setting up 'template/arr_mlt' dir took: 0:00:00.000349
2019-05-18 16:30:50.631889 starting: setting up 'template/list_org' dir
2019-05-18 16:30:50.632283 finished: setting up 'template/list_org' dir took: 0:00:00.000394
2019-05-18 16:30:50.632496 starting: setting up 'template/list_mlt' dir
2019-05-18 16:30:50.633003 finished: setting up 'template/list_mlt' dir took: 0:00:00.000507
2019-05-18 16:30:50.633357 starting: processing temporal_list_props
2019-05-18 16:30:50.663343 finished: processing temporal_list_props took: 0:00:00.029986
2019-05-18 16:30:50.663924 starting: processing spatial_list_props
2019-05-18 16:30:50.851057 finished: processing spatial_list_props took: 0:00:00.187133
2019-05-18 16:30:50.904906 forward_run line:pyemu.helpers.apply_list_pars()

2019-05-18 16:30:50.936567 'extra' pak detected:extra.prsity
2019-05-18 16:30:50.975991 'extra' pak detected:extra.prsity
2019-05-18 16:30:51.016572 'extra' pak detected:extra.prsity
2019-05-18 16:30:51.065168 'extra' pak detected:extra.prsity
2019-05-18 16:30:51.098238 'extra' pak detected:extra.prsity
2019-05-18 16:30:51.133541 'extra' pak detected:extra.prsity
2019-05-18 16:30:51.178373 'extra' pak detected:extra.prsity
2019-05-18 16:30:51.213386 'extra' pak detected:extra.prsity
2019-05-18 16:30:51.249448 'extra' pak detected:extra.prsity
2019-05-18 16:30:51.330940 starting: writing grid tpl:hk3.dat_gr.tpl
2019-05-18 16:30:51.339848 finished: writing grid tpl:hk3.dat_gr.tpl took: 0:00:00.008908
2019-05-18 16:30:51.343166 starting: writing grid tpl:vka3.dat_gr.tpl
2019-05-18 16:30:51.352583 finished: writing grid tpl:vka3.dat_gr.tpl took: 0:00:00.009417
2019-05-18 16:30:51.355809 starting: writing grid tpl:ss3.dat_gr.tpl
2019-05-18 16:30:51.365108 finished: writing grid tpl:ss3.dat_gr.tpl took: 0:00:00.009299
2019-05-18 16:30:51.367844 starting: writing grid tpl:sy3.dat_gr.tpl
2019-05-18 16:30:51.377168 finished: writing grid tpl:sy3.dat_gr.tpl took: 0:00:00.009324
2019-05-18 16:30:51.379946 starting: writing grid tpl:strt3.dat_gr.tpl
2019-05-18 16:30:51.389650 finished: writing grid tpl:strt3.dat_gr.tpl took: 0:00:00.009704
2019-05-18 16:30:51.392504 starting: writing grid tpl:prsity3.dat_gr.tpl
2019-05-18 16:30:51.404212 finished: writing grid tpl:prsity3.dat_gr.tpl took: 0:00:00.011708
2019-05-18 16:30:51.406997 starting: writing grid tpl:hk4.dat_gr.tpl
2019-05-18 16:30:51.416139 finished: writing grid tpl:hk4.dat_gr.tpl took: 0:00:00.009142
```

```
2019-05-18 16:30:51.418891 starting: writing grid tpl:vka4.dat_gr.tpl
2019-05-18 16:30:51.427761 finished: writing grid tpl:vka4.dat_gr.tpl took: 0:00:00.008870
2019-05-18 16:30:51.430481 starting: writing grid tpl:ss4.dat_gr.tpl
2019-05-18 16:30:51.439969 finished: writing grid tpl:ss4.dat_gr.tpl took: 0:00:00.009488
2019-05-18 16:30:51.442758 starting: writing grid tpl:sy4.dat_gr.tpl
2019-05-18 16:30:51.451964 finished: writing grid tpl:sy4.dat_gr.tpl took: 0:00:00.009206
2019-05-18 16:30:51.454868 starting: writing grid tpl:strt4.dat_gr.tpl
2019-05-18 16:30:51.464053 finished: writing grid tpl:strt4.dat_gr.tpl took: 0:00:00.009185
2019-05-18 16:30:51.466853 starting: writing grid tpl:prsity4.dat_gr.tpl
2019-05-18 16:30:51.478169 finished: writing grid tpl:prsity4.dat_gr.tpl took: 0:00:00.011316
2019-05-18 16:30:51.481066 starting: writing grid tpl:hk5.dat_gr.tpl
2019-05-18 16:30:51.490523 finished: writing grid tpl:hk5.dat_gr.tpl took: 0:00:00.009457
2019-05-18 16:30:51.493286 starting: writing grid tpl:vka5.dat_gr.tpl
2019-05-18 16:30:51.502923 finished: writing grid tpl:vka5.dat_gr.tpl took: 0:00:00.009637
2019-05-18 16:30:51.505754 starting: writing grid tpl:ss5.dat_gr.tpl
2019-05-18 16:30:51.515167 finished: writing grid tpl:ss5.dat_gr.tpl took: 0:00:00.009413
2019-05-18 16:30:51.517931 starting: writing grid tpl:sy5.dat_gr.tpl
2019-05-18 16:30:51.527055 finished: writing grid tpl:sy5.dat_gr.tpl took: 0:00:00.009124
2019-05-18 16:30:51.529829 starting: writing grid tpl:strt5.dat_gr.tpl
2019-05-18 16:30:51.539794 finished: writing grid tpl:strt5.dat_gr.tpl took: 0:00:00.009965
2019-05-18 16:30:51.542703 starting: writing grid tpl:prsity5.dat_gr.tpl
2019-05-18 16:30:51.554082 finished: writing grid tpl:prsity5.dat_gr.tpl took: 0:00:00.011379
2019-05-18 16:30:51.556846 starting: writing grid tpl:rech2.dat_gr.tpl
2019-05-18 16:30:51.566028 finished: writing grid tpl:rech2.dat_gr.tpl took: 0:00:00.009182
2019-05-18 16:30:51.568788 starting: writing grid tpl:rech3.dat_gr.tpl
2019-05-18 16:30:51.577978 finished: writing grid tpl:rech3.dat_gr.tpl took: 0:00:00.009190
2019-05-18 16:30:51.580809 starting: writing const tpl:hk6.dat_cn.tpl
2019-05-18 16:30:51.586629 finished: writing const tpl:hk6.dat_cn.tpl took: 0:00:00.005820
2019-05-18 16:30:51.589326 starting: writing const tpl:vka6.dat_cn.tpl
2019-05-18 16:30:51.595230 finished: writing const tpl:vka6.dat_cn.tpl took: 0:00:00.005904
2019-05-18 16:30:51.598710 starting: writing const tpl:ss6.dat_cn.tpl
2019-05-18 16:30:51.605725 finished: writing const tpl:ss6.dat_cn.tpl took: 0:00:00.007015
2019-05-18 16:30:51.608879 starting: writing const tpl:sy6.dat_cn.tpl
2019-05-18 16:30:51.614925 finished: writing const tpl:sy6.dat_cn.tpl took: 0:00:00.006046
2019-05-18 16:30:51.617546 starting: writing const tpl:strt6.dat_cn.tpl
2019-05-18 16:30:51.623919 finished: writing const tpl:strt6.dat_cn.tpl took: 0:00:00.006373
2019-05-18 16:30:51.626725 starting: writing const tpl:prsity6.dat_cn.tpl
2019-05-18 16:30:51.632762 finished: writing const tpl:prsity6.dat_cn.tpl took: 0:00:00.006037
2019-05-18 16:30:51.635413 starting: writing const tpl:hk7.dat_cn.tpl
2019-05-18 16:30:51.641195 finished: writing const tpl:hk7.dat_cn.tpl took: 0:00:00.005782
2019-05-18 16:30:51.643826 starting: writing const tpl:vka7.dat_cn.tpl
2019-05-18 16:30:51.649725 finished: writing const tpl:vka7.dat_cn.tpl took: 0:00:00.005899
2019-05-18 16:30:51.652391 starting: writing const tpl:ss7.dat_cn.tpl
2019-05-18 16:30:51.658297 finished: writing const tpl:ss7.dat_cn.tpl took: 0:00:00.005906
2019-05-18 16:30:51.660951 starting: writing const tpl:sy7.dat_cn.tpl
2019-05-18 16:30:51.666730 finished: writing const tpl:sy7.dat_cn.tpl took: 0:00:00.005779
2019-05-18 16:30:51.669374 starting: writing const tpl:strt7.dat_cn.tpl
2019-05-18 16:30:51.675280 finished: writing const tpl:strt7.dat_cn.tpl took: 0:00:00.005906
```

```
2019-05-18 16:30:51.677976 starting: writing const tpl:prsity7.dat_cn.tpl
2019-05-18 16:30:51.683774 finished: writing const tpl:prsity7.dat_cn.tpl took: 0:00:00.005798
2019-05-18 16:30:51.686398 starting: writing const tpl:hk8.dat_cn.tpl
2019-05-18 16:30:51.692309 finished: writing const tpl:hk8.dat_cn.tpl took: 0:00:00.005911
2019-05-18 16:30:51.695013 starting: writing const tpl:vka8.dat_cn.tpl
2019-05-18 16:30:51.701265 finished: writing const tpl:vka8.dat_cn.tpl took: 0:00:00.006252
2019-05-18 16:30:51.704000 starting: writing const tpl:ss8.dat_cn.tpl
2019-05-18 16:30:51.709816 finished: writing const tpl:ss8.dat_cn.tpl took: 0:00:00.005816
2019-05-18 16:30:51.712451 starting: writing const tpl:sy8.dat_cn.tpl
2019-05-18 16:30:51.718360 finished: writing const tpl:sy8.dat_cn.tpl took: 0:00:00.005909
2019-05-18 16:30:51.721230 starting: writing const tpl:strt8.dat_cn.tpl
2019-05-18 16:30:51.727082 finished: writing const tpl:strt8.dat_cn.tpl took: 0:00:00.005852
2019-05-18 16:30:51.729793 starting: writing const tpl:prsity8.dat_cn.tpl
2019-05-18 16:30:51.735635 finished: writing const tpl:prsity8.dat_cn.tpl took: 0:00:00.005842
2019-05-18 16:30:51.738231 starting: writing const tpl:rech4.dat_cn.tpl
2019-05-18 16:30:51.744773 finished: writing const tpl:rech4.dat_cn.tpl took: 0:00:00.006542
2019-05-18 16:30:51.747624 starting: writing const tpl:rech5.dat_cn.tpl
2019-05-18 16:30:51.754756 finished: writing const tpl:rech5.dat_cn.tpl took: 0:00:00.007132
2019-05-18 16:30:51.780449 starting: setting up pilot point process
2019-05-18 16:30:51.780835 WARNING: pp_geostruct is None, using ExpVario with contribution=1 ar
2019-05-18 16:30:51.783742 pp_dict: {0: ['hk0', 'prsity0', 'rech0', 'rech1', 'ss0', 'strt0', 's
2019-05-18 16:30:51.784156 starting: calling setup_pilot_point_grid()
2019-05-18 16:30:52.358576 640 pilot point parameters created
2019-05-18 16:30:52.359354 pilot point 'pargp':hk0,prsity0,rech0,rech1,ss0,strt0,sy0,vka0,hk1,p
2019-05-18 16:30:52.359411 finished: calling setup_pilot_point_grid() took: 0:00:00.575255
2019-05-18 16:30:52.361496 starting: calculating factors for p=hk0, k=0
2019-05-18 16:30:52.362298 saving krige variance file:template/pp_k0_general_zn.fac
2019-05-18 16:30:52.362351 saving krige factors file:template/pp_k0_general_zn.fac
starting interp point loop for 800 points
took 2.420879 seconds
2019-05-18 16:30:54.833008 finished: calculating factors for p=hk0, k=0 took: 0:00:02.471512
2019-05-18 16:30:54.834093 starting: calculating factors for p=prsity0, k=0
2019-05-18 16:30:54.834992 finished: calculating factors for p=prsity0, k=0 took: 0:00:00.0008
2019-05-18 16:30:54.836217 starting: calculating factors for p=rech0, k=0
2019-05-18 16:30:54.837153 finished: calculating factors for p=rech0, k=0 took: 0:00:00.000936
2019-05-18 16:30:54.838398 starting: calculating factors for p=rech1, k=0
2019-05-18 16:30:54.839517 finished: calculating factors for p=rech1, k=0 took: 0:00:00.001119
2019-05-18 16:30:54.840326 starting: calculating factors for p=ss0, k=0
2019-05-18 16:30:54.841086 finished: calculating factors for p=ss0, k=0 took: 0:00:00.000760
2019-05-18 16:30:54.842144 starting: calculating factors for p=strt0, k=0
2019-05-18 16:30:54.843424 finished: calculating factors for p=strt0, k=0 took: 0:00:00.001280
2019-05-18 16:30:54.844302 starting: calculating factors for p=sy0, k=0
2019-05-18 16:30:54.845283 finished: calculating factors for p=sy0, k=0 took: 0:00:00.000981
2019-05-18 16:30:54.846283 starting: calculating factors for p=vka0, k=0
2019-05-18 16:30:54.847133 finished: calculating factors for p=vka0, k=0 took: 0:00:00.000850
2019-05-18 16:30:54.848403 starting: calculating factors for p=hk1, k=1
2019-05-18 16:30:54.849210 saving krige variance file:template/pp_k1_general_zn.fac
2019-05-18 16:30:54.849310 saving krige factors file:template/pp_k1_general_zn.fac
```

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starting interp point loop for 800 points
took 2.406036 seconds
2019-05-18 16:30:57.308835 finished: calculating factors for p=hk1, k=1 took: 0:00:02.460432
2019-05-18 16:30:57.309914 starting: calculating factors for p=prsity1, k=1
2019-05-18 16:30:57.310829 finished: calculating factors for p=prsity1, k=1 took: 0:00:00.0009
2019-05-18 16:30:57.311951 starting: calculating factors for p=ss1, k=1
2019-05-18 16:30:57.312809 finished: calculating factors for p=ss1, k=1 took: 0:00:00.000858
2019-05-18 16:30:57.314131 starting: calculating factors for p=strt1, k=1
2019-05-18 16:30:57.315284 finished: calculating factors for p=strt1, k=1 took: 0:00:00.001153
2019-05-18 16:30:57.316319 starting: calculating factors for p=sy1, k=1
2019-05-18 16:30:57.317097 finished: calculating factors for p=sy1, k=1 took: 0:00:00.000778
2019-05-18 16:30:57.317932 starting: calculating factors for p=vka1, k=1
2019-05-18 16:30:57.318668 finished: calculating factors for p=vka1, k=1 took: 0:00:00.000736
2019-05-18 16:30:57.319241 starting: calculating factors for p=hk2, k=2
2019-05-18 16:30:57.320156 saving krige variance file:template/pp_k2_general_zn.fac
2019-05-18 16:30:57.320260 saving krige factors file:template/pp_k2_general_zn.fac
starting interp point loop for 800 points
took 2.461186 seconds
2019-05-18 16:30:59.826591 finished: calculating factors for p=hk2, k=2 took: 0:00:02.507350
2019-05-18 16:30:59.827475 starting: calculating factors for p=prsity2, k=2
2019-05-18 16:30:59.828189 finished: calculating factors for p=prsity2, k=2 took: 0:00:00.0007
2019-05-18 16:30:59.828725 starting: calculating factors for p=ss2, k=2
2019-05-18 16:30:59.829780 finished: calculating factors for p=ss2, k=2 took: 0:00:00.001055
2019-05-18 16:30:59.830537 starting: calculating factors for p=strt2, k=2
2019-05-18 16:30:59.831180 finished: calculating factors for p=strt2, k=2 took: 0:00:00.000643
2019-05-18 16:30:59.832770 starting: calculating factors for p=sy2, k=2
2019-05-18 16:30:59.833570 finished: calculating factors for p=sy2, k=2 took: 0:00:00.000800
2019-05-18 16:30:59.834759 starting: calculating factors for p=vka2, k=2
2019-05-18 16:30:59.835855 finished: calculating factors for p=vka2, k=2 took: 0:00:00.001096
2019-05-18 16:30:59.835968 starting: processing pp_prefix:strt0
2019-05-18 16:30:59.847751 starting: processing pp_prefix:prsity2
2019-05-18 16:30:59.856459 starting: processing pp_prefix:hk0
2019-05-18 16:30:59.864674 starting: processing pp_prefix:vka0
2019-05-18 16:30:59.872890 starting: processing pp_prefix:vka1
2019-05-18 16:30:59.881541 starting: processing pp_prefix:vka2
2019-05-18 16:30:59.890418 starting: processing pp_prefix:ss0
2019-05-18 16:30:59.898755 starting: processing pp_prefix:prsity0
2019-05-18 16:30:59.907213 starting: processing pp_prefix:rech1
2019-05-18 16:30:59.915562 starting: processing pp_prefix:ss1
2019-05-18 16:30:59.923550 starting: processing pp_prefix:sy0
2019-05-18 16:30:59.932119 starting: processing pp_prefix:hk1
2019-05-18 16:30:59.941915 starting: processing pp_prefix:ss2
2019-05-18 16:30:59.950639 starting: processing pp_prefix:sy2
2019-05-18 16:30:59.960108 starting: processing pp_prefix:rech0
2019-05-18 16:30:59.969468 starting: processing pp_prefix:prsity1
2019-05-18 16:30:59.978339 starting: processing pp_prefix:strt1
2019-05-18 16:30:59.986830 starting: processing pp_prefix:strt2
2019-05-18 16:30:59.995907 starting: processing pp_prefix:sy1
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2019-05-18 16:31:00.005245 starting: processing pp_prefix:hk2
2019-05-18 16:31:00.116702 finished: setting up pilot point process took: 0:00:08.336253
2019-05-18 16:31:00.117499 starting: setting up grid process
2019-05-18 16:31:00.117917 WARNING: grid_geostruct is None, using ExpVario with contribution=1
2019-05-18 16:31:00.118132 finished: setting up grid process took: 0:00:00.000633
2019-05-18 16:31:00.121722 starting: save test mlt array arr_mlt/hk0.dat_pp
2019-05-18 16:31:00.124251 finished: save test mlt array arr_mlt/hk0.dat_pp took: 0:00:00.0025
2019-05-18 16:31:00.125399 starting: save test mlt array arr_mlt/vka0.dat_pp
2019-05-18 16:31:00.129148 finished: save test mlt array arr_mlt/vka0.dat_pp took: 0:00:00.003
2019-05-18 16:31:00.130146 starting: save test mlt array arr_mlt/ss0.dat_pp
2019-05-18 16:31:00.132418 finished: save test mlt array arr_mlt/ss0.dat_pp took: 0:00:00.0022
2019-05-18 16:31:00.133486 starting: save test mlt array arr_mlt/sy0.dat_pp
2019-05-18 16:31:00.135913 finished: save test mlt array arr_mlt/sy0.dat_pp took: 0:00:00.0024
2019-05-18 16:31:00.136691 starting: save test mlt array arr_mlt/strt0.dat_pp
2019-05-18 16:31:00.139163 finished: save test mlt array arr_mlt/strt0.dat_pp took: 0:00:00.002
2019-05-18 16:31:00.140141 starting: save test mlt array arr_mlt/prsity0.dat_pp
2019-05-18 16:31:00.142457 finished: save test mlt array arr_mlt/prsity0.dat_pp took: 0:00:00.0
2019-05-18 16:31:00.143767 starting: save test mlt array arr_mlt/hk1.dat_pp
2019-05-18 16:31:00.148813 finished: save test mlt array arr_mlt/hk1.dat_pp took: 0:00:00.0050
2019-05-18 16:31:00.150015 starting: save test mlt array arr_mlt/vka1.dat_pp
2019-05-18 16:31:00.158588 finished: save test mlt array arr_mlt/vka1.dat_pp took: 0:00:00.0085
2019-05-18 16:31:00.159452 starting: save test mlt array arr_mlt/ss1.dat_pp
2019-05-18 16:31:00.163380 finished: save test mlt array arr_mlt/ss1.dat_pp took: 0:00:00.0039
2019-05-18 16:31:00.164375 starting: save test mlt array arr_mlt/sy1.dat_pp
2019-05-18 16:31:00.168108 finished: save test mlt array arr_mlt/sy1.dat_pp took: 0:00:00.0037
2019-05-18 16:31:00.168892 starting: save test mlt array arr_mlt/strt1.dat_pp
2019-05-18 16:31:00.174150 finished: save test mlt array arr_mlt/strt1.dat_pp took: 0:00:00.005
2019-05-18 16:31:00.175219 starting: save test mlt array arr_mlt/prsity1.dat_pp
2019-05-18 16:31:00.177331 finished: save test mlt array arr_mlt/prsity1.dat_pp took: 0:00:00.0
2019-05-18 16:31:00.178431 starting: save test mlt array arr_mlt/hk2.dat_pp
2019-05-18 16:31:00.181158 finished: save test mlt array arr_mlt/hk2.dat_pp took: 0:00:00.0027
2019-05-18 16:31:00.182222 starting: save test mlt array arr_mlt/vka2.dat_pp
2019-05-18 16:31:00.185381 finished: save test mlt array arr_mlt/vka2.dat_pp took: 0:00:00.0031
2019-05-18 16:31:00.186468 starting: save test mlt array arr_mlt/ss2.dat_pp
2019-05-18 16:31:00.188917 finished: save test mlt array arr_mlt/ss2.dat_pp took: 0:00:00.0024
2019-05-18 16:31:00.189905 starting: save test mlt array arr_mlt/sy2.dat_pp
2019-05-18 16:31:00.193062 finished: save test mlt array arr_mlt/sy2.dat_pp took: 0:00:00.0031
2019-05-18 16:31:00.194310 starting: save test mlt array arr_mlt/strt2.dat_pp
2019-05-18 16:31:00.197582 finished: save test mlt array arr_mlt/strt2.dat_pp took: 0:00:00.003
2019-05-18 16:31:00.198779 starting: save test mlt array arr_mlt/prsity2.dat_pp
2019-05-18 16:31:00.204179 finished: save test mlt array arr_mlt/prsity2.dat_pp took: 0:00:00.0
2019-05-18 16:31:00.205670 starting: save test mlt array arr_mlt/rech0.dat_pp
2019-05-18 16:31:00.208773 finished: save test mlt array arr_mlt/rech0.dat_pp took: 0:00:00.003
2019-05-18 16:31:00.210141 starting: save test mlt array arr_mlt/rech1.dat_pp
2019-05-18 16:31:00.213225 finished: save test mlt array arr_mlt/rech1.dat_pp took: 0:00:00.003
2019-05-18 16:31:00.214781 starting: save test mlt array arr_mlt/hk3.dat_gr
2019-05-18 16:31:00.217730 finished: save test mlt array arr_mlt/hk3.dat_gr took: 0:00:00.0029
2019-05-18 16:31:00.218800 starting: save test mlt array arr_mlt/vka3.dat_gr
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2019-05-18 16:31:00.221297 finished: save test mlt array arr_mlt/vka3.dat_gr took: 0:00:00.0024
2019-05-18 16:31:00.222775 starting: save test mlt array arr_mlt/ss3.dat_gr
2019-05-18 16:31:00.225909 finished: save test mlt array arr_mlt/ss3.dat_gr took: 0:00:00.0031
2019-05-18 16:31:00.227566 starting: save test mlt array arr_mlt/sy3.dat_gr
2019-05-18 16:31:00.230582 finished: save test mlt array arr_mlt/sy3.dat_gr took: 0:00:00.0030
2019-05-18 16:31:00.232049 starting: save test mlt array arr_mlt/strt3.dat_gr
2019-05-18 16:31:00.235126 finished: save test mlt array arr_mlt/strt3.dat_gr took: 0:00:00.003
2019-05-18 16:31:00.236824 starting: save test mlt array arr_mlt/prsity3.dat_gr
2019-05-18 16:31:00.240182 finished: save test mlt array arr_mlt/prsity3.dat_gr took: 0:00:00.0
2019-05-18 16:31:00.241211 starting: save test mlt array arr_mlt/hk4.dat_gr
2019-05-18 16:31:00.244040 finished: save test mlt array arr_mlt/hk4.dat_gr took: 0:00:00.0028
2019-05-18 16:31:00.245051 starting: save test mlt array arr_mlt/vka4.dat_gr
2019-05-18 16:31:00.248059 finished: save test mlt array arr_mlt/vka4.dat_gr took: 0:00:00.0030
2019-05-18 16:31:00.249281 starting: save test mlt array arr_mlt/ss4.dat_gr
2019-05-18 16:31:00.253343 finished: save test mlt array arr_mlt/ss4.dat_gr took: 0:00:00.0040
2019-05-18 16:31:00.254510 starting: save test mlt array arr_mlt/sy4.dat_gr
2019-05-18 16:31:00.258436 finished: save test mlt array arr_mlt/sy4.dat_gr took: 0:00:00.0039
2019-05-18 16:31:00.259774 starting: save test mlt array arr_mlt/strt4.dat_gr
2019-05-18 16:31:00.264064 finished: save test mlt array arr_mlt/strt4.dat_gr took: 0:00:00.004
2019-05-18 16:31:00.265415 starting: save test mlt array arr_mlt/prsity4.dat_gr
2019-05-18 16:31:00.269041 finished: save test mlt array arr_mlt/prsity4.dat_gr took: 0:00:00.0
2019-05-18 16:31:00.270367 starting: save test mlt array arr_mlt/hk5.dat_gr
2019-05-18 16:31:00.272940 finished: save test mlt array arr_mlt/hk5.dat_gr took: 0:00:00.0025
2019-05-18 16:31:00.273952 starting: save test mlt array arr_mlt/vka5.dat_gr
2019-05-18 16:31:00.276745 finished: save test mlt array arr_mlt/vka5.dat_gr took: 0:00:00.0027
2019-05-18 16:31:00.278098 starting: save test mlt array arr_mlt/ss5.dat_gr
2019-05-18 16:31:00.280831 finished: save test mlt array arr_mlt/ss5.dat_gr took: 0:00:00.0027
2019-05-18 16:31:00.282013 starting: save test mlt array arr_mlt/sy5.dat_gr
2019-05-18 16:31:00.285423 finished: save test mlt array arr_mlt/sy5.dat_gr took: 0:00:00.0034
2019-05-18 16:31:00.286903 starting: save test mlt array arr_mlt/strt5.dat_gr
2019-05-18 16:31:00.290659 finished: save test mlt array arr_mlt/strt5.dat_gr took: 0:00:00.003
2019-05-18 16:31:00.292044 starting: save test mlt array arr_mlt/prsity5.dat_gr
2019-05-18 16:31:00.295495 finished: save test mlt array arr_mlt/prsity5.dat_gr took: 0:00:00.0
2019-05-18 16:31:00.296976 starting: save test mlt array arr_mlt/rech2.dat_gr
2019-05-18 16:31:00.300726 finished: save test mlt array arr_mlt/rech2.dat_gr took: 0:00:00.003
2019-05-18 16:31:00.302138 starting: save test mlt array arr_mlt/rech3.dat_gr
2019-05-18 16:31:00.305564 finished: save test mlt array arr_mlt/rech3.dat_gr took: 0:00:00.003
2019-05-18 16:31:00.307044 starting: save test mlt array arr_mlt/hk6.dat_cn
2019-05-18 16:31:00.310719 finished: save test mlt array arr_mlt/hk6.dat_cn took: 0:00:00.0036
2019-05-18 16:31:00.312124 starting: save test mlt array arr_mlt/vka6.dat_cn
2019-05-18 16:31:00.316550 finished: save test mlt array arr_mlt/vka6.dat_cn took: 0:00:00.0044
2019-05-18 16:31:00.317662 starting: save test mlt array arr_mlt/ss6.dat_cn
2019-05-18 16:31:00.321141 finished: save test mlt array arr_mlt/ss6.dat_cn took: 0:00:00.0034
2019-05-18 16:31:00.322594 starting: save test mlt array arr_mlt/sy6.dat_cn
2019-05-18 16:31:00.325356 finished: save test mlt array arr_mlt/sy6.dat_cn took: 0:00:00.0027
2019-05-18 16:31:00.326731 starting: save test mlt array arr_mlt/strt6.dat_cn
2019-05-18 16:31:00.330186 finished: save test mlt array arr_mlt/strt6.dat_cn took: 0:00:00.003
2019-05-18 16:31:00.331644 starting: save test mlt array arr_mlt/prsity6.dat_cn
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2019-05-18 16:31:00.335317 finished: save test mlt array arr_mlt/prsity6.dat_cn took: 0:00:00.0
2019-05-18 16:31:00.336933 starting: save test mlt array arr_mlt/hk7.dat_cn
2019-05-18 16:31:00.342377 finished: save test mlt array arr_mlt/hk7.dat_cn took: 0:00:00.0054
2019-05-18 16:31:00.343814 starting: save test mlt array arr_mlt/vka7.dat_cn
2019-05-18 16:31:00.347584 finished: save test mlt array arr_mlt/vka7.dat_cn took: 0:00:00.003
2019-05-18 16:31:00.349163 starting: save test mlt array arr_mlt/ss7.dat_cn
2019-05-18 16:31:00.352835 finished: save test mlt array arr_mlt/ss7.dat_cn took: 0:00:00.0036
2019-05-18 16:31:00.354403 starting: save test mlt array arr_mlt/sy7.dat_cn
2019-05-18 16:31:00.357946 finished: save test mlt array arr_mlt/sy7.dat_cn took: 0:00:00.0035
2019-05-18 16:31:00.359410 starting: save test mlt array arr_mlt/strt7.dat_cn
2019-05-18 16:31:00.363052 finished: save test mlt array arr_mlt/strt7.dat_cn took: 0:00:00.003
2019-05-18 16:31:00.364591 starting: save test mlt array arr_mlt/prsity7.dat_cn
2019-05-18 16:31:00.368251 finished: save test mlt array arr_mlt/prsity7.dat_cn took: 0:00:00.0
2019-05-18 16:31:00.369933 starting: save test mlt array arr_mlt/hk8.dat_cn
2019-05-18 16:31:00.373338 finished: save test mlt array arr_mlt/hk8.dat_cn took: 0:00:00.0034
2019-05-18 16:31:00.374602 starting: save test mlt array arr_mlt/vka8.dat_cn
2019-05-18 16:31:00.378449 finished: save test mlt array arr_mlt/vka8.dat_cn took: 0:00:00.0038
2019-05-18 16:31:00.379996 starting: save test mlt array arr_mlt/ss8.dat_cn
2019-05-18 16:31:00.384807 finished: save test mlt array arr_mlt/ss8.dat_cn took: 0:00:00.0048
2019-05-18 16:31:00.386294 starting: save test mlt array arr_mlt/sy8.dat_cn
2019-05-18 16:31:00.389873 finished: save test mlt array arr_mlt/sy8.dat_cn took: 0:00:00.0035
2019-05-18 16:31:00.391355 starting: save test mlt array arr_mlt/strt8.dat_cn
2019-05-18 16:31:00.396576 finished: save test mlt array arr_mlt/strt8.dat_cn took: 0:00:00.005
2019-05-18 16:31:00.398403 starting: save test mlt array arr_mlt/prsity8.dat_cn
2019-05-18 16:31:00.408455 finished: save test mlt array arr_mlt/prsity8.dat_cn took: 0:00:00.0
2019-05-18 16:31:00.410055 starting: save test mlt array arr_mlt/rech4.dat_cn
2019-05-18 16:31:00.413862 finished: save test mlt array arr_mlt/rech4.dat_cn took: 0:00:00.003
2019-05-18 16:31:00.415329 starting: save test mlt array arr_mlt/rech5.dat_cn
2019-05-18 16:31:00.418803 finished: save test mlt array arr_mlt/rech5.dat_cn took: 0:00:00.003
2019-05-18 16:31:01.038544 forward_run line:pyemu.helpers.apply_array_pars()

all zeros for runoff...skipping...
all zeros for hcond1...skipping...
all zeros for pptsw...skipping...
2019-05-18 16:31:01.168268 starting: processing obs type mflist water budget obs
2019-05-18 16:31:01.288216 forward_run line:pyemu.gw_utils.apply_mflist_budget_obs('freyberg.li
2019-05-18 16:31:01.288635 finished: processing obs type mflist water budget obs took: 0:00:00
2019-05-18 16:31:01.288697 starting: processing obs type hyd file
2019-05-18 16:31:01.288781 finished: processing obs type hyd file took: 0:00:00.000084
2019-05-18 16:31:01.288828 starting: processing obs type external obs-sim smp files
2019-05-18 16:31:01.289064 finished: processing obs type external obs-sim smp files took: 0:00
2019-05-18 16:31:01.289509 starting: processing obs type hob
2019-05-18 16:31:01.290121 finished: processing obs type hob took: 0:00:00.000612
2019-05-18 16:31:01.290383 starting: processing obs type hds
[[0, 0], [0, 1], [0, 2], [1, 0], [1, 1], [1, 2]]
2019-05-18 16:31:01.755105 finished: processing obs type hds took: 0:00:00.464722
2019-05-18 16:31:01.755538 starting: processing obs type sfr
writing 'sfr_obs.config' to template/sfr_obs.config
```

```
2019-05-18 16:31:02.145508 finished: processing obs type sfr took: 0:00:00.389970
2019-05-18 16:31:02.145990 changing dir in to template
2019-05-18 16:31:02.146734 starting: instantiating control file from i/o files
2019-05-18 16:31:02.146824 tpl files: drn.csv.tpl,wel.csv.tpl,hk3.dat_gr.tpl,vka3.dat_gr.tpl,ss
2019-05-18 16:31:02.146870 ins files: freyberg.hds.dat.ins,vol.dat.ins,freyberg.sfr.out.process
2019-05-18 16:31:02.482804 finished: instantiating control file from i/o files took: 0:00:00.33
2019-05-18 16:31:02.732601 starting: writing forward_run.py
2019-05-18 16:31:02.733387 finished: writing forward_run.py took: 0:00:00.000786
2019-05-18 16:31:02.733485 writing pst template/freyberg.pst
noptmax:0, npar_adj:14819, nnz_obs:4434
2019-05-18 16:31:04.609075 starting: running pestchek on freyberg.pst
2019-05-18 16:31:04.715757 pestcheck:PESTCHEK Version 13.0. Watermark Numerical Computing.
2019-05-18 16:31:04.716110 pestcheck:
2019-05-18 16:31:04.716169 pestcheck:Errors ----->
2019-05-18 16:31:04.716228 pestcheck:Line 2403 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.716266 pestcheck:12 characters long.
2019-05-18 16:31:04.716325 pestcheck:Line 2404 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.716683 pestcheck:12 characters long.
2019-05-18 16:31:04.716740 pestcheck:Line 2404 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.716779 pestcheck:once.
2019-05-18 16:31:04.716835 pestcheck:Line 2405 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.716872 pestcheck:12 characters long.
2019-05-18 16:31:04.717412 pestcheck:Line 2405 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.717472 pestcheck:once.
2019-05-18 16:31:04.717622 pestcheck:Line 2406 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.717699 pestcheck:12 characters long.
2019-05-18 16:31:04.717809 pestcheck:Line 2406 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.718330 pestcheck:once.
2019-05-18 16:31:04.718393 pestcheck:Line 2407 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.718491 pestcheck:12 characters long.
2019-05-18 16:31:04.718602 pestcheck:Line 2407 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.718652 pestcheck:once.
2019-05-18 16:31:04.718765 pestcheck:Line 2408 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.718874 pestcheck:12 characters long.
2019-05-18 16:31:04.719008 pestcheck:Line 2408 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.719484 pestcheck:once.
2019-05-18 16:31:04.719596 pestcheck:Line 2409 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.719747 pestcheck:12 characters long.
2019-05-18 16:31:04.719833 pestcheck:Line 2409 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.719913 pestcheck:once.
2019-05-18 16:31:04.720000 pestcheck:Line 2410 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.720150 pestcheck:12 characters long.
2019-05-18 16:31:04.720217 pestcheck:Line 2410 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.720281 pestcheck:once.
2019-05-18 16:31:04.720341 pestcheck:Line 2411 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.720431 pestcheck:12 characters long.
2019-05-18 16:31:04.720602 pestcheck:Line 2411 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.720822 pestcheck:once.
```

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2019-05-18 16:31:04.721000 pestcheck:Line 2412 of file freyberg.pst: parameter name "prsity3000
2019-05-18 16:31:04.721069 pestcheck:12 characters long.
2019-05-18 16:31:04.721143 pestcheck:Line 2412 of file freyberg.pst: parameter name "prsity3000
2019-05-18 16:31:04.721217 pestcheck:once.
2019-05-18 16:31:04.721329 pestcheck:Line 2413 of file freyberg.pst: parameter name "prsity3000
2019-05-18 16:31:04.721383 pestcheck:12 characters long.
2019-05-18 16:31:04.721501 pestcheck:Line 2414 of file freyberg.pst: parameter name "prsity3000
2019-05-18 16:31:04.721551 pestcheck:12 characters long.
2019-05-18 16:31:04.721589 pestcheck:Line 2414 of file freyberg.pst: parameter name "prsity3000
2019-05-18 16:31:04.721702 pestcheck:once.
2019-05-18 16:31:04.721753 pestcheck:Line 2415 of file freyberg.pst: parameter name "prsity3000
2019-05-18 16:31:04.721851 pestcheck:12 characters long.
2019-05-18 16:31:04.721908 pestcheck:Line 2415 of file freyberg.pst: parameter name "prsity3000
2019-05-18 16:31:04.722009 pestcheck:once.
2019-05-18 16:31:04.722116 pestcheck:Line 2416 of file freyberg.pst: parameter name "prsity3000
2019-05-18 16:31:04.722163 pestcheck:12 characters long.
2019-05-18 16:31:04.722266 pestcheck:Line 2416 of file freyberg.pst: parameter name "prsity3000
2019-05-18 16:31:04.722371 pestcheck:once.
2019-05-18 16:31:04.722418 pestcheck:Line 2417 of file freyberg.pst: parameter name "prsity3000
2019-05-18 16:31:04.722525 pestcheck:12 characters long.
2019-05-18 16:31:04.722630 pestcheck:Line 2417 of file freyberg.pst: parameter name "prsity3000
2019-05-18 16:31:04.722677 pestcheck:once.
2019-05-18 16:31:04.722785 pestcheck:Line 2418 of file freyberg.pst: parameter name "prsity3000
2019-05-18 16:31:04.722890 pestcheck:12 characters long.
2019-05-18 16:31:04.723008 pestcheck:Line 2418 of file freyberg.pst: parameter name "prsity3000
2019-05-18 16:31:04.723113 pestcheck:once.
2019-05-18 16:31:04.723159 pestcheck:Line 2419 of file freyberg.pst: parameter name "prsity3000
2019-05-18 16:31:04.723197 pestcheck:12 characters long.
2019-05-18 16:31:04.723296 pestcheck:Line 2419 of file freyberg.pst: parameter name "prsity3000
2019-05-18 16:31:04.723401 pestcheck:once.
2019-05-18 16:31:04.723514 pestcheck:Line 2420 of file freyberg.pst: parameter name "prsity3000
2019-05-18 16:31:04.723619 pestcheck:12 characters long.
2019-05-18 16:31:04.723732 pestcheck:Line 2420 of file freyberg.pst: parameter name "prsity3000
2019-05-18 16:31:04.723836 pestcheck:once.
2019-05-18 16:31:04.723884 pestcheck:Line 2421 of file freyberg.pst: parameter name "prsity3000
2019-05-18 16:31:04.724061 pestcheck:12 characters long.
2019-05-18 16:31:04.724110 pestcheck:Line 2421 of file freyberg.pst: parameter name "prsity3000
2019-05-18 16:31:04.724149 pestcheck:once.
2019-05-18 16:31:04.724249 pestcheck:Line 2422 of file freyberg.pst: parameter name "prsity3000
2019-05-18 16:31:04.724352 pestcheck:12 characters long.
2019-05-18 16:31:04.724399 pestcheck:Line 2422 of file freyberg.pst: parameter name "prsity3000
2019-05-18 16:31:04.724502 pestcheck:once.
2019-05-18 16:31:04.724605 pestcheck:Line 2423 of file freyberg.pst: parameter name "prsity3001
2019-05-18 16:31:04.724718 pestcheck:12 characters long.
2019-05-18 16:31:04.724825 pestcheck:Line 2424 of file freyberg.pst: parameter name "prsity3001
2019-05-18 16:31:04.724873 pestcheck:12 characters long.
2019-05-18 16:31:04.725051 pestcheck:Line 2424 of file freyberg.pst: parameter name "prsity3001
2019-05-18 16:31:04.725102 pestcheck:once.
```

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2019-05-18 16:31:04.725141 pestcheck:Line 2425 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.725241 pestcheck:12 characters long.
2019-05-18 16:31:04.725348 pestcheck:Line 2425 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.725395 pestcheck:once.
2019-05-18 16:31:04.725433 pestcheck:Line 2426 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.725533 pestcheck:12 characters long.
2019-05-18 16:31:04.725637 pestcheck:Line 2426 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.725685 pestcheck:once.
2019-05-18 16:31:04.725724 pestcheck:Line 2427 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.725823 pestcheck:12 characters long.
2019-05-18 16:31:04.725927 pestcheck:Line 2427 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.726062 pestcheck:once.
2019-05-18 16:31:04.726165 pestcheck:Line 2428 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.726210 pestcheck:12 characters long.
2019-05-18 16:31:04.726310 pestcheck:Line 2428 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.726412 pestcheck:once.
2019-05-18 16:31:04.726460 pestcheck:Line 2429 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.726498 pestcheck:12 characters long.
2019-05-18 16:31:04.726594 pestcheck:Line 2429 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.726695 pestcheck:once.
2019-05-18 16:31:04.726740 pestcheck:Line 2430 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.726778 pestcheck:12 characters long.
2019-05-18 16:31:04.726874 pestcheck:Line 2430 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.726975 pestcheck:once.
2019-05-18 16:31:04.727098 pestcheck:Line 2431 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.727149 pestcheck:12 characters long.
2019-05-18 16:31:04.727241 pestcheck:Line 2431 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.727287 pestcheck:once.
2019-05-18 16:31:04.727324 pestcheck:Line 2432 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.727421 pestcheck:12 characters long.
2019-05-18 16:31:04.727522 pestcheck:Line 2432 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.727632 pestcheck:once.
2019-05-18 16:31:04.727733 pestcheck:Line 2433 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.727778 pestcheck:12 characters long.
2019-05-18 16:31:04.727816 pestcheck:Line 2434 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.727912 pestcheck:12 characters long.
2019-05-18 16:31:04.728013 pestcheck:Line 2434 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.728068 pestcheck:once.
2019-05-18 16:31:04.728165 pestcheck:Line 2435 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.728266 pestcheck:12 characters long.
2019-05-18 16:31:04.728312 pestcheck:Line 2435 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.728349 pestcheck:once.
2019-05-18 16:31:04.728447 pestcheck:Line 2436 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.728551 pestcheck:12 characters long.
2019-05-18 16:31:04.728597 pestcheck:Line 2436 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.728635 pestcheck:once.
2019-05-18 16:31:04.728734 pestcheck:Line 2437 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.728835 pestcheck:12 characters long.
```

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2019-05-18 16:31:04.728881 pestcheck:Line 2437 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.728918 pestcheck:once.
2019-05-18 16:31:04.729015 pestcheck:Line 2438 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.729126 pestcheck:12 characters long.
2019-05-18 16:31:04.729237 pestcheck:Line 2438 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.729340 pestcheck:once.
2019-05-18 16:31:04.729385 pestcheck:Line 2439 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.729423 pestcheck:12 characters long.
2019-05-18 16:31:04.729520 pestcheck:Line 2439 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.729570 pestcheck:once.
2019-05-18 16:31:04.729662 pestcheck:Line 2440 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.729707 pestcheck:12 characters long.
2019-05-18 16:31:04.729745 pestcheck:Line 2440 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.729842 pestcheck:once.
2019-05-18 16:31:04.729943 pestcheck:Line 2441 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.729988 pestcheck:12 characters long.
2019-05-18 16:31:04.730161 pestcheck:Line 2441 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.730272 pestcheck:once.
2019-05-18 16:31:04.730374 pestcheck:Line 2442 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.730420 pestcheck:12 characters long.
2019-05-18 16:31:04.730519 pestcheck:Line 2442 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.730620 pestcheck:once.
2019-05-18 16:31:04.730700 pestcheck:Line 2443 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.730770 pestcheck:12 characters long.
2019-05-18 16:31:04.730872 pestcheck:Line 2444 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.730984 pestcheck:12 characters long.
2019-05-18 16:31:04.731099 pestcheck:Line 2444 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.731203 pestcheck:once.
2019-05-18 16:31:04.731305 pestcheck:Line 2445 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.731352 pestcheck:12 characters long.
2019-05-18 16:31:04.731390 pestcheck:Line 2445 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.731487 pestcheck:once.
2019-05-18 16:31:04.731588 pestcheck:Line 2446 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.731634 pestcheck:12 characters long.
2019-05-18 16:31:04.731672 pestcheck:Line 2446 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.731768 pestcheck:once.
2019-05-18 16:31:04.731869 pestcheck:Line 2447 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.731914 pestcheck:12 characters long.
2019-05-18 16:31:04.731952 pestcheck:Line 2447 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.732117 pestcheck:once.
2019-05-18 16:31:04.732307 pestcheck:Line 2448 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.732356 pestcheck:12 characters long.
2019-05-18 16:31:04.732394 pestcheck:Line 2448 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.732492 pestcheck:once.
2019-05-18 16:31:04.732592 pestcheck:Line 2449 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.732638 pestcheck:12 characters long.
2019-05-18 16:31:04.732675 pestcheck:Line 2449 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.732772 pestcheck:once.
```

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2019-05-18 16:31:04.732874 pestcheck:Line 2450 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.732921 pestcheck:12 characters long.
2019-05-18 16:31:04.733092 pestcheck:Line 2450 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.733137 pestcheck:once.
2019-05-18 16:31:04.733175 pestcheck:Line 2451 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.733273 pestcheck:12 characters long.
2019-05-18 16:31:04.733377 pestcheck:Line 2451 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.733487 pestcheck:once.
2019-05-18 16:31:04.733589 pestcheck:Line 2452 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.733635 pestcheck:12 characters long.
2019-05-18 16:31:04.733673 pestcheck:Line 2452 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.733769 pestcheck:once.
2019-05-18 16:31:04.733871 pestcheck:Line 2453 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.733918 pestcheck:12 characters long.
2019-05-18 16:31:04.734092 pestcheck:Line 2454 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.734138 pestcheck:12 characters long.
2019-05-18 16:31:04.734176 pestcheck:Line 2454 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.734273 pestcheck:once.
2019-05-18 16:31:04.734375 pestcheck:Line 2455 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.734420 pestcheck:12 characters long.
2019-05-18 16:31:04.734457 pestcheck:Line 2455 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.734555 pestcheck:once.
2019-05-18 16:31:04.734654 pestcheck:Line 2456 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.734701 pestcheck:12 characters long.
2019-05-18 16:31:04.734739 pestcheck:Line 2456 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.734836 pestcheck:once.
2019-05-18 16:31:04.734938 pestcheck:Line 2457 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.735055 pestcheck:12 characters long.
2019-05-18 16:31:04.735157 pestcheck:Line 2457 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.735204 pestcheck:once.
2019-05-18 16:31:04.735242 pestcheck:Line 2458 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.735339 pestcheck:12 characters long.
2019-05-18 16:31:04.735440 pestcheck:Line 2458 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.735485 pestcheck:once.
2019-05-18 16:31:04.735523 pestcheck:Line 2459 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.735626 pestcheck:12 characters long.
2019-05-18 16:31:04.735754 pestcheck:Line 2459 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.735806 pestcheck:once.
2019-05-18 16:31:04.735908 pestcheck:Line 2460 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.735962 pestcheck:12 characters long.
2019-05-18 16:31:04.736072 pestcheck:Line 2460 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.736178 pestcheck:once.
2019-05-18 16:31:04.736223 pestcheck:Line 2461 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.736261 pestcheck:12 characters long.
2019-05-18 16:31:04.736308 pestcheck:Line 2461 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.736408 pestcheck:once.
2019-05-18 16:31:04.736458 pestcheck:Line 2462 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.736535 pestcheck:12 characters long.
```

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2019-05-18 16:31:04.736608 pestcheck:Line 2462 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.736762 pestcheck:once.
2019-05-18 16:31:04.736938 pestcheck:Line 2463 of file freyberg.pst: parameter name "prsity3003
2019-05-18 16:31:04.737026 pestcheck:12 characters long.
2019-05-18 16:31:04.737104 pestcheck:Line 2464 of file freyberg.pst: parameter name "prsity3003
2019-05-18 16:31:04.737193 pestcheck:12 characters long.
2019-05-18 16:31:04.737259 pestcheck:Line 2464 of file freyberg.pst: parameter name "prsity3003
2019-05-18 16:31:04.737323 pestcheck:once.
2019-05-18 16:31:04.737382 pestcheck:Line 2465 of file freyberg.pst: parameter name "prsity3003
2019-05-18 16:31:04.737527 pestcheck:12 characters long.
2019-05-18 16:31:04.737647 pestcheck:Line 2465 of file freyberg.pst: parameter name "prsity3003
2019-05-18 16:31:04.737695 pestcheck:once.
2019-05-18 16:31:04.737734 pestcheck:Line 2466 of file freyberg.pst: parameter name "prsity3003
2019-05-18 16:31:04.737843 pestcheck:12 characters long.
2019-05-18 16:31:04.737897 pestcheck:Line 2466 of file freyberg.pst: parameter name "prsity3003
2019-05-18 16:31:04.737995 pestcheck:once.
2019-05-18 16:31:04.738117 pestcheck:Line 2467 of file freyberg.pst: parameter name "prsity3003
2019-05-18 16:31:04.738224 pestcheck:12 characters long.
2019-05-18 16:31:04.738272 pestcheck:Line 2467 of file freyberg.pst: parameter name "prsity3003
2019-05-18 16:31:04.738312 pestcheck:once.
2019-05-18 16:31:04.738414 pestcheck:Line 2468 of file freyberg.pst: parameter name "prsity3003
2019-05-18 16:31:04.738520 pestcheck:12 characters long.
2019-05-18 16:31:04.738567 pestcheck:Line 2468 of file freyberg.pst: parameter name "prsity3003
2019-05-18 16:31:04.738684 pestcheck:once.
2019-05-18 16:31:04.738807 pestcheck:Line 2469 of file freyberg.pst: parameter name "prsity3003
2019-05-18 16:31:04.738934 pestcheck:12 characters long.
2019-05-18 16:31:04.739044 pestcheck:Line 2469 of file freyberg.pst: parameter name "prsity3003
2019-05-18 16:31:04.739165 pestcheck:once.
2019-05-18 16:31:04.739271 pestcheck:Line 2470 of file freyberg.pst: parameter name "prsity3003
2019-05-18 16:31:04.739321 pestcheck:12 characters long.
2019-05-18 16:31:04.739360 pestcheck:Line 2470 of file freyberg.pst: parameter name "prsity3003
2019-05-18 16:31:04.739460 pestcheck:once.
2019-05-18 16:31:04.739565 pestcheck:Line 2471 of file freyberg.pst: parameter name "prsity3003
2019-05-18 16:31:04.739679 pestcheck:12 characters long.
2019-05-18 16:31:04.739784 pestcheck:Line 2471 of file freyberg.pst: parameter name "prsity3003
2019-05-18 16:31:04.739907 pestcheck:once.
2019-05-18 16:31:04.740034 pestcheck:Line 2472 of file freyberg.pst: parameter name "prsity3003
2019-05-18 16:31:04.740160 pestcheck:12 characters long.
2019-05-18 16:31:04.740267 pestcheck:Line 2472 of file freyberg.pst: parameter name "prsity3003
2019-05-18 16:31:04.740381 pestcheck:once.
2019-05-18 16:31:04.740486 pestcheck:Line 2473 of file freyberg.pst: parameter name "prsity3003
2019-05-18 16:31:04.740536 pestcheck:12 characters long.
2019-05-18 16:31:04.740641 pestcheck:Line 2474 of file freyberg.pst: parameter name "prsity3003
2019-05-18 16:31:04.740745 pestcheck:12 characters long.
2019-05-18 16:31:04.740792 pestcheck:Line 2474 of file freyberg.pst: parameter name "prsity3003
2019-05-18 16:31:04.740830 pestcheck:once.
2019-05-18 16:31:04.740930 pestcheck:Line 2475 of file freyberg.pst: parameter name "prsity3003
2019-05-18 16:31:04.741033 pestcheck:12 characters long.
```

```
2019-05-18 16:31:04.741090 pestcheck:Line 2475 of file freyberg.pst: parameter name "prsity3003
2019-05-18 16:31:04.741190 pestcheck:once.
2019-05-18 16:31:04.741294 pestcheck:Line 2476 of file freyberg.pst: parameter name "prsity3003
2019-05-18 16:31:04.741407 pestcheck:12 characters long.
2019-05-18 16:31:04.741511 pestcheck:Line 2476 of file freyberg.pst: parameter name "prsity3003
2019-05-18 16:31:04.741624 pestcheck:once.
2019-05-18 16:31:04.741729 pestcheck:Line 2477 of file freyberg.pst: parameter name "prsity3003
2019-05-18 16:31:04.741778 pestcheck:12 characters long.
2019-05-18 16:31:04.741817 pestcheck:Line 2477 of file freyberg.pst: parameter name "prsity3003
2019-05-18 16:31:04.741917 pestcheck:once.
2019-05-18 16:31:04.742021 pestcheck:Line 2478 of file freyberg.pst: parameter name "prsity3003
2019-05-18 16:31:04.742075 pestcheck:12 characters long.
2019-05-18 16:31:04.742174 pestcheck:Line 2478 of file freyberg.pst: parameter name "prsity3003
2019-05-18 16:31:04.742278 pestcheck:once.
2019-05-18 16:31:04.742327 pestcheck:Line 2479 of file freyberg.pst: parameter name "prsity3003
2019-05-18 16:31:04.742365 pestcheck:12 characters long.
2019-05-18 16:31:04.742464 pestcheck:Line 2479 of file freyberg.pst: parameter name "prsity3003
2019-05-18 16:31:04.742569 pestcheck:once.
2019-05-18 16:31:04.742615 pestcheck:Line 2480 of file freyberg.pst: parameter name "prsity3003
2019-05-18 16:31:04.742654 pestcheck:12 characters long.
2019-05-18 16:31:04.742753 pestcheck:Line 2480 of file freyberg.pst: parameter name "prsity3003
2019-05-18 16:31:04.742858 pestcheck:once.
2019-05-18 16:31:04.742904 pestcheck:Line 2481 of file freyberg.pst: parameter name "prsity3003
2019-05-18 16:31:04.742942 pestcheck:12 characters long.
2019-05-18 16:31:04.743042 pestcheck:Line 2481 of file freyberg.pst: parameter name "prsity3003
2019-05-18 16:31:04.743162 pestcheck:once.
2019-05-18 16:31:04.743264 pestcheck:Line 2482 of file freyberg.pst: parameter name "prsity3003
2019-05-18 16:31:04.743370 pestcheck:12 characters long.
2019-05-18 16:31:04.743417 pestcheck:Line 2482 of file freyberg.pst: parameter name "prsity3003
2019-05-18 16:31:04.743455 pestcheck:once.
2019-05-18 16:31:04.743555 pestcheck:Line 2483 of file freyberg.pst: parameter name "prsity3004
2019-05-18 16:31:04.743660 pestcheck:12 characters long.
2019-05-18 16:31:04.743778 pestcheck:Line 2484 of file freyberg.pst: parameter name "prsity3004
2019-05-18 16:31:04.743884 pestcheck:12 characters long.
2019-05-18 16:31:04.743998 pestcheck:Line 2484 of file freyberg.pst: parameter name "prsity3004
2019-05-18 16:31:04.744103 pestcheck:once.
2019-05-18 16:31:04.744159 pestcheck:Line 2485 of file freyberg.pst: parameter name "prsity3004
2019-05-18 16:31:04.744258 pestcheck:12 characters long.
2019-05-18 16:31:04.744363 pestcheck:Line 2485 of file freyberg.pst: parameter name "prsity3004
2019-05-18 16:31:04.744409 pestcheck:once.
2019-05-18 16:31:04.744448 pestcheck:Line 2486 of file freyberg.pst: parameter name "prsity3004
2019-05-18 16:31:04.744547 pestcheck:12 characters long.
2019-05-18 16:31:04.744652 pestcheck:Line 2486 of file freyberg.pst: parameter name "prsity3004
2019-05-18 16:31:04.744735 pestcheck:once.
2019-05-18 16:31:04.744806 pestcheck:Line 2487 of file freyberg.pst: parameter name "prsity3004
2019-05-18 16:31:04.744910 pestcheck:12 characters long.
2019-05-18 16:31:04.745024 pestcheck:Line 2487 of file freyberg.pst: parameter name "prsity3004
2019-05-18 16:31:04.745129 pestcheck:once.
```

```
2019-05-18 16:31:04.745247 pestcheck:Line 2488 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.745352 pestcheck:12 characters long.
2019-05-18 16:31:04.745464 pestcheck:Line 2488 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.745568 pestcheck:once.
2019-05-18 16:31:04.745617 pestcheck:Line 2489 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.745659 pestcheck:12 characters long.
2019-05-18 16:31:04.745760 pestcheck:Line 2489 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.745864 pestcheck:once.
2019-05-18 16:31:04.745977 pestcheck:Line 2490 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.746081 pestcheck:12 characters long.
2019-05-18 16:31:04.746130 pestcheck:Line 2490 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.746308 pestcheck:once.
2019-05-18 16:31:04.746422 pestcheck:Line 2491 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.746527 pestcheck:12 characters long.
2019-05-18 16:31:04.746641 pestcheck:Line 2491 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.746745 pestcheck:once.
2019-05-18 16:31:04.746857 pestcheck:Line 2492 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.746962 pestcheck:12 characters long.
2019-05-18 16:31:04.747075 pestcheck:Line 2492 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.747179 pestcheck:once.
2019-05-18 16:31:04.747303 pestcheck:Line 2493 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.747434 pestcheck:12 characters long.
2019-05-18 16:31:04.747537 pestcheck:Line 2494 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.747642 pestcheck:12 characters long.
2019-05-18 16:31:04.747689 pestcheck:Line 2494 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.747727 pestcheck:once.
2019-05-18 16:31:04.747827 pestcheck:Line 2495 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.747931 pestcheck:12 characters long.
2019-05-18 16:31:04.748041 pestcheck:Line 2495 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.748147 pestcheck:once.
2019-05-18 16:31:04.748263 pestcheck:Line 2496 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.748368 pestcheck:12 characters long.
2019-05-18 16:31:04.748481 pestcheck:Line 2496 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.748585 pestcheck:once.
2019-05-18 16:31:04.748698 pestcheck:Line 2497 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.748803 pestcheck:12 characters long.
2019-05-18 16:31:04.748917 pestcheck:Line 2497 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.749021 pestcheck:once.
2019-05-18 16:31:04.749135 pestcheck:Line 2498 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.749253 pestcheck:12 characters long.
2019-05-18 16:31:04.749292 pestcheck:Line 2498 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.749390 pestcheck:once.
2019-05-18 16:31:04.749495 pestcheck:Line 2499 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.749546 pestcheck:12 characters long.
2019-05-18 16:31:04.749584 pestcheck:Line 2499 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.749634 pestcheck:once.
2019-05-18 16:31:04.749740 pestcheck:Line 2500 of file freyberg.pst: parameter name "prsity300
2019-05-18 16:31:04.749790 pestcheck:12 characters long.
```

```
2019-05-18 16:31:04.749889 pestcheck:Line 2500 of file freyberg.pst: parameter name "prsity3004
2019-05-18 16:31:04.749936 pestcheck:once.
2019-05-18 16:31:04.749974 pestcheck:Line 2501 of file freyberg.pst: parameter name "prsity3004
2019-05-18 16:31:04.750079 pestcheck:12 characters long.
2019-05-18 16:31:04.750187 pestcheck:Line 2501 of file freyberg.pst: parameter name "prsity3004
2019-05-18 16:31:04.750308 pestcheck:once.
2019-05-18 16:31:04.750415 pestcheck:Line 2502 of file freyberg.pst: parameter name "prsity3004
2019-05-18 16:31:04.750462 pestcheck:12 characters long.
2019-05-18 16:31:04.750501 pestcheck:Line 2502 of file freyberg.pst: parameter name "prsity3004
2019-05-18 16:31:04.750602 pestcheck:once.
2019-05-18 16:31:04.750708 pestcheck:Line 2503 of file freyberg.pst: parameter name "prsity3005
2019-05-18 16:31:04.750755 pestcheck:12 characters long.
2019-05-18 16:31:04.750793 pestcheck:Line 2504 of file freyberg.pst: parameter name "prsity3005
2019-05-18 16:31:04.750894 pestcheck:12 characters long.
2019-05-18 16:31:04.750998 pestcheck:Line 2504 of file freyberg.pst: parameter name "prsity3005
2019-05-18 16:31:04.751044 pestcheck:once.
2019-05-18 16:31:04.751083 pestcheck:Line 2505 of file freyberg.pst: parameter name "prsity3005
2019-05-18 16:31:04.751184 pestcheck:12 characters long.
2019-05-18 16:31:04.751306 pestcheck:Line 2505 of file freyberg.pst: parameter name "prsity3005
2019-05-18 16:31:04.751345 pestcheck:once.
2019-05-18 16:31:04.751447 pestcheck:Line 2506 of file freyberg.pst: parameter name "prsity3005
2019-05-18 16:31:04.751552 pestcheck:12 characters long.
2019-05-18 16:31:04.751603 pestcheck:Line 2506 of file freyberg.pst: parameter name "prsity3005
2019-05-18 16:31:04.751712 pestcheck:once.
2019-05-18 16:31:04.751818 pestcheck:Line 2507 of file freyberg.pst: parameter name "prsity3005
2019-05-18 16:31:04.751865 pestcheck:12 characters long.
2019-05-18 16:31:04.751906 pestcheck:Line 2507 of file freyberg.pst: parameter name "prsity3005
2019-05-18 16:31:04.752008 pestcheck:once.
2019-05-18 16:31:04.752113 pestcheck:Line 2508 of file freyberg.pst: parameter name "prsity3005
2019-05-18 16:31:04.752160 pestcheck:12 characters long.
2019-05-18 16:31:04.752533 finished: running pestchek on freyberg.pst took: 0:00:00.143458
2019-05-18 16:31:04.752679 starting: saving intermediate _setup_<> dfs into template
2019-05-18 16:31:04.888316 finished: saving intermediate _setup_<> dfs into template took: 0:0
2019-05-18 16:31:04.888743 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 filed 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
```

```
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.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 [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 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 [18]: 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 [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)
```

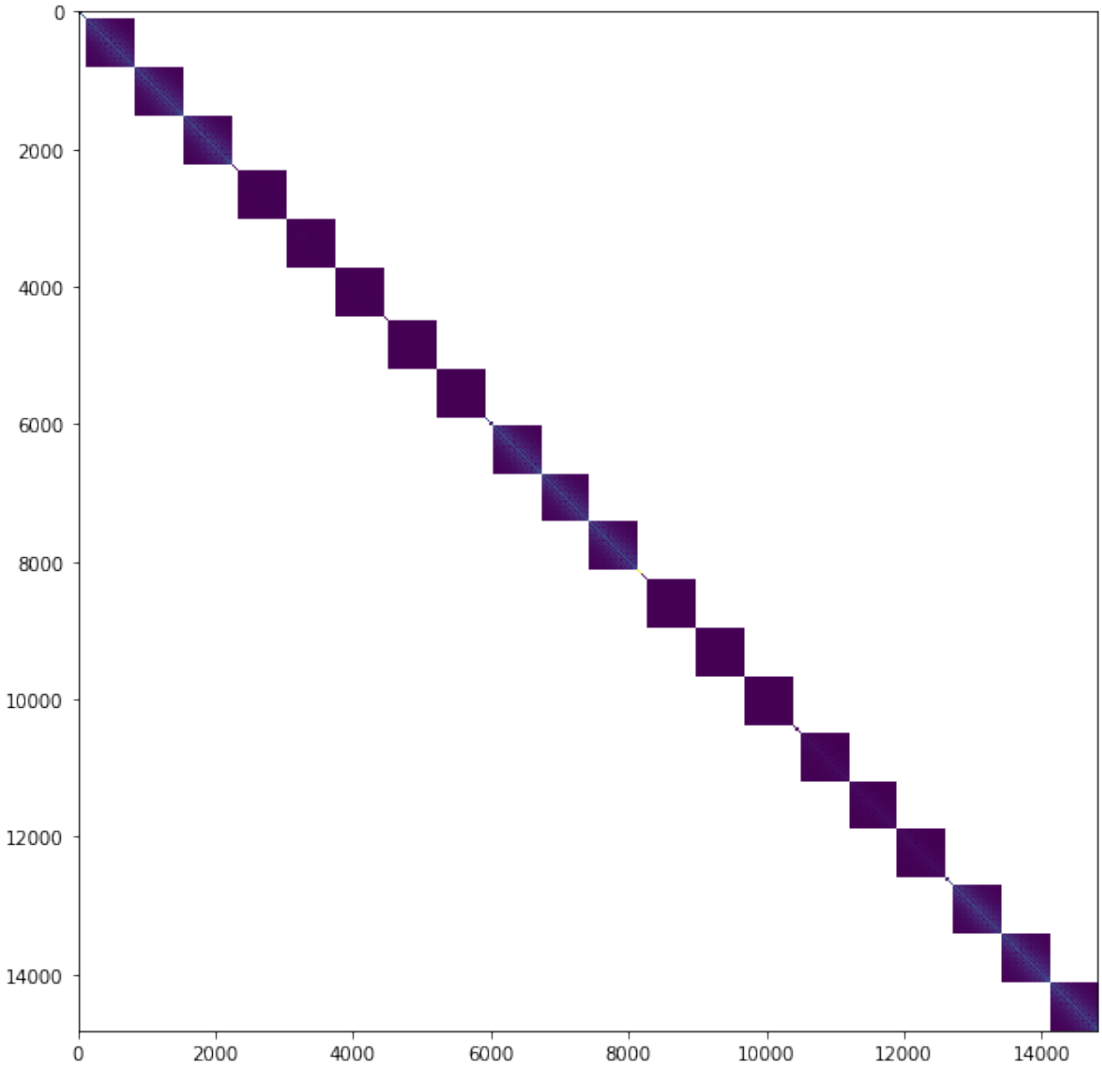
```
noptmax:0, npar_adj:14819, nnz_obs:4436
```

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
             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
```

```
2019-05-18 16:31:14.301694 starting: building prior covariance matrix
2019-05-18 16:31:14.407725 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


2019-05-18 16:31:20.420225 saving prior covariance matrix to file template/prior_cov.jcb
2019-05-18 16:31:24.494956 finished: building prior covariance matrix took: 0:00:10.193262
```



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

```
In [25]: pe = pst_helper.draw(1000)

2019-05-18 16:31:38.205543 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']
```

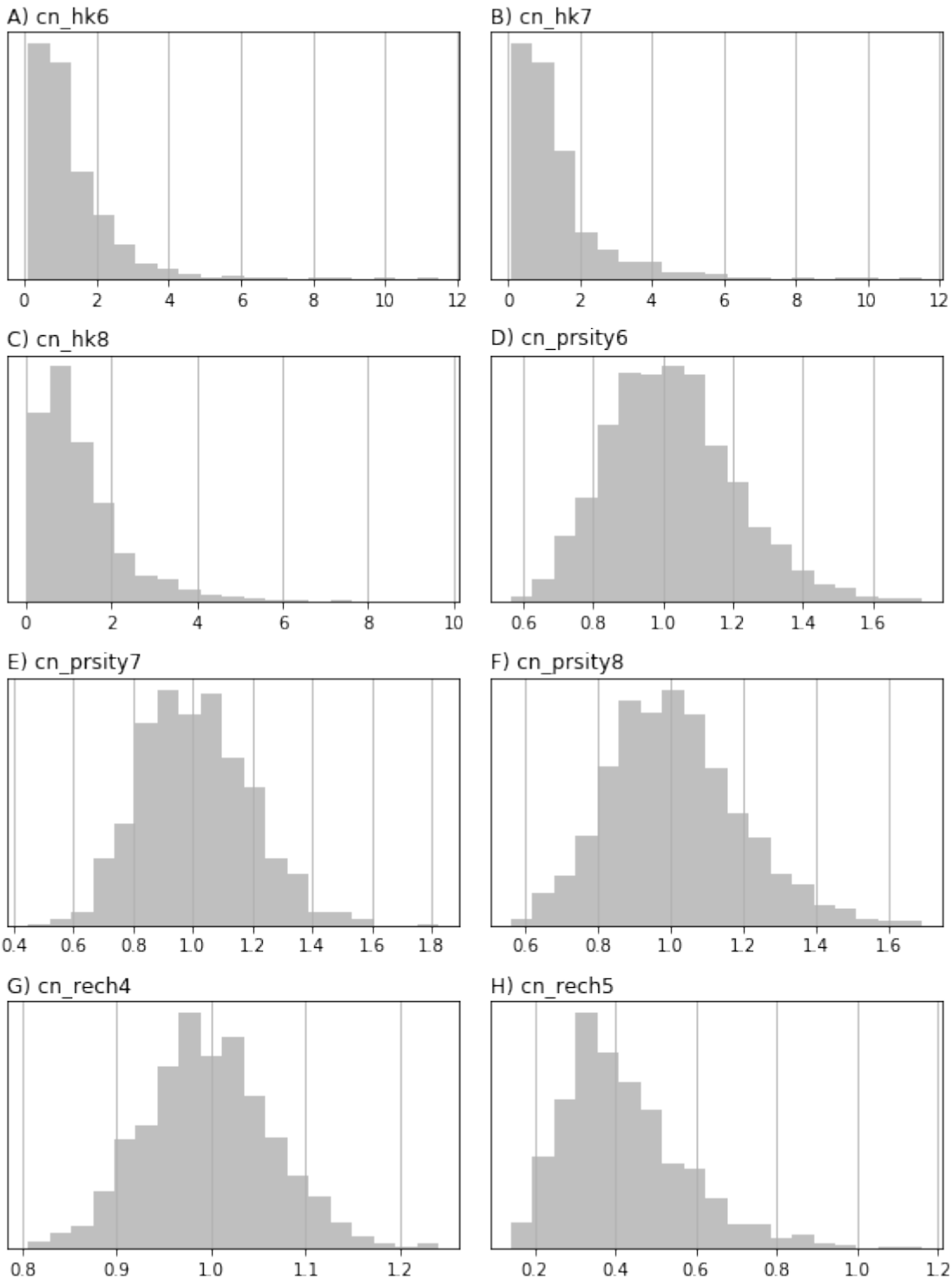
```
build cov matrix
done
getting diag var cov 32
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['pp_vka1']
build cov matrix
done
getting diag var cov 32
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['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:
```

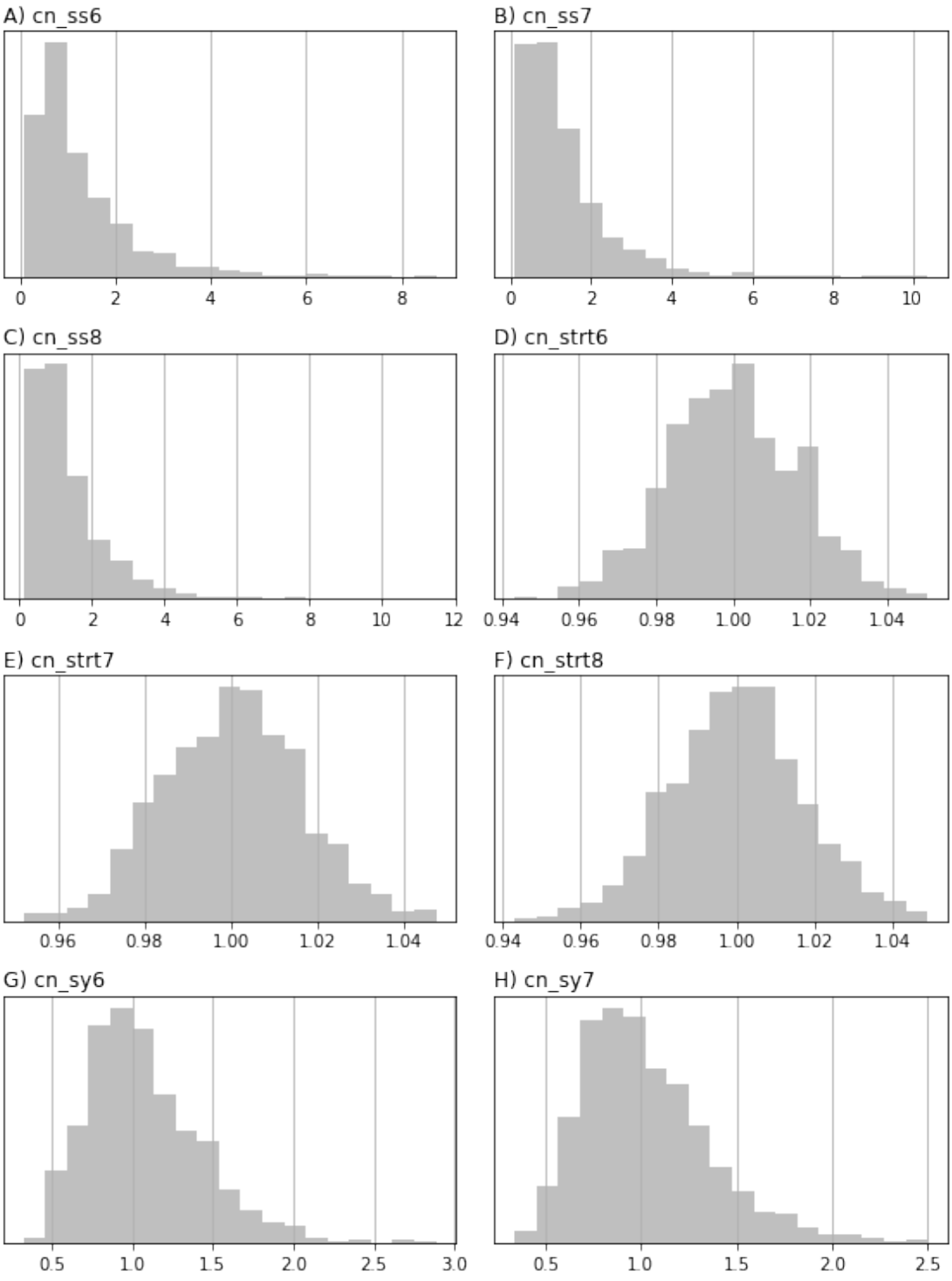
```
name:var1,contribution:1.0,a:2500.0,anisotropy:1.0,bearing:0.0

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
working on pargroups ['welflux_k02']


/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


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
2019-05-18 16:31:52.527485 finished: drawing realizations took: 0:00:14.321942
```

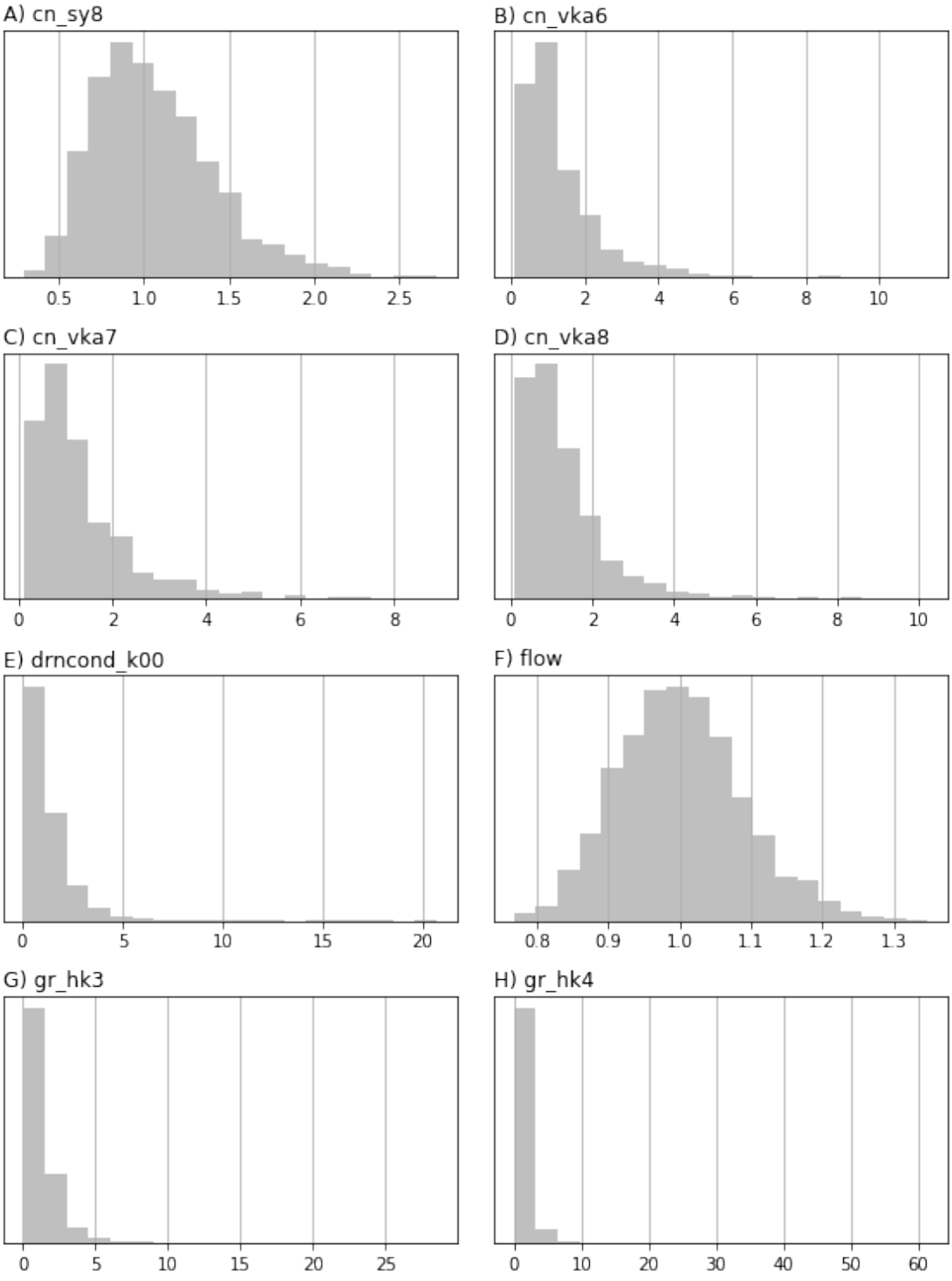
You can see that parameters are treated in parameter group (pargp) blocks for this ensemble generation. Let's plot one parameter:

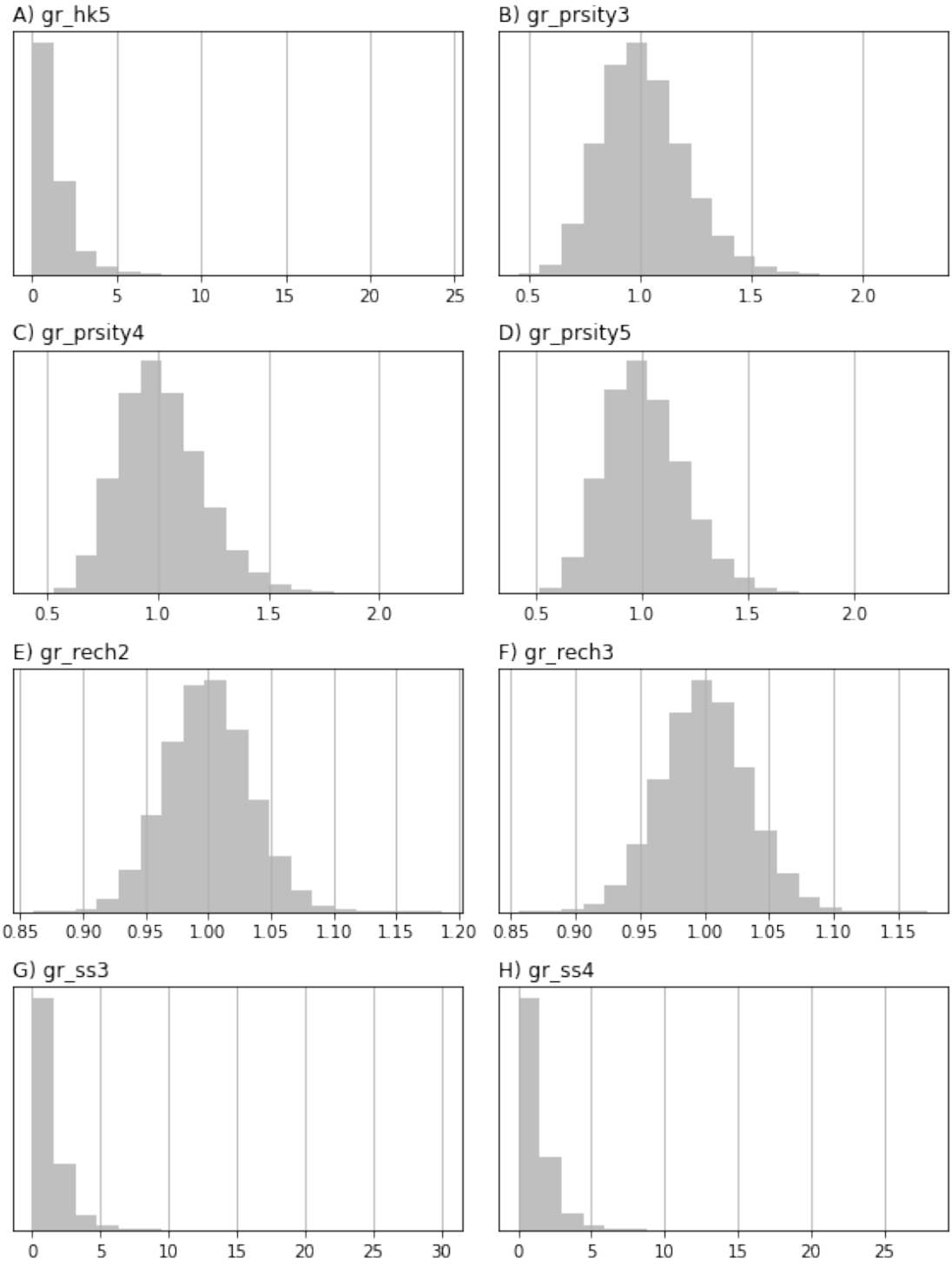
```
In [26]: par = pst_helper.pst.parameter_data
         pyemu.plot_utils.ensemble_helper(pe,plot_cols=par.groupby("pargp").groups,bins=20)
         plt.show()
```

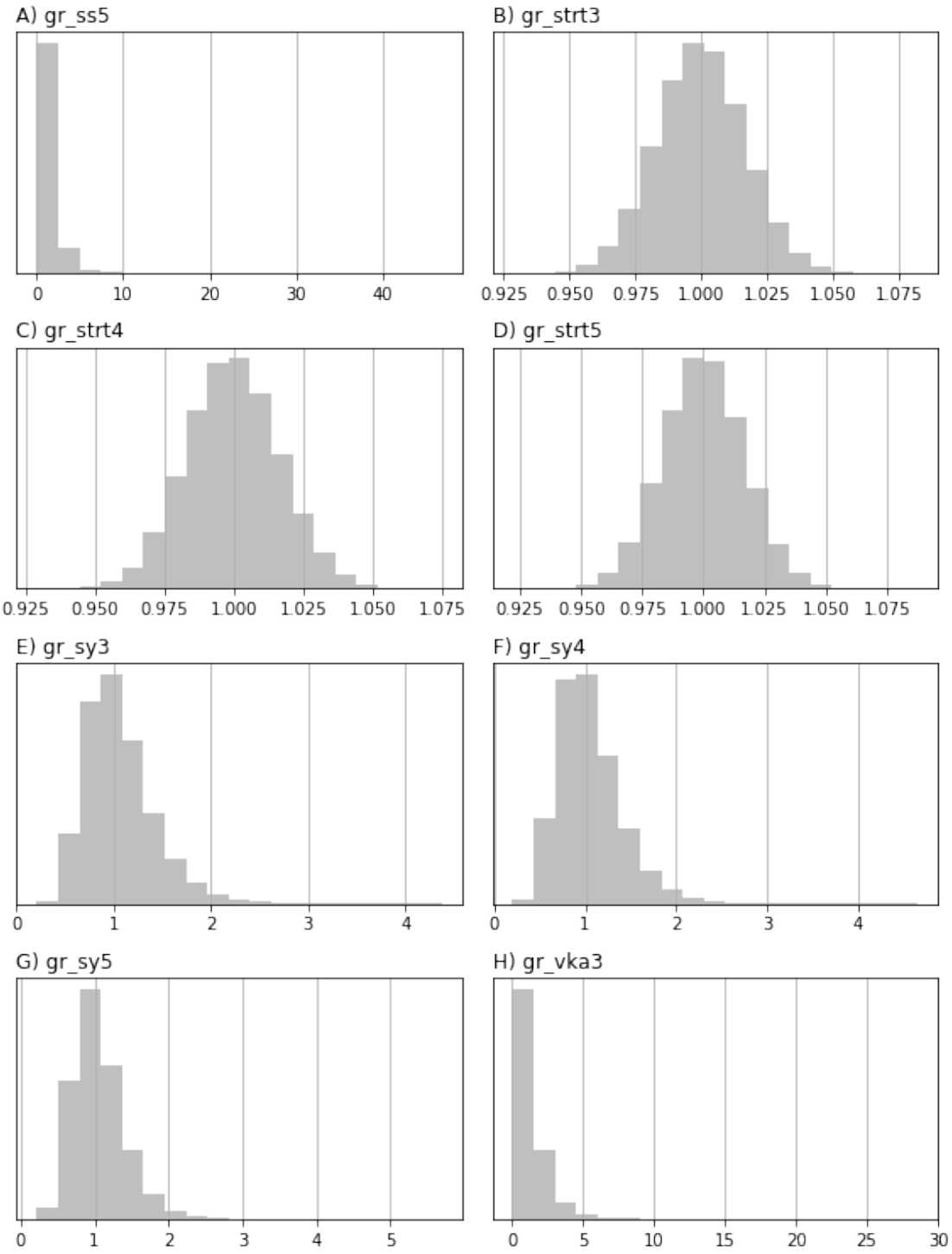
<Figure size 576x756 with 0 Axes>

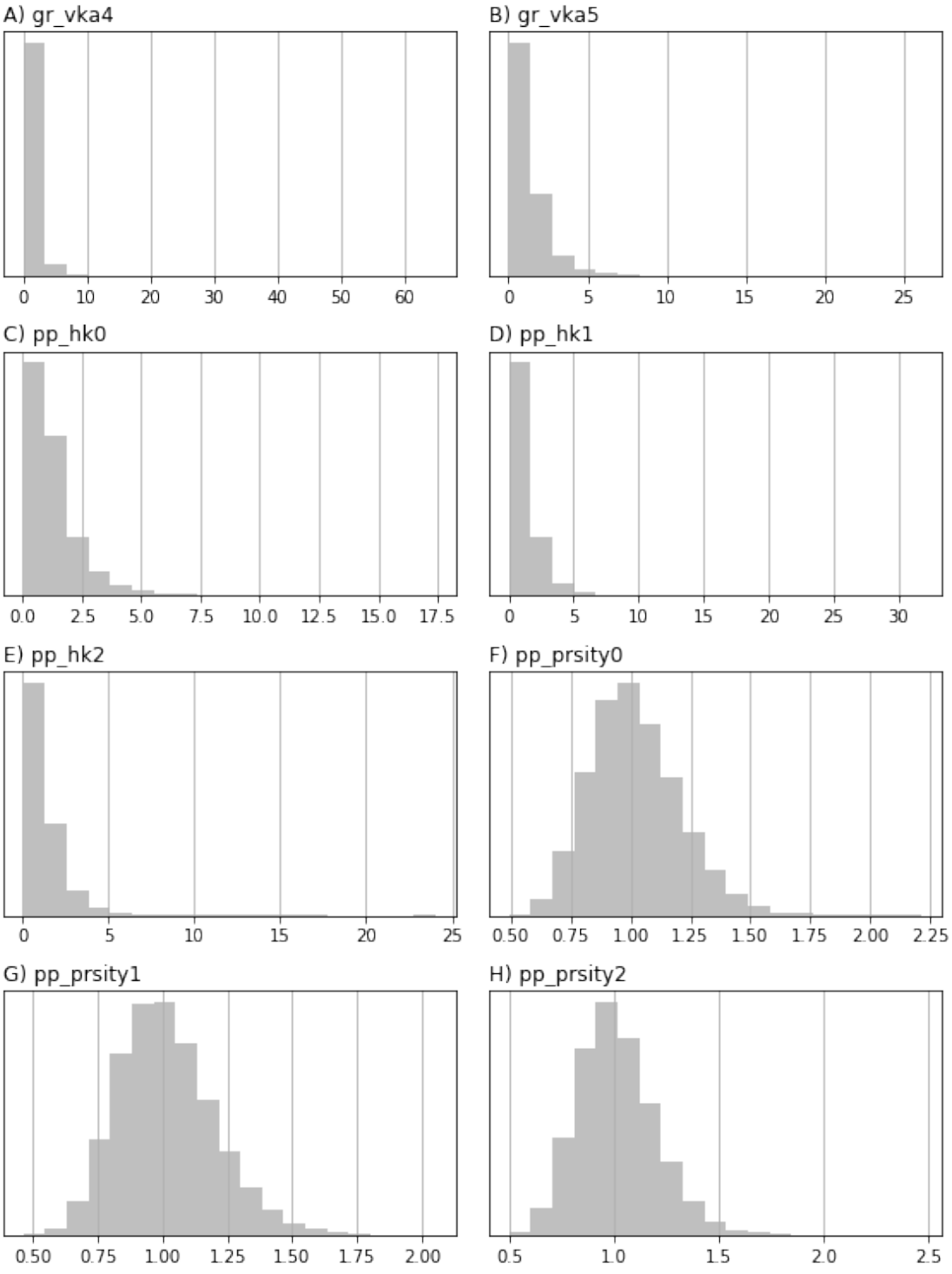


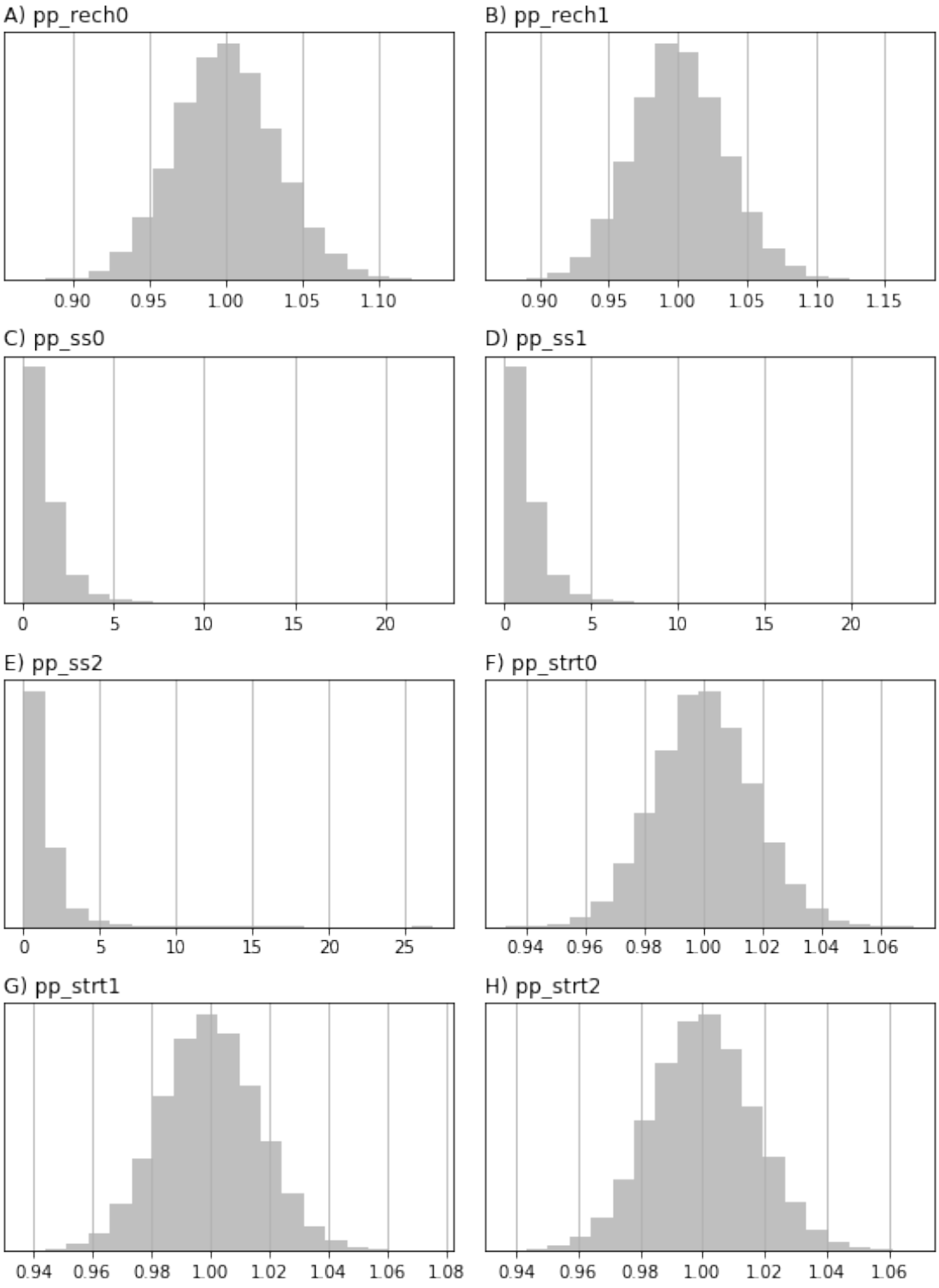

A) cn_ss6
0
2
4
6
8
B) cn_ss7
0
2
4
6
8
10
C) cn_ss8
0
2
4
6
8
10
12
D) cn_strt6
0.94
0.96
0.98
1.00
1.02
1.04
E) cn_strt7
0.96
0.98
1.00
1.02
1.04
F) cn_strt8
0.94
0.96
0.98
1.00
1.02
1.04
G) cn_sy6
0.5
1.0
1.5
2.0
2.5
3.0
H) cn_sy7
0.5
1.0
1.5
2.0
2.5

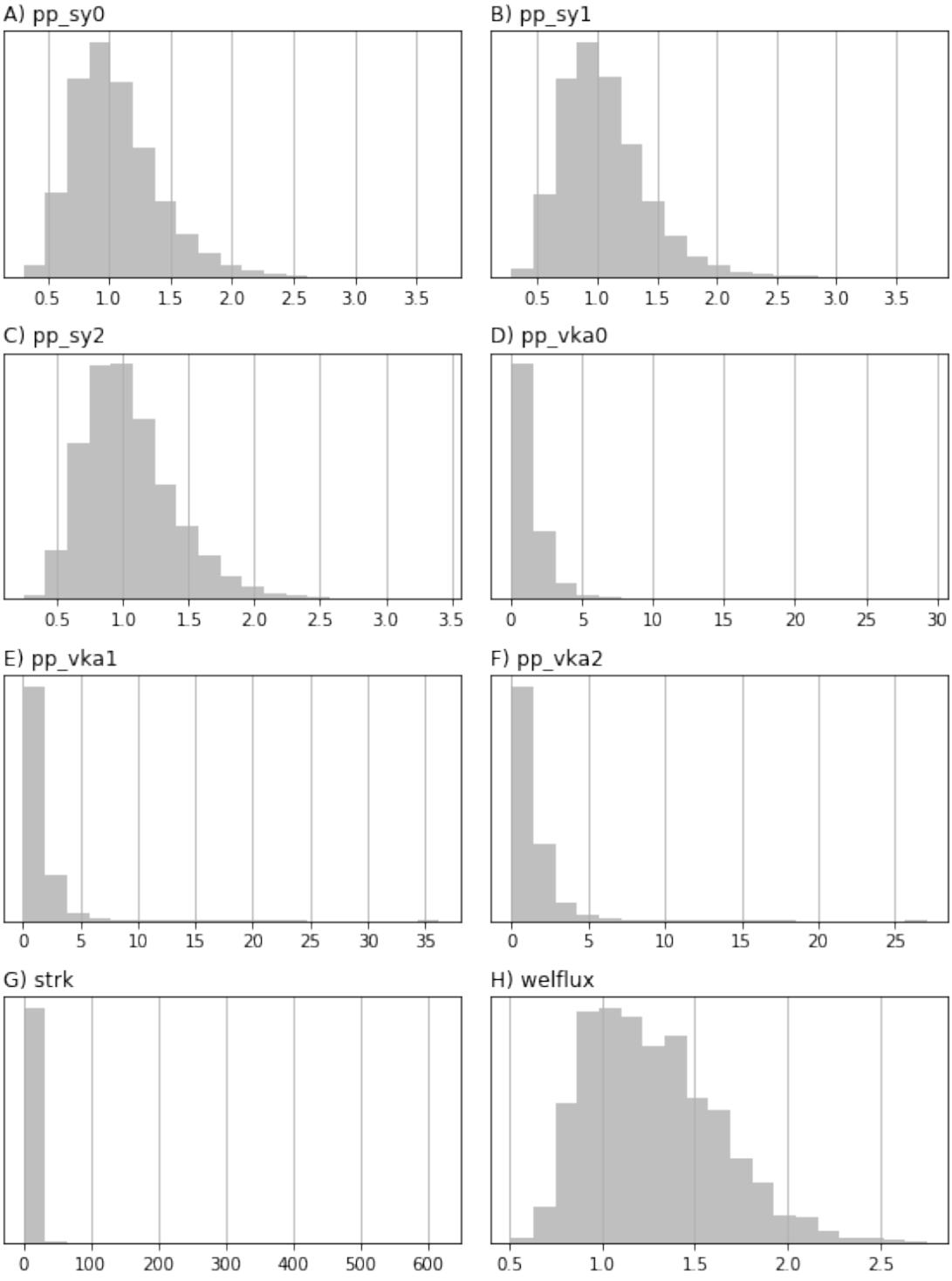

A) cn_sy8
0.5
1.0
1.5
2.0
2.5
B) cn_vka6
0
2
4
6
8
10
C) cn_vka7
0
2
4
6
8
D) cn_vka8
0
2
4
6
8
10
E) drncond_k00
0
5
10
15
20
F) flow
0.8
0.9
1.0
1.1
1.2
1.3
G) gr_hk3
0
5
10
15
20
25
H) gr_hk4
0
10
20
30
40
50
60

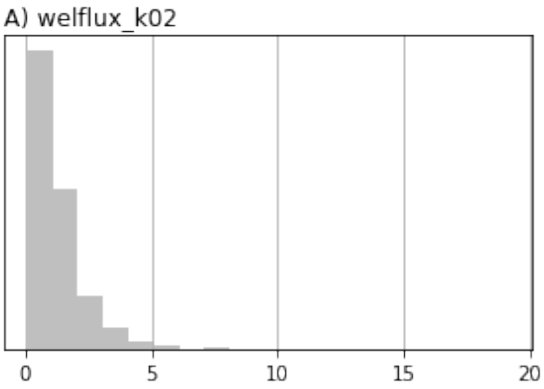

A) gr_hk5
0
5
10
15
20
25
B) gr_prsity3
0.5
1.0
1.5
2.0
C) gr_prsity4
0.5
1.0
1.5
2.0
D) gr_prsity5
0.5
1.0
1.5
2.0
E) gr_rech2
0.85
0.90
0.95
1.00
1.05
1.10
1.15
1.20
F) gr_rech3
0.85
0.90
0.95
1.00
1.05
1.10
1.15
G) gr_ss3
0
5
10
15
20
25
30
H) gr_ss4
0
5
10
15
20
25


A) gr_ss5
0
10
20
30
40
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
0
1
2
3
4
F) gr_sy4
0
1
2
3
4
G) gr_sy5
0
1
2
3
4
5
H) gr_vka3
0
5
10
15
20
25
30


A) gr_vka4
0
10
20
30
40
50
60
B) gr_vka5
0
5
10
15
20
25
C) pp_hk0
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
D) pp_hk1
0
5
10
15
20
25
30
E) pp_hk2
0
5
10
15
20
25
F) pp_prsity0
0.50
0.75
1.00
1.25
1.50
1.75
2.00
2.25
G) pp_prsity1
0.50
0.75
1.00
1.25
1.50
1.75
2.00
H) pp_prsity2
0.5
1.0
1.5
2.0
2.5


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 1.15
C) pp_ss0
0 5 10 15 20
D) pp_ss1
0 5 10 15 20
E) pp_ss2
0 5 10 15 20 25
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 1.08
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 3.5
C) pp_sy2
0.5 1.0 1.5 2.0 2.5 3.0 3.5
D) pp_vka0
0 5 10 15 20 25 30
E) pp_vka1
0 5 10 15 20 25 30 35
F) pp_vka2
0 5 10 15 20 25
G) strk
0 100 200 300 400 500 600
H) welflux
0.5 1.0 1.5 2.0 2.5



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"))
```

```
In [28]: pe.iloc[-1,-1]
```

```
Out[28]: 1.2795487817916409
```

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 [29]: 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[29]:     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 [30]: 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[30]: ['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 [31]: swgw_forecasts = obs.loc[obs.obsnme.apply(lambda x: "fa" in x and ("hw" in x or "tw" i
         print(swgw_forecasts)
         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"))
```

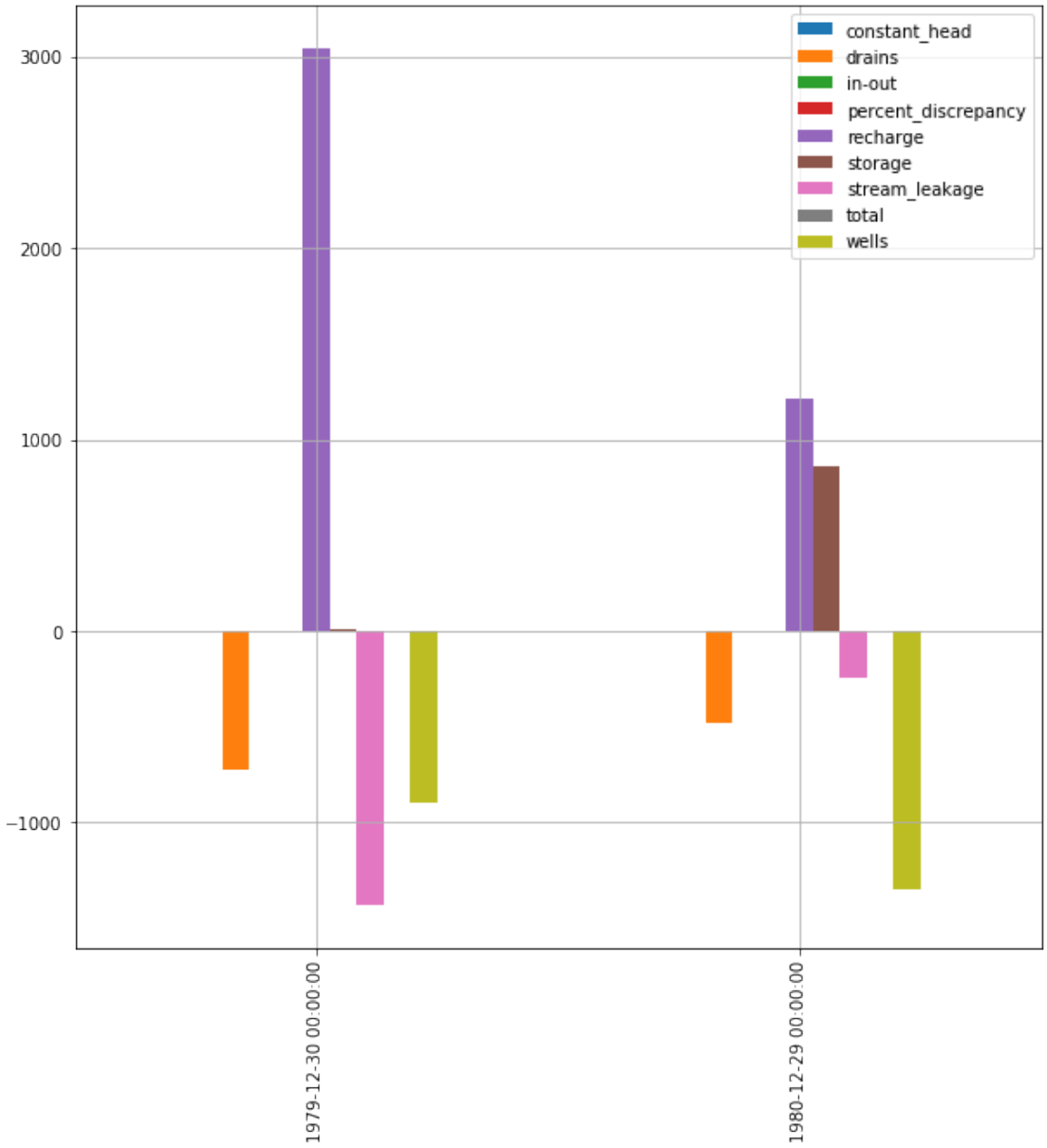
```
['fa_hw_19791230', 'fa_hw_19801229', 'fa_tw_19791230', 'fa_tw_19801229']
noptmax:0, npar_adj:14819, nnz_obs:14
```

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 [32]: 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[32]: 9.456182577320024e-19
```

```
In [33]: 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.