pestpp-ies

May 1, 2019

1 Run PESTPP-IES

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"
m_d = "master_ies"
```

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	upper bound	\
gr_ss3	gr_ss3	log	705	0	1	
gr_hk5	gr_hk5	log	705	0	1	
strk	strk	log	40	0	2	
drncond_k00	drncond_k00	log	10	0	1	
pp_prsity1	pp_prsity1	log	32	0	0	
flow	flow	log	1	0	0.09691	
cn_hk7	cn_hk7	log	1	0	1	
gr_sy4	gr_sy4	log	705	0	0.243038	
pp_sy2	pp_sy2	log	32	0	0.243038	
cn_ss7	cn_ss7	log	1	0	1	
gr_vka5	gr_vka5	log	705	0	1	
cn_hk8	cn_hk8	log	1	0	1	
pp_sy1	pp_sy1	log	32	0	0.243038	
cn_ss8	cn_ss8	log	1	0	1	
gr_rech3	gr_rech3	log	705	0	0.0413927	
cn_prsity8	cn_prsity8	log	1	0	0	
gr_prsity3	gr_prsity3	log	705	0	0	

gr_prsity5	gr_prsity5	log	705	0	0
pp_vka1	pp_vka1	log	32	0	1
gr_ss4	gr_ss4	log	705	0	1
pp_ss0	pp_ss0	log	32	0	1
gr_prsity4	gr_prsity4	log	705	0	0
pp_hk2	pp_hk2	log	32	0	1
cn_vka6	cn_vka6	log	1	0	1
gr_ss5	gr_ss5	log	705	0	1
pp_hk1	pp_hk1	log	32	0	1
cn_sy8	cn_sy8	log	1	0	0.243038
pp_strt1	pp_strt1	log	32	0	0.0211893
gr_strt4	gr_strt4	log	705	0	0.0211893
gr_vka4	gr_vka4	log	705	0	1
...	...	...	...	...	...
gr_strt3	gr_strt3	log	705	0	0.0211893
cn_sy6	cn_sy6	log	1	0	0.243038
cn_ss6	cn_ss6	log	1	0	1
cn_vka7	cn_vka7	log	1	0	1
gr_rech2	gr_rech2	log	705	0	0.0413927
cn_hk6	cn_hk6	log	1	0	1
gr_sy5	gr_sy5	log	705	0	0.243038
pp_vka2	pp_vka2	log	32	0	1
pp_sy0	pp_sy0	log	32	0	0.243038
cn_rech5	cn_rech5	log	1	-0.39794	-0.09691
cn_prsity6	cn_prsity6	log	1	0	0
pp_rech0	pp_rech0	log	32	0	0.0413927
pp_hk0	pp_hk0	log	32	0	1
gr_sy3	gr_sy3	log	705	0	0.243038
gr_strt5	gr_strt5	log	705	0	0.0211893
pp_vka0	pp_vka0	log	32	0	1
pp_ss2	pp_ss2	log	32	0	1
pp_prsity2	pp_prsity2	log	32	0	0
gr_vka3	gr_vka3	log	705	0	1
cn_vka8	cn_vka8	log	1	0	1
gr_hk4	gr_hk4	log	705	0	1
pp_strt0	pp_strt0	log	32	0	0.0211893
pp_strt2	pp_strt2	log	32	0	0.0211893
cn_strt8	cn_strt8	log	1	0	0.0211893
pp_prsity0	pp_prsity0	log	32	0	0
welflux_k02	welflux_k02	log	6	0	1
cn_prsity7	cn_prsity7	log	1	0	0
cn_sy7	cn_sy7	log	1	0	0.243038
cn_strt6	cn_strt6	log	1	0	0.0211893
pp_ss1	pp_ss1	log	32	0	1

	lower bound	standard deviation
gr_ss3	-1	0.5
gr_hk5	-1	0.5

strk	-2	1
drncond_k00	-1	0.5
pp_prsity1	-1	0.25
flow	-0.124939	0.0554622
cn_hk7	-1	0.5
gr_sy4	-0.60206	0.211275
pp_sy2	-0.60206	0.211275
cn_ss7	-1	0.5
gr_vka5	-1	0.5
cn_hk8	-1	0.5
pp_sy1	-0.60206	0.211275
cn_ss8	-1	0.5
gr_rech3	-0.0457575	0.0217875
cn_prsity8	-1	0.25
gr_prsity3	-1	0.25
gr_prsity5	-1	0.25
pp_vka1	-1	0.5
gr_ss4	-1	0.5
pp_ss0	-1	0.5
gr_prsity4	-1	0.25
pp_hk2	-1	0.5
cn_vka6	-1	0.5
gr_ss5	-1	0.5
pp_hk1	-1	0.5
cn_sy8	-0.60206	0.211275
pp_strt1	-0.0222764	0.0108664
gr_strt4	-0.0222764	0.0108664
gr_vka4	-1	0.5
...	...	...
gr_strt3	-0.0222764	0.0108664
cn_sy6	-0.60206	0.211275
cn_ss6	-1	0.5
cn_vka7	-1	0.5
gr_rech2	-0.0457575	0.0217875
cn_hk6	-1	0.5
gr_sy5	-0.60206	0.211275
pp_vka2	-1	0.5
pp_sy0	-0.60206	0.211275
cn_rech5	-1	0.225772
cn_prsity6	-1	0.25
pp_rech0	-0.0457575	0.0217875
pp_hk0	-1	0.5
gr_sy3	-0.60206	0.211275
gr_strt5	-0.0222764	0.0108664
pp_vka0	-1	0.5
pp_ss2	-1	0.5
pp_prsity2	-1	0.25
gr_vka3	-1	0.5

```
cn_vka8              -1               0.5
gr_hk4               -1               0.5
pp_strt0     -0.0222764         0.0108664
pp_strt2     -0.0222764         0.0108664
cn_strt8     -0.0222764         0.0108664
pp_prsity0           -1              0.25
welflux_k02          -1               0.5
cn_prsity7           -1              0.25
cn_sy7          -0.60206          0.211275
cn_strt6     -0.0222764         0.0108664
pp_ss1               -1               0.5

[65 rows x 7 columns]
```

Should we fix either PP or grids?

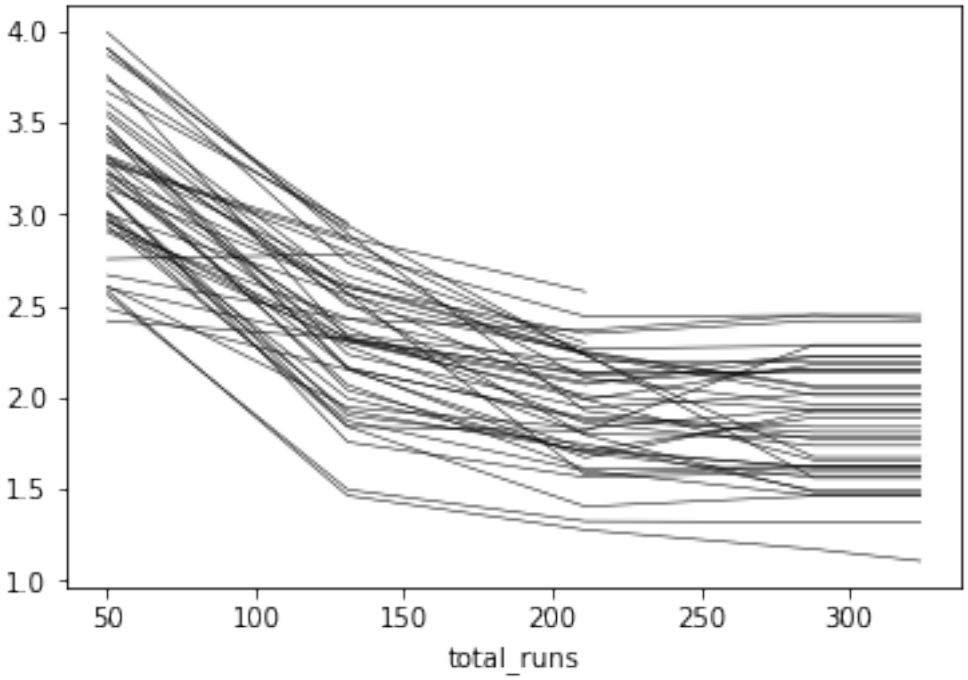
```
In [4]: par = pst.parameter_data
        # grid pars
        #should_fix = par.loc[par.pargp.apply(lambda x: "gr" in x),"parnme"]
        # pp pars
        should_fix = par.loc[par.pargp.apply(lambda x: "pp" in x),"parnme"]

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

1.0.1 Run PESTPP-IES in original mode and post process

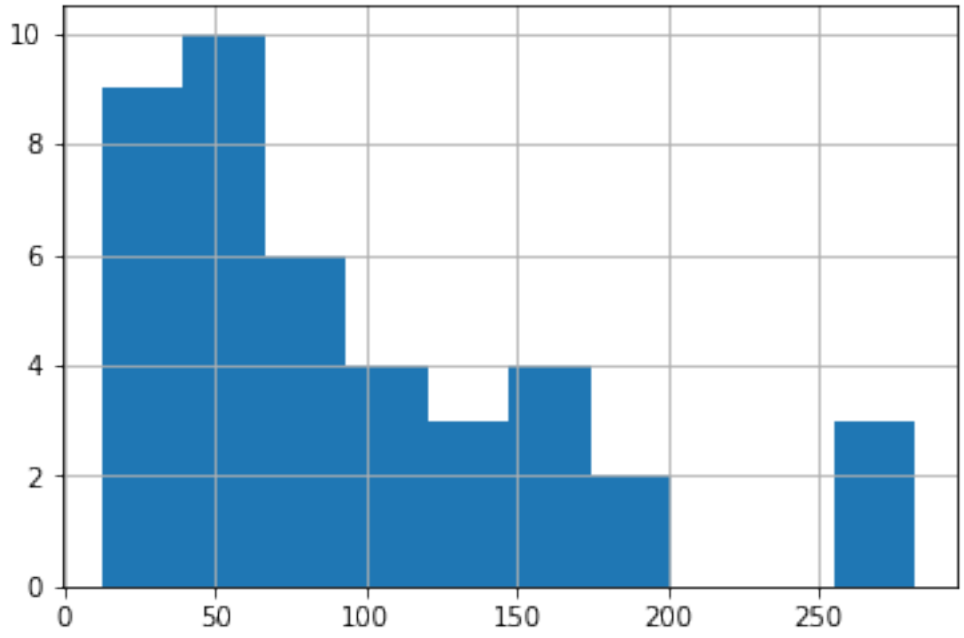
```
In [5]: pst.pestpp_options["ies_num_reals"] = 50
        pst.pestpp_options["ies_par_en"] = "prior.jcb"
        pst.pestpp_options["ies_bad_phi_sigma"] = 2.0
        pst.pestpp_options["overdue_giveup_fac"] = 10.0
        pst.control_data.noptmax = 4

In [6]: pst.write(os.path.join(t_d,"freyberg_ies.pst"))

In [7]: pyemu.os_utils.start_slaves(t_d,"pestpp-ies","freyberg_ies.pst",num_slaves=20,master_d
```

A cheap phi progress plot

```
In [8]: 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.show()
        phi.iloc[-1,6:].hist()
```

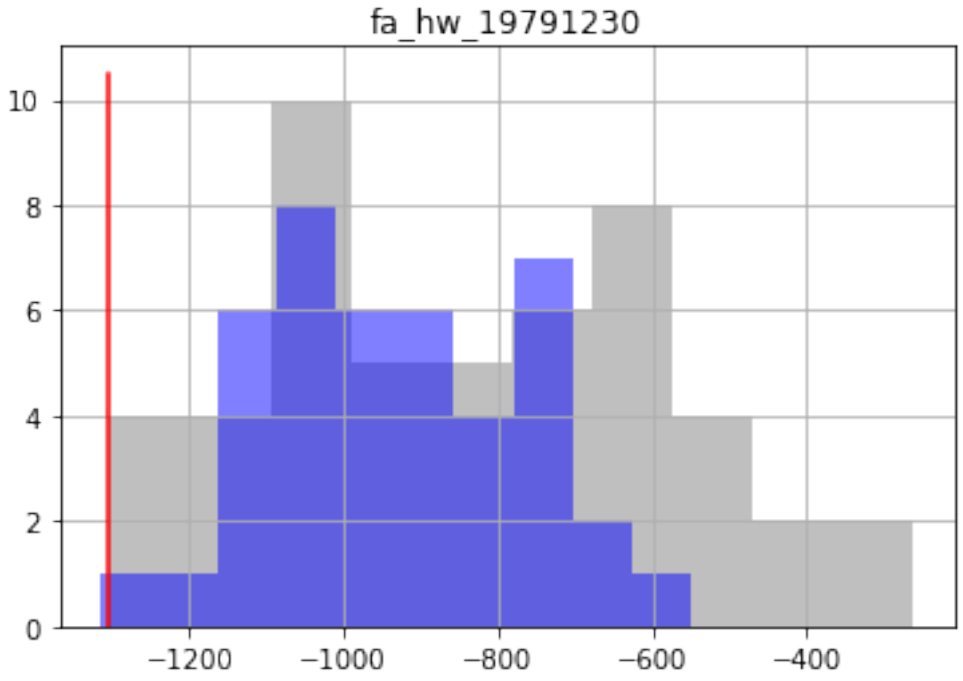


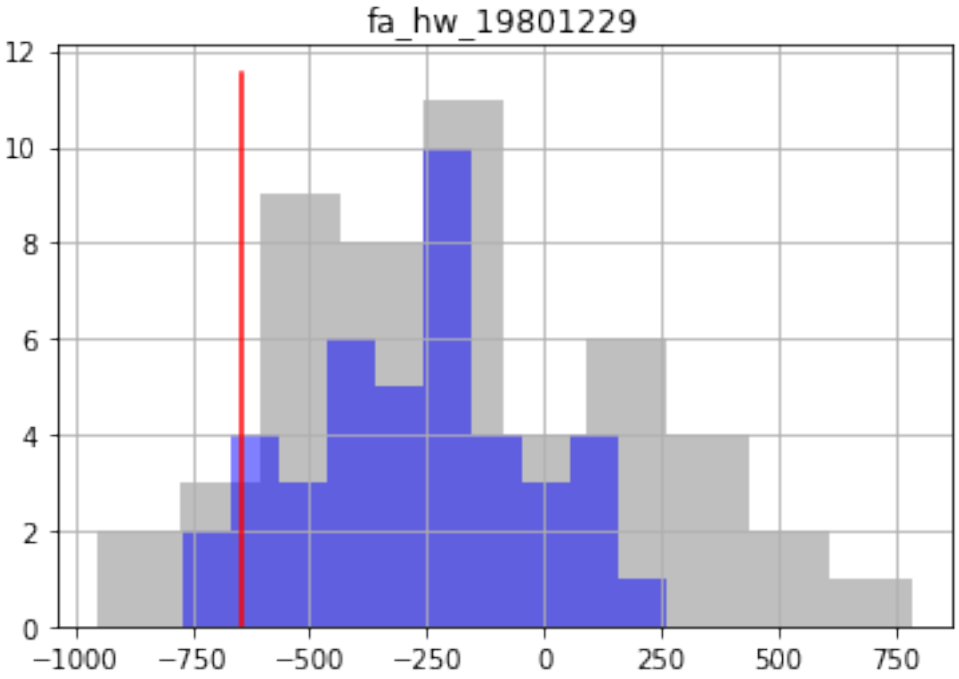
Out[8]: <matplotlib.axes._subplots.AxesSubplot at 0x181825ceb8>

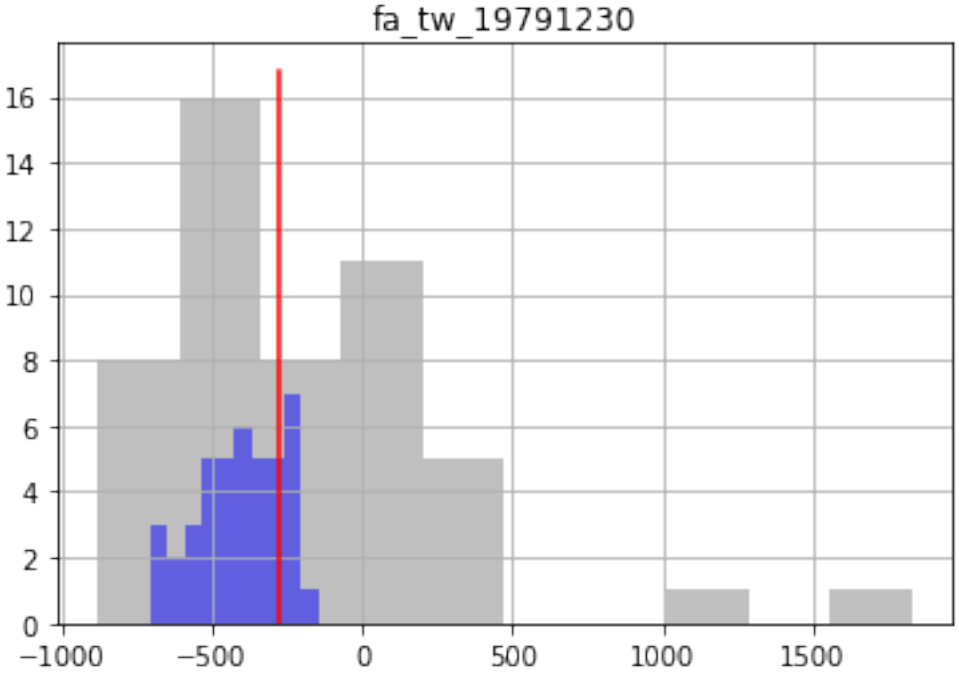


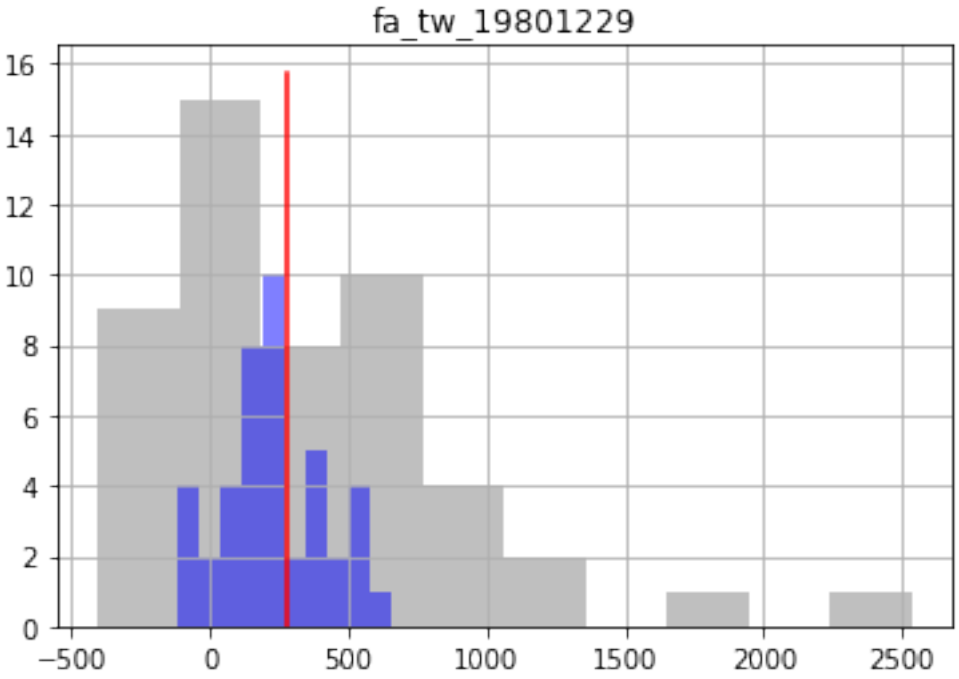
Plot forecast prior and posterior histograms with "truth" (red line)

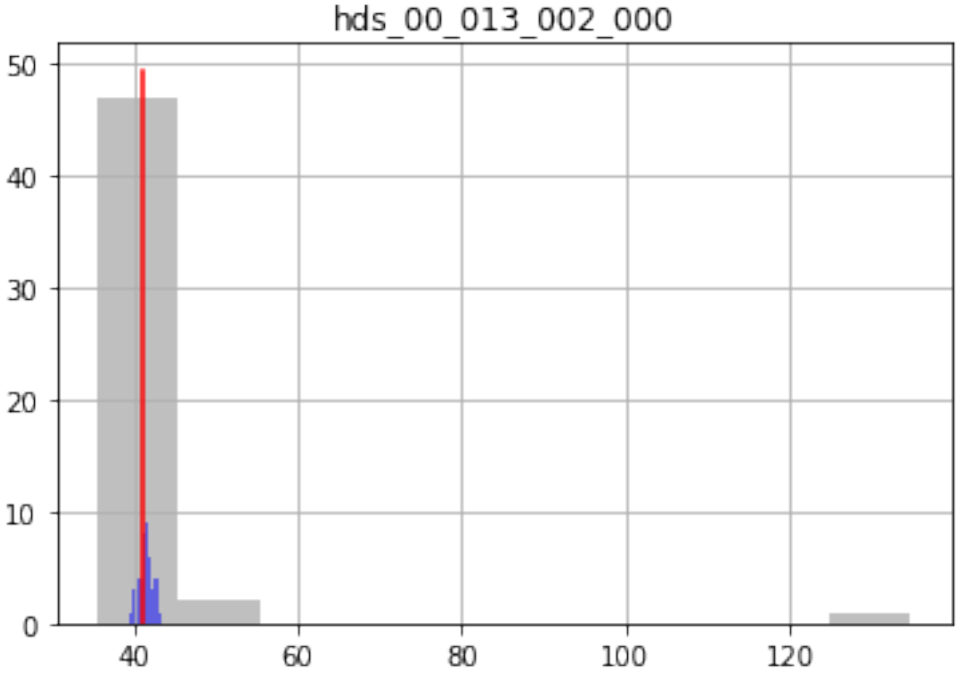
In [9]:
```
oe_pr = pd.read_csv(os.path.join(m_d,"freyberg_ies.0.obs.csv"),index_col=0)
oe_pt = pd.read_csv(os.path.join(m_d,"freyberg_ies.{0}.obs.csv".format(pst.control_data
obs = pst.observation_data
fnames = pst.pestpp_options["forecasts"].split(",")
for forecast in fnames:
    ax = plt.subplot(111)
    oe_pr.loc[:,forecast].hist(ax=ax,color="0.5",alpha=0.5)
    oe_pt.loc[:,forecast].hist(ax=ax,color="b",alpha=0.5)
    ax.plot([obs.loc[forecast,"obsval"],obs.loc[forecast,"obsval"]],ax.get_ylim(),"r")
    ax.set_title(forecast)
    plt.show()
```

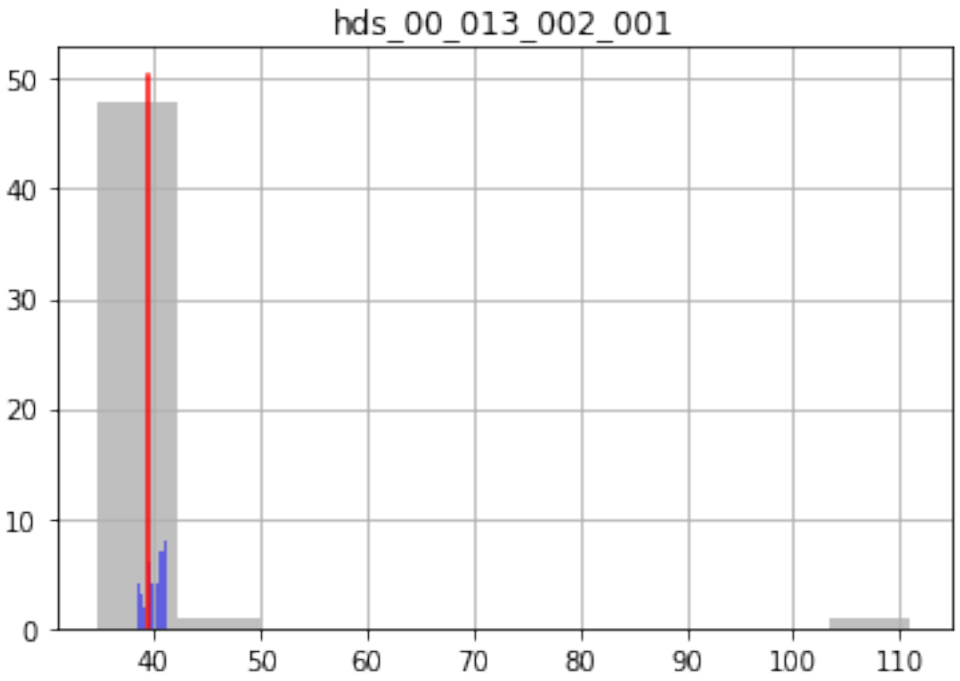



fa_hw_19801229
12
10
8
6
4
2
0
−1000
−750
−500
−250
0
250
500
750


fa_tw_19791230
16
14
12
10
8
6
4
2
0
−1000
−500
0
500
1000
1500


fa_tw_19801229
16
14
12
10
8
6
4
2
0
−500
0
500
1000
1500
2000
2500

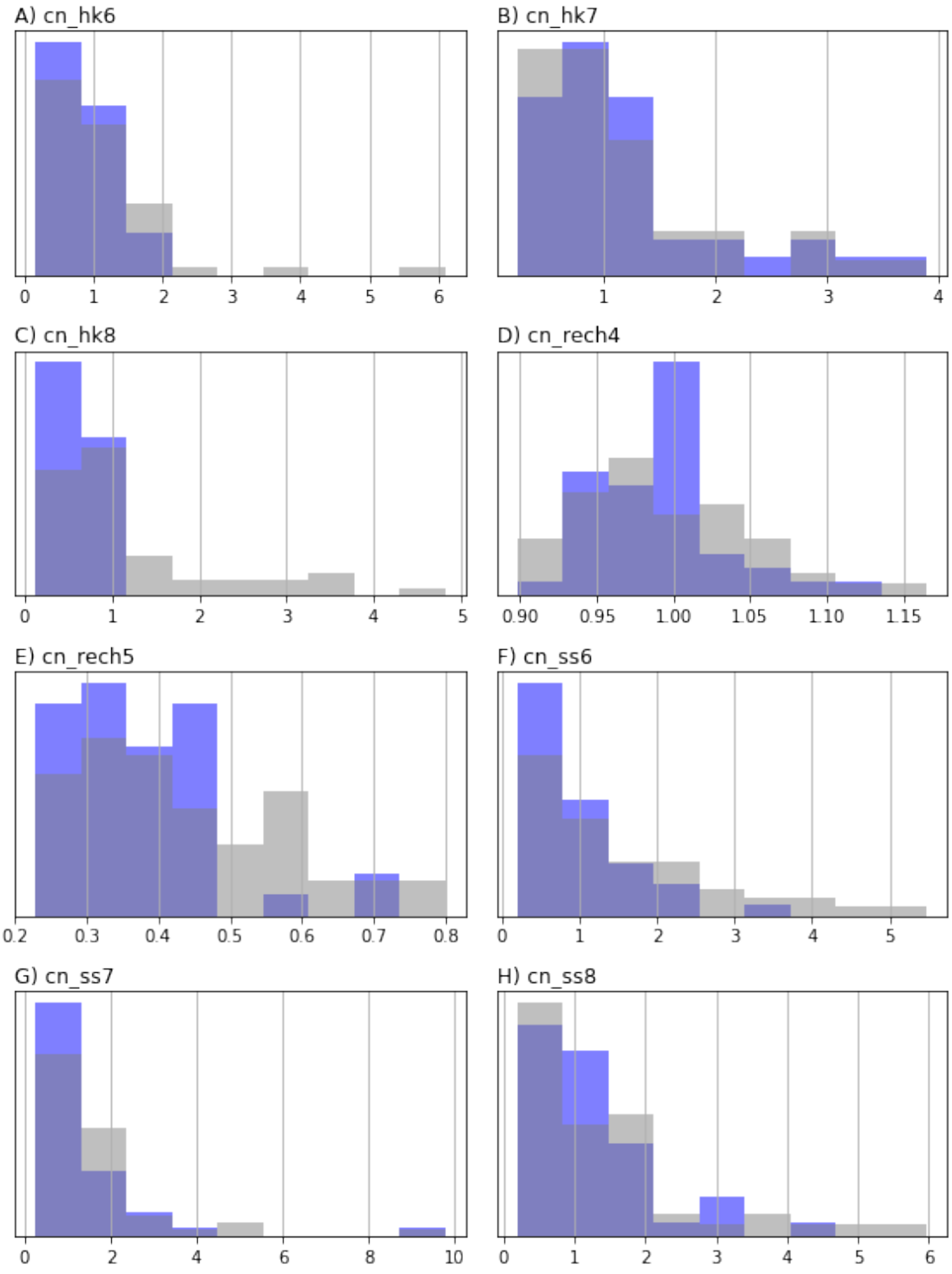

hds_00_013_002_000
50
40
30
20
10
0
40
60
80
100
120

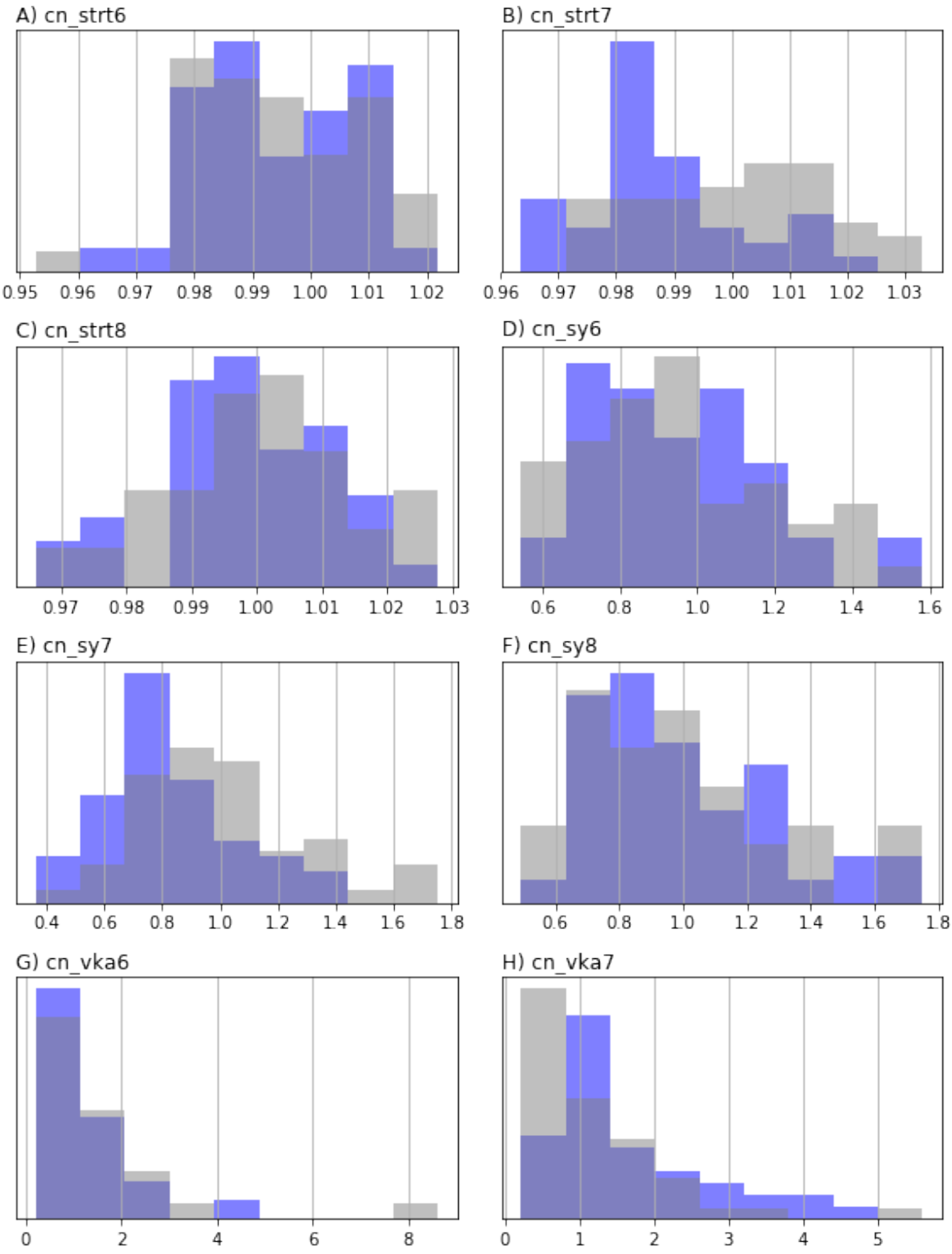


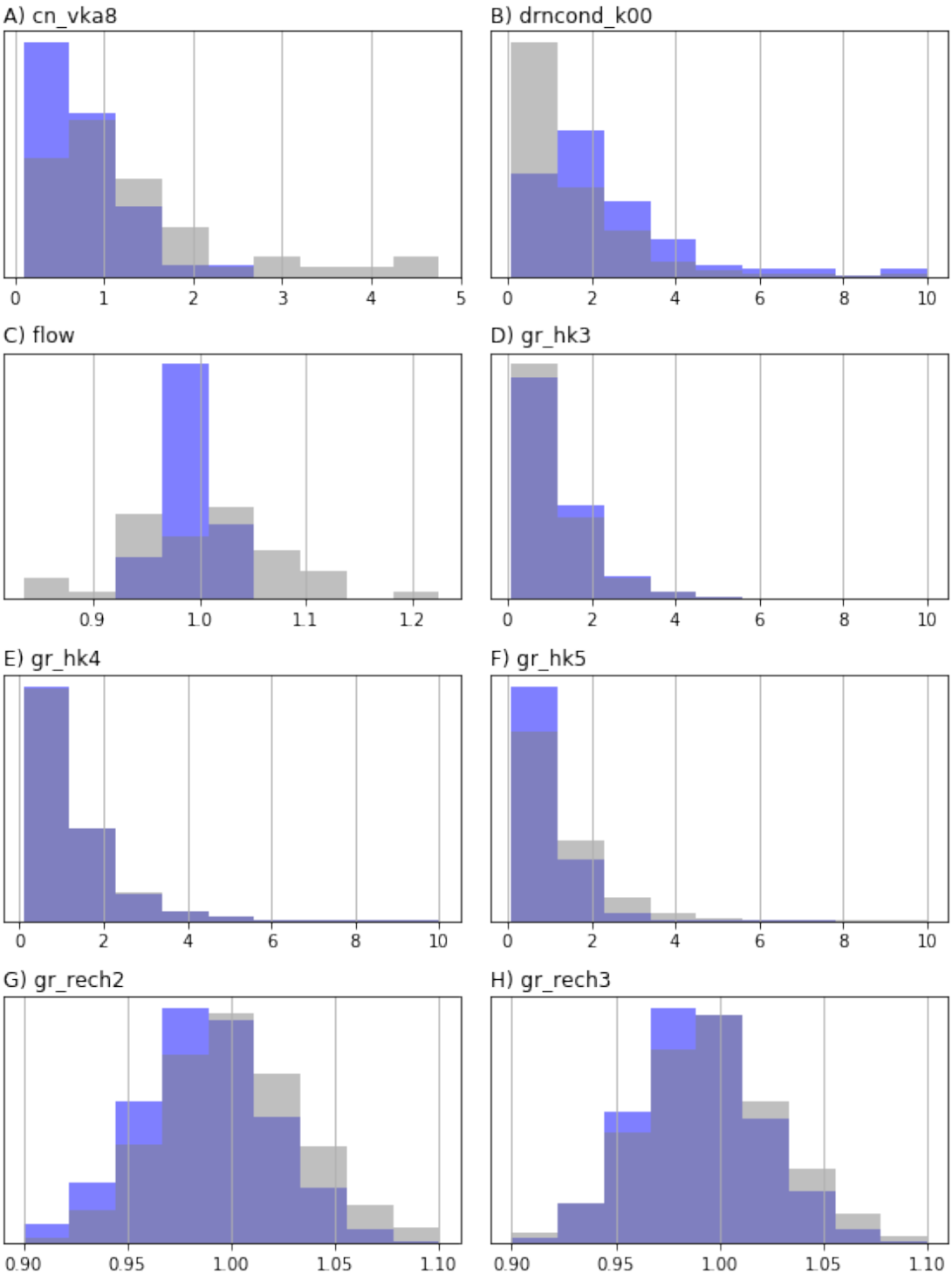
Plot parameter histograms by group

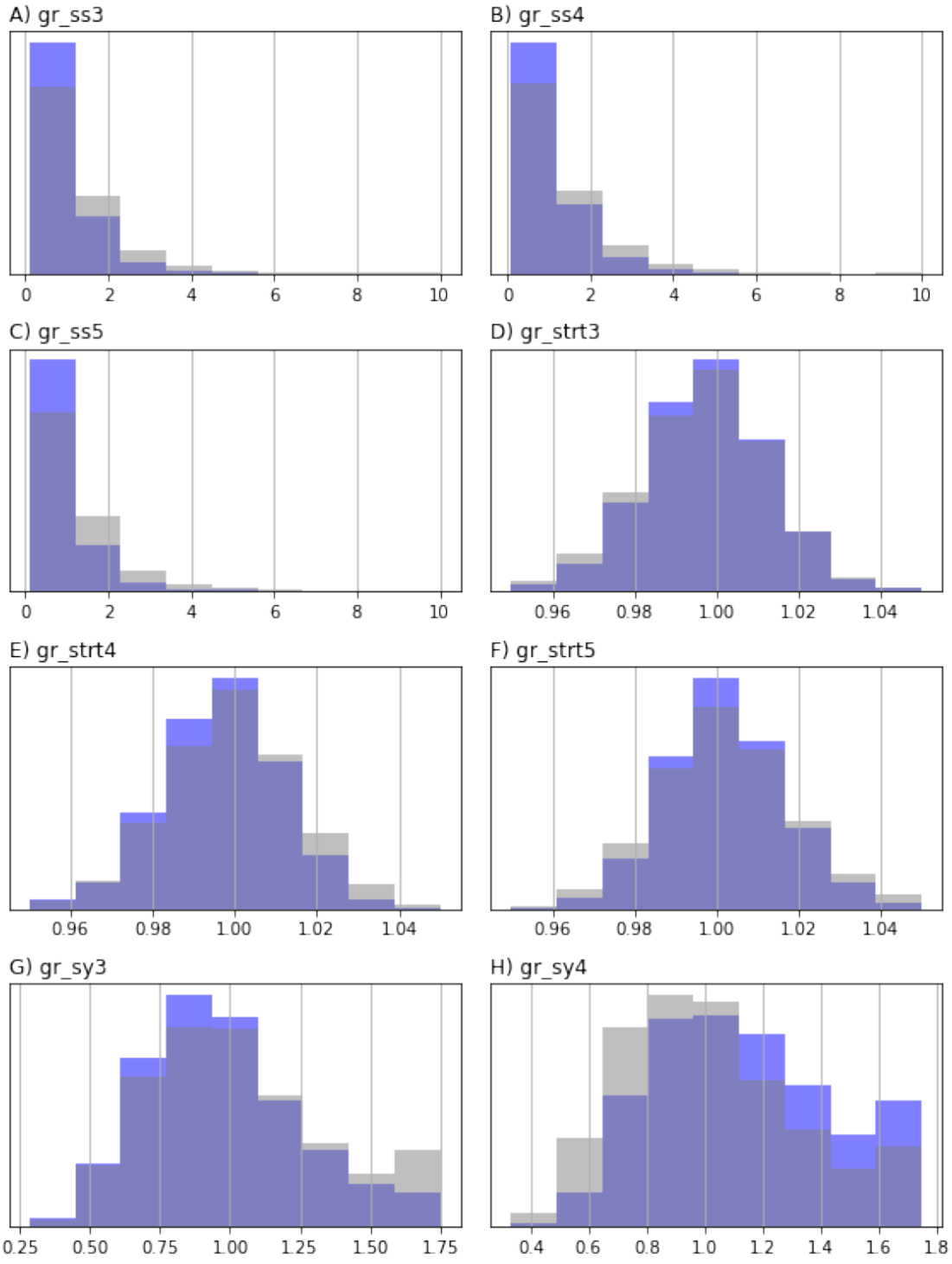
```
In [10]: pe_pr = pd.read_csv(os.path.join(m_d,"freyberg_ies.0.par.csv"),index_col=0)
         pe_pt = pd.read_csv(os.path.join(m_d,"freyberg_ies.{0}.par.csv".format(pst.control_da
         par = pst.parameter_data
         pdict = par.groupby("pargp").groups
         pyemu.plot_utils.ensemble_helper({"0.5":pe_pr,"b":pe_pt},plot_cols=pdict)
```

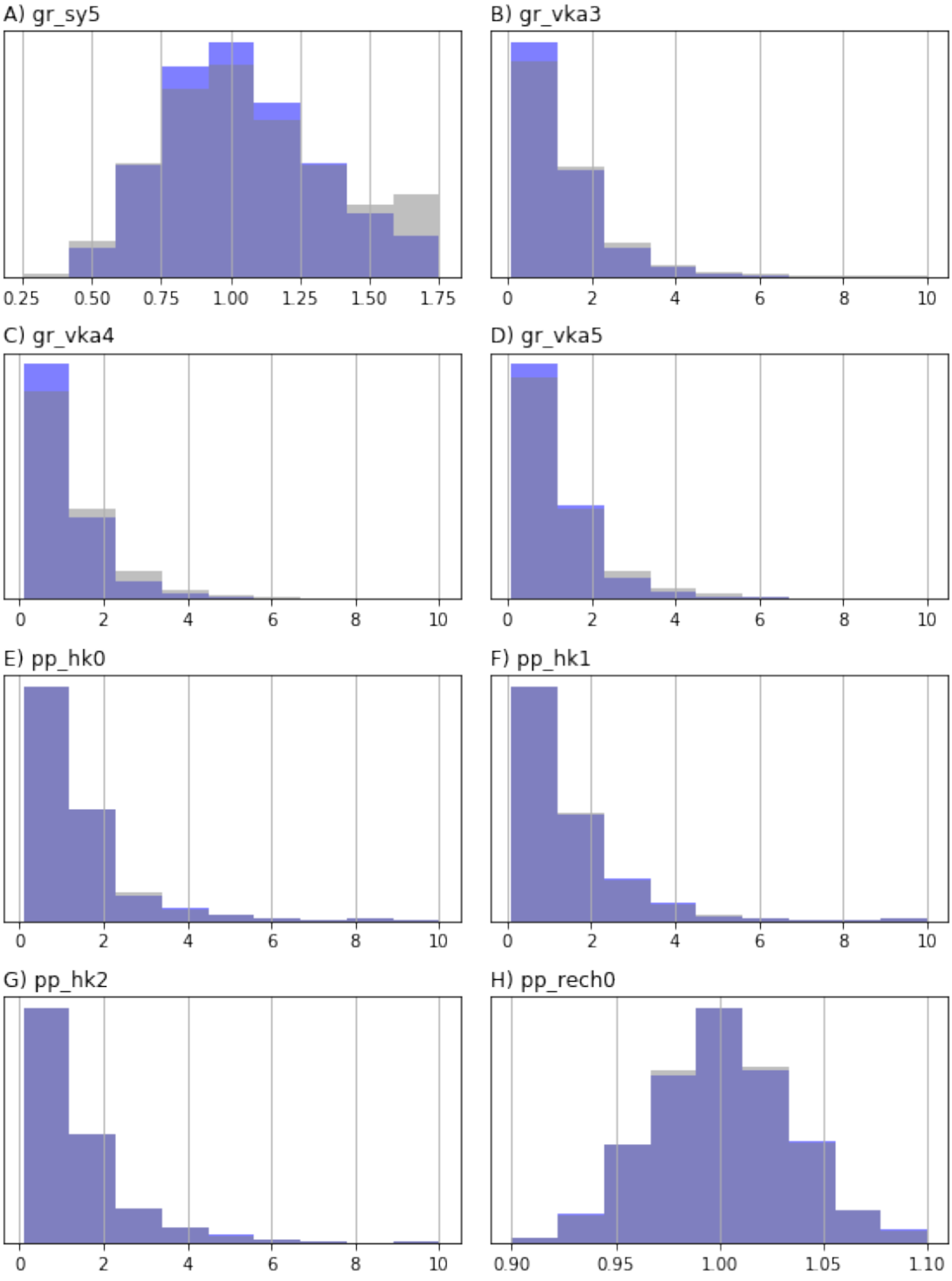
```
<Figure size 576x756 with 0 Axes>
```

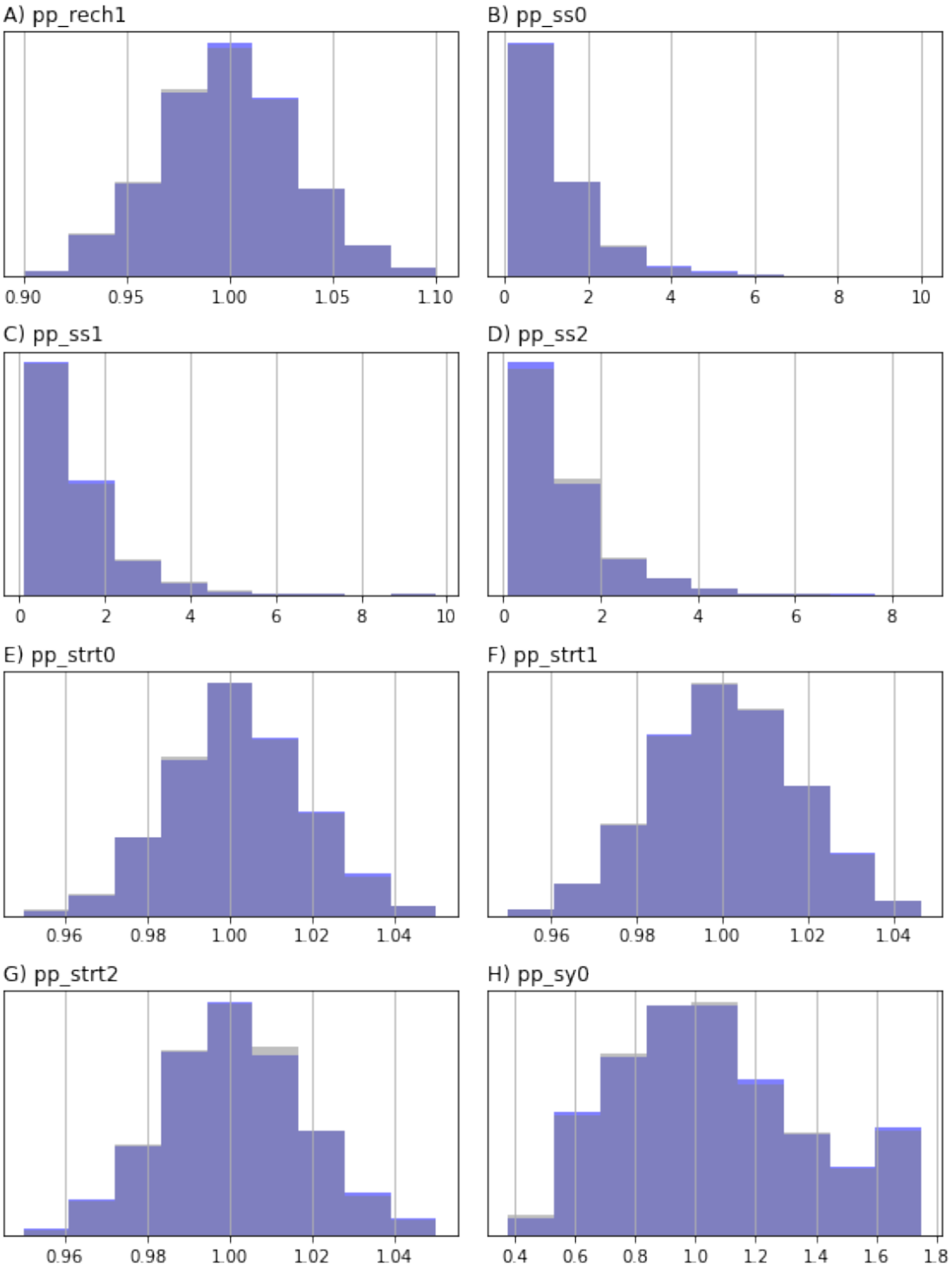

A) cn_hk6
B) cn_hk7
C) cn_hk8
D) cn_rech4
E) cn_rech5
F) cn_ss6
G) cn_ss7
H) cn_ss8

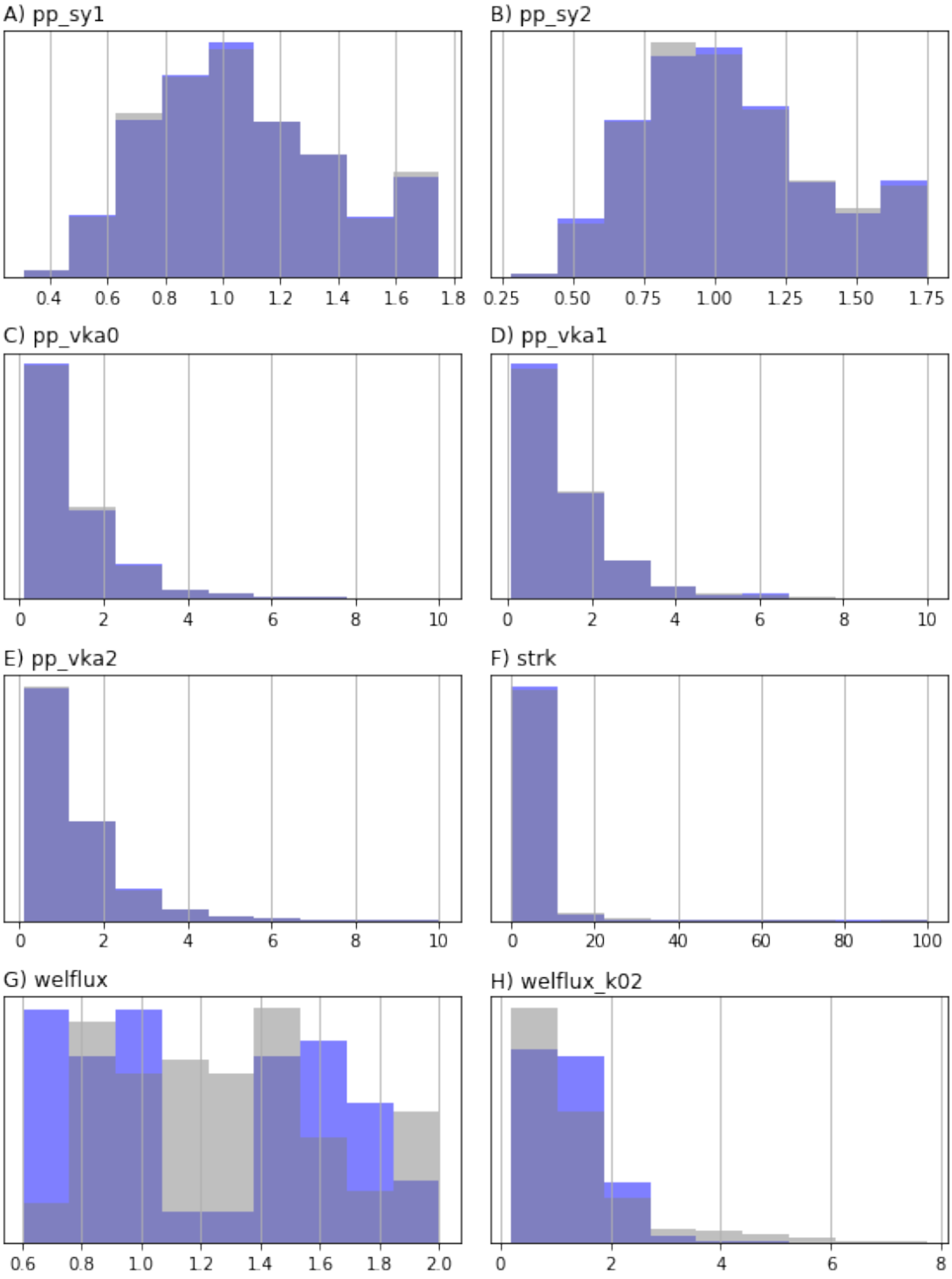

A) cn_strt6
0.95 0.96 0.97 0.98 0.99 1.00 1.01 1.02
B) cn_strt7
0.96 0.97 0.98 0.99 1.00 1.01 1.02 1.03
C) cn_strt8
0.97 0.98 0.99 1.00 1.01 1.02 1.03
D) cn_sy6
0.6 0.8 1.0 1.2 1.4 1.6
E) cn_sy7
0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8
F) cn_sy8
0.6 0.8 1.0 1.2 1.4 1.6 1.8
G) cn_vka6
0 2 4 6 8
H) cn_vka7
0 1 2 3 4 5


A) cn_vka8
0
1
2
3
4
5
B) drncond_k00
0
2
4
6
8
10
C) flow
0.9
1.0
1.1
1.2
D) gr_hk3
0
2
4
6
8
10
E) gr_hk4
0
2
4
6
8
10
F) gr_hk5
0
2
4
6
8
10
G) gr_rech2
0.90
0.95
1.00
1.05
1.10
H) gr_rech3
0.90
0.95
1.00
1.05
1.10


A) gr_ss3
0
2
4
6
8
10
B) gr_ss4
0
2
4
6
8
10
C) gr_ss5
0
2
4
6
8
10
D) gr_strt3
0.96
0.98
1.00
1.02
1.04
E) gr_strt4
0.96
0.98
1.00
1.02
1.04
F) gr_strt5
0.96
0.98
1.00
1.02
1.04
G) gr_sy3
0.25
0.50
0.75
1.00
1.25
1.50
1.75
H) gr_sy4
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8


A) gr_sy5
0.25
0.50
0.75
1.00
1.25
1.50
1.75
B) gr_vka3
0
2
4
6
8
10
C) gr_vka4
0
2
4
6
8
10
D) gr_vka5
0
2
4
6
8
10
E) pp_hk0
0
2
4
6
8
10
F) pp_hk1
0
2
4
6
8
10
G) pp_hk2
0
2
4
6
8
10
H) pp_rech0
0.90
0.95
1.00
1.05
1.10


A) pp_rech1
0.90
0.95
1.00
1.05
1.10
B) pp_ss0
0
2
4
6
8
10
C) pp_ss1
0
2
4
6
8
10
D) pp_ss2
0
2
4
6
8
E) pp_strt0
0.96
0.98
1.00
1.02
1.04
F) pp_strt1
0.96
0.98
1.00
1.02
1.04
G) pp_strt2
0.96
0.98
1.00
1.02
1.04
H) pp_sy0
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8

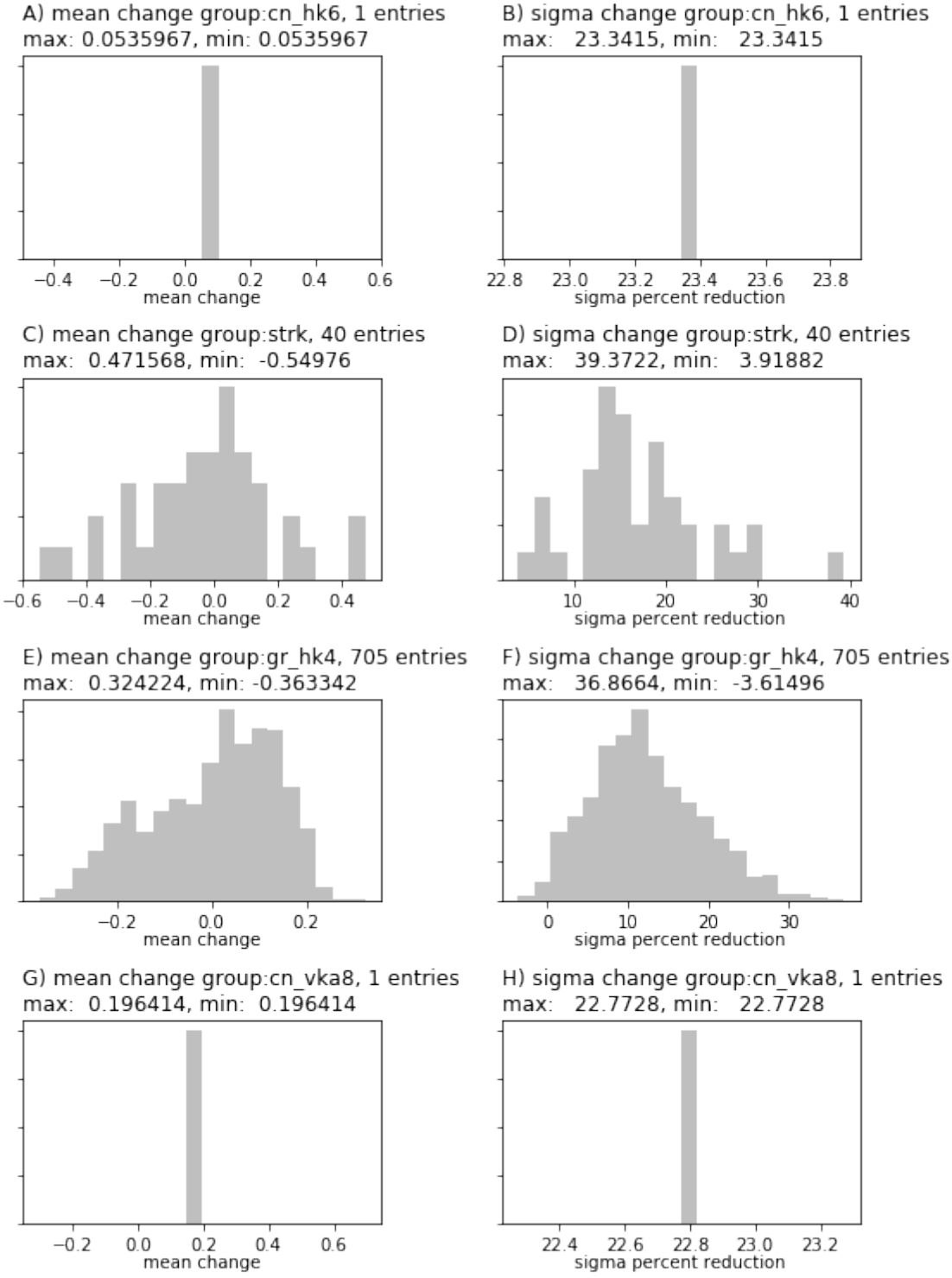



```
In [11]: pyemu.plot_utils.ensemble_change_summary(pe_pr,pe_pt,pst=pst,bins=20)
         par = pst.parameter_data
         li = par.partrans=="log"
```

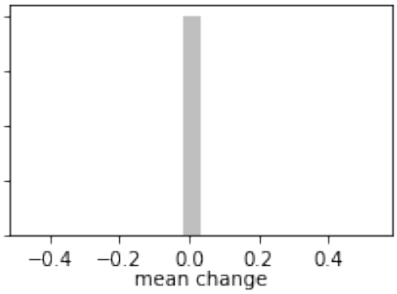
```
        pe_pr.loc[:,li] = pe_pr.loc[:,li].apply(np.log10)
        pe_pr.shape
```

```
Out[11]: (50, 12605)
```

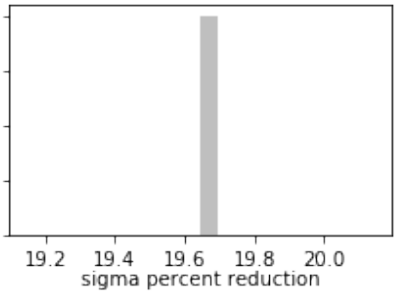
```
<Figure size 576x756 with 0 Axes>
```



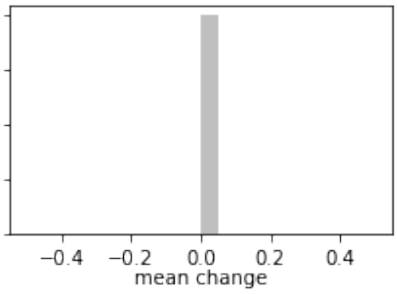
A) mean change group:cn_vka6, 1 entries
max: 0.0329439, min: 0.0329439



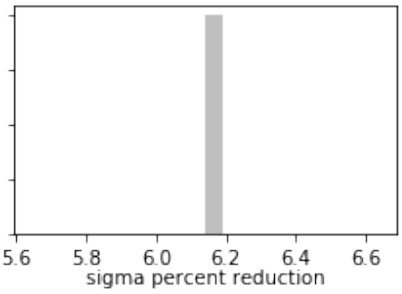
B) sigma change group:cn_vka6, 1 entries
max: 19.643, min: 19.643



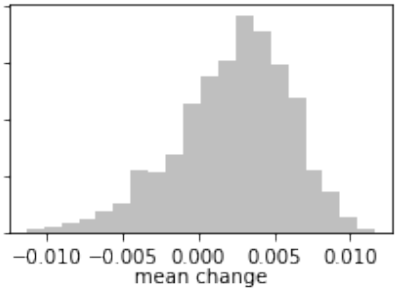
C) mean change group:cn_strt6, 1 entries
max:0.000149052, min:0.000149052



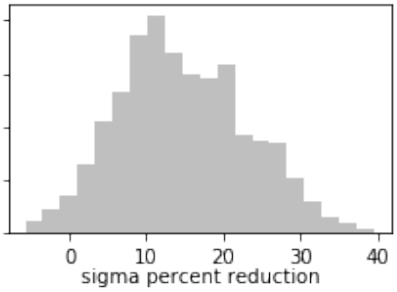
D) sigma change group:cn_strt6, 1 entries
max: 6.13959, min: 6.13959



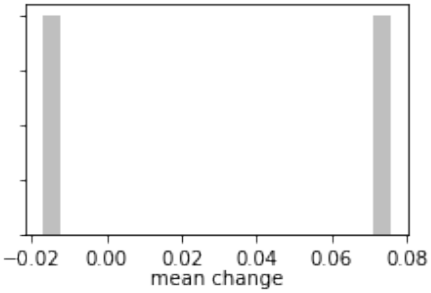
E) mean change group:gr_rech3, 705 entries
max: 0.0116333, min:-0.0113122



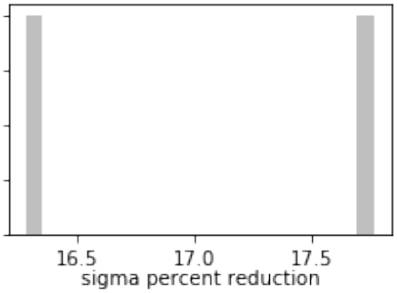
F) sigma change group:gr_rech3, 705 entries
max: 39.5754, min: -5.72218



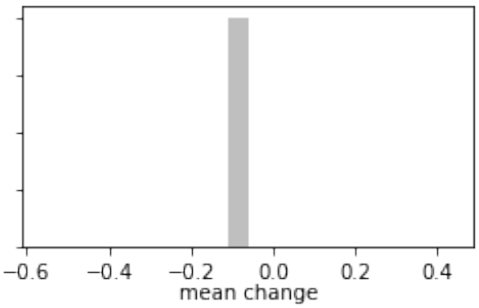
G) mean change group:welflux, 2 entries
max: 0.0758996, min:-0.0172252



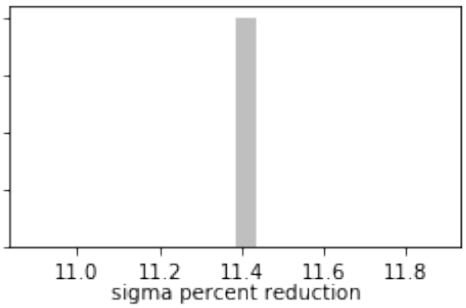
H) sigma change group:welflux, 2 entries
max: 17.7645, min: 16.2826



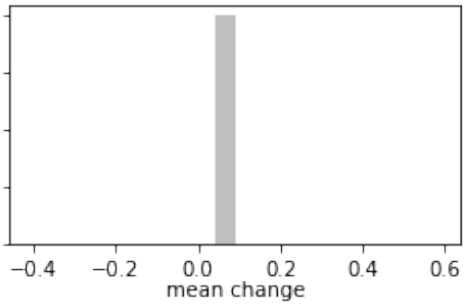
A) mean change group:cn_hk7, 1 entries
max:-0.0596944, min:-0.0596944



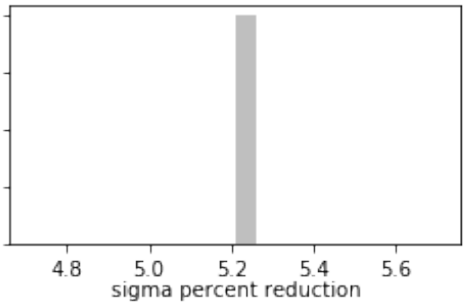
B) sigma change group:cn_hk7, 1 entries
max: 11.3856, min: 11.3856



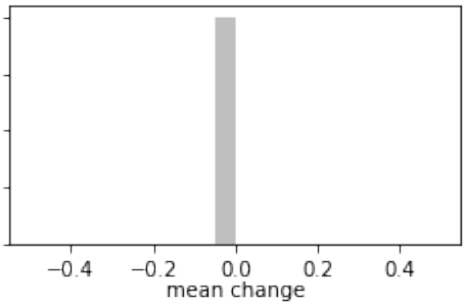
C) mean change group:cn_sy7, 1 entries
max: 0.0907642, min: 0.0907642



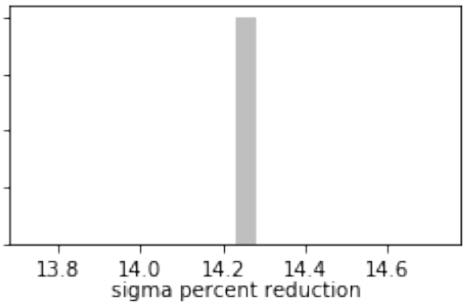
D) sigma change group:cn_sy7, 1 entries
max: 5.21094, min: 5.21094



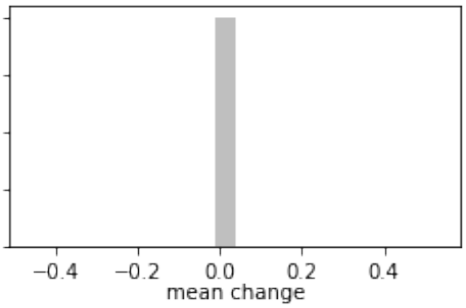
E) mean change group:cn_sy6, 1 entries
max:0.000725263, min:0.000725263



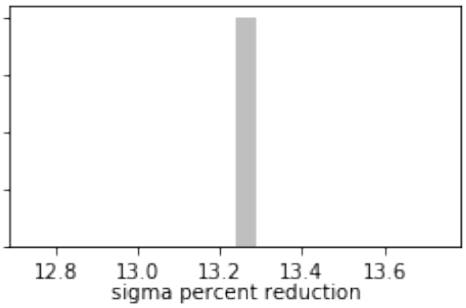
F) sigma change group:cn_sy6, 1 entries
max: 14.2313, min: 14.2313



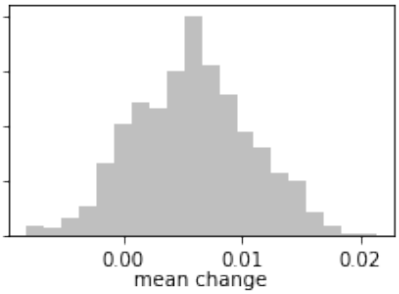
G) mean change group:cn_ss7, 1 entries
max: 0.0385976, min: 0.0385976



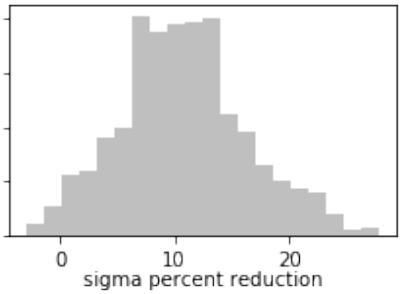
H) sigma change group:cn_ss7, 1 entries
max: 13.2389, min: 13.2389



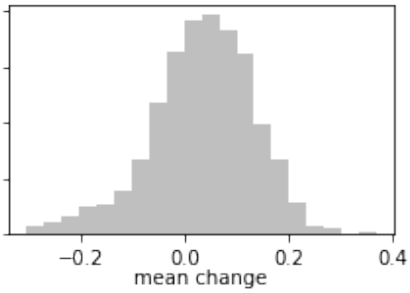
A) mean change group:gr_rech2, 705 entries
max: 0.0214063, min:-0.00821101



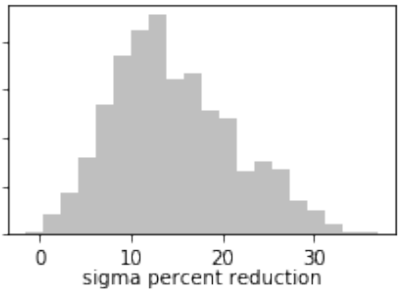
B) sigma change group:gr_rech2, 705 entries
max: 27.7582, min: -2.83578



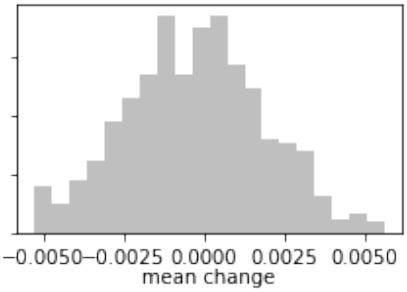
C) mean change group:gr_vka3, 705 entries
max: 0.369658, min: -0.306856



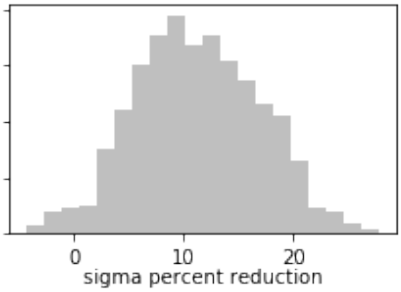
D) sigma change group:gr_vka3, 705 entries
max: 36.9392, min: -1.50828



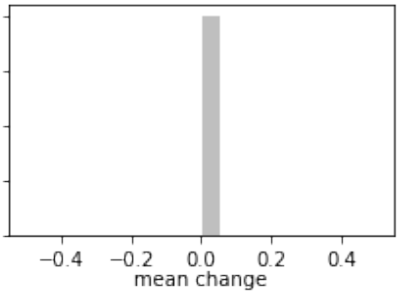
E) mean change group:gr_strt3, 705 entries
max:0.00564556, min:-0.00528867



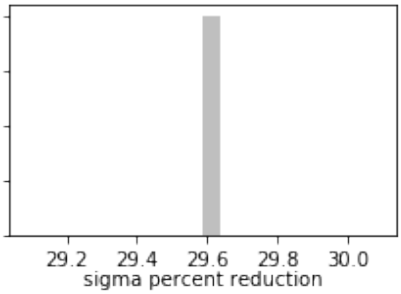
F) sigma change group:gr_strt3, 705 entries
max: 27.7136, min: -4.22393



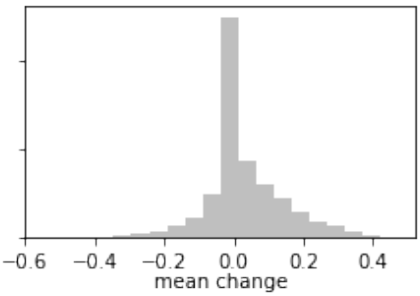
G) mean change group:cn_rech4, 1 entries
max:0.00105349, min:0.00105349



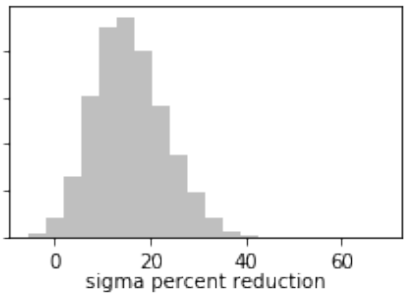
H) sigma change group:cn_rech4, 1 entries
max: 29.5873, min: 29.5873



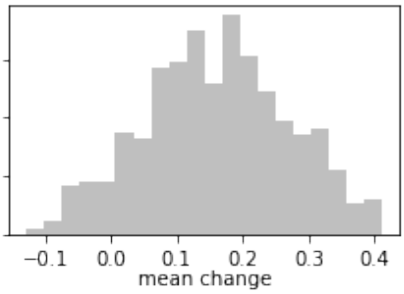
A) mean change group:all, 12061 entries
max: 0.471568, min: -0.54976



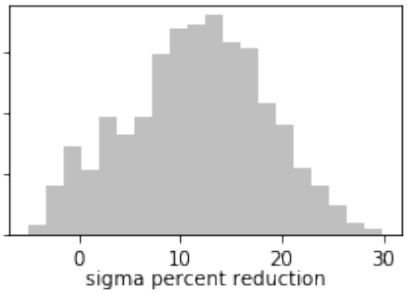
B) sigma change group:all, 12061 entries
max: 68.6195, min: -5.72218



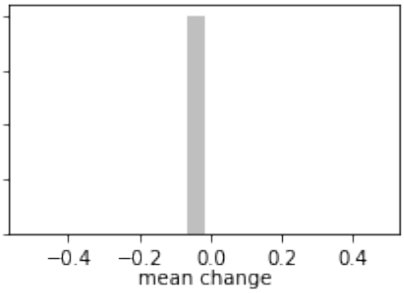
C) mean change group:gr_ss5, 705 entries
max: 0.411245, min: -0.127912



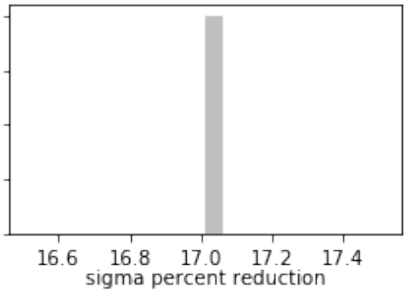
D) sigma change group:gr_ss5, 705 entries
max: 29.9607, min: -5.07292



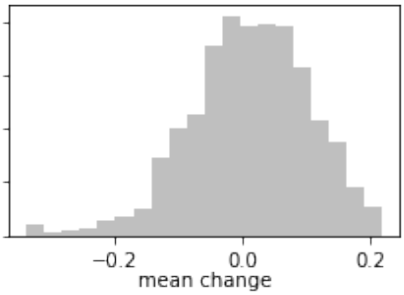
E) mean change group:cn_sy8, 1 entries
max:-0.0174705, min:-0.0174705



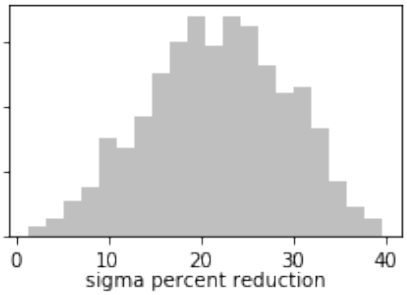
F) sigma change group:cn_sy8, 1 entries
max: 17.0121, min: 17.0121



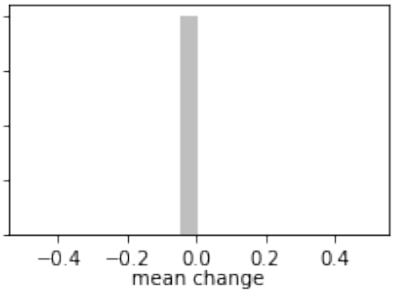
G) mean change group:gr_vka5, 705 entries
max: 0.217356, min: -0.336701



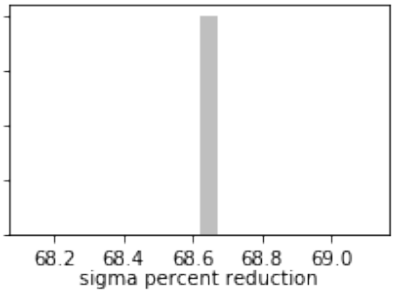
H) sigma change group:gr_vka5, 705 entries
max: 39.7558, min: 1.26606



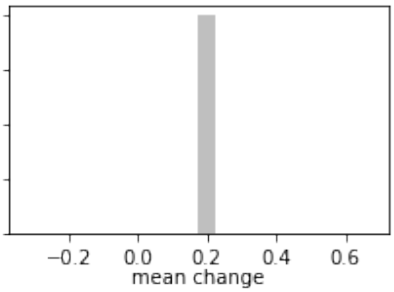
A) mean change group:flow, 1 entries
max:0.00446975, min:0.00446975



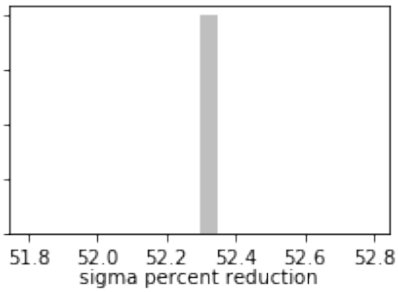
B) sigma change group:flow, 1 entries
max: 68.6195, min: 68.6195



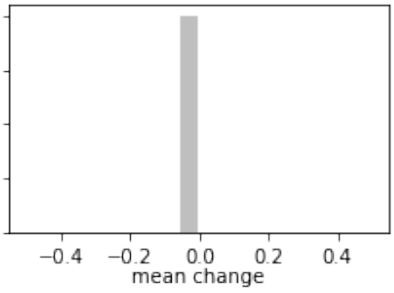
C) mean change group:cn_hk8, 1 entries
max: 0.174294, min: 0.174294



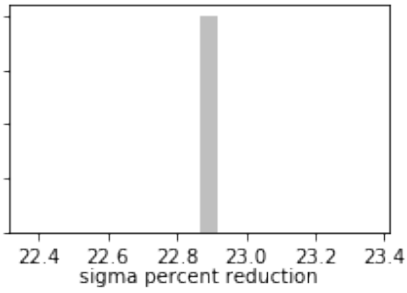
D) sigma change group:cn_hk8, 1 entries
max: 52.2953, min: 52.2953



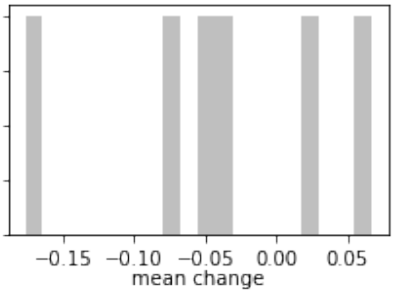
E) mean change group:cn_ss8, 1 entries
max:-0.00408272, min:-0.00408272



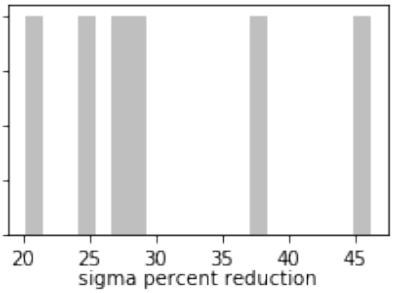
F) sigma change group:cn_ss8, 1 entries
max: 22.8652, min: 22.8652



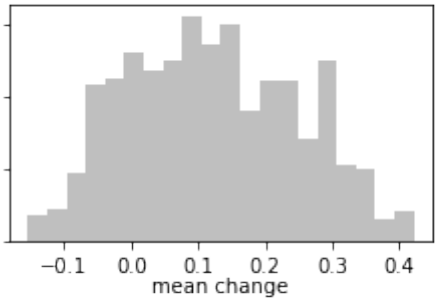
G) mean change group:welflux_k02, 6 entries
max: 0.0663363, min: -0.17623



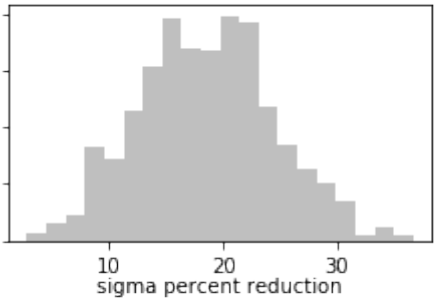
H) sigma change group:welflux_k02, 6 entries
max: 46.2345, min: 20.1801



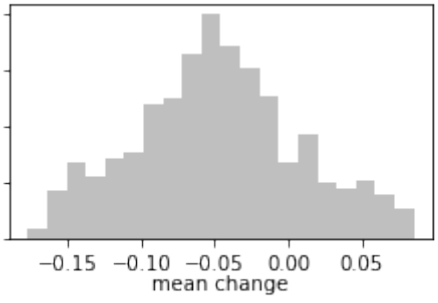
A) mean change group:gr_ss3, 705 entries
max: 0.422241, min: -0.154452



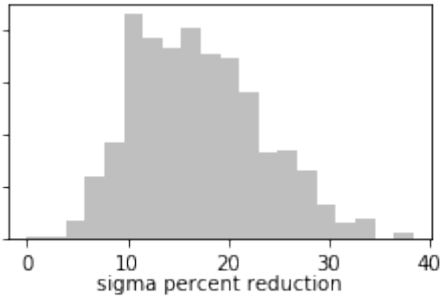
B) sigma change group:gr_ss3, 705 entries
max: 36.6727, min: 2.76372



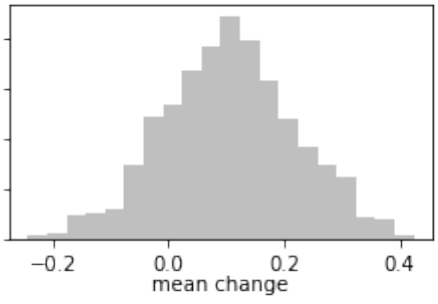
C) mean change group:gr_sy4, 705 entries
max: 0.085491, min: -0.176988



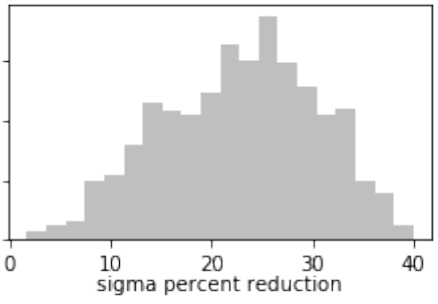
D) sigma change group:gr_sy4, 705 entries
max: 38.3749, min:0.00263762



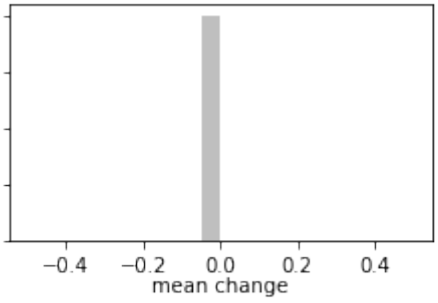
E) mean change group:gr_hk5, 705 entries
max: 0.424512, min: -0.243609



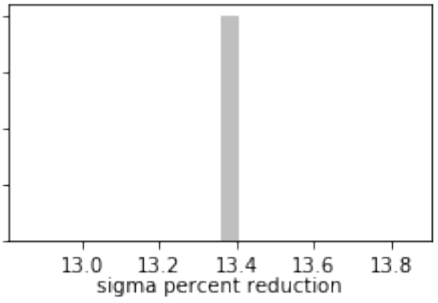
F) sigma change group:gr_hk5, 705 entries
max: 39.9214, min: 1.75323



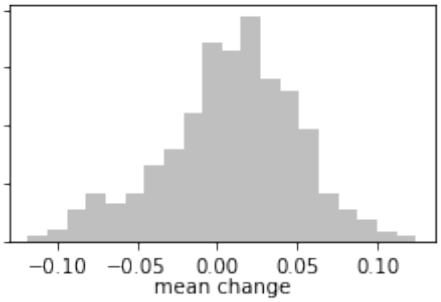
G) mean change group:cn_strt8, 1 entries
max:0.000837971, min:0.000837971



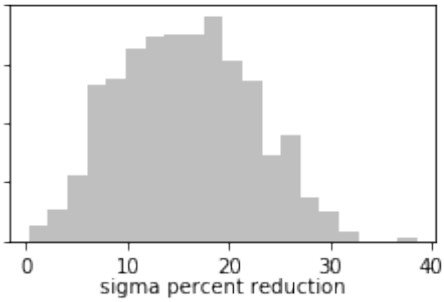
H) sigma change group:cn_strt8, 1 entries
max: 13.3581, min: 13.3581



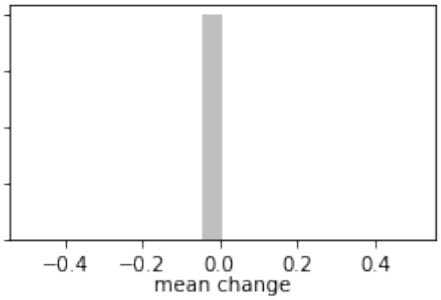
A) mean change group:gr_sy5, 705 entries
max: 0.124226, min: -0.118093



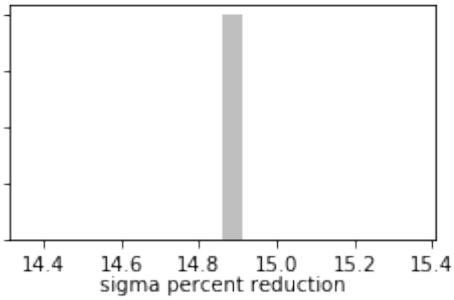
B) sigma change group:gr_sy5, 705 entries
max: 38.5472, min: 0.278489



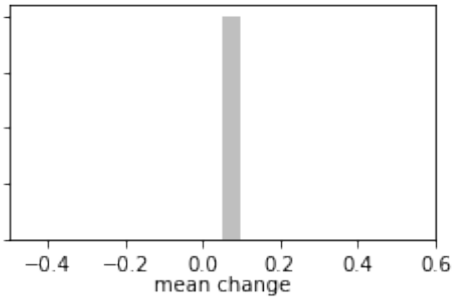
C) mean change group:cn_strt7, 1 entries
max:0.00577033, min:0.00577033



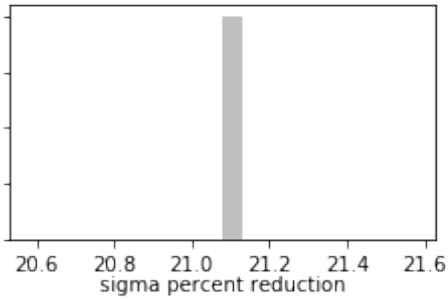
D) sigma change group:cn_strt7, 1 entries
max: 14.8615, min: 14.8615



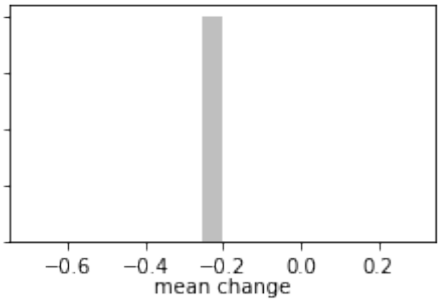
E) mean change group:cn_rech5, 1 entries
max: 0.0498836, min: 0.0498836



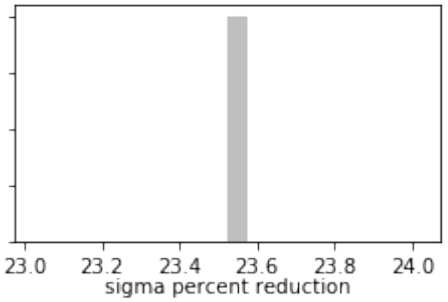
F) sigma change group:cn_rech5, 1 entries
max: 21.0799, min: 21.0799



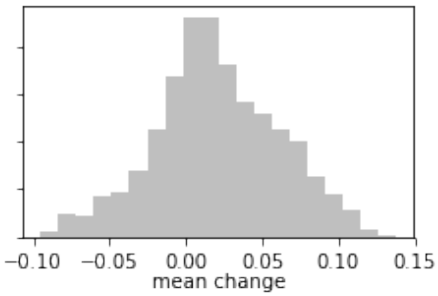
G) mean change group:cn_vka7, 1 entries
max: -0.202767, min: -0.202767



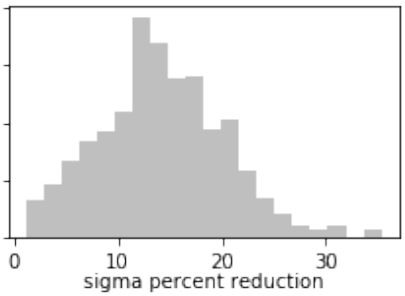
H) sigma change group:cn_vka7, 1 entries
max: 23.525, min: 23.525



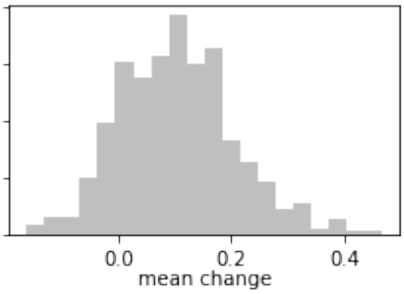
A) mean change group:gr_sy3, 705 entries
max: 0.13773, min:-0.0954256



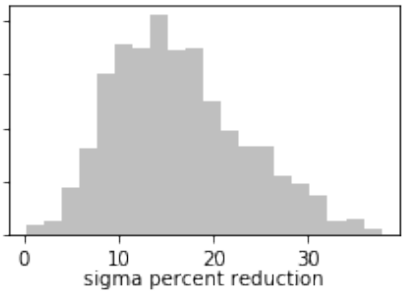
B) sigma change group:gr_sy3, 705 entries
max: 35.3306, min: 1.10531



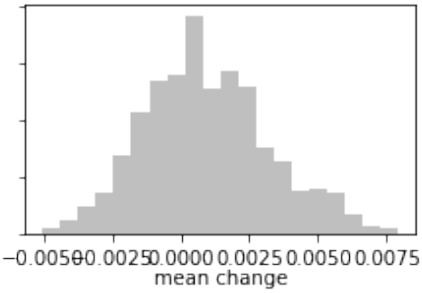
C) mean change group:gr_ss4, 705 entries
max: 0.466516, min: -0.161659



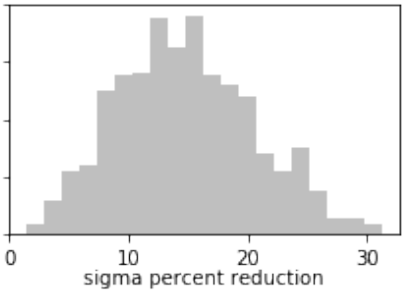
D) sigma change group:gr_ss4, 705 entries
max: 37.7474, min: 0.124608



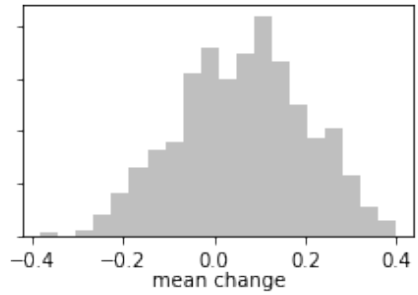
E) mean change group:gr_strt4, 705 entries
max:0.00792188, min:-0.00503652



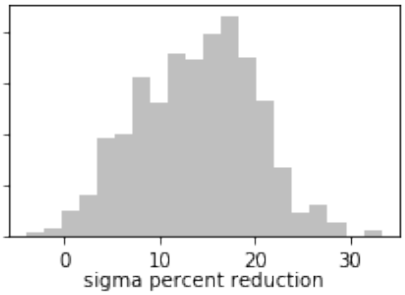
F) sigma change group:gr_strt4, 705 entries
max: 31.1919, min: 1.37948

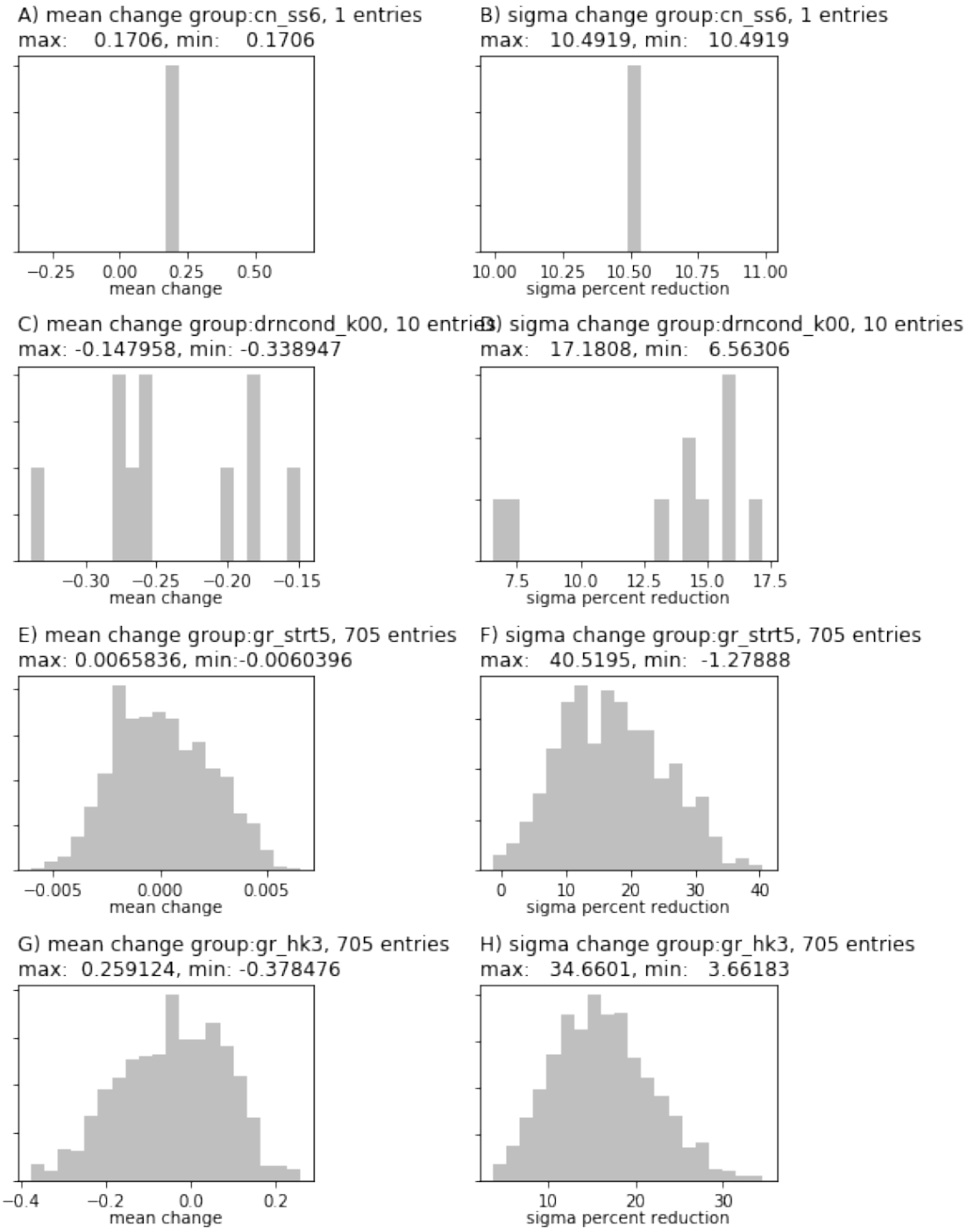


G) mean change group:gr_vka4, 705 entries
max: 0.398956, min: -0.381361



H) sigma change group:gr_vka4, 705 entries
max: 33.2833, min: -4.08826





Those are some pretty extreme variance reductions, considering we are conditioning 10K+ pars on 13 water levels and one flux. This is a well-known issue with low-rank ensemble method ("ensemble collapse"). This is over come with localization. . . .

1.0.2 PESTPP-IES with simple temporal localization

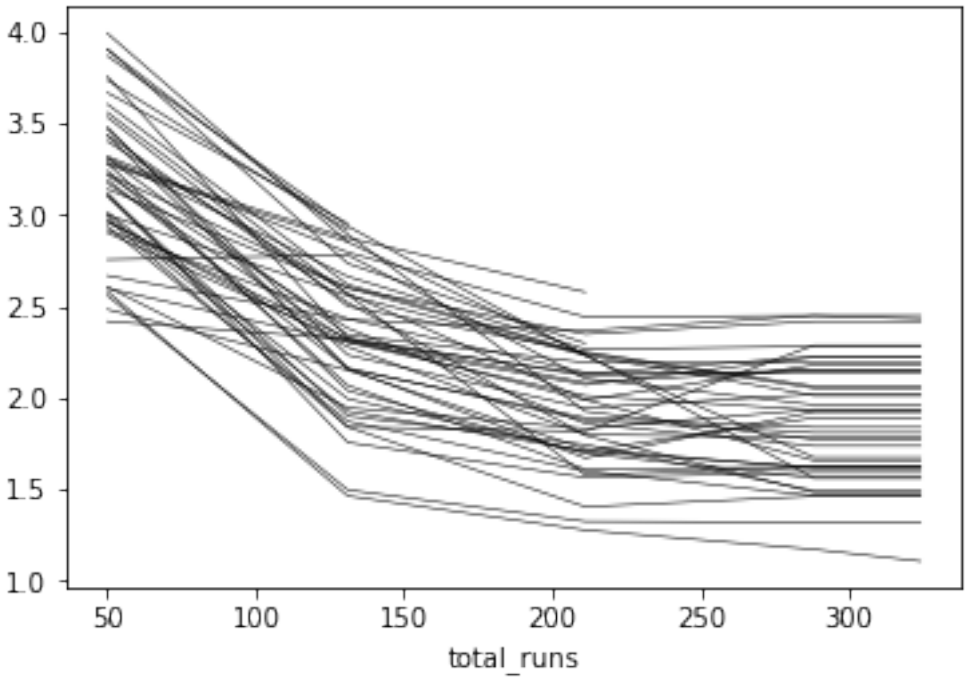
Now let's add some localization. The obvious stuff is temporal - scenario parameters can't influence historic observations (and the inverse is true) so let's tell PESTPP-IES about this:

In [12]:
```
par = pst.parameter_data
#parameter groups for future recharge
scen_groups = ["grrech3","pp_rech1","rech5_cn"]
scen_groups = [g for g in scen_groups if g in pst.adj_par_groups]
scen_pars = par.loc[par.pargp.apply(lambda x: x in scen_groups),"parnme"].tolist()
scen_pars.append("welflux_001")
```

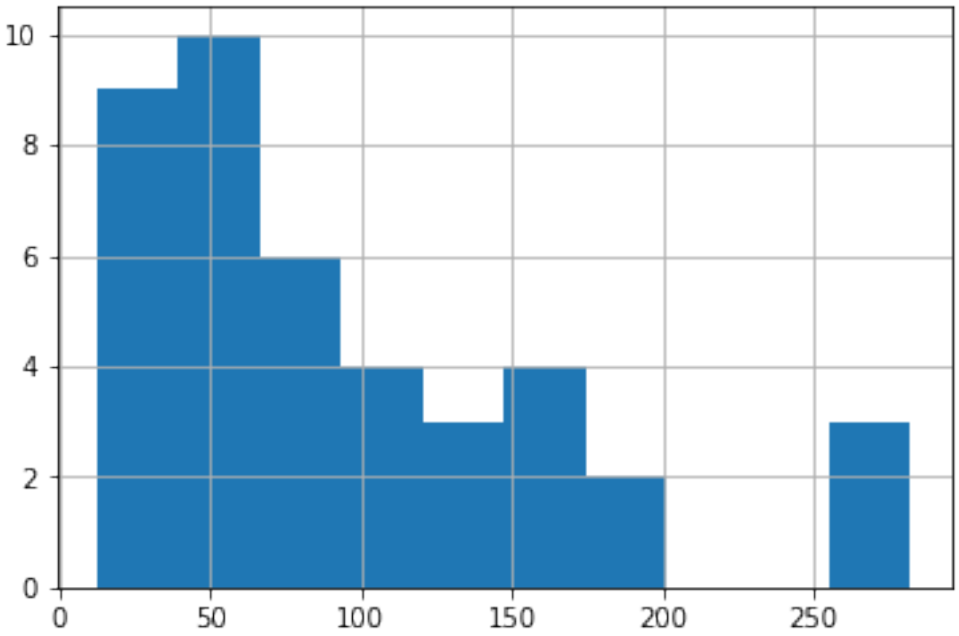
In [13]:
```
loc = pyemu.Matrix.from_names(pst.nnz_obs_names,pst.adj_par_groups).to_dataframe()
loc.loc[:,:]= 1.0
loc.loc[:,scen_groups] = 0.0
pyemu.Matrix.from_dataframe(loc).to_ascii(os.path.join(t_d,"loc.mat"))
```

In [14]:
```
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=20,master_
```

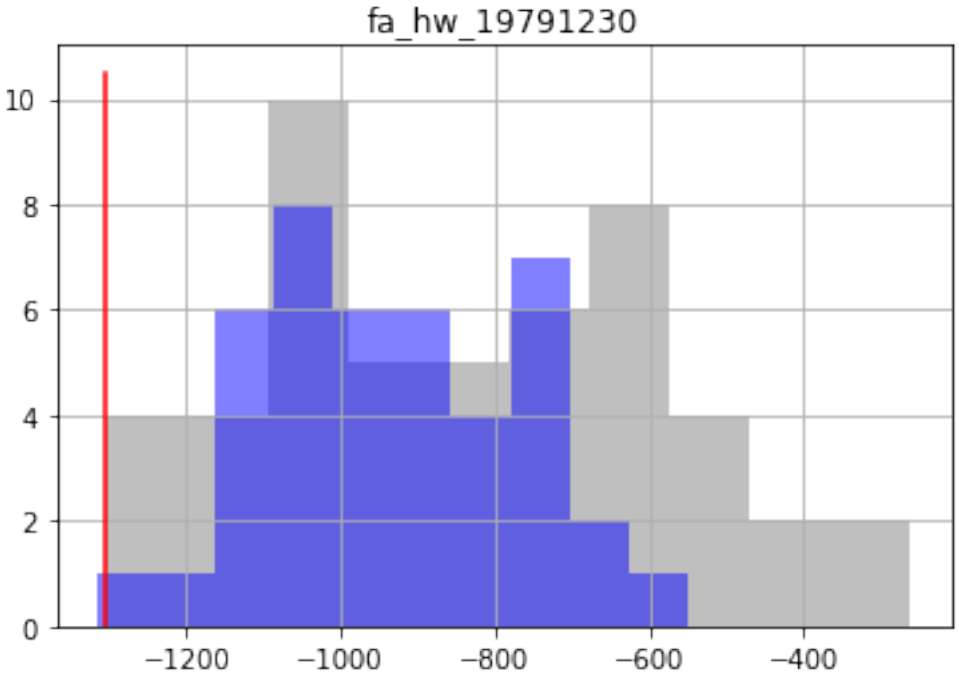
In [15]:
```
phi = pd.read_csv(os.path.join(m_d,"freyberg_ies.phi.actual.csv"),index_col=0)
phi.index = phi.total_runs
phi.iloc[:,6:].apply(np.log10).plot(legend=False,lw=0.5,color='k')
plt.show()
phi.iloc[-1,6:].hist()
```

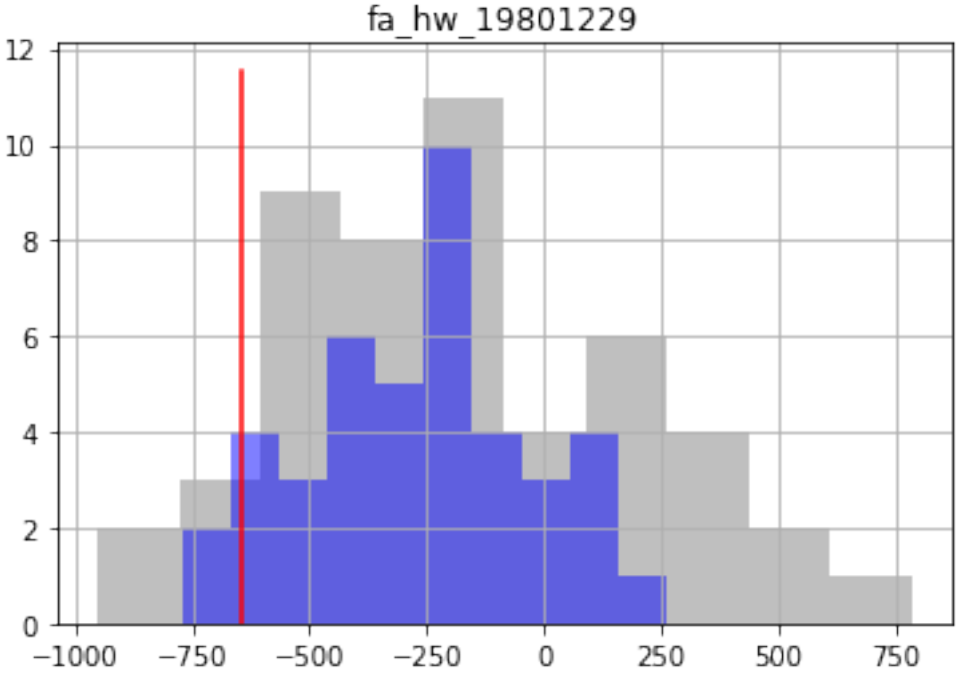


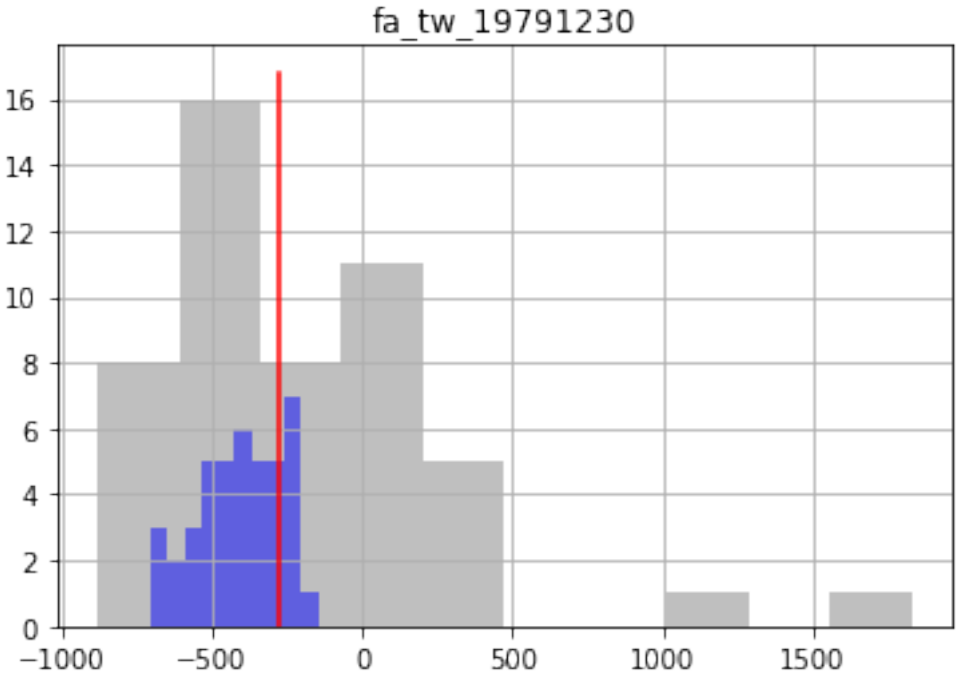
Out[15]: <matplotlib.axes._subplots.AxesSubplot at 0x181d5ad3c8>

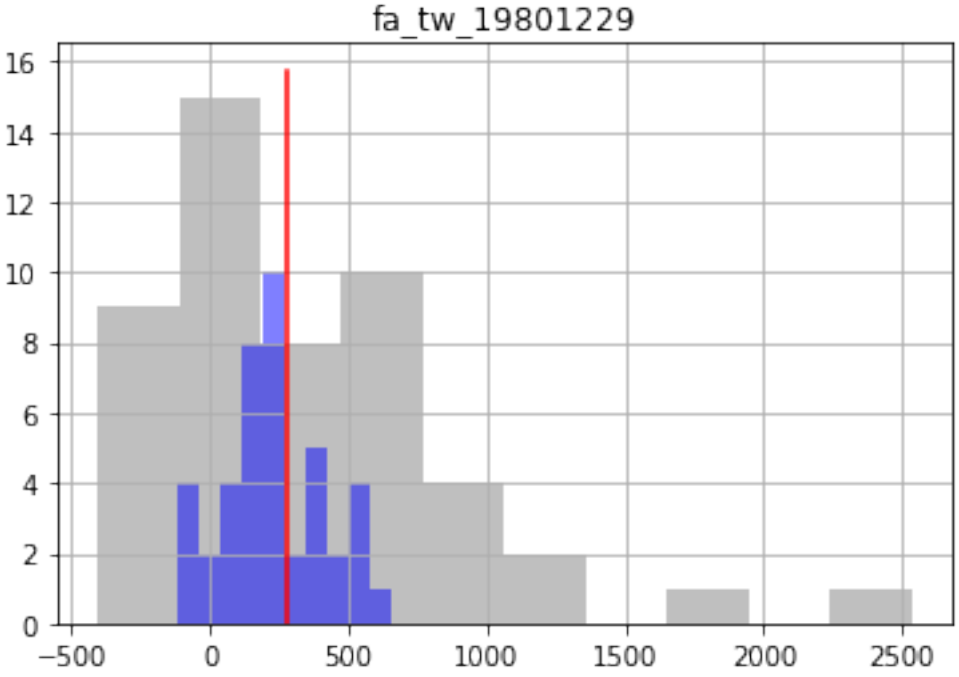


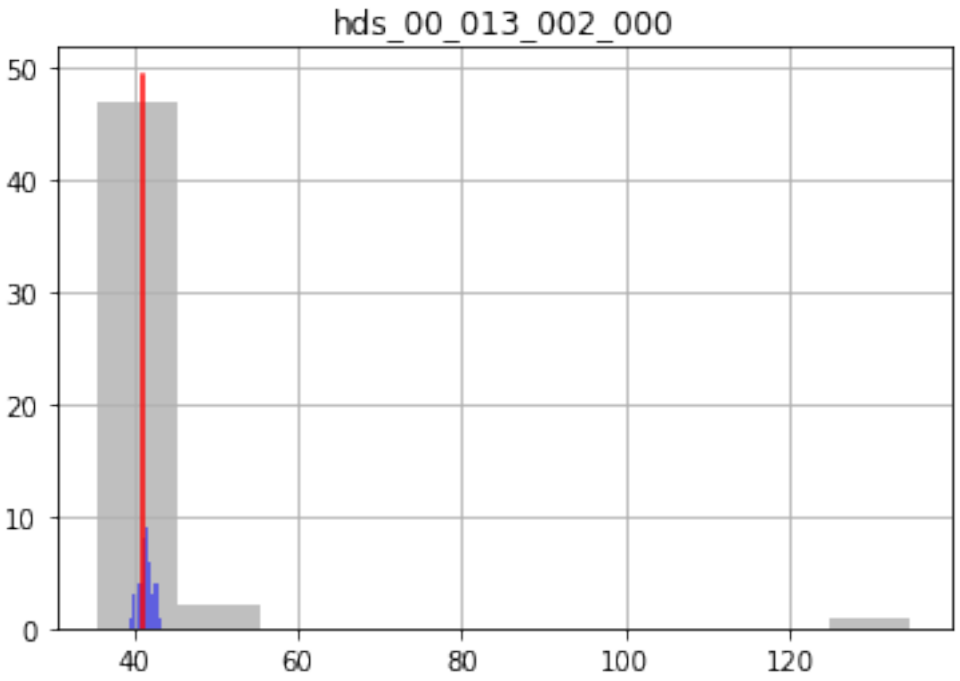
In [16]:
```
oe_pr = pd.read_csv(os.path.join(m_d,"freyberg_ies.0.obs.csv"),index_col=0)
oe_pt = pd.read_csv(os.path.join(m_d,"freyberg_ies.{0}.obs.csv".format(pst.control_dat
obs = pst.observation_data
fnames = pst.pestpp_options["forecasts"].split(",")
for forecast in fnames:
    ax = plt.subplot(111)
    oe_pr.loc[:,forecast].hist(ax=ax,color="0.5",alpha=0.5)
    oe_pt.loc[:,forecast].hist(ax=ax,color="b",alpha=0.5)
    ax.plot([obs.loc[forecast,"obsval"],obs.loc[forecast,"obsval"]],ax.get_ylim(),"r"
    ax.set_title(forecast)
    plt.show()
```

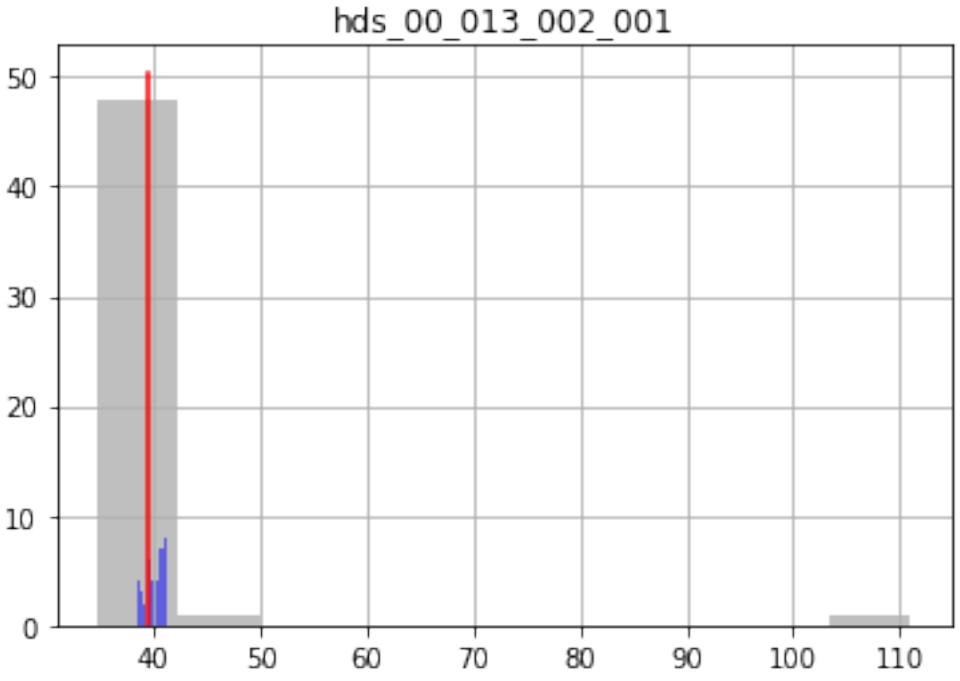

fa_hw_19791230
10
8
6
4
2
0
−1200
−1000
−800
−600
−400


fa_hw_19801229
12
10
8
6
4
2
0
−1000
−750
−500
−250
0
250
500
750


fa_tw_19791230
16
14
12
10
8
6
4
2
0
−1000
−500
0
500
1000
1500


fa_tw_19801229
16
14
12
10
8
6
4
2
0
−500
0
500
1000
1500
2000
2500



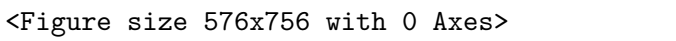


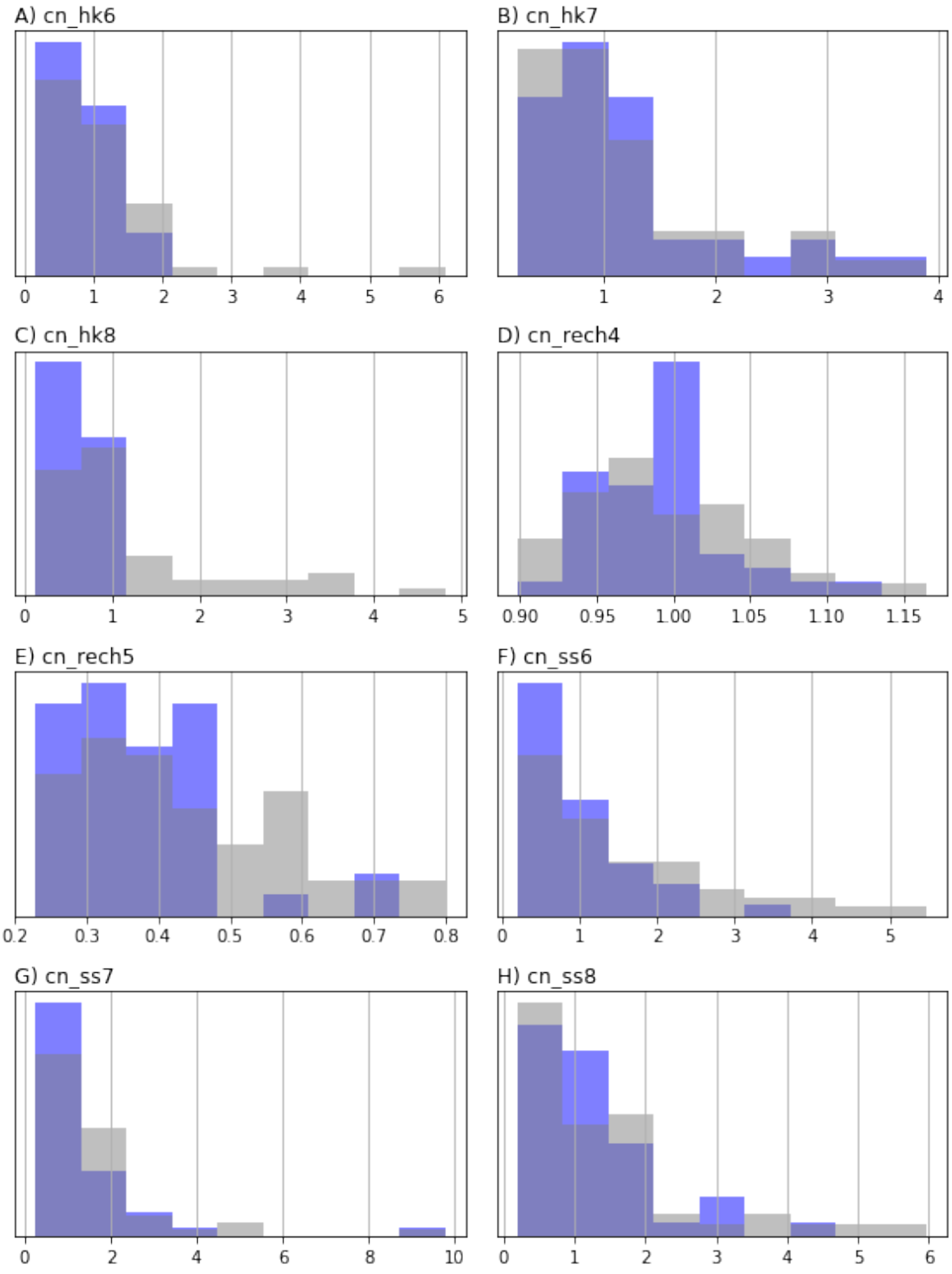

```
In [17]: pe_pr = pd.read_csv(os.path.join(m_d,"freyberg_ies.0.par.csv"),index_col=0)
         pe_pt = pd.read_csv(os.path.join(m_d,"freyberg_ies.{0}.par.csv".format(pst.control_da
```

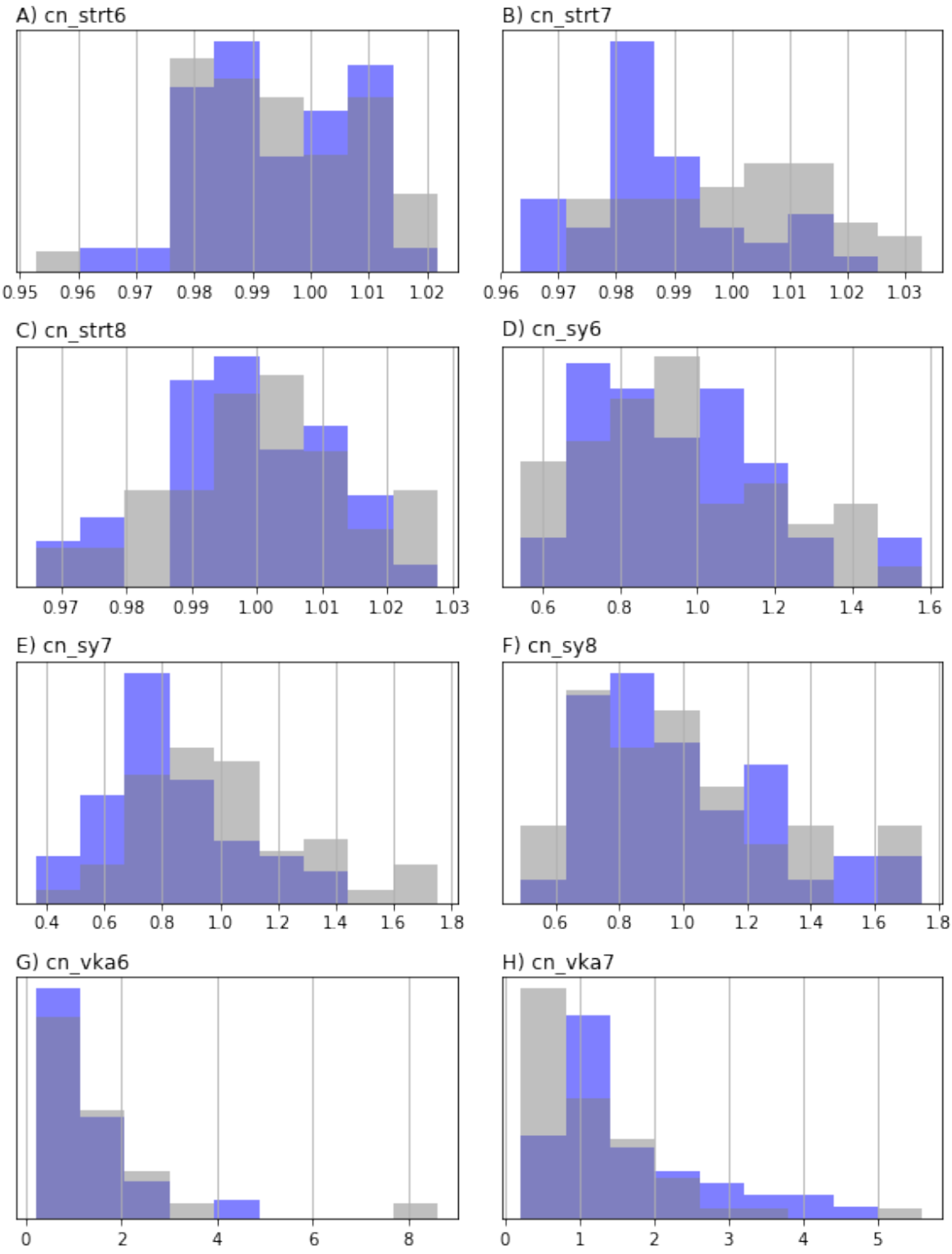
```
        #pe_pr.index = pe_pt.index
        #par = pst.parameter_data
        print(pe_pr.shape,pe_pt.shape)
        pdict = par.groupby("pargp").groups
        pyemu.plot_utils.ensemble_helper({"0.5":pe_pr,"b":pe_pt},plot_cols=pdict)
        pyemu.plot_utils.ensemble_change_summary(pe_pr,pe_pt,pst=pst,bins=20)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

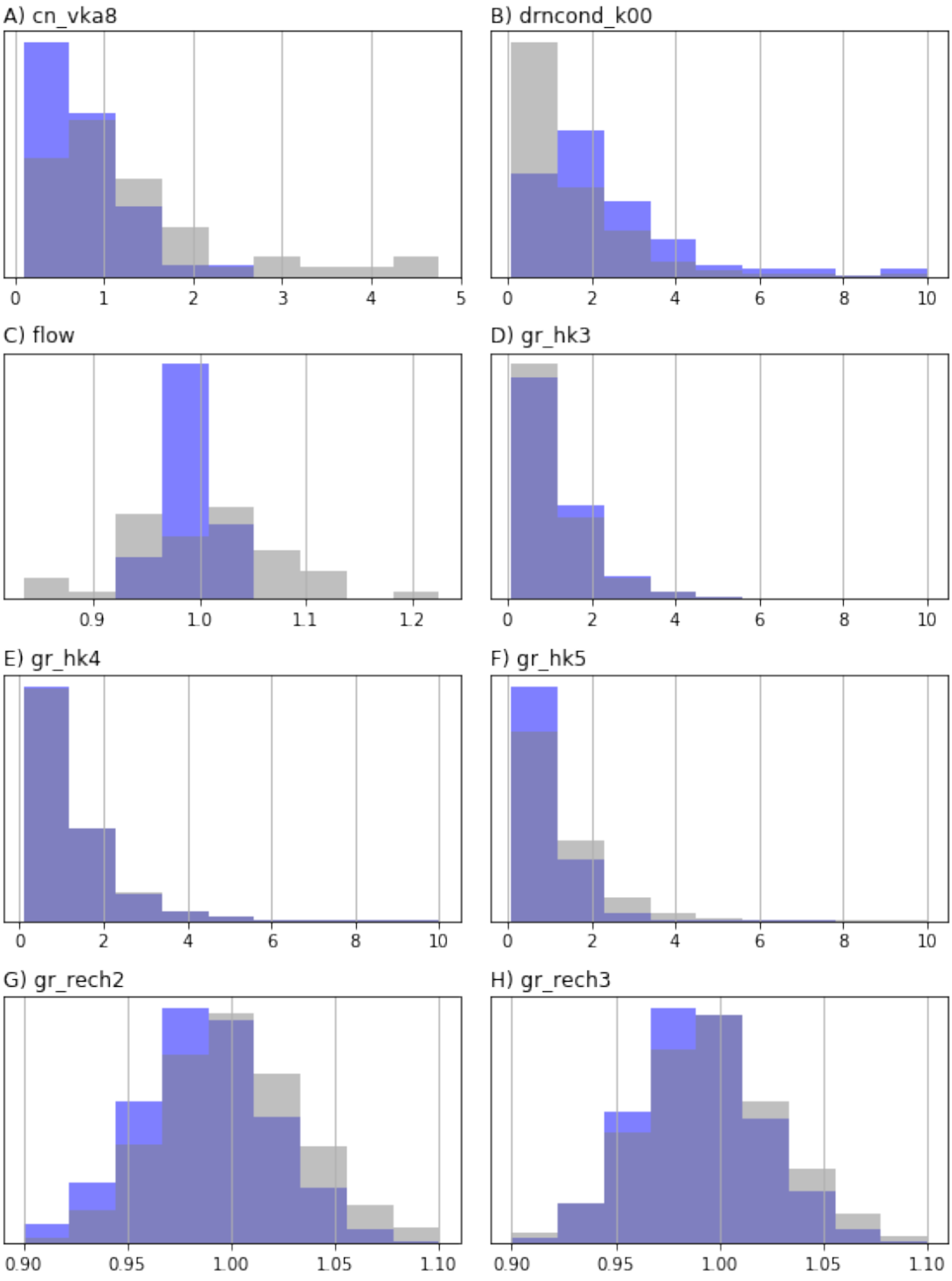
```
(50, 12605) (42, 12605)
```

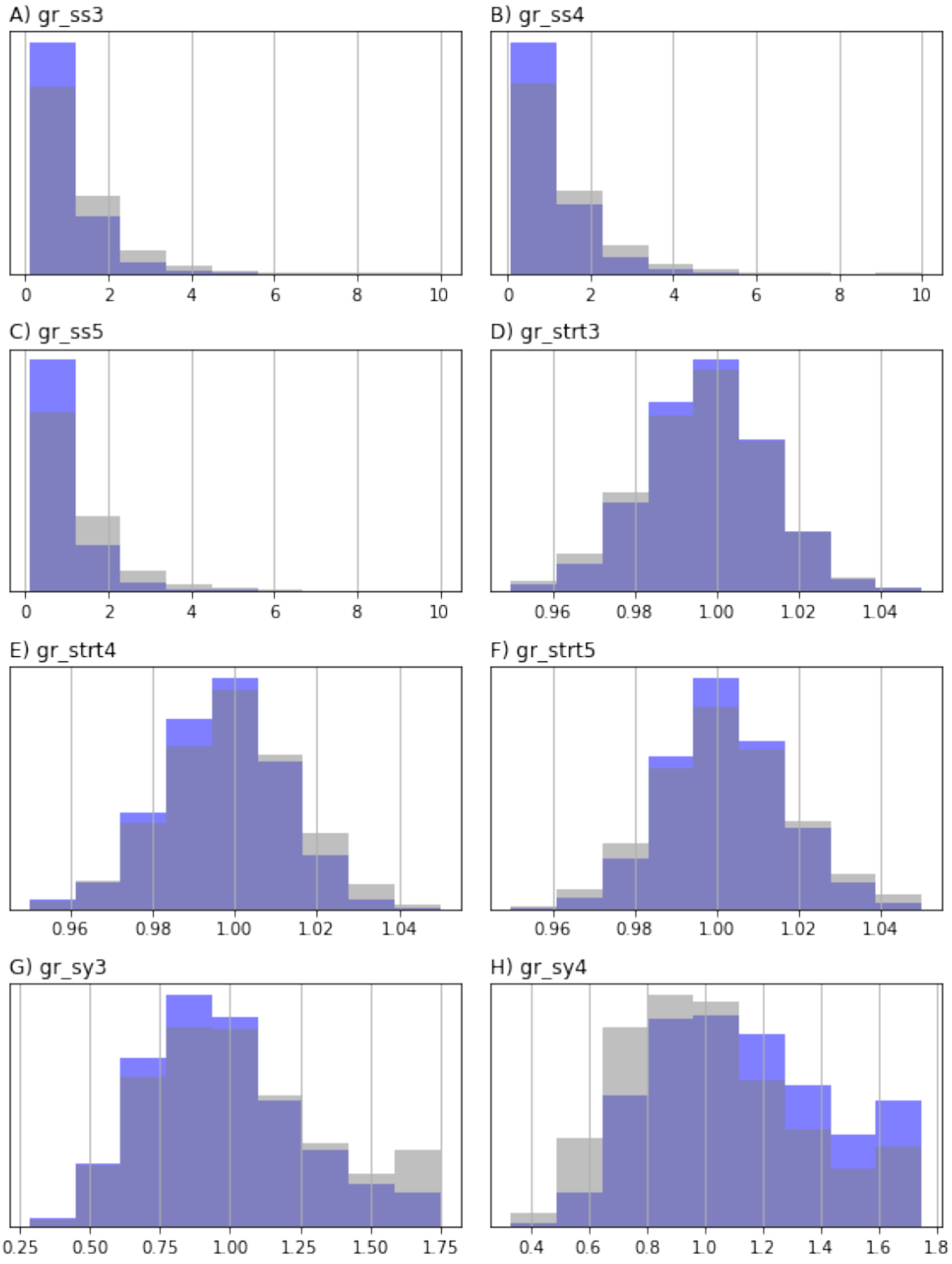
```
Out[17]: [<Figure size 576x756 with 0 Axes>,
          <Figure size 576x756 with 8 Axes>,
          <Figure size 576x756 with 8 Axes>,
          <Figure size 576x756 with 8 Axes>,
          <Figure size 576x756 with 8 Axes>,
          <Figure size 576x756 with 8 Axes>,
          <Figure size 576x756 with 8 Axes>,
          <Figure size 576x756 with 8 Axes>,
          <Figure size 576x756 with 8 Axes>,
          <Figure size 576x756 with 8 Axes>,
          <Figure size 576x756 with 8 Axes>]
```

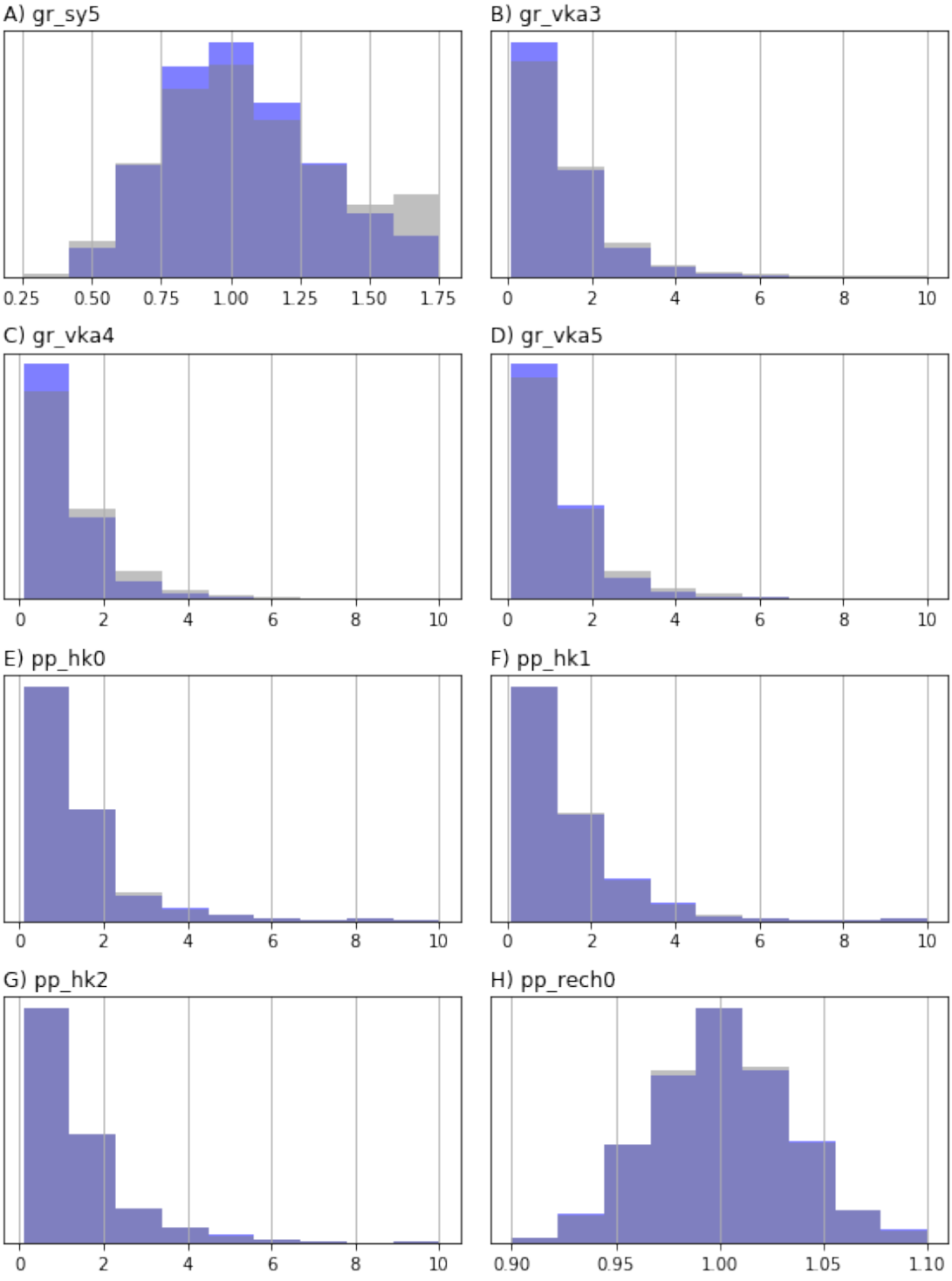


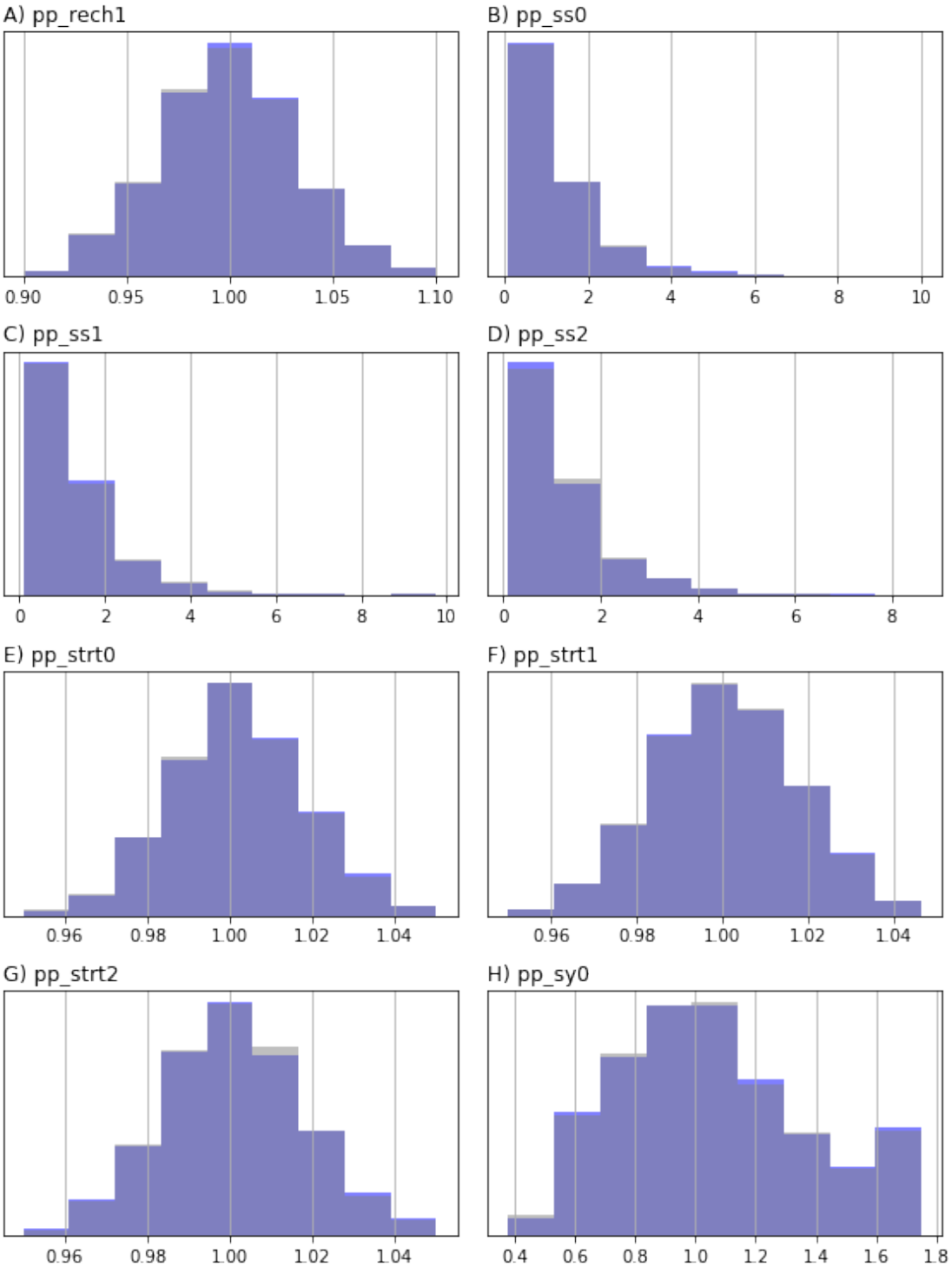

A) cn_hk6
B) cn_hk7
C) cn_hk8
D) cn_rech4
E) cn_rech5
F) cn_ss6
G) cn_ss7
H) cn_ss8

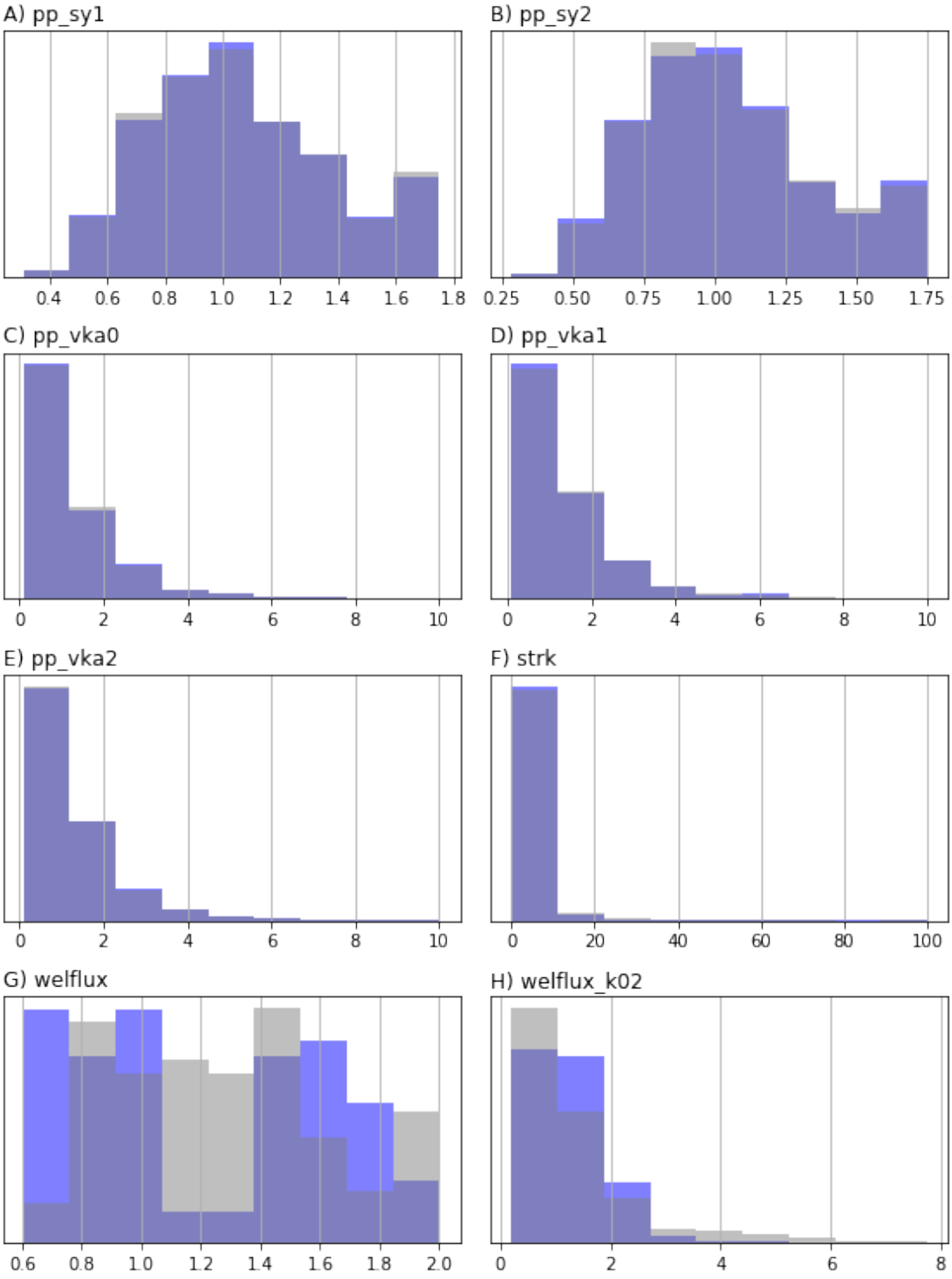

A) cn_strt6
0.95 0.96 0.97 0.98 0.99 1.00 1.01 1.02
B) cn_strt7
0.96 0.97 0.98 0.99 1.00 1.01 1.02 1.03
C) cn_strt8
0.97 0.98 0.99 1.00 1.01 1.02 1.03
D) cn_sy6
0.6 0.8 1.0 1.2 1.4 1.6
E) cn_sy7
0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8
F) cn_sy8
0.6 0.8 1.0 1.2 1.4 1.6 1.8
G) cn_vka6
0 2 4 6 8
H) cn_vka7
0 1 2 3 4 5


A) cn_vka8
0
1
2
3
4
5
B) drncond_k00
0
2
4
6
8
10
C) flow
0.9
1.0
1.1
1.2
D) gr_hk3
0
2
4
6
8
10
E) gr_hk4
0
2
4
6
8
10
F) gr_hk5
0
2
4
6
8
10
G) gr_rech2
0.90
0.95
1.00
1.05
1.10
H) gr_rech3
0.90
0.95
1.00
1.05
1.10


A) gr_ss3
0
2
4
6
8
10
B) gr_ss4
0
2
4
6
8
10
C) gr_ss5
0
2
4
6
8
10
D) gr_strt3
0.96
0.98
1.00
1.02
1.04
E) gr_strt4
0.96
0.98
1.00
1.02
1.04
F) gr_strt5
0.96
0.98
1.00
1.02
1.04
G) gr_sy3
0.25
0.50
0.75
1.00
1.25
1.50
1.75
H) gr_sy4
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8

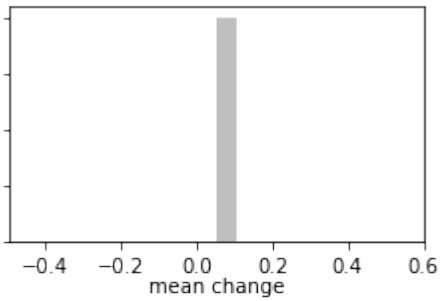

A) gr_sy5
0.25
0.50
0.75
1.00
1.25
1.50
1.75
B) gr_vka3
0
2
4
6
8
10
C) gr_vka4
0
2
4
6
8
10
D) gr_vka5
0
2
4
6
8
10
E) pp_hk0
0
2
4
6
8
10
F) pp_hk1
0
2
4
6
8
10
G) pp_hk2
0
2
4
6
8
10
H) pp_rech0
0.90
0.95
1.00
1.05
1.10


A) pp_rech1
0.90
0.95
1.00
1.05
1.10
B) pp_ss0
0
2
4
6
8
10
C) pp_ss1
0
2
4
6
8
10
D) pp_ss2
0
2
4
6
8
E) pp_strt0
0.96
0.98
1.00
1.02
1.04
F) pp_strt1
0.96
0.98
1.00
1.02
1.04
G) pp_strt2
0.96
0.98
1.00
1.02
1.04
H) pp_sy0
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8

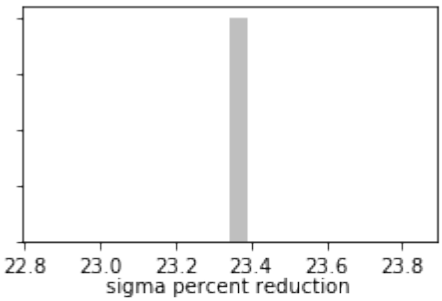


<Figure size 576x756 with 0 Axes>

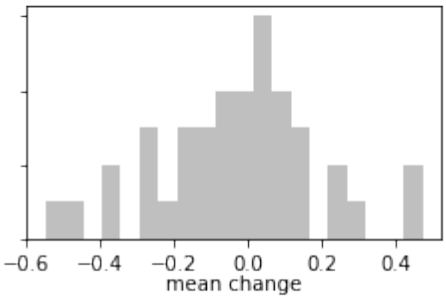
A) mean change group:cn_hk6, 1 entries
max: 0.0535967, min: 0.0535967



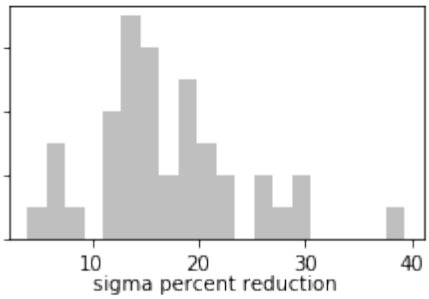
B) sigma change group:cn_hk6, 1 entries
max: 23.3415, min: 23.3415



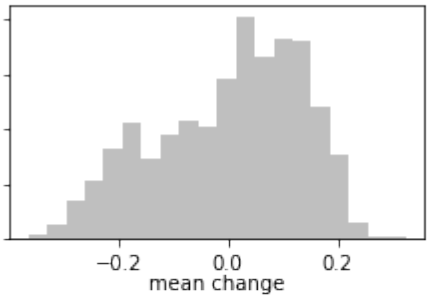
C) mean change group:strk, 40 entries
max: 0.471568, min: -0.54976



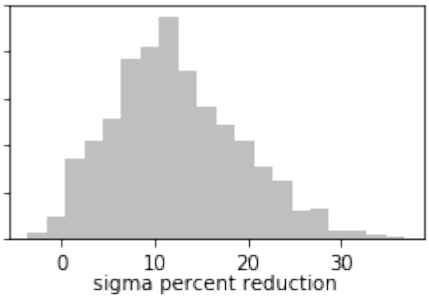
D) sigma change group:strk, 40 entries
max: 39.3722, min: 3.91882



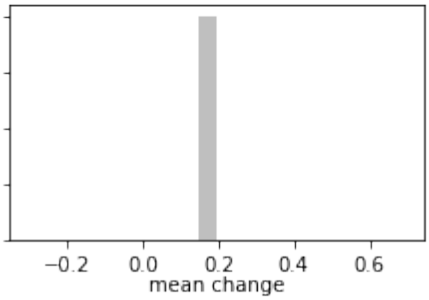
E) mean change group:gr_hk4, 705 entries
max: 0.324224, min: -0.363342



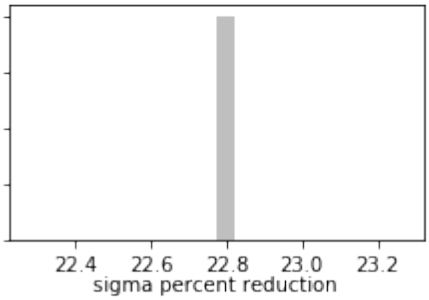
F) sigma change group:gr_hk4, 705 entries
max: 36.8664, min: -3.61496



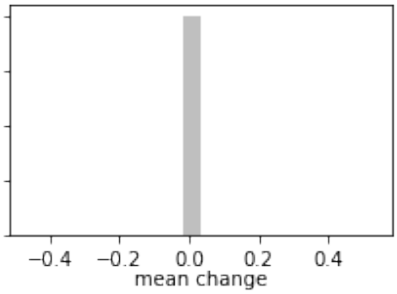
G) mean change group:cn_vka8, 1 entries
max: 0.196414, min: 0.196414



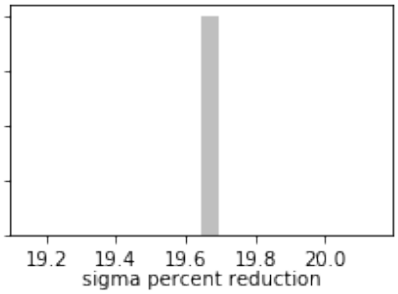
H) sigma change group:cn_vka8, 1 entries
max: 22.7728, min: 22.7728



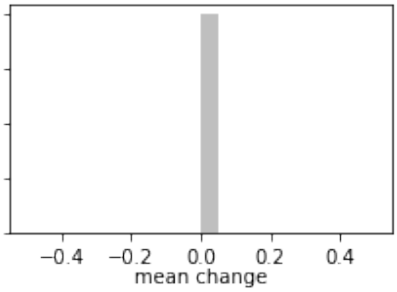
A) mean change group:cn_vka6, 1 entries
max: 0.0329439, min: 0.0329439



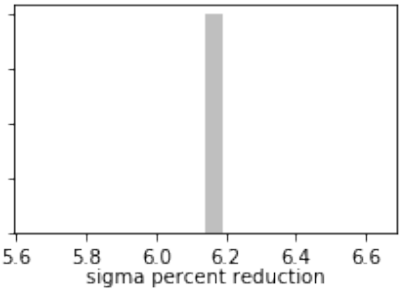
B) sigma change group:cn_vka6, 1 entries
max: 19.643, min: 19.643



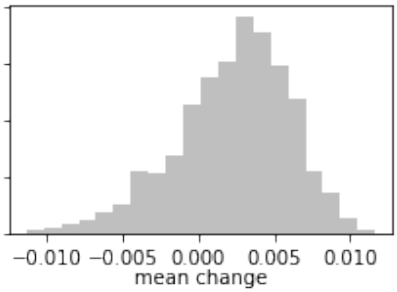
C) mean change group:cn_strt6, 1 entries
max:0.000149052, min:0.000149052



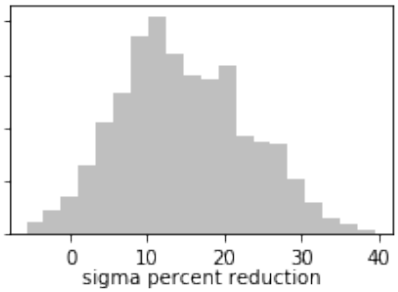
D) sigma change group:cn_strt6, 1 entries
max: 6.13959, min: 6.13959



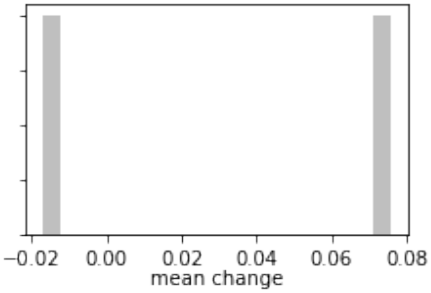
E) mean change group:gr_rech3, 705 entries
max: 0.0116333, min:-0.0113122



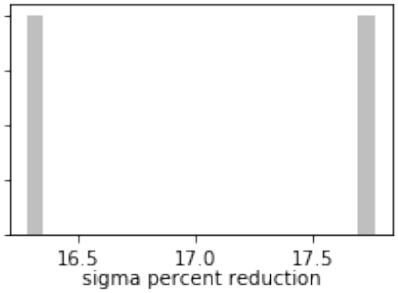
F) sigma change group:gr_rech3, 705 entries
max: 39.5754, min: -5.72218



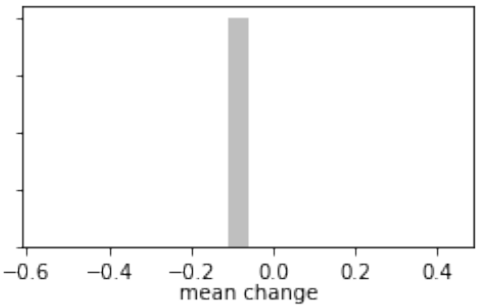
G) mean change group:welflux, 2 entries
max: 0.0758996, min:-0.0172252



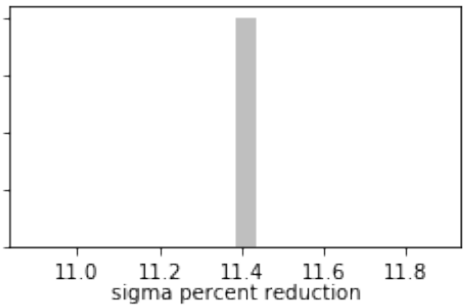
H) sigma change group:welflux, 2 entries
max: 17.7645, min: 16.2826



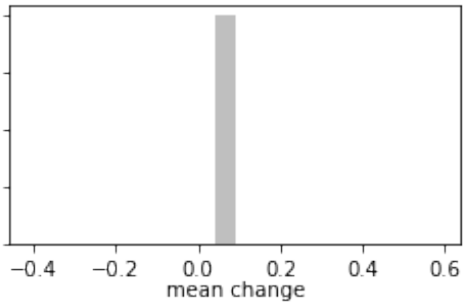
A) mean change group:cn_hk7, 1 entries
max:-0.0596944, min:-0.0596944



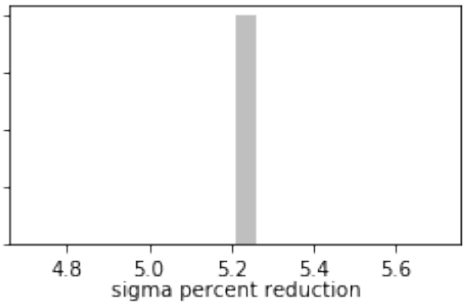
B) sigma change group:cn_hk7, 1 entries
max: 11.3856, min: 11.3856



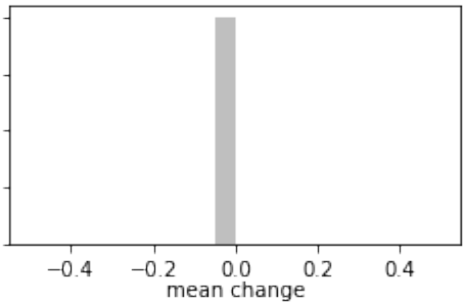
C) mean change group:cn_sy7, 1 entries
max: 0.0907642, min: 0.0907642



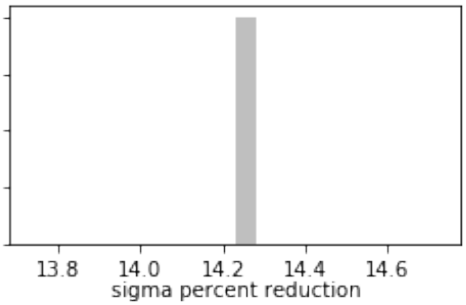
D) sigma change group:cn_sy7, 1 entries
max: 5.21094, min: 5.21094



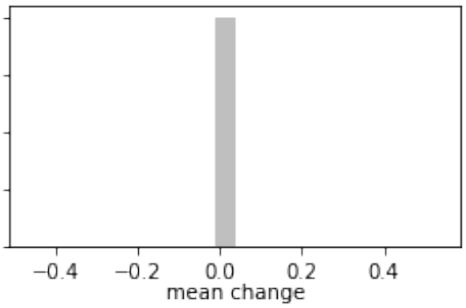
E) mean change group:cn_sy6, 1 entries
max:0.000725263, min:0.000725263



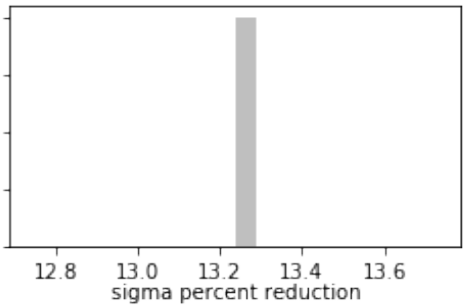
F) sigma change group:cn_sy6, 1 entries
max: 14.2313, min: 14.2313



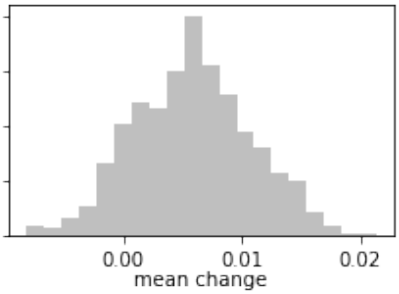
G) mean change group:cn_ss7, 1 entries
max: 0.0385976, min: 0.0385976



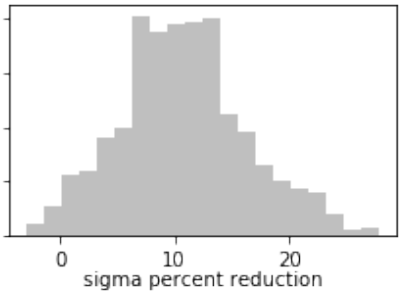
H) sigma change group:cn_ss7, 1 entries
max: 13.2389, min: 13.2389



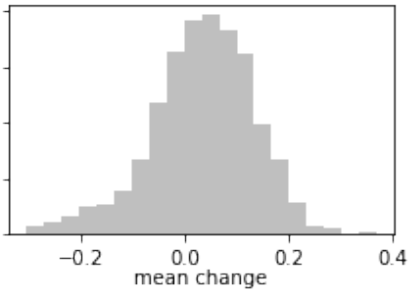
A) mean change group:gr_rech2, 705 entries
max: 0.0214063, min:-0.00821101



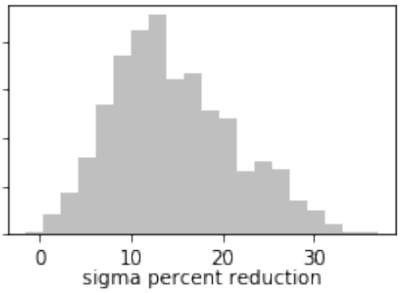
B) sigma change group:gr_rech2, 705 entries
max: 27.7582, min: -2.83578



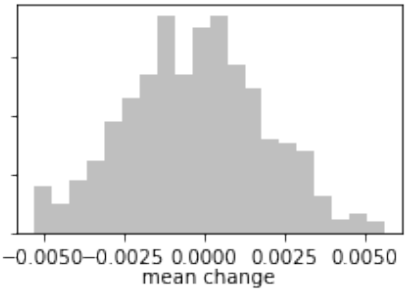
C) mean change group:gr_vka3, 705 entries
max: 0.369658, min: -0.306856



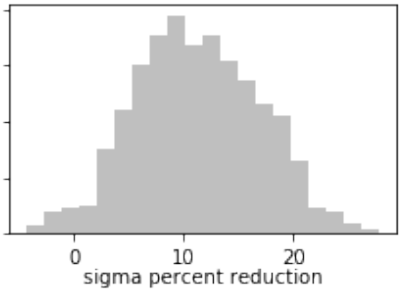
D) sigma change group:gr_vka3, 705 entries
max: 36.9392, min: -1.50828



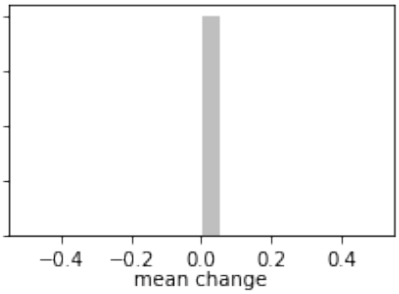
E) mean change group:gr_strt3, 705 entries
max:0.00564556, min:-0.00528867



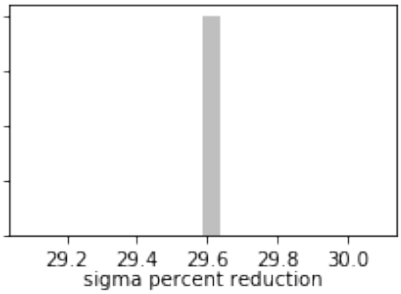
F) sigma change group:gr_strt3, 705 entries
max: 27.7136, min: -4.22393



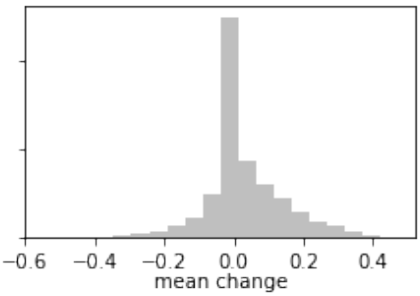
G) mean change group:cn_rech4, 1 entries
max:0.00105349, min:0.00105349



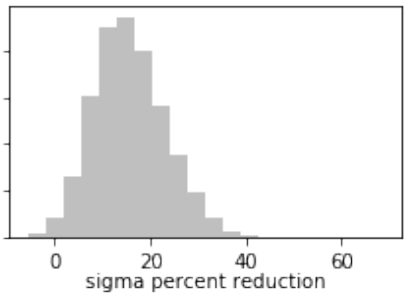
H) sigma change group:cn_rech4, 1 entries
max: 29.5873, min: 29.5873



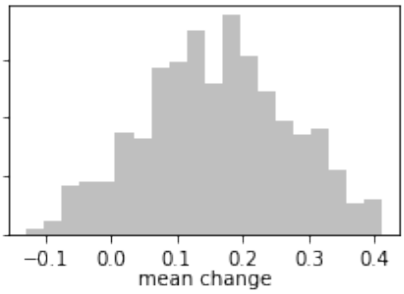
A) mean change group:all, 12061 entries
max: 0.471568, min: -0.54976



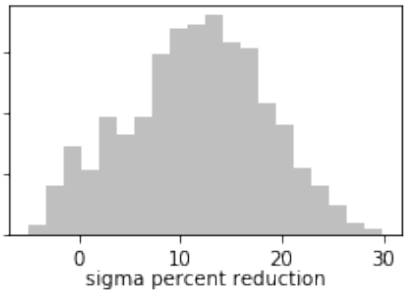
B) sigma change group:all, 12061 entries
max: 68.6195, min: -5.72218



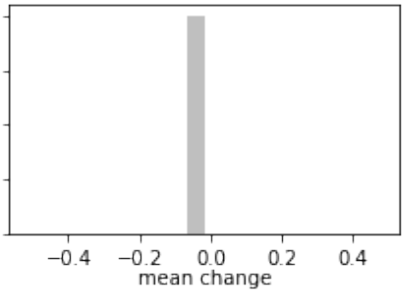
C) mean change group:gr_ss5, 705 entries
max: 0.411245, min: -0.127912



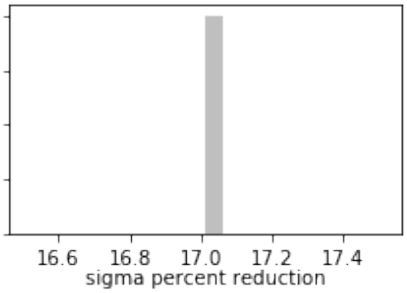
D) sigma change group:gr_ss5, 705 entries
max: 29.9607, min: -5.07292



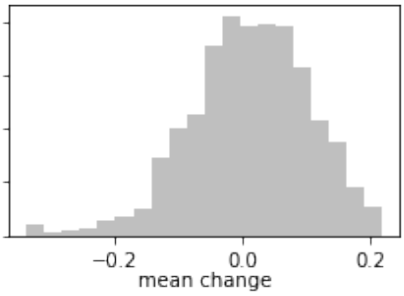
E) mean change group:cn_sy8, 1 entries
max:-0.0174705, min:-0.0174705



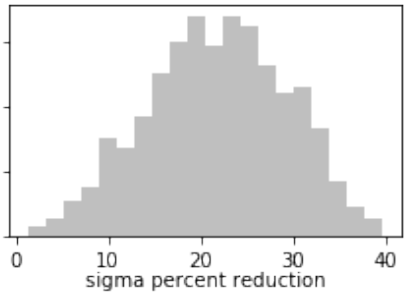
F) sigma change group:cn_sy8, 1 entries
max: 17.0121, min: 17.0121



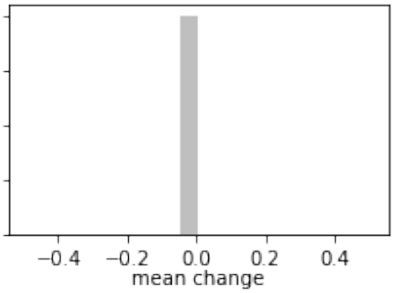
G) mean change group:gr_vka5, 705 entries
max: 0.217356, min: -0.336701



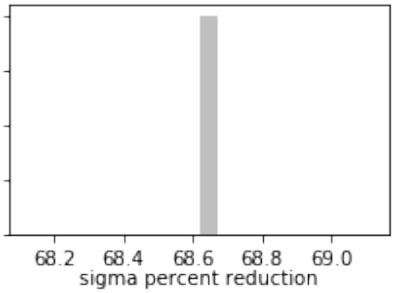
H) sigma change group:gr_vka5, 705 entries
max: 39.7558, min: 1.26606



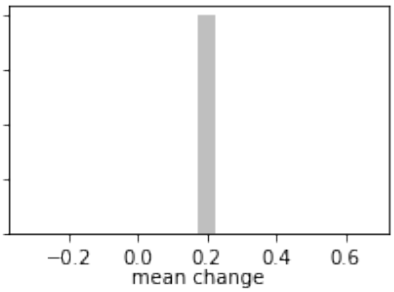
A) mean change group:flow, 1 entries
max:0.00446975, min:0.00446975



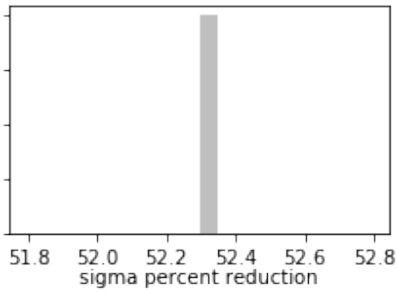
B) sigma change group:flow, 1 entries
max: 68.6195, min: 68.6195



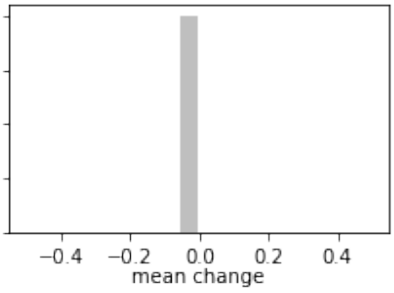
C) mean change group:cn_hk8, 1 entries
max: 0.174294, min: 0.174294



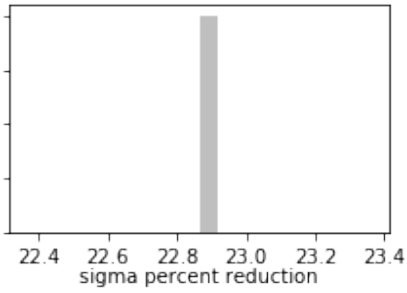
D) sigma change group:cn_hk8, 1 entries
max: 52.2953, min: 52.2953



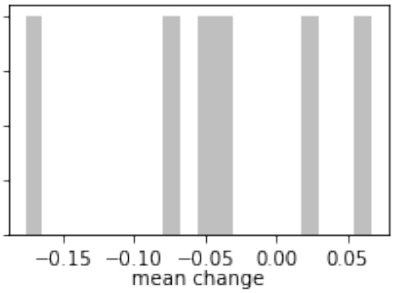
E) mean change group:cn_ss8, 1 entries
max:-0.00408272, min:-0.00408272



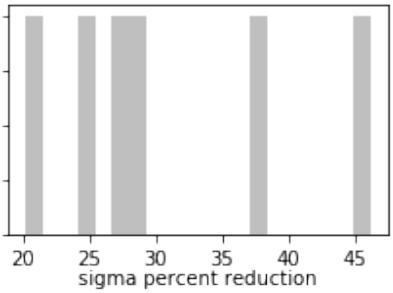
F) sigma change group:cn_ss8, 1 entries
max: 22.8652, min: 22.8652



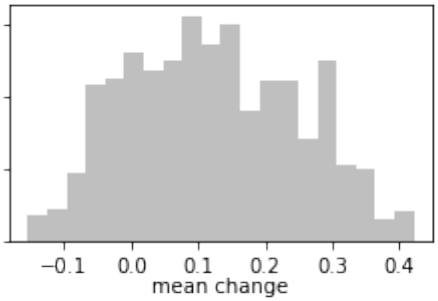
G) mean change group:welflux_k02, 6 entries
max: 0.0663363, min: -0.17623



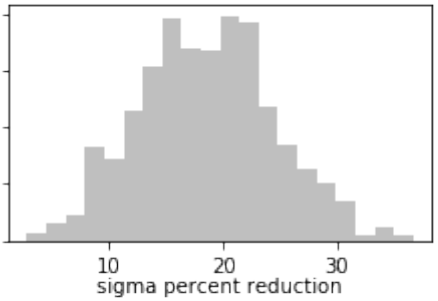
H) sigma change group:welflux_k02, 6 entries
max: 46.2345, min: 20.1801



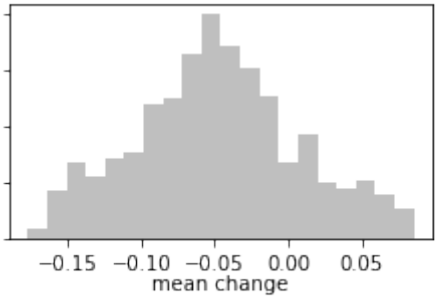
A) mean change group:gr_ss3, 705 entries
max: 0.422241, min: -0.154452



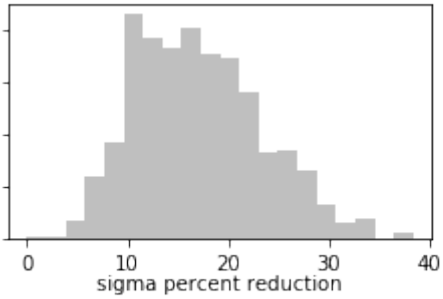
B) sigma change group:gr_ss3, 705 entries
max: 36.6727, min: 2.76372



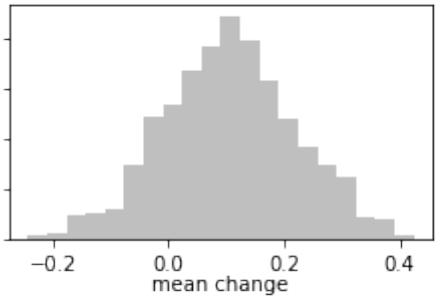
C) mean change group:gr_sy4, 705 entries
max: 0.085491, min: -0.176988



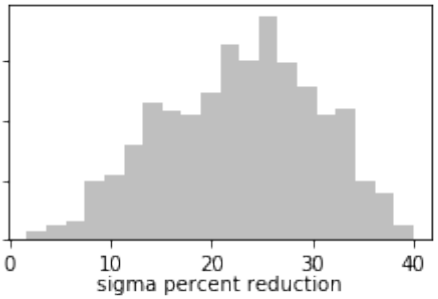
D) sigma change group:gr_sy4, 705 entries
max: 38.3749, min:0.00263762



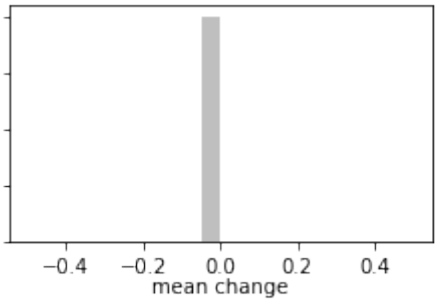
E) mean change group:gr_hk5, 705 entries
max: 0.424512, min: -0.243609



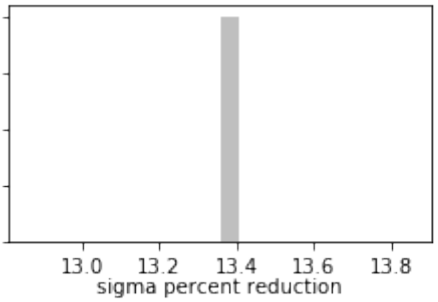
F) sigma change group:gr_hk5, 705 entries
max: 39.9214, min: 1.75323



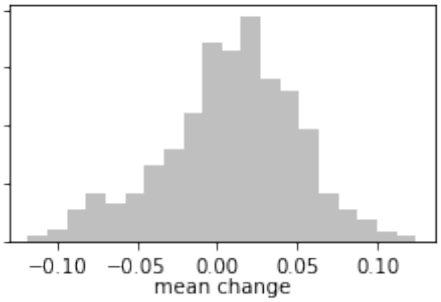
G) mean change group:cn_strt8, 1 entries
max:0.000837971, min:0.000837971



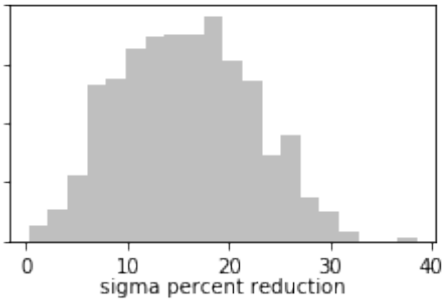
H) sigma change group:cn_strt8, 1 entries
max: 13.3581, min: 13.3581



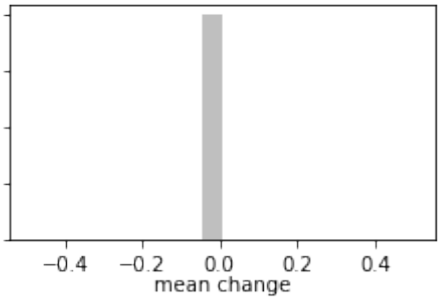
A) mean change group:gr_sy5, 705 entries
max: 0.124226, min: -0.118093



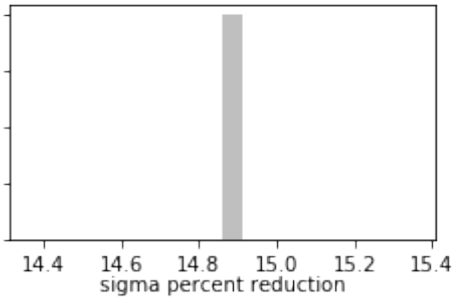
B) sigma change group:gr_sy5, 705 entries
max: 38.5472, min: 0.278489



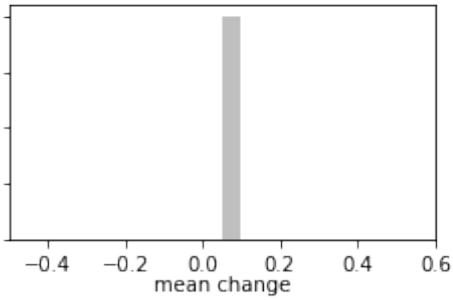
C) mean change group:cn_strt7, 1 entries
max:0.00577033, min:0.00577033



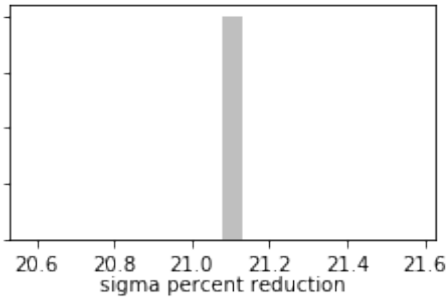
D) sigma change group:cn_strt7, 1 entries
max: 14.8615, min: 14.8615



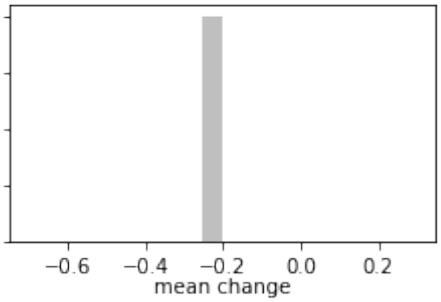
E) mean change group:cn_rech5, 1 entries
max: 0.0498836, min: 0.0498836



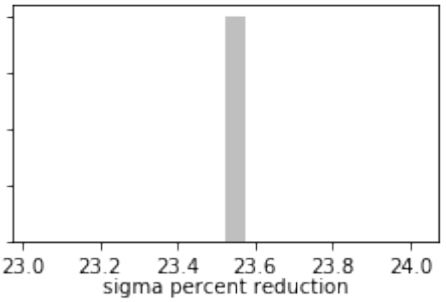
F) sigma change group:cn_rech5, 1 entries
max: 21.0799, min: 21.0799



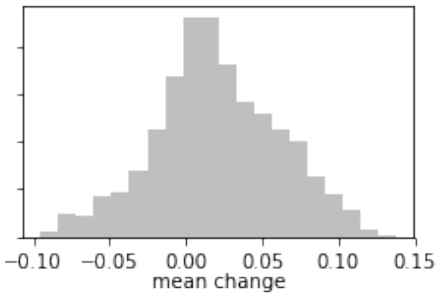
G) mean change group:cn_vka7, 1 entries
max: -0.202767, min: -0.202767



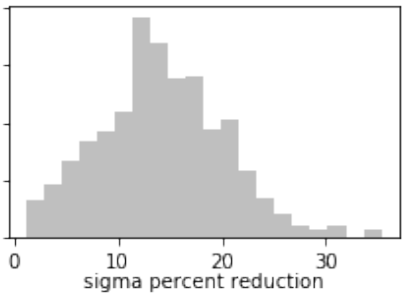
H) sigma change group:cn_vka7, 1 entries
max: 23.525, min: 23.525



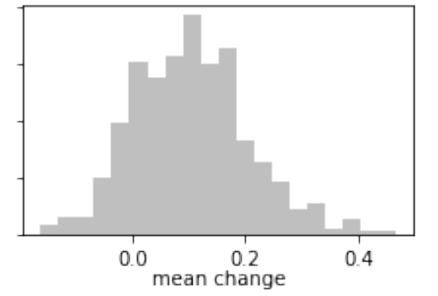
A) mean change group:gr_sy3, 705 entries
max: 0.13773, min:-0.0954256



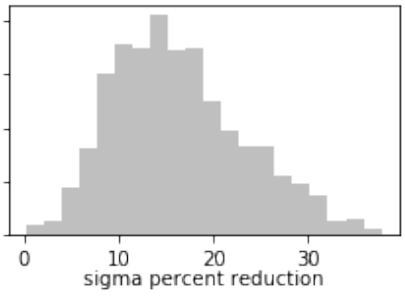
B) sigma change group:gr_sy3, 705 entries
max: 35.3306, min: 1.10531



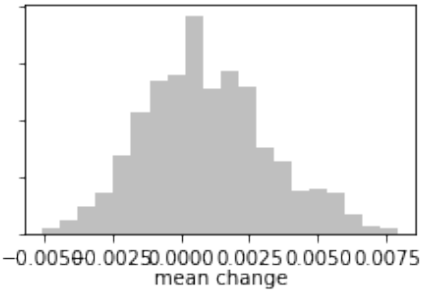
C) mean change group:gr_ss4, 705 entries
max: 0.466516, min: -0.161659



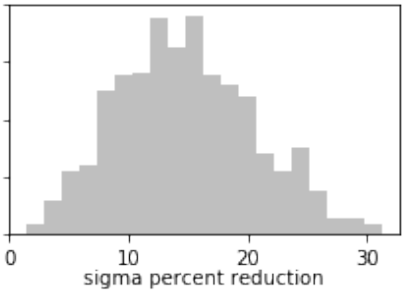
D) sigma change group:gr_ss4, 705 entries
max: 37.7474, min: 0.124608



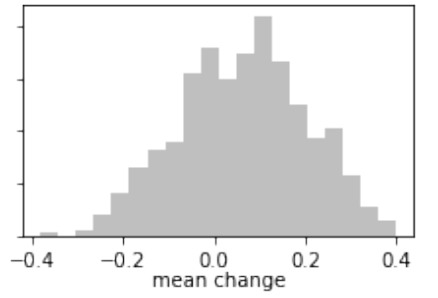
E) mean change group:gr_strt4, 705 entries
max:0.00792188, min:-0.00503652



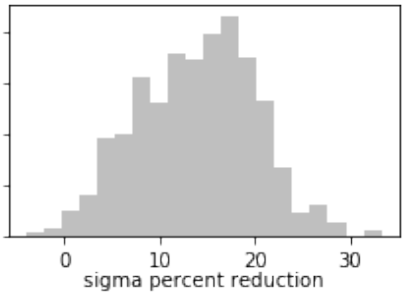
F) sigma change group:gr_strt4, 705 entries
max: 31.1919, min: 1.37948

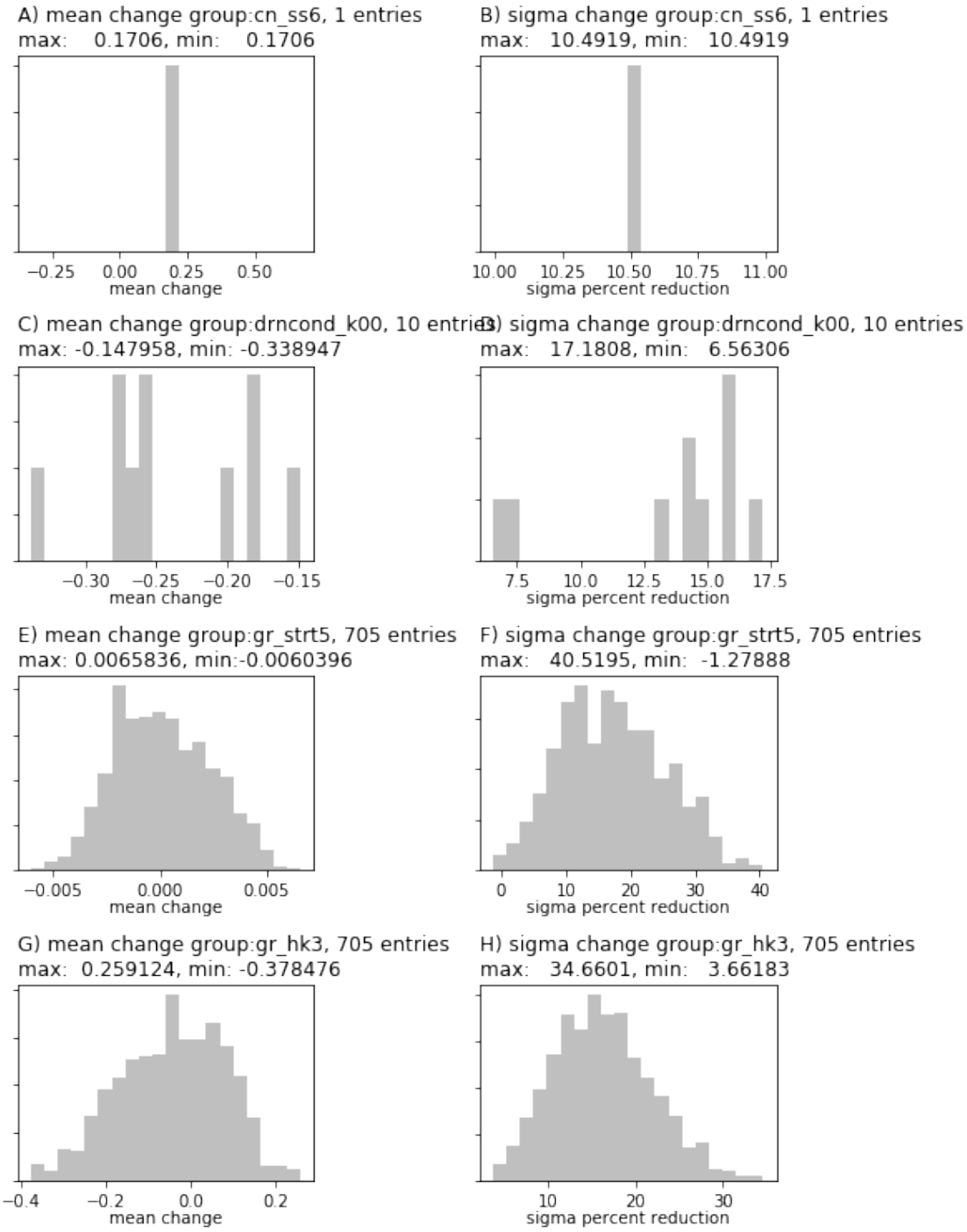


G) mean change group:gr_vka4, 705 entries
max: 0.398956, min: -0.381361



H) sigma change group:gr_vka4, 705 entries
max: 33.2833, min: -4.08826





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

```
In [18]: m = flopy.modflow.Modflow.load("freyberg.nam",model_ws="template")
```

```
In [19]: par = pst.parameter_data
```

```
        gr_par = par.loc[par.pargp.apply(lambda x: "gr" in x),:].copy()
        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()

In [20]: 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)
        for oname in obs.loc[obs.obgnme=="calhead","obsnme"]:
            xx,yy = nobs.loc[oname,['x','y']]

            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

            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[:,scen_pars] = 0.0
        #spars = par.loc[par.parnme.apply(lambda x: "ss" in x or "sy" in x),"parnme"]
        #loc.loc[:,spars] = 0.0
        loc.sum(axis=1)

hds_00_002_009_000 0.46382978723404256 0.0
hds_00_002_015_000 0.4794326241134752 0.0
hds_00_003_008_000 0.43829787234042555 0.0
hds_00_009_001_000 0.3304964539007092 0.0
```

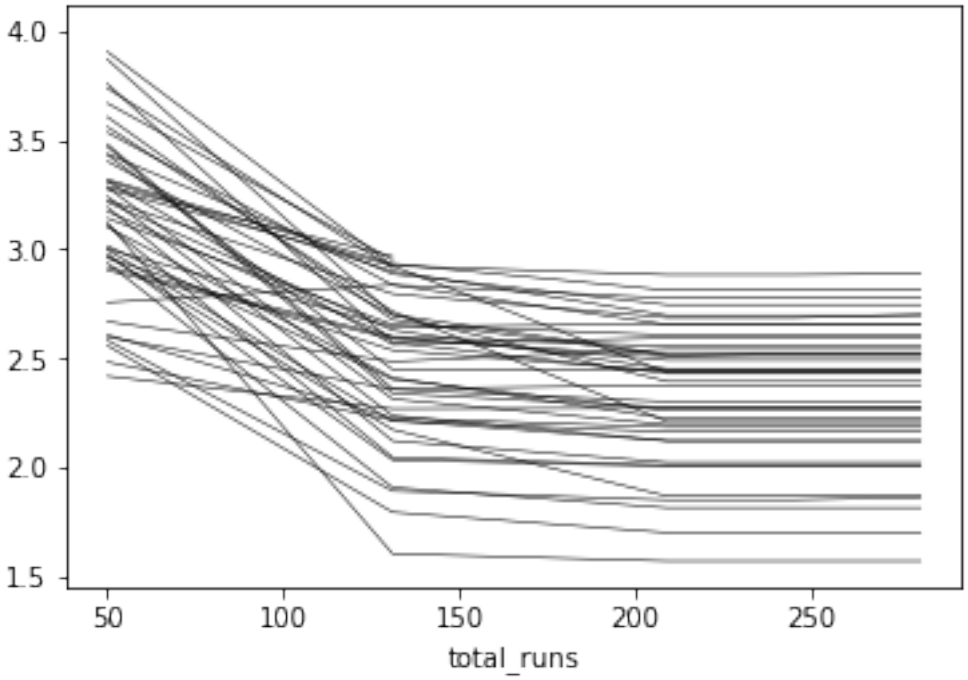
```
hds_00_013_010_000 0.15319148936170213 0.0
hds_00_015_016_000 0.13900709219858157 0.0
hds_00_021_010_000 0.06950354609929078 0.0
hds_00_022_015_000 0.12198581560283688 0.0
hds_00_024_004_000 0.17872340425531916 0.0
hds_00_026_006_000 0.2198581560283688 0.0
hds_00_029_015_000 0.29929078014184396 0.0
hds_00_033_007_000 0.3829787234042553 0.0
hds_00_034_010_000 0.4 0.0
```

```
Out[20]: fo_39_19791230        1350.0
         hds_00_002_009_000    1350.0
         hds_00_002_015_000    1350.0
         hds_00_003_008_000    1350.0
         hds_00_009_001_000    1350.0
         hds_00_013_010_000    1350.0
         hds_00_015_016_000    1350.0
         hds_00_021_010_000    1350.0
         hds_00_022_015_000    1350.0
         hds_00_024_004_000    1350.0
         hds_00_026_006_000    1350.0
         hds_00_029_015_000    1350.0
         hds_00_033_007_000    1350.0
         hds_00_034_010_000    1350.0
         dtype: float64
```

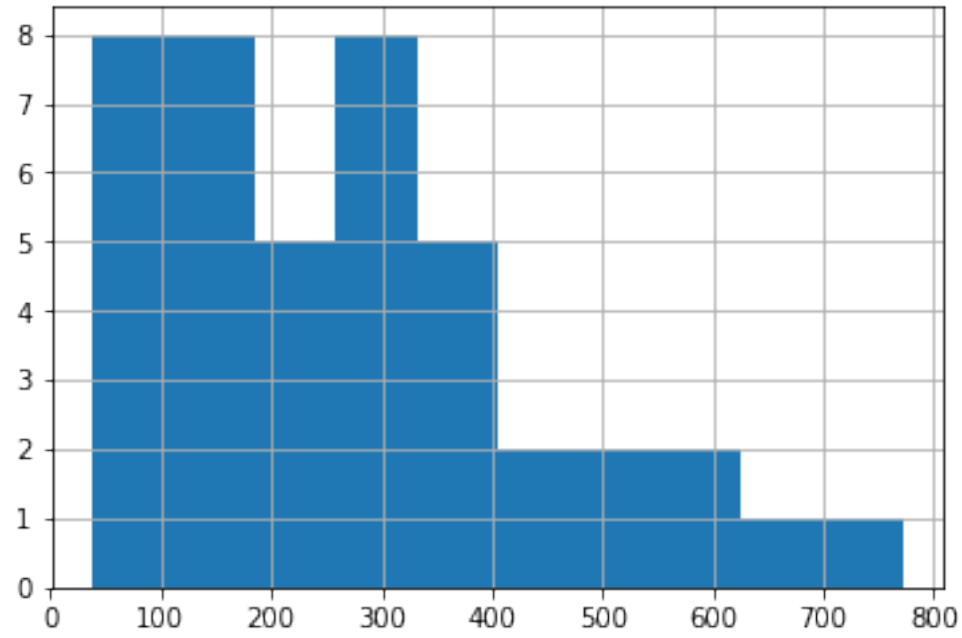
```
In [21]: pyemu.Matrix.from_dataframe(loc).to_coo(os.path.join(t_d,"loc.jcb"))
         pst.pestpp_options["ies_localizer"] = "loc.jcb"
         pst.write(os.path.join(t_d,"freyberg_ies.pst"))
```

```
In [22]: pyemu.os_utils.start_slaves(t_d,"pestpp-ies","freyberg_ies.pst",num_slaves=20,master_
```

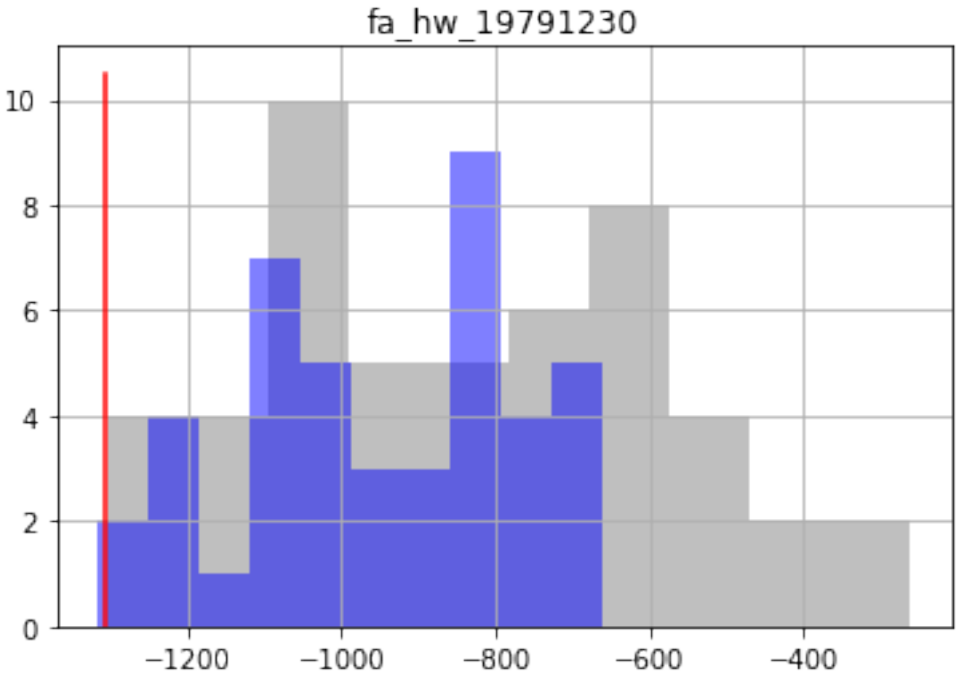
```
In [23]: phi = pd.read_csv(os.path.join(m_d,"freyberg_ies.phi.actual.csv"),index_col=0)
         phi.index = phi.total_runs
         phi.iloc[:,6:].apply(np.log10).plot(legend=False,lw=0.5,color='k')
         plt.show()
         phi.iloc[-1,6:].hist()
```

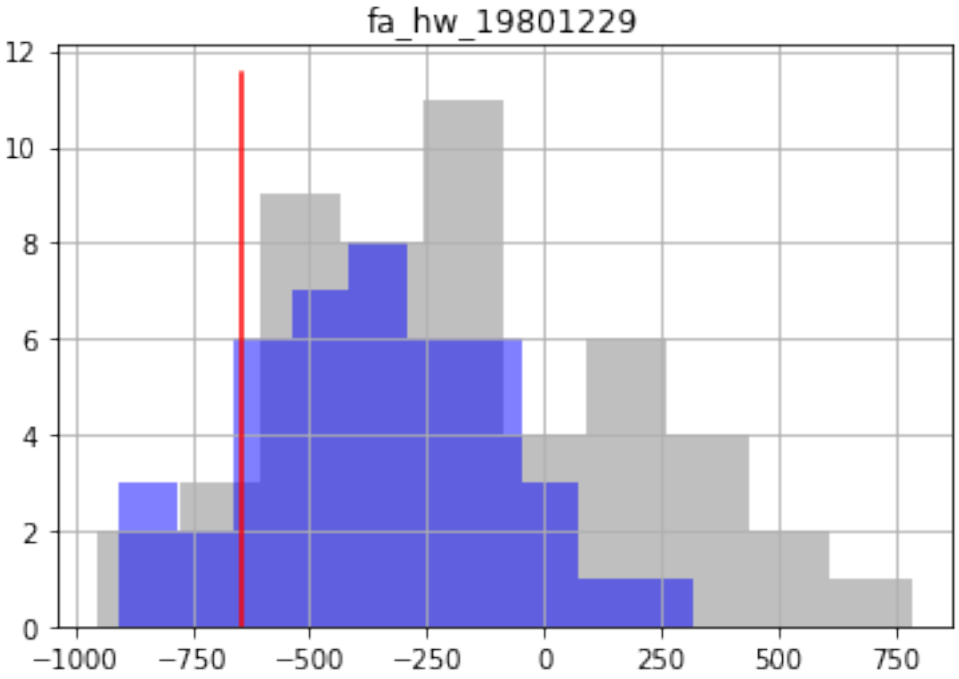


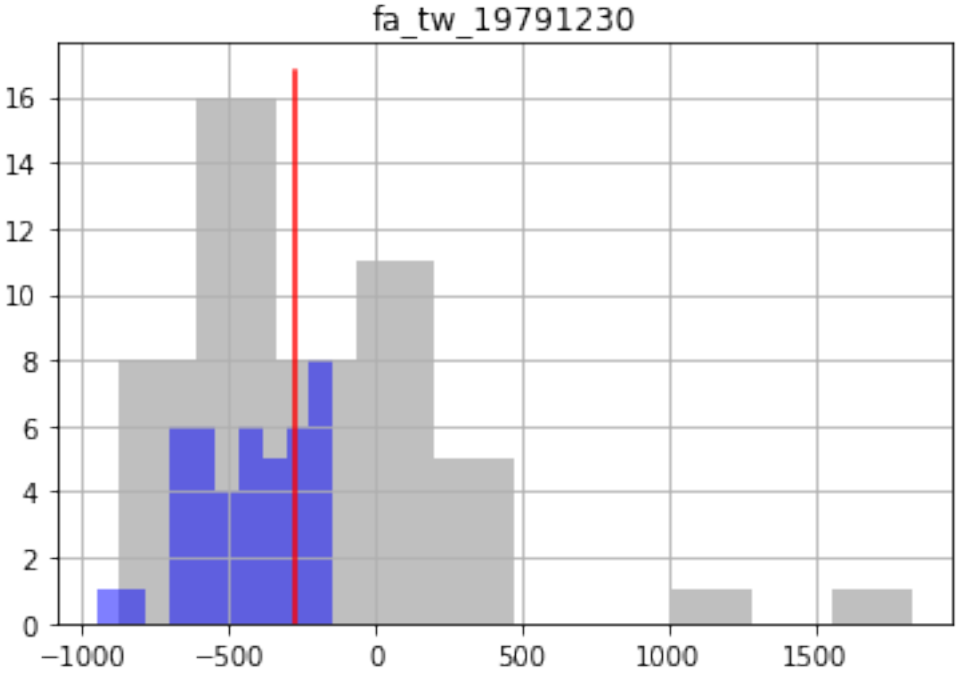
Out[23]: <matplotlib.axes._subplots.AxesSubplot at 0x181f3ab668>

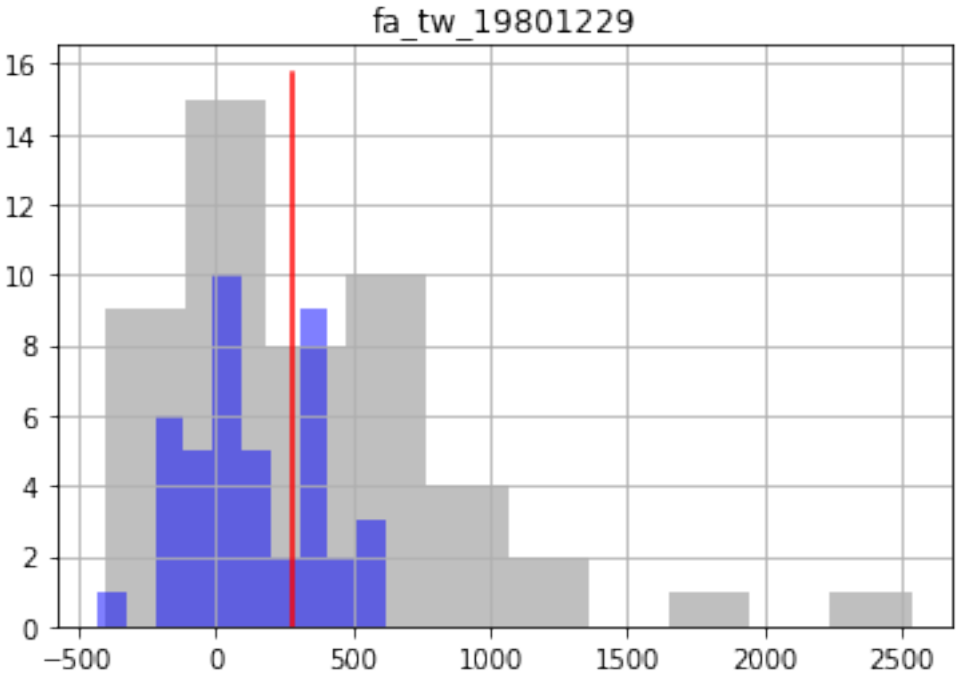


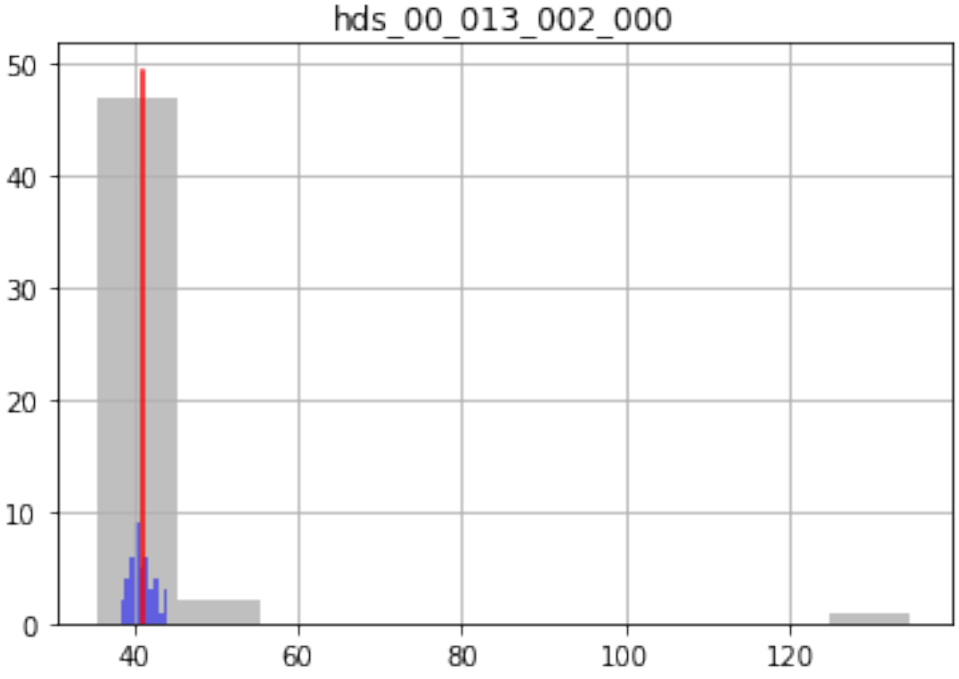
In [24]:
```
oe_pr = pd.read_csv(os.path.join(m_d,"freyberg_ies.0.obs.csv"),index_col=0)
oe_pt = pd.read_csv(os.path.join(m_d,"freyberg_ies.{0}.obs.csv".format(pst.control_dat
obs = pst.observation_data
fnames = pst.pestpp_options["forecasts"].split(",")
for forecast in fnames:
    ax = plt.subplot(111)
    oe_pr.loc[:,forecast].hist(ax=ax,color="0.5",alpha=0.5)
    oe_pt.loc[:,forecast].hist(ax=ax,color="b",alpha=0.5)
    ax.plot([obs.loc[forecast,"obsval"],obs.loc[forecast,"obsval"]],ax.get_ylim(),"r"
    ax.set_title(forecast)
    plt.show()
```

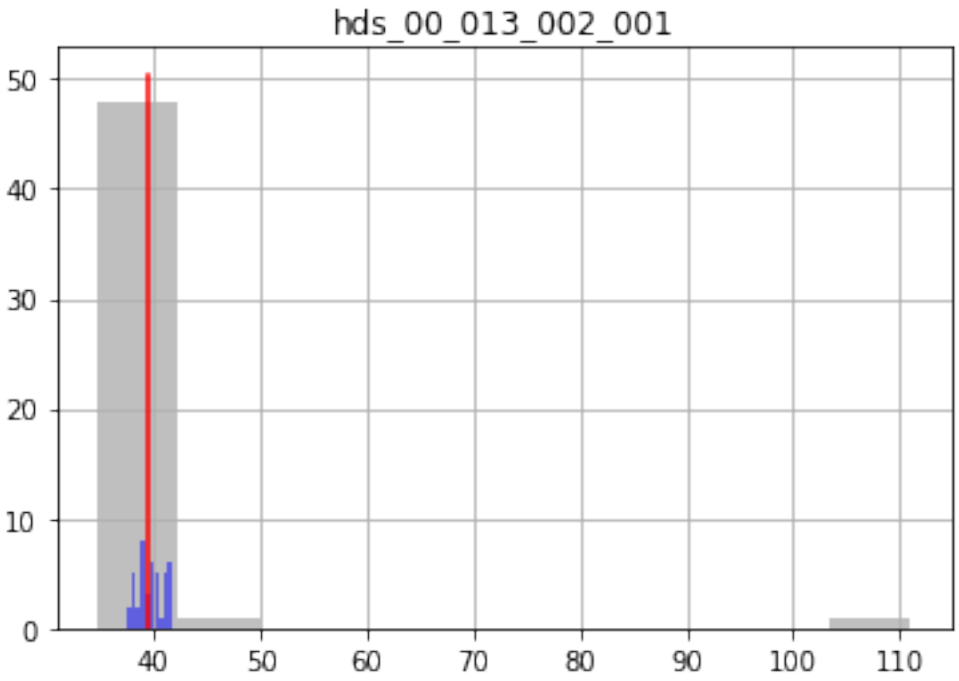



fa_hw_19801229
12
10
8
6
4
2
0
−1000
−750
−500
−250
0
250
500
750

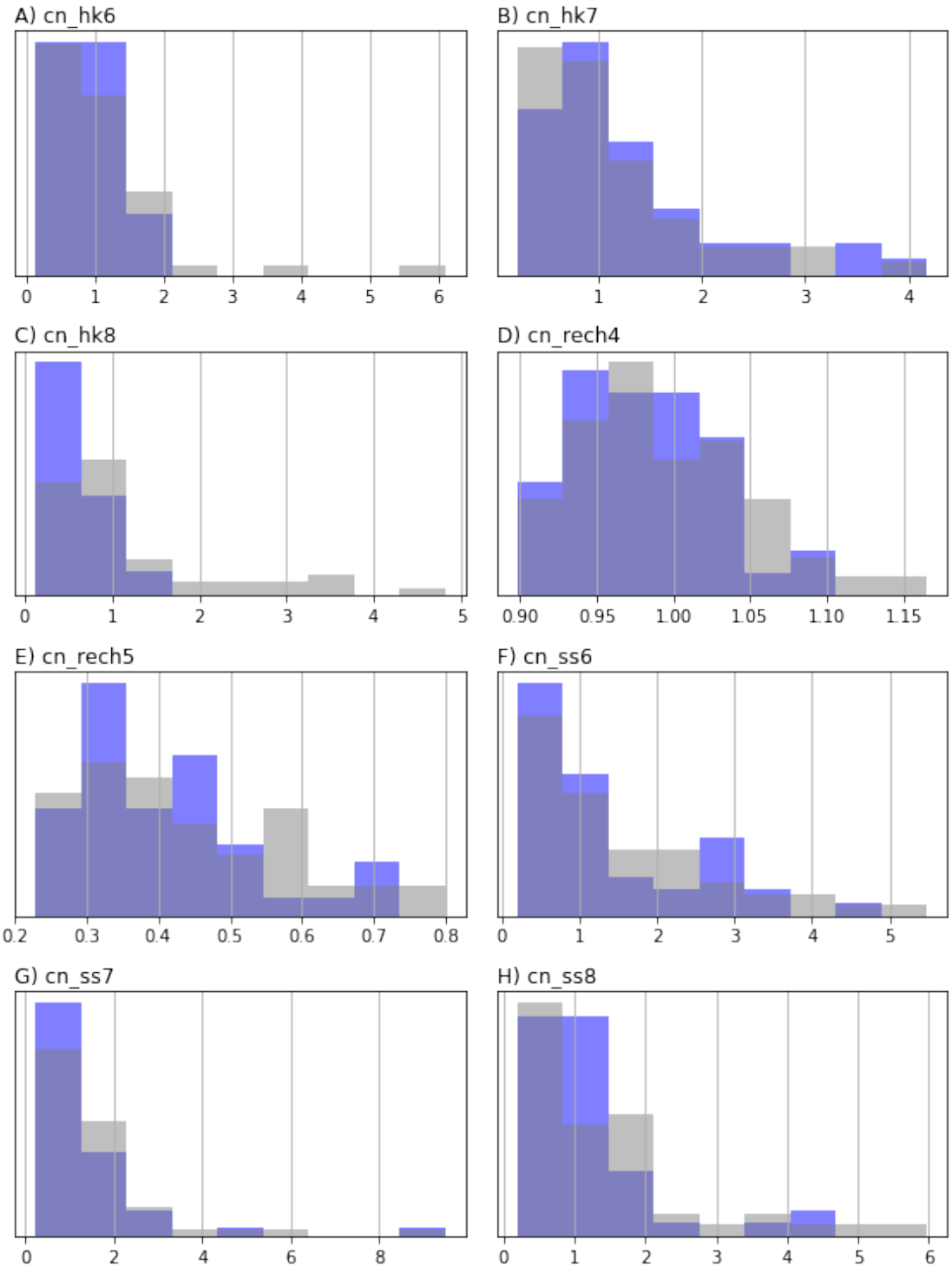

fa_tw_19791230
16
14
12
10
8
6
4
2
0
−1000
−500
0
500
1000
1500

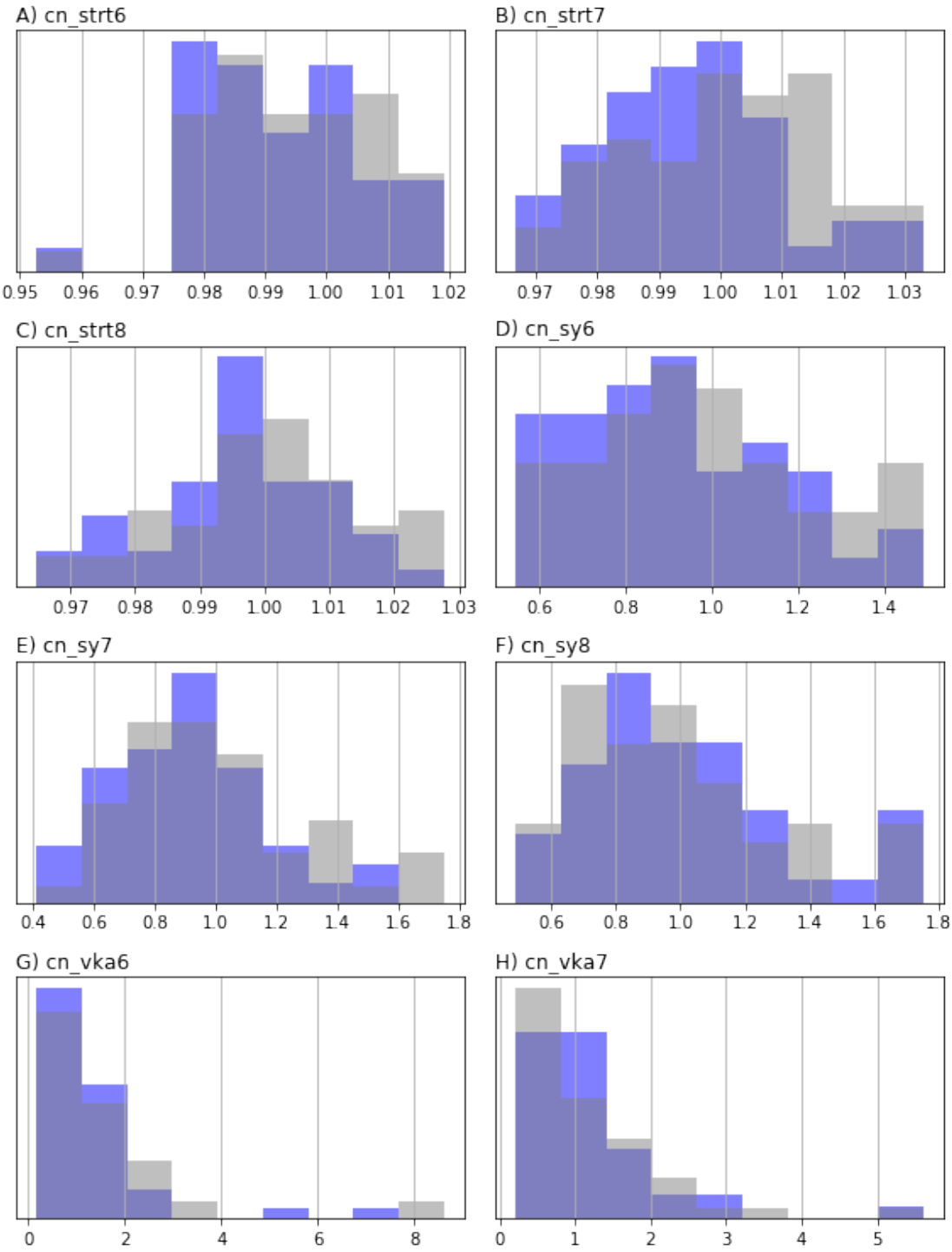

fa_tw_19801229
16
14
12
10
8
6
4
2
0
−500
0
500
1000
1500
2000
2500

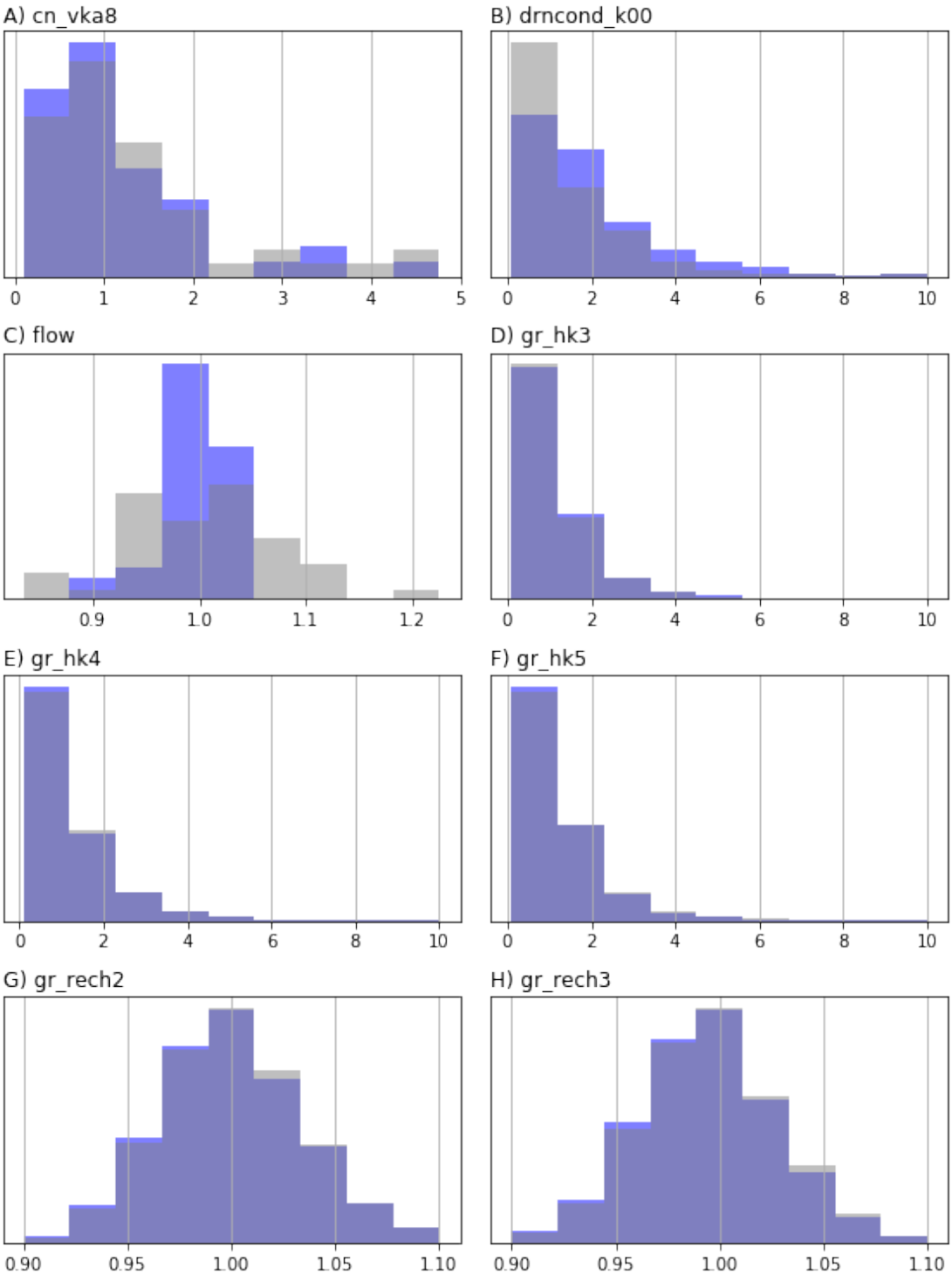

hds_00_013_002_000
50
40
30
20
10
0
40
60
80
100
120

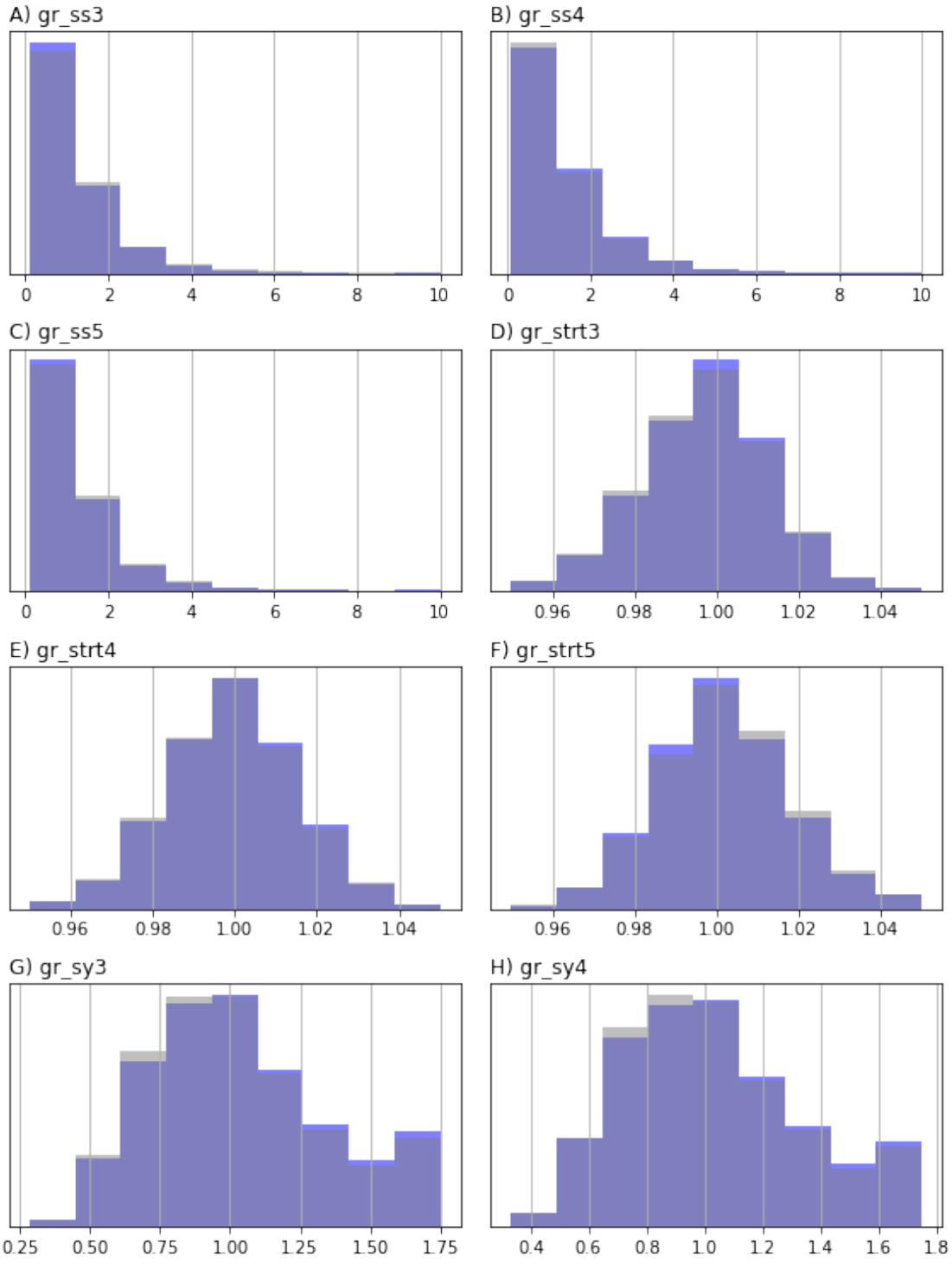


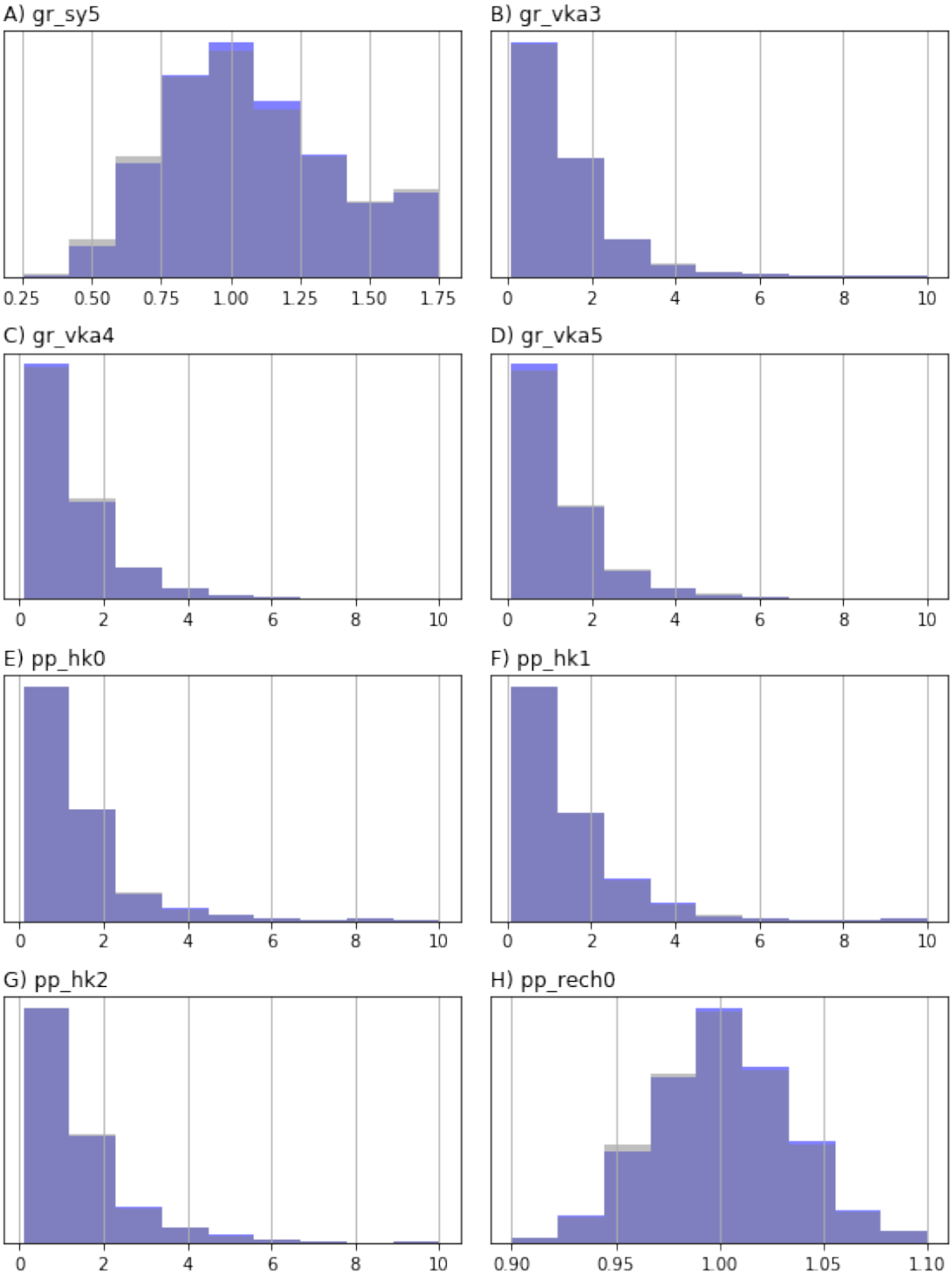

```
In [25]: pe_pr = pd.read_csv(os.path.join(m_d,"freyberg_ies.0.par.csv"),index_col=0)
         pe_pt = pd.read_csv(os.path.join(m_d,"freyberg_ies.{0}.par.csv".format(pst.control_dat
         par = pst.parameter_data
         pdict = par.groupby("pargp").groups
         pyemu.plot_utils.ensemble_helper({"0.5":pe_pr,"b":pe_pt},plot_cols=pdict)
         pyemu.plot_utils.ensemble_change_summary(pe_pr,pe_pt,pst=pst,bins=20)

Out[25]: [<Figure size 576x756 with 0 Axes>,
          <Figure size 576x756 with 8 Axes>,
          <Figure size 576x756 with 8 Axes>,
          <Figure size 576x756 with 8 Axes>,
          <Figure size 576x756 with 8 Axes>,
          <Figure size 576x756 with 8 Axes>,
          <Figure size 576x756 with 8 Axes>,
          <Figure size 576x756 with 8 Axes>,
          <Figure size 576x756 with 8 Axes>,
          <Figure size 576x756 with 8 Axes>,
          <Figure size 576x756 with 8 Axes>]

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

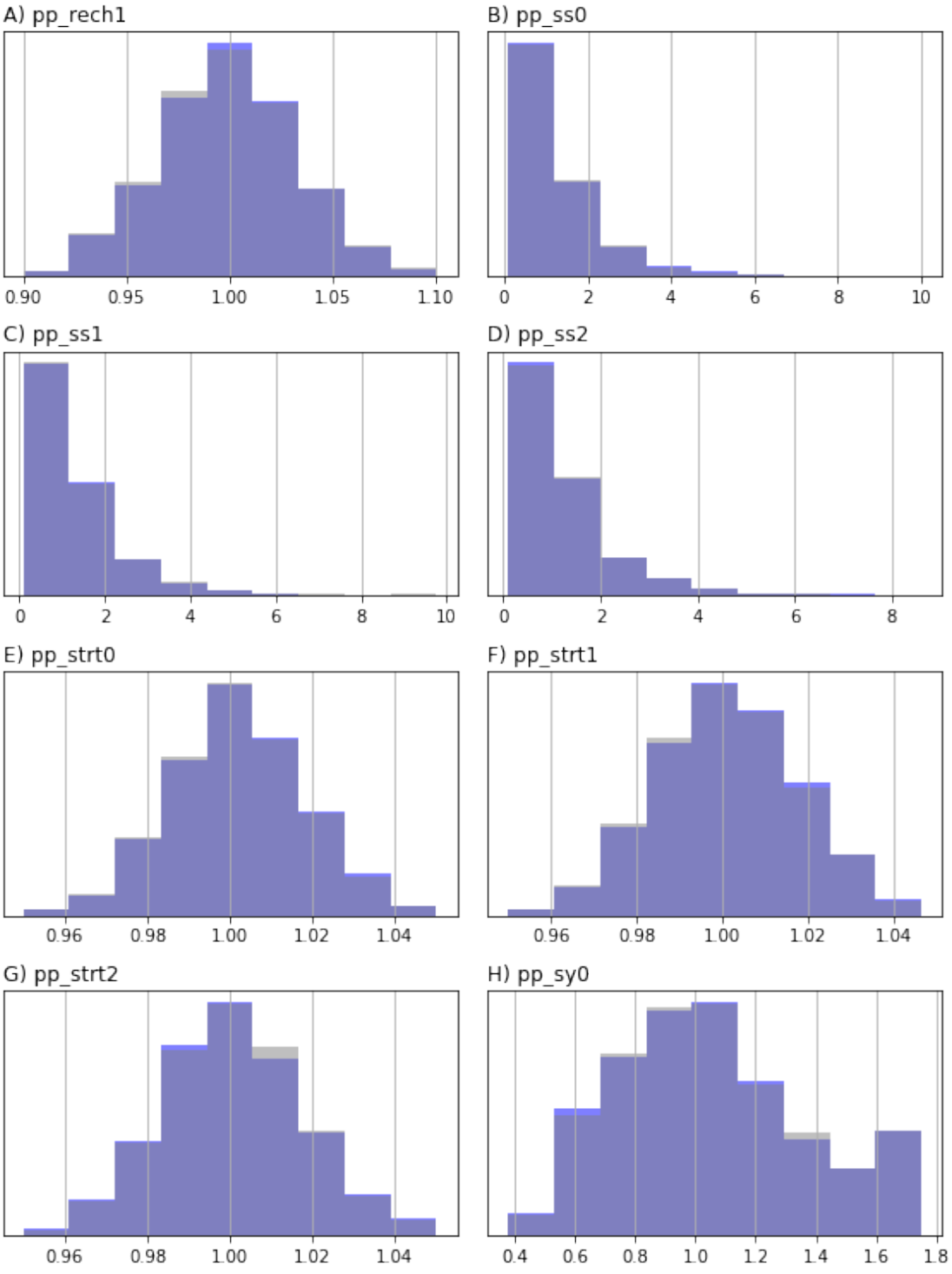

A) cn_hk6
B) cn_hk7
C) cn_hk8
D) cn_rech4
E) cn_rech5
F) cn_ss6
G) cn_ss7
H) cn_ss8

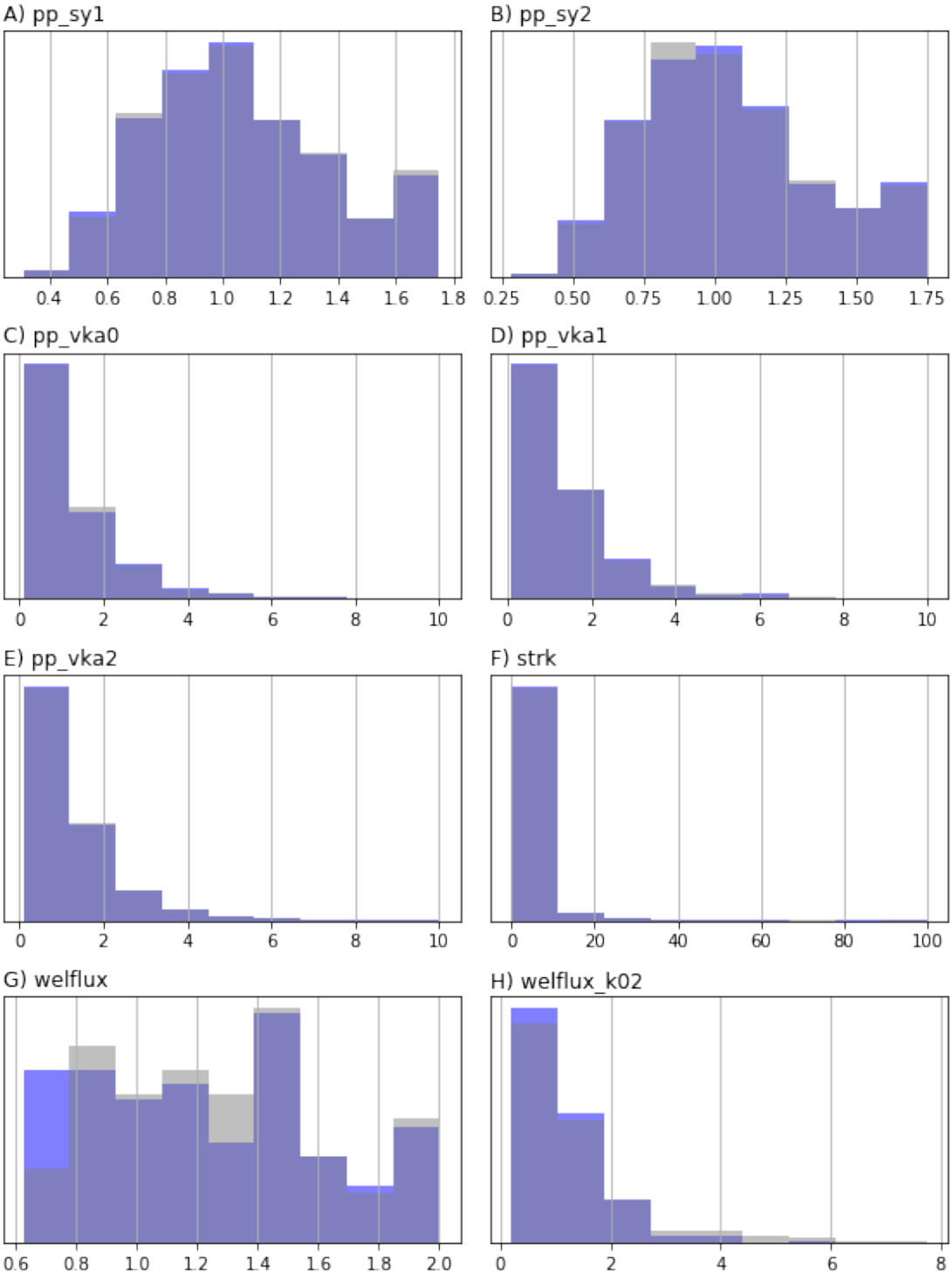

A) cn_strt6
0.95 0.96 0.97 0.98 0.99 1.00 1.01 1.02
B) cn_strt7
0.97 0.98 0.99 1.00 1.01 1.02 1.03
C) cn_strt8
0.97 0.98 0.99 1.00 1.01 1.02 1.03
D) cn_sy6
0.6 0.8 1.0 1.2 1.4
E) cn_sy7
0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8
F) cn_sy8
0.6 0.8 1.0 1.2 1.4 1.6 1.8
G) cn_vka6
0 2 4 6 8
H) cn_vka7
0 1 2 3 4 5


A) cn_vka8
0
1
2
3
4
5
B) drncond_k00
0
2
4
6
8
10
C) flow
0.9
1.0
1.1
1.2
D) gr_hk3
0
2
4
6
8
10
E) gr_hk4
0
2
4
6
8
10
F) gr_hk5
0
2
4
6
8
10
G) gr_rech2
0.90
0.95
1.00
1.05
1.10
H) gr_rech3
0.90
0.95
1.00
1.05
1.10


A) gr_ss3
0
2
4
6
8
10
B) gr_ss4
0
2
4
6
8
10
C) gr_ss5
0
2
4
6
8
10
D) gr_strt3
0.96
0.98
1.00
1.02
1.04
E) gr_strt4
0.96
0.98
1.00
1.02
1.04
F) gr_strt5
0.96
0.98
1.00
1.02
1.04
G) gr_sy3
0.25
0.50
0.75
1.00
1.25
1.50
1.75
H) gr_sy4
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8

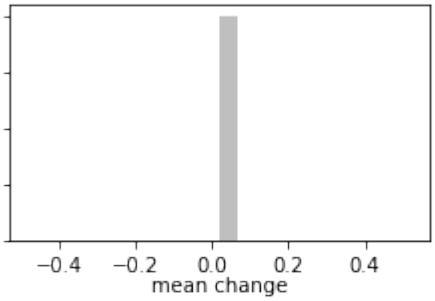

A) gr_sy5
0.25
0.50
0.75
1.00
1.25
1.50
1.75
B) gr_vka3
0
2
4
6
8
10
C) gr_vka4
0
2
4
6
8
10
D) gr_vka5
0
2
4
6
8
10
E) pp_hk0
0
2
4
6
8
10
F) pp_hk1
0
2
4
6
8
10
G) pp_hk2
0
2
4
6
8
10
H) pp_rech0
0.90
0.95
1.00
1.05
1.10


A) pp_rech1
0.90
0.95
1.00
1.05
1.10
B) pp_ss0
0
2
4
6
8
10
C) pp_ss1
0
2
4
6
8
10
D) pp_ss2
0
2
4
6
8
E) pp_strt0
0.96
0.98
1.00
1.02
1.04
F) pp_strt1
0.96
0.98
1.00
1.02
1.04
G) pp_strt2
0.96
0.98
1.00
1.02
1.04
H) pp_sy0
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8

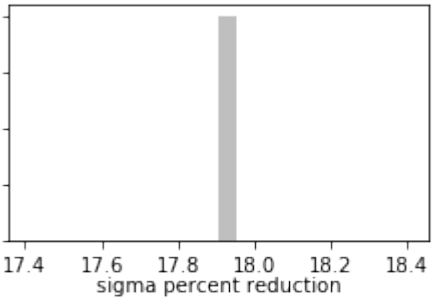


<Figure size 576x756 with 0 Axes>

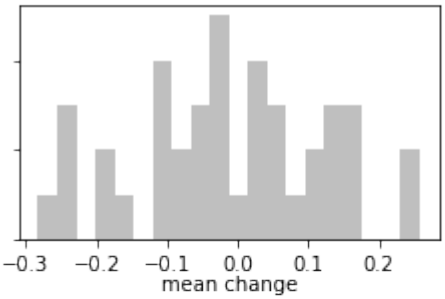
A) mean change group:cn_hk6, 1 entries
max: 0.0176294, min: 0.0176294



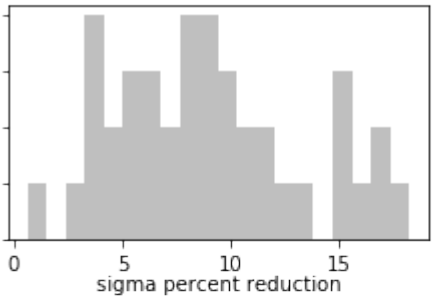
B) sigma change group:cn_hk6, 1 entries
max: 17.9058, min: 17.9058



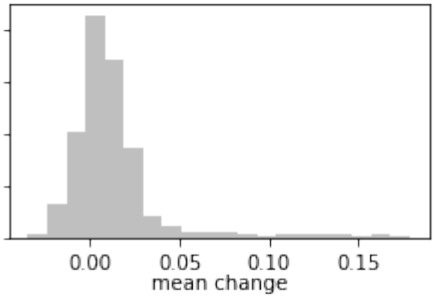
C) mean change group:strk, 40 entries
max: 0.257931, min: -0.282452



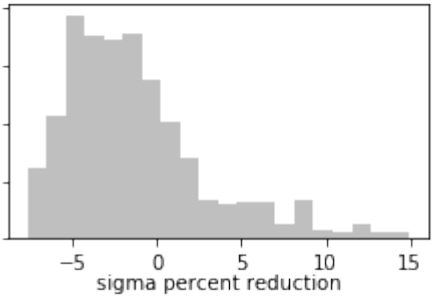
D) sigma change group:strk, 40 entries
max: 18.2067, min: 0.608138



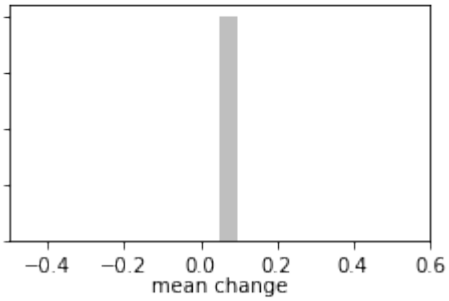
E) mean change group:gr_hk4, 705 entries
max: 0.178529, min:-0.0343672



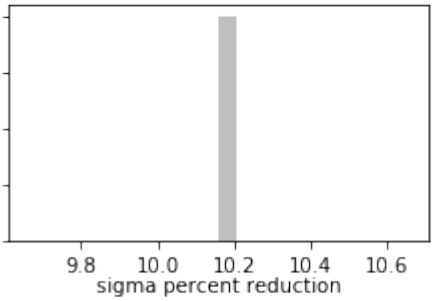
F) sigma change group:gr_hk4, 705 entries
max: 14.9271, min: -7.65365



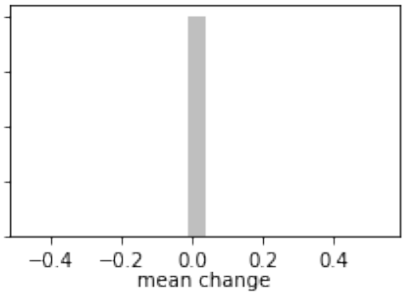
G) mean change group:cn_vka8, 1 entries
max: 0.0483258, min: 0.0483258



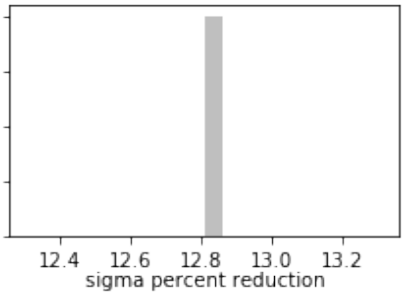
H) sigma change group:cn_vka8, 1 entries
max: 10.1589, min: 10.1589



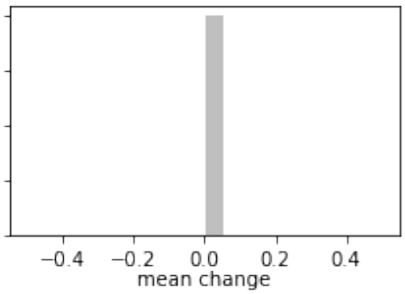
A) mean change group:cn_vka6, 1 entries
max: 0.0358863, min: 0.0358863



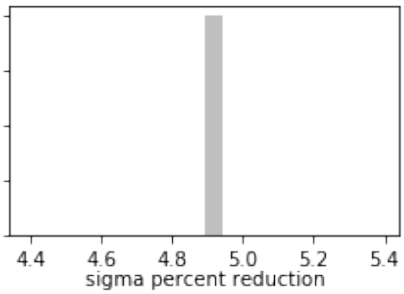
B) sigma change group:cn_vka6, 1 entries
max: 12.8092, min: 12.8092



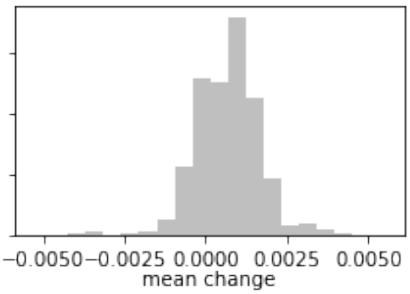
C) mean change group:cn_strt6, 1 entries
max:0.000971346, min:0.000971346



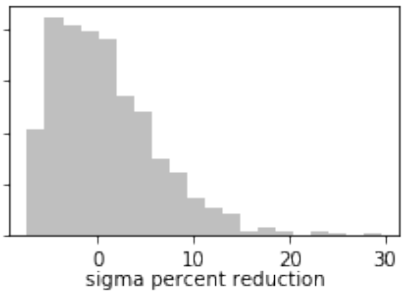
D) sigma change group:cn_strt6, 1 entries
max: 4.89129, min: 4.89129



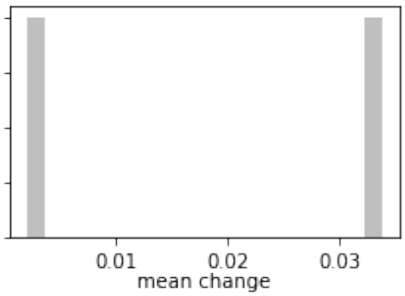
E) mean change group:gr_rech3, 705 entries
max:0.00558457, min:-0.0053247



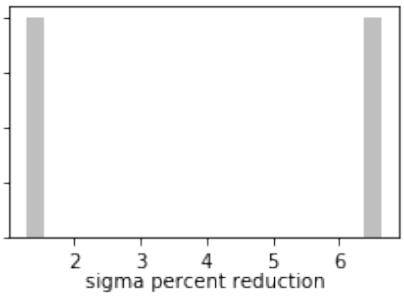
F) sigma change group:gr_rech3, 705 entries
max: 29.5993, min: -7.34737



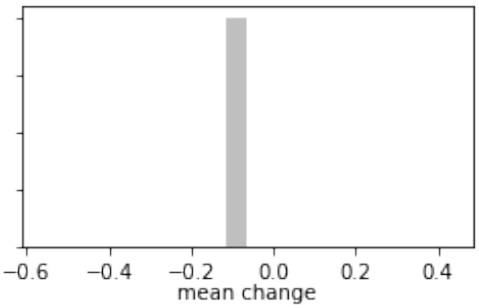
G) mean change group:welflux, 2 entries
max: 0.0337873, min:0.00214735



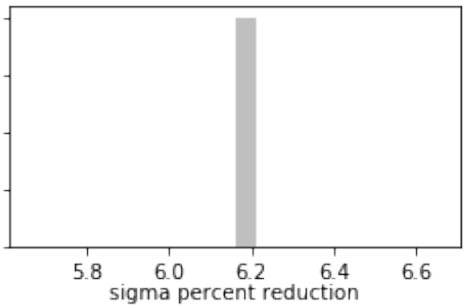
H) sigma change group:welflux, 2 entries
max: 6.64547, min: 1.28916



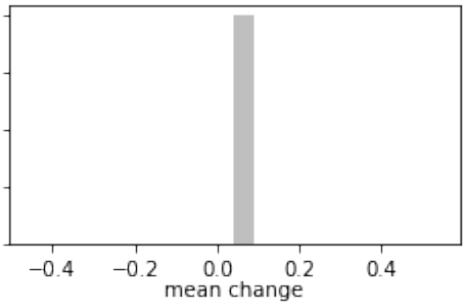
A) mean change group:cn_hk7, 1 entries
max:-0.0631798, min:-0.0631798



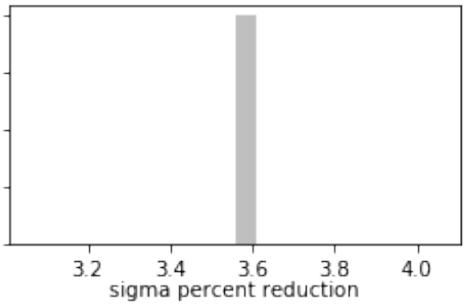
B) sigma change group:cn_hk7, 1 entries
max: 6.16017, min: 6.16017



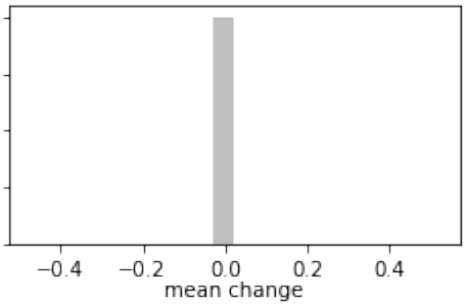
C) mean change group:cn_sy7, 1 entries
max: 0.042681, min: 0.042681



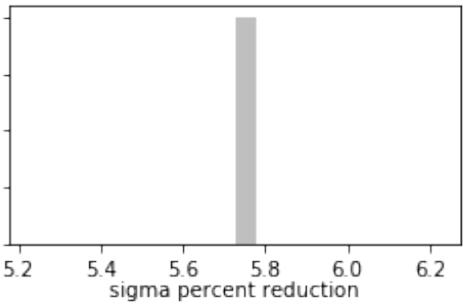
D) sigma change group:cn_sy7, 1 entries
max: 3.55813, min: 3.55813



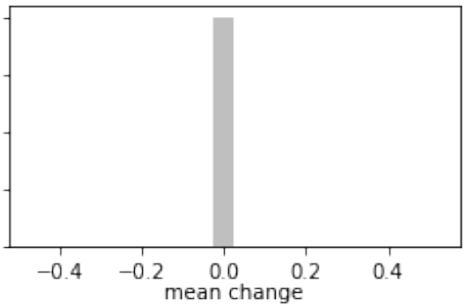
E) mean change group:cn_sy6, 1 entries
max: 0.0229556, min: 0.0229556



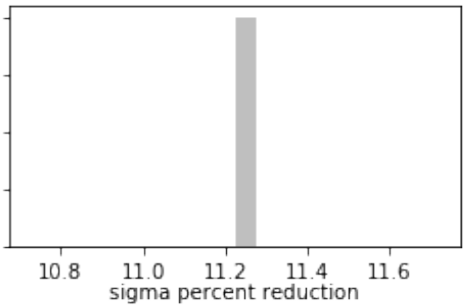
F) sigma change group:cn_sy6, 1 entries
max: 5.72728, min: 5.72728



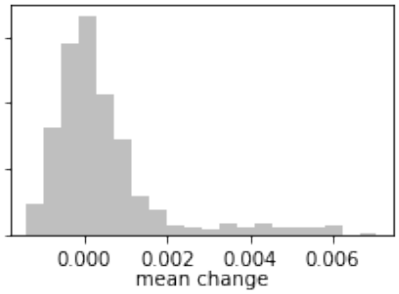
G) mean change group:cn_ss7, 1 entries
max: 0.0256908, min: 0.0256908



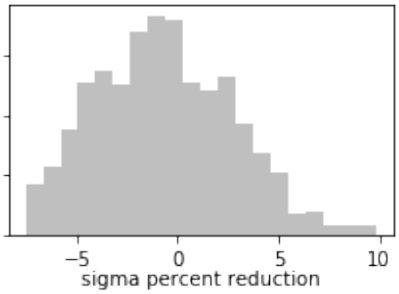
H) sigma change group:cn_ss7, 1 entries
max: 11.2239, min: 11.2239



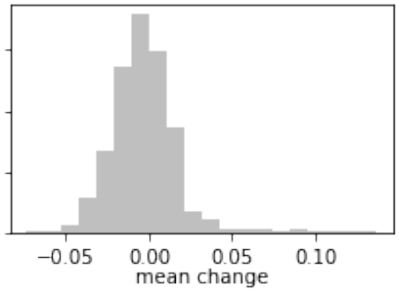
A) mean change group:gr_rech2, 705 entries
max:0.00705899, min:-0.00139167



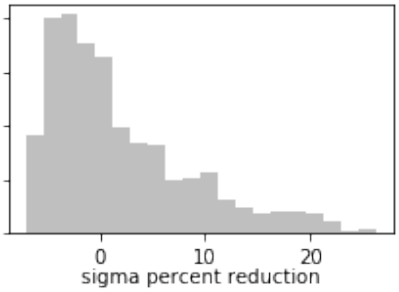
B) sigma change group:gr_rech2, 705 entries
max: 9.81395, min: -7.54857



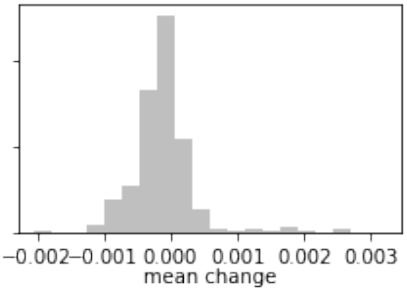
C) mean change group:gr_vka3, 705 entries
max: 0.136859, min:-0.0732887



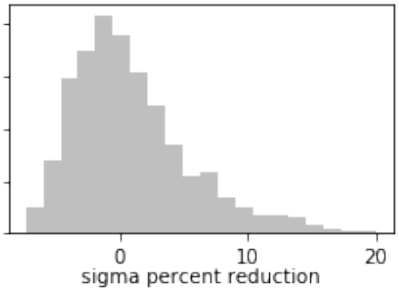
D) sigma change group:gr_vka3, 705 entries
max: 26.1904, min: -7.05279



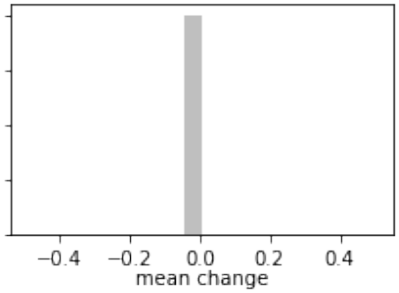
E) mean change group:gr_strt3, 705 entries
max:0.00320391, min:-0.00203238



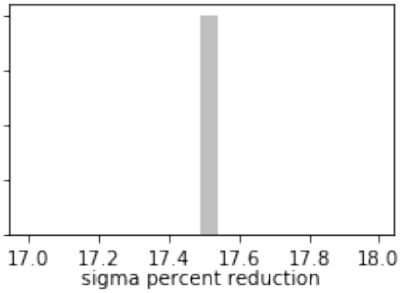
F) sigma change group:gr_strt3, 705 entries
max: 19.9399, min: -7.34993



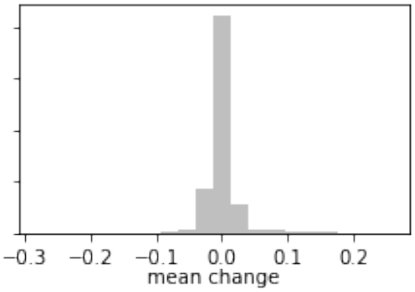
G) mean change group:cn_rech4, 1 entries
max:0.00557857, min:0.00557857



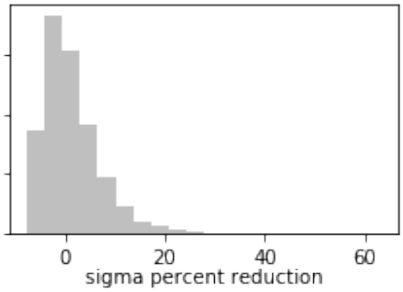
H) sigma change group:cn_rech4, 1 entries
max: 17.4903, min: 17.4903



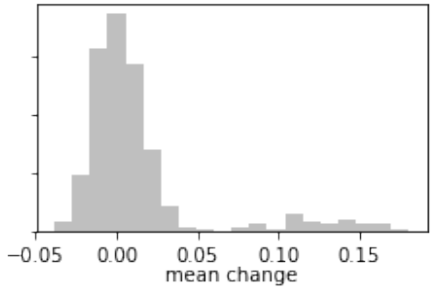
A) mean change group:all, 12061 entries
max: 0.257931, min: -0.282452



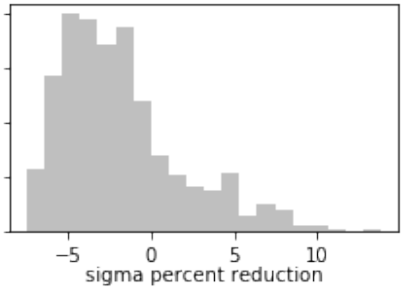
B) sigma change group:all, 12061 entries
max: 63.3711, min: -7.6746



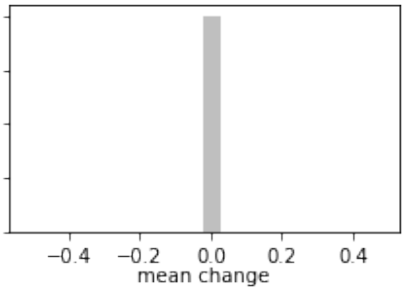
C) mean change group:gr_ss5, 705 entries
max: 0.180752, min:-0.0384441



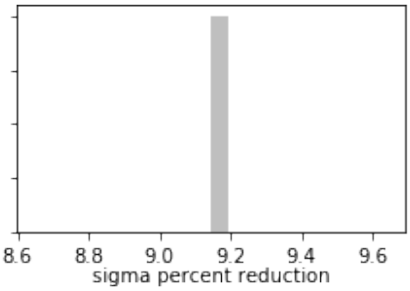
D) sigma change group:gr_ss5, 705 entries
max: 13.8606, min: -7.49701



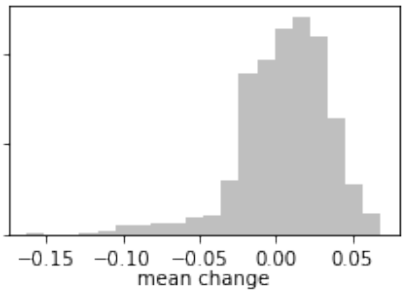
E) mean change group:cn_sy8, 1 entries
max:-0.0203465, min:-0.0203465



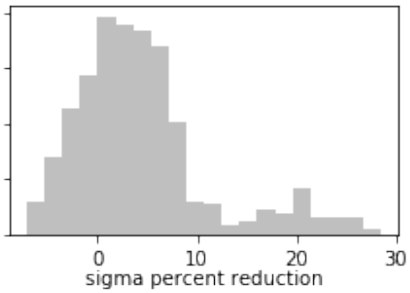
F) sigma change group:cn_sy8, 1 entries
max: 9.14487, min: 9.14487



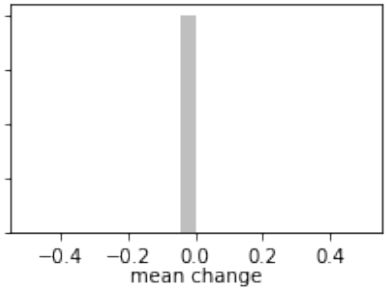
G) mean change group:gr_vka5, 705 entries
max: 0.06875, min: -0.162825



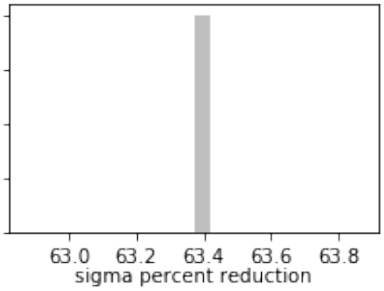
H) sigma change group:gr_vka5, 705 entries
max: 28.5442, min: -7.14812



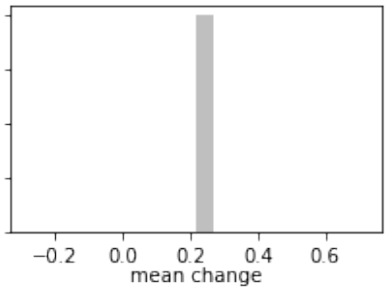
A) mean change group:flow, 1 entries
max: 0.0039107, min: 0.0039107



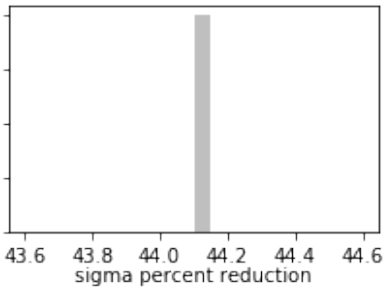
B) sigma change group:flow, 1 entries
max: 63.3711, min: 63.3711



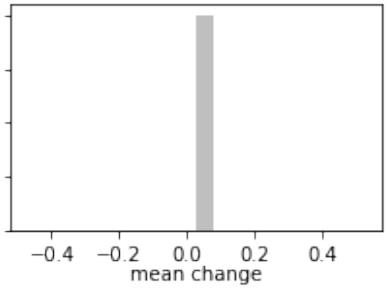
C) mean change group:cn_hk8, 1 entries
max: 0.218268, min: 0.218268



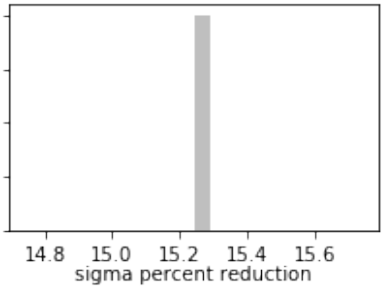
D) sigma change group:cn_hk8, 1 entries
max: 44.1008, min: 44.1008



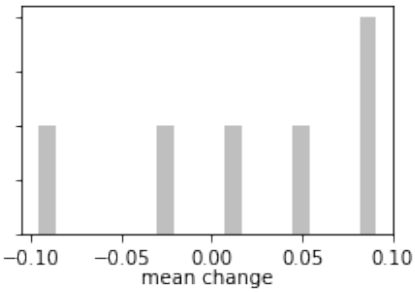
E) mean change group:cn_ss8, 1 entries
max: 0.0293406, min: 0.0293406



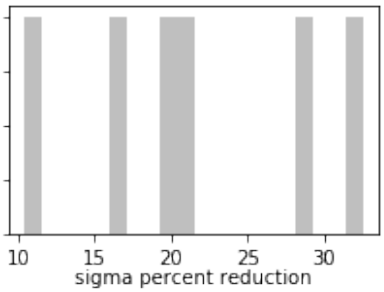
F) sigma change group:cn_ss8, 1 entries
max: 15.2421, min: 15.2421



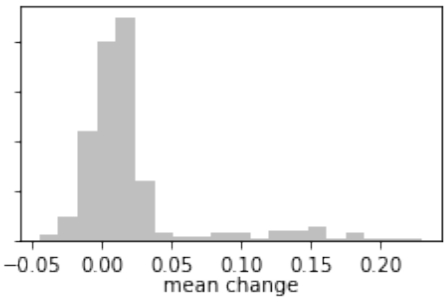
G) mean change group:welflux_k02, 6 entries
max: 0.091288, min:-0.0960216



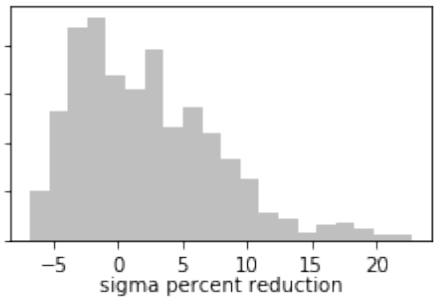
H) sigma change group:welflux_k02, 6 entries
max: 32.5356, min: 10.4291



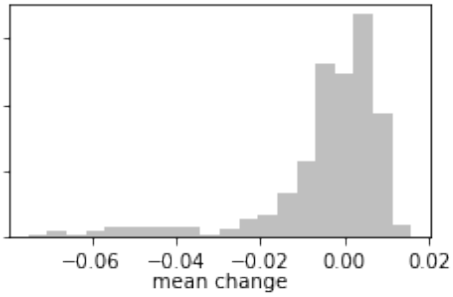
A) mean change group:gr_ss3, 705 entries
max: 0.230436, min:-0.0450849



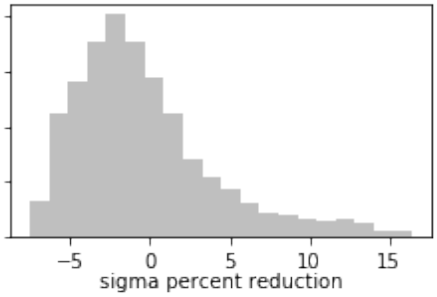
B) sigma change group:gr_ss3, 705 entries
max: 22.8126, min: -6.81584



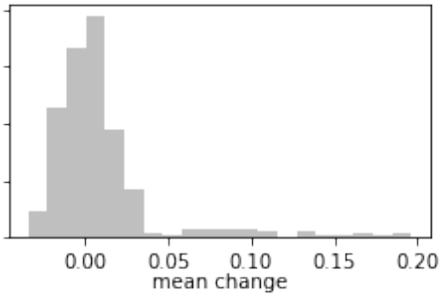
C) mean change group:gr_sy4, 705 entries
max: 0.0158256, min:-0.0749318



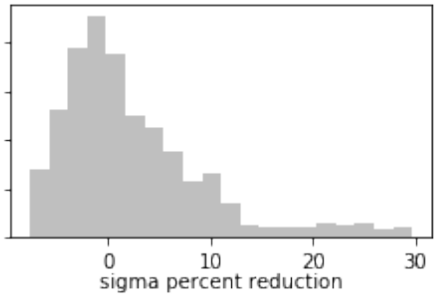
D) sigma change group:gr_sy4, 705 entries
max: 16.4455, min: -7.52924



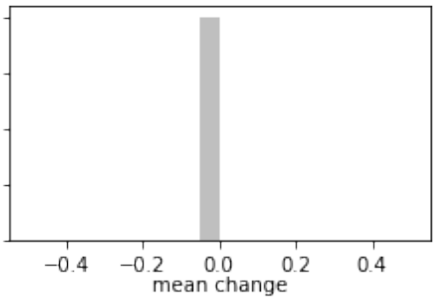
E) mean change group:gr_hk5, 705 entries
max: 0.196282, min:-0.0341604



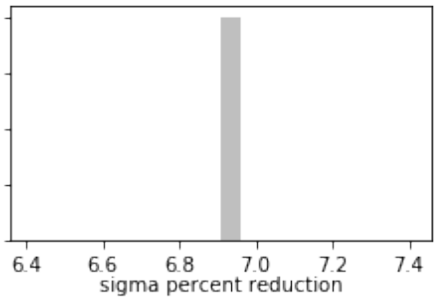
F) sigma change group:gr_hk5, 705 entries
max: 29.7439, min: -7.6746



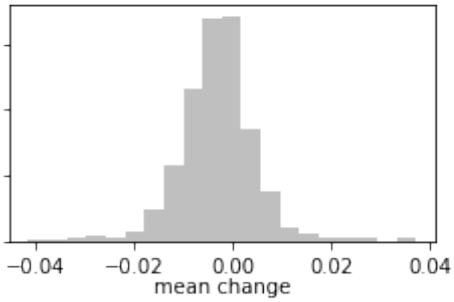
G) mean change group:cn_strt8, 1 entries
max:0.00176656, min:0.00176656



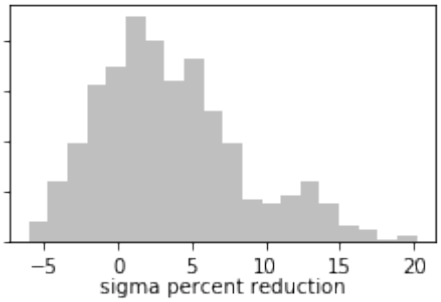
H) sigma change group:cn_strt8, 1 entries
max: 6.90931, min: 6.90931



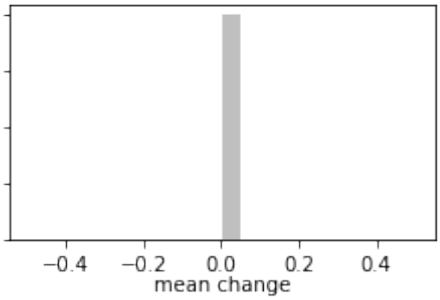
A) mean change group:gr_sy5, 705 entries
max: 0.0372717, min:-0.0415198



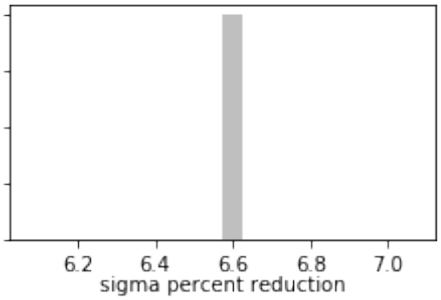
B) sigma change group:gr_sy5, 705 entries
max: 20.2242, min: -6.02721



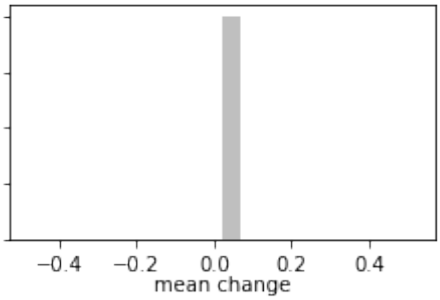
C) mean change group:cn_strt7, 1 entries
max:0.00263284, min:0.00263284



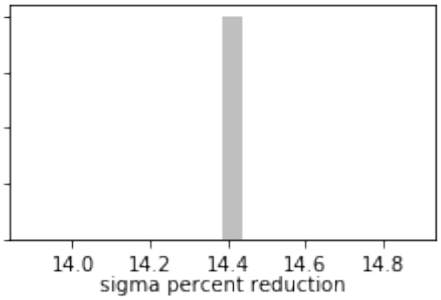
D) sigma change group:cn_strt7, 1 entries
max: 6.57396, min: 6.57396



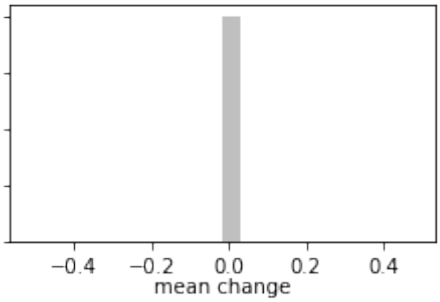
E) mean change group:cn_rech5, 1 entries
max: 0.0206144, min: 0.0206144



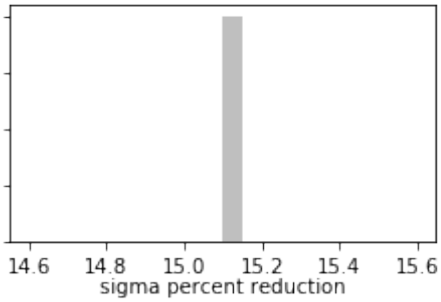
F) sigma change group:cn_rech5, 1 entries
max: 14.3875, min: 14.3875



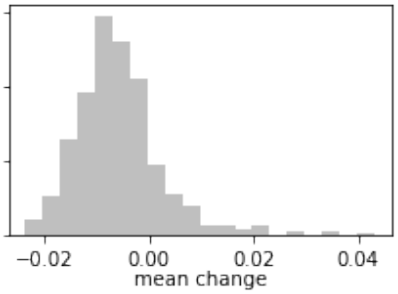
G) mean change group:cn_vka7, 1 entries
max: -0.017307, min: -0.017307



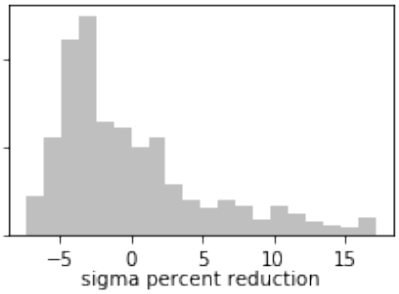
H) sigma change group:cn_vka7, 1 entries
max: 15.0998, min: 15.0998



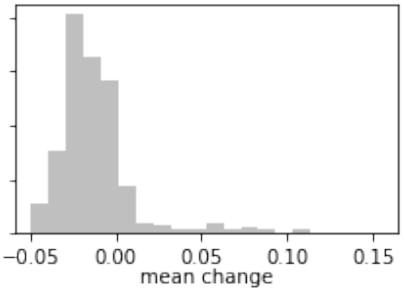
A) mean change group:gr_sy3, 705 entries
max: 0.0430162, min:-0.0235092



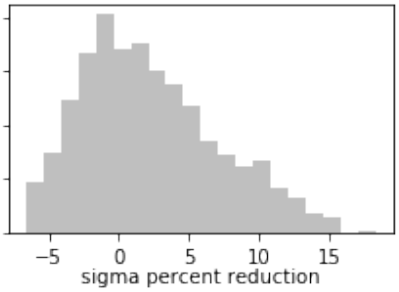
B) sigma change group:gr_sy3, 705 entries
max: 17.1321, min: -7.35737



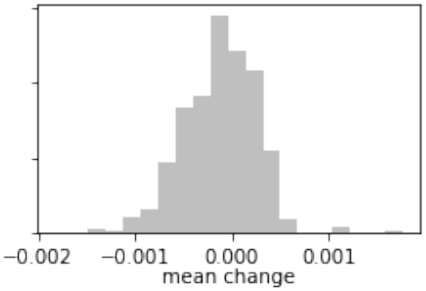
C) mean change group:gr_ss4, 705 entries
max: 0.154333, min:-0.0492342



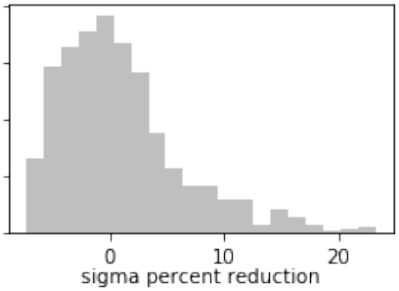
D) sigma change group:gr_ss4, 705 entries
max: 18.2678, min: -6.5969



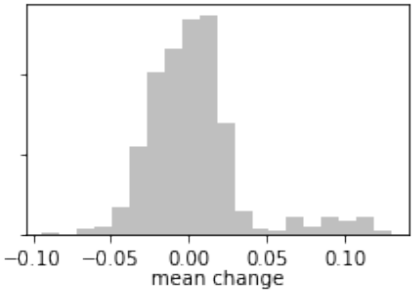
E) mean change group:gr_strt4, 705 entries
max:0.00176365, min:-0.0018413



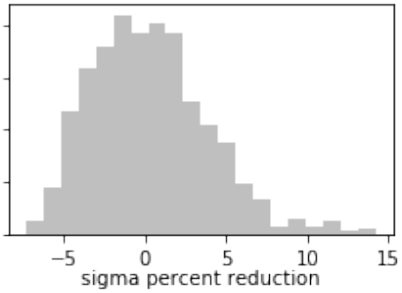
F) sigma change group:gr_strt4, 705 entries
max: 23.2695, min: -7.27776



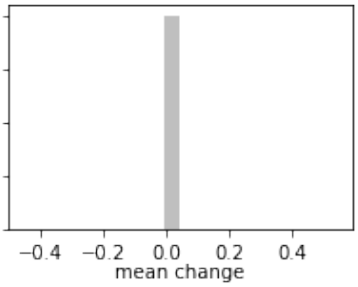
G) mean change group:gr_vka4, 705 entries
max: 0.129793, min:-0.0939331



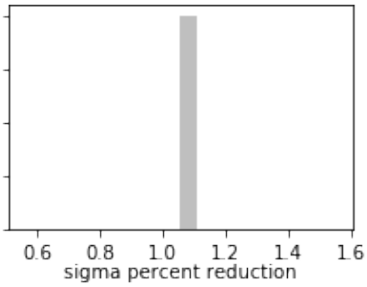
H) sigma change group:gr_vka4, 705 entries
max: 14.1951, min: -7.29506



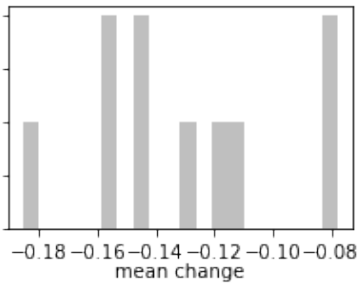
A) mean change group:cn_ss6, 1 entries
max: 0.0458744, min: 0.0458744



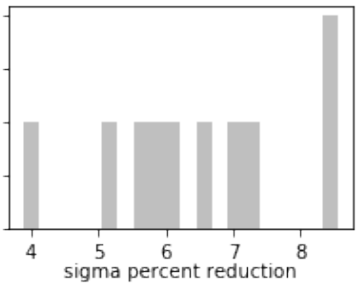
B) sigma change group:cn_ss6, 1 entries
max: 1.05704, min: 1.05704



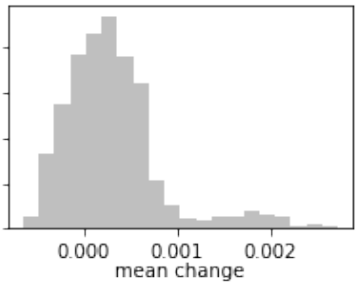
C) mean change group:drncond_k00, 10 entries
max:-0.0777135, min: -0.185375



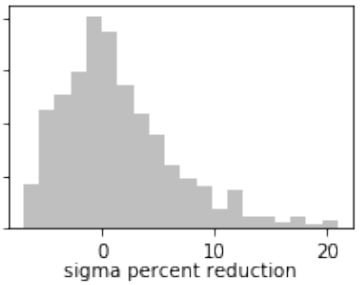
D) sigma change group:drncond_k00, 10 entries
max: 8.55008, min: 3.89718



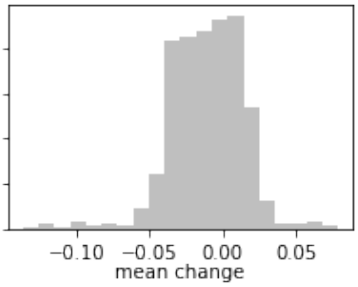
E) mean change group:gr_strt5, 705 entries
max:0.00271423, min:-0.000651308



F) sigma change group:gr_strt5, 705 entries
max: 20.9335, min: -7.01551



G) mean change group:gr_hk3, 705 entries
max: 0.0779455, min: -0.135868



H) sigma change group:gr_hk3, 705 entries
max: 23.6121, min: -7.29914