setup_pest_interface

May 1, 2019

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

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

```
In [1]: 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

flopy is installed in /Users/jeremyw/Dev/gw1876/activities_2day_mfm/notebooks/flopy
```

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

This seemingly simple function call will spatially rediscretize the original freyberg model by cutting each row and column by 3's

```
In [3]: #redis_fac = 3
        #mr = redis.redis_freyberg(fac=redis_fac,b_d=b_d)
        #b_d = mr.model_ws
```

1.0.1 load the model and run once to make sure everything is good-to-go

```
In [4]: m = flopy.modflow.Modflow.load(nam_file,model_ws=b_d,check=False,forgive=False)
```

```
In [5]: m.exe_name = "mfnwt"
        m.change_model_ws("temp",reset_external=True)
        m.write_input()
        prep_deps.prep_template(t_d="temp")
        pyemu.os_utils.run("{0} {1}".format("mfnwt",m.name+".nam"),cwd=m.model_ws)
```

```
changing model workspace...
   temp
```

```
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]
ax = df.plot(kind="bar",figsize=(6,6))
ax.set_xticklabels(["historic","scenario"])
```

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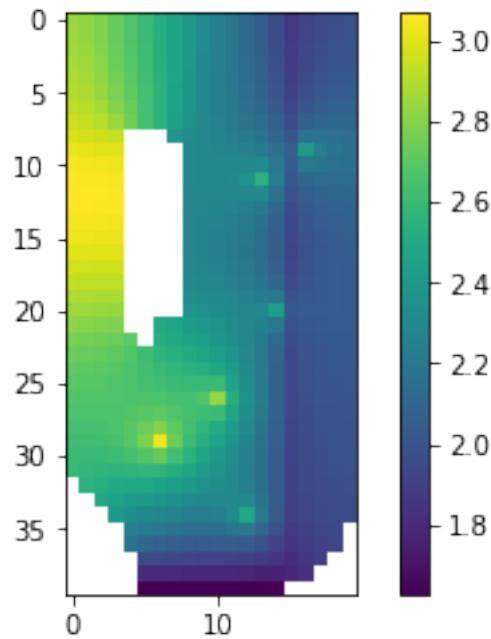

data Layer 1
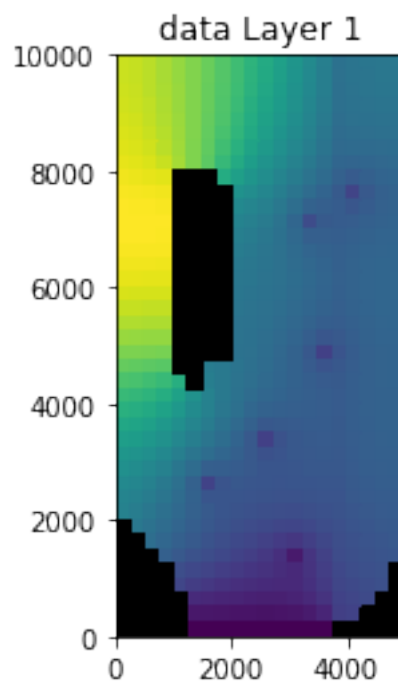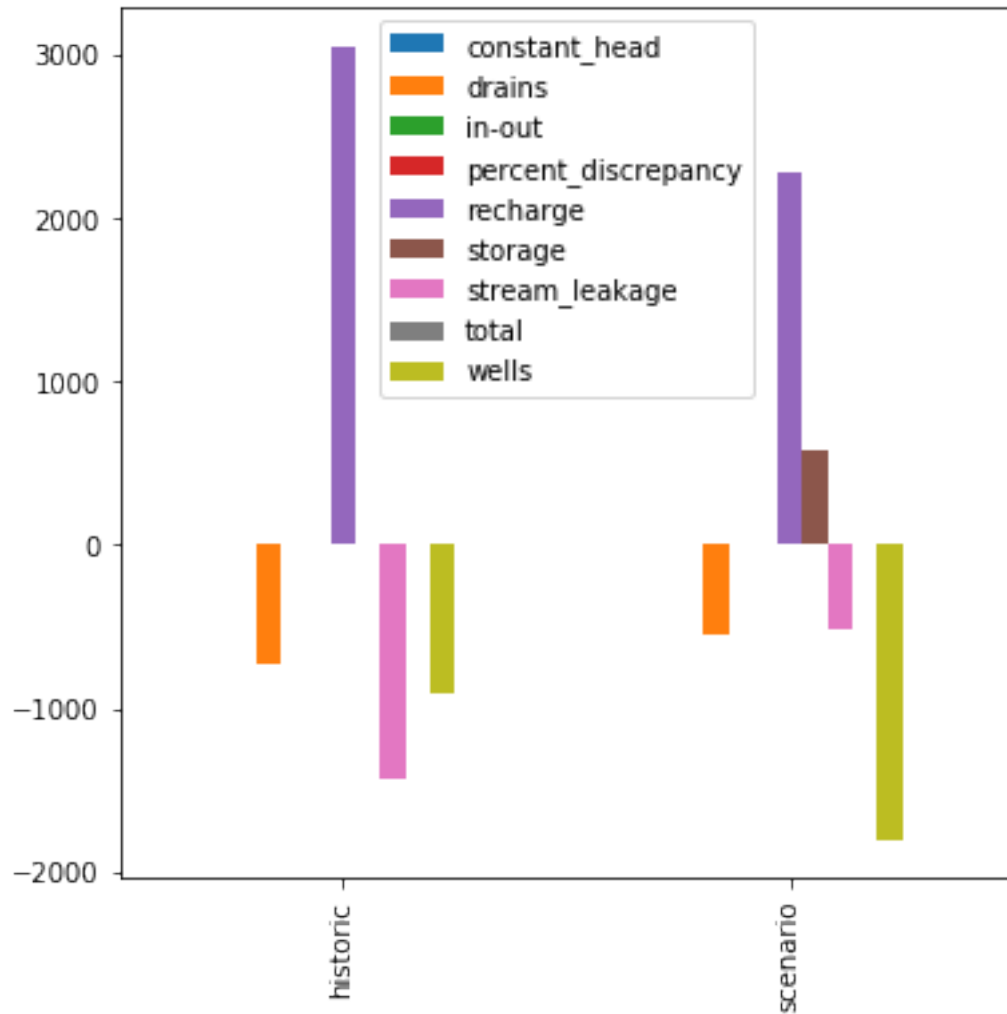
We can see the effect of the "scenario" in the second stress period with less recharge and more abstraction.

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.colorbar(c)
        plt.show()
```

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"])

Out[8]:  [Text(0, 0, 'historic'), Text(0, 0, 'scenario')]
```

data Layer 1
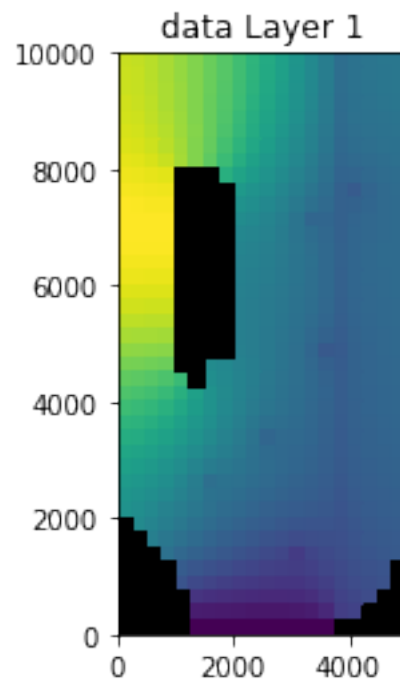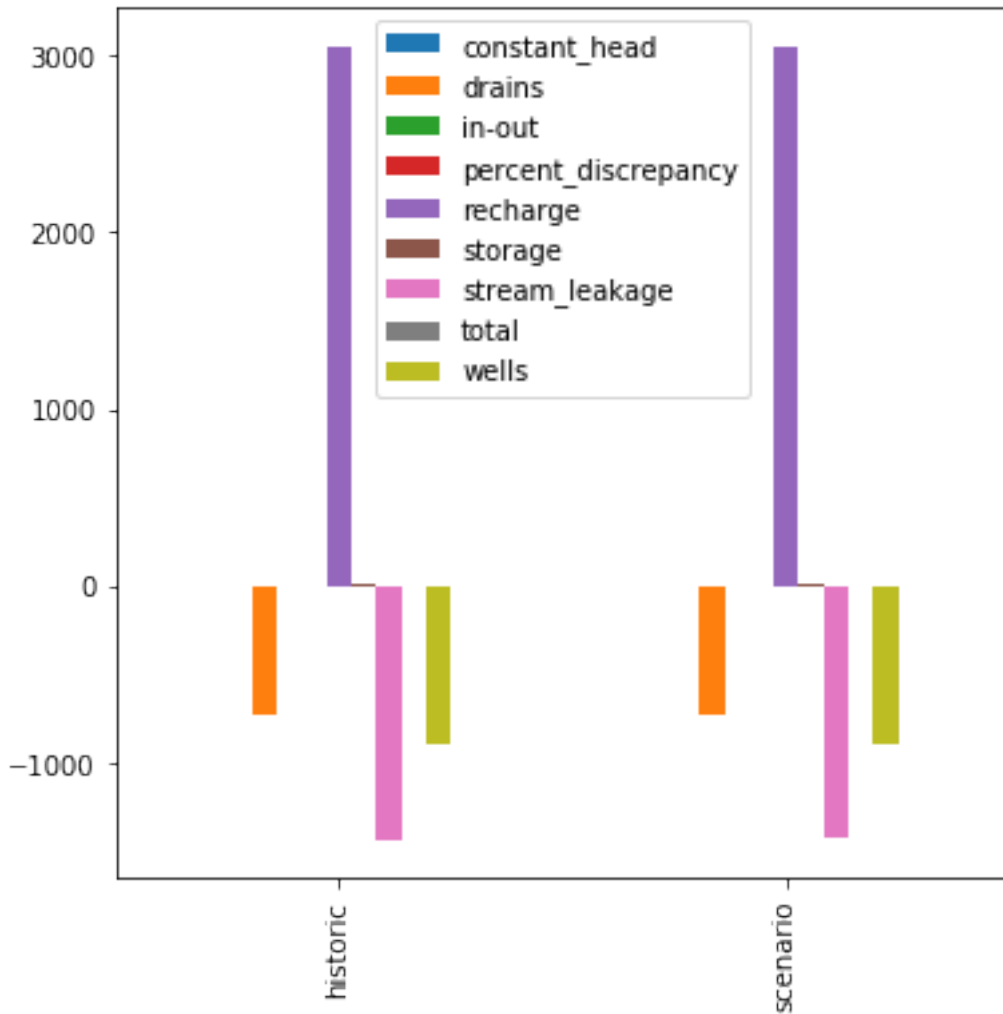
Now we see that the scenario and historic periods have the same water balance

1.0.2 setup data structures related to what we want to parameterize and what we want to observe

```
In [9]: props = []
        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])
        props.append(["rch.rech",0])
        props.append(["rch.rech",1])

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

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

Here 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
```

1.0.3 here we go...

This 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 parmaeters 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!

```
In [13]: pst_helper = pyemu.helpers.PstFromFlopyModel(nam_file,new_model_ws="template",org_mod
                                           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,mc
                                           pp_space=4)
         prep_deps.prep_template(t_d=pst_helper.new_model_ws)

2019-05-01 16:57:59.713348 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
2019-05-01 16:57:59.745267 finished: loading flopy model took: 0:00:00.031919
2019-05-01 16:57:59.745413 starting: updating model attributes
2019-05-01 16:57:59.745500 finished: updating model attributes took: 0:00:00.000087
2019-05-01 16:57:59.745633 WARNING: removing existing 'new_model_ws

creating model workspace...
   template

changing model workspace...
   template
2019-05-01 16:58:00.948506 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


2019-05-01 16:58:01.084049 finished: writing new modflow input files took: 0:00:00.135543
2019-05-01 16:58:01.085516 forward_run line:pyemu.os_utils.run('mfnwt freyberg.nam 1>freyberg.r
2019-05-01 16:58:01.085915 starting: setting up 'template/arr_org' dir
2019-05-01 16:58:01.086999 finished: setting up 'template/arr_org' dir took: 0:00:00.001084
2019-05-01 16:58:01.087423 starting: setting up 'template/arr_mlt' dir
2019-05-01 16:58:01.088087 finished: setting up 'template/arr_mlt' dir took: 0:00:00.000664
2019-05-01 16:58:01.088525 starting: setting up 'template/list_org' dir
2019-05-01 16:58:01.089240 finished: setting up 'template/list_org' dir took: 0:00:00.000715
2019-05-01 16:58:01.089620 starting: setting up 'template/list_mlt' dir
2019-05-01 16:58:01.090352 finished: setting up 'template/list_mlt' dir took: 0:00:00.000732
2019-05-01 16:58:01.091036 starting: processing temporal_list_props
2019-05-01 16:58:01.126883 finished: processing temporal_list_props took: 0:00:00.035847
```

```
2019-05-01 16:58:01.127255 starting: processing spatial_list_props
2019-05-01 16:58:01.295398 finished: processing spatial_list_props took: 0:00:00.168143
2019-05-01 16:58:01.352502 forward_run line:pyemu.helpers.apply_list_pars()


2019-05-01 16:58:01.384370 'extra' pak detected:extra.prsity
2019-05-01 16:58:01.425225 'extra' pak detected:extra.prsity
2019-05-01 16:58:01.470705 'extra' pak detected:extra.prsity
2019-05-01 16:58:01.526102 'extra' pak detected:extra.prsity
2019-05-01 16:58:01.564937 'extra' pak detected:extra.prsity
2019-05-01 16:58:01.601488 'extra' pak detected:extra.prsity
2019-05-01 16:58:01.651195 'extra' pak detected:extra.prsity
2019-05-01 16:58:01.687875 'extra' pak detected:extra.prsity
2019-05-01 16:58:01.724639 'extra' pak detected:extra.prsity
2019-05-01 16:58:01.808561 starting: writing grid tpl:hk3.dat_gr.tpl
2019-05-01 16:58:01.817105 finished: writing grid tpl:hk3.dat_gr.tpl took: 0:00:00.008544
2019-05-01 16:58:01.819999 starting: writing grid tpl:vka3.dat_gr.tpl
2019-05-01 16:58:01.828867 finished: writing grid tpl:vka3.dat_gr.tpl took: 0:00:00.008868
2019-05-01 16:58:01.832166 starting: writing grid tpl:ss3.dat_gr.tpl
2019-05-01 16:58:01.841412 finished: writing grid tpl:ss3.dat_gr.tpl took: 0:00:00.009246
2019-05-01 16:58:01.844080 starting: writing grid tpl:sy3.dat_gr.tpl
2019-05-01 16:58:01.852570 finished: writing grid tpl:sy3.dat_gr.tpl took: 0:00:00.008490
2019-05-01 16:58:01.855310 starting: writing grid tpl:strt3.dat_gr.tpl
2019-05-01 16:58:01.864004 finished: writing grid tpl:strt3.dat_gr.tpl took: 0:00:00.008694
2019-05-01 16:58:01.866773 starting: writing grid tpl:prsity3.dat_gr.tpl
2019-05-01 16:58:01.879695 finished: writing grid tpl:prsity3.dat_gr.tpl took: 0:00:00.012922
2019-05-01 16:58:01.882432 starting: writing grid tpl:hk4.dat_gr.tpl
2019-05-01 16:58:01.891444 finished: writing grid tpl:hk4.dat_gr.tpl took: 0:00:00.009012
2019-05-01 16:58:01.894352 starting: writing grid tpl:vka4.dat_gr.tpl
2019-05-01 16:58:01.903396 finished: writing grid tpl:vka4.dat_gr.tpl took: 0:00:00.009044
2019-05-01 16:58:01.906186 starting: writing grid tpl:ss4.dat_gr.tpl
2019-05-01 16:58:01.915118 finished: writing grid tpl:ss4.dat_gr.tpl took: 0:00:00.008932
2019-05-01 16:58:01.917732 starting: writing grid tpl:sy4.dat_gr.tpl
2019-05-01 16:58:01.926290 finished: writing grid tpl:sy4.dat_gr.tpl took: 0:00:00.008558
2019-05-01 16:58:01.929208 starting: writing grid tpl:strt4.dat_gr.tpl
2019-05-01 16:58:01.938596 finished: writing grid tpl:strt4.dat_gr.tpl took: 0:00:00.009388
2019-05-01 16:58:01.941663 starting: writing grid tpl:prsity4.dat_gr.tpl
2019-05-01 16:58:01.953545 finished: writing grid tpl:prsity4.dat_gr.tpl took: 0:00:00.011882
2019-05-01 16:58:01.956549 starting: writing grid tpl:hk5.dat_gr.tpl
2019-05-01 16:58:01.966317 finished: writing grid tpl:hk5.dat_gr.tpl took: 0:00:00.009768
2019-05-01 16:58:01.969213 starting: writing grid tpl:vka5.dat_gr.tpl
2019-05-01 16:58:01.977848 finished: writing grid tpl:vka5.dat_gr.tpl took: 0:00:00.008635
2019-05-01 16:58:01.980574 starting: writing grid tpl:ss5.dat_gr.tpl
2019-05-01 16:58:01.989423 finished: writing grid tpl:ss5.dat_gr.tpl took: 0:00:00.008849
2019-05-01 16:58:01.992025 starting: writing grid tpl:sy5.dat_gr.tpl
2019-05-01 16:58:02.001261 finished: writing grid tpl:sy5.dat_gr.tpl took: 0:00:00.009236
2019-05-01 16:58:02.004441 starting: writing grid tpl:strt5.dat_gr.tpl
2019-05-01 16:58:02.014529 finished: writing grid tpl:strt5.dat_gr.tpl took: 0:00:00.010088
2019-05-01 16:58:02.017567 starting: writing grid tpl:prsity5.dat_gr.tpl
```

```
2019-05-01 16:58:02.028661 finished: writing grid tpl:prsity5.dat_gr.tpl took: 0:00:00.011094
2019-05-01 16:58:02.031305 starting: writing grid tpl:rech2.dat_gr.tpl
2019-05-01 16:58:02.039988 finished: writing grid tpl:rech2.dat_gr.tpl took: 0:00:00.008683
2019-05-01 16:58:02.043746 starting: writing grid tpl:rech3.dat_gr.tpl
2019-05-01 16:58:02.052909 finished: writing grid tpl:rech3.dat_gr.tpl took: 0:00:00.009163
2019-05-01 16:58:02.055591 starting: writing const tpl:hk6.dat_cn.tpl
2019-05-01 16:58:02.061706 finished: writing const tpl:hk6.dat_cn.tpl took: 0:00:00.006115
2019-05-01 16:58:02.064402 starting: writing const tpl:vka6.dat_cn.tpl
2019-05-01 16:58:02.070696 finished: writing const tpl:vka6.dat_cn.tpl took: 0:00:00.006294
2019-05-01 16:58:02.072970 starting: writing const tpl:ss6.dat_cn.tpl
2019-05-01 16:58:02.078847 finished: writing const tpl:ss6.dat_cn.tpl took: 0:00:00.005877
2019-05-01 16:58:02.081322 starting: writing const tpl:sy6.dat_cn.tpl
2019-05-01 16:58:02.086486 finished: writing const tpl:sy6.dat_cn.tpl took: 0:00:00.005164
2019-05-01 16:58:02.088755 starting: writing const tpl:strt6.dat_cn.tpl
2019-05-01 16:58:02.095352 finished: writing const tpl:strt6.dat_cn.tpl took: 0:00:00.006597
2019-05-01 16:58:02.099093 starting: writing const tpl:prsity6.dat_cn.tpl
2019-05-01 16:58:02.109385 finished: writing const tpl:prsity6.dat_cn.tpl took: 0:00:00.010292
2019-05-01 16:58:02.112761 starting: writing const tpl:hk7.dat_cn.tpl
2019-05-01 16:58:02.118780 finished: writing const tpl:hk7.dat_cn.tpl took: 0:00:00.006019
2019-05-01 16:58:02.121562 starting: writing const tpl:vka7.dat_cn.tpl
2019-05-01 16:58:02.129019 finished: writing const tpl:vka7.dat_cn.tpl took: 0:00:00.007457
2019-05-01 16:58:02.131909 starting: writing const tpl:ss7.dat_cn.tpl
2019-05-01 16:58:02.137416 finished: writing const tpl:ss7.dat_cn.tpl took: 0:00:00.005507
2019-05-01 16:58:02.140032 starting: writing const tpl:sy7.dat_cn.tpl
2019-05-01 16:58:02.147290 finished: writing const tpl:sy7.dat_cn.tpl took: 0:00:00.007258
2019-05-01 16:58:02.151222 starting: writing const tpl:strt7.dat_cn.tpl
2019-05-01 16:58:02.158851 finished: writing const tpl:strt7.dat_cn.tpl took: 0:00:00.007629
2019-05-01 16:58:02.161534 starting: writing const tpl:prsity7.dat_cn.tpl
2019-05-01 16:58:02.168733 finished: writing const tpl:prsity7.dat_cn.tpl took: 0:00:00.007199
2019-05-01 16:58:02.171776 starting: writing const tpl:hk8.dat_cn.tpl
2019-05-01 16:58:02.177609 finished: writing const tpl:hk8.dat_cn.tpl took: 0:00:00.005833
2019-05-01 16:58:02.180175 starting: writing const tpl:vka8.dat_cn.tpl
2019-05-01 16:58:02.185817 finished: writing const tpl:vka8.dat_cn.tpl took: 0:00:00.005642
2019-05-01 16:58:02.188404 starting: writing const tpl:ss8.dat_cn.tpl
2019-05-01 16:58:02.194797 finished: writing const tpl:ss8.dat_cn.tpl took: 0:00:00.006393
2019-05-01 16:58:02.199053 starting: writing const tpl:sy8.dat_cn.tpl
2019-05-01 16:58:02.207130 finished: writing const tpl:sy8.dat_cn.tpl took: 0:00:00.008077
2019-05-01 16:58:02.210512 starting: writing const tpl:strt8.dat_cn.tpl
2019-05-01 16:58:02.216515 finished: writing const tpl:strt8.dat_cn.tpl took: 0:00:00.006003
2019-05-01 16:58:02.219368 starting: writing const tpl:prsity8.dat_cn.tpl
2019-05-01 16:58:02.225706 finished: writing const tpl:prsity8.dat_cn.tpl took: 0:00:00.006338
2019-05-01 16:58:02.228413 starting: writing const tpl:rech4.dat_cn.tpl
2019-05-01 16:58:02.234191 finished: writing const tpl:rech4.dat_cn.tpl took: 0:00:00.005778
2019-05-01 16:58:02.236814 starting: writing const tpl:rech5.dat_cn.tpl
2019-05-01 16:58:02.243074 finished: writing const tpl:rech5.dat_cn.tpl took: 0:00:00.006260
2019-05-01 16:58:02.269869 starting: setting up pilot point process
2019-05-01 16:58:02.270325 WARNING: pp_geostruct is None, using ExpVario with contribution=1 a
2019-05-01 16:58:02.273861 pp_dict: {0: ['hk0', 'vka0', 'ss0', 'sy0', 'strt0', 'prsity0', 'rec
```

```
2019-05-01 16:58:02.274148 starting: calling setup_pilot_point_grid()
2019-05-01 16:58:02.892961 640 pilot point parameters created
2019-05-01 16:58:02.893887 pilot point 'pargp':hk0,vka0,ss0,sy0,strt0,prsity0,rech0,rech1,ss1,s
2019-05-01 16:58:02.893943 finished: calling setup_pilot_point_grid() took: 0:00:00.619795
2019-05-01 16:58:02.895975 starting: calculating factors for p=hk0, k=0
2019-05-01 16:58:02.896946 saving krige variance file:template/pp_k0_general_zn.fac
2019-05-01 16:58:02.897250 saving krige factors file:template/pp_k0_general_zn.fac
starting interp point loop for 800 points
took 2.692069 seconds
2019-05-01 16:58:05.635781 finished: calculating factors for p=hk0, k=0 took: 0:00:02.739806
2019-05-01 16:58:05.636846 starting: calculating factors for p=vka0, k=0
2019-05-01 16:58:05.638617 finished: calculating factors for p=vka0, k=0 took: 0:00:00.001771
2019-05-01 16:58:05.639563 starting: calculating factors for p=ss0, k=0
2019-05-01 16:58:05.640551 finished: calculating factors for p=ss0, k=0 took: 0:00:00.000988
2019-05-01 16:58:05.641433 starting: calculating factors for p=sy0, k=0
2019-05-01 16:58:05.642543 finished: calculating factors for p=sy0, k=0 took: 0:00:00.001110
2019-05-01 16:58:05.643787 starting: calculating factors for p=strt0, k=0
2019-05-01 16:58:05.644745 finished: calculating factors for p=strt0, k=0 took: 0:00:00.000958
2019-05-01 16:58:05.645404 starting: calculating factors for p=prsity0, k=0
2019-05-01 16:58:05.646228 finished: calculating factors for p=prsity0, k=0 took: 0:00:00.0008
2019-05-01 16:58:05.647641 starting: calculating factors for p=rech0, k=0
2019-05-01 16:58:05.648466 finished: calculating factors for p=rech0, k=0 took: 0:00:00.000825
2019-05-01 16:58:05.649618 starting: calculating factors for p=rech1, k=0
2019-05-01 16:58:05.650644 finished: calculating factors for p=rech1, k=0 took: 0:00:00.001026
2019-05-01 16:58:05.652046 starting: calculating factors for p=ss1, k=1
2019-05-01 16:58:05.653132 saving krige variance file:template/pp_k1_general_zn.fac
2019-05-01 16:58:05.653472 saving krige factors file:template/pp_k1_general_zn.fac
starting interp point loop for 800 points
took 2.684768 seconds
2019-05-01 16:58:08.384265 finished: calculating factors for p=ss1, k=1 took: 0:00:02.732219
2019-05-01 16:58:08.385555 starting: calculating factors for p=strt1, k=1
2019-05-01 16:58:08.386651 finished: calculating factors for p=strt1, k=1 took: 0:00:00.001096
2019-05-01 16:58:08.387540 starting: calculating factors for p=vka1, k=1
2019-05-01 16:58:08.388540 finished: calculating factors for p=vka1, k=1 took: 0:00:00.001000
2019-05-01 16:58:08.389455 starting: calculating factors for p=sy1, k=1
2019-05-01 16:58:08.390346 finished: calculating factors for p=sy1, k=1 took: 0:00:00.000891
2019-05-01 16:58:08.390882 starting: calculating factors for p=prsity1, k=1
2019-05-01 16:58:08.392076 finished: calculating factors for p=prsity1, k=1 took: 0:00:00.0011
2019-05-01 16:58:08.393010 starting: calculating factors for p=hk1, k=1
2019-05-01 16:58:08.394002 finished: calculating factors for p=hk1, k=1 took: 0:00:00.000992
2019-05-01 16:58:08.394948 starting: calculating factors for p=prsity2, k=2
2019-05-01 16:58:08.395887 saving krige variance file:template/pp_k2_general_zn.fac
2019-05-01 16:58:08.395945 saving krige factors file:template/pp_k2_general_zn.fac
starting interp point loop for 800 points
took 2.759431 seconds
2019-05-01 16:58:11.203286 finished: calculating factors for p=prsity2, k=2 took: 0:00:02.8083
2019-05-01 16:58:11.204467 starting: calculating factors for p=sy2, k=2
2019-05-01 16:58:11.205758 finished: calculating factors for p=sy2, k=2 took: 0:00:00.001291
```

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2019-05-01 16:58:11.206540 starting: calculating factors for p=ss2, k=2
2019-05-01 16:58:11.207469 finished: calculating factors for p=ss2, k=2 took: 0:00:00.000929
2019-05-01 16:58:11.208320 starting: calculating factors for p=strt2, k=2
2019-05-01 16:58:11.209520 finished: calculating factors for p=strt2, k=2 took: 0:00:00.001200
2019-05-01 16:58:11.210610 starting: calculating factors for p=hk2, k=2
2019-05-01 16:58:11.211698 finished: calculating factors for p=hk2, k=2 took: 0:00:00.001088
2019-05-01 16:58:11.212542 starting: calculating factors for p=vka2, k=2
2019-05-01 16:58:11.213583 finished: calculating factors for p=vka2, k=2 took: 0:00:00.001041
2019-05-01 16:58:11.213890 starting: processing pp_prefix:rech0
2019-05-01 16:58:11.225975 starting: processing pp_prefix:hk1
2019-05-01 16:58:11.235053 starting: processing pp_prefix:prsity1
2019-05-01 16:58:11.243819 starting: processing pp_prefix:vka2
2019-05-01 16:58:11.252540 starting: processing pp_prefix:strt2
2019-05-01 16:58:11.262711 starting: processing pp_prefix:vka0
2019-05-01 16:58:11.273136 starting: processing pp_prefix:hk0
2019-05-01 16:58:11.281882 starting: processing pp_prefix:ss1
2019-05-01 16:58:11.290379 starting: processing pp_prefix:prsity0
2019-05-01 16:58:11.301763 starting: processing pp_prefix:sy1
2019-05-01 16:58:11.310930 starting: processing pp_prefix:prsity2
2019-05-01 16:58:11.319695 starting: processing pp_prefix:sy2
2019-05-01 16:58:11.328640 starting: processing pp_prefix:ss2
2019-05-01 16:58:11.337139 starting: processing pp_prefix:ss0
2019-05-01 16:58:11.345699 starting: processing pp_prefix:sy0
2019-05-01 16:58:11.354867 starting: processing pp_prefix:strt1
2019-05-01 16:58:11.363410 starting: processing pp_prefix:vka1
2019-05-01 16:58:11.372171 starting: processing pp_prefix:strt0
2019-05-01 16:58:11.380906 starting: processing pp_prefix:rech1
2019-05-01 16:58:11.389210 starting: processing pp_prefix:hk2
2019-05-01 16:58:11.499544 finished: setting up pilot point process took: 0:00:09.229675
2019-05-01 16:58:11.500219 starting: setting up grid process
2019-05-01 16:58:11.500305 WARNING: grid_geostruct is None, using ExpVario with contribution=1
2019-05-01 16:58:11.500435 finished: setting up grid process took: 0:00:00.000216
2019-05-01 16:58:11.503298 starting: save test mlt array arr_mlt/hk0.dat_pp
2019-05-01 16:58:11.506475 finished: save test mlt array arr_mlt/hk0.dat_pp took: 0:00:00.0031
2019-05-01 16:58:11.507523 starting: save test mlt array arr_mlt/vka0.dat_pp
2019-05-01 16:58:11.510472 finished: save test mlt array arr_mlt/vka0.dat_pp took: 0:00:00.0029
2019-05-01 16:58:11.511364 starting: save test mlt array arr_mlt/ss0.dat_pp
2019-05-01 16:58:11.514210 finished: save test mlt array arr_mlt/ss0.dat_pp took: 0:00:00.0028
2019-05-01 16:58:11.515265 starting: save test mlt array arr_mlt/sy0.dat_pp
2019-05-01 16:58:11.518391 finished: save test mlt array arr_mlt/sy0.dat_pp took: 0:00:00.0031
2019-05-01 16:58:11.519512 starting: save test mlt array arr_mlt/strt0.dat_pp
2019-05-01 16:58:11.522605 finished: save test mlt array arr_mlt/strt0.dat_pp took: 0:00:00.003
2019-05-01 16:58:11.523642 starting: save test mlt array arr_mlt/prsity0.dat_pp
2019-05-01 16:58:11.526324 finished: save test mlt array arr_mlt/prsity0.dat_pp took: 0:00:00.0
2019-05-01 16:58:11.527067 starting: save test mlt array arr_mlt/hk1.dat_pp
2019-05-01 16:58:11.530079 finished: save test mlt array arr_mlt/hk1.dat_pp took: 0:00:00.0030
2019-05-01 16:58:11.530996 starting: save test mlt array arr_mlt/vka1.dat_pp
2019-05-01 16:58:11.533917 finished: save test mlt array arr_mlt/vka1.dat_pp took: 0:00:00.0029
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2019-05-01 16:58:11.534834 starting: save test mlt array arr_mlt/ss1.dat_pp
2019-05-01 16:58:11.537694 finished: save test mlt array arr_mlt/ss1.dat_pp took: 0:00:00.00286
2019-05-01 16:58:11.538650 starting: save test mlt array arr_mlt/sy1.dat_pp
2019-05-01 16:58:11.541615 finished: save test mlt array arr_mlt/sy1.dat_pp took: 0:00:00.00296
2019-05-01 16:58:11.542721 starting: save test mlt array arr_mlt/strt1.dat_pp
2019-05-01 16:58:11.545735 finished: save test mlt array arr_mlt/strt1.dat_pp took: 0:00:00.003
2019-05-01 16:58:11.546491 starting: save test mlt array arr_mlt/prsity1.dat_pp
2019-05-01 16:58:11.549117 finished: save test mlt array arr_mlt/prsity1.dat_pp took: 0:00:00.0
2019-05-01 16:58:11.549979 starting: save test mlt array arr_mlt/hk2.dat_pp
2019-05-01 16:58:11.553016 finished: save test mlt array arr_mlt/hk2.dat_pp took: 0:00:00.00303
2019-05-01 16:58:11.553984 starting: save test mlt array arr_mlt/vka2.dat_pp
2019-05-01 16:58:11.557187 finished: save test mlt array arr_mlt/vka2.dat_pp took: 0:00:00.0032
2019-05-01 16:58:11.558147 starting: save test mlt array arr_mlt/ss2.dat_pp
2019-05-01 16:58:11.560981 finished: save test mlt array arr_mlt/ss2.dat_pp took: 0:00:00.00283
2019-05-01 16:58:11.562001 starting: save test mlt array arr_mlt/sy2.dat_pp
2019-05-01 16:58:11.565672 finished: save test mlt array arr_mlt/sy2.dat_pp took: 0:00:00.00367
2019-05-01 16:58:11.566592 starting: save test mlt array arr_mlt/strt2.dat_pp
2019-05-01 16:58:11.569627 finished: save test mlt array arr_mlt/strt2.dat_pp took: 0:00:00.003
2019-05-01 16:58:11.570824 starting: save test mlt array arr_mlt/prsity2.dat_pp
2019-05-01 16:58:11.573675 finished: save test mlt array arr_mlt/prsity2.dat_pp took: 0:00:00.0
2019-05-01 16:58:11.574715 starting: save test mlt array arr_mlt/rech0.dat_pp
2019-05-01 16:58:11.578132 finished: save test mlt array arr_mlt/rech0.dat_pp took: 0:00:00.003
2019-05-01 16:58:11.579499 starting: save test mlt array arr_mlt/rech1.dat_pp
2019-05-01 16:58:11.582759 finished: save test mlt array arr_mlt/rech1.dat_pp took: 0:00:00.003
2019-05-01 16:58:11.583643 starting: save test mlt array arr_mlt/hk3.dat_gr
2019-05-01 16:58:11.586895 finished: save test mlt array arr_mlt/hk3.dat_gr took: 0:00:00.0032!
2019-05-01 16:58:11.587835 starting: save test mlt array arr_mlt/vka3.dat_gr
2019-05-01 16:58:11.590659 finished: save test mlt array arr_mlt/vka3.dat_gr took: 0:00:00.0028
2019-05-01 16:58:11.591785 starting: save test mlt array arr_mlt/ss3.dat_gr
2019-05-01 16:58:11.594656 finished: save test mlt array arr_mlt/ss3.dat_gr took: 0:00:00.0028
2019-05-01 16:58:11.595617 starting: save test mlt array arr_mlt/sy3.dat_gr
2019-05-01 16:58:11.598534 finished: save test mlt array arr_mlt/sy3.dat_gr took: 0:00:00.0029
2019-05-01 16:58:11.599655 starting: save test mlt array arr_mlt/strt3.dat_gr
2019-05-01 16:58:11.602557 finished: save test mlt array arr_mlt/strt3.dat_gr took: 0:00:00.002
2019-05-01 16:58:11.603639 starting: save test mlt array arr_mlt/prsity3.dat_gr
2019-05-01 16:58:11.607900 finished: save test mlt array arr_mlt/prsity3.dat_gr took: 0:00:00.0
2019-05-01 16:58:11.609302 starting: save test mlt array arr_mlt/hk4.dat_gr
2019-05-01 16:58:11.613730 finished: save test mlt array arr_mlt/hk4.dat_gr took: 0:00:00.0044
2019-05-01 16:58:11.615160 starting: save test mlt array arr_mlt/vka4.dat_gr
2019-05-01 16:58:11.619627 finished: save test mlt array arr_mlt/vka4.dat_gr took: 0:00:00.0044
2019-05-01 16:58:11.620953 starting: save test mlt array arr_mlt/ss4.dat_gr
2019-05-01 16:58:11.624109 finished: save test mlt array arr_mlt/ss4.dat_gr took: 0:00:00.00315
2019-05-01 16:58:11.625024 starting: save test mlt array arr_mlt/sy4.dat_gr
2019-05-01 16:58:11.628346 finished: save test mlt array arr_mlt/sy4.dat_gr took: 0:00:00.0033
2019-05-01 16:58:11.629366 starting: save test mlt array arr_mlt/strt4.dat_gr
2019-05-01 16:58:11.632809 finished: save test mlt array arr_mlt/strt4.dat_gr took: 0:00:00.003
2019-05-01 16:58:11.633869 starting: save test mlt array arr_mlt/prsity4.dat_gr
2019-05-01 16:58:11.637077 finished: save test mlt array arr_mlt/prsity4.dat_gr took: 0:00:00.0
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2019-05-01 16:58:11.638023 starting: save test mlt array arr_mlt/hk5.dat_gr
2019-05-01 16:58:11.641084 finished: save test mlt array arr_mlt/hk5.dat_gr took: 0:00:00.00300
2019-05-01 16:58:11.642075 starting: save test mlt array arr_mlt/vka5.dat_gr
2019-05-01 16:58:11.644652 finished: save test mlt array arr_mlt/vka5.dat_gr took: 0:00:00.0025
2019-05-01 16:58:11.645560 starting: save test mlt array arr_mlt/ss5.dat_gr
2019-05-01 16:58:11.648559 finished: save test mlt array arr_mlt/ss5.dat_gr took: 0:00:00.00299
2019-05-01 16:58:11.649498 starting: save test mlt array arr_mlt/sy5.dat_gr
2019-05-01 16:58:11.652729 finished: save test mlt array arr_mlt/sy5.dat_gr took: 0:00:00.00323
2019-05-01 16:58:11.654123 starting: save test mlt array arr_mlt/strt5.dat_gr
2019-05-01 16:58:11.658351 finished: save test mlt array arr_mlt/strt5.dat_gr took: 0:00:00.004
2019-05-01 16:58:11.659883 starting: save test mlt array arr_mlt/prsity5.dat_gr
2019-05-01 16:58:11.664215 finished: save test mlt array arr_mlt/prsity5.dat_gr took: 0:00:00.0
2019-05-01 16:58:11.665717 starting: save test mlt array arr_mlt/rech2.dat_gr
2019-05-01 16:58:11.670338 finished: save test mlt array arr_mlt/rech2.dat_gr took: 0:00:00.004
2019-05-01 16:58:11.671644 starting: save test mlt array arr_mlt/rech3.dat_gr
2019-05-01 16:58:11.675206 finished: save test mlt array arr_mlt/rech3.dat_gr took: 0:00:00.003
2019-05-01 16:58:11.676277 starting: save test mlt array arr_mlt/hk6.dat_cn
2019-05-01 16:58:11.679300 finished: save test mlt array arr_mlt/hk6.dat_cn took: 0:00:00.00302
2019-05-01 16:58:11.680225 starting: save test mlt array arr_mlt/vka6.dat_cn
2019-05-01 16:58:11.682993 finished: save test mlt array arr_mlt/vka6.dat_cn took: 0:00:00.0027
2019-05-01 16:58:11.684041 starting: save test mlt array arr_mlt/ss6.dat_cn
2019-05-01 16:58:11.687058 finished: save test mlt array arr_mlt/ss6.dat_cn took: 0:00:00.00301
2019-05-01 16:58:11.688026 starting: save test mlt array arr_mlt/sy6.dat_cn
2019-05-01 16:58:11.690957 finished: save test mlt array arr_mlt/sy6.dat_cn took: 0:00:00.00293
2019-05-01 16:58:11.691942 starting: save test mlt array arr_mlt/strt6.dat_cn
2019-05-01 16:58:11.694608 finished: save test mlt array arr_mlt/strt6.dat_cn took: 0:00:00.002
2019-05-01 16:58:11.695573 starting: save test mlt array arr_mlt/prsity6.dat_cn
2019-05-01 16:58:11.698565 finished: save test mlt array arr_mlt/prsity6.dat_cn took: 0:00:00.0
2019-05-01 16:58:11.699499 starting: save test mlt array arr_mlt/hk7.dat_cn
2019-05-01 16:58:11.702353 finished: save test mlt array arr_mlt/hk7.dat_cn took: 0:00:00.00285
2019-05-01 16:58:11.703740 starting: save test mlt array arr_mlt/vka7.dat_cn
2019-05-01 16:58:11.708249 finished: save test mlt array arr_mlt/vka7.dat_cn took: 0:00:00.0045
2019-05-01 16:58:11.709748 starting: save test mlt array arr_mlt/ss7.dat_cn
2019-05-01 16:58:11.714546 finished: save test mlt array arr_mlt/ss7.dat_cn took: 0:00:00.00479
2019-05-01 16:58:11.716459 starting: save test mlt array arr_mlt/sy7.dat_cn
2019-05-01 16:58:11.720590 finished: save test mlt array arr_mlt/sy7.dat_cn took: 0:00:00.00413
2019-05-01 16:58:11.721762 starting: save test mlt array arr_mlt/strt7.dat_cn
2019-05-01 16:58:11.725045 finished: save test mlt array arr_mlt/strt7.dat_cn took: 0:00:00.003
2019-05-01 16:58:11.726194 starting: save test mlt array arr_mlt/prsity7.dat_cn
2019-05-01 16:58:11.729090 finished: save test mlt array arr_mlt/prsity7.dat_cn took: 0:00:00.0
2019-05-01 16:58:11.730151 starting: save test mlt array arr_mlt/hk8.dat_cn
2019-05-01 16:58:11.733238 finished: save test mlt array arr_mlt/hk8.dat_cn took: 0:00:00.00308
2019-05-01 16:58:11.734266 starting: save test mlt array arr_mlt/vka8.dat_cn
2019-05-01 16:58:11.737387 finished: save test mlt array arr_mlt/vka8.dat_cn took: 0:00:00.003
2019-05-01 16:58:11.738233 starting: save test mlt array arr_mlt/ss8.dat_cn
2019-05-01 16:58:11.741372 finished: save test mlt array arr_mlt/ss8.dat_cn took: 0:00:00.00313
2019-05-01 16:58:11.742473 starting: save test mlt array arr_mlt/sy8.dat_cn
2019-05-01 16:58:11.745450 finished: save test mlt array arr_mlt/sy8.dat_cn took: 0:00:00.0029
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2019-05-01 16:58:11.746462 starting: save test mlt array arr_mlt/strt8.dat_cn
2019-05-01 16:58:11.749554 finished: save test mlt array arr_mlt/strt8.dat_cn took: 0:00:00.003
2019-05-01 16:58:11.750612 starting: save test mlt array arr_mlt/prsity8.dat_cn
2019-05-01 16:58:11.753912 finished: save test mlt array arr_mlt/prsity8.dat_cn took: 0:00:00.0
2019-05-01 16:58:11.755343 starting: save test mlt array arr_mlt/rech4.dat_cn
2019-05-01 16:58:11.760447 finished: save test mlt array arr_mlt/rech4.dat_cn took: 0:00:00.005
2019-05-01 16:58:11.762950 starting: save test mlt array arr_mlt/rech5.dat_cn
2019-05-01 16:58:11.768417 finished: save test mlt array arr_mlt/rech5.dat_cn took: 0:00:00.005
2019-05-01 16:58:12.472155 forward_run line:pyemu.helpers.apply_array_pars()

all zeros for runoff...skipping...
all zeros for hcond1...skipping...
all zeros for pptsw...skipping...
2019-05-01 16:58:12.612607 starting: processing obs type mflist water budget obs
2019-05-01 16:58:12.758191 forward_run line:pyemu.gw_utils.apply_mflist_budget_obs('freyberg.l
2019-05-01 16:58:12.758521 finished: processing obs type mflist water budget obs took: 0:00:00
2019-05-01 16:58:12.758624 starting: processing obs type hyd file
2019-05-01 16:58:12.758841 finished: processing obs type hyd file took: 0:00:00.000217
2019-05-01 16:58:12.758921 starting: processing obs type external obs-sim smp files
2019-05-01 16:58:12.759180 finished: processing obs type external obs-sim smp files took: 0:00
2019-05-01 16:58:12.759366 starting: processing obs type hob
2019-05-01 16:58:12.759712 finished: processing obs type hob took: 0:00:00.000346
2019-05-01 16:58:12.759961 starting: processing obs type hds
[[0, 0], [0, 1], [0, 2], [1, 0], [1, 1], [1, 2]]
2019-05-01 16:58:13.218846 finished: processing obs type hds took: 0:00:00.458885
2019-05-01 16:58:13.219477 starting: processing obs type sfr
writing 'sfr_obs.config' to template/sfr_obs.config
2019-05-01 16:58:13.586523 finished: processing obs type sfr took: 0:00:00.367046
2019-05-01 16:58:13.586976 changing dir in to template
2019-05-01 16:58:13.587719 starting: instantiating control file from i/o files
2019-05-01 16:58:13.587810 tpl files: drn.csv.tpl,wel.csv.tpl,hk3.dat_gr.tpl,vka3.dat_gr.tpl,s
2019-05-01 16:58:13.587854 ins files: freyberg.hds.dat.ins,vol.dat.ins,freyberg.sfr.out.process
2019-05-01 16:58:13.968418 finished: instantiating control file from i/o files took: 0:00:00.38
2019-05-01 16:58:14.228120 starting: writing forward_run.py
2019-05-01 16:58:14.229068 finished: writing forward_run.py took: 0:00:00.000948
2019-05-01 16:58:14.229497 writing pst template/freyberg.pst
2019-05-01 16:58:16.128739 starting: running pestchek on freyberg.pst
2019-05-01 16:58:16.242738 pestcheck:PESTCHEK Version 13.0. Watermark Numerical Computing.
2019-05-01 16:58:16.243156 pestcheck:
2019-05-01 16:58:16.243225 pestcheck:Errors ----->
2019-05-01 16:58:16.243675 pestcheck:Line 2403 of file freyberg.pst: parameter name "prsity300
2019-05-01 16:58:16.243749 pestcheck:12 characters long.
2019-05-01 16:58:16.243795 pestcheck:Line 2404 of file freyberg.pst: parameter name "prsity300
2019-05-01 16:58:16.244139 pestcheck:12 characters long.
2019-05-01 16:58:16.244196 pestcheck:Line 2404 of file freyberg.pst: parameter name "prsity300
2019-05-01 16:58:16.244422 pestcheck:once.
2019-05-01 16:58:16.244480 pestcheck:Line 2405 of file freyberg.pst: parameter name "prsity300
2019-05-01 16:58:16.244519 pestcheck:12 characters long.
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2019-05-01 16:58:16.244560 pestcheck:Line 2405 of file freyberg.pst: parameter name "prsity300
2019-05-01 16:58:16.244596 pestcheck:once.
2019-05-01 16:58:16.244971 pestcheck:Line 2406 of file freyberg.pst: parameter name "prsity300
2019-05-01 16:58:16.245622 pestcheck:12 characters long.
2019-05-01 16:58:16.245683 pestcheck:Line 2406 of file freyberg.pst: parameter name "prsity300
2019-05-01 16:58:16.245723 pestcheck:once.
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2019-05-01 16:58:16.246635 pestcheck:once.
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2019-05-01 16:58:16.251232 pestcheck:once.
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2019-05-01 16:58:16.252740 pestcheck:Line 2424 of file freyberg.pst: parameter name "prsity3001
2019-05-01 16:58:16.252790 pestcheck:12 characters long.
2019-05-01 16:58:16.252896 pestcheck:Line 2424 of file freyberg.pst: parameter name "prsity3001
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2019-05-01 16:58:16.273667 pestcheck:Line 2477 of file freyberg.pst: parameter name "prsity3003
2019-05-01 16:58:16.273715 pestcheck:once.
2019-05-01 16:58:16.273821 pestcheck:Line 2478 of file freyberg.pst: parameter name "prsity3003
2019-05-01 16:58:16.273928 pestcheck:12 characters long.
2019-05-01 16:58:16.274045 pestcheck:Line 2478 of file freyberg.pst: parameter name "prsity3003
2019-05-01 16:58:16.274155 pestcheck:once.
2019-05-01 16:58:16.274278 pestcheck:Line 2479 of file freyberg.pst: parameter name "prsity3003
2019-05-01 16:58:16.274387 pestcheck:12 characters long.
2019-05-01 16:58:16.274438 pestcheck:Line 2479 of file freyberg.pst: parameter name "prsity3003
2019-05-01 16:58:16.274547 pestcheck:once.
2019-05-01 16:58:16.274654 pestcheck:Line 2480 of file freyberg.pst: parameter name "prsity3003
2019-05-01 16:58:16.274775 pestcheck:12 characters long.
2019-05-01 16:58:16.274883 pestcheck:Line 2480 of file freyberg.pst: parameter name "prsity3003
2019-05-01 16:58:16.274934 pestcheck:once.
```

```
2019-05-01 16:58:16.275043 pestcheck:Line 2481 of file freyberg.pst: parameter name "prsity3003
2019-05-01 16:58:16.275095 pestcheck:12 characters long.
2019-05-01 16:58:16.275215 pestcheck:Line 2481 of file freyberg.pst: parameter name "prsity3003
2019-05-01 16:58:16.275399 pestcheck:once.
2019-05-01 16:58:16.275507 pestcheck:Line 2482 of file freyberg.pst: parameter name "prsity3003
2019-05-01 16:58:16.275593 pestcheck:12 characters long.
2019-05-01 16:58:16.275633 pestcheck:Line 2482 of file freyberg.pst: parameter name "prsity3003
2019-05-01 16:58:16.275683 pestcheck:once.
2019-05-01 16:58:16.275788 pestcheck:Line 2483 of file freyberg.pst: parameter name "prsity3004
2019-05-01 16:58:16.275840 pestcheck:12 characters long.
2019-05-01 16:58:16.275941 pestcheck:Line 2484 of file freyberg.pst: parameter name "prsity3004
2019-05-01 16:58:16.276058 pestcheck:12 characters long.
2019-05-01 16:58:16.276164 pestcheck:Line 2484 of file freyberg.pst: parameter name "prsity3004
2019-05-01 16:58:16.276211 pestcheck:once.
2019-05-01 16:58:16.276370 pestcheck:Line 2485 of file freyberg.pst: parameter name "prsity3004
2019-05-01 16:58:16.276463 pestcheck:12 characters long.
2019-05-01 16:58:16.276512 pestcheck:Line 2485 of file freyberg.pst: parameter name "prsity3004
2019-05-01 16:58:16.276553 pestcheck:once.
2019-05-01 16:58:16.276653 pestcheck:Line 2486 of file freyberg.pst: parameter name "prsity3004
2019-05-01 16:58:16.277381 pestcheck:12 characters long.
2019-05-01 16:58:16.277894 pestcheck:Line 2486 of file freyberg.pst: parameter name "prsity3004
2019-05-01 16:58:16.278011 pestcheck:once.
2019-05-01 16:58:16.278123 pestcheck:Line 2487 of file freyberg.pst: parameter name "prsity3004
2019-05-01 16:58:16.278176 pestcheck:12 characters long.
2019-05-01 16:58:16.278285 pestcheck:Line 2487 of file freyberg.pst: parameter name "prsity3004
2019-05-01 16:58:16.278393 pestcheck:once.
2019-05-01 16:58:16.278516 pestcheck:Line 2488 of file freyberg.pst: parameter name "prsity3004
2019-05-01 16:58:16.278625 pestcheck:12 characters long.
2019-05-01 16:58:16.278676 pestcheck:Line 2488 of file freyberg.pst: parameter name "prsity3004
2019-05-01 16:58:16.278720 pestcheck:once.
2019-05-01 16:58:16.278824 pestcheck:Line 2489 of file freyberg.pst: parameter name "prsity3004
2019-05-01 16:58:16.278932 pestcheck:12 characters long.
2019-05-01 16:58:16.278983 pestcheck:Line 2489 of file freyberg.pst: parameter name "prsity3004
2019-05-01 16:58:16.279103 pestcheck:once.
2019-05-01 16:58:16.279208 pestcheck:Line 2490 of file freyberg.pst: parameter name "prsity3004
2019-05-01 16:58:16.279258 pestcheck:12 characters long.
2019-05-01 16:58:16.279327 pestcheck:Line 2490 of file freyberg.pst: parameter name "prsity3004
2019-05-01 16:58:16.279355 pestcheck:once.
2019-05-01 16:58:16.279413 pestcheck:Line 2491 of file freyberg.pst: parameter name "prsity3004
2019-05-01 16:58:16.279447 pestcheck:12 characters long.
2019-05-01 16:58:16.279507 pestcheck:Line 2491 of file freyberg.pst: parameter name "prsity3004
2019-05-01 16:58:16.279540 pestcheck:once.
2019-05-01 16:58:16.279655 pestcheck:Line 2492 of file freyberg.pst: parameter name "prsity3004
2019-05-01 16:58:16.279689 pestcheck:12 characters long.
2019-05-01 16:58:16.279739 pestcheck:Line 2492 of file freyberg.pst: parameter name "prsity3004
2019-05-01 16:58:16.279772 pestcheck:once.
2019-05-01 16:58:16.279889 pestcheck:Line 2493 of file freyberg.pst: parameter name "prsity3004
2019-05-01 16:58:16.279942 pestcheck:12 characters long.
```

```
2019-05-01 16:58:16.279976 pestcheck:Line 2494 of file freyberg.pst: parameter name "prsity3004
2019-05-01 16:58:16.280025 pestcheck:12 characters long.
2019-05-01 16:58:16.280059 pestcheck:Line 2494 of file freyberg.pst: parameter name "prsity3004
2019-05-01 16:58:16.280103 pestcheck:once.
2019-05-01 16:58:16.280136 pestcheck:Line 2495 of file freyberg.pst: parameter name "prsity3004
2019-05-01 16:58:16.280177 pestcheck:12 characters long.
2019-05-01 16:58:16.280250 pestcheck:Line 2495 of file freyberg.pst: parameter name "prsity3004
2019-05-01 16:58:16.280285 pestcheck:once.
2019-05-01 16:58:16.280404 pestcheck:Line 2496 of file freyberg.pst: parameter name "prsity3004
2019-05-01 16:58:16.280443 pestcheck:12 characters long.
2019-05-01 16:58:16.280475 pestcheck:Line 2496 of file freyberg.pst: parameter name "prsity3004
2019-05-01 16:58:16.280524 pestcheck:once.
2019-05-01 16:58:16.280628 pestcheck:Line 2497 of file freyberg.pst: parameter name "prsity3004
2019-05-01 16:58:16.280676 pestcheck:12 characters long.
2019-05-01 16:58:16.280714 pestcheck:Line 2497 of file freyberg.pst: parameter name "prsity3004
2019-05-01 16:58:16.280820 pestcheck:once.
2019-05-01 16:58:16.280872 pestcheck:Line 2498 of file freyberg.pst: parameter name "prsity3004
2019-05-01 16:58:16.280970 pestcheck:12 characters long.
2019-05-01 16:58:16.281017 pestcheck:Line 2498 of file freyberg.pst: parameter name "prsity3004
2019-05-01 16:58:16.281058 pestcheck:once.
2019-05-01 16:58:16.281161 pestcheck:Line 2499 of file freyberg.pst: parameter name "prsity3004
2019-05-01 16:58:16.281266 pestcheck:12 characters long.
2019-05-01 16:58:16.281316 pestcheck:Line 2499 of file freyberg.pst: parameter name "prsity3004
2019-05-01 16:58:16.281421 pestcheck:once.
2019-05-01 16:58:16.281641 pestcheck:Line 2500 of file freyberg.pst: parameter name "prsity3004
2019-05-01 16:58:16.281744 pestcheck:12 characters long.
2019-05-01 16:58:16.281859 pestcheck:Line 2500 of file freyberg.pst: parameter name "prsity3004
2019-05-01 16:58:16.281962 pestcheck:once.
2019-05-01 16:58:16.282009 pestcheck:Line 2501 of file freyberg.pst: parameter name "prsity3004
2019-05-01 16:58:16.282116 pestcheck:12 characters long.
2019-05-01 16:58:16.282221 pestcheck:Line 2501 of file freyberg.pst: parameter name "prsity3004
2019-05-01 16:58:16.282307 pestcheck:once.
2019-05-01 16:58:16.282390 pestcheck:Line 2502 of file freyberg.pst: parameter name "prsity3004
2019-05-01 16:58:16.282477 pestcheck:12 characters long.
2019-05-01 16:58:16.282577 pestcheck:Line 2502 of file freyberg.pst: parameter name "prsity3004
2019-05-01 16:58:16.282644 pestcheck:once.
2019-05-01 16:58:16.282708 pestcheck:Line 2503 of file freyberg.pst: parameter name "prsity3005
2019-05-01 16:58:16.282772 pestcheck:12 characters long.
2019-05-01 16:58:16.282867 pestcheck:Line 2504 of file freyberg.pst: parameter name "prsity3005
2019-05-01 16:58:16.282933 pestcheck:12 characters long.
2019-05-01 16:58:16.282997 pestcheck:Line 2504 of file freyberg.pst: parameter name "prsity3005
2019-05-01 16:58:16.283063 pestcheck:once.
2019-05-01 16:58:16.283108 pestcheck:Line 2505 of file freyberg.pst: parameter name "prsity3005
2019-05-01 16:58:16.283167 pestcheck:12 characters long.
2019-05-01 16:58:16.283235 pestcheck:Line 2505 of file freyberg.pst: parameter name "prsity3005
2019-05-01 16:58:16.283370 pestcheck:once.
2019-05-01 16:58:16.283513 pestcheck:Line 2506 of file freyberg.pst: parameter name "prsity3005
2019-05-01 16:58:16.283573 pestcheck:12 characters long.
```

```
2019-05-01 16:58:16.283677 pestcheck:Line 2506 of file freyberg.pst: parameter name "prsity300!
2019-05-01 16:58:16.283750 pestcheck:once.
2019-05-01 16:58:16.283883 pestcheck:Line 2507 of file freyberg.pst: parameter name "prsity300!
2019-05-01 16:58:16.284035 pestcheck:12 characters long.
2019-05-01 16:58:16.284123 pestcheck:Line 2507 of file freyberg.pst: parameter name "prsity300!
2019-05-01 16:58:16.284275 pestcheck:once.
2019-05-01 16:58:16.284341 pestcheck:Line 2508 of file freyberg.pst: parameter name "prsity300!
2019-05-01 16:58:16.284428 pestcheck:12 characters long.
2019-05-01 16:58:16.284706 finished: running pestchek on freyberg.pst took: 0:00:00.155967
2019-05-01 16:58:16.284842 starting: saving intermediate _setup_<> dfs into template
2019-05-01 16:58:16.437144 finished: saving intermediate _setup_<> dfs into template took: 0:00
2019-05-01 16:58:16.437414 all done
```

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

```
In [14]: pst = pst_helper.pst
         pst.npar,pst.nobs
```

```
Out[14]: (14819, 4434)
```

Oh snap!

1.0.4   Add modpath input files, instruction files and calls

```
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']
```

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

```
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
```

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

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

1.0.5 Final bits and bobs

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

```
In [19]: par = pst.parameter_data
         # properties
         tag_dict = {"hk":[0.1,10.0],"vka":[0.1,10],"strt":[0.95,1.05],"prsity":[0.1,1.0]}
         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 uniform recharge mult
         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
         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

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

```
Out[20]:                       type transform  count      initial value  \
         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	-1	0.25
cn_prsity7	0	-1	0.25
cn_prsity8	0	-1	0.25
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	-1	0.25
gr_prsity4	0	-1	0.25
gr_prsity5	0	-1	0.25
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	-1	0.25
pp_prsity1	0	-1	0.25
pp_prsity2	0	-1	0.25
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 [21]: pst.write_obs_summary_table(filename="none")

Out[21]:                 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
```

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

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

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

```
2019-05-01 16:58:26.160856 starting: building prior covariance matrix
2019-05-01 16:58:26.282218 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

2019-05-01 16:58:33.165912 saving prior covariance matrix to file template/prior_cov.jcb
2019-05-01 16:58:37.665756 finished: building prior covariance matrix took: 0:00:11.504900
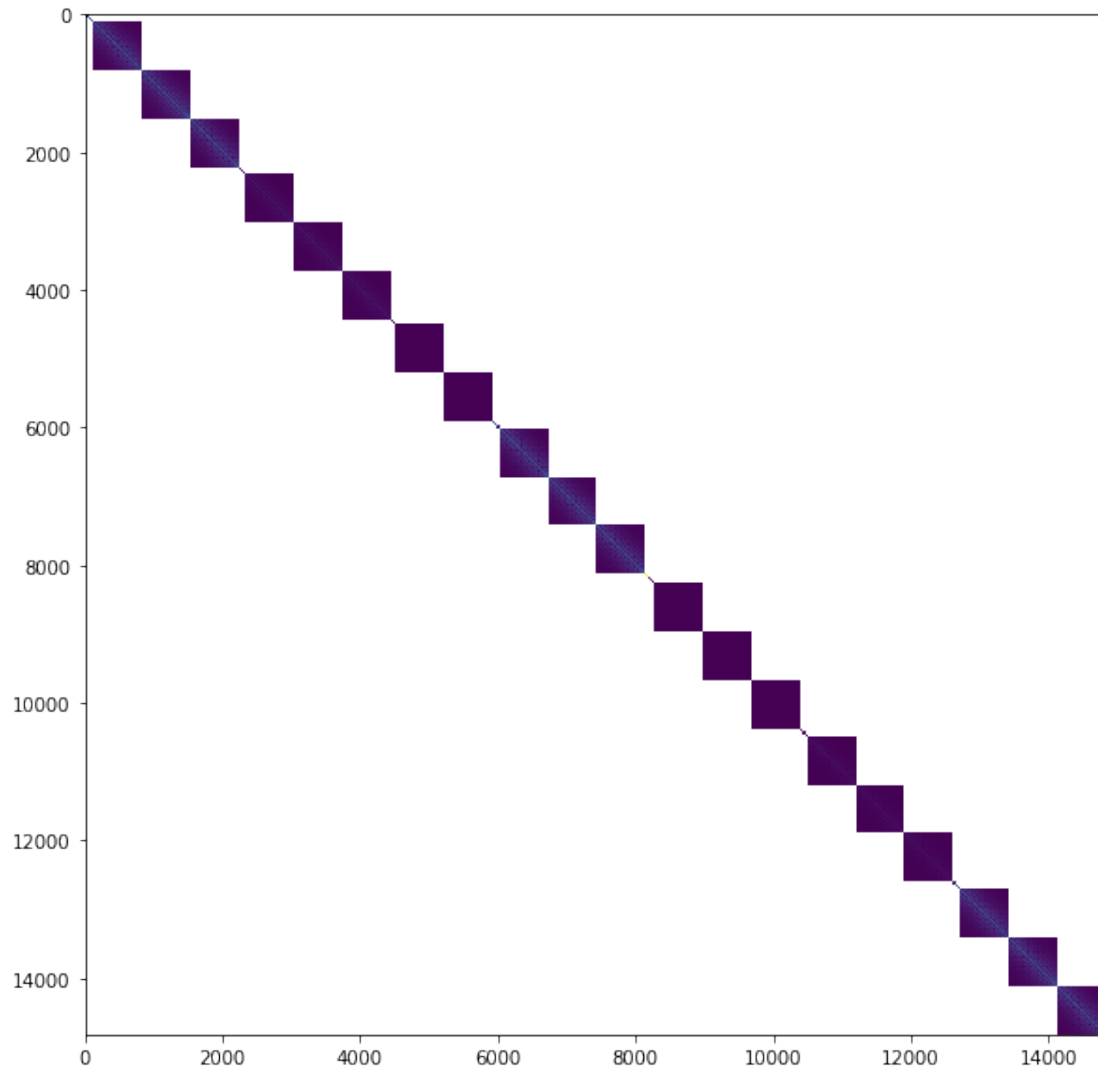
In [24]: pe = pst_helper.draw(200)

2019-05-01 16:58:56.034763 starting: drawing realizations
building diagonal cov
processing name:struct1,nugget:0.0,structures:
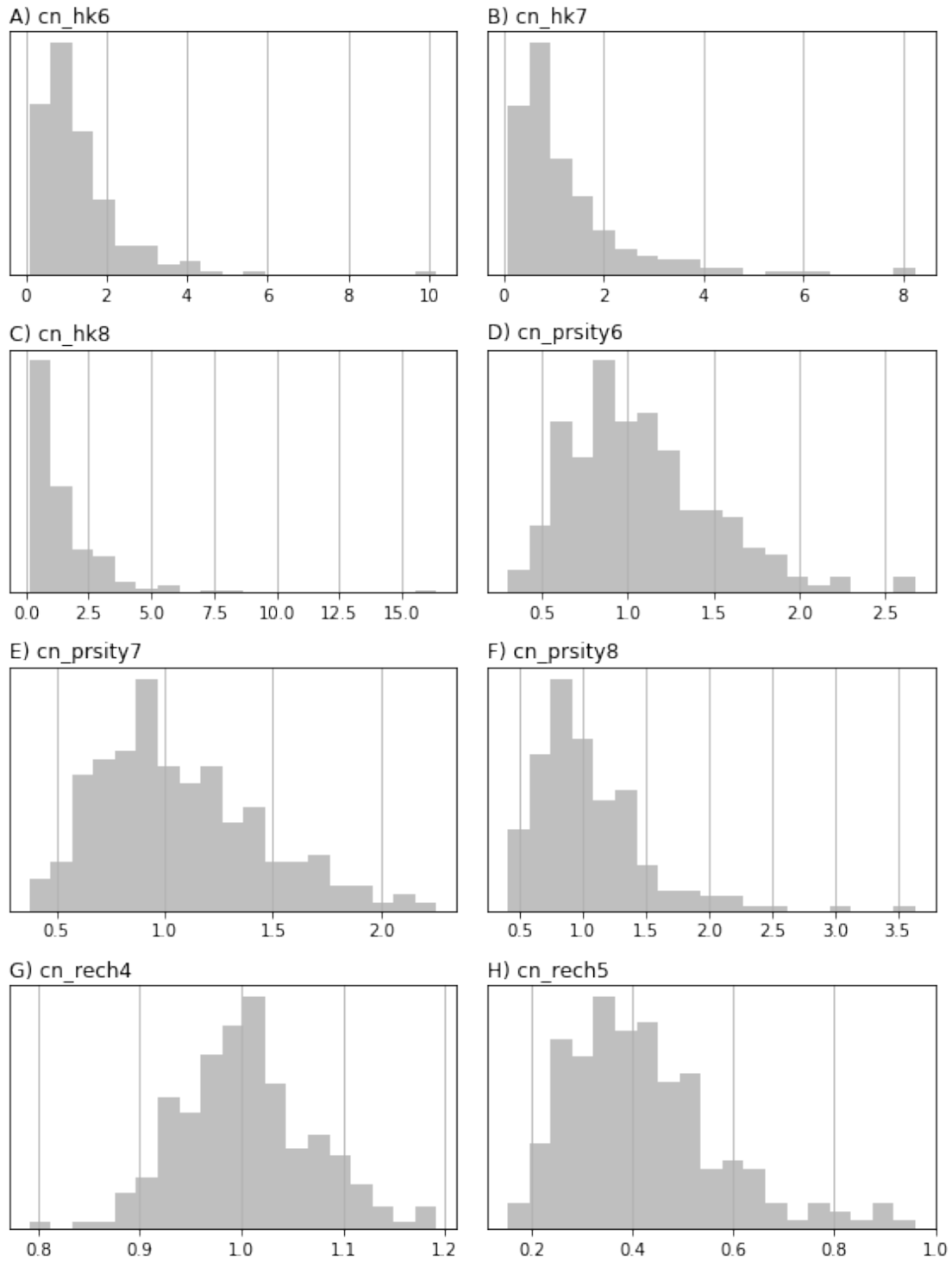name:var1,contribution:1.0,a:1000.0,anisotropy:1.0,bearing:0.0

```
working on pargroups ['pp_hk0']
build cov matrix
done
getting diag var cov 32
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['pp_vka0']
build cov matrix
done
getting diag var cov 32
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['pp_ss0']
build cov matrix
done
getting diag var cov 32
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['pp_sy0']
build cov matrix
done
getting diag var cov 32
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['pp_strt0']
build cov matrix
done
getting diag var cov 32
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['pp_prsity0']
build cov matrix
done
getting diag var cov 32
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['pp_rech0']
build cov matrix
done
getting diag var cov 32
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['pp_rech1']
build cov matrix
done
getting diag var cov 32
scaling full cov by diag var cov
making full cov draws with home-grown goodness
```

```
working on pargroups ['pp_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_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_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_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_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_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_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_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_hk2']
build cov matrix
done
getting diag var cov 32
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['pp_vka2']
build cov matrix
done
getting diag var cov 32
scaling full cov by diag var cov
making full cov draws with home-grown goodness
processing  name:struct1,nugget:0.0,structures:
name:var1,contribution:1.0,a:2500.0,anisotropy:1.0,bearing:0.0

working on pargroups ['gr_hk3']
build cov matrix
done
getting diag var cov 705
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['gr_vka3']
build cov matrix
done
getting diag var cov 705
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['gr_ss3']
build cov matrix
done
getting diag var cov 705
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['gr_sy3']
build cov matrix
done
```

```
getting diag var cov 705
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['gr_strt3']
build cov matrix
done
getting diag var cov 705
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['gr_prsity3']
build cov matrix
done
getting diag var cov 705
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['gr_hk4']
build cov matrix
done
getting diag var cov 705
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['gr_vka4']
build cov matrix
done
getting diag var cov 705
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['gr_ss4']
build cov matrix
done
getting diag var cov 705
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['gr_sy4']
build cov matrix
done
getting diag var cov 705
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['gr_strt4']
build cov matrix
done
getting diag var cov 705
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['gr_prsity4']
build cov matrix
done
```

```
getting diag var cov 705
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['gr_hk5']
build cov matrix
done
getting diag var cov 705
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['gr_vka5']
build cov matrix
done
getting diag var cov 705
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['gr_ss5']
build cov matrix
done
getting diag var cov 705
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['gr_sy5']
build cov matrix
done
getting diag var cov 705
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['gr_strt5']
build cov matrix
done
getting diag var cov 705
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['gr_prsity5']
build cov matrix
done
getting diag var cov 705
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['gr_rech2']
build cov matrix
done
getting diag var cov 705
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['gr_rech3']
build cov matrix
done
```

```
getting diag var cov 705
scaling full cov by diag var cov
making full cov draws with home-grown goodness
processing  name:struct1,nugget:0.0,structures:
name:var1,contribution:1.0,a:2500.0,anisotropy:1.0,bearing:0.0

working on pargroups ['drncond_k00']


/Users/jeremyw/miniconda3/lib/python3.5/site-packages/pandas/core/indexing.py:362: 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 10
scaling full cov by diag var cov
making full cov draws with home-grown goodness
working on pargroups ['welflux_k02']
build cov matrix
done
getting diag var cov 6
scaling full cov by diag var cov
making full cov draws with home-grown goodness
processing  name:struct1,nugget:0.0,structures:
name:var1,contribution:1.0,a:180.0,anisotropy:1.0,bearing:0.0

working on pargroups ['welflux']
build cov matrix
done
getting diag var cov 2
scaling full cov by diag var cov
making full cov draws with home-grown goodness
adding remaining parameters to diagonal
2019-05-01 16:59:04.492316 finished: drawing realizations took: 0:00:08.457553
```

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

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

<Figure size 576x756 with 0 Axes>

A) cn_hk6

B) cn_hk7

C) cn_hk8

D) cn_prsity6

E) cn_prsity7

F) cn_prsity8

G) cn_rech4

H) cn_rech5
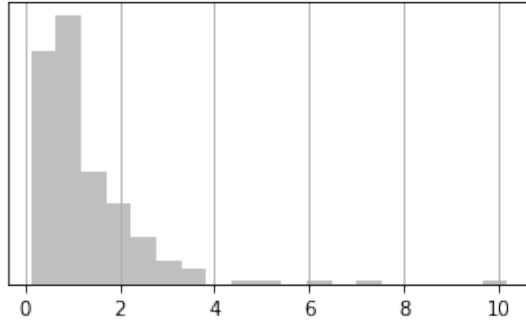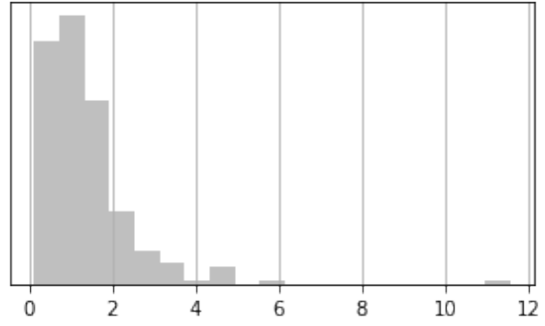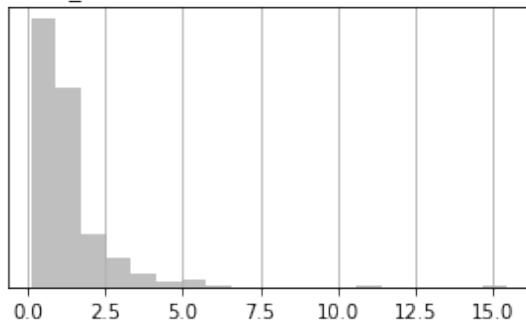
A) cn_ss6   B) cn_ss7   C) cn_ss8   D) cn_strt6   E) cn_strt7   F) cn_strt8   G) cn_sy6   H) cn_sy7
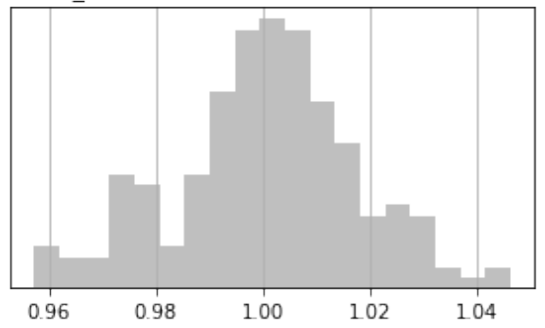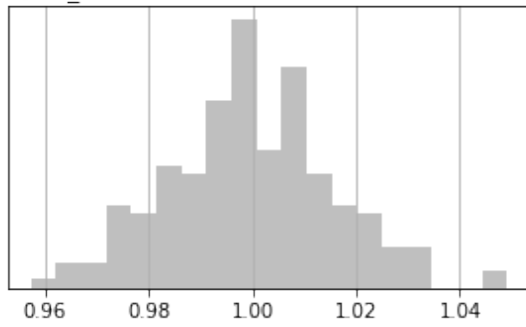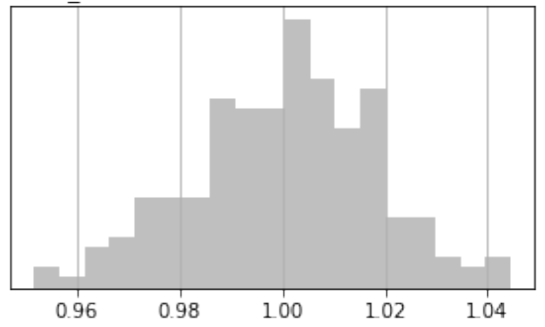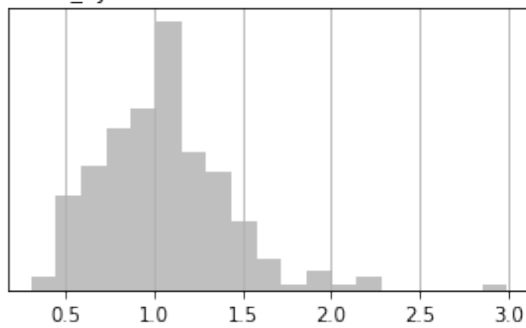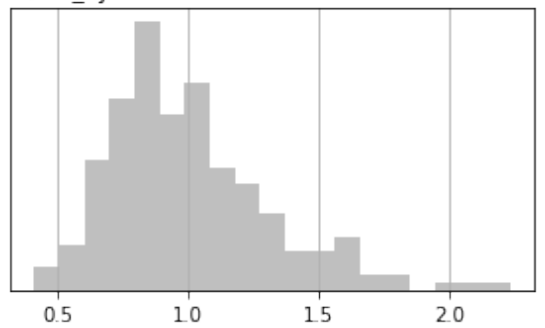
A) cn_sy8
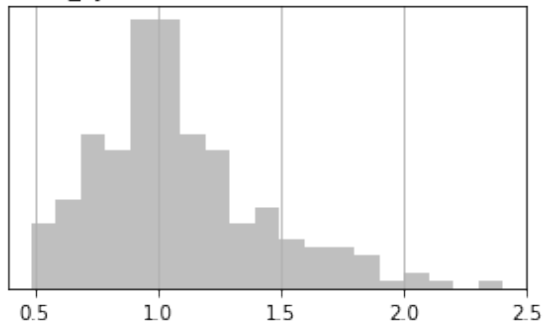
B) cn_vka6
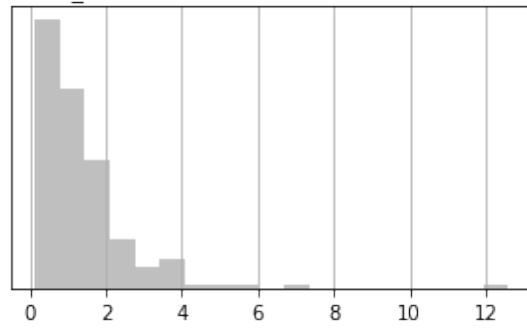
C) cn_vka7
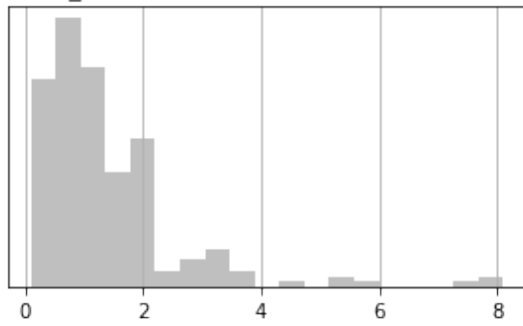
D) cn_vka8
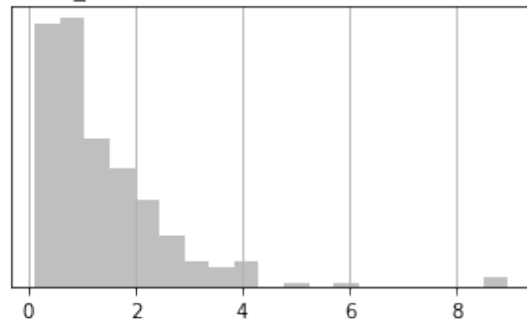
E) drncond_k00
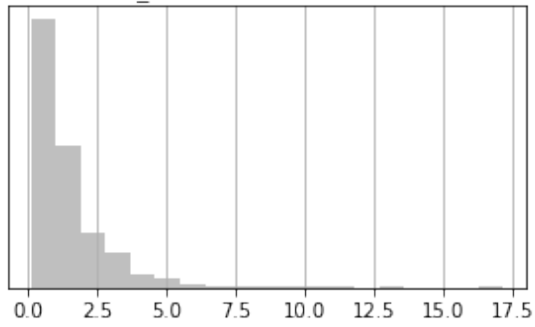
F) flow
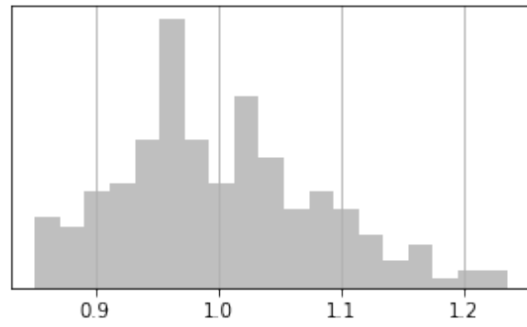
G) gr_hk3
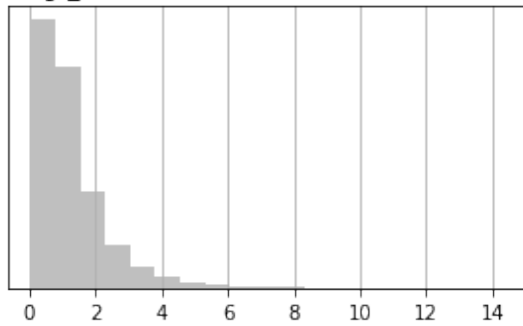
H) gr_hk4
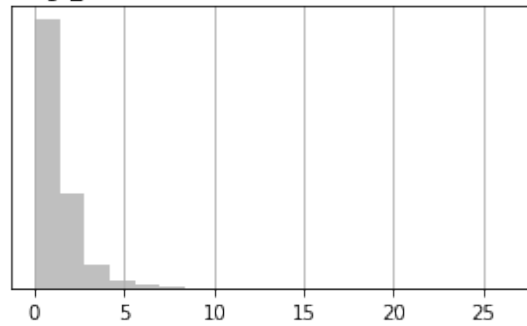
A) gr_hk5
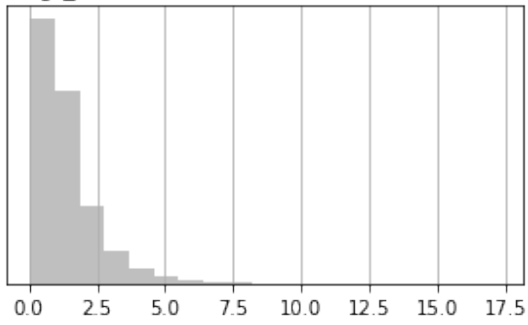
B) gr_prsity3
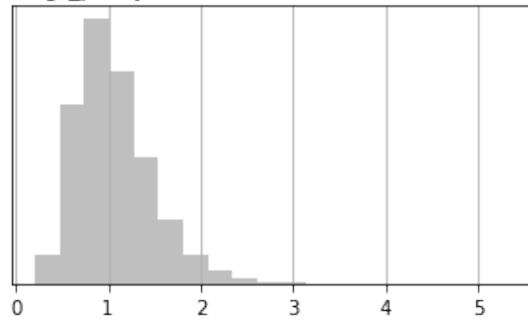
C) gr_prsity4
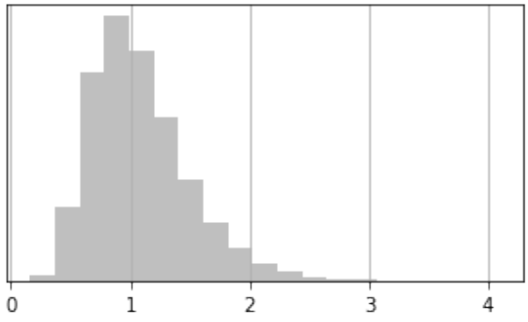
D) gr_prsity5
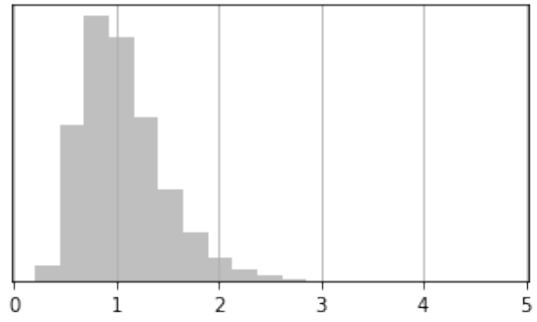
E) gr_rech2
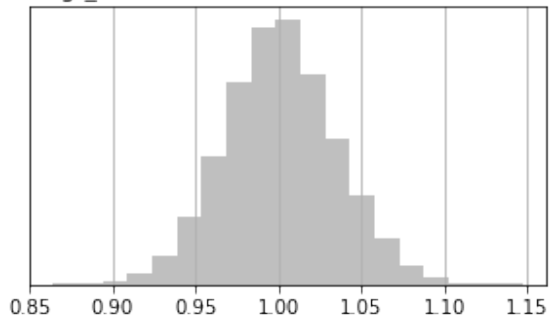
F) gr_rech3
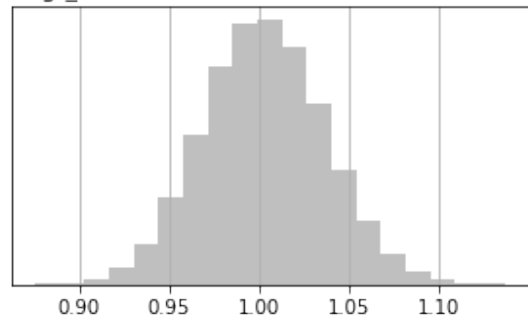
G) gr_ss3
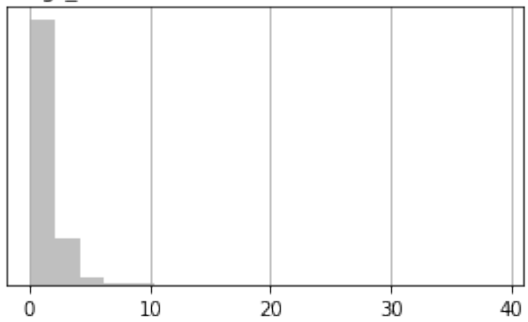
H) gr_ss4
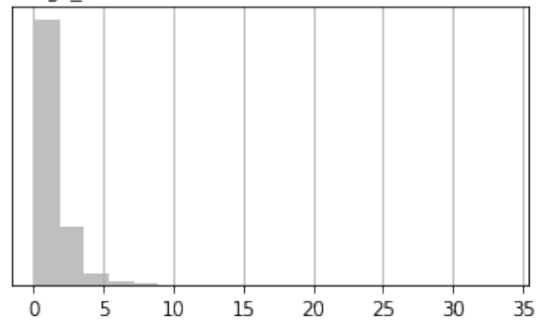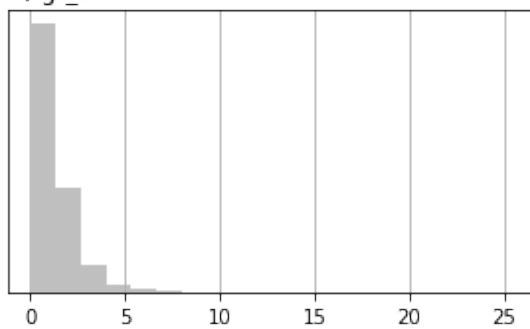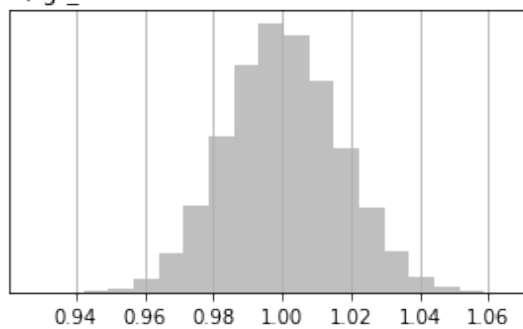
A) gr_ss5
B) gr_strt3
C) gr_strt4
D) gr_strt5
E) gr_sy3
F) gr_sy4
G) gr_sy5
H) gr_vka3
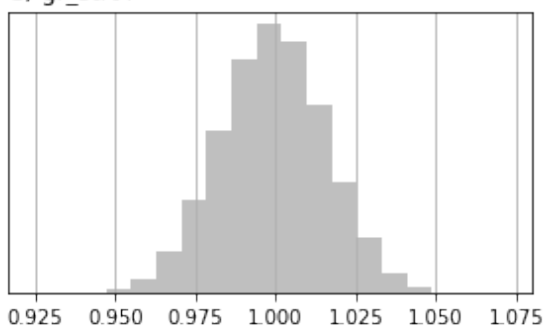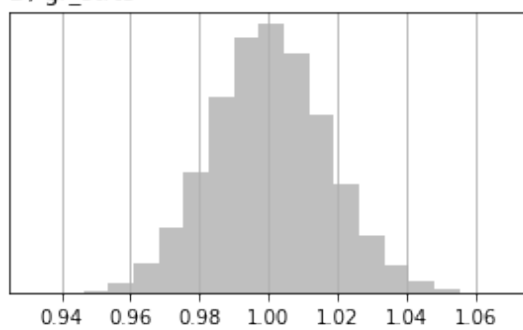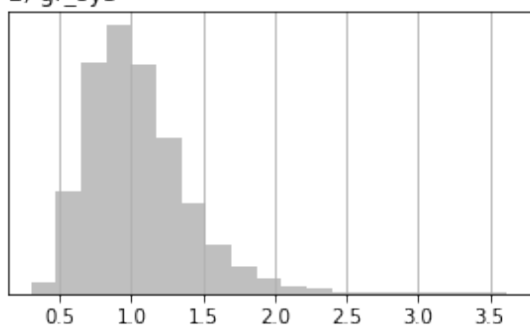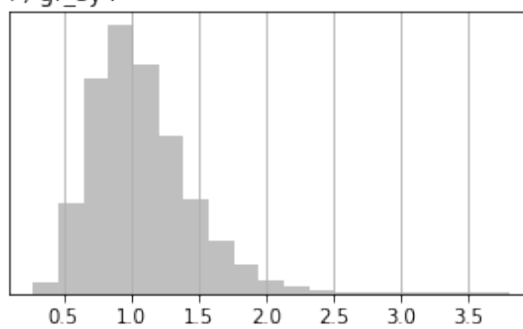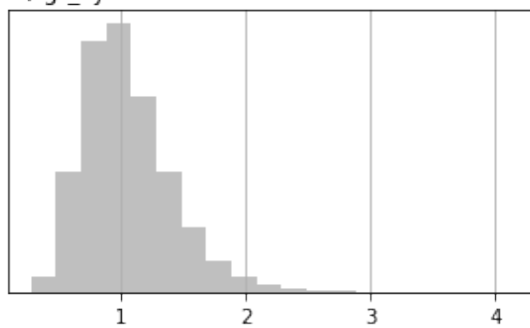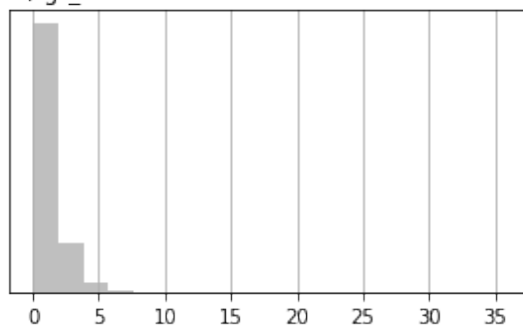
A) gr_vka4
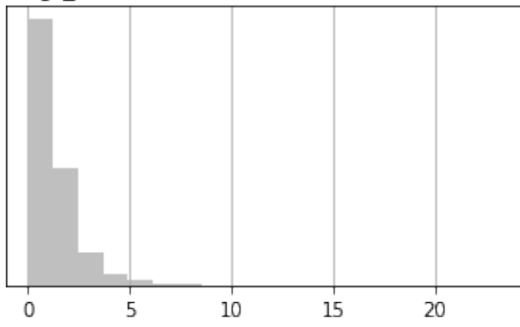
B) gr_vka5
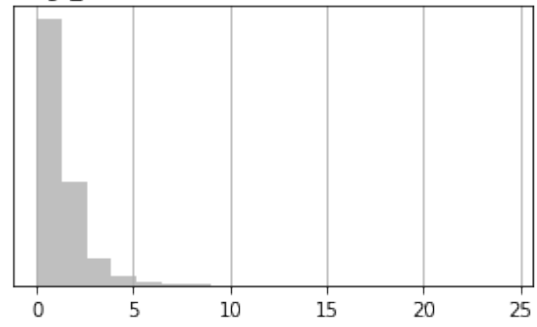
C) pp_hk0
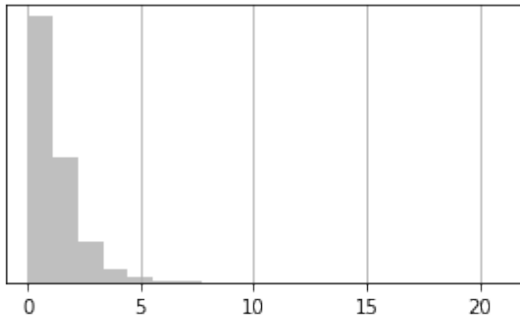
D) pp_hk1
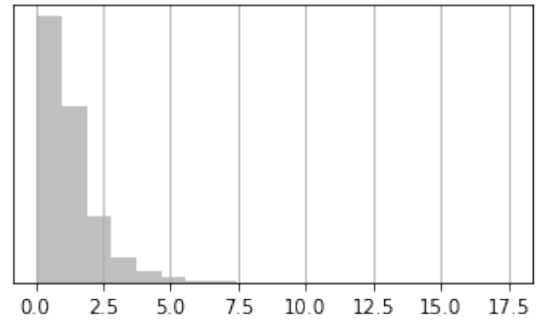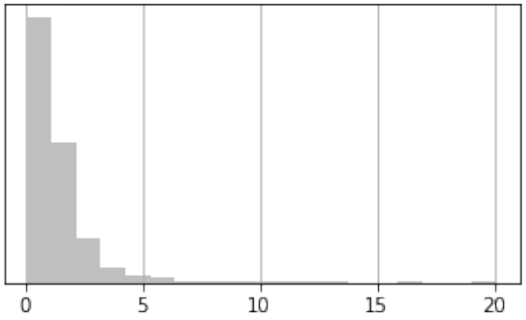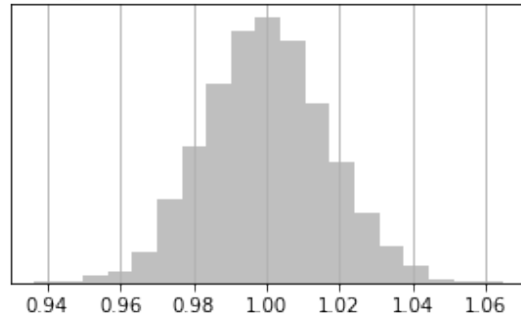
E) pp_hk2
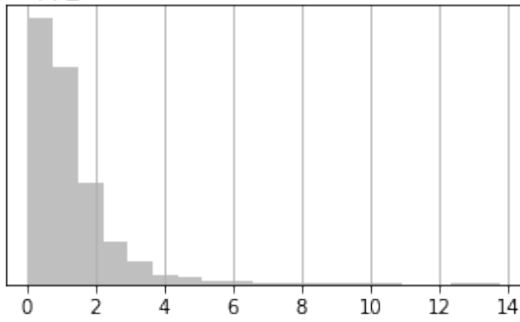
F) pp_prsity0
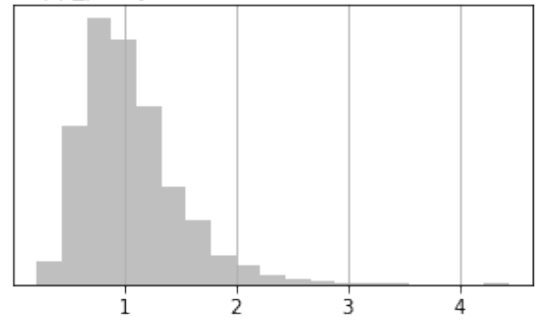
G) pp_prsity1
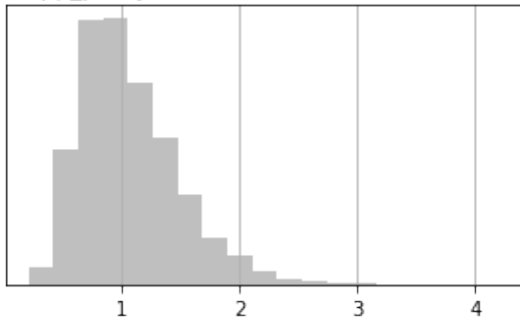
H) pp_prsity2
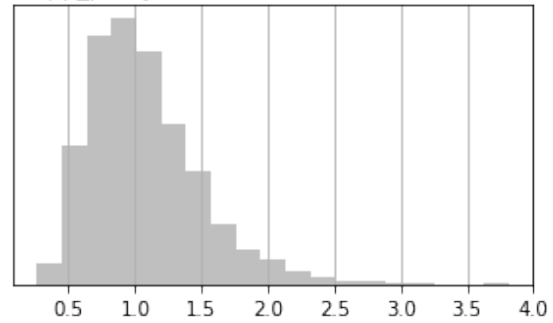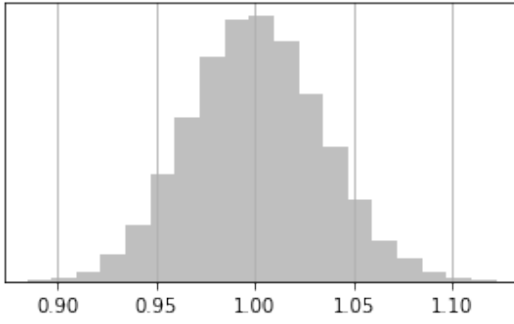
A) pp_rech0   B) pp_rech1
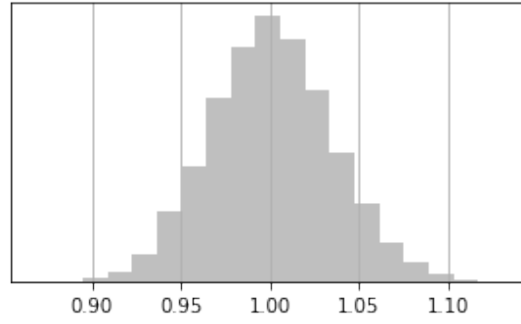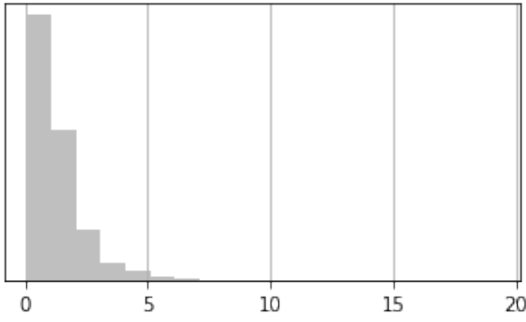
C) pp_ss0   D) pp_ss1
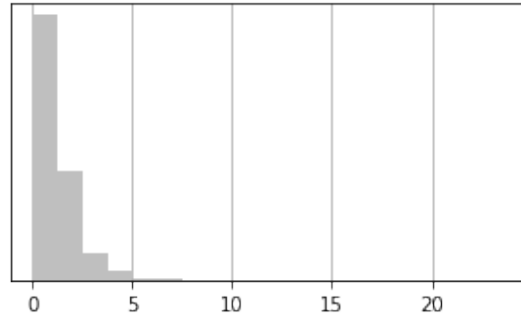
E) pp_ss2   F) pp_strt0

G) pp_strt1   H) pp_strt2

A) pp_sy0

B) pp_sy1

C) pp_sy2

D) pp_vka0

E) pp_vka1

F) pp_vka2

G) strk

H) welflux
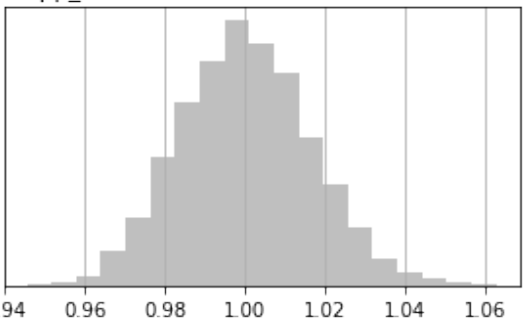
A) welflux_k02
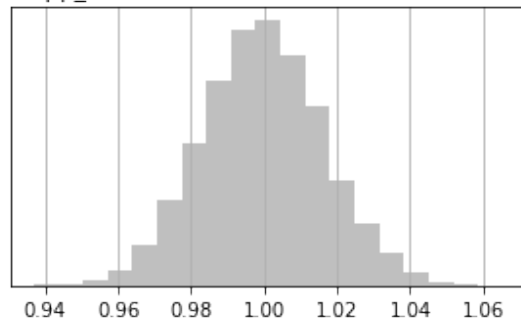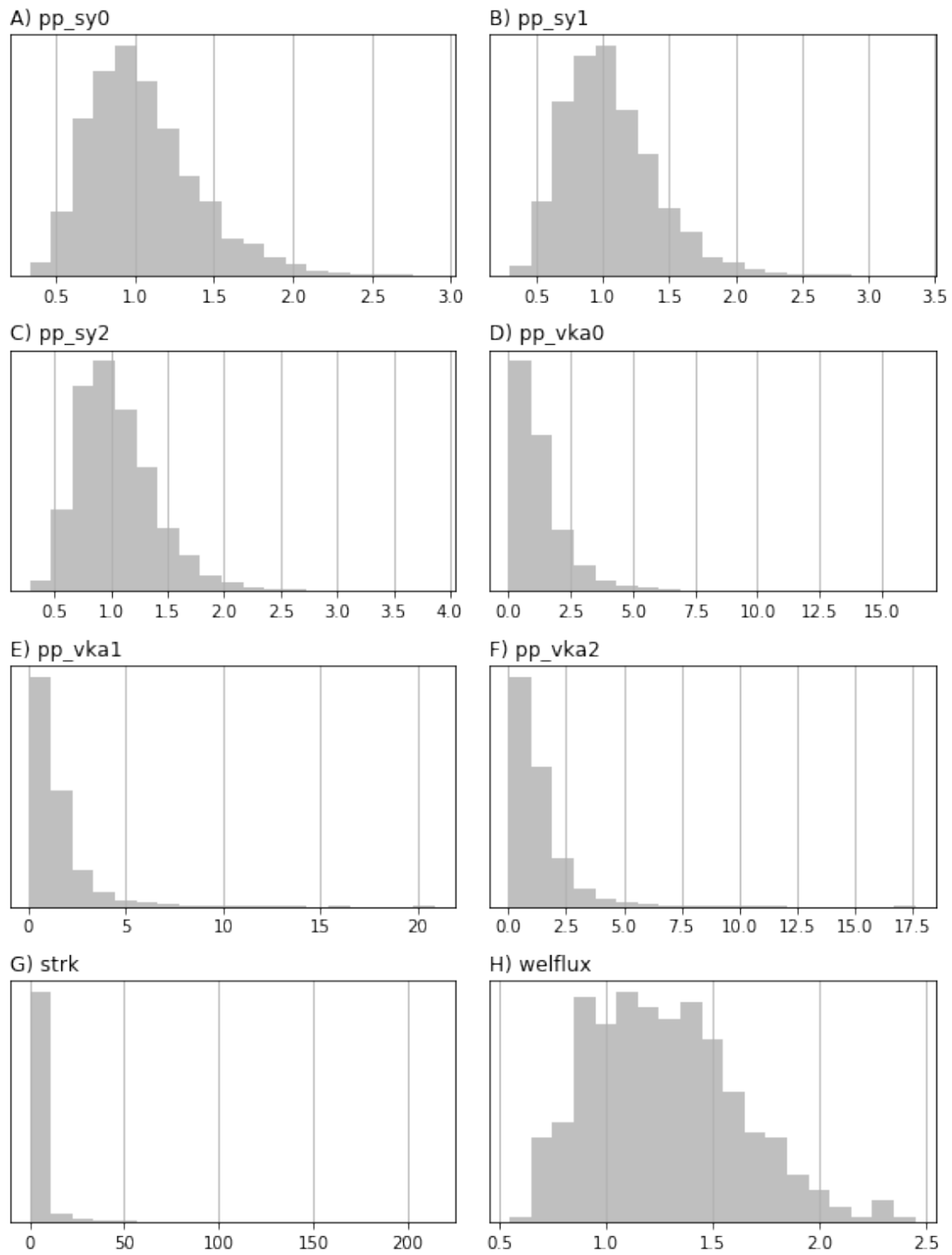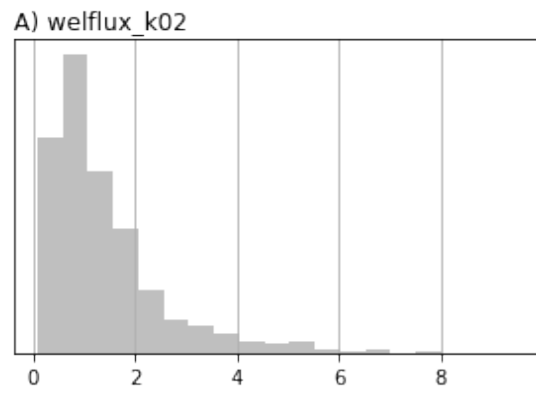

Now we need to enforce parameter bounds and save this ensemble for later

```
In [26]: pe.enforce()
         pe.to_binary(os.path.join(pst_helper.new_model_ws,"prior.jcb"))
```

1.0.6 set weights for "observations" and identify forecasts

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

```
In [27]: obs_locs = pd.read_csv(os.path.join("..","base_model_files","obs_loc.csv"))
         if pst_helper.m.nrow != 40:
             obs_locs.loc[:,"row"] = (obs_locs.row * redis_fac) + int(redis_fac / 2.0)
             obs_locs.loc[:,"col"] = (obs_locs.col * redis_fac) + int(redis_fac / 2.0)
         #build obs names that correspond to the obsnme values in the control file
         obs_locs.loc[:,"obsnme"] = obs_locs.apply(lambda x: "hds_00_{0:03d}_{1:03d}_000".forma
         obs_locs
```

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

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

```
In [28]: obs = pst.observation_data
         obs.loc[:,"weight"] = 0.0
         obs.loc[obs_locs.obsnme,"weight"] = 1.0
         obs.loc[obs_locs.obsnme,"obgnme"] = "calhead"
         fo_obs = "fo_{0}_19791230".format(pst_helper.m.nrow-1)
         obs.loc[fo_obs,"weight"] = 1.0
         obs.loc[fo_obs,"obgnme"] = "calflux"
         pst.nnz_obs_names
```

```
Out[28]: ['fo_39_19791230',
          'hds_00_002_009_000',
          'hds_00_002_015_000',
          'hds_00_003_008_000',
          'hds_00_009_001_000',
          'hds_00_013_010_000',
          'hds_00_015_016_000',
```

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

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

```
In [29]: swgw_forecasts = obs.loc[obs.obsnme.apply(lambda x: "fa" in x and ("hw" in x or "tw" :
         print(swgw_forecasts)
         hds_fore_name = "hds_00_{0:03d}_{1:03d}".format(int(pst_helper.m.nrow/3),int(pst_help
         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']
```

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

```
In [30]: pyemu.os_utils.run("pestpp-ies.exe freyberg.pst",cwd=pst_helper.new_model_ws)
         pst = pyemu.Pst(os.path.join(pst_helper.new_model_ws,"freyberg.pst"))
         pst.phi

Out[30]: 9.456182577320024e-19

In [31]: lst = flopy.utils.MfListBudget(os.path.join("template","freyberg.list"))
         df = lst.get_dataframes(diff=True)[0]
         df.plot(kind="bar",figsize=(10,10))

Out[31]: <matplotlib.axes._subplots.AxesSubplot at 0x181c0a2470>
```
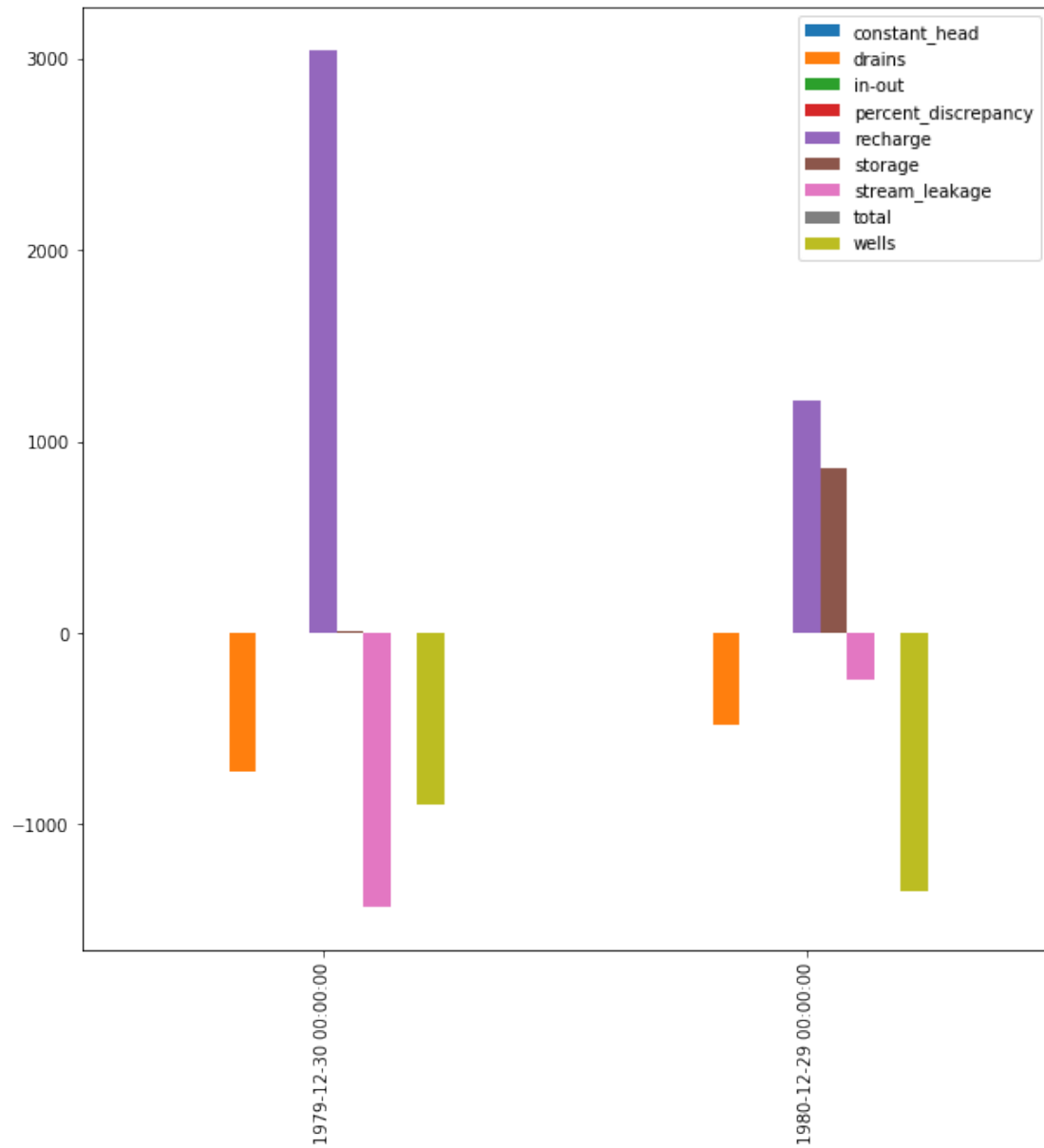
We see the effect of our parameterized scenario - a large drop in recharge and more abstraction.