pestpp-ies

June 5, 2019

1 Run PESTPP-IES

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

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

1.1 SUPER IMPORTANT: SET HOW MANY PARALLEL WORKERS TO USE

```
In [2]: num_workers = 20
```

```
In [3]: t_d = "template"
        m_d = "master_ies"
```

```
In [4]: pst = pyemu.Pst(os.path.join(t_d,"freyberg.pst"))
        pst.write_par_summary_table(filename="none")
```

Out[4]:

	type	transform	count	initial value	\
cn_sy8	cn_sy8	log	1	0	
gr_strt3	gr_strt3	log	705	0	
pp_strt1	pp_strt1	log	32	0	
gr_hk5	gr_hk5	log	705	0	
cn_vka8	cn_vka8	log	1	0	
pp_hk2	pp_hk2	log	32	0	
cn_rech4	cn_rech4	log	1	0	
gr_hk3	gr_hk3	log	705	0	
cn_vka6	cn_vka6	log	1	0	
welflux_k02	welflux_k02	log	6	0	

pp_vka2	pp_vka2	log	32	0
cn_sy6	cn_sy6	log	1	0
cn_prsity8	cn_prsity8	log	1	0
pp_rech0	pp_rech0	log	32	0
gr_prsity5	gr_prsity5	log	705	0
strk	strk	log	40	0
gr_prsity3	gr_prsity3	log	705	0
gr_sy4	gr_sy4	log	705	0
gr_strt4	gr_strt4	log	705	0
gr_ss3	gr_ss3	log	705	0
pp_rech1	pp_rech1	log	32	0
pp_ss0	pp_ss0	log	32	0
cn_sy7	cn_sy7	log	1	0
gr_ss5	gr_ss5	log	705	0
gr_vka3	gr_vka3	log	705	0
cn_rech5	cn_rech5	log	1	-0.39794
pp_sy0	pp_sy0	log	32	0
cn_hk8	cn_hk8	log	1	0
flow	flow	log	1	0
gr_sy3	gr_sy3	log	705	0
...	...	...	...	...
pp_prsity2	pp_prsity2	log	32	0
cn_prsity6	cn_prsity6	log	1	0
cn_ss6	cn_ss6	log	1	0
pp_hk1	pp_hk1	log	32	0
gr_strt5	gr_strt5	log	705	0
cn_ss8	cn_ss8	log	1	0
cn_hk6	cn_hk6	log	1	0
cn_hk7	cn_hk7	log	1	0
cn_strt8	cn_strt8	log	1	0
pp_hk0	pp_hk0	log	32	0
cn_strt6	cn_strt6	log	1	0
gr_prsity4	gr_prsity4	log	705	0
cn_vka7	cn_vka7	log	1	0
pp_vka1	pp_vka1	log	32	0
cn_prsity7	cn_prsity7	log	1	0
pp_strt0	pp_strt0	log	32	0
gr_sy5	gr_sy5	log	705	0
welflux	welflux	log	2	0 to 0.176091
pp_vka0	pp_vka0	log	32	0
gr_ss4	gr_ss4	log	705	0
gr_rech3	gr_rech3	log	705	0
cn_ss7	cn_ss7	log	1	0
drncond_k00	drncond_k00	log	10	0
pp_prsity1	pp_prsity1	log	32	0
pp_ss1	pp_ss1	log	32	0
pp_ss2	pp_ss2	log	32	0
pp_sy1	pp_sy1	log	32	0

cn_strt7	cn_strt7	log	1	0	
gr_hk4	gr_hk4	log	705	0	
gr_rech2	gr_rech2	log	705	0	

	upper bound	lower bound	standard deviation
cn_sy8	0.243038	-0.60206	0.211275
gr_strt3	0.0211893	-0.0222764	0.0108664
pp_strt1	0.0211893	-0.0222764	0.0108664
gr_hk5	1	-1	0.5
cn_vka8	1	-1	0.5
pp_hk2	1	-1	0.5
cn_rech4	0.0791812	-0.09691	0.0440228
gr_hk3	1	-1	0.5
cn_vka6	1	-1	0.5
welflux_k02	1	-1	0.5
pp_vka2	1	-1	0.5
cn_sy6	0.243038	-0.60206	0.211275
cn_prsity8	0.176091	-0.30103	0.11928
pp_rech0	0.0413927	-0.0457575	0.0217875
gr_prsity5	0.176091	-0.30103	0.11928
strk	2	-2	1
gr_prsity3	0.176091	-0.30103	0.11928
gr_sy4	0.243038	-0.60206	0.211275
gr_strt4	0.0211893	-0.0222764	0.0108664
gr_ss3	1	-1	0.5
pp_rech1	0.0413927	-0.0457575	0.0217875
pp_ss0	1	-1	0.5
cn_sy7	0.243038	-0.60206	0.211275
gr_ss5	1	-1	0.5
gr_vka3	1	-1	0.5
cn_rech5	-0.09691	-1	0.225772
pp_sy0	0.243038	-0.60206	0.211275
cn_hk8	1	-1	0.5
flow	0.09691	-0.124939	0.0554622
gr_sy3	0.243038	-0.60206	0.211275
...	...	...	...
pp_prsity2	0.176091	-0.30103	0.11928
cn_prsity6	0.176091	-0.30103	0.11928
cn_ss6	1	-1	0.5
pp_hk1	1	-1	0.5
gr_strt5	0.0211893	-0.0222764	0.0108664
cn_ss8	1	-1	0.5
cn_hk6	1	-1	0.5
cn_hk7	1	-1	0.5
cn_strt8	0.0211893	-0.0222764	0.0108664
pp_hk0	1	-1	0.5
cn_strt6	0.0211893	-0.0222764	0.0108664
gr_prsity4	0.176091	-0.30103	0.11928

```
cn_vka7                      1               -1                 0.5
pp_vka1                      1               -1                 0.5
cn_prsity7            0.176091         -0.30103             0.11928
pp_strt0              0.0211893        -0.0222764           0.0108664
gr_sy5                 0.243038          -0.60206            0.211275
welflux      0.176091 to 0.30103  -0.30103 to     0  0.0752575 to 0.11928
pp_vka0                      1               -1                 0.5
gr_ss4                       1               -1                 0.5
gr_rech3              0.0413927        -0.0457575           0.0217875
cn_ss7                       1               -1                 0.5
drncond_k00                  1               -1                 0.5
pp_prsity1            0.176091         -0.30103             0.11928
pp_ss1                       1               -1                 0.5
pp_ss2                       1               -1                 0.5
pp_sy1                 0.243038          -0.60206            0.211275
cn_strt7              0.0211893        -0.0222764           0.0108664
gr_hk4                       1               -1                 0.5
gr_rech2              0.0413927        -0.0457575           0.0217875

[65 rows x 7 columns]
```

Should we fix either PP or grids?

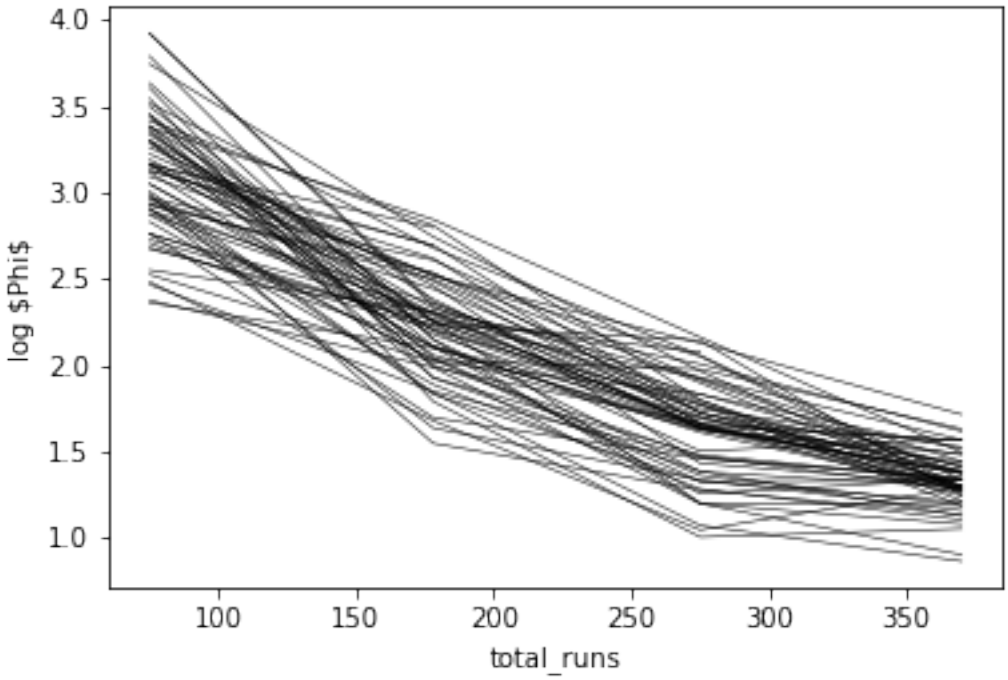
```
In [5]: par = pst.parameter_data
        # grid pars
        #should_fix = par.loc[par.pargp.apply(lambda x: "gr" in x),"parnme"]
        # pp pars
        #should_fix = par.loc[par.pargp.apply(lambda x: "pp" in x),"parnme"]

        # if we want to fix some pars, do it here
        #pst.parameter_data.loc[should_fix,"partrans"] = "fixed"
        #pst.npar,pst.npar_adj
```

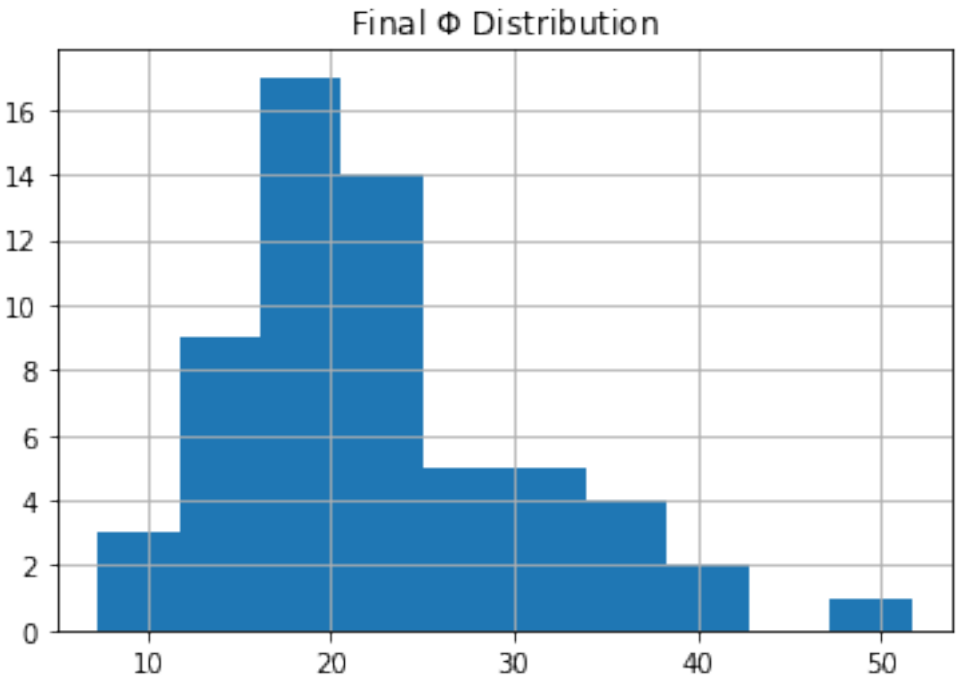
1.1.1 Run PESTPP-IES in original mode and post process

```
In [6]: #pst.pestpp_options = {}
        pst.pestpp_options["ies_num_reals"] = 75
        pst.pestpp_options["ies_par_en"] = "prior.jcb"
        pst.pestpp_options["ies_bad_phi_sigma"] = 1.75
        pst.pestpp_options["overdue_giveup_fac"] = 10.0
        pst.control_data.noptmax = 3

In [7]: pst.write(os.path.join(t_d,"freyberg_ies.pst"))

noptmax:3, npar_adj:14819, nnz_obs:14


In [8]: pyemu.os_utils.start_slaves(t_d,"pestpp-ies","freyberg_ies.pst",num_slaves=num_workers
```

A cheap phi progress plot

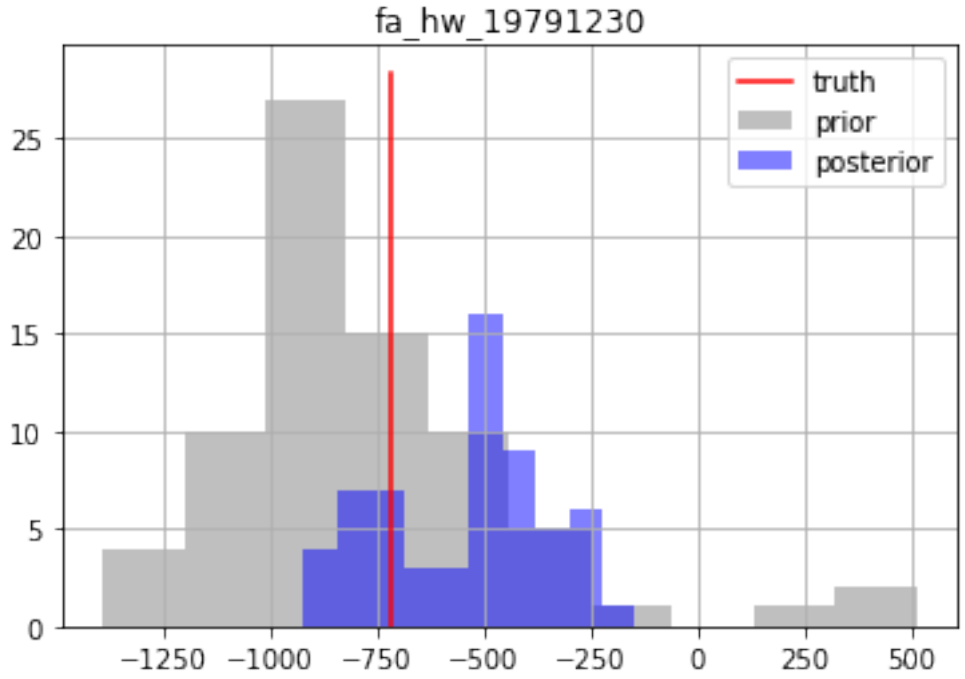
```
In [9]: phi = pd.read_csv(os.path.join(m_d,"freyberg_ies.phi.actual.csv"),index_col=0)
        phi.index = phi.total_runs
        phi.iloc[:,6:].apply(np.log10).plot(legend=False,lw=0.5,color='k')
        plt.ylabel('log \$Phi$')
        plt.figure()
        phi.iloc[-1,6:].hist()
        plt.title('Final $\Phi$ Distribution');
```

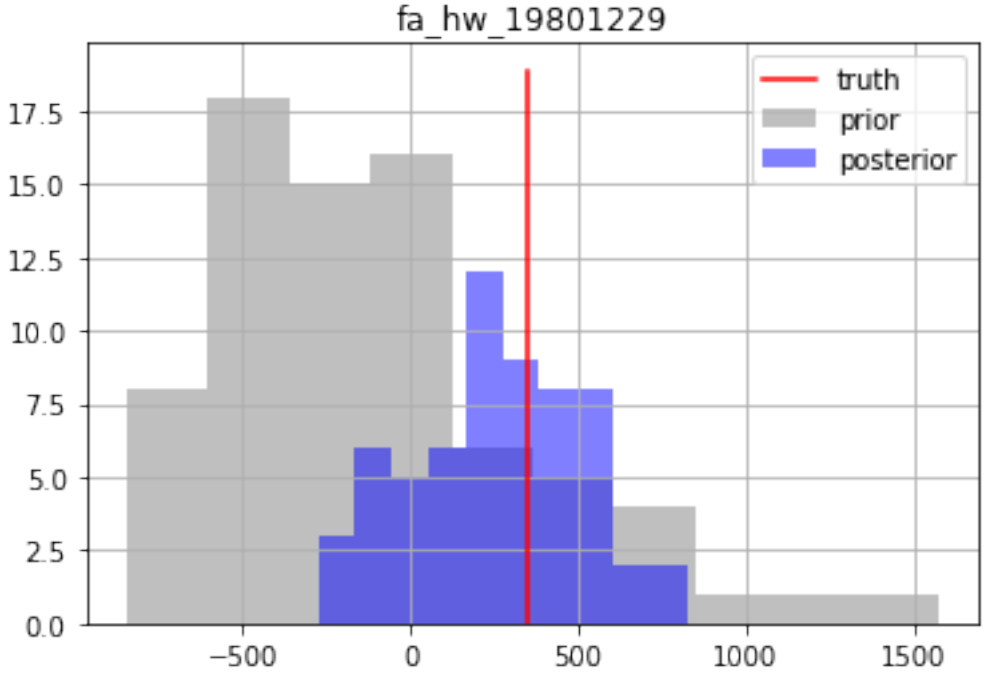


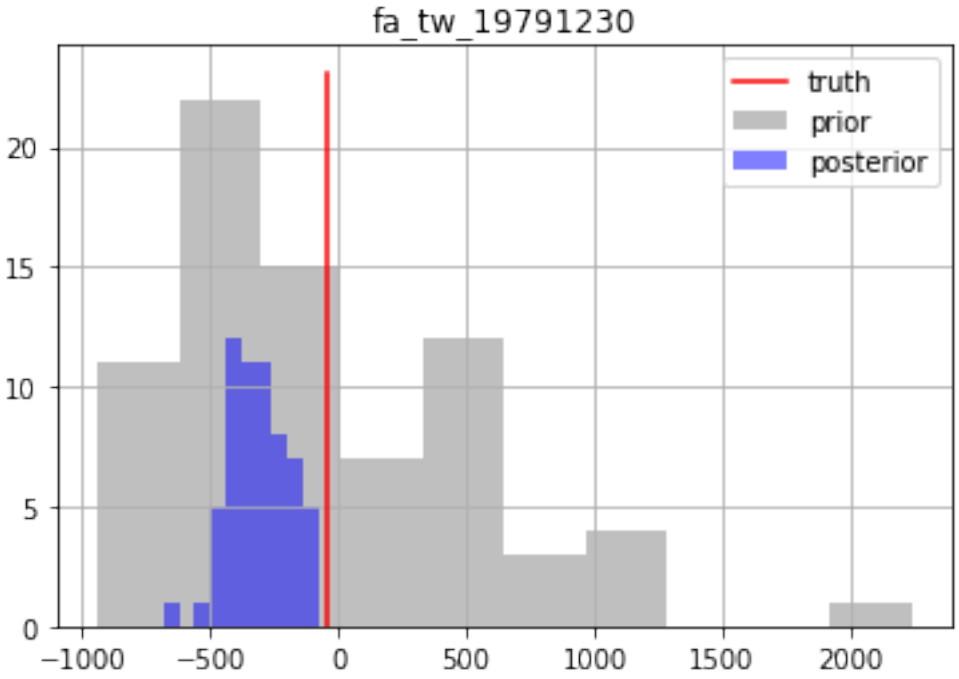


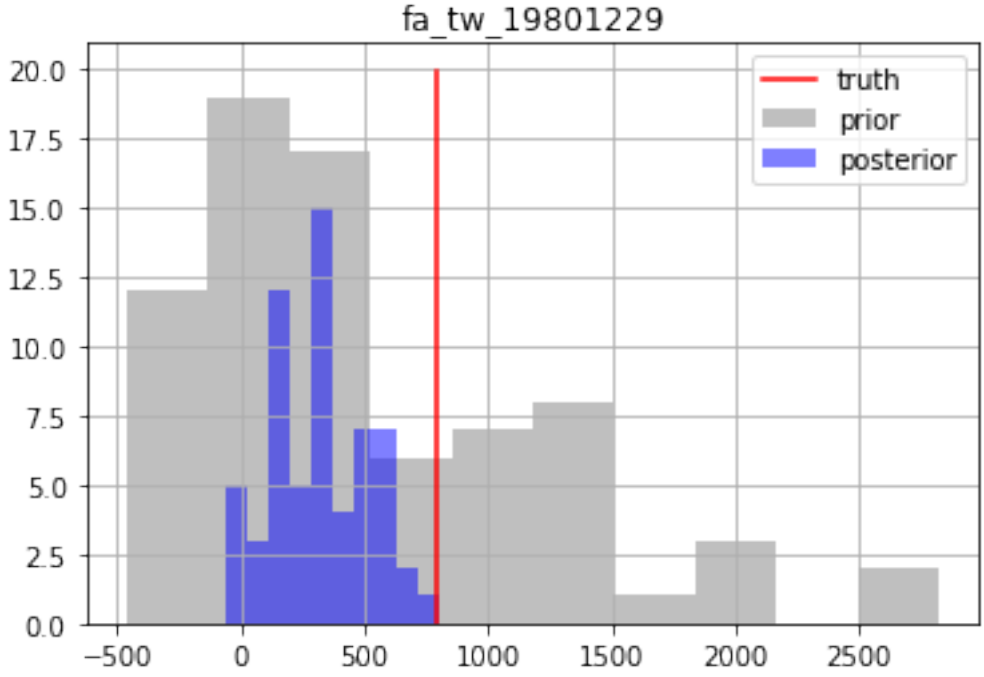
Plot forecast prior and posterior histograms with "truth" (red line)

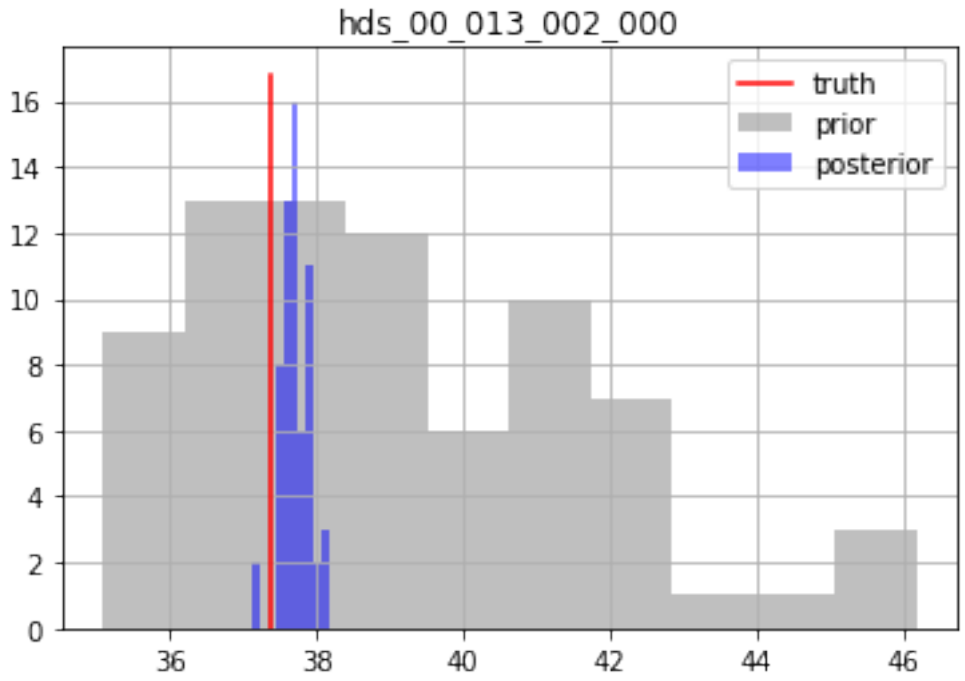
```
In [10]: oe_pr = pd.read_csv(os.path.join(m_d,"freyberg_ies.0.obs.csv"),index_col=0)
         oe_pt = pd.read_csv(os.path.join(m_d,"freyberg_ies.{0}.obs.csv".format(pst.control_dat
         obs = pst.observation_data
         fnames = pst.pestpp_options["forecasts"].split(",")
         for forecast in fnames:
             ax = plt.subplot(111)
             oe_pr.loc[:,forecast].hist(ax=ax,color="0.5",alpha=0.5, label='prior')
             oe_pt.loc[:,forecast].hist(ax=ax,color="b",alpha=0.5, label='posterior')
             ax.plot([obs.loc[forecast,"obsval"],obs.loc[forecast,"obsval"]],ax.get_ylim(),"r"
             ax.set_title(forecast)
             ax.legend(loc='upper right')
             plt.show()
```

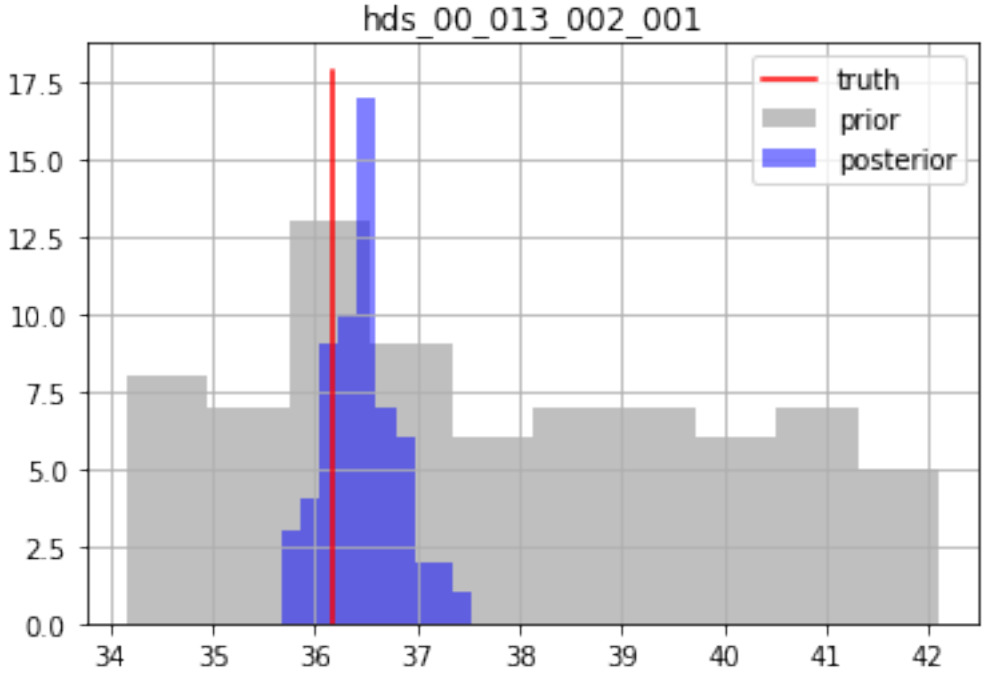

fa_hw_19791230
truth
prior
posterior
25
20
15
10
5
0
−1250
−1000
−750
−500
−250
0
250
500

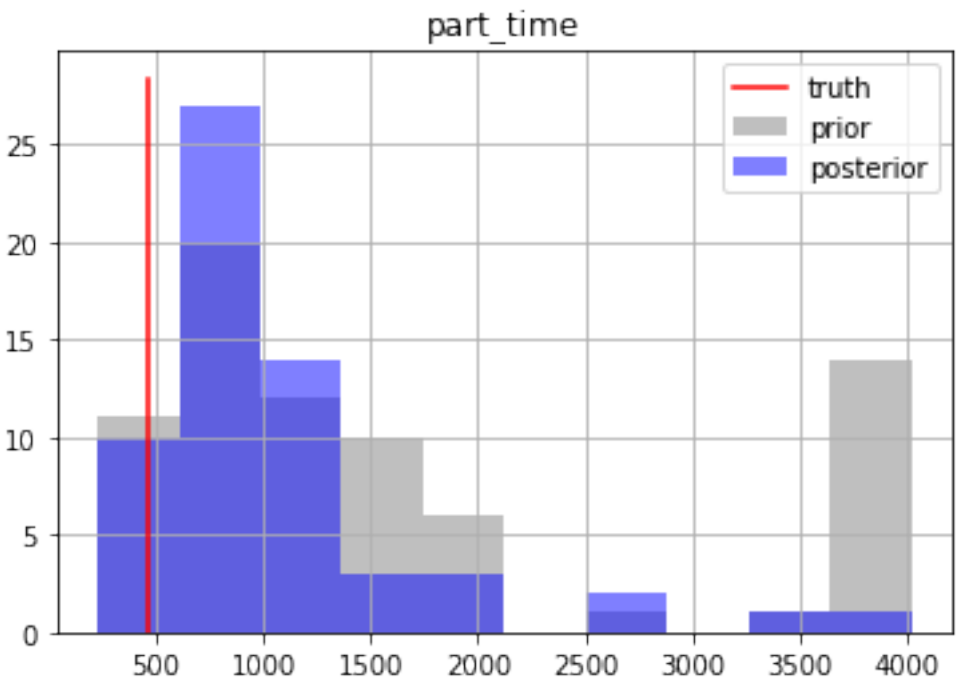

fa_hw_19801229
truth
prior
posterior
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0.0
−500
0
500
1000
1500

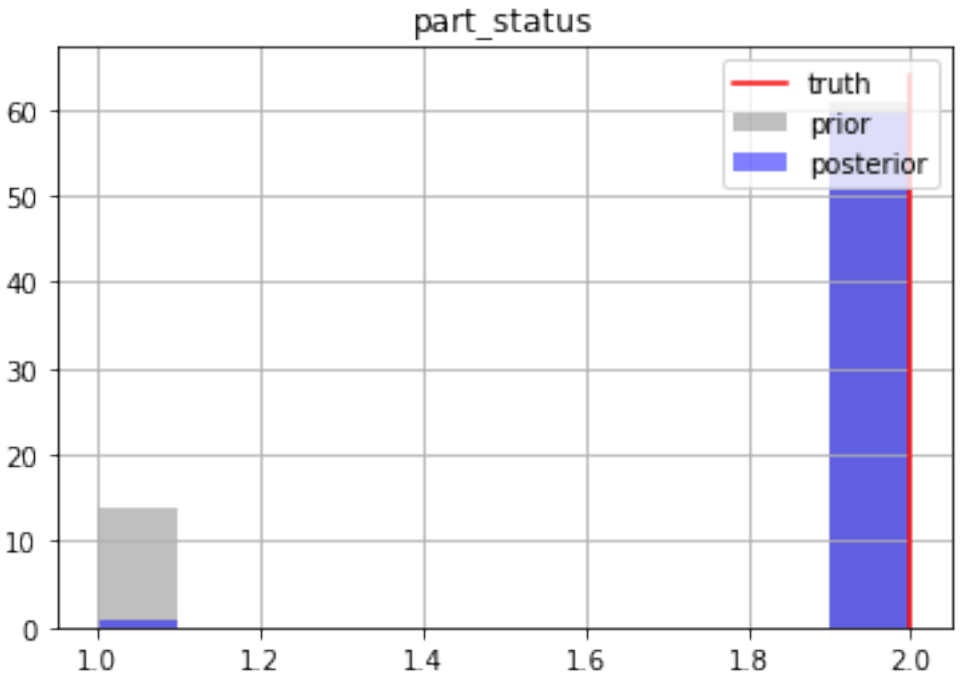

fa_tw_19791230
truth
prior
posterior
20
15
10
5
0
−1000
−500
0
500
1000
1500
2000


fa_tw_19801229
truth
prior
posterior
20.0
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0.0
−500
0
500
1000
1500
2000
2500


hds_00_013_002_000
truth
prior
posterior
0
2
4
6
8
10
12
14
16
36
38
40
42
44
46


hds_00_013_002_001
truth
prior
posterior
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
34
35
36
37
38
39
40
41
42



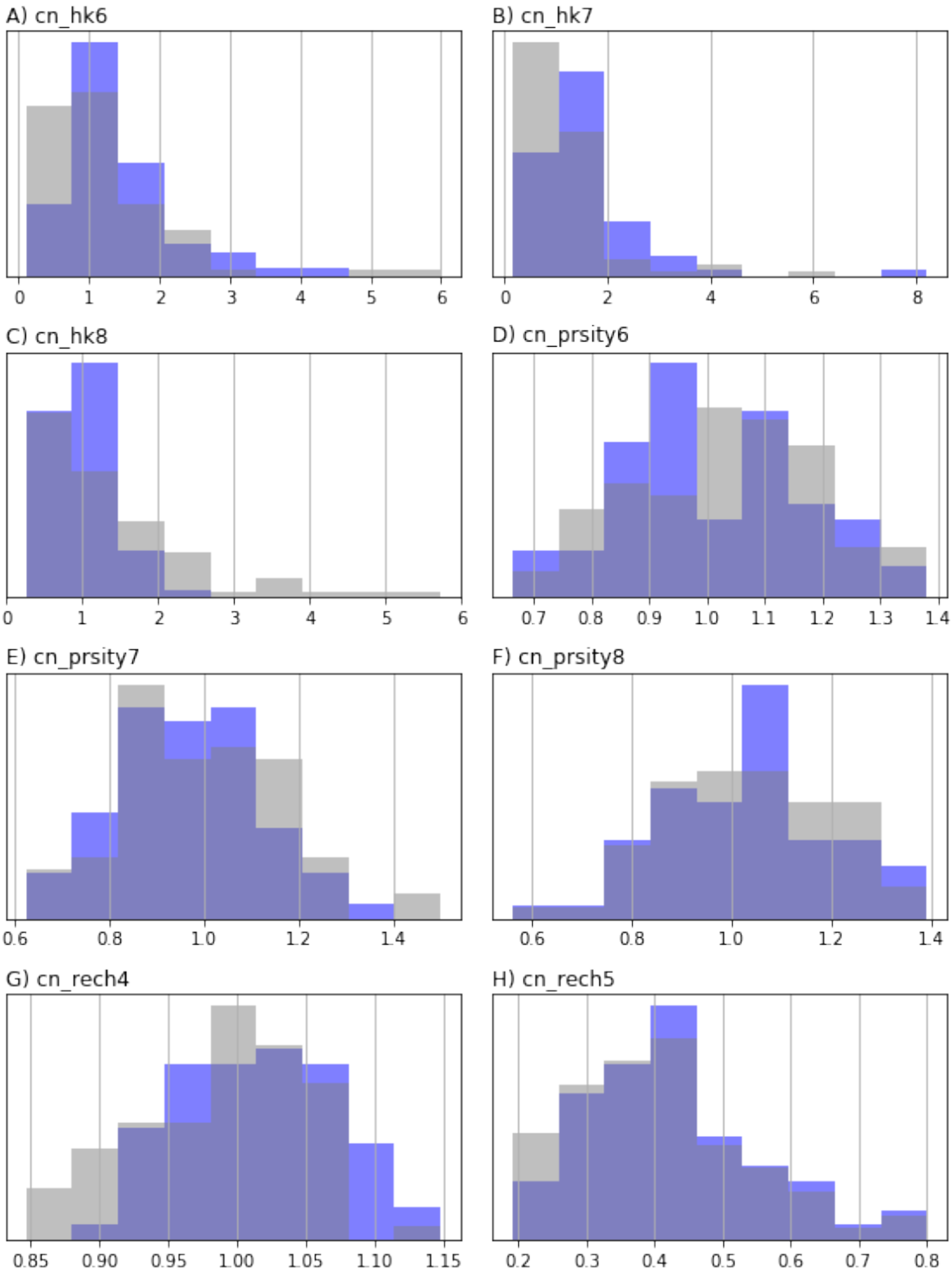


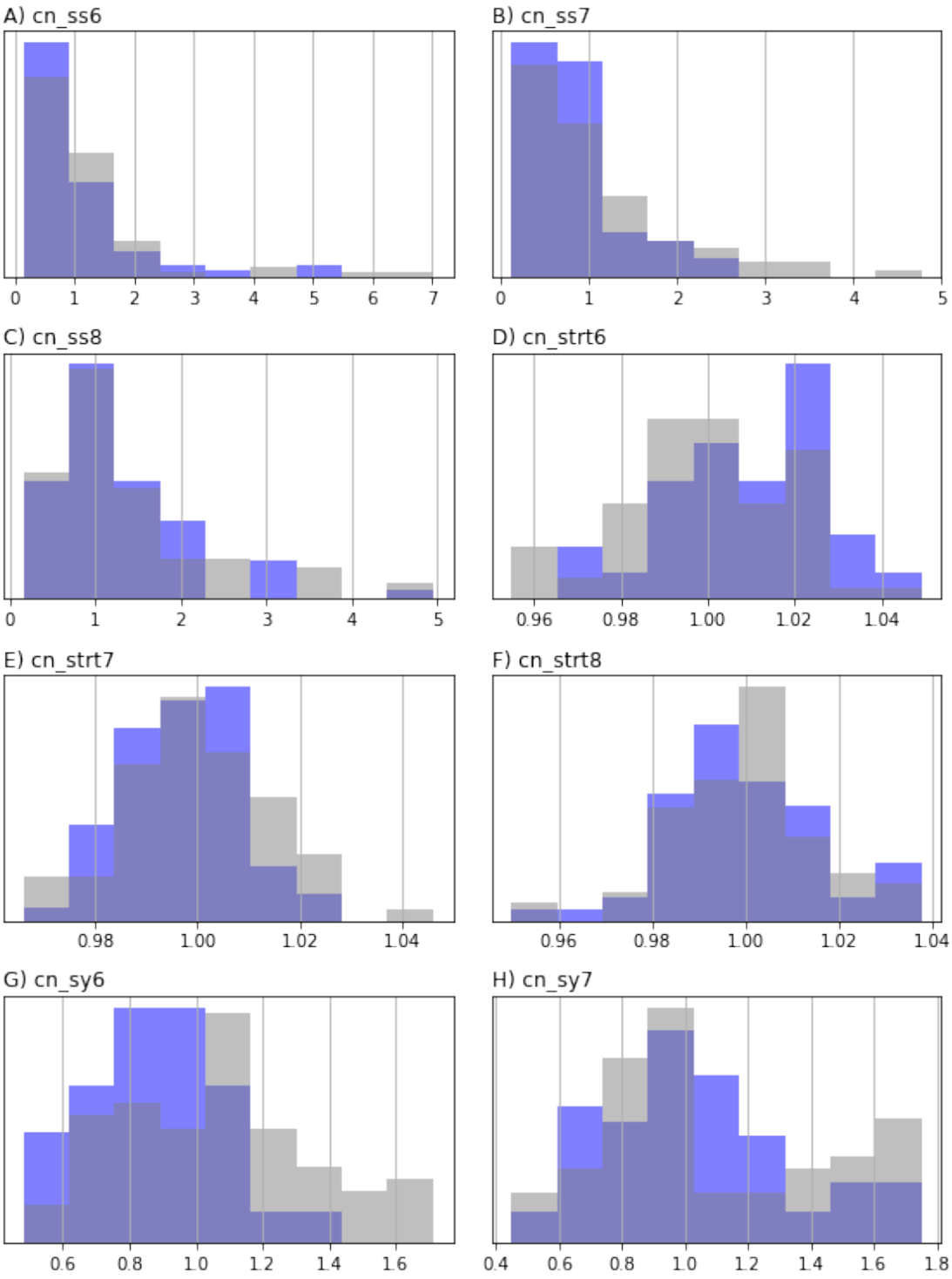
Plot parameter histograms by group

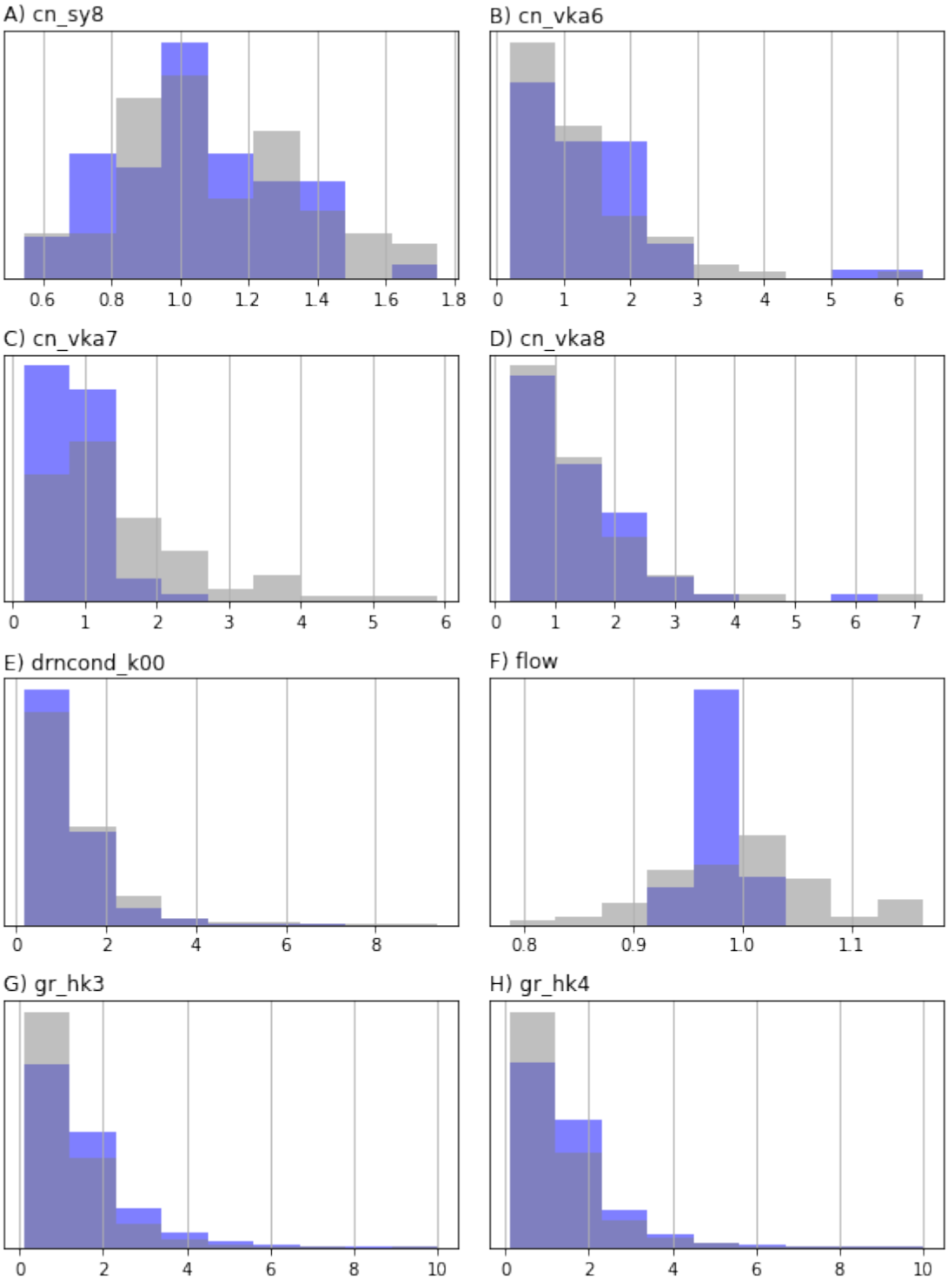
```
In [11]: pe_pr = pd.read_csv(os.path.join(m_d,"freyberg_ies.0.par.csv"),index_col=0)
         pe_pt = pd.read_csv(os.path.join(m_d,"freyberg_ies.{0}.par.csv".format(pst.control_dat
         par = pst.parameter_data
         pdict = par.groupby("pargp").groups
         pyemu.plot_utils.ensemble_helper({"0.5":pe_pr,"b":pe_pt},plot_cols=pdict)
```

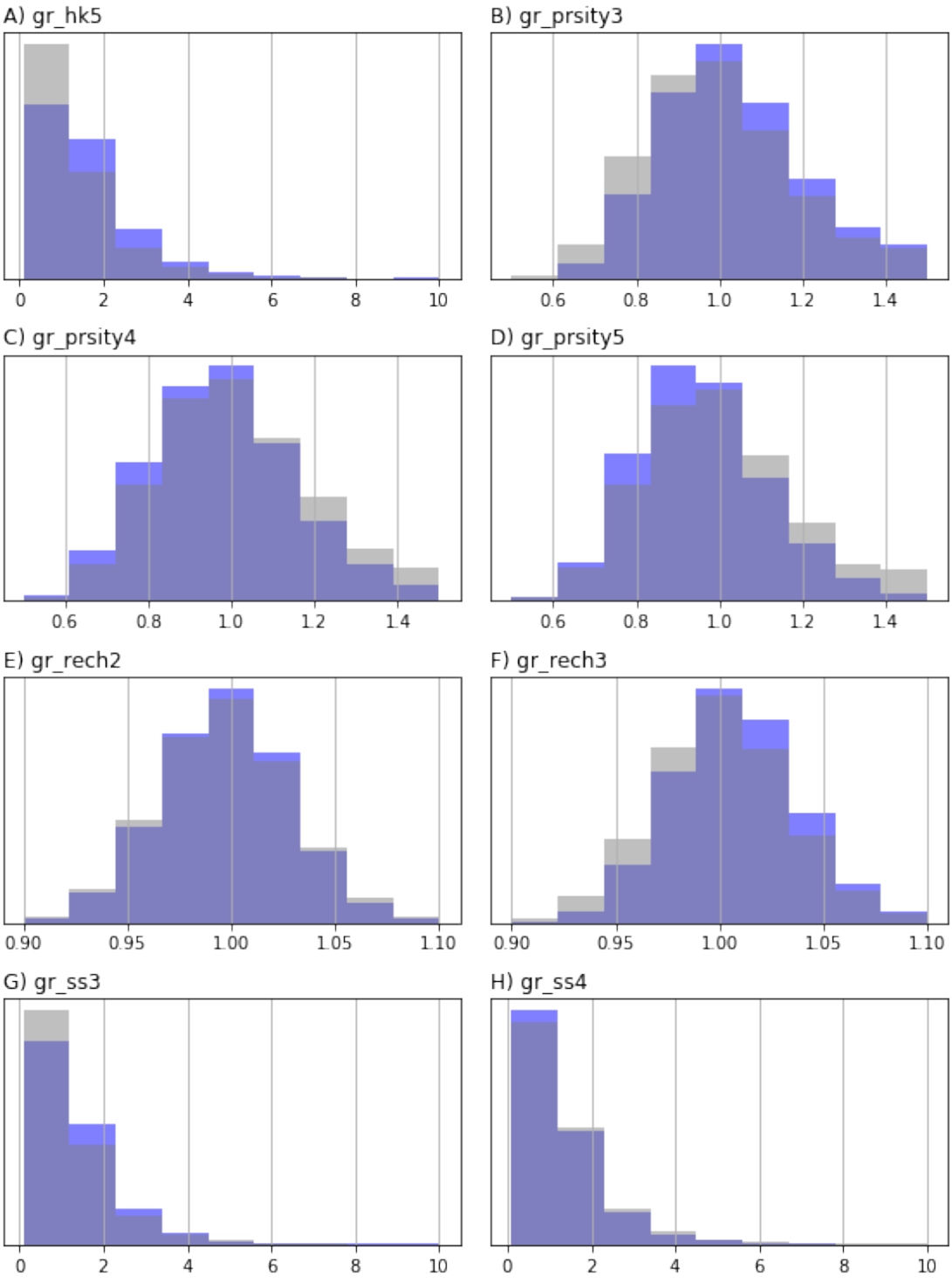
```
/Users/jeremyw/miniconda3/lib/python3.5/site-packages/IPython/core/interactiveshell.py:2785: Dt
  interactivity=interactivity, compiler=compiler, result=result)
```

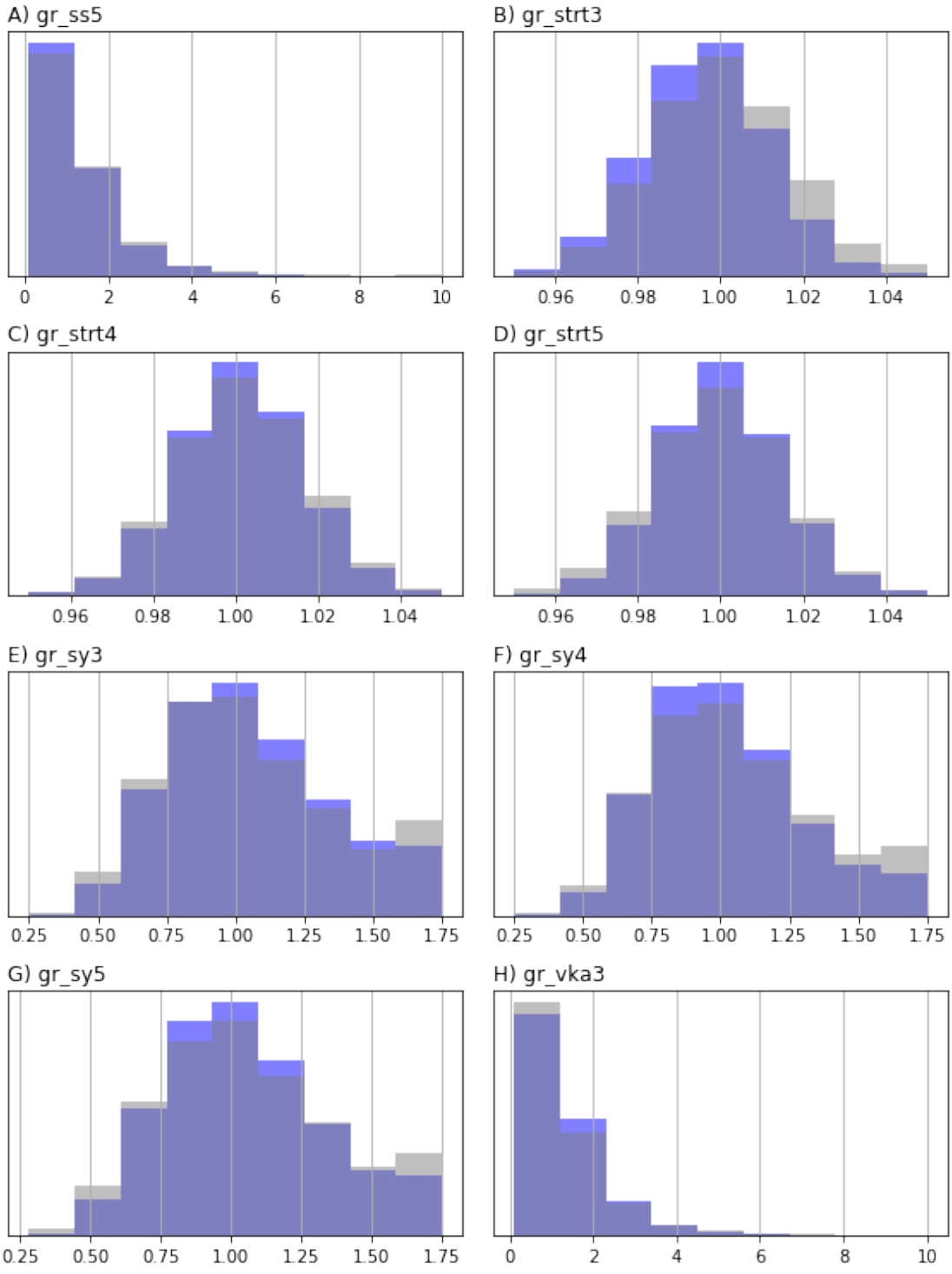
```
<Figure size 576x756 with 0 Axes>
```

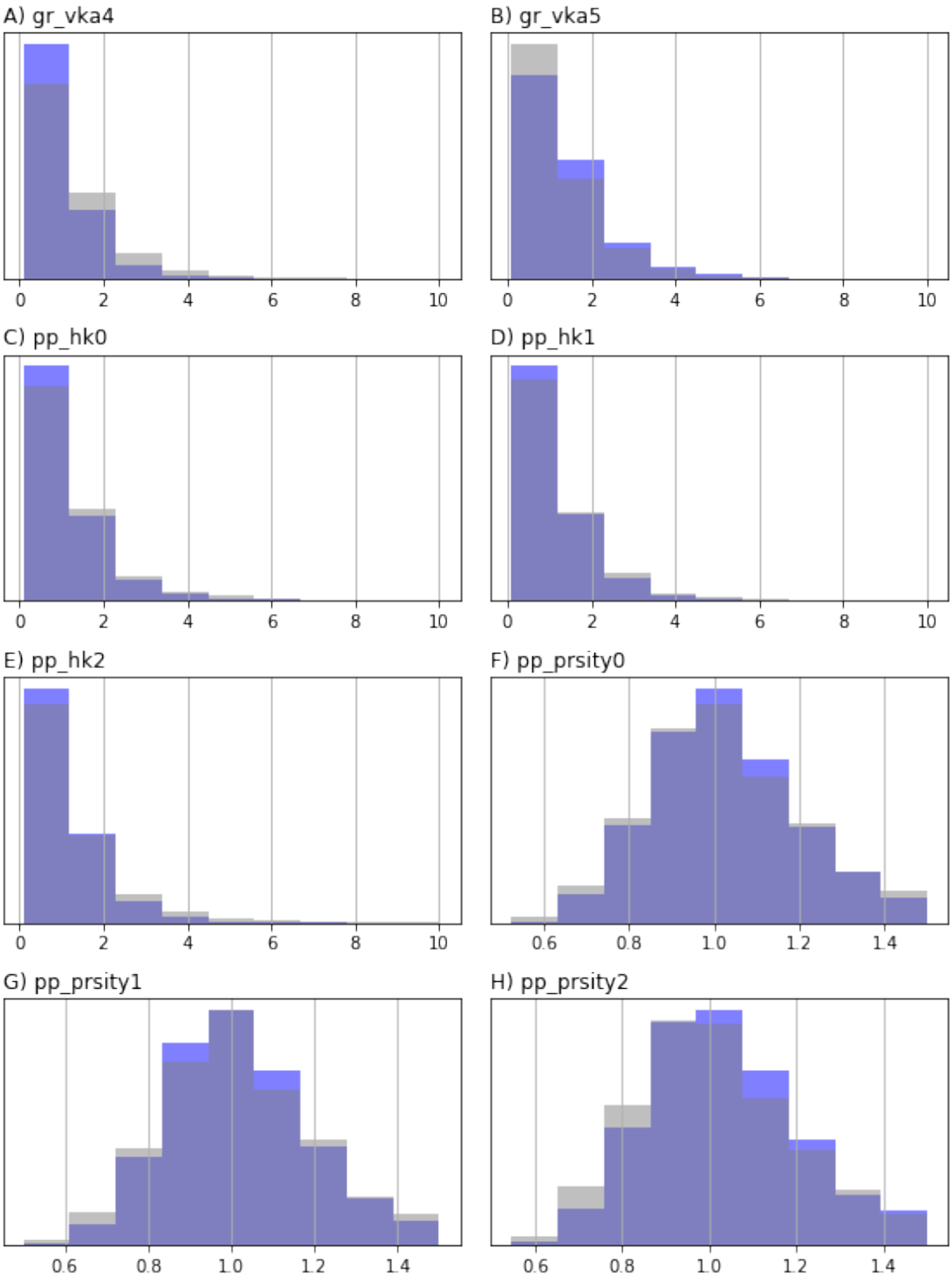

A) cn_hk6
0 1 2 3 4 5 6
B) cn_hk7
0 2 4 6 8
C) cn_hk8
0 1 2 3 4 5 6
D) cn_prsity6
0.7 0.8 0.9 1.0 1.1 1.2 1.3 1.4
E) cn_prsity7
0.6 0.8 1.0 1.2 1.4
F) cn_prsity8
0.6 0.8 1.0 1.2 1.4
G) cn_rech4
0.85 0.90 0.95 1.00 1.05 1.10 1.15
H) cn_rech5
0.2 0.3 0.4 0.5 0.6 0.7 0.8

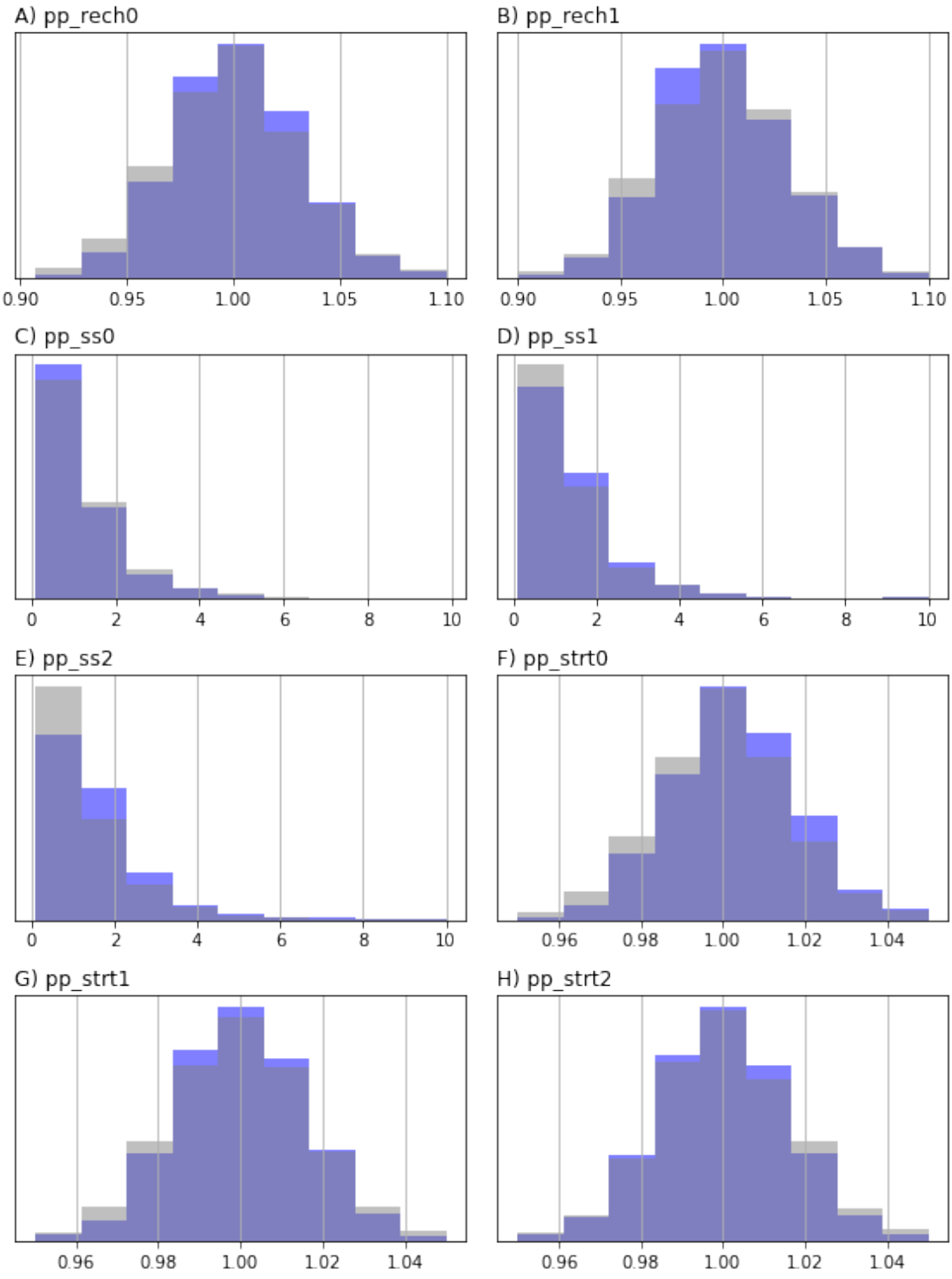

A) cn_ss6
0 1 2 3 4 5 6 7
B) cn_ss7
0 1 2 3 4 5
C) cn_ss8
0 1 2 3 4 5
D) cn_strt6
0.96 0.98 1.00 1.02 1.04
E) cn_strt7
0.98 1.00 1.02 1.04
F) cn_strt8
0.96 0.98 1.00 1.02 1.04
G) cn_sy6
0.6 0.8 1.0 1.2 1.4 1.6
H) cn_sy7
0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8

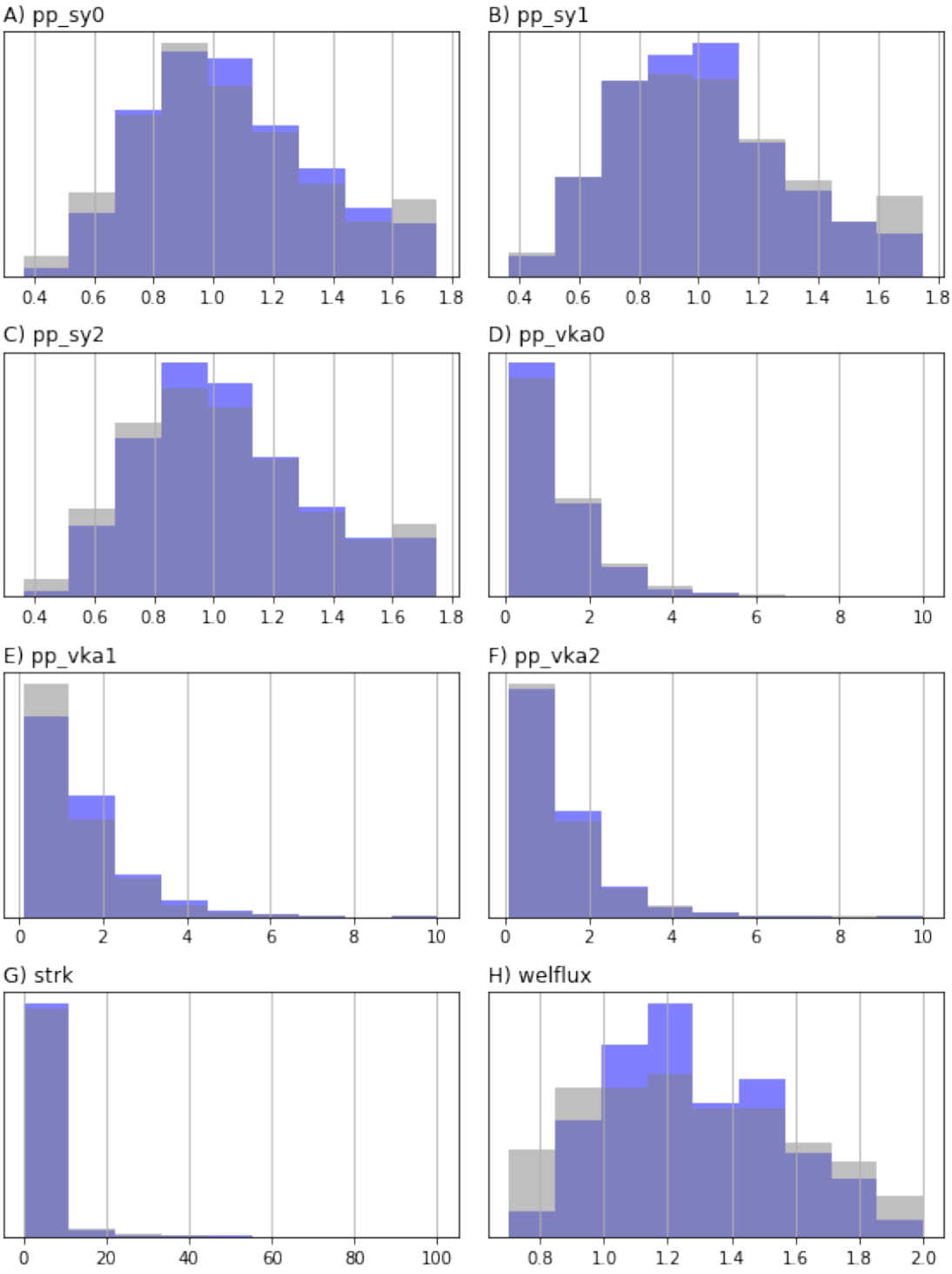

A) cn_sy8
0.6
0.8
1.0
1.2
1.4
1.6
1.8
B) cn_vka6
0
1
2
3
4
5
6
C) cn_vka7
0
1
2
3
4
5
6
D) cn_vka8
0
1
2
3
4
5
6
7
E) drncond_k00
0
2
4
6
8
F) flow
0.8
0.9
1.0
1.1
G) gr_hk3
0
2
4
6
8
10
H) gr_hk4
0
2
4
6
8
10

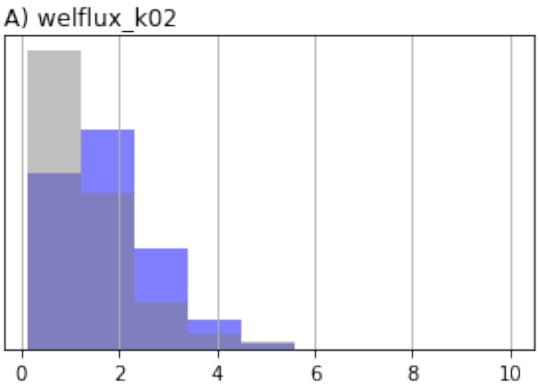

A) gr_hk5
0
2
4
6
8
10
B) gr_prsity3
0.6
0.8
1.0
1.2
1.4
C) gr_prsity4
0.6
0.8
1.0
1.2
1.4
D) gr_prsity5
0.6
0.8
1.0
1.2
1.4
E) gr_rech2
0.90
0.95
1.00
1.05
1.10
F) gr_rech3
0.90
0.95
1.00
1.05
1.10
G) gr_ss3
0
2
4
6
8
10
H) gr_ss4
0
2
4
6
8
10


A) gr_ss5
0
2
4
6
8
10
B) gr_strt3
0.96
0.98
1.00
1.02
1.04
C) gr_strt4
0.96
0.98
1.00
1.02
1.04
D) gr_strt5
0.96
0.98
1.00
1.02
1.04
E) gr_sy3
0.25
0.50
0.75
1.00
1.25
1.50
1.75
F) gr_sy4
0.25
0.50
0.75
1.00
1.25
1.50
1.75
G) gr_sy5
0.25
0.50
0.75
1.00
1.25
1.50
1.75
H) gr_vka3
0
2
4
6
8
10


A) gr_vka4
B) gr_vka5
C) pp_hk0
D) pp_hk1
E) pp_hk2
F) pp_prsity0
G) pp_prsity1
H) pp_prsity2
0
2
4
6
8
10
0.6
0.8
1.0
1.2
1.4


A) pp_rech0
0.90
0.95
1.00
1.05
1.10
B) pp_rech1
0.90
0.95
1.00
1.05
1.10
C) pp_ss0
0
2
4
6
8
10
D) pp_ss1
0
2
4
6
8
10
E) pp_ss2
0
2
4
6
8
10
F) pp_strt0
0.96
0.98
1.00
1.02
1.04
G) pp_strt1
0.96
0.98
1.00
1.02
1.04
H) pp_strt2
0.96
0.98
1.00
1.02
1.04


A) pp_sy0
0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8
B) pp_sy1
0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8
C) pp_sy2
0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8
D) pp_vka0
0 2 4 6 8 10
E) pp_vka1
0 2 4 6 8 10
F) pp_vka2
0 2 4 6 8 10
G) strk
0 20 40 60 80 100
H) welflux
0.8 1.0 1.2 1.4 1.6 1.8 2.0



In [12]:
```
# pyemu.plot_utils.ensemble_change_summary(pe_pr,pe_pt,pst=pst,bins=20)
# par = pst.parameter_data
# li = par.partrans=="log"
```

```
        # pe_pr.loc[:,li] = pe_pr.loc[:,li].apply(np.log10)
        # pe_pr.shape
```

1.1.2 PESTPP-IES with simple temporal localization (and common sense)

Now let's add some localization. The obvious stuff is temporal - scenario parameters can't influence historic observations (and the inverse is true) so let's tell PESTPP-IES about this. Also, should porosity be adjusted at all given the observations we have???

In [13]:
```
par = pst.parameter_data
#parameter groups for future recharge
dont_groups = [g for g in pst.par_groups if "pr" in g]
dont_groups.extend(["gr_rech3","pp_rech1","cn_rech5"])
dont_groups = [g for g in dont_groups if g in pst.adj_par_groups]
dont_pars = par.loc[par.pargp.apply(lambda x: x in dont_groups),"parnme"].tolist()
dont_pars.append("welflux_001")
dont_groups.append("welflux_001")
dont_groups
```

Out[13]:
```
['cn_prsity8',
 'gr_prsity5',
 'gr_prsity3',
 'pp_prsity0',
 'pp_prsity2',
 'cn_prsity6',
 'gr_prsity4',
 'cn_prsity7',
 'pp_prsity1',
 'gr_rech3',
 'pp_rech1',
 'cn_rech5',
 'welflux_001']
```

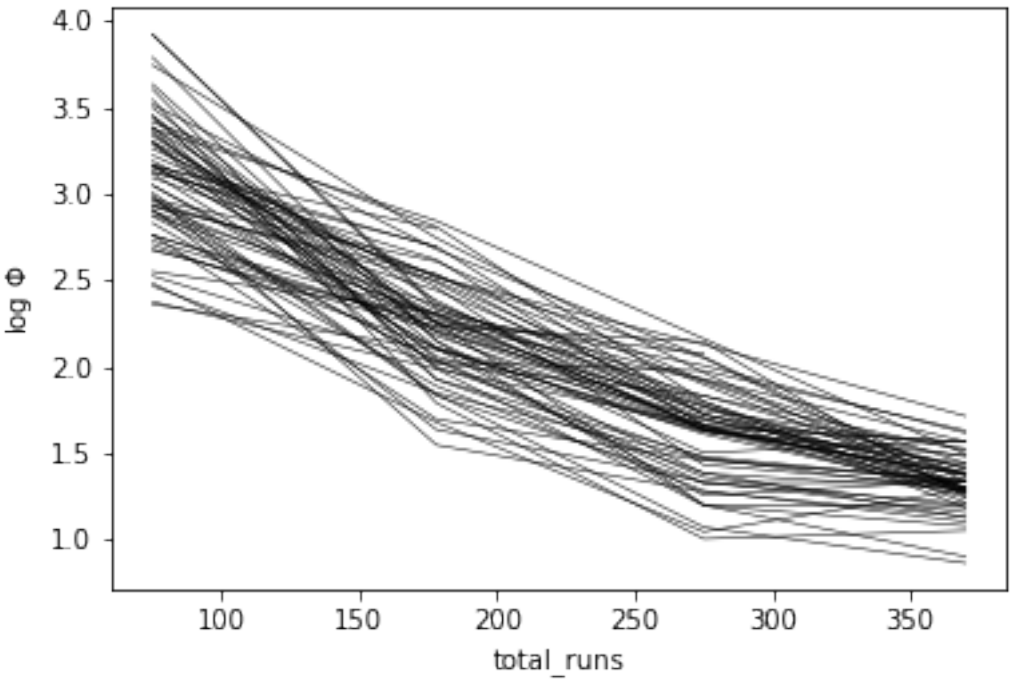
In [14]:
```
cols = pst.adj_par_groups
cols.remove("welflux")
cols.extend(["welflux_000","welflux_001"])
loc = pyemu.Matrix.from_names(pst.nnz_obs_names,cols).to_dataframe()
loc.loc[:,:]= 1.0
loc.loc[:,dont_groups] = 0.0
pyemu.Matrix.from_dataframe(loc).to_ascii(os.path.join(t_d,"loc.mat"))
```

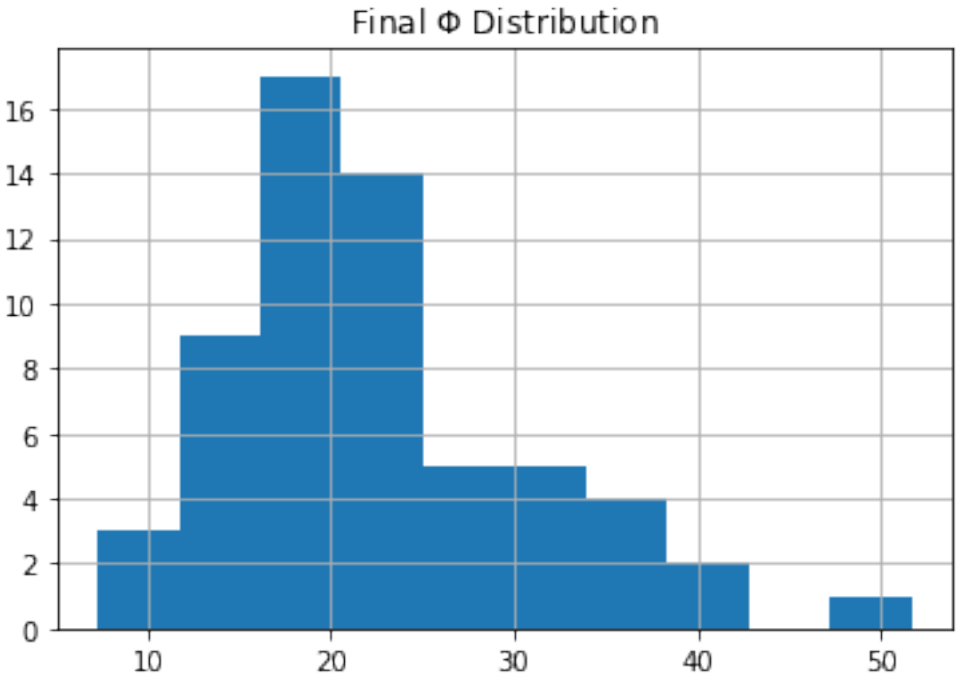
In [15]:
```
pst.pestpp_options["ies_localizer"] = "loc.mat"
pst.write(os.path.join(t_d,"freyberg_ies.pst"))
pyemu.os_utils.start_slaves(t_d,"pestpp-ies","freyberg_ies.pst",num_slaves=num_workers
```

```
noptmax:3, npar_adj:14819, nnz_obs:14
```

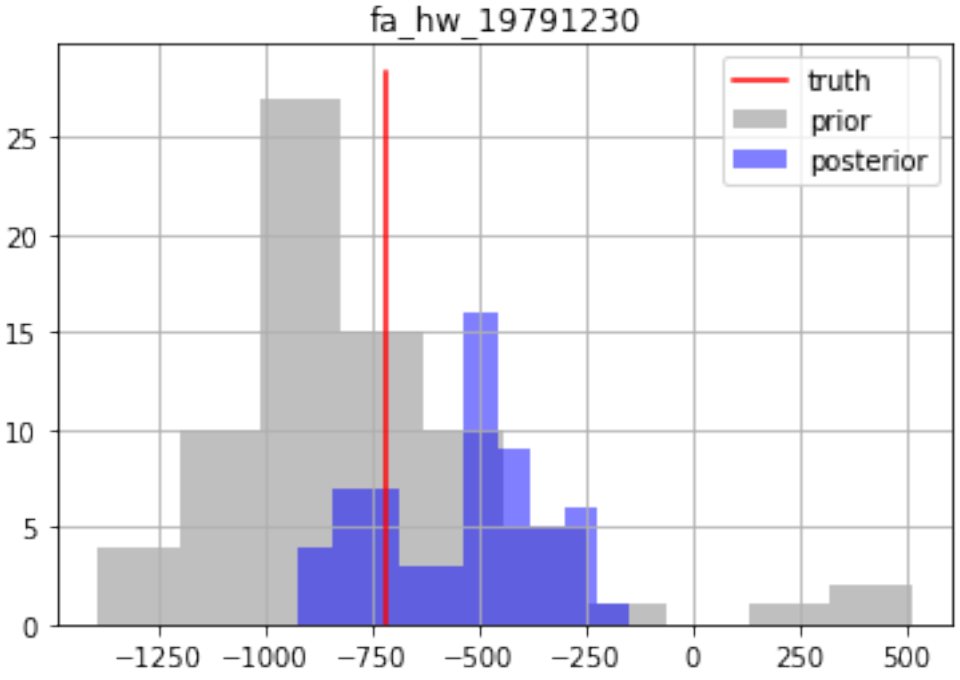
In [16]:
```
phi = pd.read_csv(os.path.join(m_d,"freyberg_ies.phi.actual.csv"),index_col=0)
phi.index = phi.total_runs
```

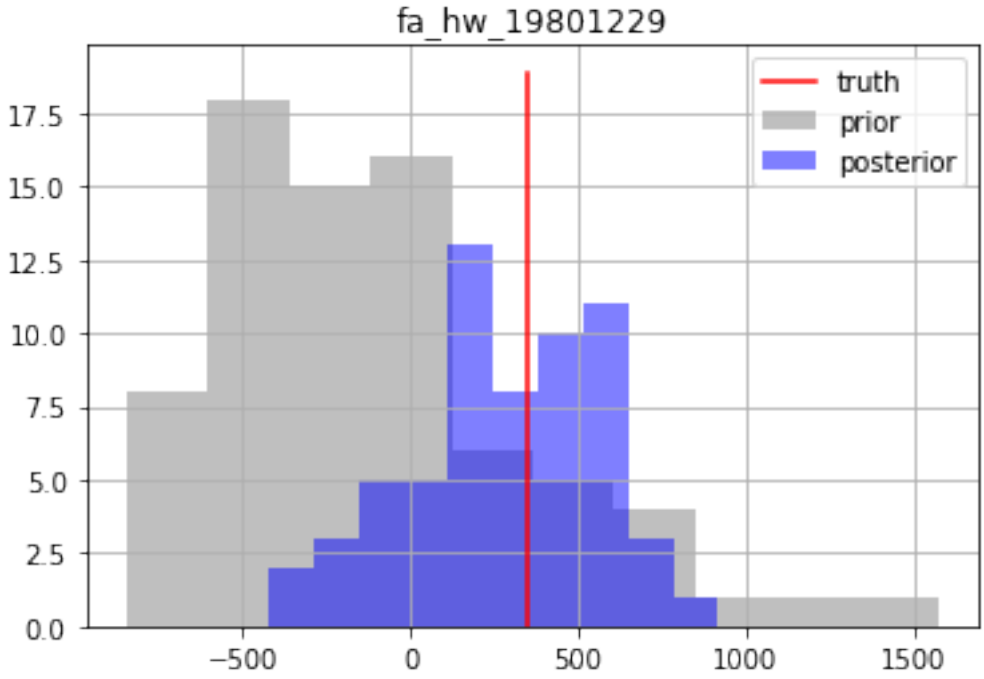
```
phi.iloc[:,6:].apply(np.log10).plot(legend=False,lw=0.5,color='k')
plt.ylabel('log $\Phi$')
plt.show()
phi.iloc[-1,6:].hist()
plt.title('Final $\Phi$ Distribution');
```

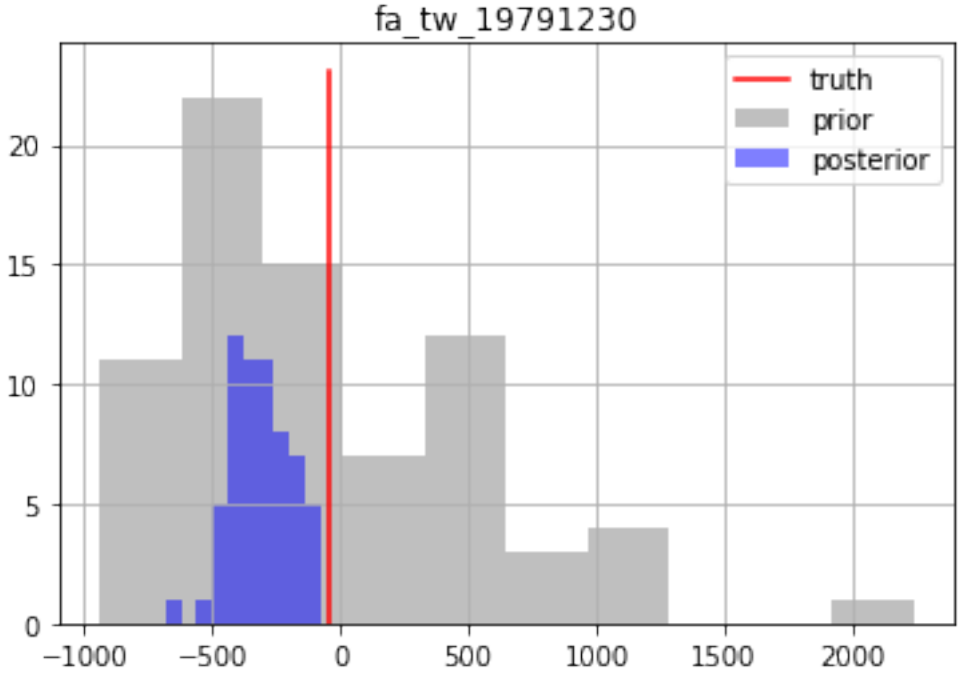


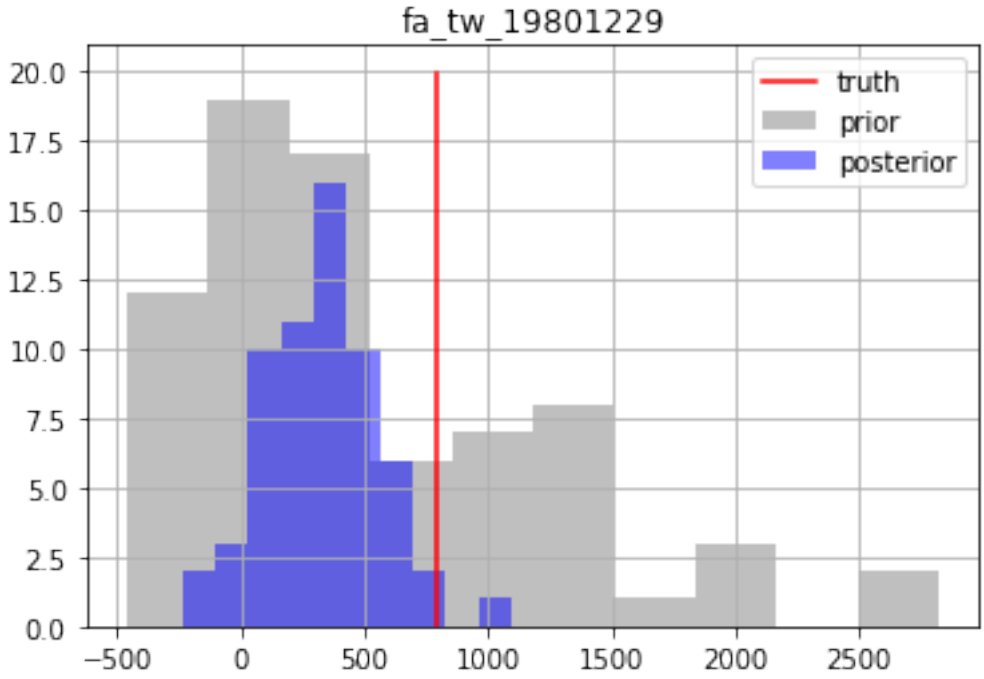


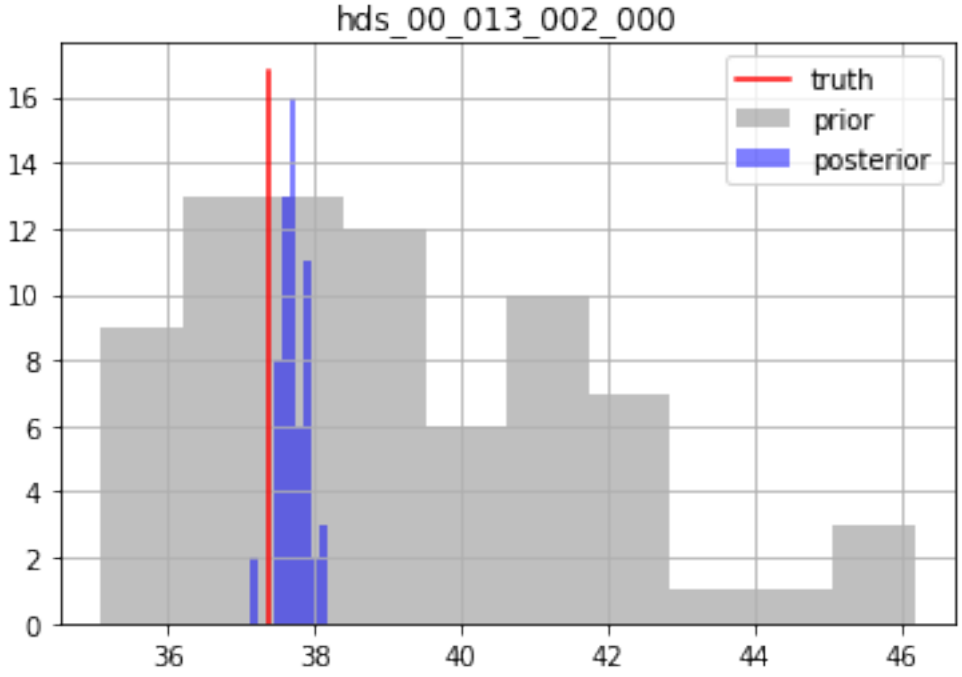
In [17]:
```
oe_pr = pd.read_csv(os.path.join(m_d,"freyberg_ies.0.obs.csv"),index_col=0)
oe_pt = pd.read_csv(os.path.join(m_d,"freyberg_ies.{0}.obs.csv".format(pst.control_dat
obs = pst.observation_data
fnames = pst.pestpp_options["forecasts"].split(",")
for forecast in fnames:
    ax = plt.subplot(111)
    oe_pr.loc[:,forecast].hist(ax=ax,color="0.5",alpha=0.5, label='prior')
    oe_pt.loc[:,forecast].hist(ax=ax,color="b",alpha=0.5, label='posterior')
    ax.plot([obs.loc[forecast,"obsval"],obs.loc[forecast,"obsval"]],ax.get_ylim(),"r"
    ax.set_title(forecast)
    ax.legend(loc='upper right')
    plt.show()
```

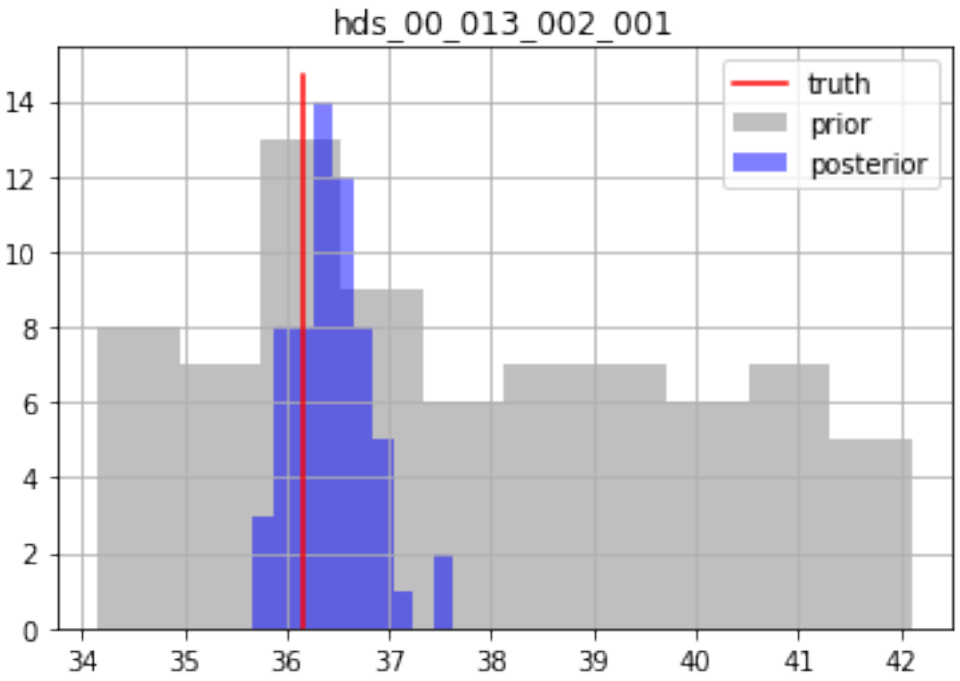


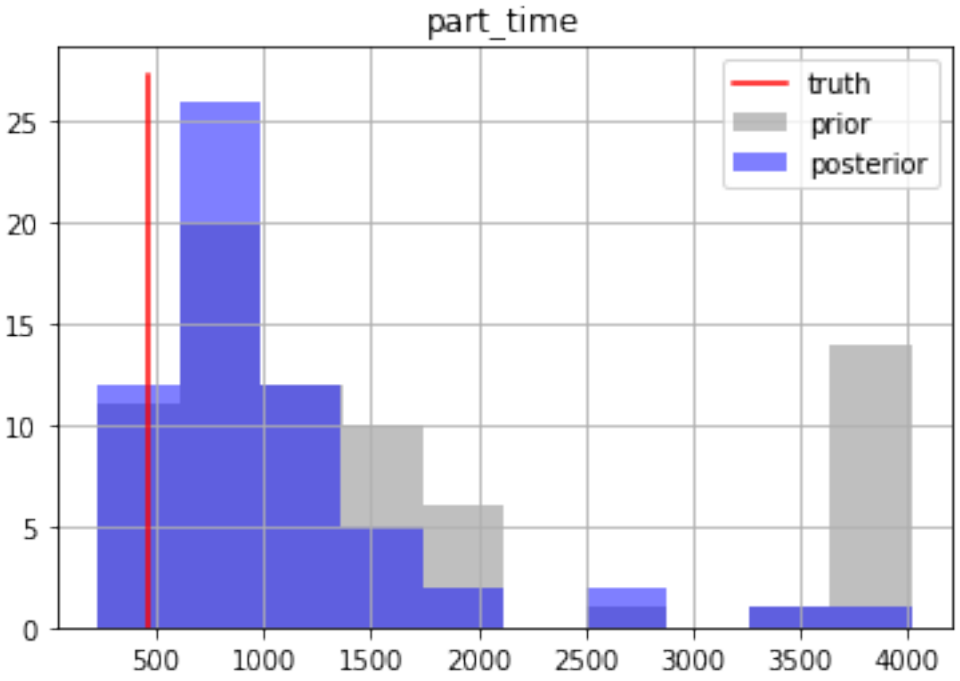

fa_hw_19801229
truth
prior
posterior
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0.0
−500
0
500
1000
1500

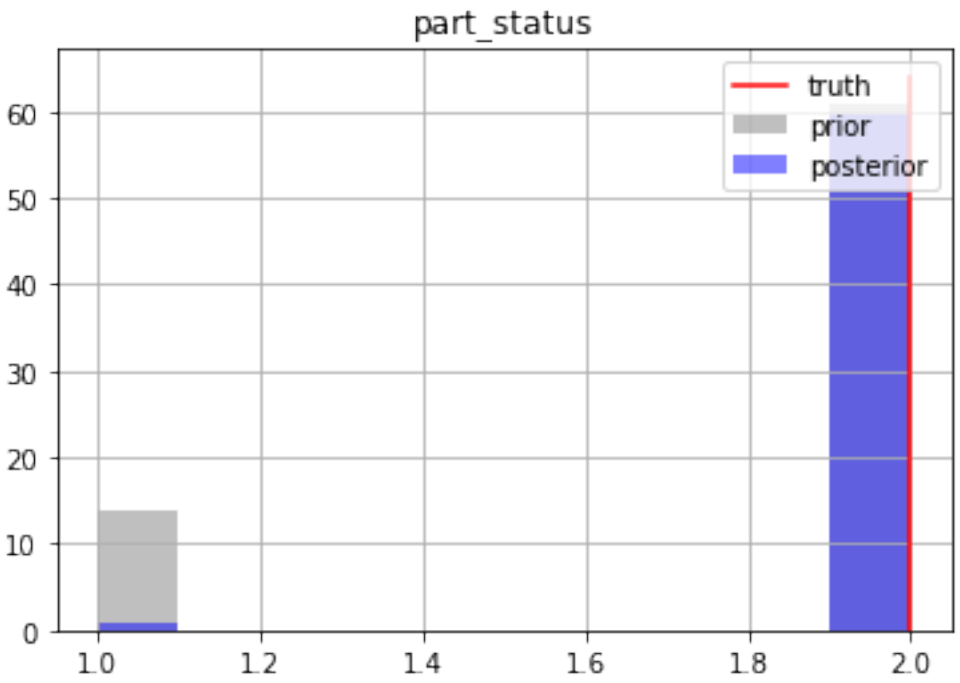

fa_tw_19791230
truth
prior
posterior
20
15
10
5
0
−1000
−500
0
500
1000
1500
2000


fa_tw_19801229
truth
prior
posterior
20.0
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0.0
−500
0
500
1000
1500
2000
2500


hds_00_013_002_000
truth
prior
posterior
16
14
12
10
8
6
4
2
0
36
38
40
42
44
46


hds_00_013_002_001
truth
prior
posterior
0
2
4
6
8
10
12
14
34
35
36
37
38
39
40
41
42


part_time
truth
prior
posterior
0
5
10
15
20
25
500
1000
1500
2000
2500
3000
3500
4000

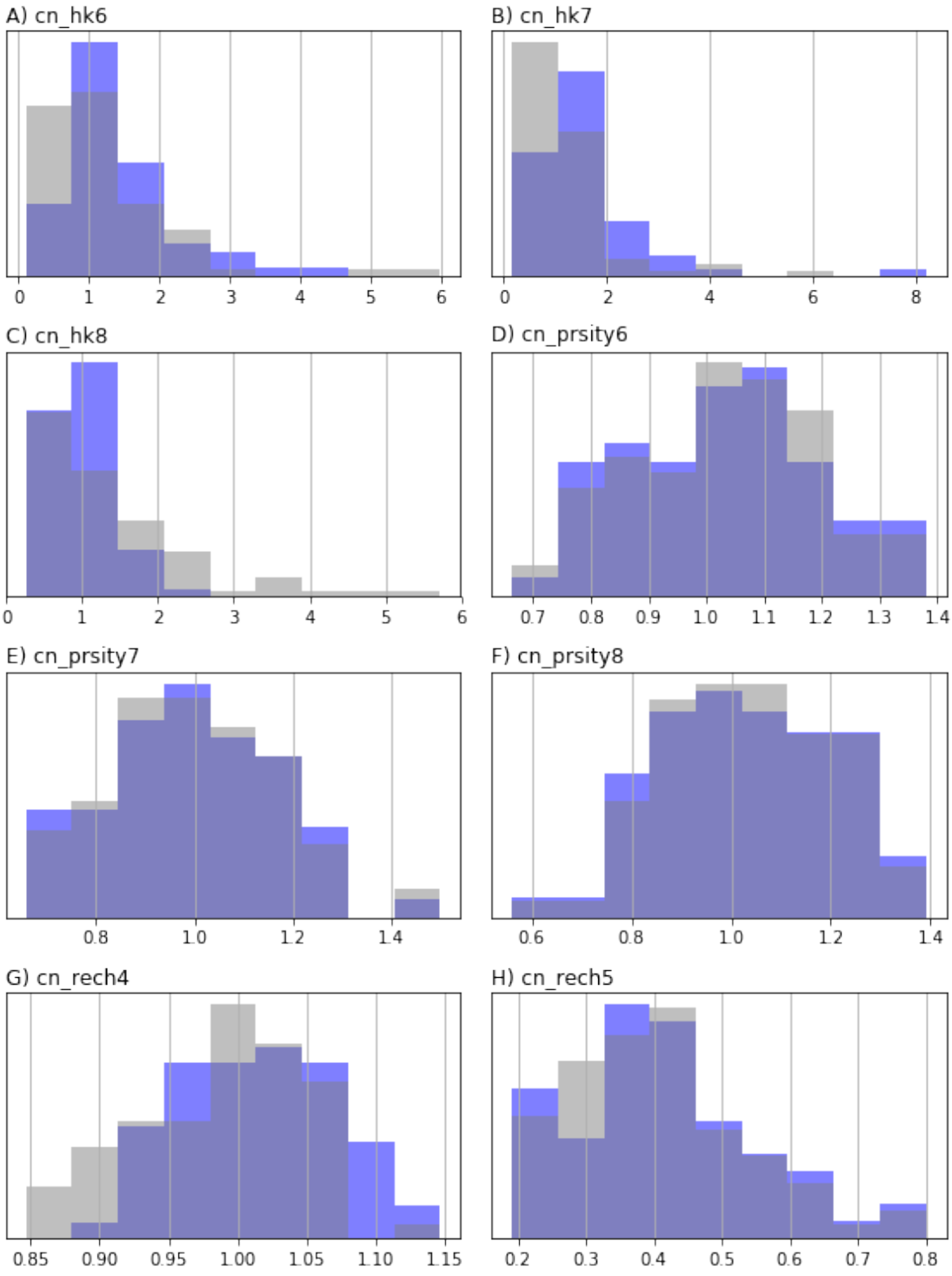


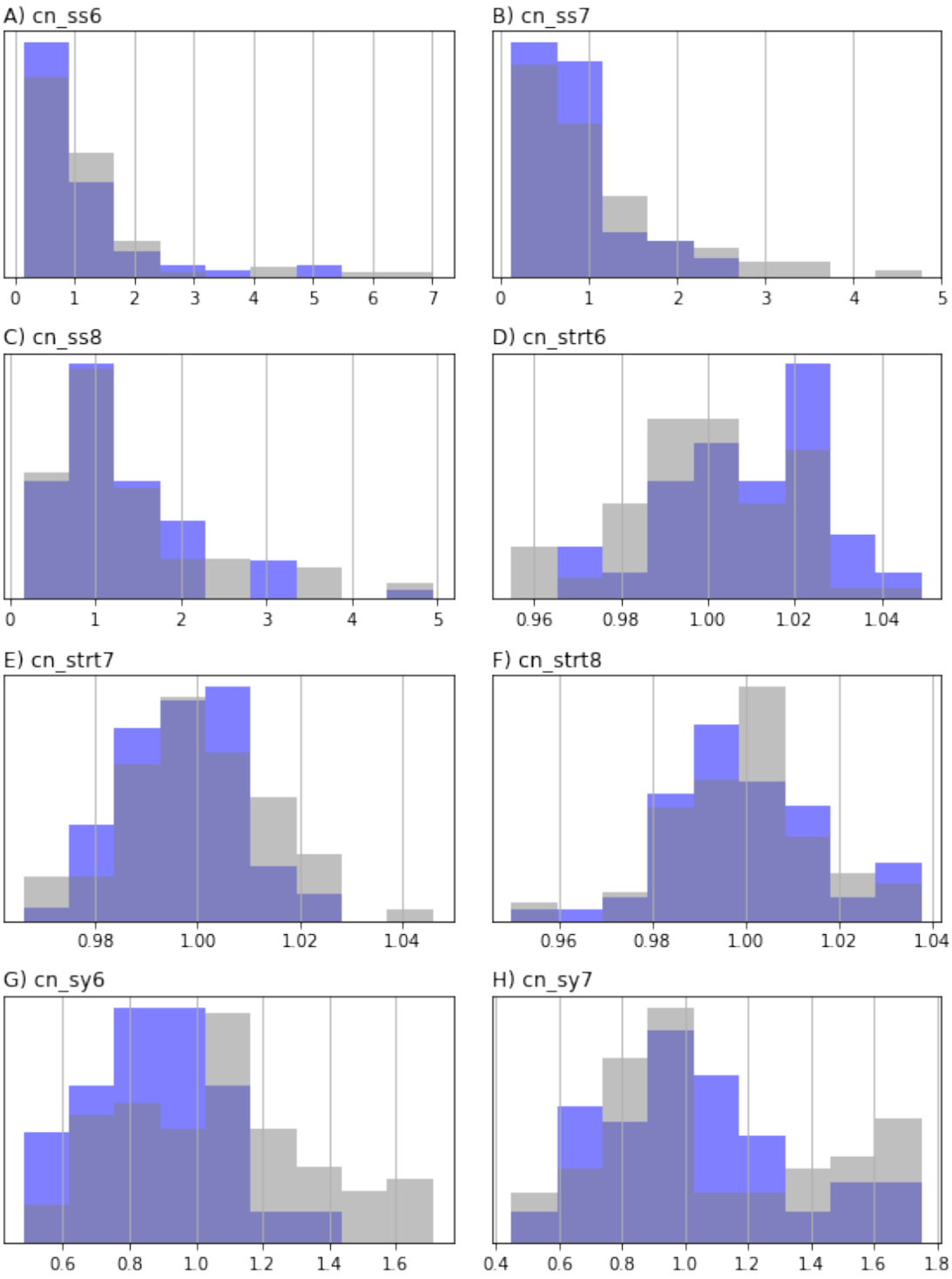

```
In [18]: pe_pr = pd.read_csv(os.path.join(m_d,"freyberg_ies.0.par.csv"),index_col=0)
         pe_pt = pd.read_csv(os.path.join(m_d,"freyberg_ies.{0}.par.csv".format(pst.control_dat
         #pe_pr.index = pe_pt.index
         #par = pst.parameter_data
         print(pe_pr.shape,pe_pt.shape)
         pdict = par.groupby("pargp").groups
         pyemu.plot_utils.ensemble_helper({"0.5":pe_pr,"b":pe_pt},plot_cols=pdict)
         #pyemu.plot_utils.ensemble_change_summary(pe_pr,pe_pt,pst=pst,bins=20)
```

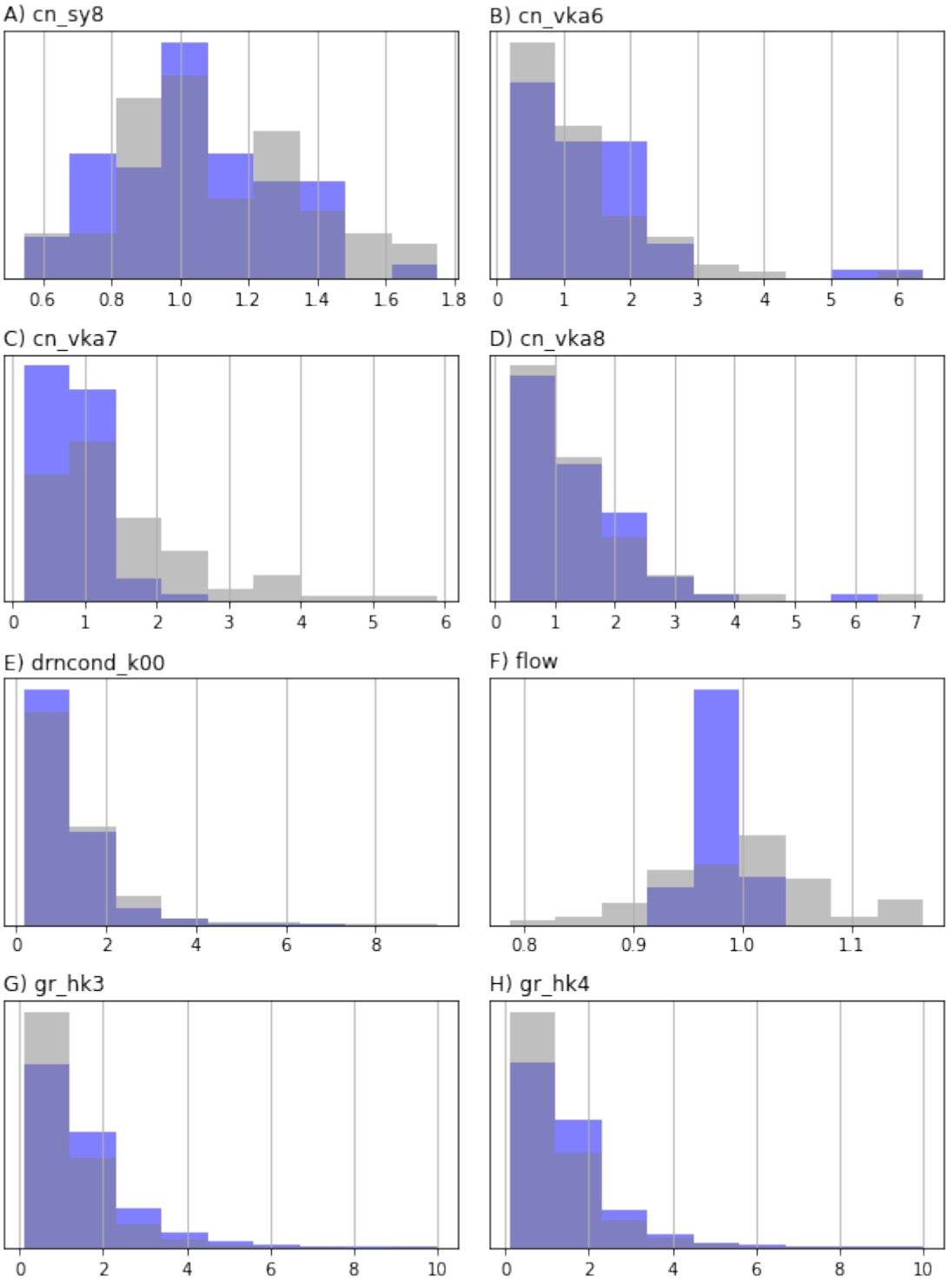
```
/Users/jeremyw/miniconda3/lib/python3.5/site-packages/IPython/core/interactiveshell.py:2785: Dt
  interactivity=interactivity, compiler=compiler, result=result)
```

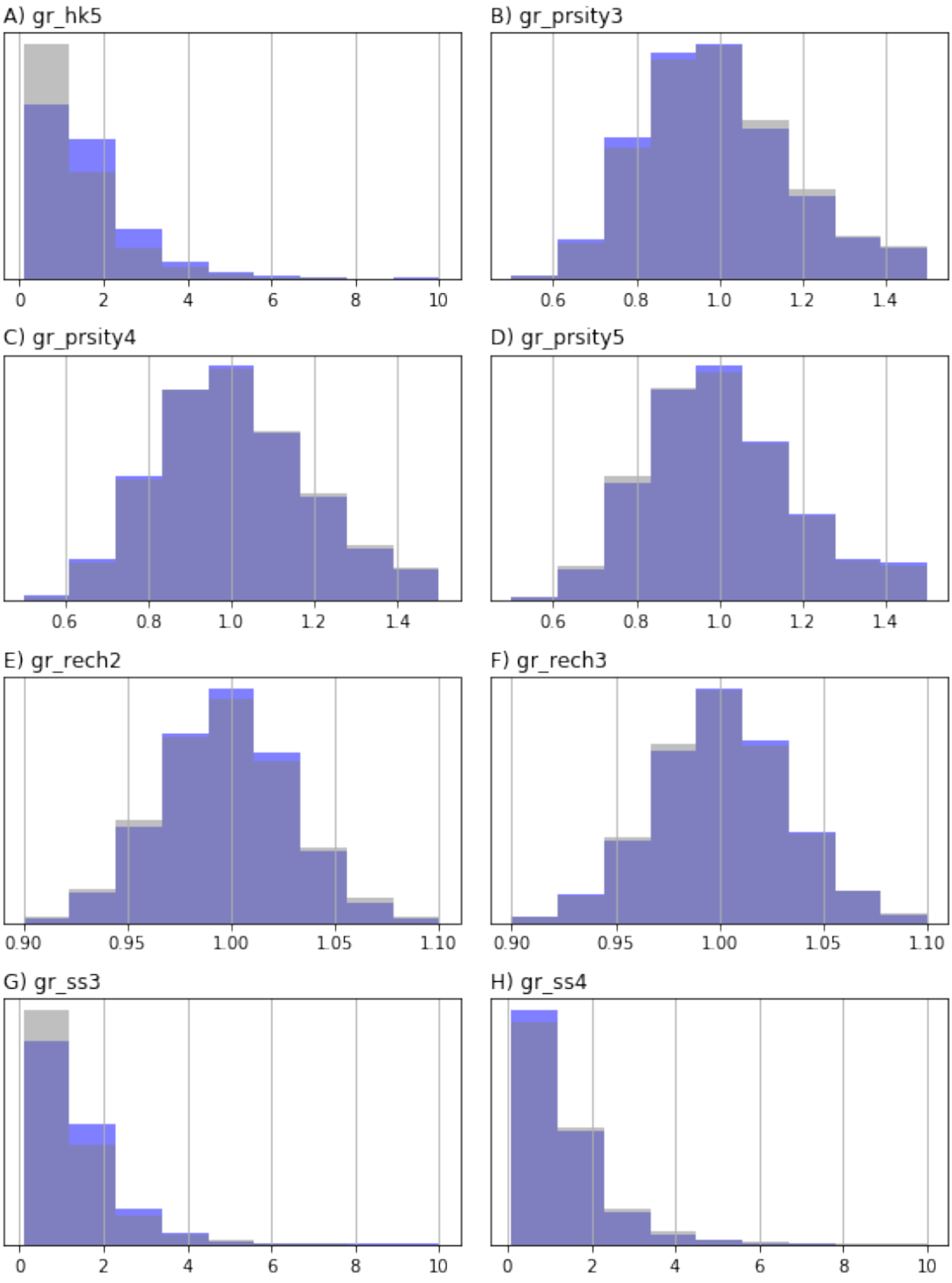
```
(75, 14819) (61, 14819)
```

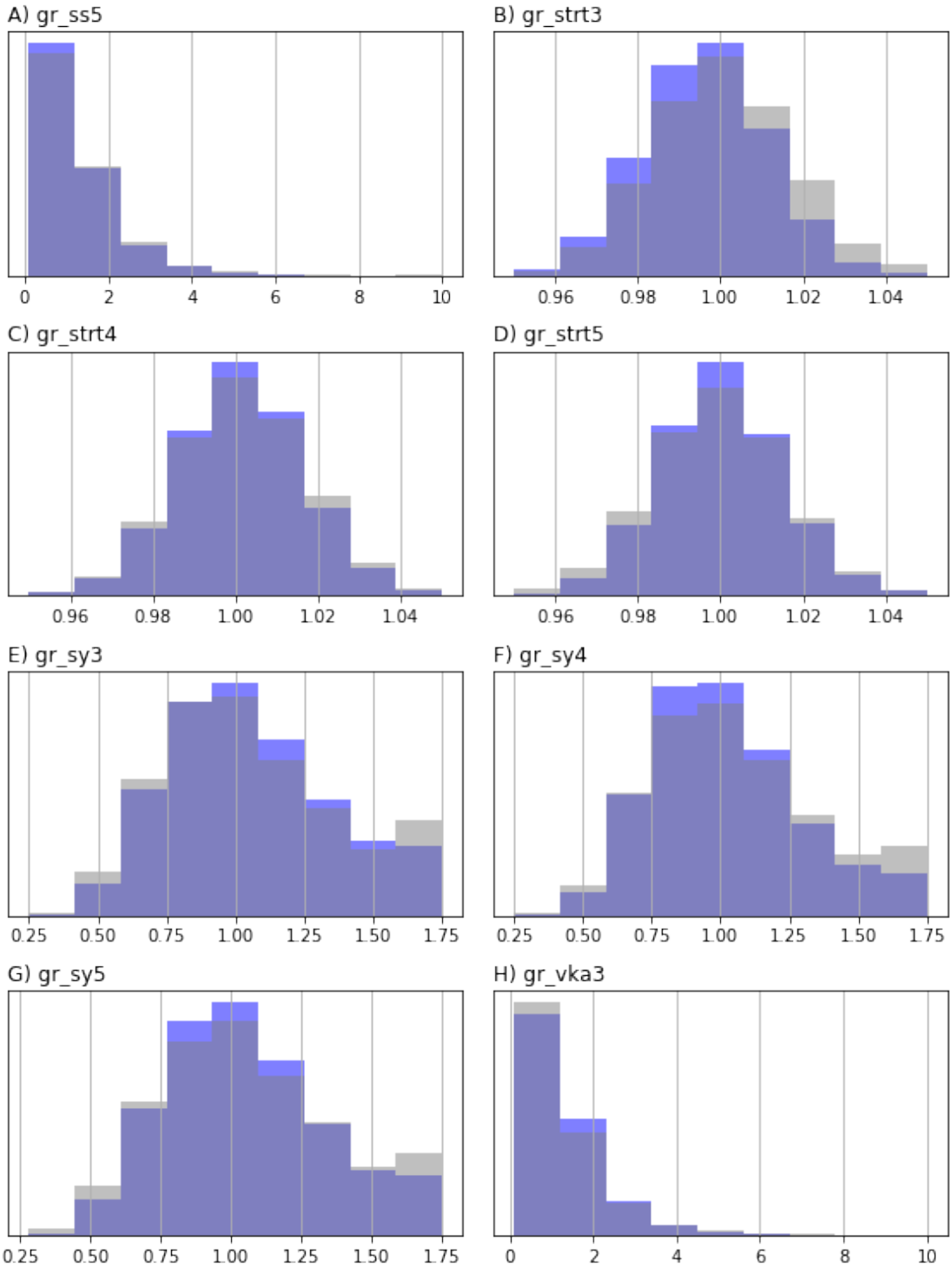
```
<Figure size 576x756 with 0 Axes>
```

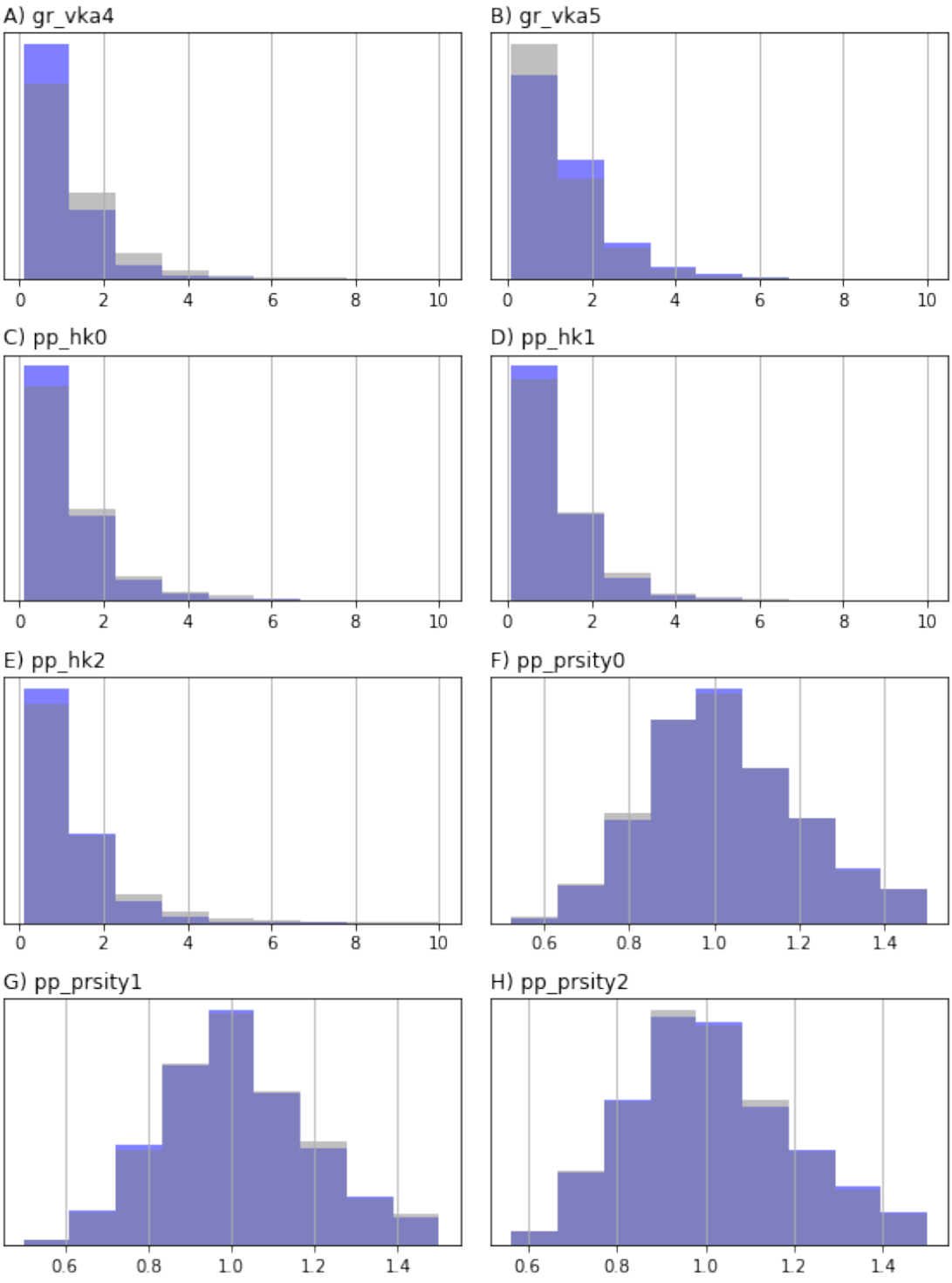

A) cn_hk6
0 1 2 3 4 5 6
B) cn_hk7
0 2 4 6 8
C) cn_hk8
0 1 2 3 4 5 6
D) cn_prsity6
0.7 0.8 0.9 1.0 1.1 1.2 1.3 1.4
E) cn_prsity7
0.8 1.0 1.2 1.4
F) cn_prsity8
0.6 0.8 1.0 1.2 1.4
G) cn_rech4
0.85 0.90 0.95 1.00 1.05 1.10 1.15
H) cn_rech5
0.2 0.3 0.4 0.5 0.6 0.7 0.8

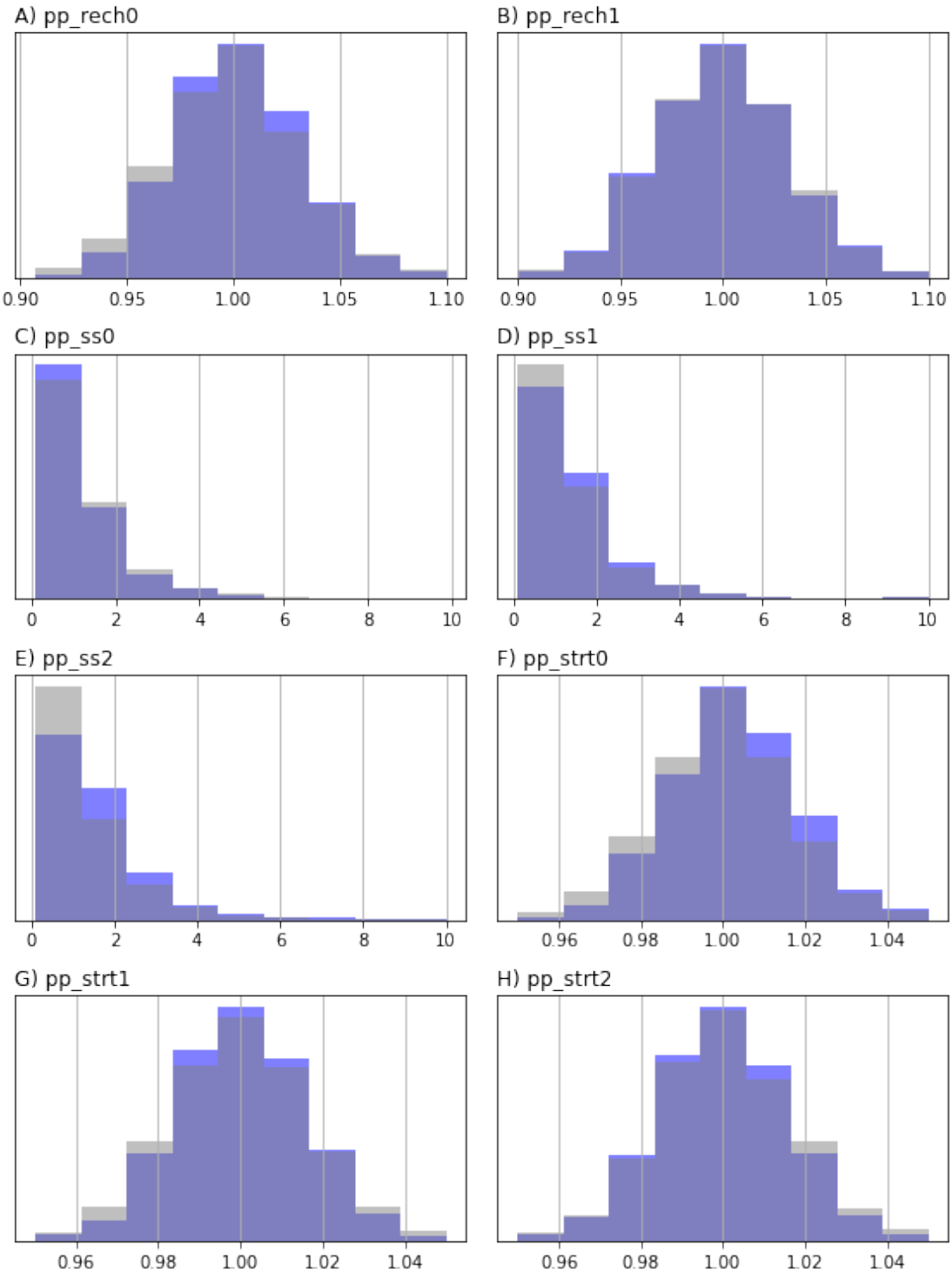

A) cn_ss6
0 1 2 3 4 5 6 7
B) cn_ss7
0 1 2 3 4 5
C) cn_ss8
0 1 2 3 4 5
D) cn_strt6
0.96 0.98 1.00 1.02 1.04
E) cn_strt7
0.98 1.00 1.02 1.04
F) cn_strt8
0.96 0.98 1.00 1.02 1.04
G) cn_sy6
0.6 0.8 1.0 1.2 1.4 1.6
H) cn_sy7
0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8

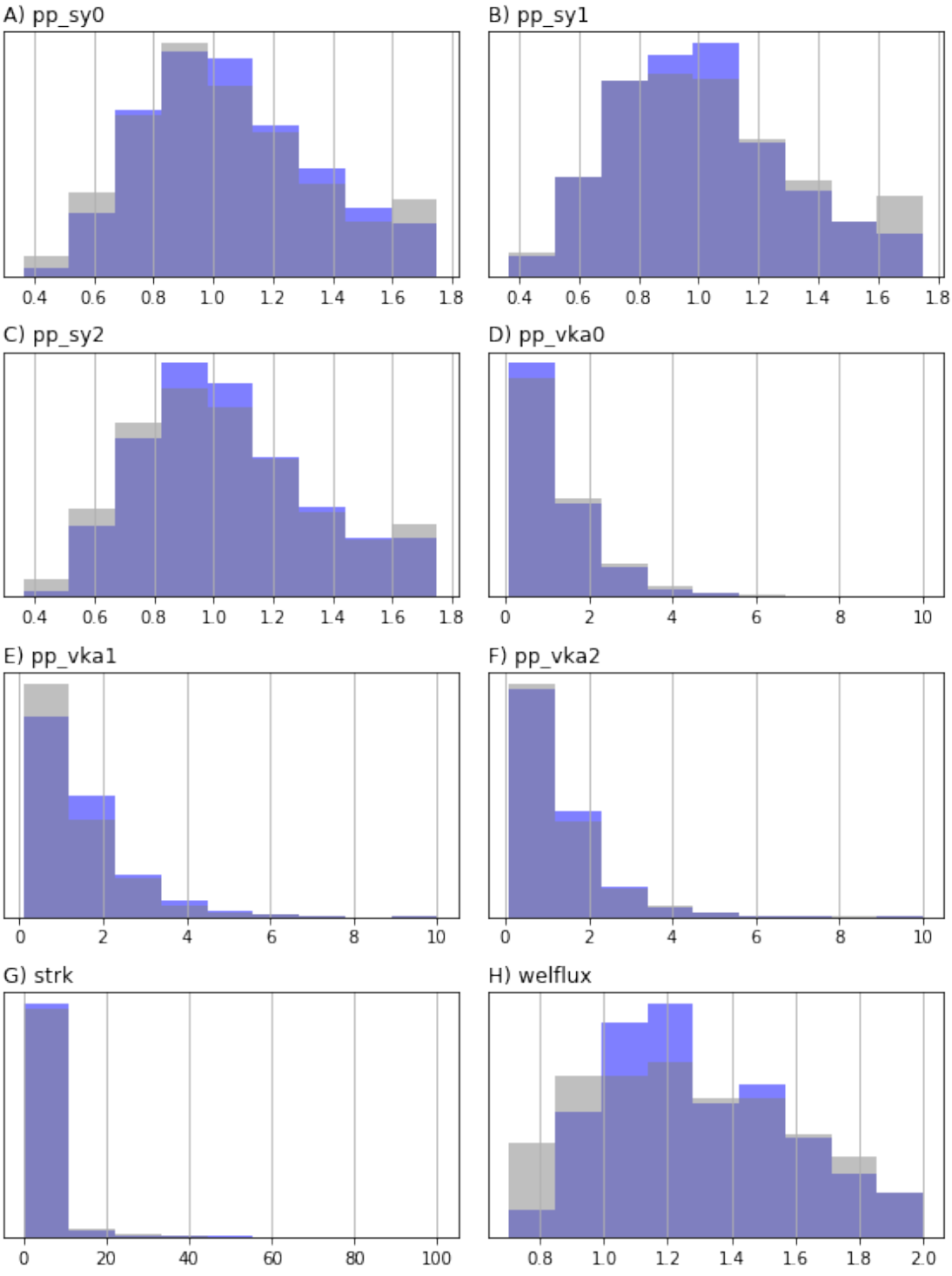

A) cn_sy8
0.6
0.8
1.0
1.2
1.4
1.6
1.8
B) cn_vka6
0
1
2
3
4
5
6
C) cn_vka7
0
1
2
3
4
5
6
D) cn_vka8
0
1
2
3
4
5
6
7
E) drncond_k00
0
2
4
6
8
F) flow
0.8
0.9
1.0
1.1
G) gr_hk3
0
2
4
6
8
10
H) gr_hk4
0
2
4
6
8
10

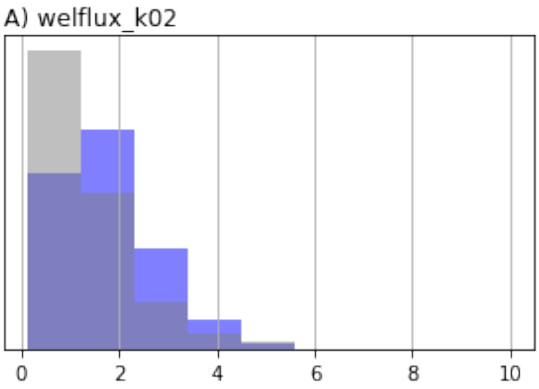

A) gr_hk5
0
2
4
6
8
10
B) gr_prsity3
0.6
0.8
1.0
1.2
1.4
C) gr_prsity4
0.6
0.8
1.0
1.2
1.4
D) gr_prsity5
0.6
0.8
1.0
1.2
1.4
E) gr_rech2
0.90
0.95
1.00
1.05
1.10
F) gr_rech3
0.90
0.95
1.00
1.05
1.10
G) gr_ss3
0
2
4
6
8
10
H) gr_ss4
0
2
4
6
8
10


A) gr_ss5
0
2
4
6
8
10
B) gr_strt3
0.96
0.98
1.00
1.02
1.04
C) gr_strt4
0.96
0.98
1.00
1.02
1.04
D) gr_strt5
0.96
0.98
1.00
1.02
1.04
E) gr_sy3
0.25
0.50
0.75
1.00
1.25
1.50
1.75
F) gr_sy4
0.25
0.50
0.75
1.00
1.25
1.50
1.75
G) gr_sy5
0.25
0.50
0.75
1.00
1.25
1.50
1.75
H) gr_vka3
0
2
4
6
8
10


A) gr_vka4
B) gr_vka5
C) pp_hk0
D) pp_hk1
E) pp_hk2
F) pp_prsity0
G) pp_prsity1
H) pp_prsity2
0
2
4
6
8
10
0.6
0.8
1.0
1.2
1.4


A) pp_rech0
0.90
0.95
1.00
1.05
1.10
B) pp_rech1
0.90
0.95
1.00
1.05
1.10
C) pp_ss0
0
2
4
6
8
10
D) pp_ss1
0
2
4
6
8
10
E) pp_ss2
0
2
4
6
8
10
F) pp_strt0
0.96
0.98
1.00
1.02
1.04
G) pp_strt1
0.96
0.98
1.00
1.02
1.04
H) pp_strt2
0.96
0.98
1.00
1.02
1.04


A) pp_sy0
0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8
B) pp_sy1
0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8
C) pp_sy2
0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8
D) pp_vka0
0 2 4 6 8 10
E) pp_vka1
0 2 4 6 8 10
F) pp_vka2
0 2 4 6 8 10
G) strk
0 20 40 60 80 100
H) welflux
0.8 1.0 1.2 1.4 1.6 1.8 2.0



1.1.3 PESTPP-IES with par-by-par distance based localization

```
In [19]: m = flopy.modflow.Modflow.load("freyberg.nam",model_ws="template")
```

```
In [20]: par = pst.parameter_data

         gr_par = par.loc[par.pargp.apply(lambda x: "gr" in x and "prsity" not in x),:].copy()
         print(gr_par.pargp.unique())
         gr_par.groupby("pargp").groups
         gr_par.loc[:,"i"] = gr_par.parnme.apply(lambda x: int(x[-6:-3]))
         gr_par.loc[:,"j"] = gr_par.parnme.apply(lambda x: int(x[-3:]))
         gr_par.loc[:,"x"] = gr_par.apply(lambda x: m.sr.xcentergrid[x.i,x.j],axis=1)
         gr_par.loc[:,"y"] = gr_par.apply(lambda x: m.sr.ycentergrid[x.i,x.j],axis=1)

         obs = pst.observation_data

         nobs = obs.loc[obs.obgnme=="calhead",:].copy()
         nobs.loc[:,"i"] = nobs.obsnme.apply(lambda x: int(x.split('_')[2]))
         nobs.loc[:,"j"] = nobs.obsnme.apply(lambda x: int(x.split('_')[3]))
         nobs.loc[:,"x"] = nobs.apply(lambda x: m.sr.xcentergrid[x.i,x.j],axis=1)
         nobs.loc[:,"y"] = nobs.apply(lambda x: m.sr.ycentergrid[x.i,x.j],axis=1)

         pp_tpl = [f for f in os.listdir(t_d) if "pp" in f and f.endswith(".tpl")]
         pp_tpl_dfs = [pyemu.pp_utils.pp_tpl_to_dataframe(os.path.join(t_d,f)) for f in pp_tpl]
         pp_par = pd.concat(pp_tpl_dfs)
         pp_par.index = pp_par.parnme
         #pp_par = par.loc[par.pargp.apply(lambda x: "pp" in x),:].copy()
```

```
['gr_hk3' 'gr_hk4' 'gr_hk5' 'gr_rech2' 'gr_rech3' 'gr_ss3' 'gr_ss4'
 'gr_ss5' 'gr_strt3' 'gr_strt4' 'gr_strt5' 'gr_sy3' 'gr_sy4' 'gr_sy5'
 'gr_vka3' 'gr_vka4' 'gr_vka5']
```

1.2 We will set up localization such that parameters are only informed by observations within a user-specfied distance (we can use 5000 meters)

```
In [21]: loc = pyemu.Matrix.from_names(pst.nnz_obs_names,pst.adj_par_names).to_dataframe()
         loc.loc[:,:] = 1.0
         loc_dist = 5000.0
         sadj = set(pst.adj_par_names)
         print('obsname            fraction grid retained   fraction pilot points retained')
         for oname in obs.loc[obs.obgnme=="calhead","obsnme"]:
             xx,yy = nobs.loc[oname,['x','y']]

             # localization for grid-based parameters
             gr_par.loc[:,"dist"] = gr_par.apply(lambda x: (x.x - xx)**2 + (x.y - yy)**2,axis=
             gr_too_far = gr_par.loc[gr_par.dist > loc_dist,"parnme"]
             gr_too_far = gr_too_far.loc[gr_too_far.apply(lambda x: x in sadj)]
             loc.loc[:,gr_too_far] = 0.0

             # localization for pilot point parameters
             pp_par.loc[:,"dist"] = pp_par.apply(lambda x: (x.x - xx)**2 + (x.y - yy)**2,axis=
```

```
            pp_too_far = pp_par.loc[pp_par.dist > loc_dist,"parnme"]
            pp_too_far = pp_too_far.loc[pp_too_far.apply(lambda x: x in sadj)]
            loc.loc[oname,pp_too_far] = 0.0
            print(oname,gr_too_far.shape[0]/gr_par.shape[0],pp_too_far.shape[0]/pp_par.shape[

        loc.loc[:,dont_pars] = 0.0
        #spars = par.loc[par.parnme.apply(lambda x: "ss" in x or "sy" in x),"parnme"]
        #loc.loc[:,spars] = 0.0
        print('\n\nTotal number of parameters still informed by each observation')
        loc.sum(axis=1)
```

```
obsname            fraction grid retained   fraction pilot points retained
hds_00_002_009_000 0.46382978723404256 0.46875
hds_00_002_015_000 0.4794326241134752 0.5
hds_00_003_008_000 0.43829787234042555 0.34375
hds_00_009_001_000 0.3304964539007092 0.25
hds_00_013_010_000 0.15319148936170213 0.09375
hds_00_015_016_000 0.13900709219858157 0.0625
hds_00_021_010_000 0.06950354609929078 0.03125
hds_00_022_015_000 0.12198581560283688 0.15625
hds_00_024_004_000 0.17872340425531916 0.15625
hds_00_026_006_000 0.2198581560283688 0.21875
hds_00_029_015_000 0.29929078014184396 0.28125
hds_00_033_007_000 0.3829787234042553 0.375
hds_00_034_010_000 0.4 0.40625


Total number of parameters still informed by each observation


Out[21]: fo_39_19791230        1786.0
         hds_00_002_009_000    1546.0
         hds_00_002_015_000    1530.0
         hds_00_003_008_000    1610.0
         hds_00_009_001_000    1658.0
         hds_00_013_010_000    1738.0
         hds_00_015_016_000    1754.0
         hds_00_021_010_000    1770.0
         hds_00_022_015_000    1706.0
         hds_00_024_004_000    1706.0
         hds_00_026_006_000    1674.0
         hds_00_029_015_000    1642.0
         hds_00_033_007_000    1594.0
         hds_00_034_010_000    1578.0
         dtype: float64
```

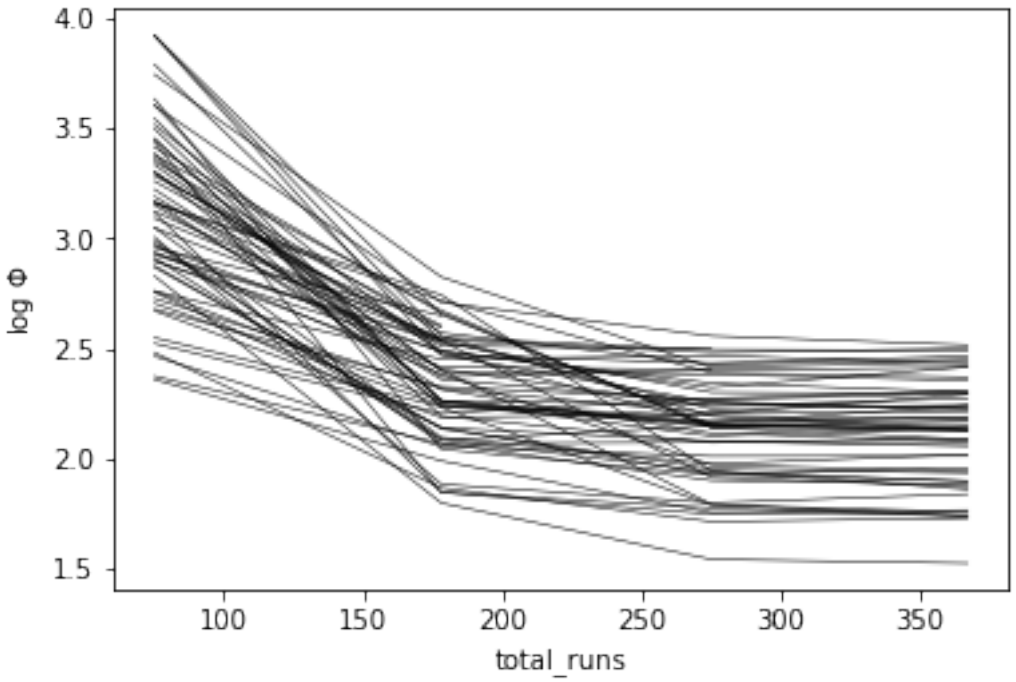
```
In [22]: pyemu.Matrix.from_dataframe(loc).to_coo(os.path.join(t_d,"loc.jcb"))
         pst.pestpp_options["ies_localizer"] = "loc.jcb"
         pst.write(os.path.join(t_d,"freyberg_ies.pst"))
```

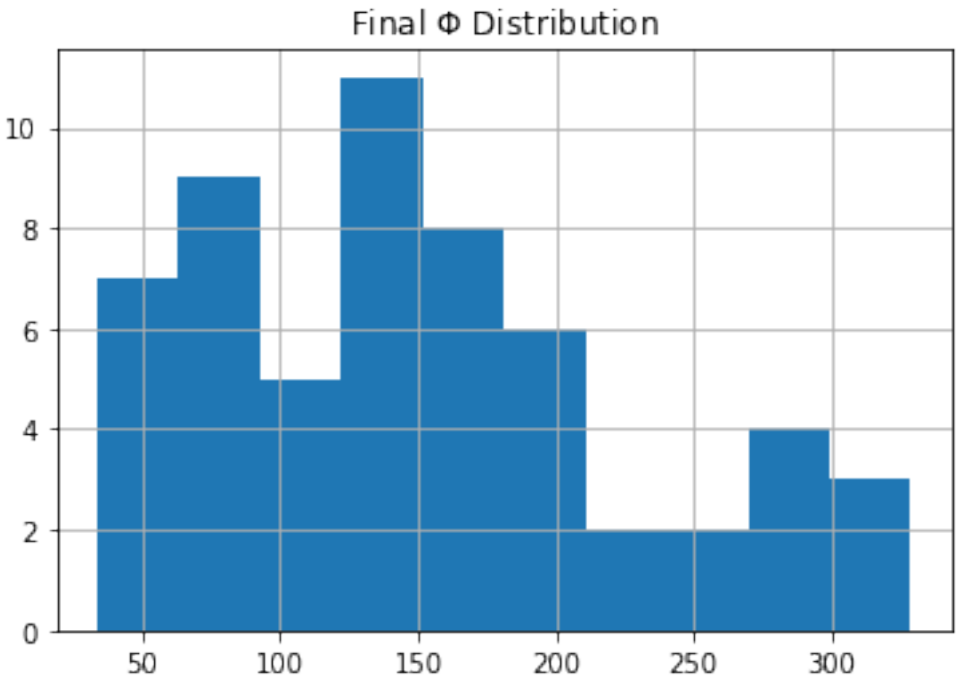
```
noptmax:3, npar_adj:14819, nnz_obs:14
```

1.2.1 now let's run it

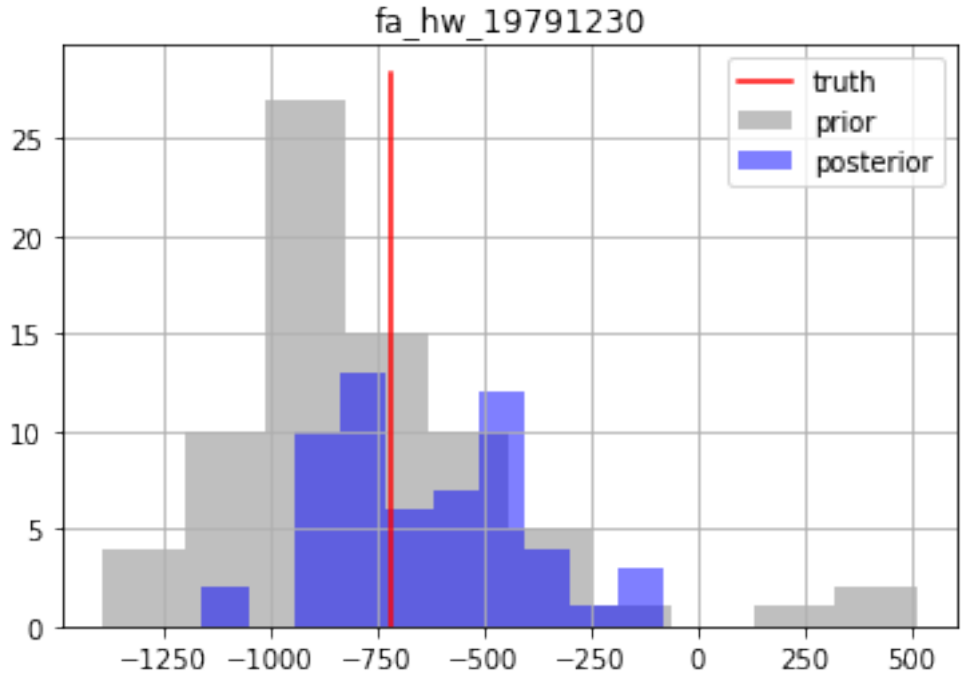
```
In [23]: pyemu.os_utils.start_slaves(t_d,"pestpp-ies","freyberg_ies.pst",num_slaves=num_workers
```

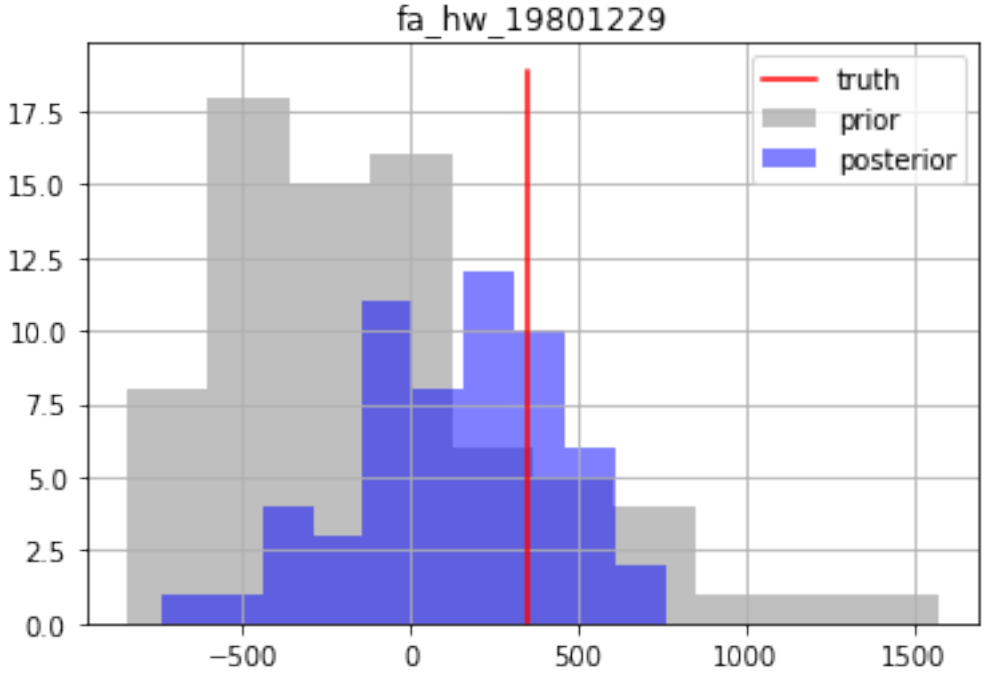
```
In [24]: phi = pd.read_csv(os.path.join(m_d,"freyberg_ies.phi.actual.csv"),index_col=0)
         phi.index = phi.total_runs
         phi.iloc[:,6:].apply(np.log10).plot(legend=False,lw=0.5,color='k')
         plt.ylabel('log $\Phi$')
         plt.show()
         phi.iloc[-1,6:].hist()
         plt.title('Final $\Phi$ Distribution');
```

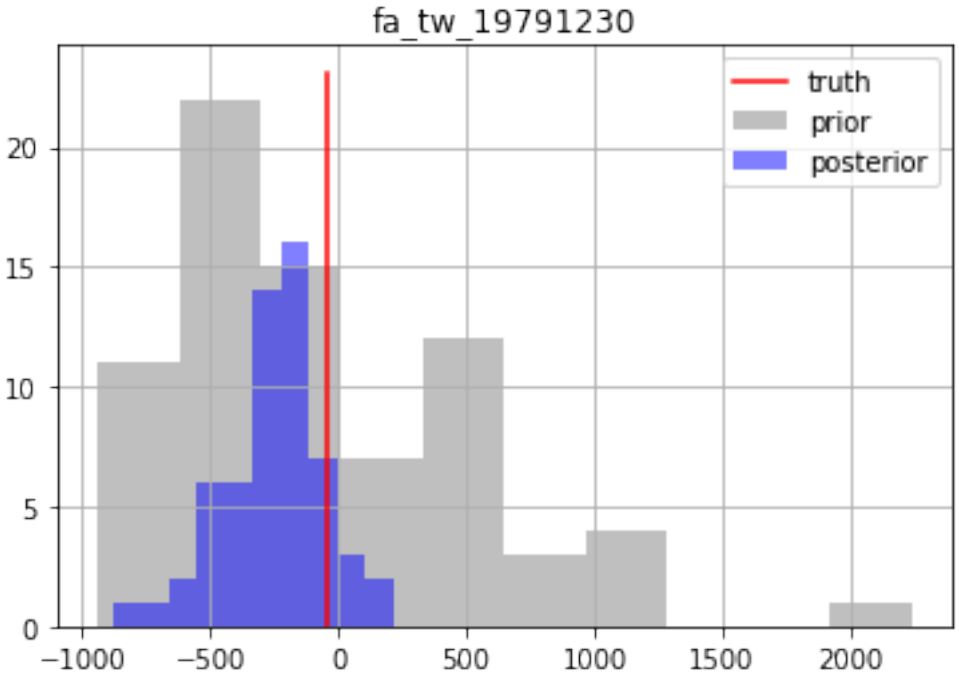


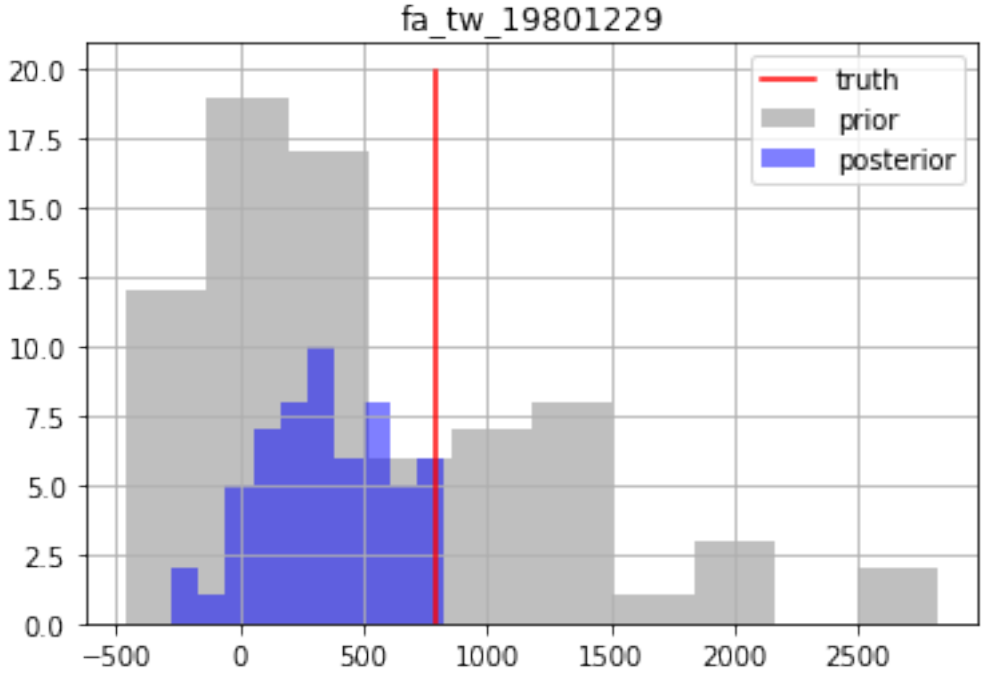


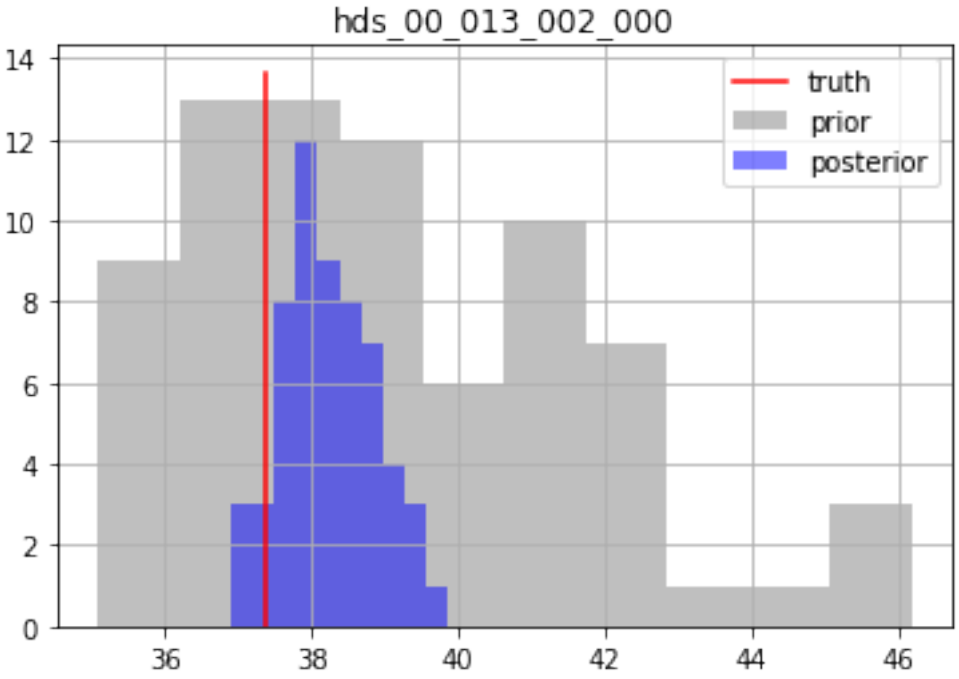

```
In [25]: oe_pr = pd.read_csv(os.path.join(m_d,"freyberg_ies.0.obs.csv"),index_col=0)
         oe_pt = pd.read_csv(os.path.join(m_d,"freyberg_ies.{0}.obs.csv".format(pst.control_da
         obs = pst.observation_data
         fnames = pst.pestpp_options["forecasts"].split(",")
         for forecast in fnames:
             ax = plt.subplot(111)
             oe_pr.loc[:,forecast].hist(ax=ax,color="0.5",alpha=0.5, label='prior')
             oe_pt.loc[:,forecast].hist(ax=ax,color="b",alpha=0.5, label='posterior')
             ax.plot([obs.loc[forecast,"obsval"],obs.loc[forecast,"obsval"]],ax.get_ylim(),"r"
             ax.set_title(forecast)
             ax.legend(loc='upper right')
             plt.show()
```

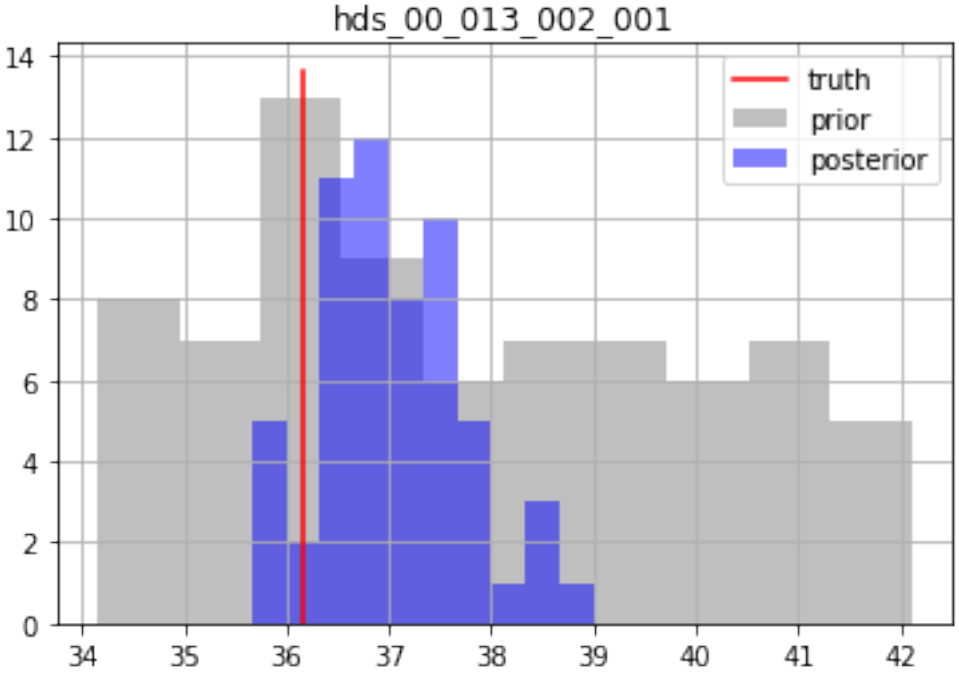

fa_hw_19791230
truth
prior
posterior
25
20
15
10
5
0
−1250
−1000
−750
−500
−250
0
250
500

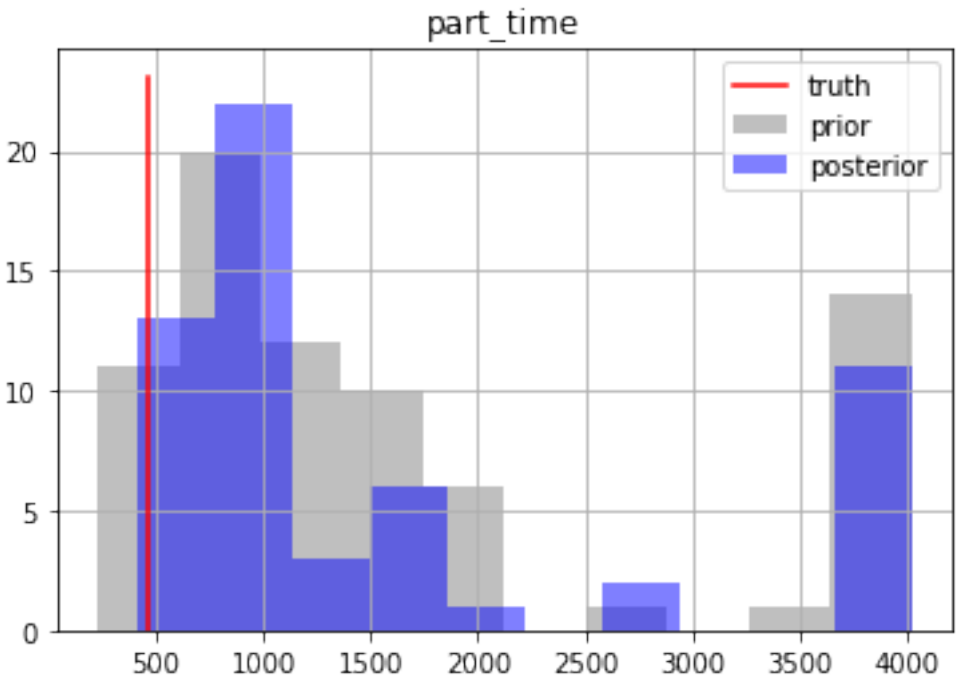

fa_hw_19801229
truth
prior
posterior
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0.0
−500
0
500
1000
1500

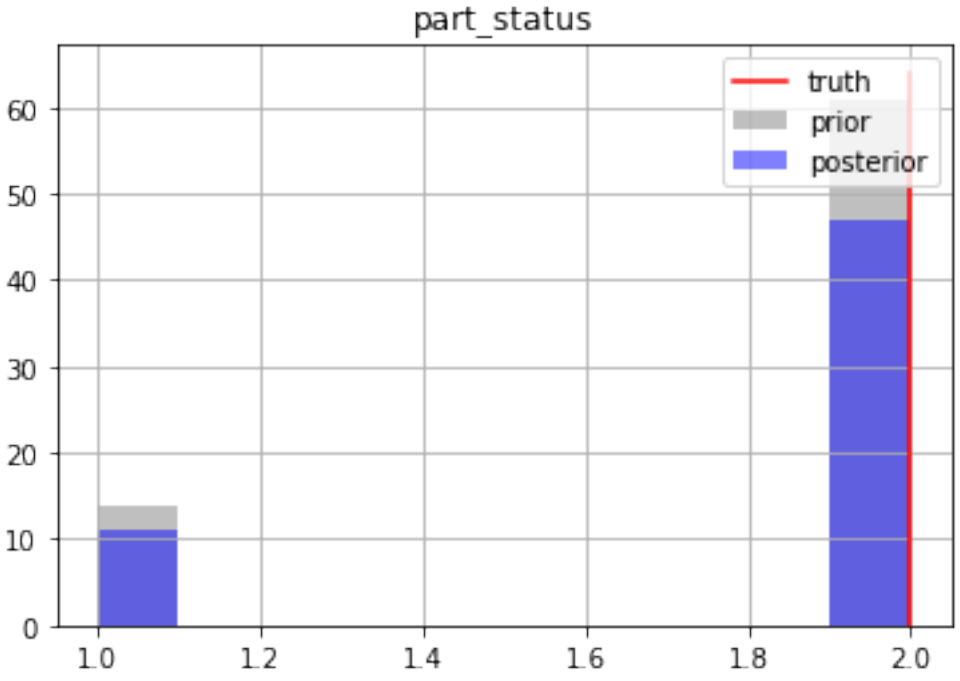

fa_tw_19791230
truth
prior
posterior
20
15
10
5
0
−1000
−500
0
500
1000
1500
2000


fa_tw_19801229
truth
prior
posterior
20.0
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0.0
−500
0
500
1000
1500
2000
2500


hds_00_013_002_000
truth
prior
posterior
0
2
4
6
8
10
12
14
36
38
40
42
44
46


hds_00_013_002_001
truth
prior
posterior
0
2
4
6
8
10
12
14
34
35
36
37
38
39
40
41
42



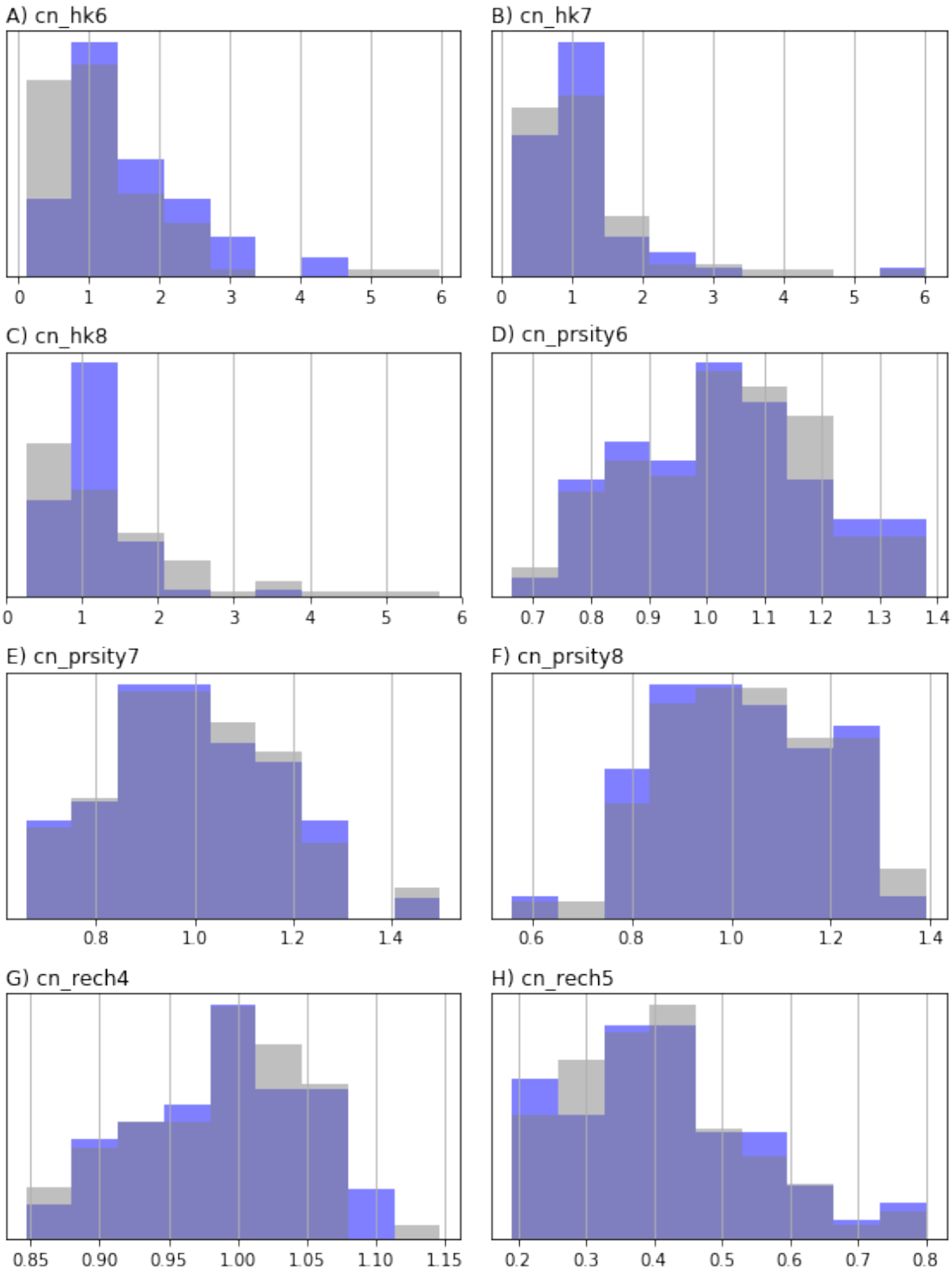


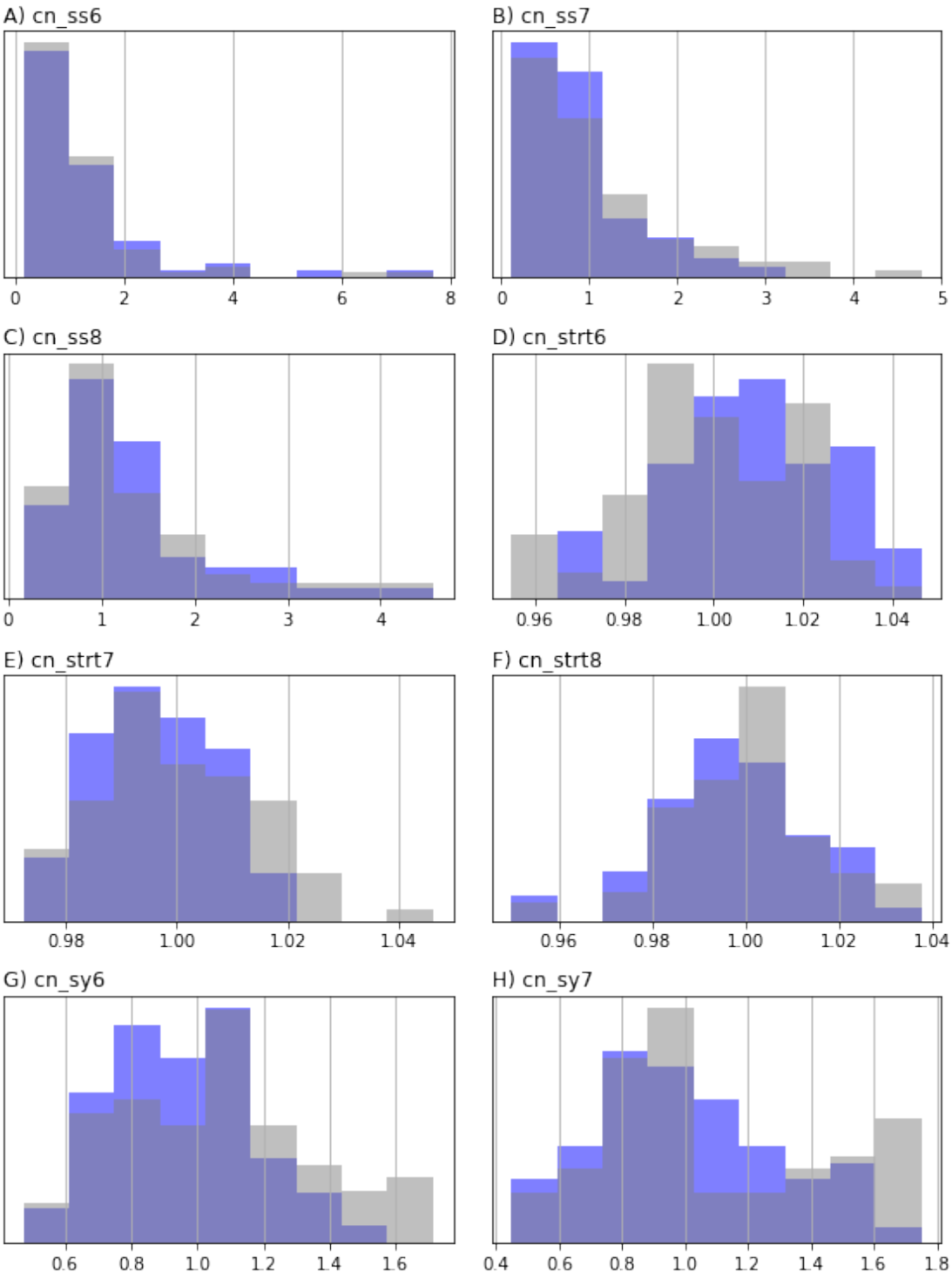

```
In [26]: pe_pr = pd.read_csv(os.path.join(m_d,"freyberg_ies.0.par.csv"),index_col=0)
         pe_pt = pd.read_csv(os.path.join(m_d,"freyberg_ies.{0}.par.csv".format(pst.control_da
```

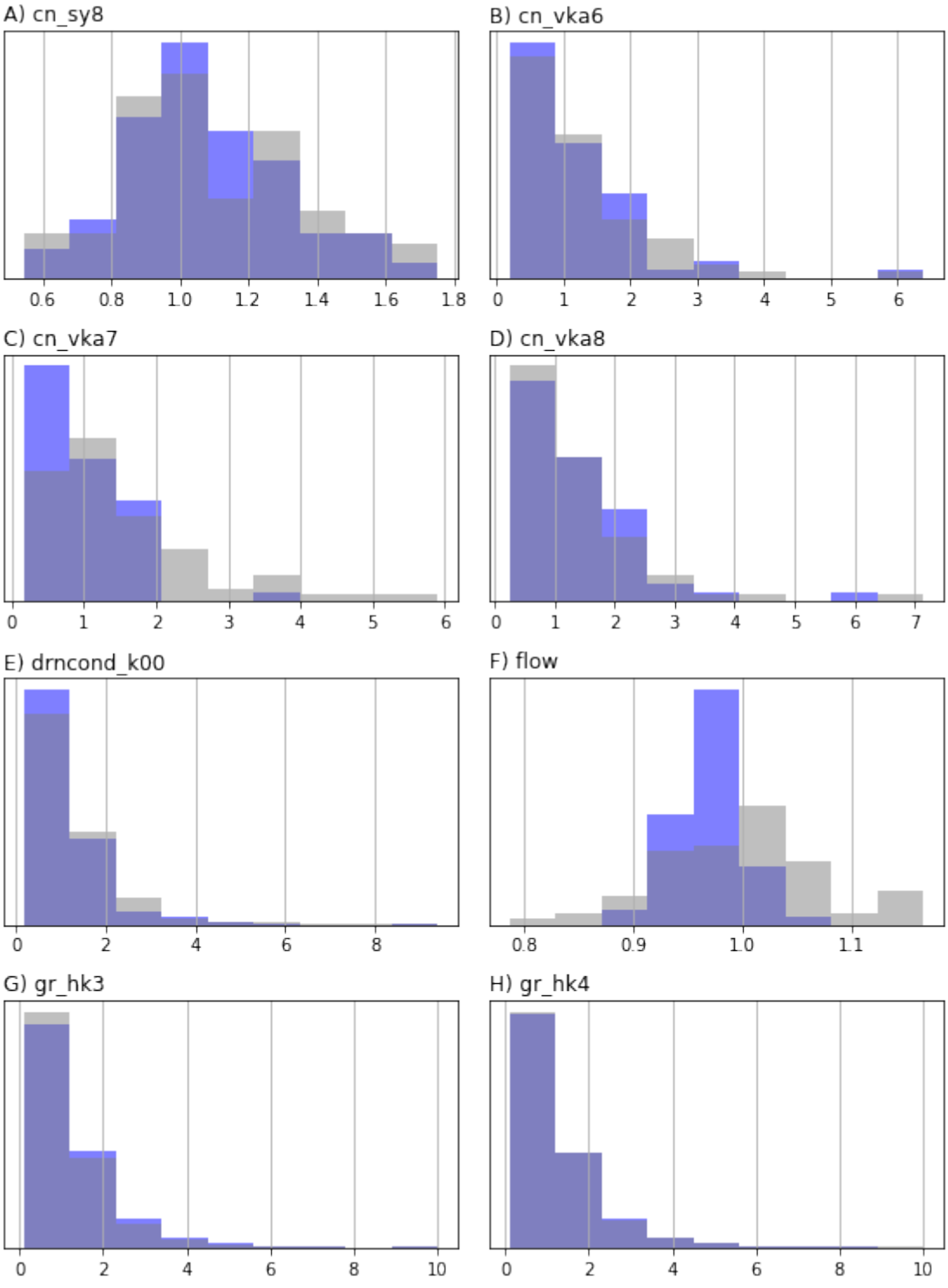
```
        par = pst.parameter_data
        pdict = par.groupby("pargp").groups
        pyemu.plot_utils.ensemble_helper({"0.5":pe_pr,"b":pe_pt},plot_cols=pdict)
        #pyemu.plot_utils.ensemble_change_summary(pe_pr,pe_pt,pst=pst,bins=20)
```

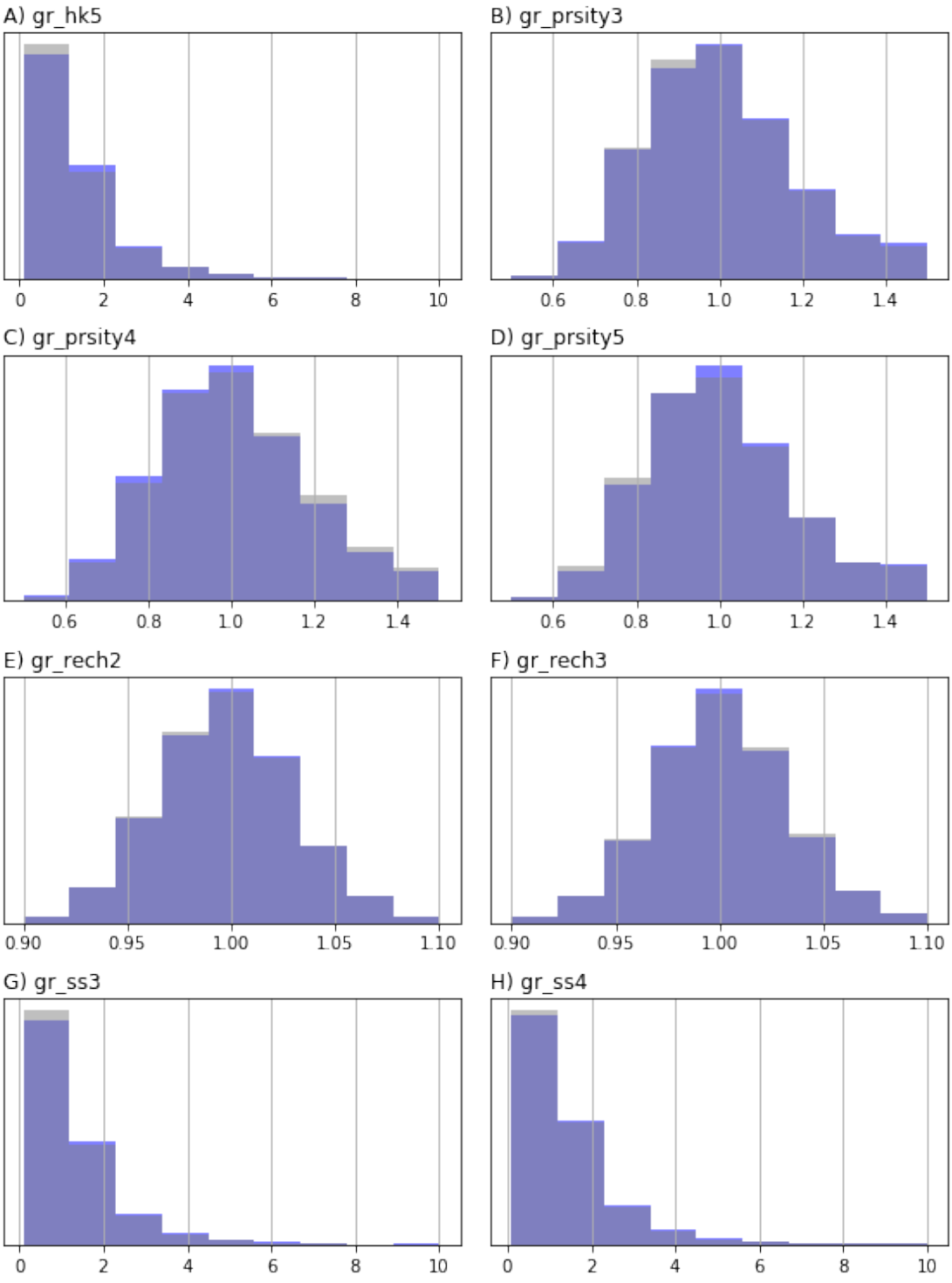
```
/Users/jeremyw/miniconda3/lib/python3.5/site-packages/IPython/core/interactiveshell.py:2785: D
  interactivity=interactivity, compiler=compiler, result=result)
```

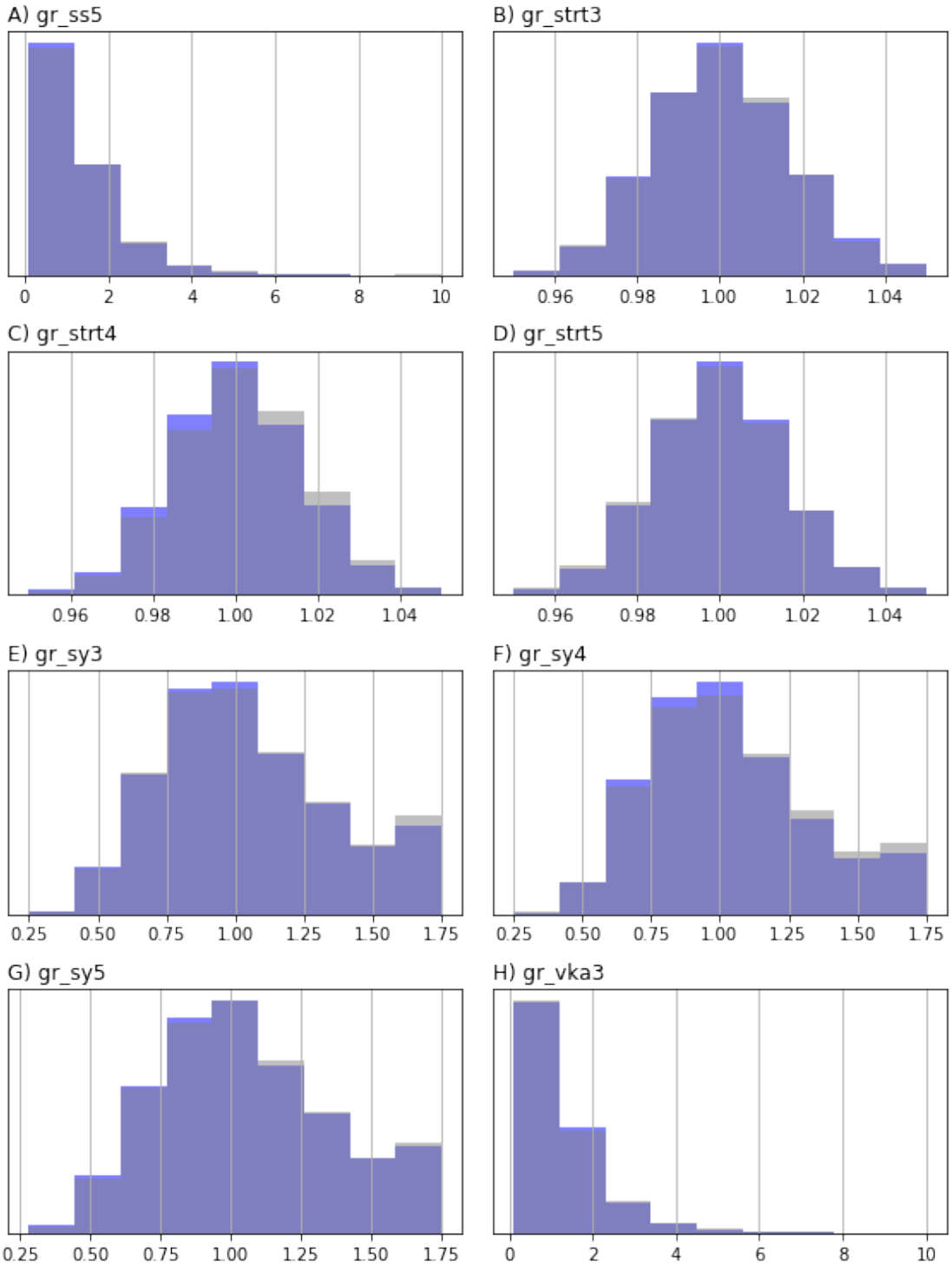
```
<Figure size 576x756 with 0 Axes>
```

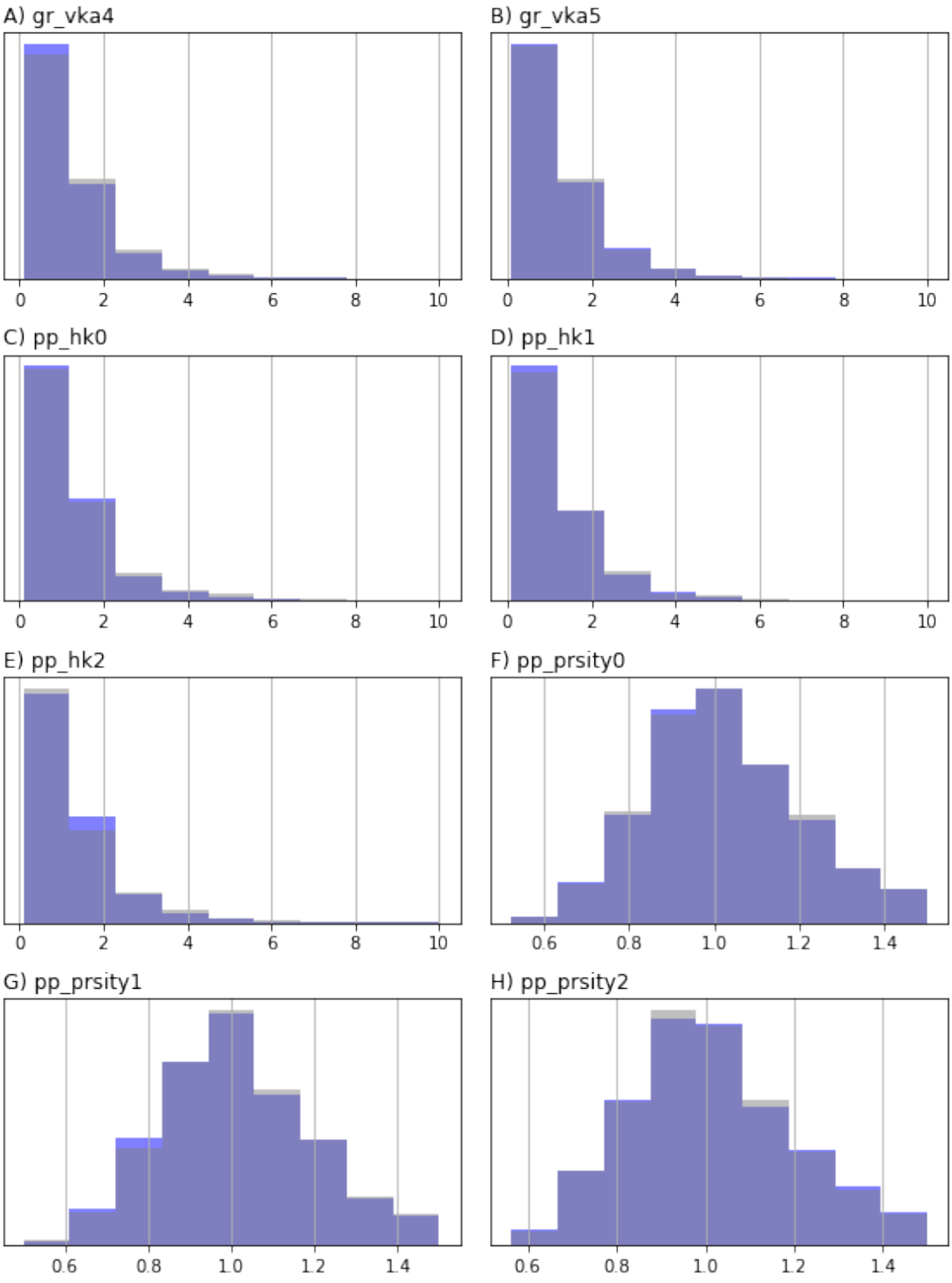

A) cn_hk6
0 1 2 3 4 5 6
B) cn_hk7
0 1 2 3 4 5 6
C) cn_hk8
0 1 2 3 4 5 6
D) cn_prsity6
0.7 0.8 0.9 1.0 1.1 1.2 1.3 1.4
E) cn_prsity7
0.8 1.0 1.2 1.4
F) cn_prsity8
0.6 0.8 1.0 1.2 1.4
G) cn_rech4
0.85 0.90 0.95 1.00 1.05 1.10 1.15
H) cn_rech5
0.2 0.3 0.4 0.5 0.6 0.7 0.8

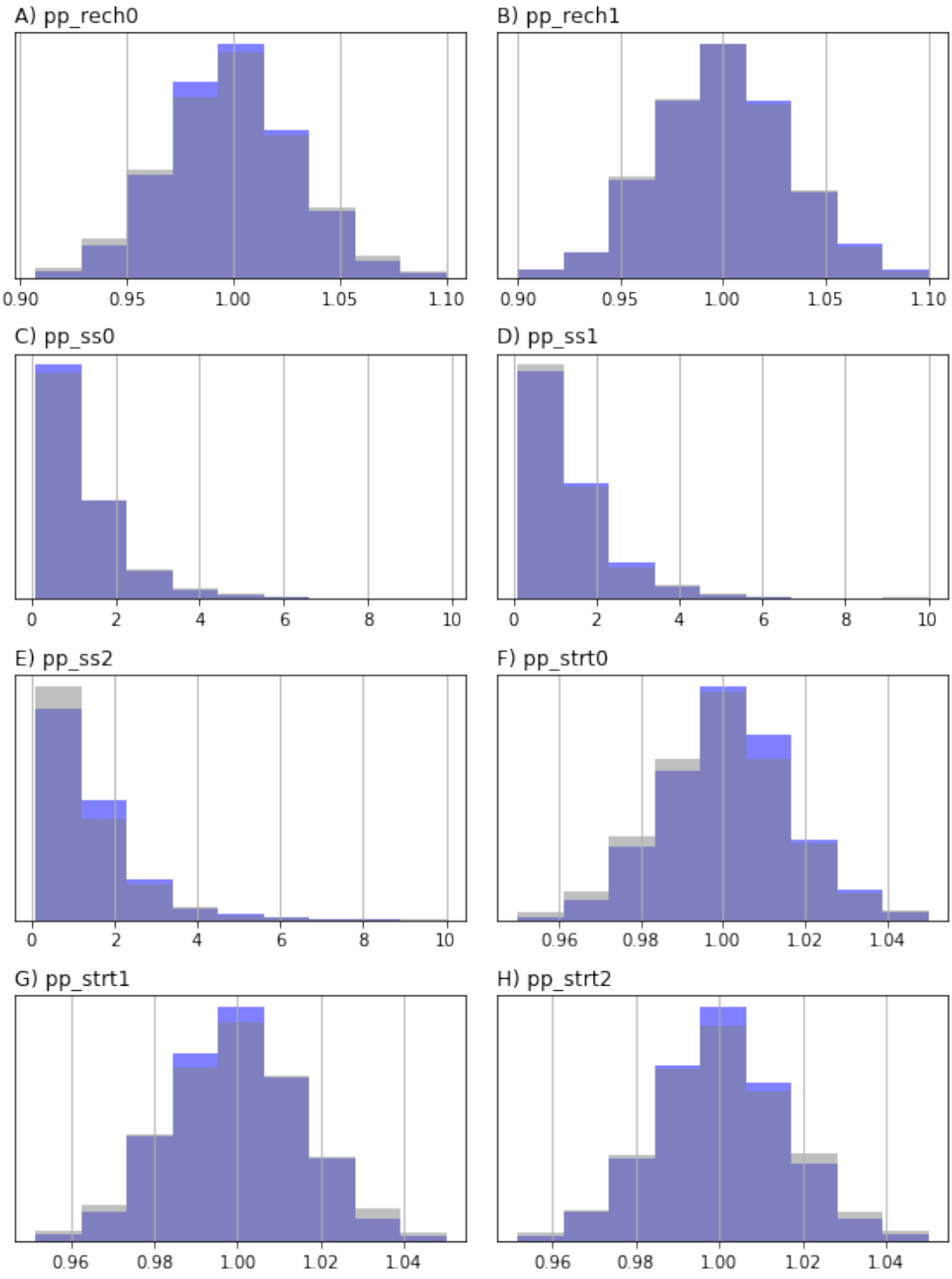

A) cn_ss6
0
2
4
6
8
B) cn_ss7
0
1
2
3
4
5
C) cn_ss8
0
1
2
3
4
D) cn_strt6
0.96
0.98
1.00
1.02
1.04
E) cn_strt7
0.98
1.00
1.02
1.04
F) cn_strt8
0.96
0.98
1.00
1.02
1.04
G) cn_sy6
0.6
0.8
1.0
1.2
1.4
1.6
H) cn_sy7
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8

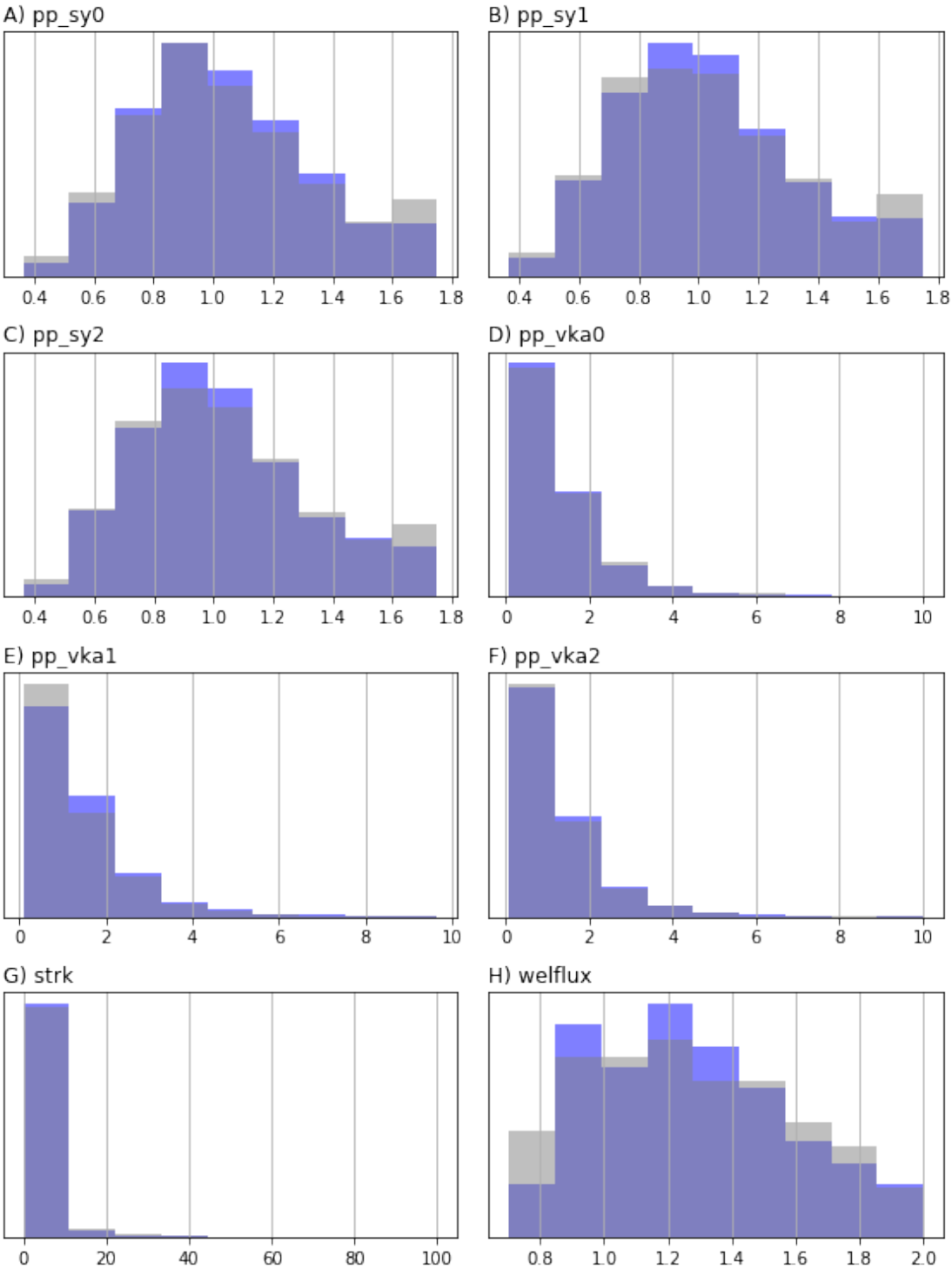

A) cn_sy8
0.6
0.8
1.0
1.2
1.4
1.6
1.8
B) cn_vka6
0
1
2
3
4
5
6
C) cn_vka7
0
1
2
3
4
5
6
D) cn_vka8
0
1
2
3
4
5
6
7
E) drncond_k00
0
2
4
6
8
F) flow
0.8
0.9
1.0
1.1
G) gr_hk3
0
2
4
6
8
10
H) gr_hk4
0
2
4
6
8
10

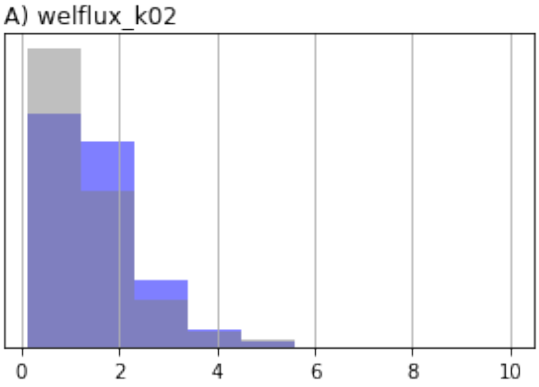

A) gr_hk5
0
2
4
6
8
10
B) gr_prsity3
0.6
0.8
1.0
1.2
1.4
C) gr_prsity4
0.6
0.8
1.0
1.2
1.4
D) gr_prsity5
0.6
0.8
1.0
1.2
1.4
E) gr_rech2
0.90
0.95
1.00
1.05
1.10
F) gr_rech3
0.90
0.95
1.00
1.05
1.10
G) gr_ss3
0
2
4
6
8
10
H) gr_ss4
0
2
4
6
8
10


A) gr_ss5
0
2
4
6
8
10
B) gr_strt3
0.96
0.98
1.00
1.02
1.04
C) gr_strt4
0.96
0.98
1.00
1.02
1.04
D) gr_strt5
0.96
0.98
1.00
1.02
1.04
E) gr_sy3
0.25
0.50
0.75
1.00
1.25
1.50
1.75
F) gr_sy4
0.25
0.50
0.75
1.00
1.25
1.50
1.75
G) gr_sy5
0.25
0.50
0.75
1.00
1.25
1.50
1.75
H) gr_vka3
0
2
4
6
8
10


A) gr_vka4
B) gr_vka5
C) pp_hk0
D) pp_hk1
E) pp_hk2
F) pp_prsity0
G) pp_prsity1
H) pp_prsity2
0
2
4
6
8
10
0.6
0.8
1.0
1.2
1.4


A) pp_rech0
0.90
0.95
1.00
1.05
1.10
B) pp_rech1
0.90
0.95
1.00
1.05
1.10
C) pp_ss0
0
2
4
6
8
10
D) pp_ss1
0
2
4
6
8
10
E) pp_ss2
0
2
4
6
8
10
F) pp_strt0
0.96
0.98
1.00
1.02
1.04
G) pp_strt1
0.96
0.98
1.00
1.02
1.04
H) pp_strt2
0.96
0.98
1.00
1.02
1.04


A) pp_sy0
0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8
B) pp_sy1
0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8
C) pp_sy2
0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8
D) pp_vka0
0 2 4 6 8 10
E) pp_vka1
0 2 4 6 8 10
F) pp_vka2
0 2 4 6 8 10
G) strk
0 20 40 60 80 100
H) welflux
0.8 1.0 1.2 1.4 1.6 1.8 2.0


A) welflux_k02
0
2
4
6
8
10