# pestpp-glm

May 8, 2019

## 1 PESTPP-GLM

In this notebook, we will run PESTPP-GLM in standard parameter estimation mode and regularization mode. In both cases, we will use the baked-in bayes-linear posterior monte carlo analysis to get posterior forecast PDFs. We will use the prior monte carlo outputs as the prior forecast PDF.

In [1]:
```
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
```

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

In [2]:
```
t_d = "template"
m_d = "master_glm"
```

In [3]:
```
pst = pyemu.Pst(os.path.join(t_d,"freyberg.pst"))
pst.write_par_summary_table(filename="none")
```

Out[3]:

| | type | transform | count | initial value \ |
|---|---|---|---|---|
| strk | strk | log | 40 | 0 |
| cn_strt7 | cn_strt7 | log | 1 | 0 |
| cn_vka6 | cn_vka6 | log | 1 | 0 |
| cn_rech4 | cn_rech4 | log | 1 | 0 |
| flow | flow | log | 1 | 0 |
| pp_hk2 | pp_hk2 | log | 32 | 0 |
| pp_vka1 | pp_vka1 | log | 32 | 0 |
| pp_hk0 | pp_hk0 | log | 32 | 0 |
| pp_strt0 | pp_strt0 | log | 32 | 0 |
| gr_ss5 | gr_ss5 | log | 705 | 0 |
| pp_vka0 | pp_vka0 | log | 32 | 0 |

| | | | | |
|---|---|---|---|---|
| cn_sy6 | cn_sy6 | log | 1 | 0 |
| cn_sy7 | cn_sy7 | log | 1 | 0 |
| gr_vka3 | gr_vka3 | log | 705 | 0 |
| gr_hk4 | gr_hk4 | log | 705 | 0 |
| gr_rech3 | gr_rech3 | log | 705 | 0 |
| pp_sy0 | pp_sy0 | log | 32 | 0 |
| gr_sy3 | gr_sy3 | log | 705 | 0 |
| pp_rech1 | pp_rech1 | log | 32 | 0 |
| gr_strt5 | gr_strt5 | log | 705 | 0 |
| pp_ss2 | pp_ss2 | log | 32 | 0 |
| pp_prsity0 | pp_prsity0 | log | 32 | 0 |
| pp_vka2 | pp_vka2 | log | 32 | 0 |
| welflux | welflux | log | 2 | 0 to 0.176091 |
| gr_hk5 | gr_hk5 | log | 705 | 0 |
| gr_rech2 | gr_rech2 | log | 705 | 0 |
| pp_sy1 | pp_sy1 | log | 32 | 0 |
| gr_strt4 | gr_strt4 | log | 705 | 0 |
| gr_ss3 | gr_ss3 | log | 705 | 0 |
| pp_prsity1 | pp_prsity1 | log | 32 | 0 |
| ... | ... | ... | ... | ... |
| gr_strt3 | gr_strt3 | log | 705 | 0 |
| cn_prsity8 | cn_prsity8 | log | 1 | 0 |
| cn_ss7 | cn_ss7 | log | 1 | 0 |
| cn_sy8 | cn_sy8 | log | 1 | 0 |
| pp_ss0 | pp_ss0 | log | 32 | 0 |
| gr_sy5 | gr_sy5 | log | 705 | 0 |
| pp_hk1 | pp_hk1 | log | 32 | 0 |
| cn_prsity6 | cn_prsity6 | log | 1 | 0 |
| gr_prsity3 | gr_prsity3 | log | 705 | 0 |
| cn_vka8 | cn_vka8 | log | 1 | 0 |
| gr_sy4 | gr_sy4 | log | 705 | 0 |
| cn_ss6 | cn_ss6 | log | 1 | 0 |
| cn_hk8 | cn_hk8 | log | 1 | 0 |
| pp_sy2 | pp_sy2 | log | 32 | 0 |
| pp_ss1 | pp_ss1 | log | 32 | 0 |
| cn_strt8 | cn_strt8 | log | 1 | 0 |
| pp_strt2 | pp_strt2 | log | 32 | 0 |
| cn_strt6 | cn_strt6 | log | 1 | 0 |
| cn_rech5 | cn_rech5 | log | 1 | -0.39794 |
| gr_hk3 | gr_hk3 | log | 705 | 0 |
| pp_rech0 | pp_rech0 | log | 32 | 0 |
| pp_prsity2 | pp_prsity2 | log | 32 | 0 |
| cn_vka7 | cn_vka7 | log | 1 | 0 |
| pp_strt1 | pp_strt1 | log | 32 | 0 |
| gr_ss4 | gr_ss4 | log | 705 | 0 |
| cn_hk7 | cn_hk7 | log | 1 | 0 |
| gr_prsity4 | gr_prsity4 | log | 705 | 0 |
| gr_prsity5 | gr_prsity5 | log | 705 | 0 |

| | | | | |
|---|---|---|---|---|
| welflux_k02 | welflux_k02 | log | 6 | 0 |
| drncond_k00 | drncond_k00 | log | 10 | 0 |

| | upper bound | lower bound | standard deviation |
|---|---|---|---|
| strk | 2 | -2 | 1 |
| cn_strt7 | 0.0211893 | -0.0222764 | 0.0108664 |
| cn_vka6 | 1 | -1 | 0.5 |
| cn_rech4 | 0.0791812 | -0.09691 | 0.0440228 |
| flow | 0.09691 | -0.124939 | 0.0554622 |
| pp_hk2 | 1 | -1 | 0.5 |
| pp_vka1 | 1 | -1 | 0.5 |
| pp_hk0 | 1 | -1 | 0.5 |
| pp_strt0 | 0.0211893 | -0.0222764 | 0.0108664 |
| gr_ss5 | 1 | -1 | 0.5 |
| pp_vka0 | 1 | -1 | 0.5 |
| cn_sy6 | 0.243038 | -0.60206 | 0.211275 |
| cn_sy7 | 0.243038 | -0.60206 | 0.211275 |
| gr_vka3 | 1 | -1 | 0.5 |
| gr_hk4 | 1 | -1 | 0.5 |
| gr_rech3 | 0.0413927 | -0.0457575 | 0.0217875 |
| pp_sy0 | 0.243038 | -0.60206 | 0.211275 |
| gr_sy3 | 0.243038 | -0.60206 | 0.211275 |
| pp_rech1 | 0.0413927 | -0.0457575 | 0.0217875 |
| gr_strt5 | 0.0211893 | -0.0222764 | 0.0108664 |
| pp_ss2 | 1 | -1 | 0.5 |
| pp_prsity0 | 0.176091 | -0.30103 | 0.11928 |
| pp_vka2 | 1 | -1 | 0.5 |
| welflux | 0.176091 to 0.30103 | -0.30103 to 0 | 0.0752575 to 0.11928 |
| gr_hk5 | 1 | -1 | 0.5 |
| gr_rech2 | 0.0413927 | -0.0457575 | 0.0217875 |
| pp_sy1 | 0.243038 | -0.60206 | 0.211275 |
| gr_strt4 | 0.0211893 | -0.0222764 | 0.0108664 |
| gr_ss3 | 1 | -1 | 0.5 |
| pp_prsity1 | 0.176091 | -0.30103 | 0.11928 |
| ... | ... | ... | ... |
| gr_strt3 | 0.0211893 | -0.0222764 | 0.0108664 |
| cn_prsity8 | 0.176091 | -0.30103 | 0.11928 |
| cn_ss7 | 1 | -1 | 0.5 |
| cn_sy8 | 0.243038 | -0.60206 | 0.211275 |
| pp_ss0 | 1 | -1 | 0.5 |
| gr_sy5 | 0.243038 | -0.60206 | 0.211275 |
| pp_hk1 | 1 | -1 | 0.5 |
| cn_prsity6 | 0.176091 | -0.30103 | 0.11928 |
| gr_prsity3 | 0.176091 | -0.30103 | 0.11928 |
| cn_vka8 | 1 | -1 | 0.5 |
| gr_sy4 | 0.243038 | -0.60206 | 0.211275 |
| cn_ss6 | 1 | -1 | 0.5 |
| cn_hk8 | 1 | -1 | 0.5 |

```
pp_sy2              0.243038     -0.60206     0.211275
pp_ss1                     1           -1          0.5
cn_strt8           0.0211893   -0.0222764    0.0108664
pp_strt2           0.0211893   -0.0222764    0.0108664
cn_strt6           0.0211893   -0.0222764    0.0108664
cn_rech5            -0.09691           -1     0.225772
gr_hk3                     1           -1          0.5
pp_rech0           0.0413927   -0.0457575    0.0217875
pp_prsity2          0.176091     -0.30103      0.11928
cn_vka7                    1           -1          0.5
pp_strt1           0.0211893   -0.0222764    0.0108664
gr_ss4                     1           -1          0.5
cn_hk7                     1           -1          0.5
gr_prsity4          0.176091     -0.30103      0.11928
gr_prsity5          0.176091     -0.30103      0.11928
welflux_k02                1           -1          0.5
drncond_k00                1           -1          0.5

[65 rows x 7 columns]
```

### 1.0.1 reduce the number of adjustable parameters

This is the painful part: we cant use 10K+ pars because we cant wait around for that many runs and then the linear algebra of factoring a 10k+ by 10K+ matrix is also difficult. So that means we need to fix a lot a parameters #frownyface

In [4]:
```
par = pst.parameter_data
```

In [5]:
```
# grid-scale pars
gr_pars = par.loc[par.pargp.apply(lambda x: "gr" in x),"parnme"]
par.loc[gr_pars,"partrans"] = "fixed"
pst.npar_adj
```

Out[5]:
```
719
```

In [6]:
```
# these are the sfr conductance parameters - Ive left all 40 adjustable
# but if you uncomment this, it will tie them into 1 parameter effectively
# strk_pars = par.loc[par.pargp=="strk","parnme"]
# p1 = strk_pars.iloc[0]
# par.loc[strk_pars.iloc[1:],"partrans"] = "tied"
# par.loc[strk_pars.iloc[1:],"partied"] = p1
pst.npar_adj
```

Out[6]:
```
719
```

In [7]:
```
par.loc[par.pargp.apply(lambda x: "pp" in x),"pargp"].unique()
```

Out[7]:
```
array(['pp_hk0', 'pp_hk1', 'pp_hk2', 'pp_prsity0', 'pp_prsity1',
       'pp_prsity2', 'pp_rech0', 'pp_rech1', 'pp_ss0', 'pp_ss1', 'pp_ss2',
       'pp_strt0', 'pp_strt1', 'pp_strt2', 'pp_sy0', 'pp_sy1', 'pp_sy2',
       'pp_vka0', 'pp_vka1', 'pp_vka2'], dtype=object)
```

Fix the storage pilot points - we still have layer-scale storage pars adjustable

In [8]:
```
#s_pars = par.loc[par.pargp.apply(lambda x: "pp" in x and ("ss" in x or "sy" in x)),"p
#par.loc[s_pars,"partrans"] = "fixed"
pst.npar_adj
```

Out[8]: 719

In [9]:
```
adj_par = par.loc[par.partrans=="log",:]
adj_par.pargp.value_counts().sort_values()
```

Out[9]:
```
cn_sy8          1
cn_strt7        1
cn_strt6        1
flow            1
cn_strt8        1
cn_ss6          1
cn_vka8         1
cn_vka7         1
cn_sy6          1
cn_prsity6      1
cn_vka6         1
cn_rech5        1
cn_hk7          1
cn_hk8          1
cn_prsity7      1
cn_hk6          1
cn_ss8          1
cn_sy7          1
cn_prsity8      1
cn_ss7          1
cn_rech4        1
welflux         2
welflux_k02     6
drncond_k00    10
pp_strt2       32
pp_ss1         32
pp_hk2         32
pp_vka1        32
pp_hk0         32
pp_strt0       32
pp_vka0        32
pp_rech1       32
pp_prsity0     32
pp_sy1         32
pp_ss0         32
pp_prsity1     32
pp_sy0         32
pp_vka2        32
```

```
pp_rech0       32
pp_ss2         32
pp_strt1       32
pp_prsity2     32
pp_sy2         32
pp_hk1         32
strk           40
Name: pargp, dtype: int64
```

fix the future recharge pilot points, vka in layers 1 and 3 and the initial condition pilot points (we still have layer-scale pars for each of these types)

```
In [10]: fi_grps = ["pp_rech1","pp_vka0","pp_vka2","pp_strt0","pp_strt1","pp_strt2"]
         par.loc[par.pargp.apply(lambda x: x in fi_grps),"partrans"] = "fixed"
         pst.npar_adj
```

```
Out[10]: 527
```

Ok, thats better. . . so lets run PESTPP-GLM. We will use a single "base parameter" jacobian matrix as the basis for 6 super parameter iterations. Then we will draw 100 realizations from the FOSM posterior parameter covariance matrix and run those 100 realizations to get the psoterior forecast PDFs

```
In [11]: pst.control_data.noptmax = 3
         pst.pestpp_options["n_iter_base"] = -1
         pst.pestpp_options["n_iter_super"] = 3
         pst.pestpp_options["num_reals"] = 50 # this is how many ies uses
         pst.pestpp_options["parcov"] = "prior_cov.jcb"
         pst.write(os.path.join(t_d,"freyberg_pp.pst"))
```

```
noptmax:3, npar_adj:527, nnz_obs:14
```

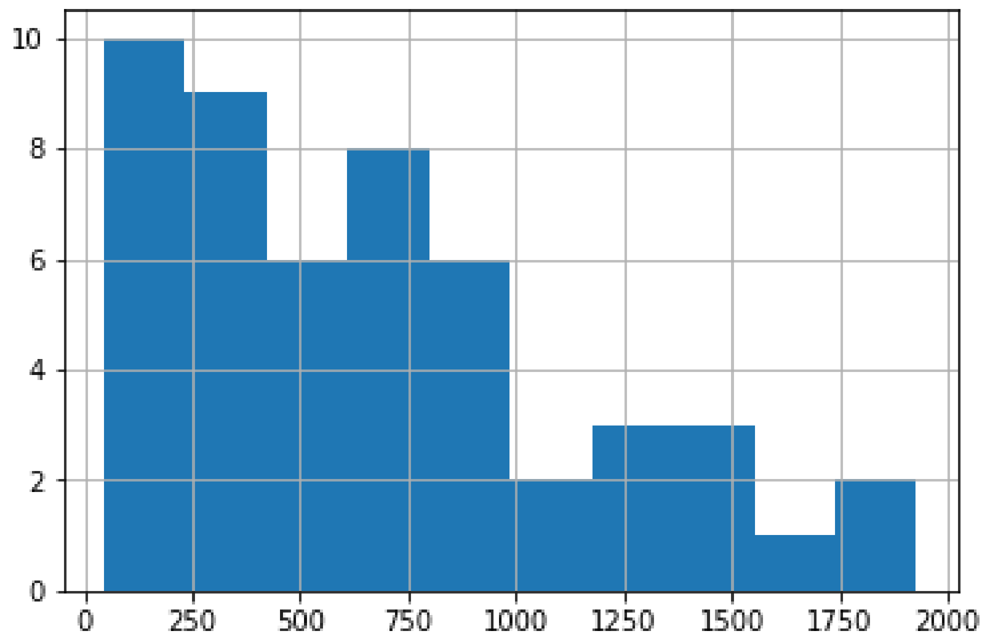
```
In [12]: pyemu.os_utils.start_slaves(t_d,"pestpp-glm","freyberg_pp.pst",num_slaves=20,slave_roo
                                     master_dir=m_d)
```

```
In [13]: df = df=pd.read_csv(os.path.join(m_d,"freyberg_pp.post.obsen.csv"),index_col=0)
         oe = pyemu.ObservationEnsemble.from_dataframe(pst=pst,df=df)
```

```
In [14]: ax = oe.phi_vector.hist()#bins=np.linspace(0,100,20))
         oe.phi_vector.sort_values().iloc[:20]
```

```
Out[14]: real_name
         26     46.191686
         33     50.133181
         22     78.966334
         45    104.201496
         6     150.527134
         39    162.855897
```

```
44     182.309884
4      198.399998
25     213.785635
8      223.866355
24     235.213232
34     260.489654
36     277.081856
37     291.151834
7      319.812527
38     345.631323
1      358.939679
5      406.013088
48     419.277056
19     449.939136
dtype: float64
```




Here we see the distribution of phi values across the 100 posterior realizations. Should we accept all of these??? The theoretical phi we should accept is number of nonzero obs (14).

To get a "posterior" ensemble, we need to throw out the realizations with large phi - lets just take the 20 best:

In [15]:
```
oe_pt = oe.loc[oe.phi_vector.sort_values().index[:20],:] #just take the 20 lowest phi
```

We can also load and plot the FOSM forecast results along side of the ensemble results:

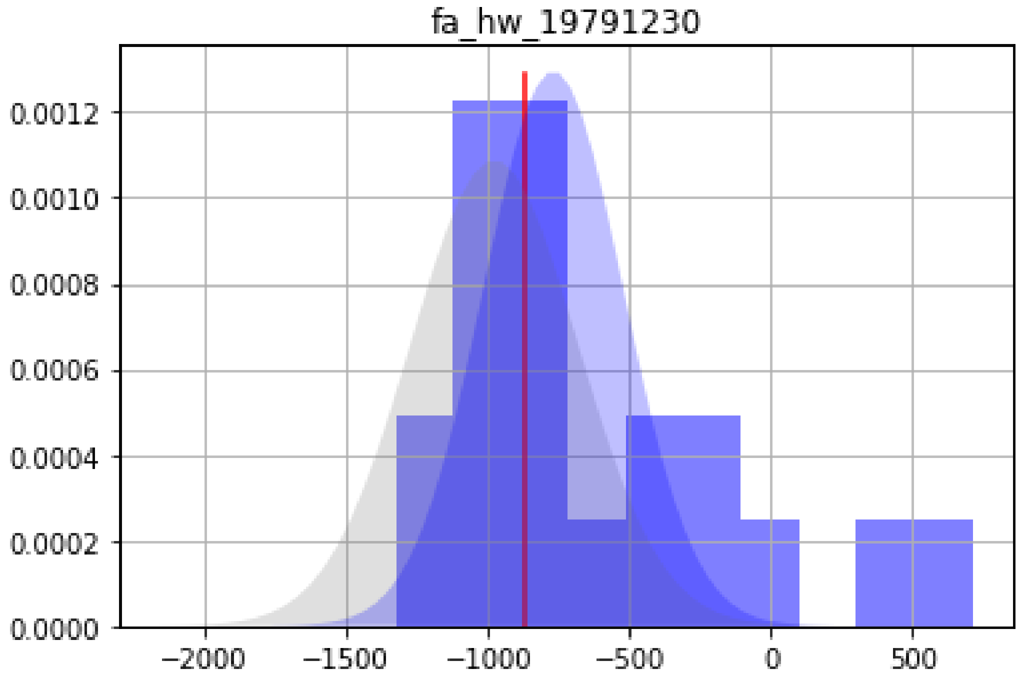
In [16]:
```
f_df = pd.read_csv(os.path.join(m_d,"freyberg_pp.pred.usum.csv"),index_col=0)
f_df.index = f_df.index.map(str.lower)
f_df
```

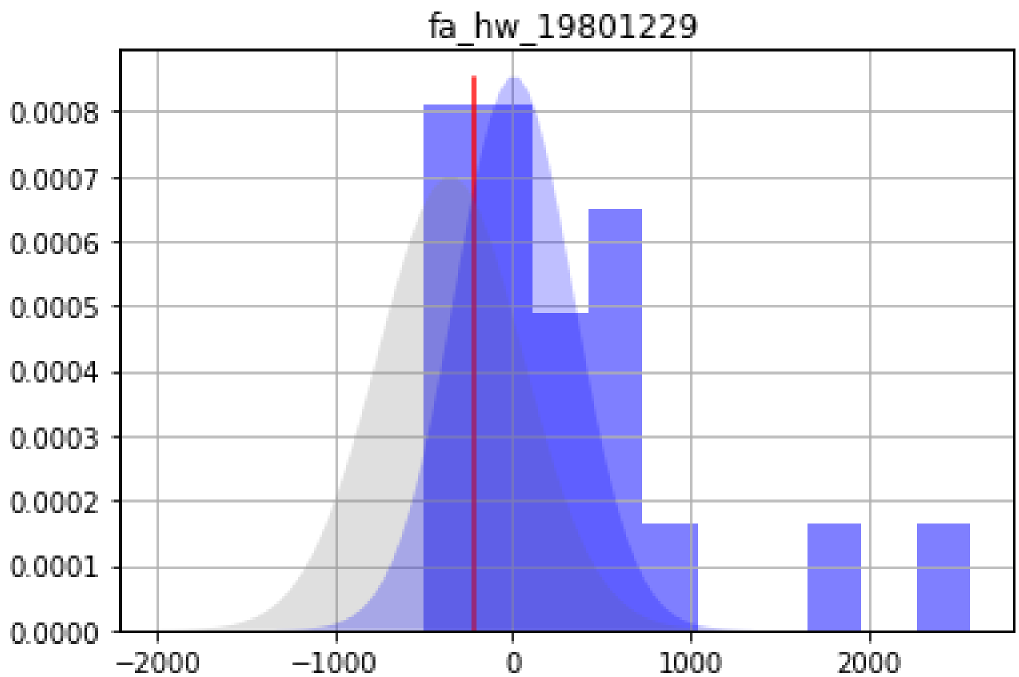
Out[16]:

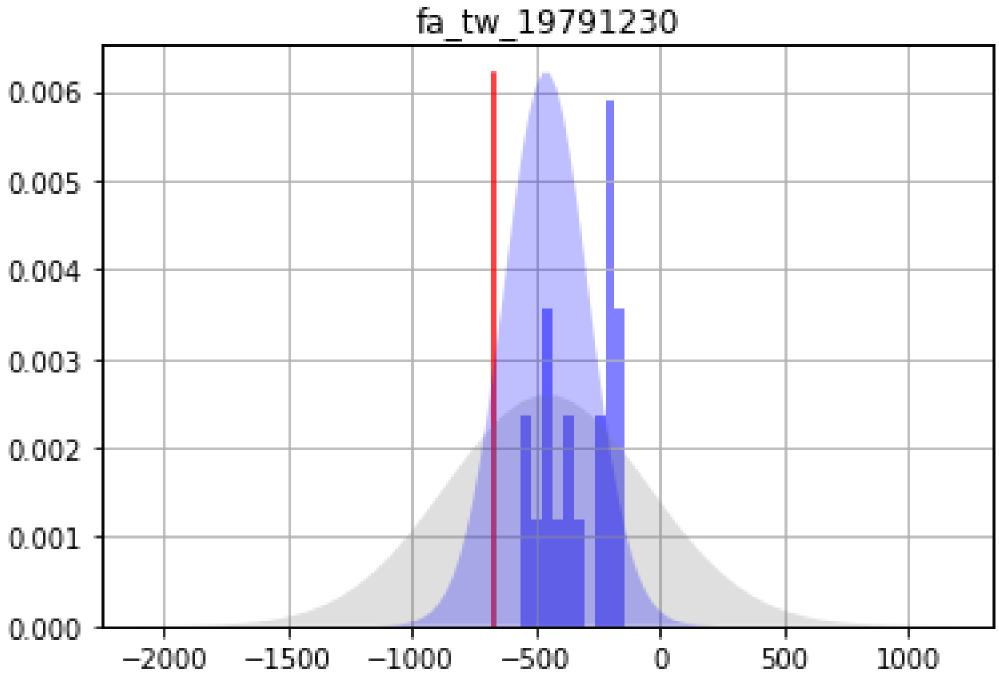
| name | prior_mean | prior_stdev | prior_lower_bound | prior_upper_bound | post_mean | post_stdev | post_lower_bound | post_upper_bound |
|---|---|---|---|---|---|---|---|---|
| fa_hw_19791230 | -977.2390 | 295.32800 | -1567.8900 | -386.5840 | -768.6480 | 247.865000 | -1264.3800 | -272.9190 |
| fa_hw_19801229 | -351.2160 | 409.77000 | -1170.7600 | 468.3240 | 7.9229 | 335.551000 | -663.1800 | 679.0260 |
| fa_tw_19791230 | -453.0330 | 409.35100 | -1271.7400 | 365.6690 | -457.3560 | 170.577000 | -798.5100 | -116.2010 |
| fa_tw_19801229 | 108.9600 | 506.73200 | -904.5040 | 1122.4200 | 202.7350 | 263.681000 | -324.6270 | 730.0980 |
| hds_00_013_002_000 | 39.6102 | 3.96314 | 31.6840 | 47.5365 | 37.7577 | 0.273990 | 37.2097 | 38.3057 |
| hds_00_013_002_001 | 38.3838 | 4.05782 | 30.2681 | 46.4994 | 36.5032 | 0.687836 | 35.1275 | 37.8789 |
| part_status | 2.0000 | 0.00000 | 2.0000 | 2.0000 | 2.0000 | 0.000000 | 2.0000 | 2.0000 |
| part_time | 907.7020 | 570.98600 | -234.2690 | 2049.6700 | 625.6070 | 436.946000 | -248.2860 | 1499.5000 |

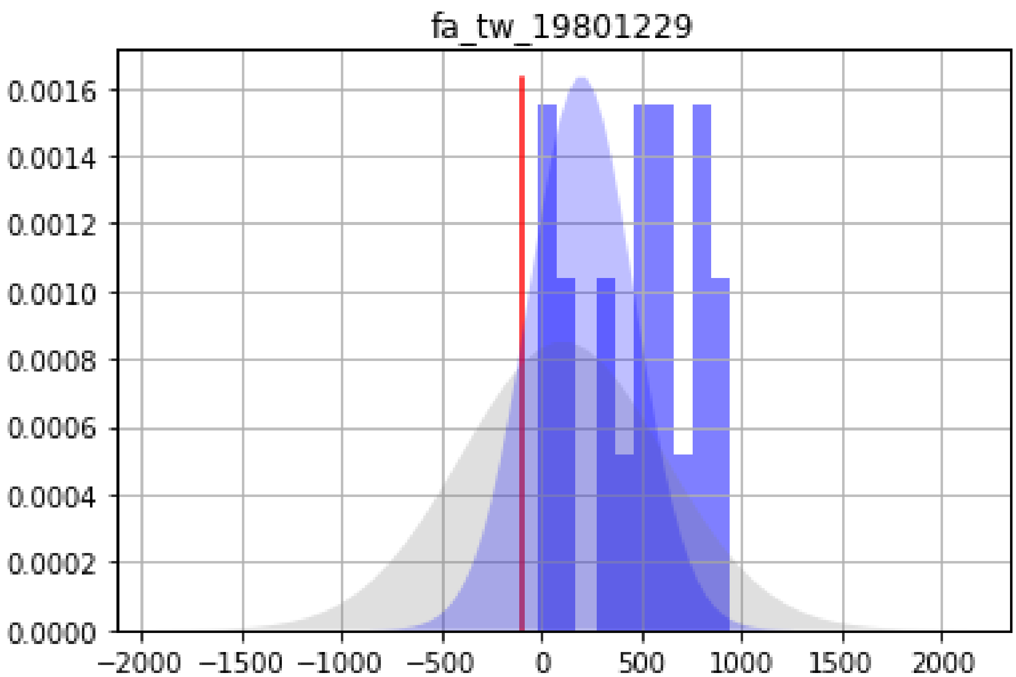
In [17]:

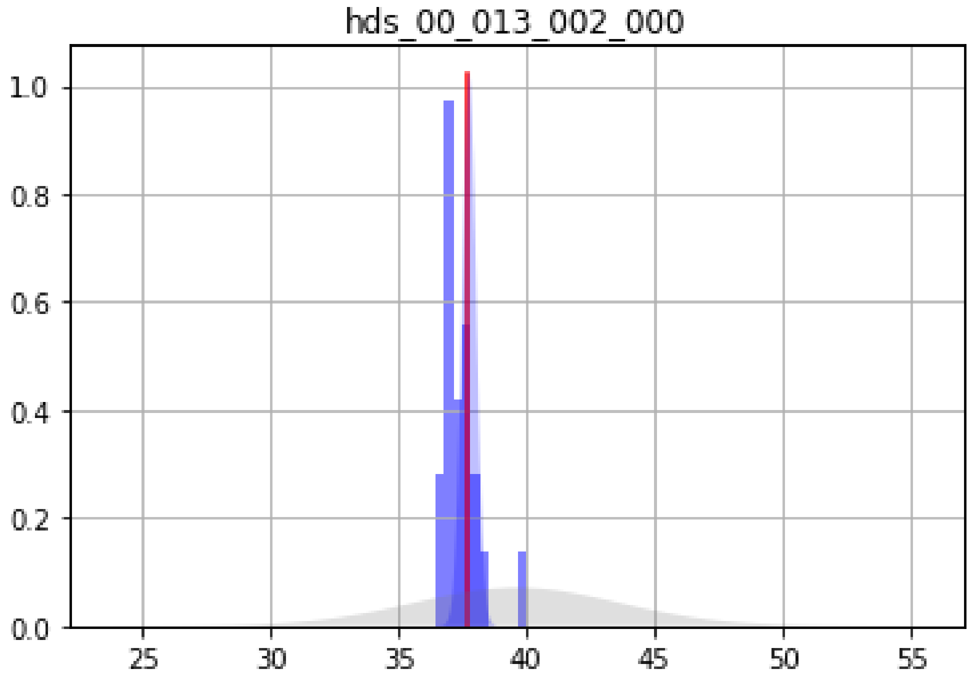
```python
obs = pst.observation_data
fnames = pst.pestpp_options["forecasts"].split(",")
for forecast in fnames:
    ax = plt.subplot(111)
    oe_pt.loc[:,forecast].hist(ax=ax,color="b",alpha=0.5,normed=True)
    ax.plot([obs.loc[forecast,"obsval"],obs.loc[forecast,"obsval"]],ax.get_ylim(),"r"
    axt = plt.twinx()
    x,y = pyemu.plot_utils.gaussian_distribution(f_df.loc[forecast,"prior_mean"],f_df
    axt.fill_between(x,0,y,facecolor="0.5",alpha=0.25)
    x,y = pyemu.plot_utils.gaussian_distribution(f_df.loc[forecast,"post_mean"],f_df.
    axt.fill_between(x,0,y,facecolor="b",alpha=0.25)
    axt.set_ylim(0,axt.get_ylim()[1])
    axt.set_yticks([])
    ax.set_title(forecast)
    plt.show()
```

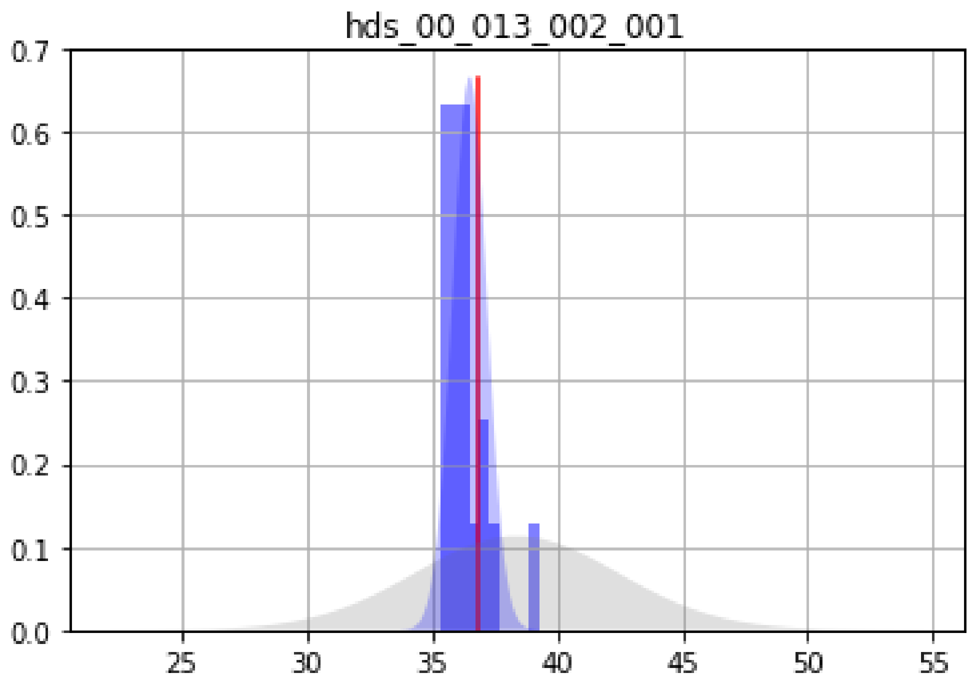

fa_hw_19791230
0.0012
0.0010
0.0008
0.0006
0.0004
0.0002
0.0000
−2000
−1500
−1000
−500
0
500

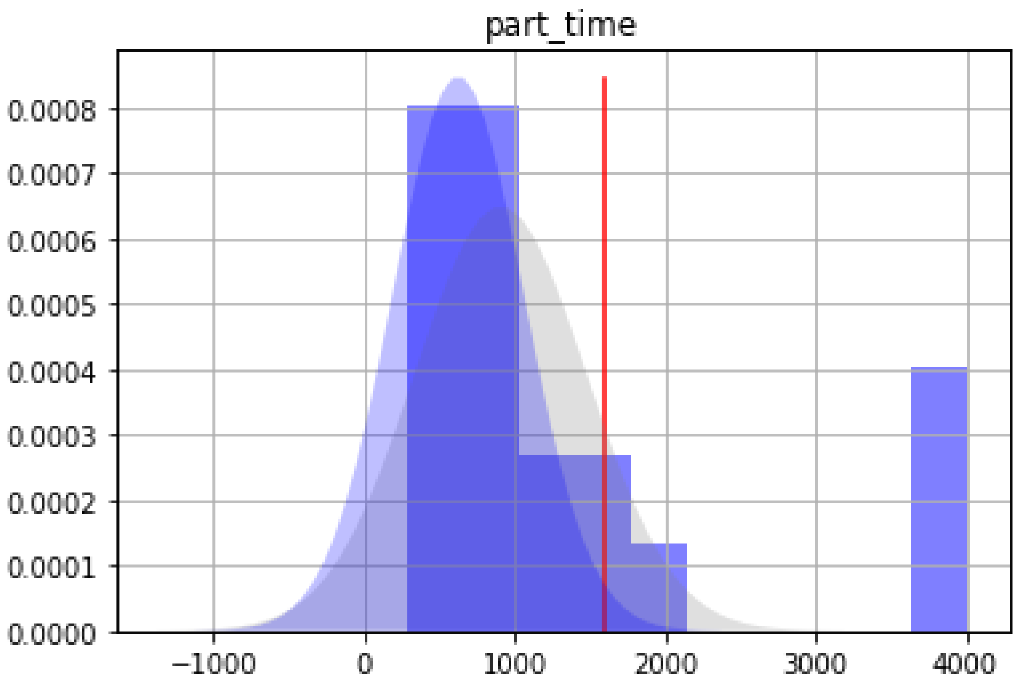

fa_hw_19801229
0.0008
0.0007
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
0.0000
−2000
−1000
0
1000
2000

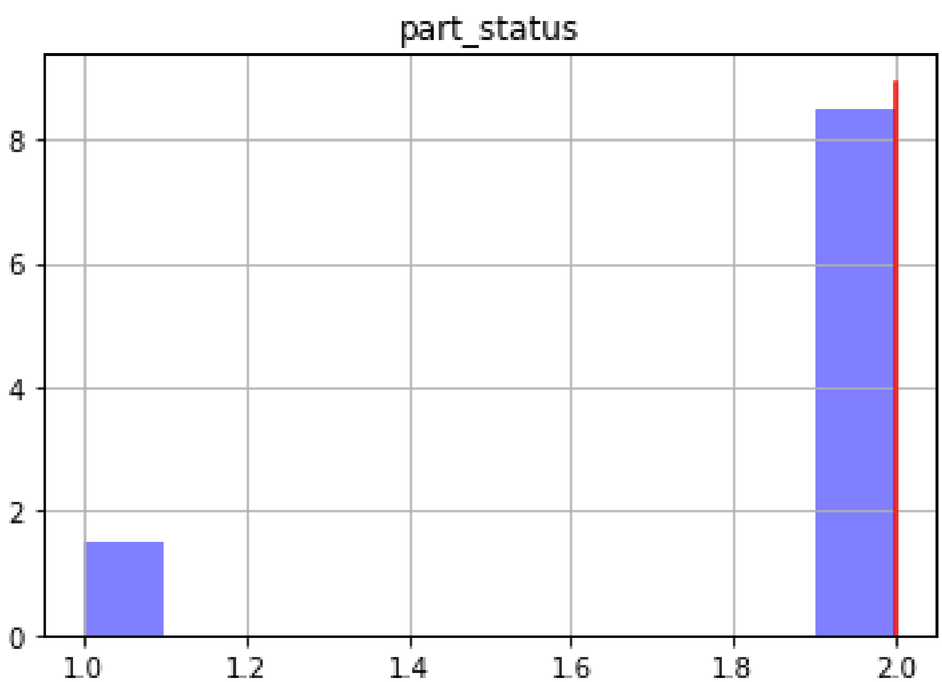

fa_tw_19791230
0.006
0.005
0.004
0.003
0.002
0.001
0.000
−2000
−1500
−1000
−500
0
500
1000


fa_tw_19801229
0.0016
0.0014
0.0012
0.0010
0.0008
0.0006
0.0004
0.0002
0.0000
−2000
−1500
−1000
−500
0
500
1000
1500
2000


hds_00_013_002_000
1.0
0.8
0.6
0.4
0.2
0.0
25
30
35
40
45
50
55


hds_00_013_002_001
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
25
30
35
40
45
50
55


part_time
0.0008
0.0007
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
0.0000
−1000
0
1000
2000
3000
4000


part_status
8
6
4
2
0
1.0
1.2
1.4
1.6
1.8
2.0

### 1.0.2 Setup of Tikhonov regularization

Now lets setup and use some formal regularization to bring the final phi up to around 14. We will use first-order regularization based on the covariance matrix we build earlier:

```
In [18]: cov = pyemu.Cov.from_binary(os.path.join(t_d,"prior_cov.jcb"))
```

```
new binary format detected...
```

```
In [19]: pyemu.helpers.first_order_pearson_tikhonov(pst,cov)
```

```
getting CC matrix
processing
```

```
In [20]: pst.prior_information.head()
```

```
Out[20]:                                                         equation    obgnme  \
         pilbl
         pcc_1  1.0 * log(dc0000390005) - 1.0 * log(dc0000390006) = 0.0  regul_cc
         pcc_2  1.0 * log(dc0000390005) - 1.0 * log(dc0000390007) = 0.0  regul_cc
         pcc_3  1.0 * log(dc0000390005) - 1.0 * log(dc0000390008) = 0.0  regul_cc
         pcc_4  1.0 * log(dc0000390005) - 1.0 * log(dc0000390009) = 0.0  regul_cc
         pcc_5  1.0 * log(dc0000390005) - 1.0 * log(dc0000390010) = 0.0  regul_cc

                pilbl    weight
         pilbl
         pcc_1  pcc_1  0.904837
         pcc_2  pcc_2  0.818731
         pcc_3  pcc_3  0.740818
         pcc_4  pcc_4  0.670320
         pcc_5  pcc_5  0.606531
```

```
In [21]: shutil.copy2(os.path.join(m_d,"freyberg_pp.jcb"),os.path.join(t_d,"restart_pp.jcb"))
```

```
Out[21]: 'template/restart_pp.jcb'
```

```
In [22]: pst.pestpp_options["base_jacobian"] = "restart_pp.jcb"
         pst.reg_data.phimlim = pst.nnz_obs
         pst.reg_data.phimaccept = pst.reg_data.phimlim * 1.1
         pst.write(os.path.join(t_d,"freyberg_pp.pst"))
```

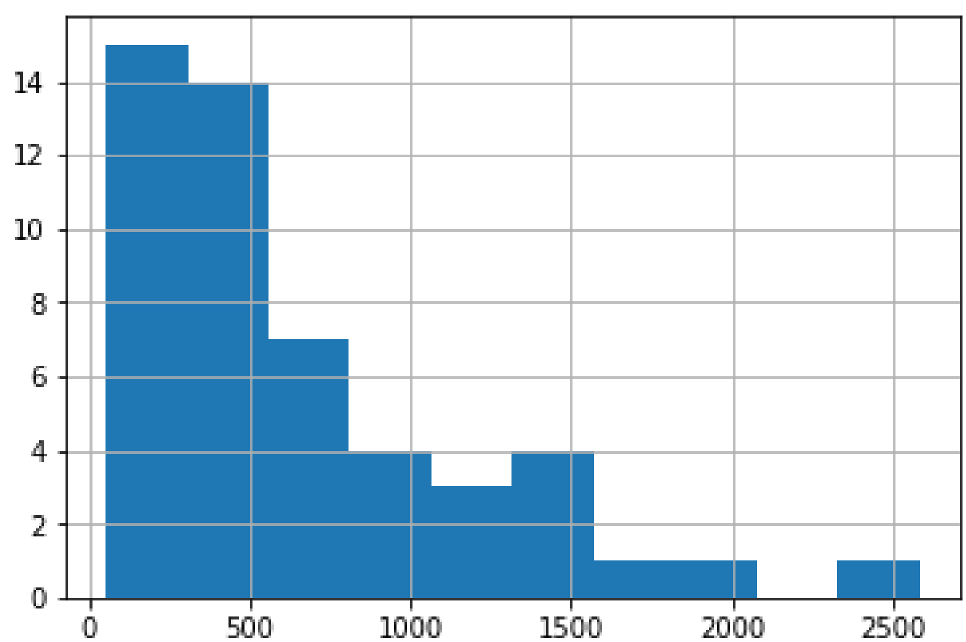
```
noptmax:3, npar_adj:527, nnz_obs:14
```

```
In [23]: pyemu.os_utils.start_slaves(t_d,"pestpp-glm","freyberg_pp.pst",num_slaves=20,slave_roo
                                     master_dir=m_d)
```

```
In [24]: df = df=pd.read_csv(os.path.join(m_d,"freyberg_pp.post.obsen.csv"),index_col=0)
         oe = pyemu.ObservationEnsemble.from_dataframe(pst=pst,df=df)
```

```
In [25]: ax = oe.phi_vector.hist()#bins=np.linspace(0,100,20))
         oe.phi_vector.sort_values().iloc[:20]
```

```
Out[25]: real_name
         22     54.591342
         7      87.763570
         33    114.809819
         6     151.999381
         45    153.352166
         8     159.662178
         38    194.678541
         36    204.110779
         44    204.652000
         25    208.760907
         48    255.259568
         5     260.044390
         26    296.510784
         21    298.986449
         39    301.643241
         4     309.887794
         34    324.068743
         1     335.343373
         47    337.147487
         9     376.227949
         dtype: float64
```



Same as before, to get a "posterior" ensemble, we need to throw out the realizations with large phi - lets just take the 20 best:

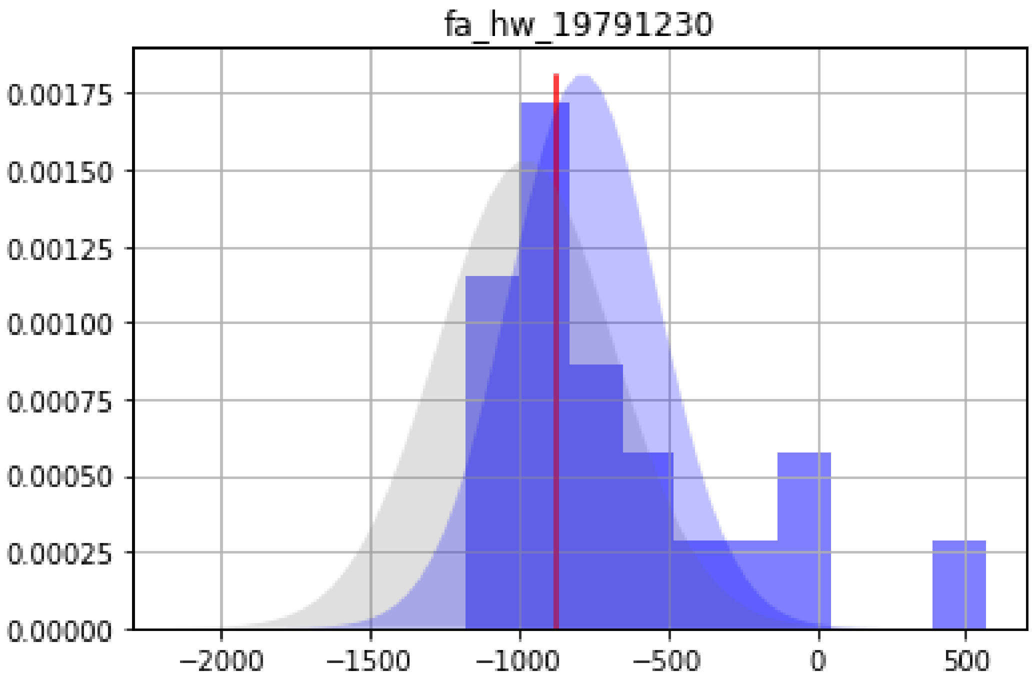
```
In [26]: oe_pt = oe.loc[oe.phi_vector.sort_values().index[:20],:]
```

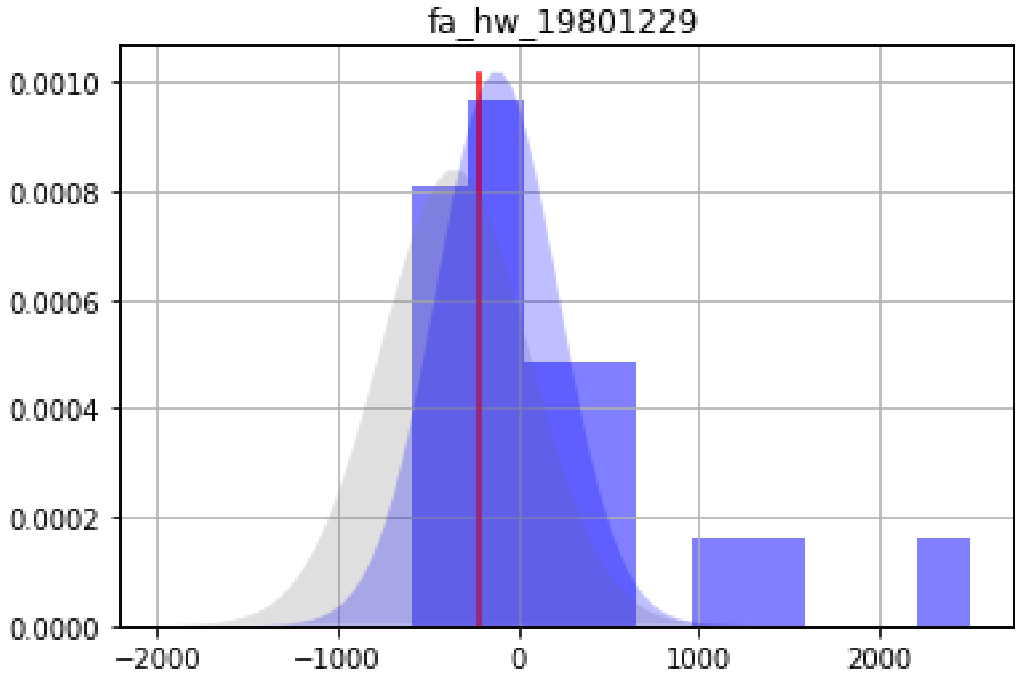
```
In [27]: f_df = pd.read_csv(os.path.join(m_d,"freyberg_pp.pred.usum.csv"),index_col=0)
         f_df.index = f_df.index.map(str.lower)
         f_df
```

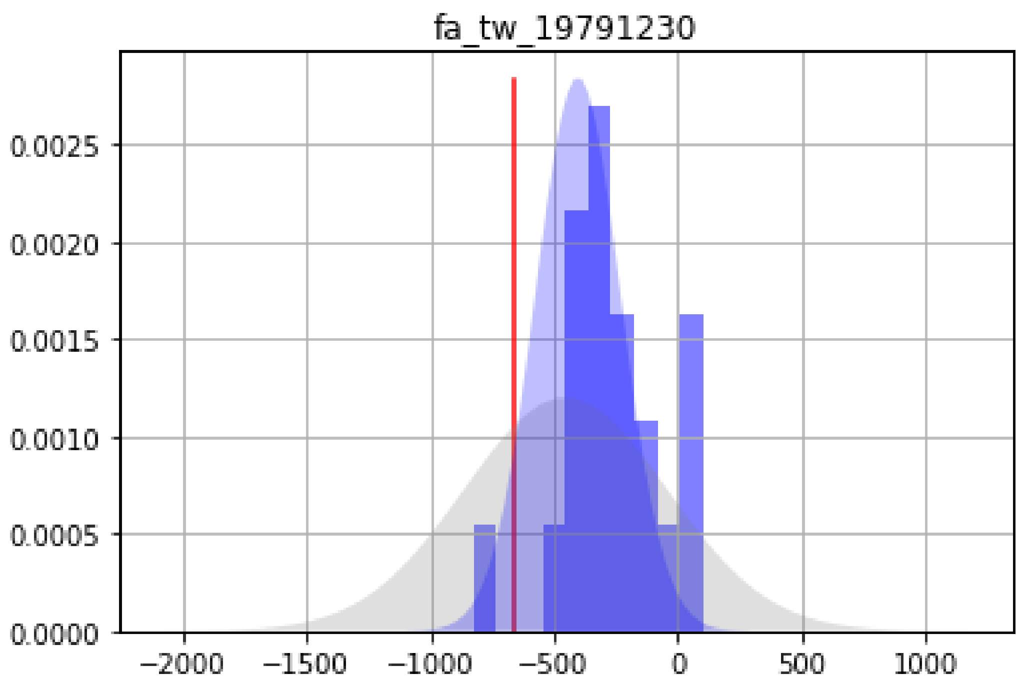
```
Out[27]:                      prior_mean  prior_stdev  prior_lower_bound  \
         name
         fa_hw_19791230        -977.2390    295.32800         -1567.8900
         fa_hw_19801229        -351.2160    409.77000         -1170.7600
         fa_tw_19791230        -453.0330    409.35100         -1271.7400
         fa_tw_19801229         108.9600    506.73200          -904.5040
         hds_00_013_002_000      39.6102      3.96314            31.6840
         hds_00_013_002_001      38.3838      4.05782            30.2681
         part_status              2.0000      0.00000             2.0000
         part_time              907.7020    570.98600          -234.2690

                             prior_upper_bound  post_mean  post_stdev  \
         name
         fa_hw_19791230               -386.5840  -784.6750  249.208000
         fa_hw_19801229                468.3240  -114.9500  337.529000
         fa_tw_19791230                365.6690  -403.2130  172.728000
         fa_tw_19801229               1122.4200   189.5360  265.455000
         hds_00_013_002_000             47.5365    37.9889    0.338210
         hds_00_013_002_001             46.4994    36.8297    0.714465
         part_status                     2.0000     2.0000    0.000000
         part_time                    2049.6700   711.0970  437.090000

                             post_lower_bound  post_upper_bound
         name
         fa_hw_19791230             -1283.0900         -286.2600
         fa_hw_19801229              -790.0080          560.1080
         fa_tw_19791230              -748.6690          -57.7566
         fa_tw_19801229              -341.3740          720.4470
         hds_00_013_002_000            37.3124           38.6653
         hds_00_013_002_001            35.4008           38.2587
         part_status                    2.0000            2.0000
         part_time                   -163.0820         1585.2800
```

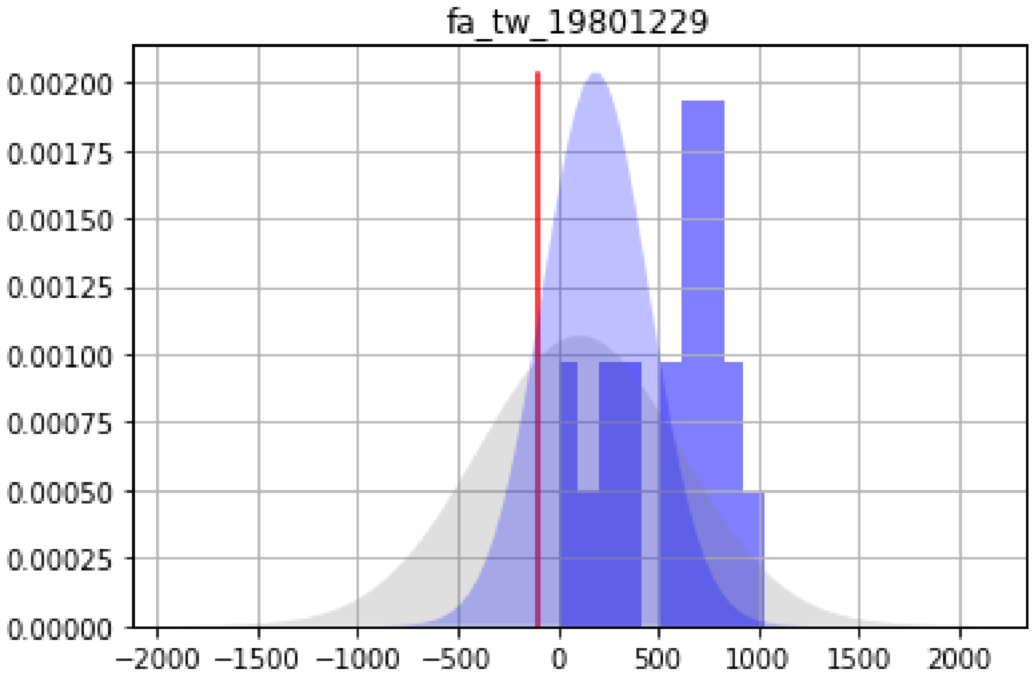
```
In [28]: obs = pst.observation_data
         fnames = pst.pestpp_options["forecasts"].split(",")
         for forecast in fnames:
             ax = plt.subplot(111)
             oe_pt.loc[:,forecast].hist(ax=ax,color="b",alpha=0.5,normed=True)
             ax.plot([obs.loc[forecast,"obsval"],obs.loc[forecast,"obsval"]],ax.get_ylim(),"r"
             axt = plt.twinx()
```

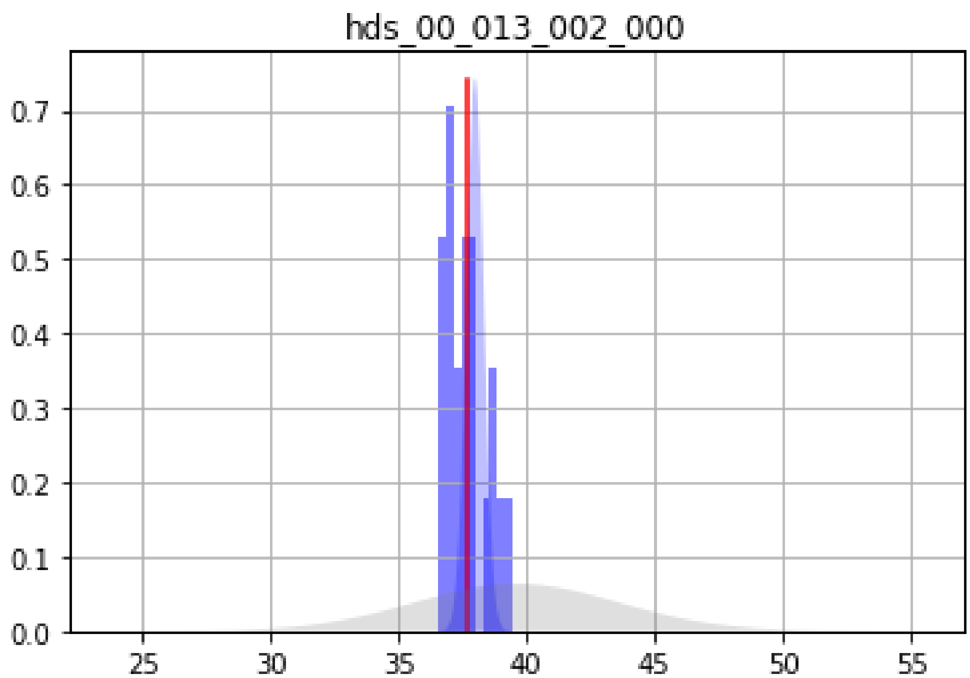
```
x,y = pyemu.plot_utils.gaussian_distribution(f_df.loc[forecast,"prior_mean"],f_df
axt.fill_between(x,0,y,facecolor="0.5",alpha=0.25)
x,y = pyemu.plot_utils.gaussian_distribution(f_df.loc[forecast,"post_mean"],f_df.l
axt.fill_between(x,0,y,facecolor="b",alpha=0.25)
axt.set_ylim(0,axt.get_ylim()[1])
axt.set_yticks([])
ax.set_title(forecast)
plt.show()
```

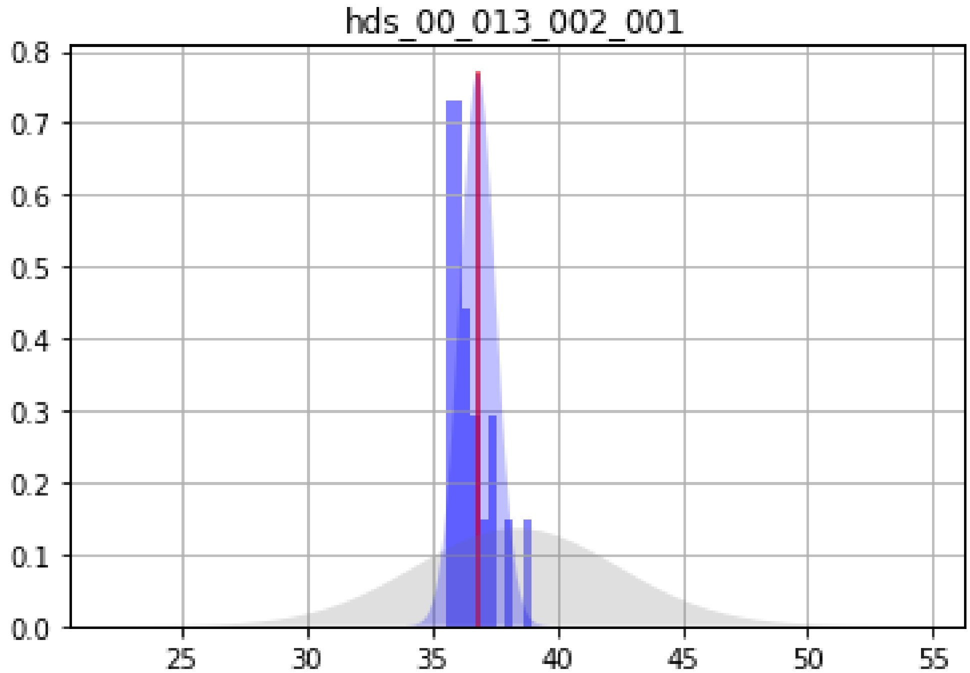



fa_hw_19801229
0.0010
0.0008
0.0006
0.0004
0.0002
0.0000
−2000
−1000
0
1000
2000

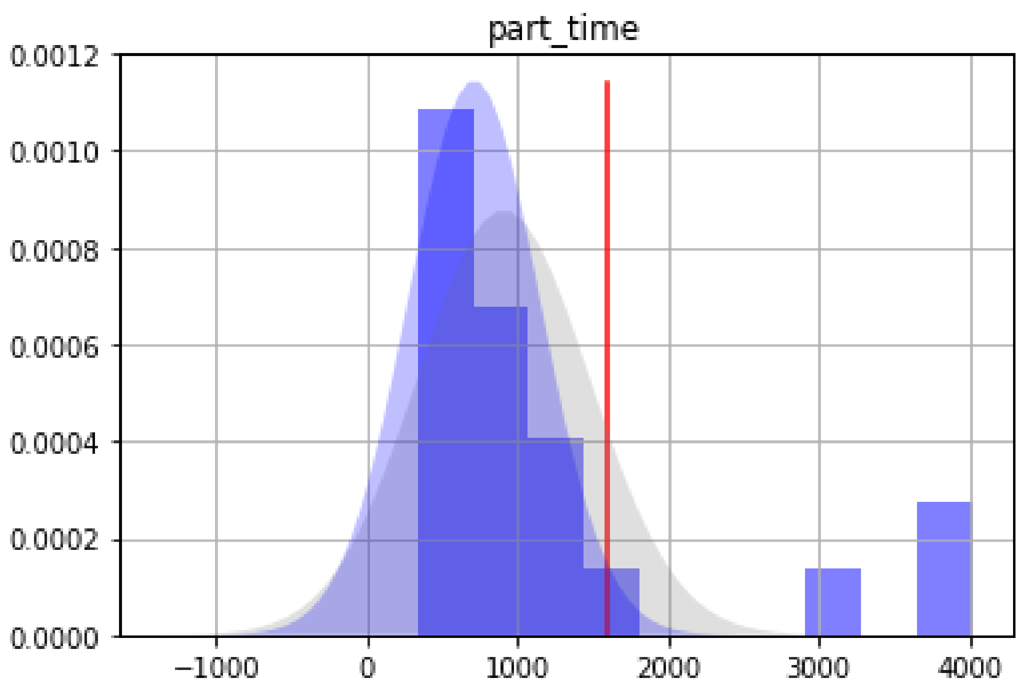

fa_tw_19791230
0.0025
0.0020
0.0015
0.0010
0.0005
0.0000
−2000
−1500
−1000
−500
0
500
1000


fa_tw_19801229
0.00200
0.00175
0.00150
0.00125
0.00100
0.00075
0.00050
0.00025
0.00000
−2000 −1500 −1000 −500 0 500 1000 1500 2000

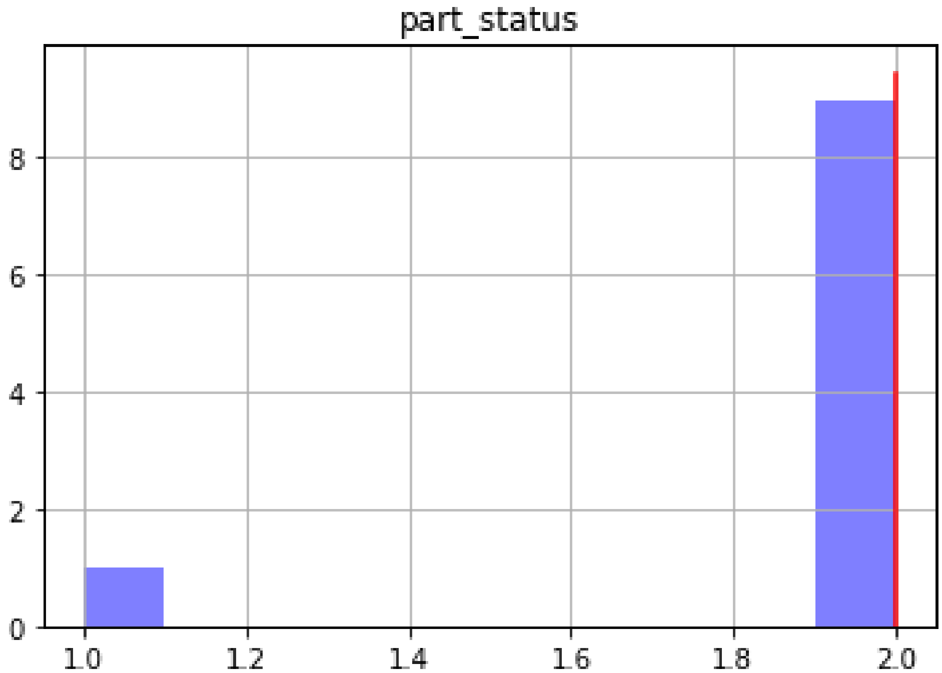

hds_00_013_002_000
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
25 30 35 40 45 50 55



hds_00_013_002_001
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
25
30
35
40
45
50
55

part_time
0.0012
0.0010
0.0008
0.0006
0.0004
0.0002
0.0000
−1000
0
1000
2000
3000
4000


part_status
0
2
4
6
8
1.0
1.2
1.4
1.6
1.8
2.0