prior_montecarlo

April 28, 2019

1 Run and process the prior monte carlo and pick a "truth" realization

```
In [1]: import os
        import shutil
        import numpy as np
        import pandas as pd
        import matplotlib.pyplot as plt
        import flopy
        import pyemu
```

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

```
In [2]: t_d = "template"
        pst = pyemu.Pst(os.path.join(t_d,"freyberg.pst"))
```

1.0.1 Decide what pars are uncertain in the truth

We need to decide what our truth looks like - should the pilot points or the grid-scale pars be the source of spatial variability?

```
In [3]: 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"]
        #pst.npar - should_fix.shape[0]
```

```
In [4]: pe = pyemu.ParameterEnsemble.from_binary(pst=pst,filename=os.path.join(t_d,"prior.jcb"))
        pe.loc[:,should_fix] = 1.0
        pe.to_csv(os.path.join(t_d,"sweep_in.csv"))
```

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

1.0.2 run the prior ensemble in parallel locally

```
In [5]: m_d = "master_prior_sweep"
        pyemu.os_utils.start_slaves(t_d,"pestpp-swp","freyberg.pst",num_slaves=20,slave_root="
```

1.0.3 Load the output ensemble and plot a few things

```
In [6]: obs_df = pd.read_csv(os.path.join(m_d,"sweep_out.csv"),index_col=0)
        obs_df.shape
```

```
Out[6]: (200, 4445)
```

drop any failed runs

```
In [7]: obs_df = obs_df.loc[obs_df.failed_flag==0,:]
        obs_df.shape
```

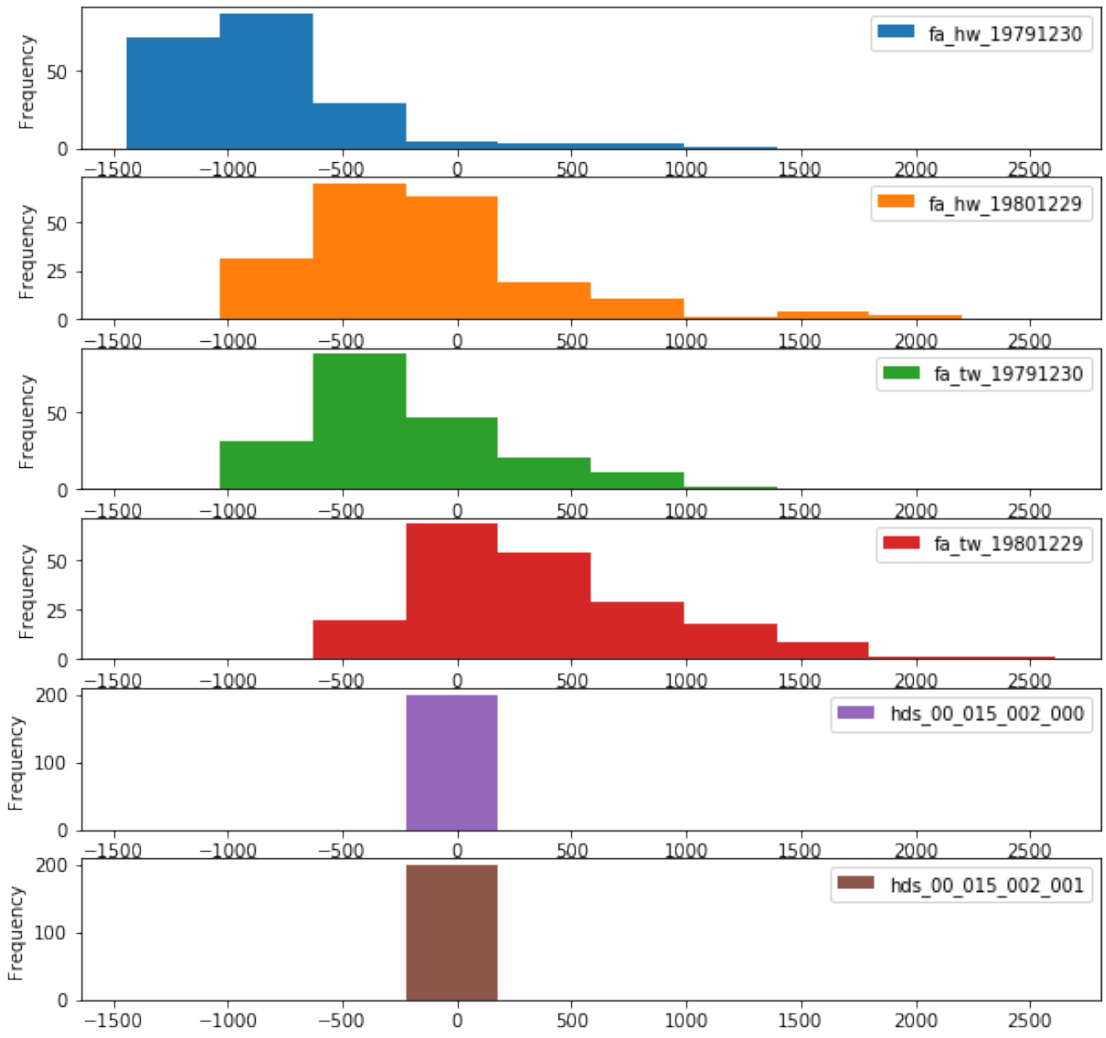
```
Out[7]: (200, 4445)
```

```
In [8]: fnames = pst.pestpp_options["forecasts"].split(',')
        fnames
```

```
Out[8]: ['fa_hw_19791230',
         'fa_hw_19801229',
         'fa_tw_19791230',
         'fa_tw_19801229',
         'hds_00_015_002_000',
         'hds_00_015_002_001']
```

```
In [9]: obs_df.loc[:,fnames].plot(kind="hist",subplots=True,figsize=(10,10),sharex=False)
```

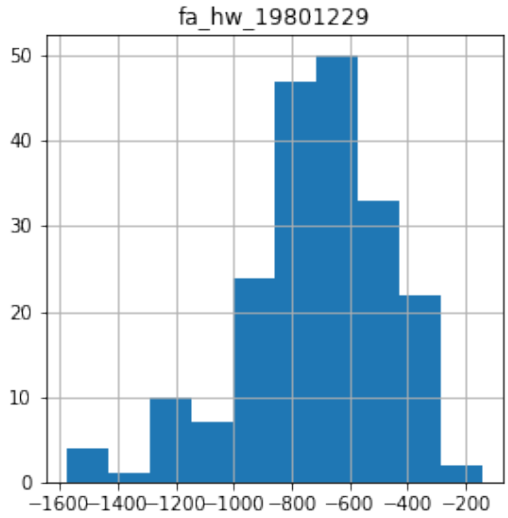
```
Out[9]: array([<matplotlib.axes._subplots.AxesSubplot object at 0x181da81b00>,
               <matplotlib.axes._subplots.AxesSubplot object at 0x181d9ab780>,
               <matplotlib.axes._subplots.AxesSubplot object at 0x181d9b5cf8>,
               <matplotlib.axes._subplots.AxesSubplot object at 0x1083f72b0>,
               <matplotlib.axes._subplots.AxesSubplot object at 0x108419828>,
               <matplotlib.axes._subplots.AxesSubplot object at 0x113a10da0>],
              dtype=object)
```

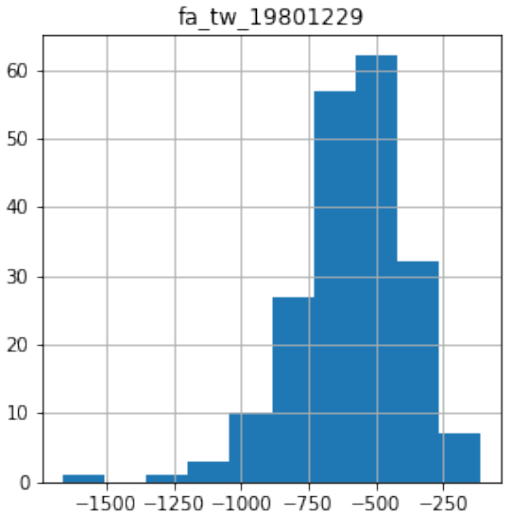


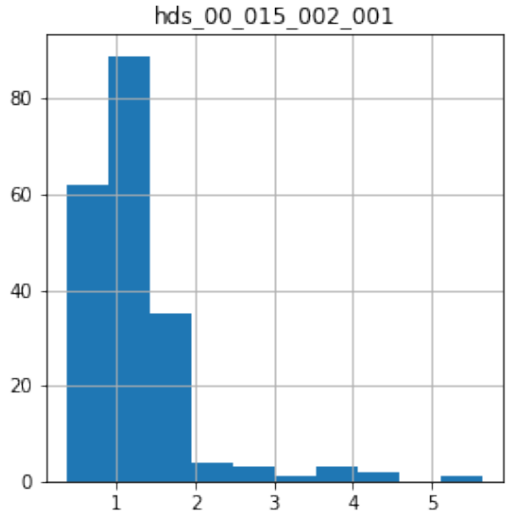
We see that under scenario conditions, many more realizations for the flow to the aquifer in the headwaters are postive (as expected). Lets difference these two:

```
In [10]: sfnames = [f for f in fnames if "1980" in f or "_001" in f]
         hfnames = [f for f in fnames if "1979" in f or "_000" in f]
         diff = obs_df.loc[:,hfnames].values - obs_df.loc[:,sfnames].values
         diff = pd.DataFrame(diff,columns=sfnames)
         diff.hist(figsize=(10,10))
```

```
Out[10]: array([[<matplotlib.axes._subplots.AxesSubplot object at 0x10845a588>,
                 <matplotlib.axes._subplots.AxesSubplot object at 0x181da979e8>],
                [<matplotlib.axes._subplots.AxesSubplot object at 0x181daaeef0>,
                 <matplotlib.axes._subplots.AxesSubplot object at 0x1091b34a8>]],
               dtype=object)
```







We now see that the most extreme scenario yields a large decrease in flow from the aquifer to the headwaters (the most negative value)

1.0.4 setting the "truth"

We just need to replace the observed values (`obsval`) in the control file with the outputs for one of the realizations on `obs_df`. In this way, we now have the nonzero values for history matching, but also the `truth` values for comparing how we are doing with other unobserved quantities. Im going to pick a realization that yields an "average" variability of the observed gw levels:

```
In [11]: # choose the realization with a historic gw to sw headwater flux
         hist_swgw = obs_df.loc[:,"fa_hw_19791230"].sort_values()
         idx = hist_swgw.index[20]

In [12]: obs_df.loc[idx,pst.nnz_obs_names]
```

```
Out[12]: fo_39_19791230        11469.000000
         hds_00_002_009_000       37.762375
         hds_00_002_015_000       35.533577
         hds_00_003_008_000       38.118275
         hds_00_009_001_000       40.013752
         hds_00_013_010_000       35.797760
         hds_00_015_016_000       34.970028
         hds_00_021_010_000       35.883907
         hds_00_022_015_000       34.855595
         hds_00_024_004_000       38.254478
         hds_00_026_006_000       37.210945
         hds_00_029_015_000       34.562653
         hds_00_033_007_000       35.690334
         hds_00_034_010_000       34.577950
         Name: 159, dtype: float64
```

Lets see how our selected truth does with the swgw forecasts:

```
In [13]: obs_df.loc[idx,fnames]
```

```
Out[13]: fa_hw_19791230       -1256.133800
         fa_hw_19801229        -708.594700
         fa_tw_19791230        -658.232200
         fa_tw_19801229        -214.870210
         hds_00_015_002_000      39.905678
         hds_00_015_002_001      38.688923
         Name: 159, dtype: float64
```

```
In [14]: pst = pyemu.Pst(os.path.join(t_d,"freyberg.pst"))
         obs = pst.observation_data
         obs.loc[:,"obsval"] = obs_df.loc[idx,pst.obs_names]
         obs.loc[obs.obgnme=="calhead","weight"] = 10.0
         obs.loc["fo_39_19791230","weight"] = 0.025
         obs.weight.value_counts()
```

```
Out[14]: 0.000     4420
         10.000      13
         0.025        1
         Name: weight, dtype: int64
```

Now, it is custom to add noise to the observed values…we will use the classic Gaussian noise…zero mean and standard deviation of 1 over the weight

```
In [15]: # this should give the same standard normal draws each time
         np.random.seed(seed=0)
         snd = np.random.randn(pst.nnz_obs)
         snd
```

```
Out[15]: array([ 1.76405235,  0.40015721,  0.97873798,  2.2408932 ,  1.86755799,
                -0.97727788,  0.95008842, -0.15135721, -0.10321885,  0.4105985 ,
                 0.14404357,  1.45427351,  0.76103773,  0.12167502])
```

```
In [16]: noise = snd * 1./obs.loc[pst.nnz_obs_names,"weight"]
         noise
```

```
Out[16]: obsnme
         fo_39_19791230        70.562094
         hds_00_002_009_000     0.040016
         hds_00_002_015_000     0.097874
         hds_00_003_008_000     0.224089
         hds_00_009_001_000     0.186756
         hds_00_013_010_000    -0.097728
         hds_00_015_016_000     0.095009
         hds_00_021_010_000    -0.015136
         hds_00_022_015_000    -0.010322
         hds_00_024_004_000     0.041060
         hds_00_026_006_000     0.014404
         hds_00_029_015_000     0.145427
         hds_00_033_007_000     0.076104
         hds_00_034_010_000     0.012168
         Name: weight, dtype: float64
```

Only run this block once!!!

```
In [17]: pst.observation_data.loc[noise.index,"obsval"] += noise
         pst.write(os.path.join(t_d,"freyberg.pst"))
         pyemu.os_utils.run("pestpp-ies freyberg.pst",cwd=t_d)
```

```
In [18]: pst = pyemu.Pst(os.path.join(t_d,"freyberg.pst"))
         print(pst.phi)
         pst.res.loc[pst.nnz_obs_names,:]
```

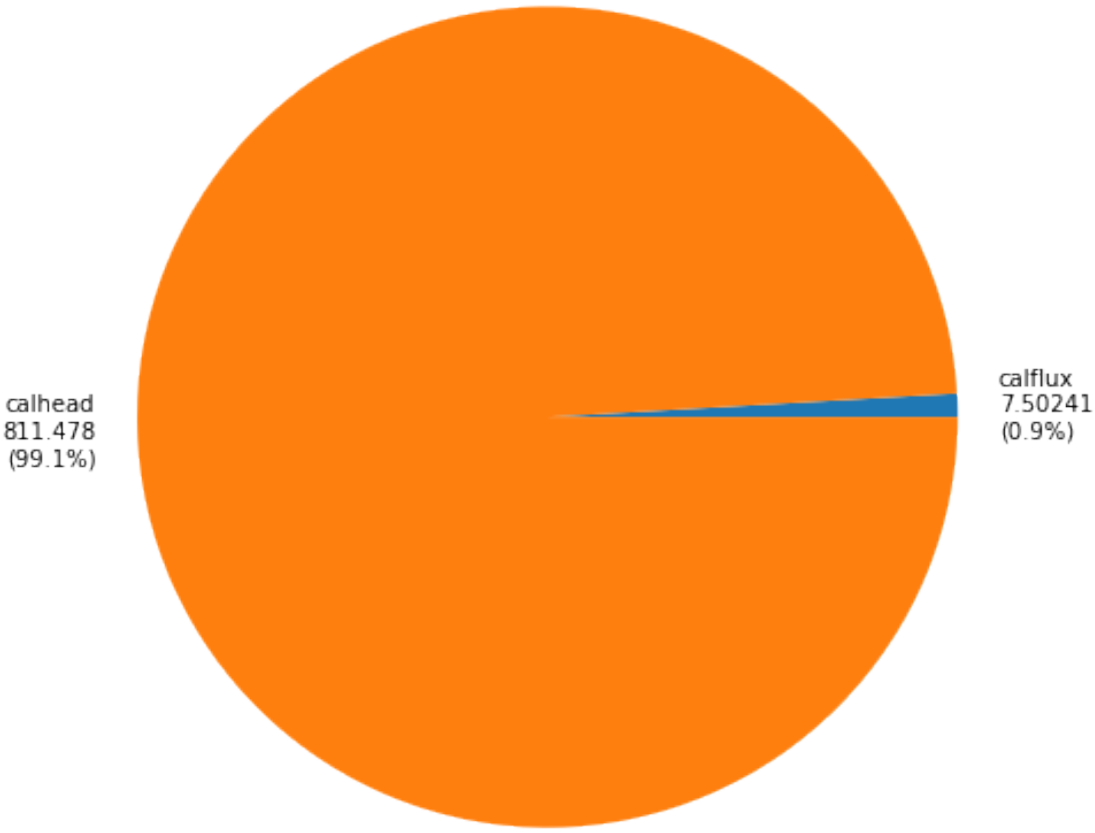
```
818.9806345994934
```

```
Out[18]:                                    name    group      measured      modelled  \
         name
         fo_39_19791230          fo_39_19791230  calflux  11539.562094  11430.000000
         hds_00_002_009_000  hds_00_002_009_000  calhead     37.802391     37.107498
         hds_00_002_015_000  hds_00_002_015_000  calhead     35.631451     35.045185
         hds_00_003_008_000  hds_00_003_008_000  calhead     38.342364     37.397289
         hds_00_009_001_000  hds_00_009_001_000  calhead     40.200508     39.546417
         hds_00_013_010_000  hds_00_013_010_000  calhead     35.700032     35.571774
         hds_00_015_016_000  hds_00_015_016_000  calhead     35.065037     34.835716
         hds_00_021_010_000  hds_00_021_010_000  calhead     35.868772     35.386250
         hds_00_022_015_000  hds_00_022_015_000  calhead     34.845273     34.577492
         hds_00_024_004_000  hds_00_024_004_000  calhead     38.295538     36.760464
         hds_00_026_006_000  hds_00_026_006_000  calhead     37.225349     35.896149
         hds_00_029_015_000  hds_00_029_015_000  calhead     34.708080     34.453842
         hds_00_033_007_000  hds_00_033_007_000  calhead     35.766438     34.678810
         hds_00_034_010_000  hds_00_034_010_000  calhead     34.590117     34.118073
```

```
                          residual  weight
name
fo_39_19791230      109.562094   0.025
hds_00_002_009_000    0.694892  10.000
hds_00_002_015_000    0.586266  10.000
hds_00_003_008_000    0.945075  10.000
hds_00_009_001_000    0.654091  10.000
hds_00_013_010_000    0.128259  10.000
hds_00_015_016_000    0.229321  10.000
hds_00_021_010_000    0.482522  10.000
hds_00_022_015_000    0.267781  10.000
hds_00_024_004_000    1.535075  10.000
hds_00_026_006_000    1.329201  10.000
hds_00_029_015_000    0.254238  10.000
hds_00_033_007_000    1.087628  10.000
hds_00_034_010_000    0.472045  10.000
```

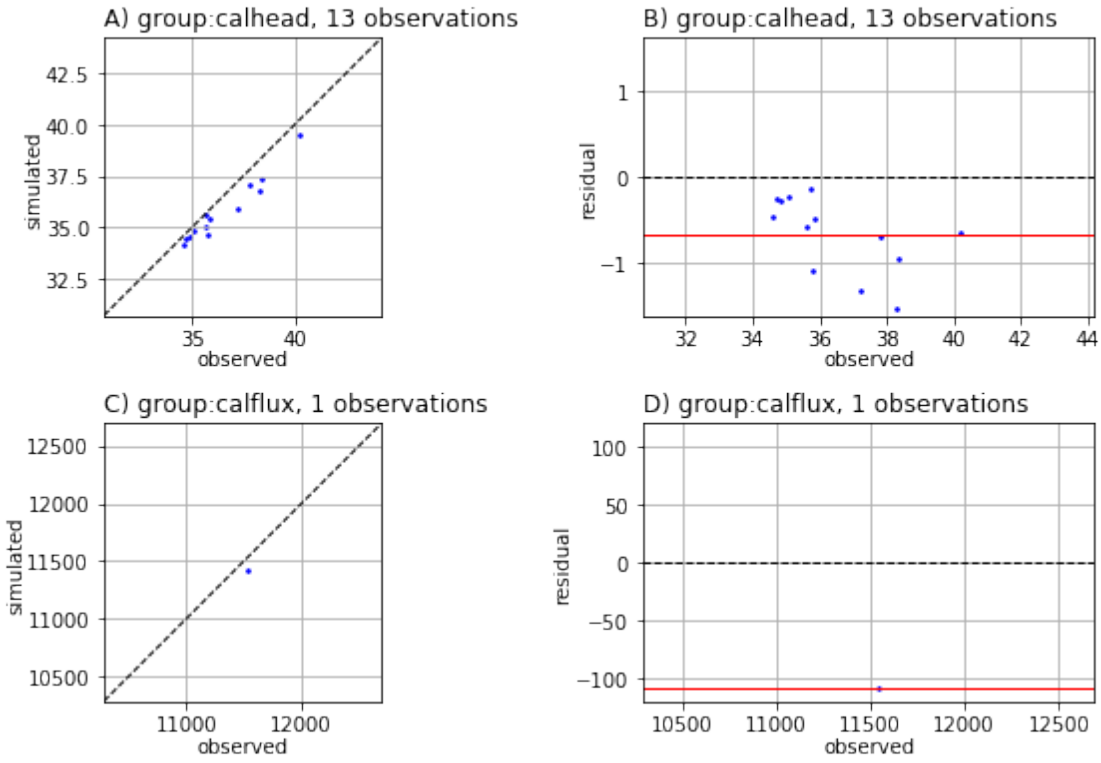
In [19]:
```
pst.phi_components
pst.plot(kind='phi_pie')
```

Out[19]:
```
<matplotlib.axes._subplots.AxesSubplot at 0x181e18f0f0>
```




```
In [20]: figs = pst.plot(kind="1to1")
```

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



Publication ready figs - oh snap!

Just to make sure we have everything working right, we should be able to load the truth parameters, run the model once and have a `phi` equivalent to the noise vector:

In [21]:
```
par_df = pd.read_csv(os.path.join(m_d,"sweep_in.csv"),index_col=0)
pst.parameter_data.loc[:,"parval1"] = par_df.loc[idx,pst.par_names]
pst.write(os.path.join(m_d,"test.pst"))
pyemu.os_utils.run("pestpp-ies.exe test.pst",cwd=m_d)
pst = pyemu.Pst(os.path.join(m_d,"test.pst"))
print(pst.phi)
pst.res.loc[pst.nnz_obs_names,:]
```

```
17.528847284852887
```

Out[21]:

	name	group	measured	modelled	residual	weight
name						
fo_39_19791230	fo_39_19791230	calflux	11539.562094	11469.000000	70.562094	0.025
hds_00_002_009_000	hds_00_002_009_000	calhead	37.802391	37.762375	0.040016	10.000
hds_00_002_015_000	hds_00_002_015_000	calhead	35.631451	35.533577	0.097874	10.000
hds_00_003_008_000	hds_00_003_008_000	calhead	38.342364	38.118275	0.224089	10.000
hds_00_009_001_000	hds_00_009_001_000	calhead	40.200508	40.013752	0.186756	10.000
hds_00_013_010_000	hds_00_013_010_000	calhead	35.700032	35.797760	-0.097728	10.000
hds_00_015_016_000	hds_00_015_016_000	calhead	35.065037	34.970028	0.095009	10.000
hds_00_021_010_000	hds_00_021_010_000	calhead	35.868772	35.883907	-0.015136	10.000
hds_00_022_015_000	hds_00_022_015_000	calhead	34.845273	34.855595	-0.010322	10.000
hds_00_024_004_000	hds_00_024_004_000	calhead	38.295538	38.254478	0.041060	10.000
hds_00_026_006_000	hds_00_026_006_000	calhead	37.225349	37.210945	0.014404	10.000
hds_00_029_015_000	hds_00_029_015_000	calhead	34.708080	34.562653	0.145427	10.000
hds_00_033_007_000	hds_00_033_007_000	calhead	35.766438	35.690334	0.076104	10.000
hds_00_034_010_000	hds_00_034_010_000	calhead	34.590117	34.577950	0.012168	10.000

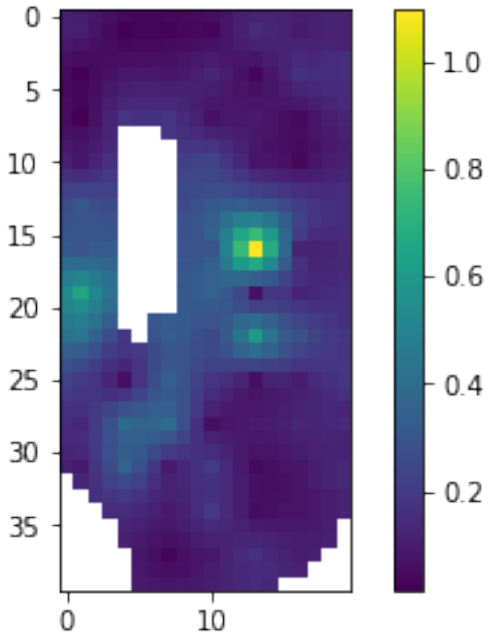
The residual should be exactly the noise values from above.Lets load the model (that was just run using the true pars) and check some things

In [22]:
```
m = flopy.modflow.Modflow.load("freyberg.nam",model_ws=m_d)
```

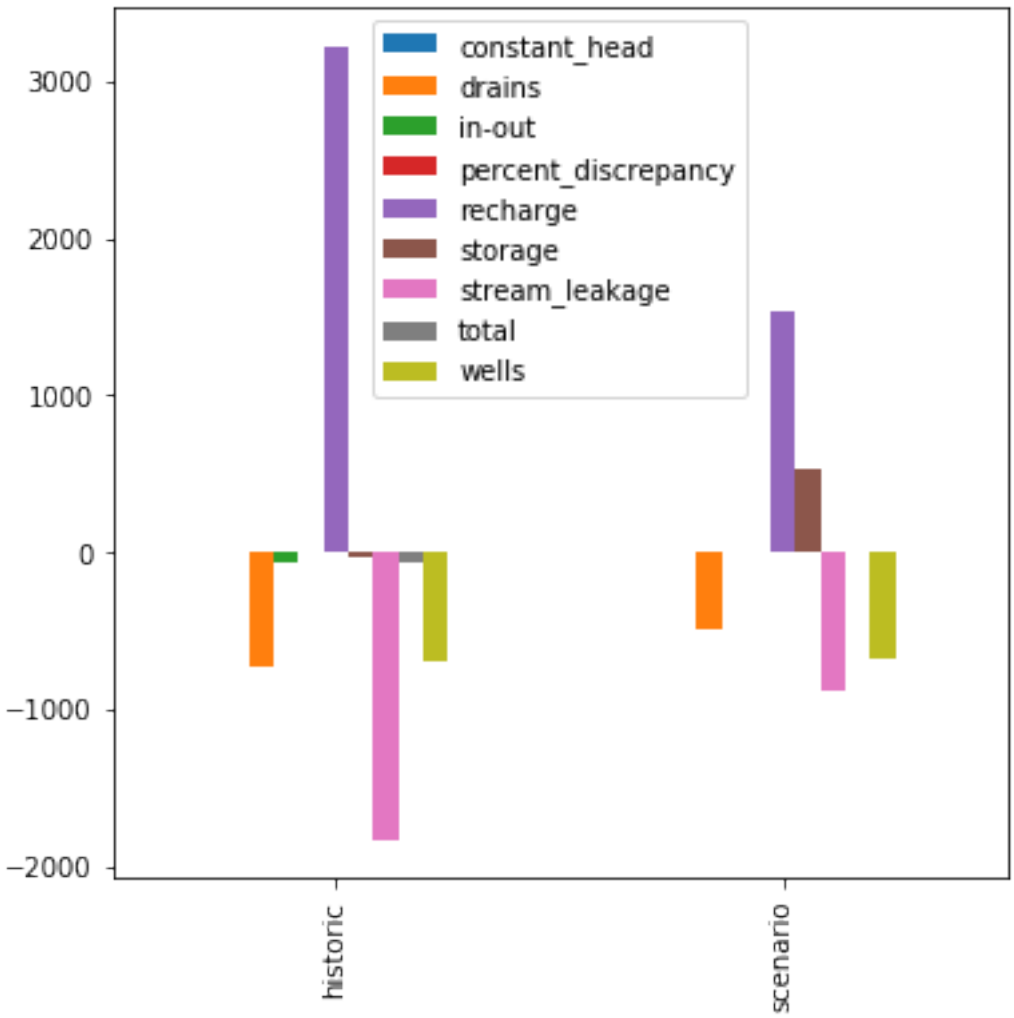
In [23]:
```
a = m.upw.vka[1].array
#a = m.rch.rech[0].array
a = np.ma.masked_where(m.bas6.ibound[0].array==0,a)
print(a.min(),a.max())
c = plt.imshow(a)
plt.colorbar(c)
```

```
0.01556885 1.095735
```

Out[23]: <matplotlib.colorbar.Colorbar at 0x181ede8c88>



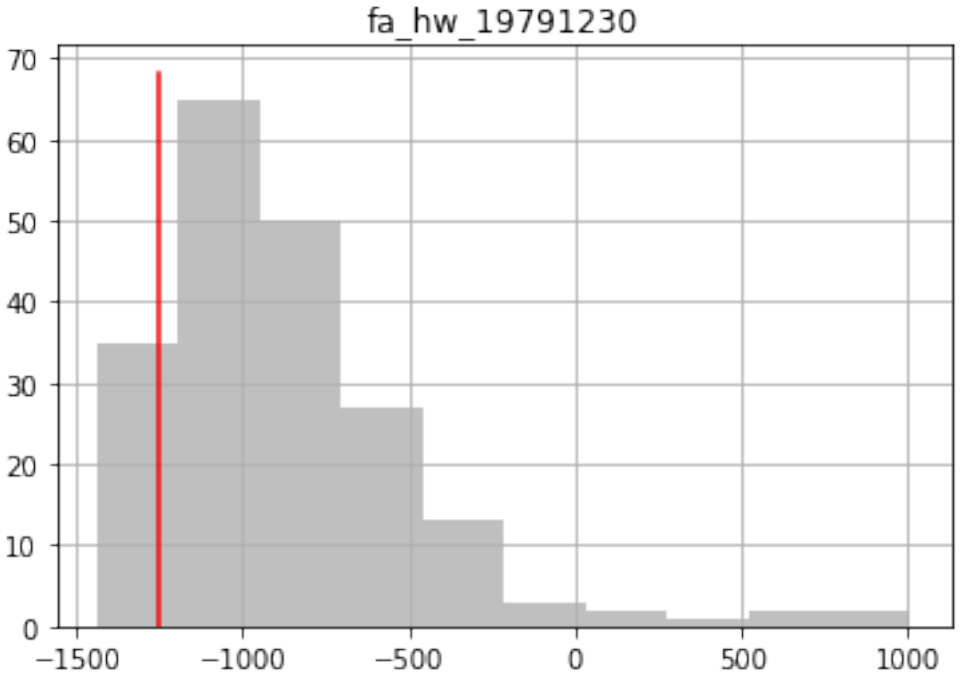
In [24]:
```
lst = flopy.utils.MfListBudget(os.path.join(m_d,"freyberg.list"))
df = lst.get_dataframes(diff=True)[0]
ax = df.plot(kind="bar",figsize=(6,6))
a = ax.set_xticklabels(["historic","scenario"],rotation=90)
```

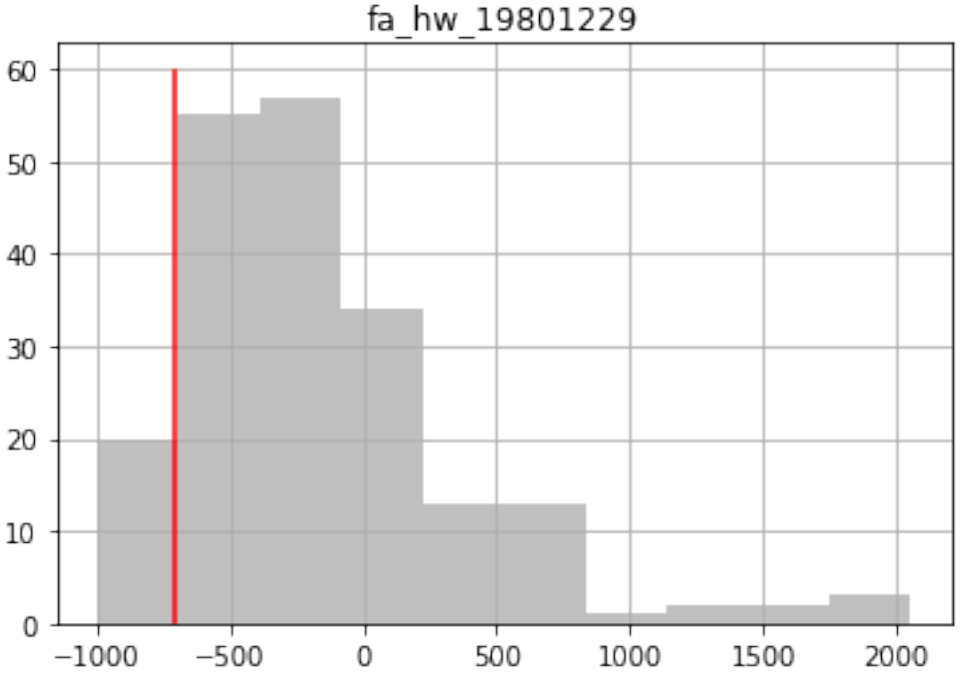


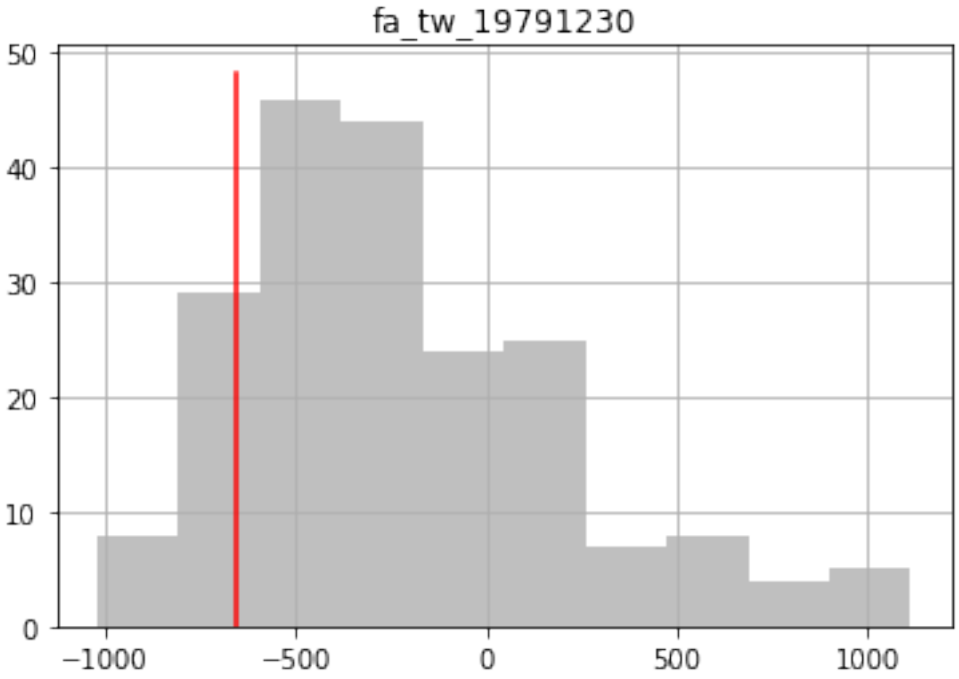
1.0.5 see how our existing observation ensemble compares to the truth

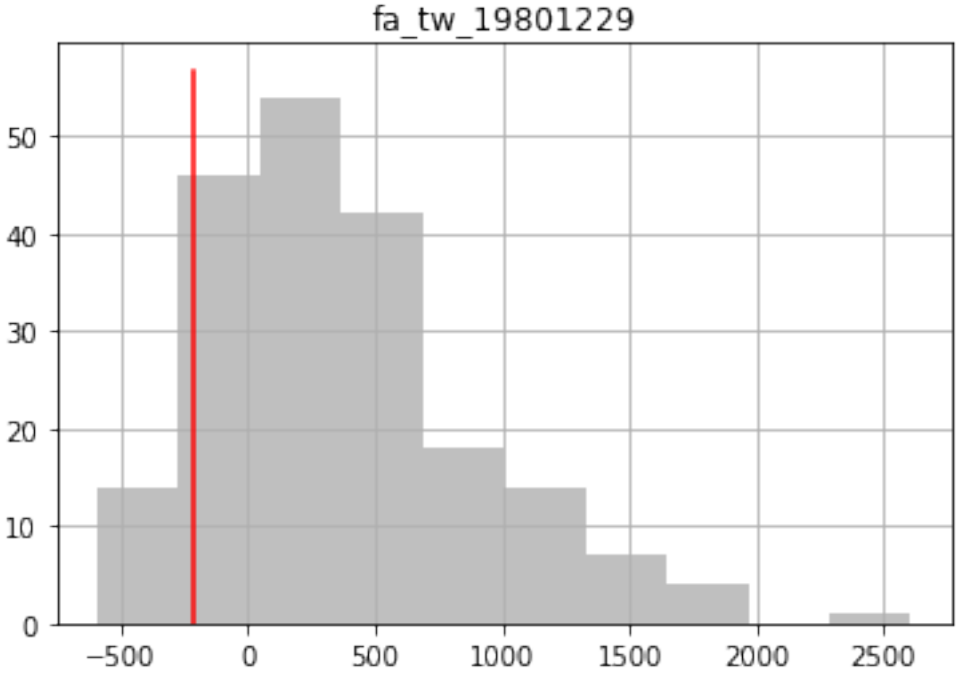
sw-gw outputs:

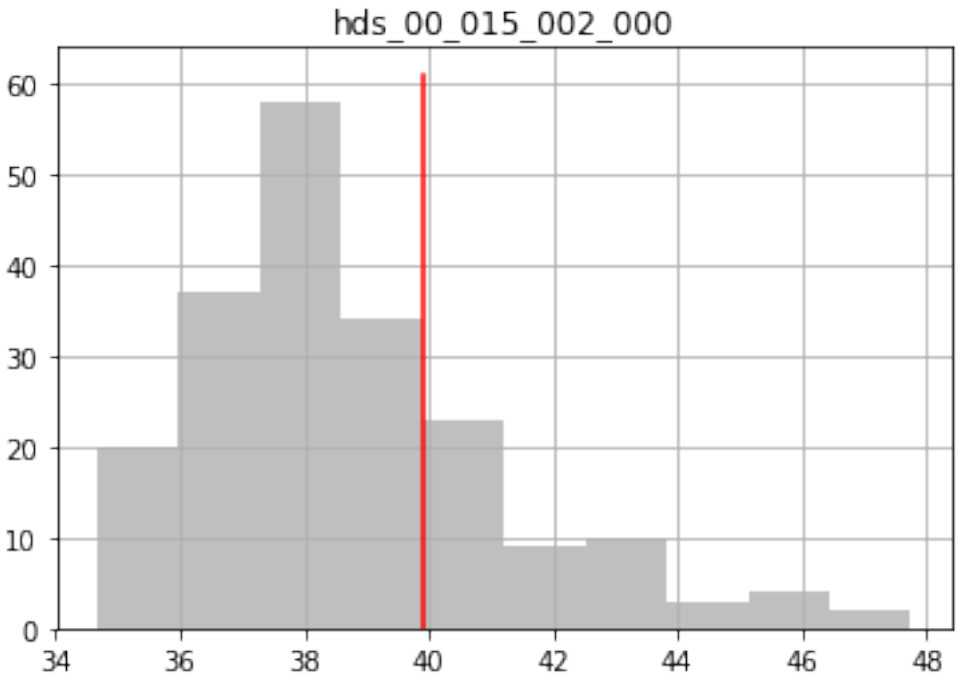
```
In [25]: obs = pst.observation_data

         for forecast in fnames:
             ax = plt.subplot(111)
             obs_df.loc[:,forecast].hist(ax=ax,color="0.5",alpha=0.5)
             ax.plot([obs.loc[forecast,"obsval"],obs.loc[forecast,"obsval"]],ax.get_ylim(),"r"
             ax.set_title(forecast)
             plt.show()
```

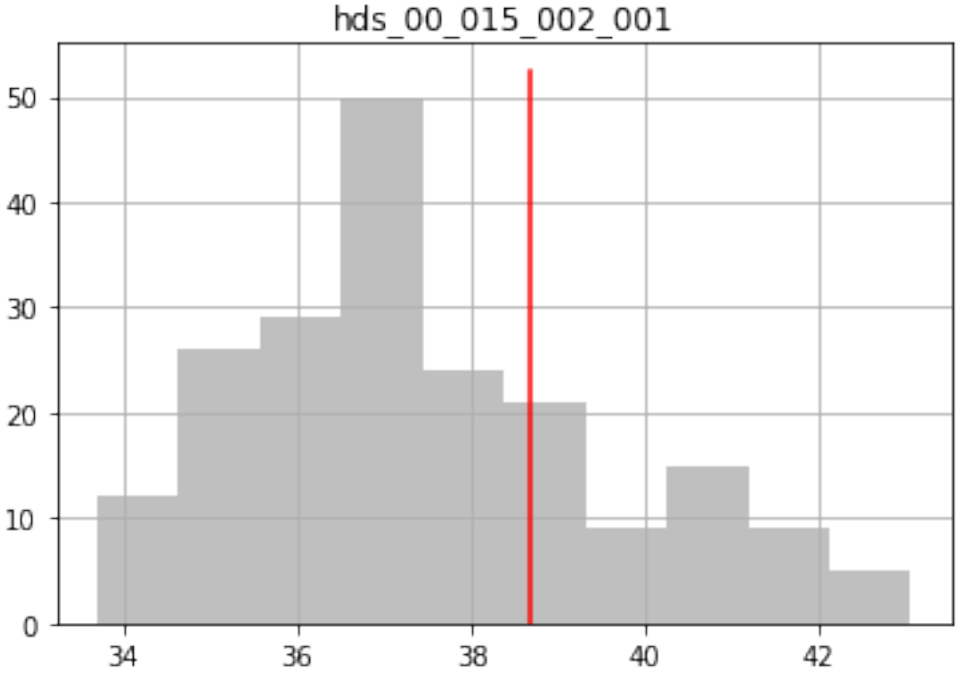

fa_hw_19791230
70
60
50
40
30
20
10
0
−1500
−1000
−500
0
500
1000


fa_hw_19801229
60
50
40
30
20
10
0
−1000
−500
0
500
1000
1500
2000


fa_tw_19791230
50
40
30
20
10
0
−1000
−500
0
500
1000

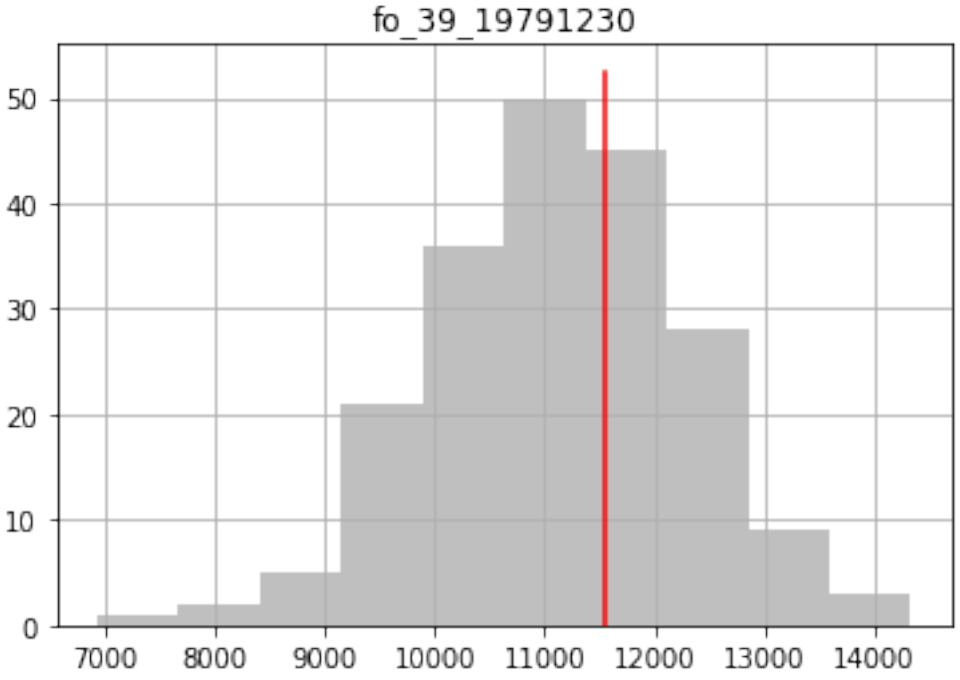

fa_tw_19801229
50
40
30
20
10
0
−500
0
500
1000
1500
2000
2500

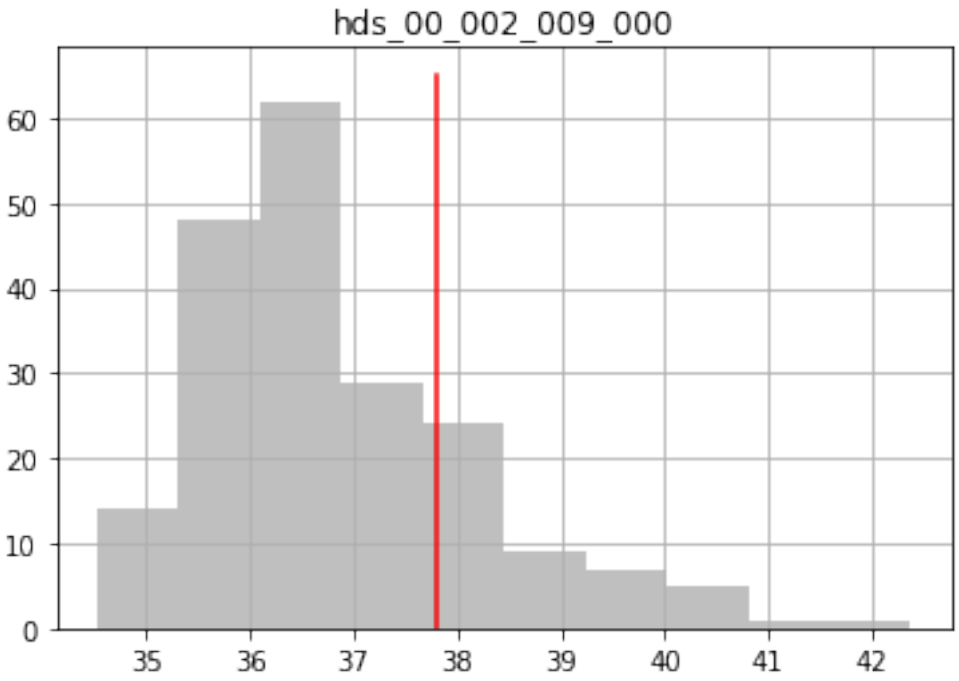


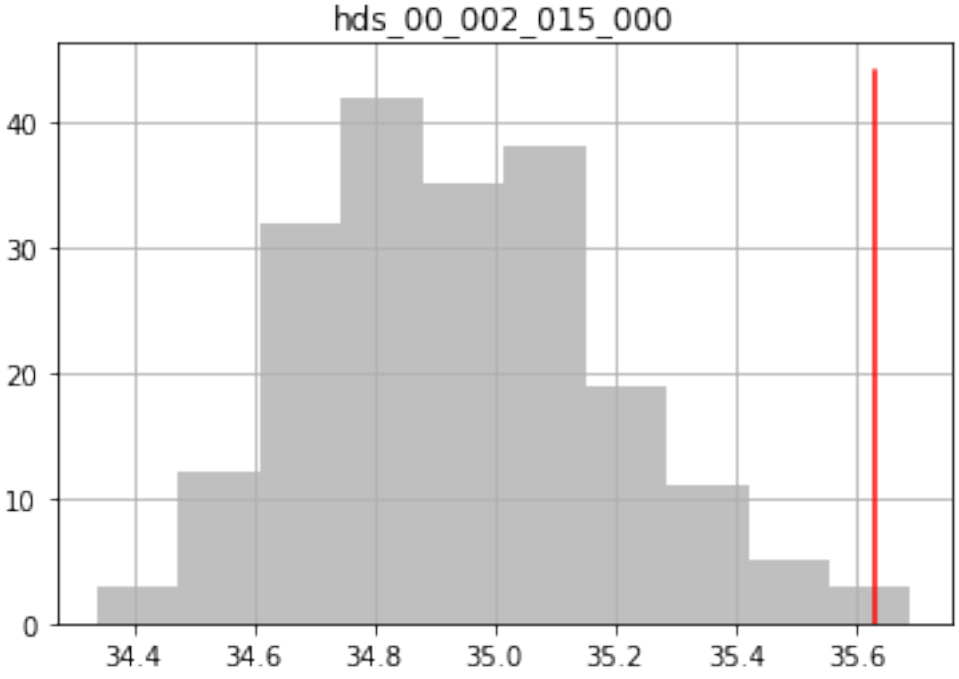


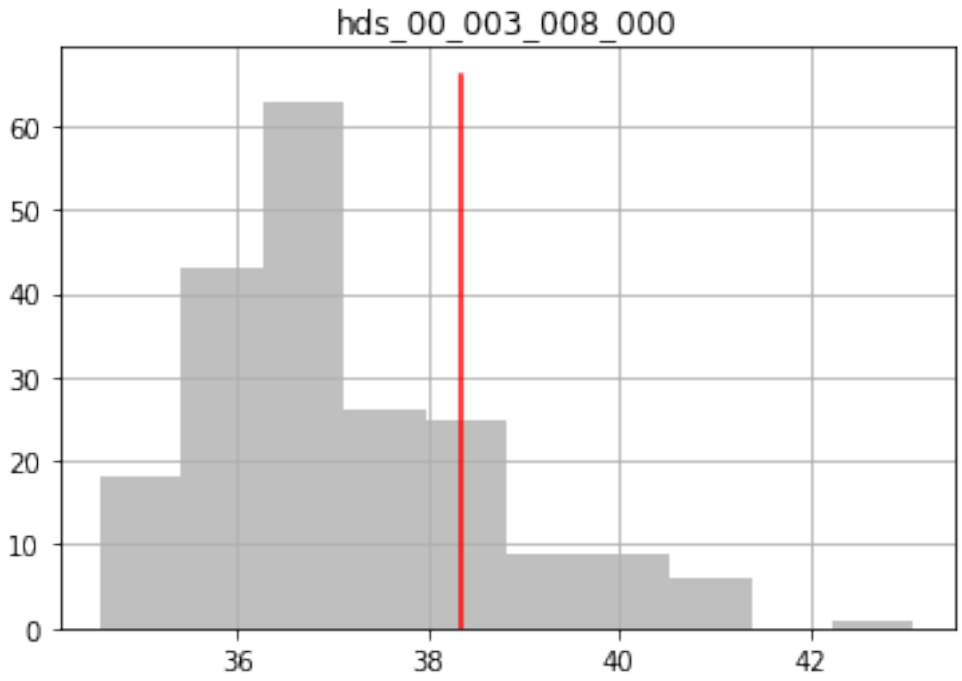
observations:

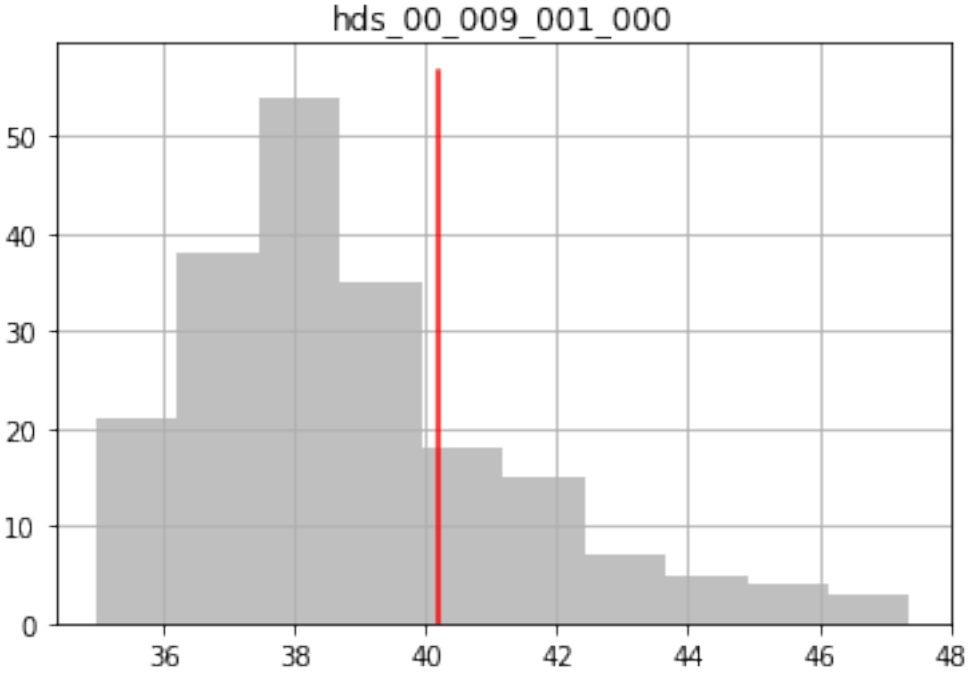
```
In [26]: for oname in pst.nnz_obs_names:
             ax = plt.subplot(111)
             obs_df.loc[:,oname].hist(ax=ax,color="0.5",alpha=0.5)
             ax.plot([obs.loc[oname,"obsval"],obs.loc[oname,"obsval"]],ax.get_ylim(),"r")
             ax.set_title(oname)
             plt.show()
```




hds_00_002_009_000
60
50
40
30
20
10
0
35
36
37
38
39
40
41
42


hds_00_002_015_000
40
30
20
10
0
34.4
34.6
34.8
35.0
35.2
35.4
35.6


hds_00_003_008_000
60
50
40
30
20
10
0
36
38
40
42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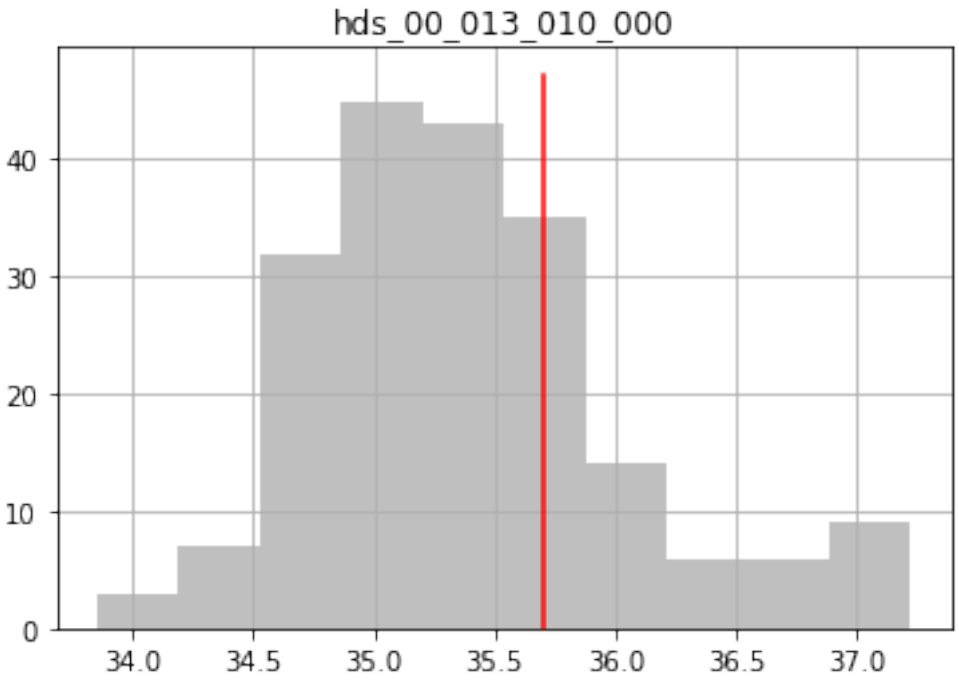
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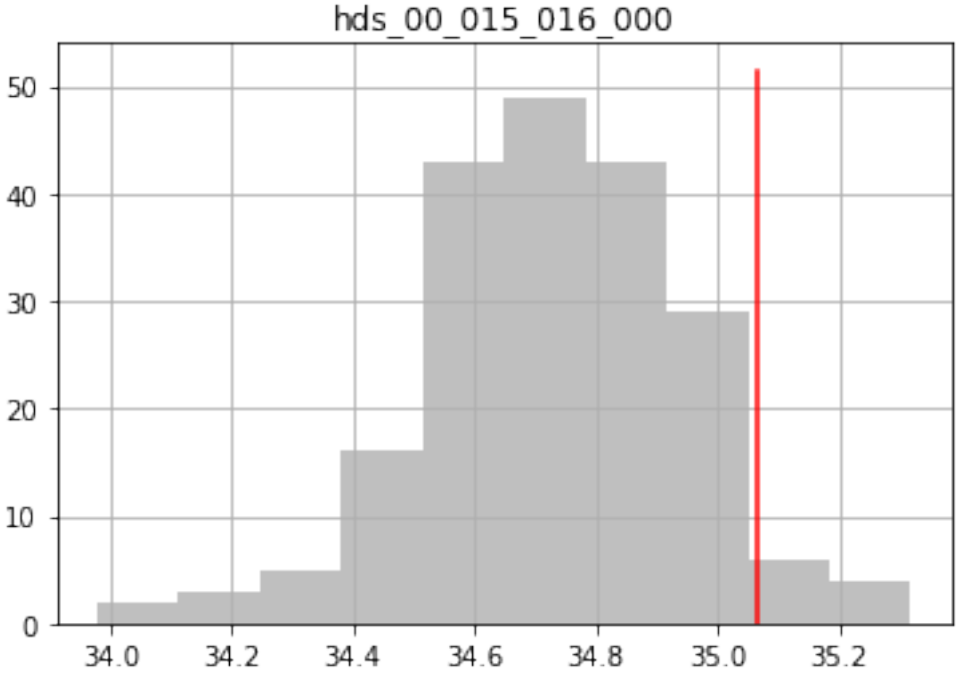
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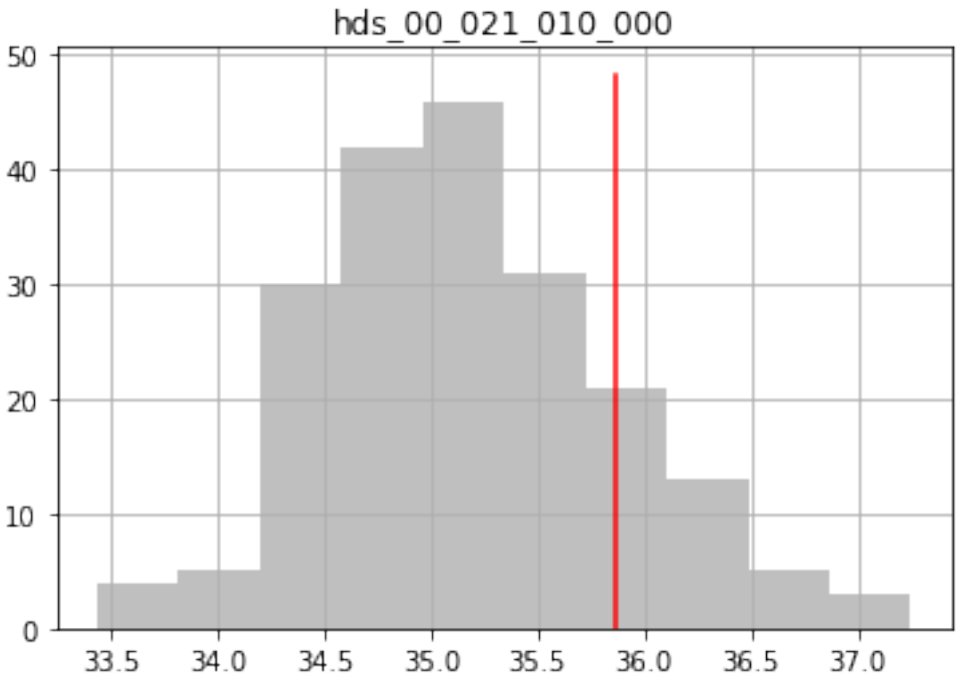
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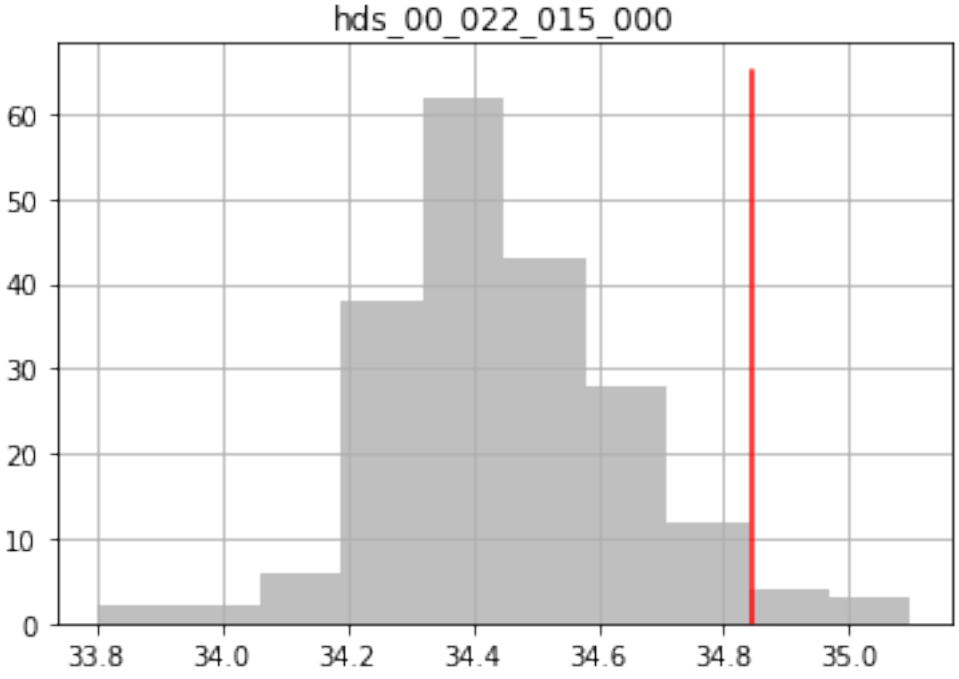
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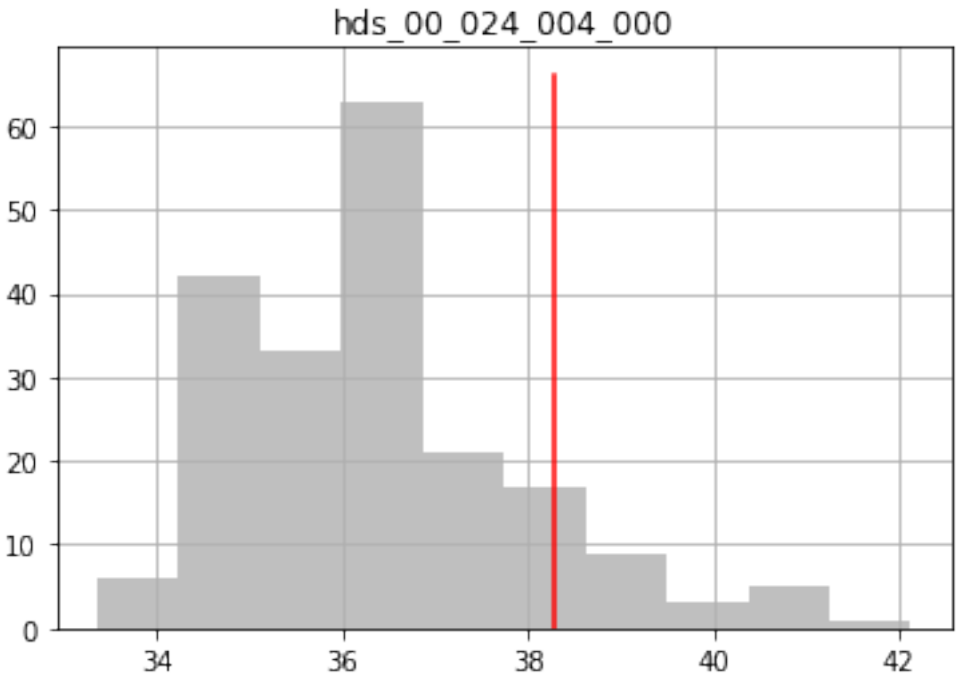
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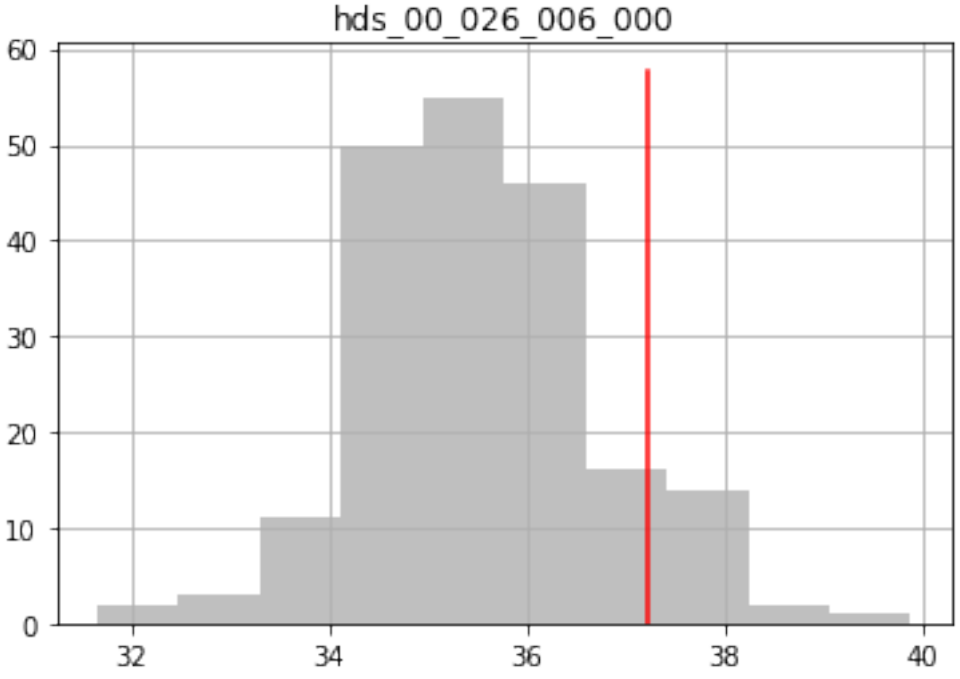
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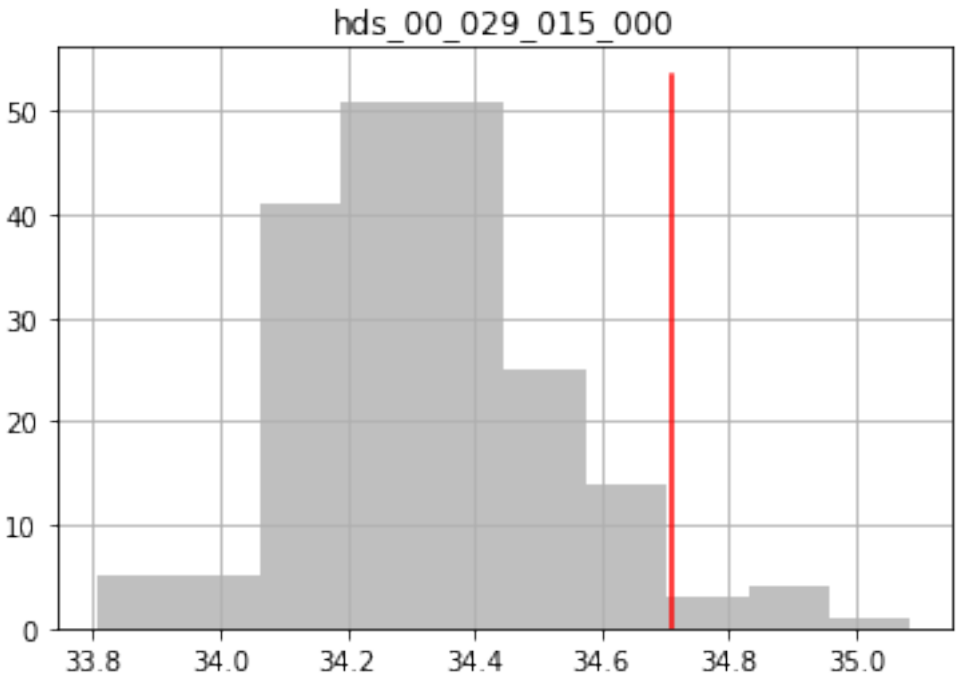
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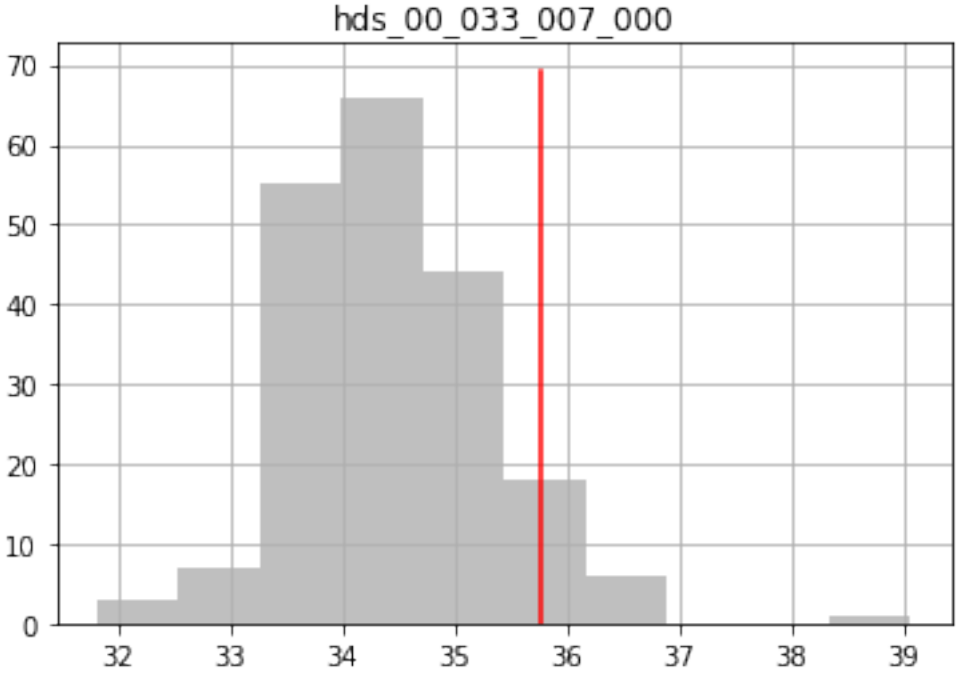
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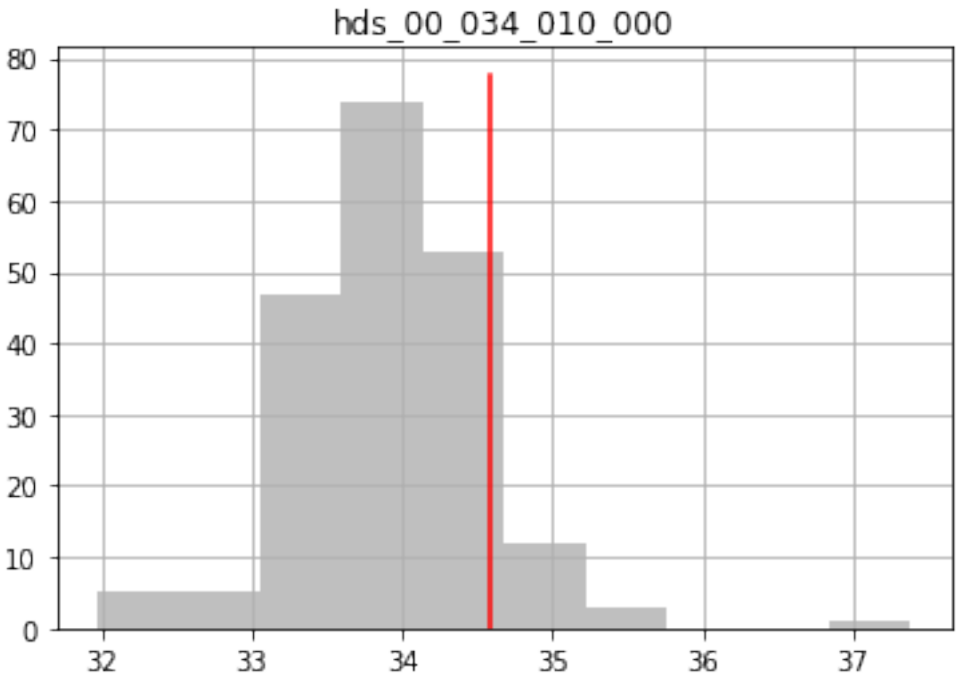
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