pestpp-ies

April 28, 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	\
ss6_cn	ss6_cn	log	1	0	
vka6_cn	vka6_cn	log	1	0	
grss5	grss5	log	705	0	
grss3	grss3	log	705	0	
grhk5	grhk5	log	705	0	
strk	strk	log	40	0	
vka8_cn	vka8_cn	log	1	0	
pp_strt0	pp_strt0	log	67	0	
pp_vka2	pp_vka2	log	67	0	
grsy5	grsy5	log	705	0	
pp_hk0	pp_hk0	log	67	0	
grrech2	grrech2	log	705	0	
pp_rech1	pp_rech1	log	67	0	
pp_vka0	pp_vka0	log	67	0	
grvka3	grvka3	log	705	0	
hk6_cn	hk6_cn	log	1	0	
grhk4	grhk4	log	705	0	

ss8_cn	ss8_cn	log	1	0
strt7_cn	strt7_cn	log	1	0
welflux_k02	welflux_k02	log	6	0
grsy3	grsy3	log	705	0
strt6_cn	strt6_cn	log	1	0
grstrt5	grstrt5	log	705	0
pp_hk2	pp_hk2	log	67	0
pp_ss0	pp_ss0	log	67	0
pp_sy1	pp_sy1	log	67	0
sy7_cn	sy7_cn	log	1	0
grvka4	grvka4	log	705	0
pp_rech0	pp_rech0	log	67	0
pp_hk1	pp_hk1	log	67	0
hk7_cn	hk7_cn	log	1	0
welflux	welflux	log	2	0 to 0.176091
vka7_cn	vka7_cn	log	1	0
grrech3	grrech3	log	705	0
grss4	grss4	log	705	0
pp_ss1	pp_ss1	log	67	0
pp_strt1	pp_strt1	log	67	0
pp_sy0	pp_sy0	log	67	0
rech4_cn	rech4_cn	log	1	0
pp_sy2	pp_sy2	log	67	0
sy6_cn	sy6_cn	log	1	0
grstrt4	grstrt4	log	705	0
drncond_k00	drncond_k00	log	10	0
pp_ss2	pp_ss2	log	67	0
pp_vka1	pp_vka1	log	67	0
sy8_cn	sy8_cn	log	1	0
grvka5	grvka5	log	705	0
rech5_cn	rech5_cn	log	1	-0.39794
grsy4	grsy4	log	705	0
grstrt3	grstrt3	log	705	0
grhk3	grhk3	log	705	0
strt8_cn	strt8_cn	log	1	0
pp_strt2	pp_strt2	log	67	0
hk8_cn	hk8_cn	log	1	0
ss7_cn	ss7_cn	log	1	0
flow	flow	log	1	0

	upper bound	lower bound	standard deviation
ss6_cn	1	-1	0.5
vka6_cn	1	-1	0.5
grss5	1	-1	0.5
grss3	1	-1	0.5
grhk5	1	-1	0.5
strk	2	-2	1
vka8_cn	1	-1	0.5

pp_strt0	0.0211893	-0.0222764	0.0108664
pp_vka2	1	-1	0.5
grsy5	0.243038	-0.60206	0.211275
pp_hk0	1	-1	0.5
grrech2	0.0413927	-0.0457575	0.0217875
pp_rech1	0.0413927	-0.0457575	0.0217875
pp_vka0	1	-1	0.5
grvka3	1	-1	0.5
hk6_cn	1	-1	0.5
grhk4	1	-1	0.5
ss8_cn	1	-1	0.5
strt7_cn	0.0211893	-0.0222764	0.0108664
welflux_k02	1	-1	0.5
grsy3	0.243038	-0.60206	0.211275
strt6_cn	0.0211893	-0.0222764	0.0108664
grstrt5	0.0211893	-0.0222764	0.0108664
pp_hk2	1	-1	0.5
pp_ss0	1	-1	0.5
pp_sy1	0.243038	-0.60206	0.211275
sy7_cn	0.243038	-0.60206	0.211275
grvka4	1	-1	0.5
pp_rech0	0.0413927	-0.0457575	0.0217875
pp_hk1	1	-1	0.5
hk7_cn	1	-1	0.5
welflux	0.176091 to 0.30103	-0.30103 to 0	0.0752575 to 0.11928
vka7_cn	1	-1	0.5
grrech3	0.0413927	-0.0457575	0.0217875
grss4	1	-1	0.5
pp_ss1	1	-1	0.5
pp_strt1	0.0211893	-0.0222764	0.0108664
pp_sy0	0.243038	-0.60206	0.211275
rech4_cn	0.0791812	-0.09691	0.0440228
pp_sy2	0.243038	-0.60206	0.211275
sy6_cn	0.243038	-0.60206	0.211275
grstrt4	0.0211893	-0.0222764	0.0108664
drncond_k00	1	-1	0.5
pp_ss2	1	-1	0.5
pp_vka1	1	-1	0.5
sy8_cn	0.243038	-0.60206	0.211275
grvka5	1	-1	0.5
rech5_cn	-0.09691	-1	0.225772
grsy4	0.243038	-0.60206	0.211275
grstrt3	0.0211893	-0.0222764	0.0108664
grhk3	1	-1	0.5
strt8_cn	0.0211893	-0.0222764	0.0108664
pp_strt2	0.0211893	-0.0222764	0.0108664
hk8_cn	1	-1	0.5
ss7_cn	1	-1	0.5

```
flow                    0.09691          -0.124939          0.0554622
```

Should we fix either PP or grids?

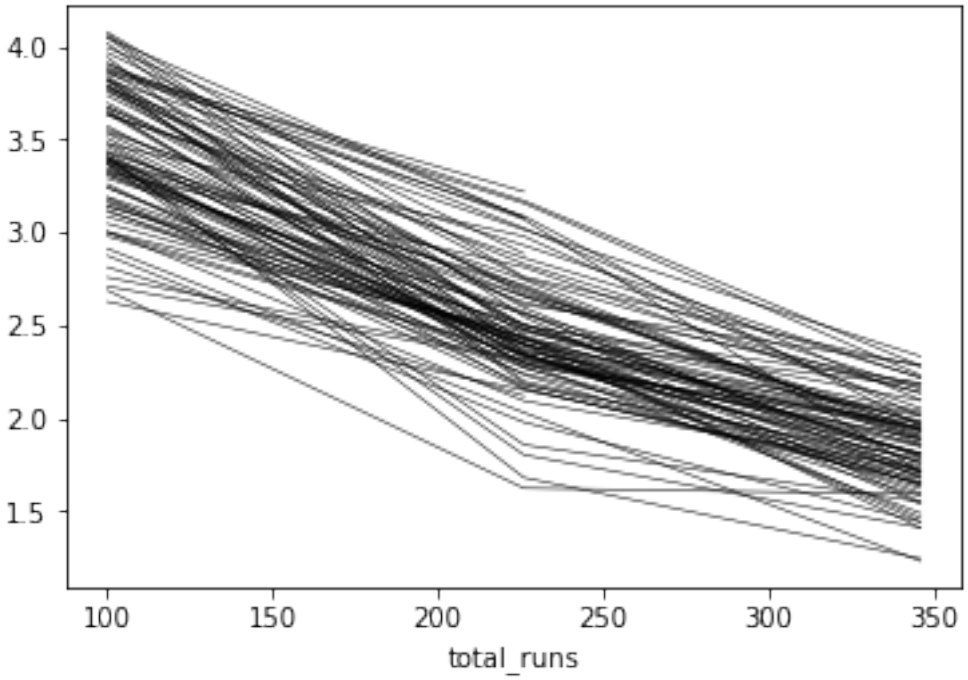
```
In [4]: par = pst.parameter_data
        # grid pars
        #should_fix = par.loc[par.pargp.apply(lambda x: "gr" in x),"parnme"]
        # pp pars
        #should_fix = par.loc[par.pargp.apply(lambda x: "pp" in x),"parnme"]

        # 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

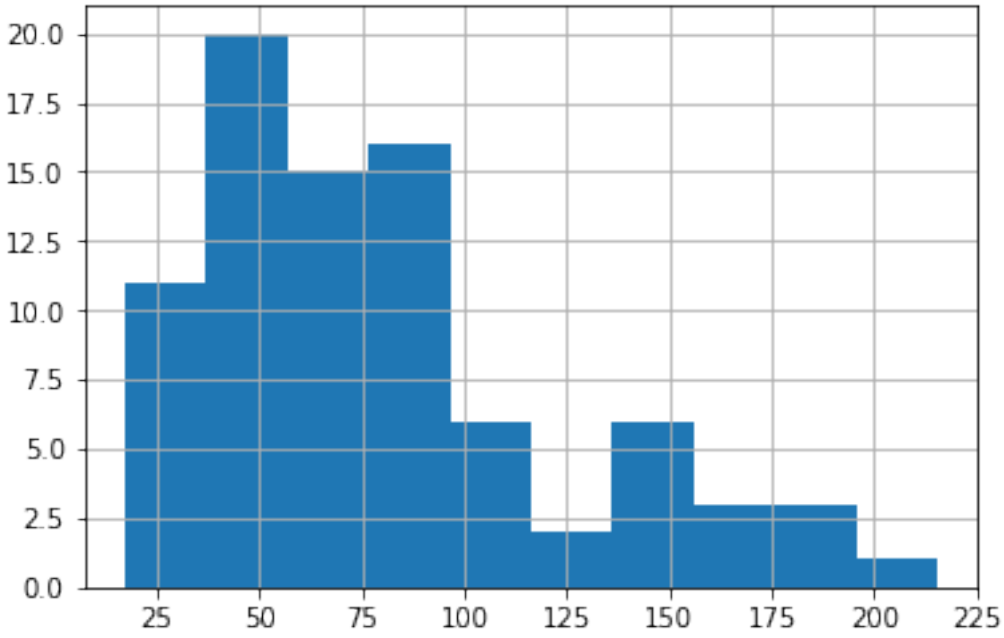
```
In [5]: pst.pestpp_options["ies_num_reals"] = 100
        pst.pestpp_options["ies_par_en"] = "prior.jcb"
        pst.pestpp_options["ies_bad_phi_sigma"] = 2.0
        pst.pestpp_options["overdue_giveup_fac"] = 10.0
        pst.control_data.noptmax = 2

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()
```

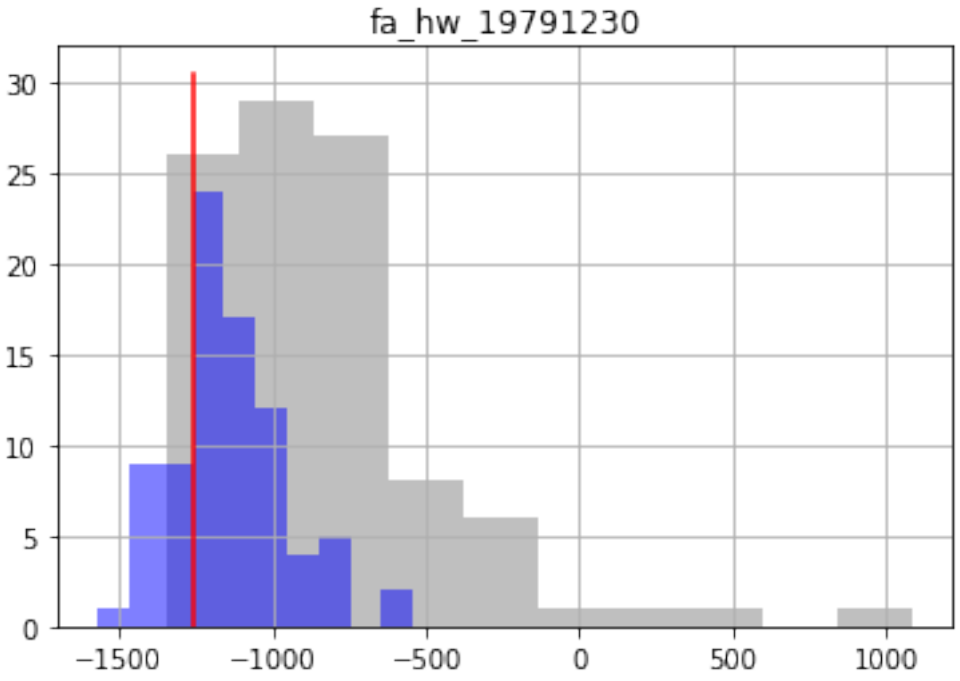


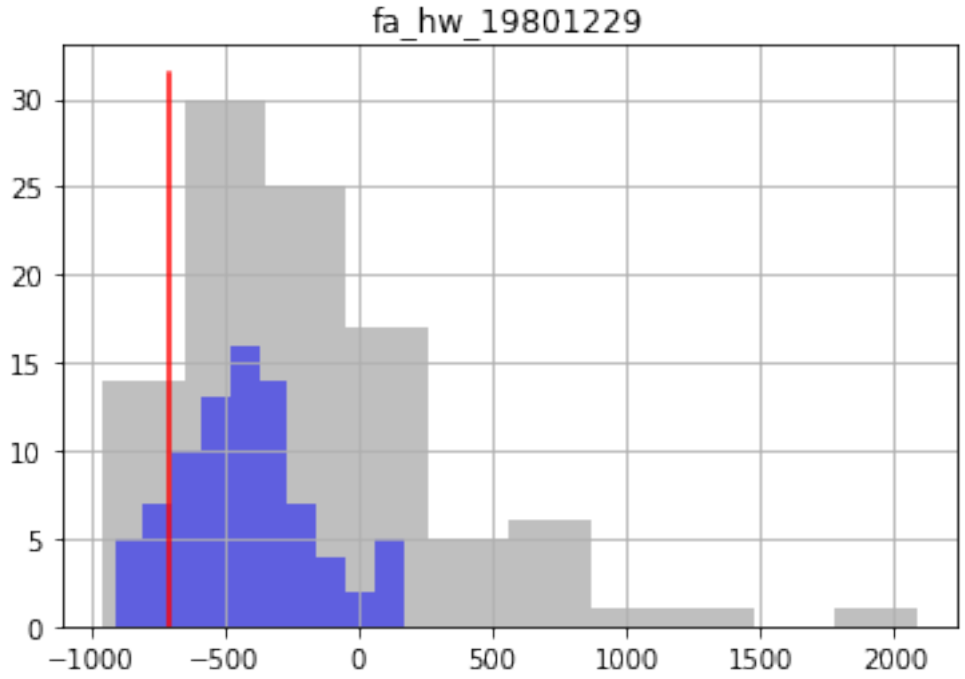
Out[8]: <matplotlib.axes._subplots.AxesSubplot at 0x1817e82400>

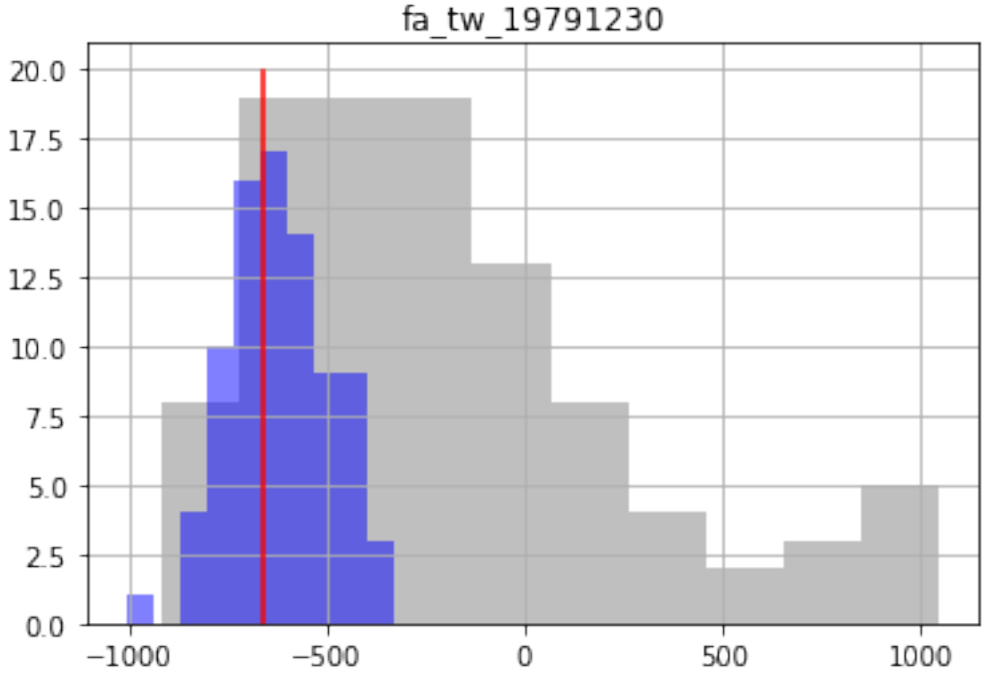


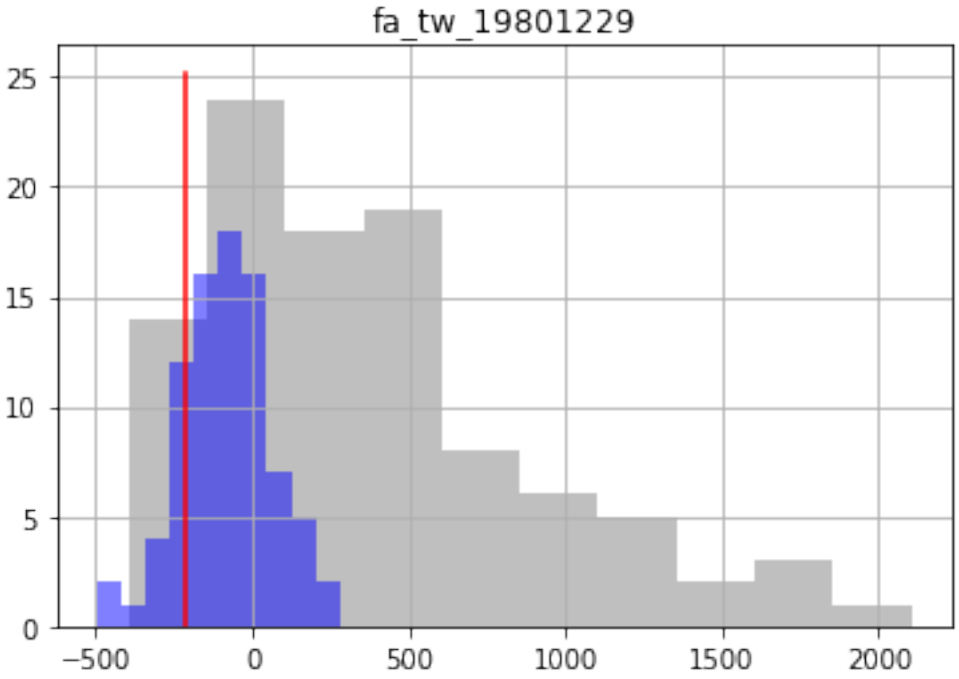
Crushed phi! this must be the perfect model!
Plot forecast prior and posterior histograms with "truth" (red line)

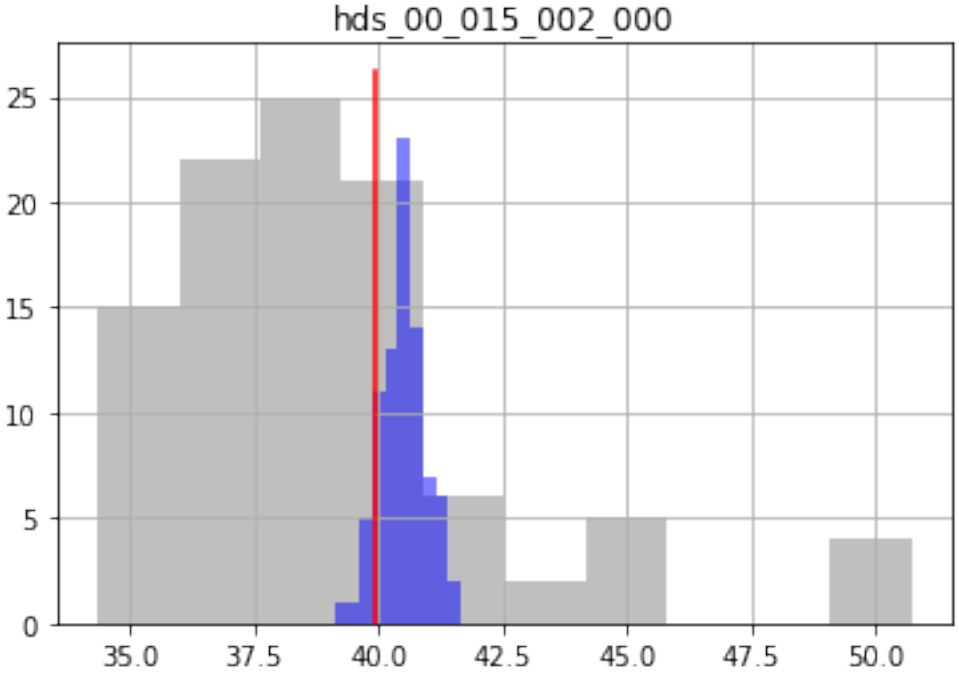
In [9]:
```
oe_pr = pd.read_csv(os.path.join(m_d,"freyberg_ies.0.obs.csv"),index_col=0)
oe_pt = pd.read_csv(os.path.join(m_d,"freyberg_ies.{0}.obs.csv".format(pst.control_data
obs = pst.observation_data
fnames = pst.pestpp_options["forecasts"].split(",")
for forecast in fnames:
    ax = plt.subplot(111)
    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()
```

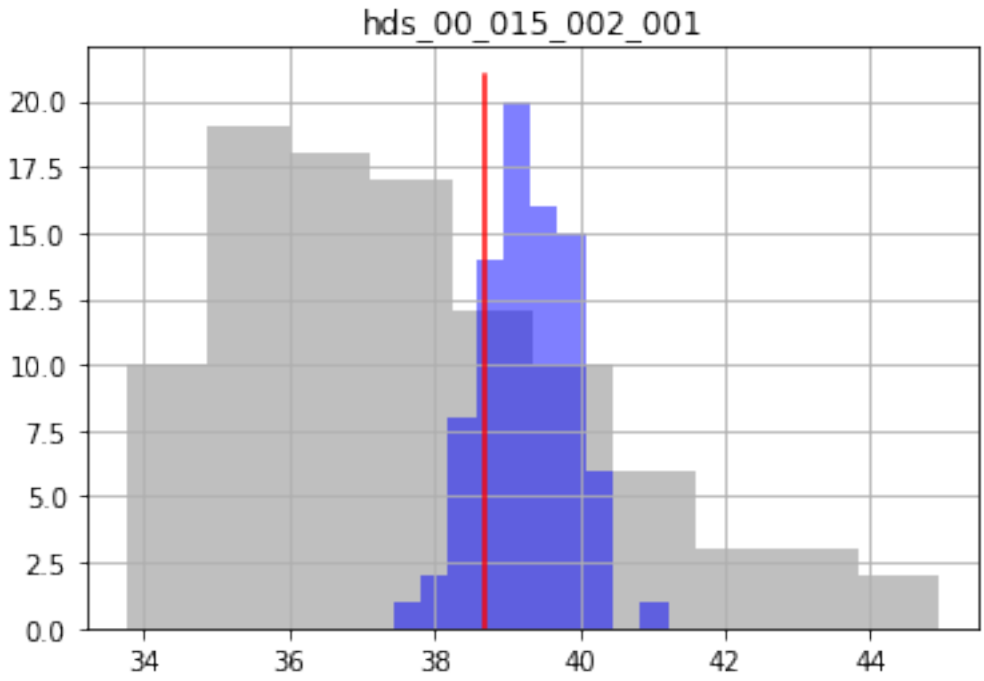



fa_hw_19801229
30
25
20
15
10
5
0
−1000
−500
0
500
1000
1500
2000


fa_tw_19791230
20.0
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0.0
−1000
−500
0
500
1000


fa_tw_19801229
25
20
15
10
5
0
−500
0
500
1000
1500
2000


hds_00_015_002_000
25
20
15
10
5
0
35.0
37.5
40.0
42.5
45.0
47.5
50.0

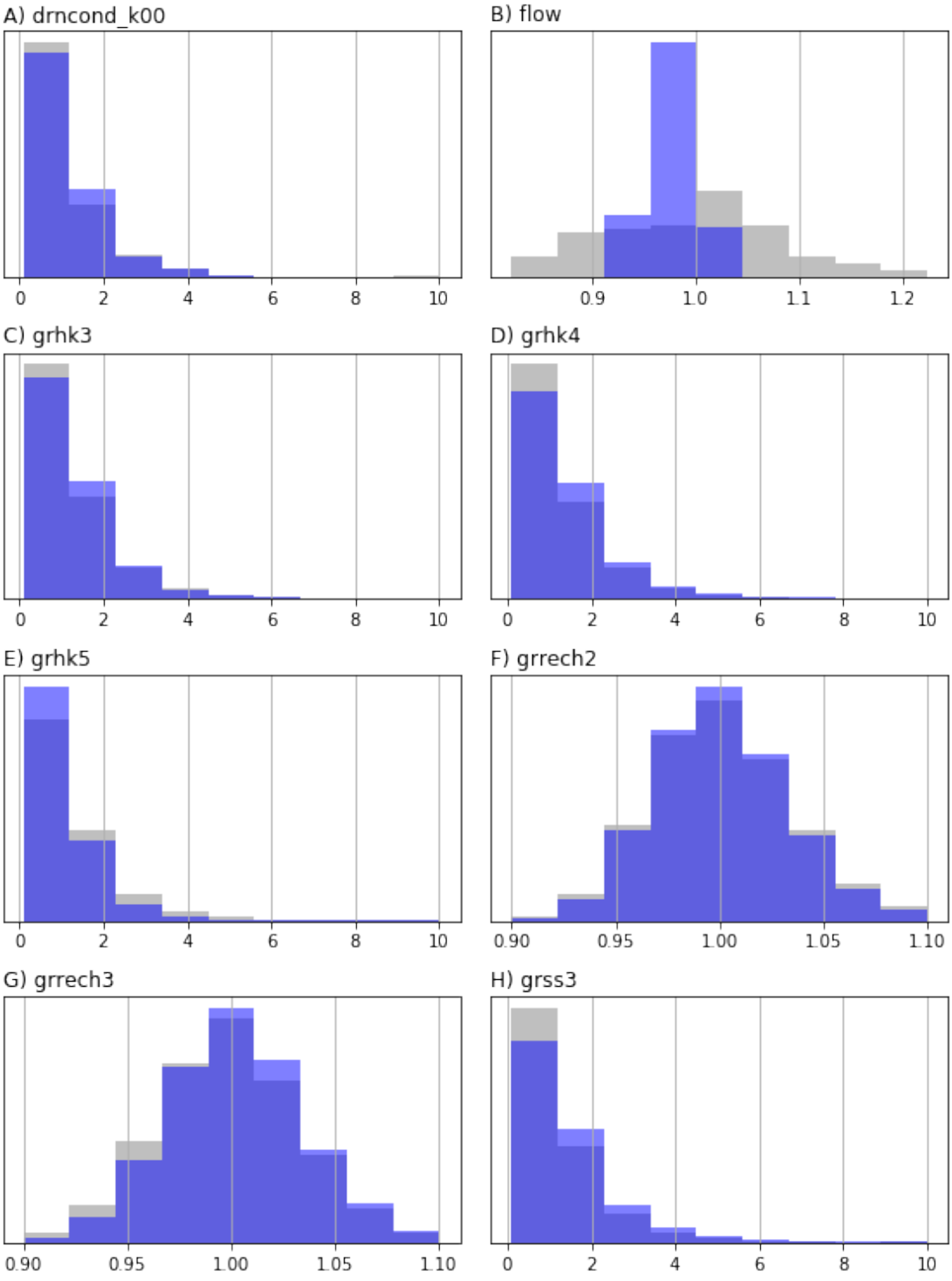


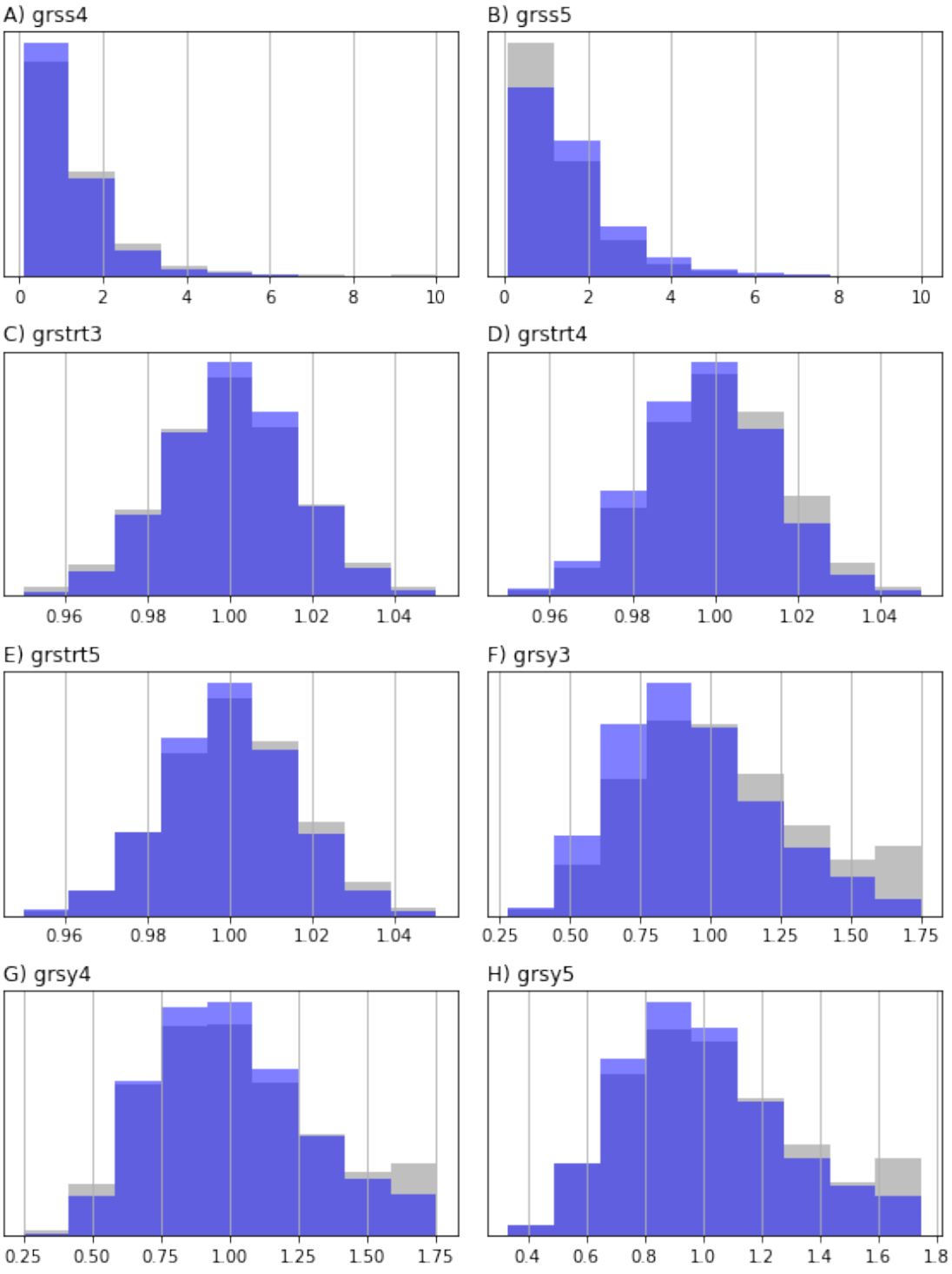
Plot parameter histograms by group

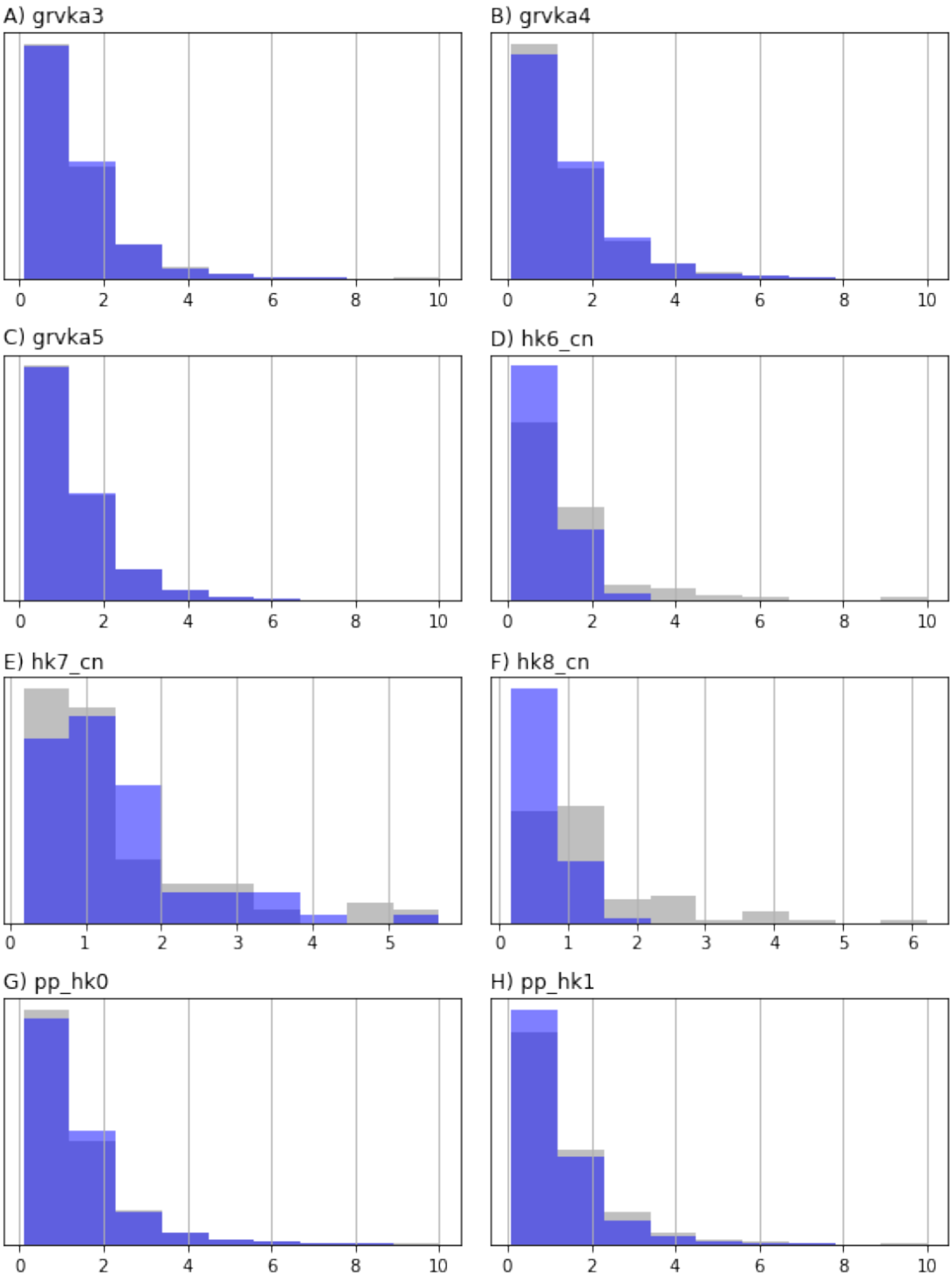
```
In [10]: pe_pr = pd.read_csv(os.path.join(m_d,"freyberg_ies.0.par.csv"),index_col=0)
         pe_pt = pd.read_csv(os.path.join(m_d,"freyberg_ies.{0}.par.csv".format(pst.control_dat
         par = pst.parameter_data
         pdict = par.groupby("pargp").groups
         pyemu.plot_utils.ensemble_helper({"0.5":pe_pr,"b":pe_pt},plot_cols=pdict)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

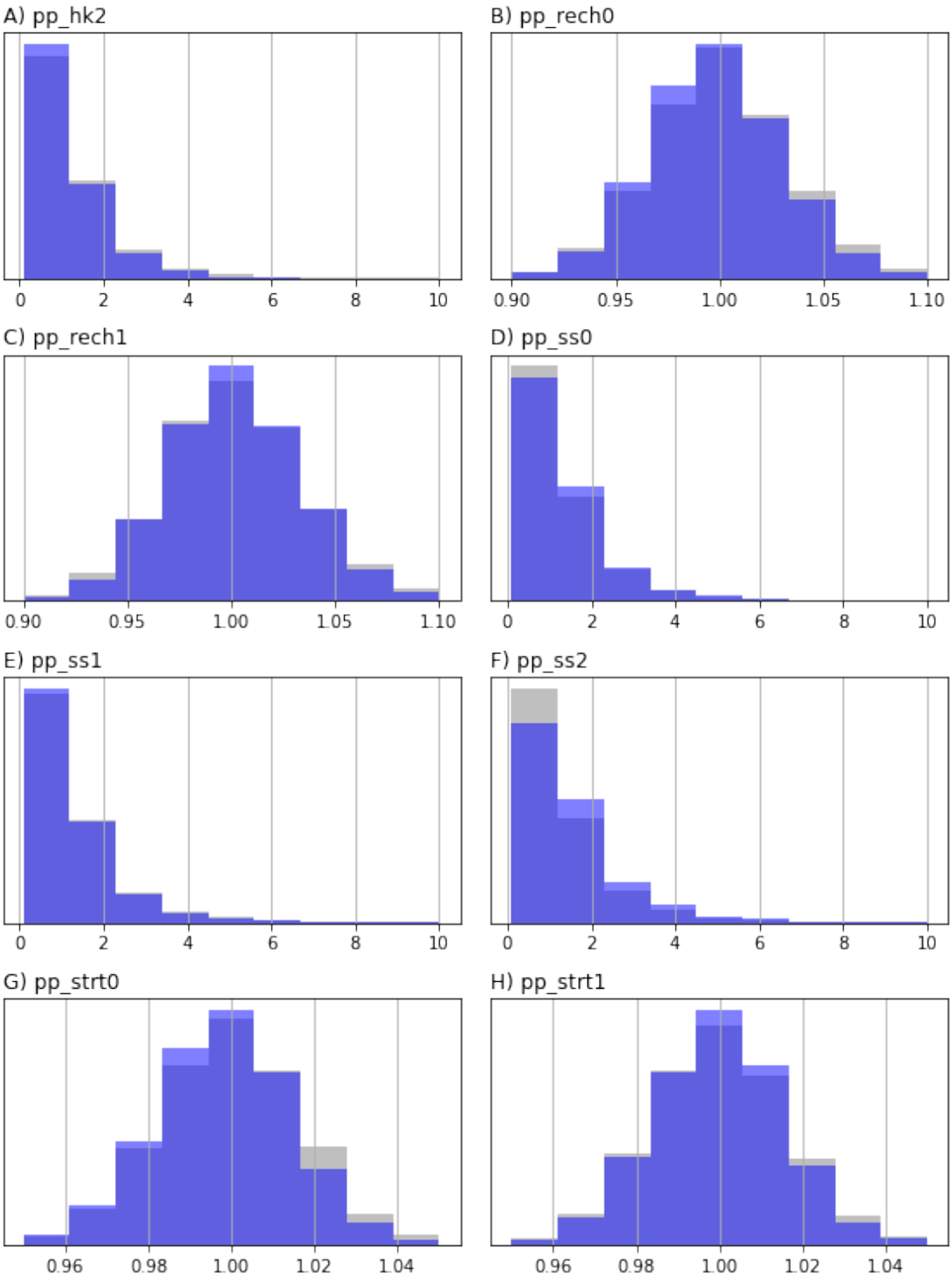
```
/Users/jeremyw/miniconda3/lib/python3.5/site-packages/IPython/core/interactiveshell.py:2785: Dt
  interactivity=interactivity, compiler=compiler, result=result)
```

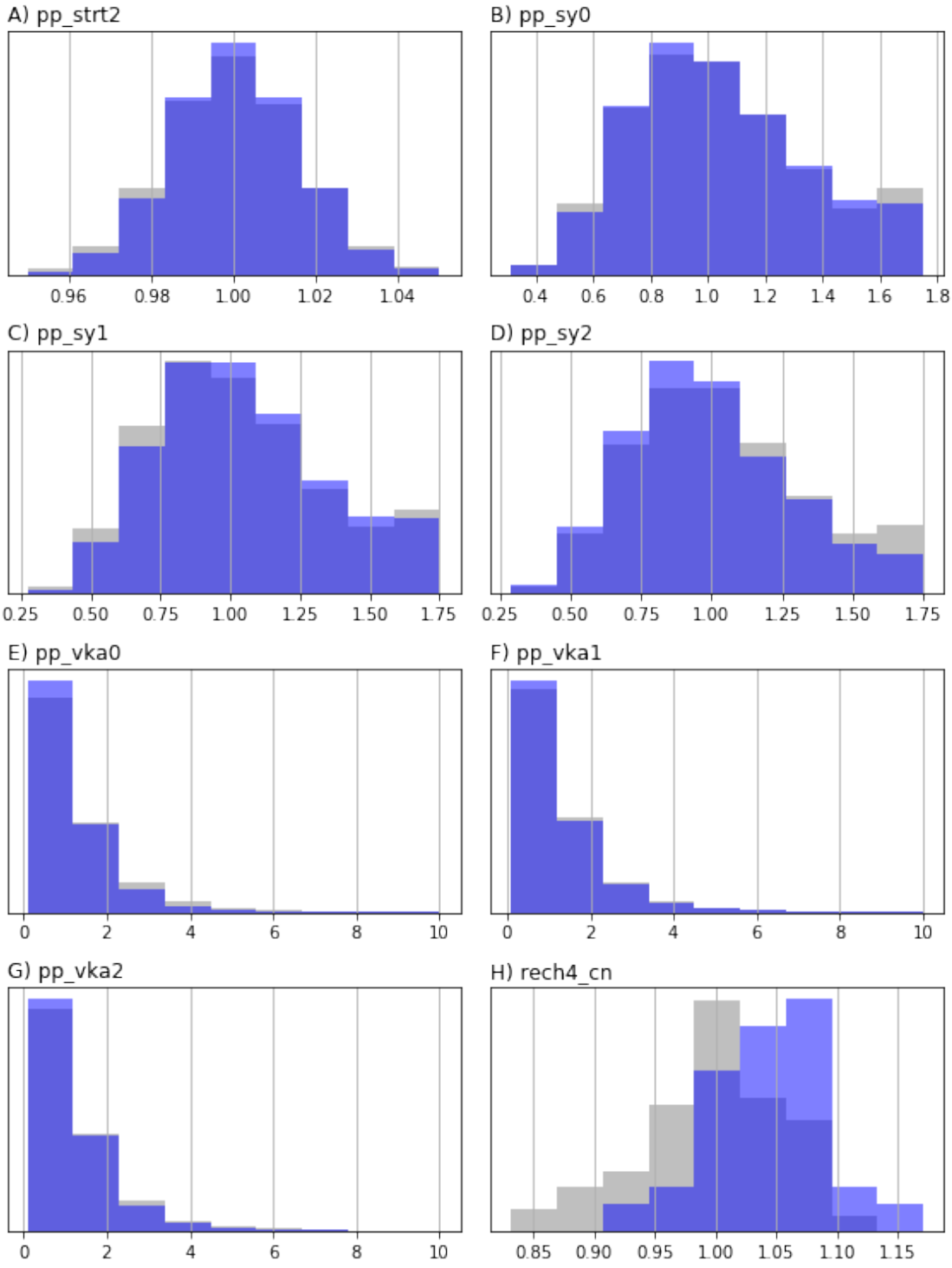
```
<Figure size 576x756 with 0 Axes>
```

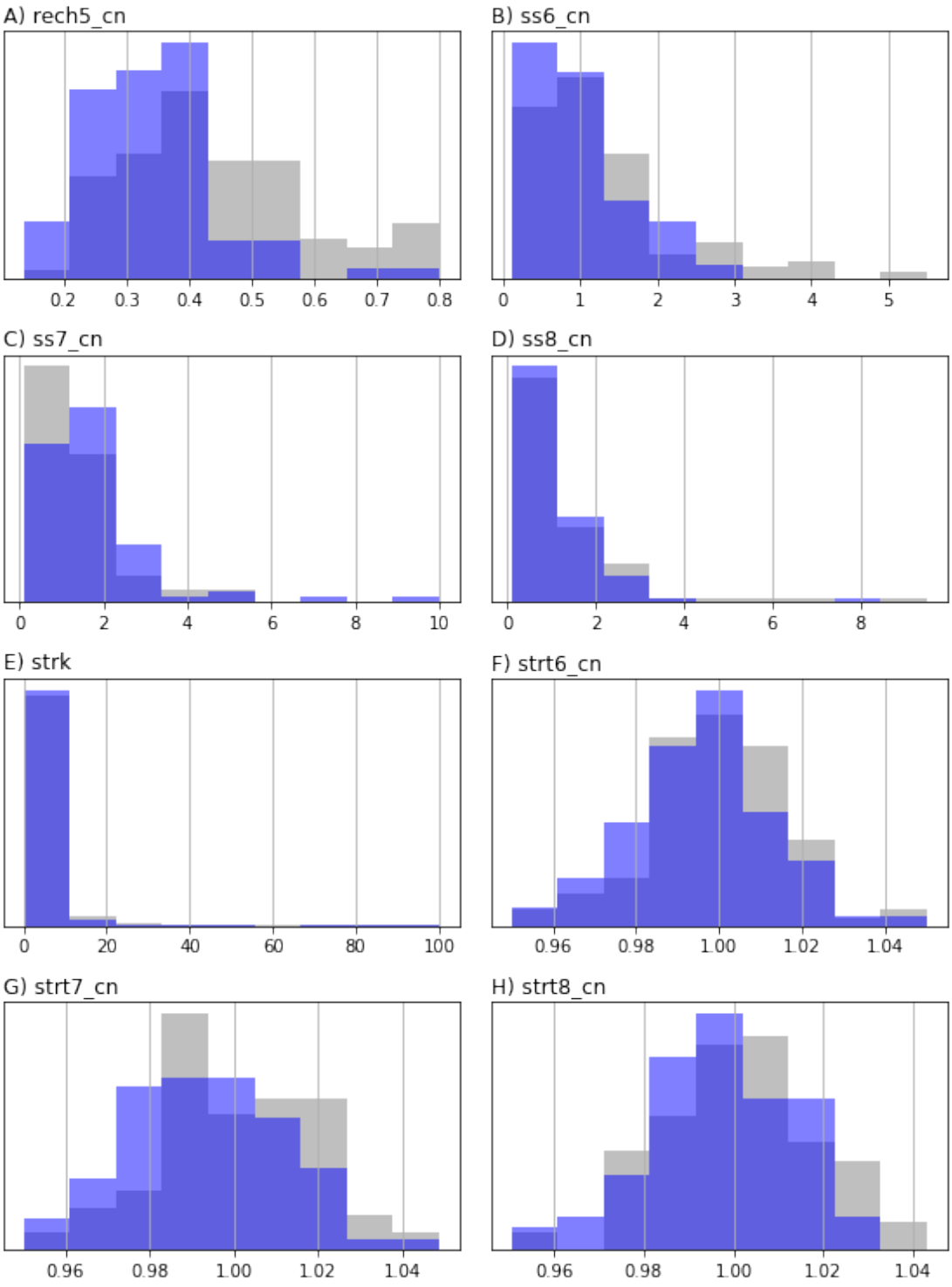

A) drncond_k00
0
2
4
6
8
10
B) flow
0.9
1.0
1.1
1.2
C) grhk3
0
2
4
6
8
10
D) grhk4
0
2
4
6
8
10
E) grhk5
0
2
4
6
8
10
F) grrech2
0.90
0.95
1.00
1.05
1.10
G) grrech3
0.90
0.95
1.00
1.05
1.10
H) grss3
0
2
4
6
8
10

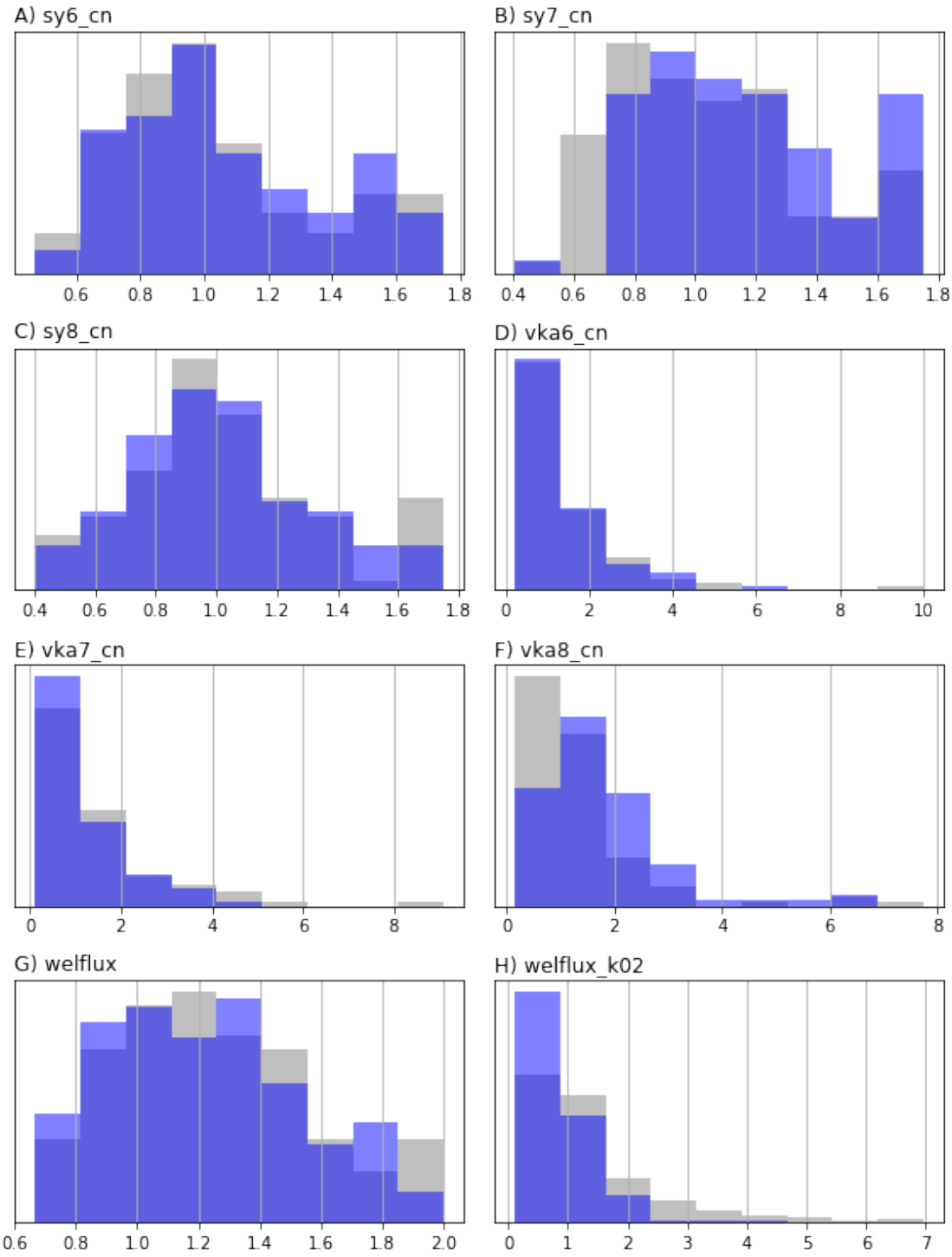

A) grss4
0
2
4
6
8
10
B) grss5
0
2
4
6
8
10
C) grstrt3
0.96
0.98
1.00
1.02
1.04
D) grstrt4
0.96
0.98
1.00
1.02
1.04
E) grstrt5
0.96
0.98
1.00
1.02
1.04
F) grsy3
0.25
0.50
0.75
1.00
1.25
1.50
1.75
G) grsy4
0.25
0.50
0.75
1.00
1.25
1.50
1.75
H) grsy5
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8


A) grvka3
B) grvka4
C) grvka5
D) hk6_cn
E) hk7_cn
F) hk8_cn
G) pp_hk0
H) pp_hk1


A) pp_hk2
0
2
4
6
8
10
B) pp_rech0
0.90
0.95
1.00
1.05
1.10
C) pp_rech1
0.90
0.95
1.00
1.05
1.10
D) pp_ss0
0
2
4
6
8
10
E) pp_ss1
0
2
4
6
8
10
F) pp_ss2
0
2
4
6
8
10
G) pp_strt0
0.96
0.98
1.00
1.02
1.04
H) pp_strt1
0.96
0.98
1.00
1.02
1.04


A) pp_strt2
0.96
0.98
1.00
1.02
1.04
B) pp_sy0
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
C) pp_sy1
0.25
0.50
0.75
1.00
1.25
1.50
1.75
D) pp_sy2
0.25
0.50
0.75
1.00
1.25
1.50
1.75
E) pp_vka0
0
2
4
6
8
10
F) pp_vka1
0
2
4
6
8
10
G) pp_vka2
0
2
4
6
8
10
H) rech4_cn
0.85
0.90
0.95
1.00
1.05
1.10
1.15


A) rech5_cn
0.2
0.3
0.4
0.5
0.6
0.7
0.8
B) ss6_cn
0
1
2
3
4
5
C) ss7_cn
0
2
4
6
8
10
D) ss8_cn
0
2
4
6
8
E) strk
0
20
40
60
80
100
F) strt6_cn
0.96
0.98
1.00
1.02
1.04
G) strt7_cn
0.96
0.98
1.00
1.02
1.04
H) strt8_cn
0.96
0.98
1.00
1.02
1.04



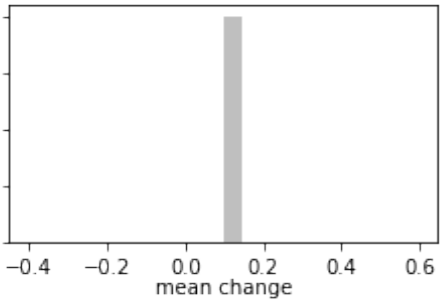

```
In [11]: pyemu.plot_utils.ensemble_change_summary(pe_pr,pe_pt,pst=pst,bins=20)
         par = pst.parameter_data
         li = par.partrans=="log"
```

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

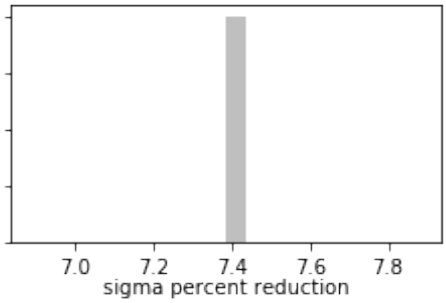
```
Out[11]: (100, 13200)
```

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

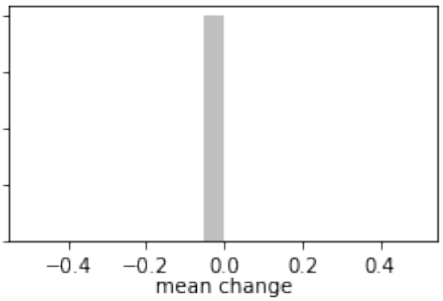
A) mean change group:ss6_cn, 1 entries
max: 0.0971803, min: 0.0971803



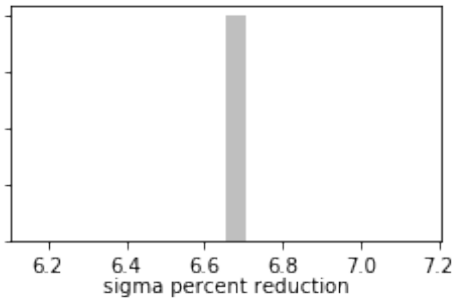
B) sigma change group:ss6_cn, 1 entries
max: 7.3844, min: 7.3844



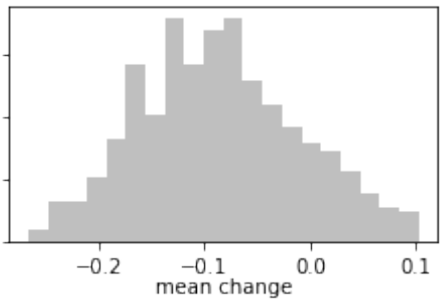
C) mean change group:vka6_cn, 1 entries
max:-0.00205207, min:-0.00205207



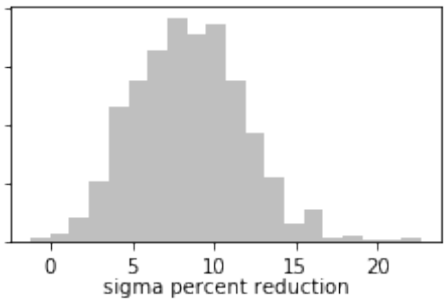
D) sigma change group:vka6_cn, 1 entries
max: 6.65533, min: 6.65533



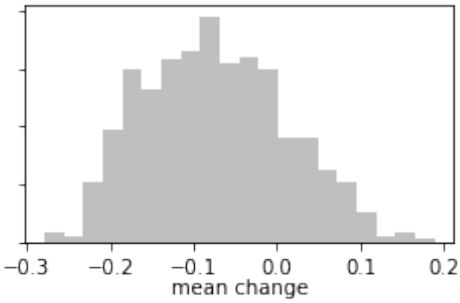
E) mean change group:grss5, 705 entries
max: 0.102548, min: -0.266688



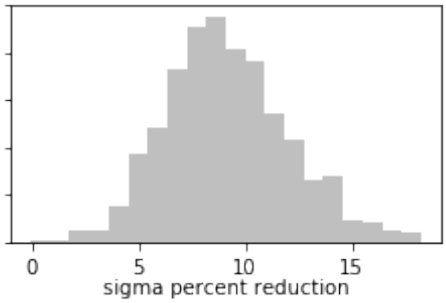
F) sigma change group:grss5, 705 entries
max: 22.6526, min: -1.21124



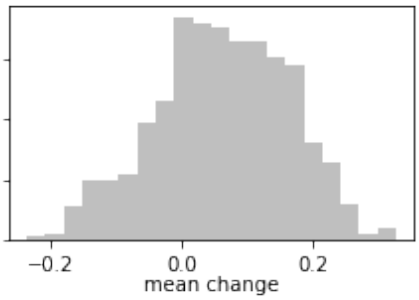
G) mean change group:grss3, 705 entries
max: 0.188897, min: -0.279149



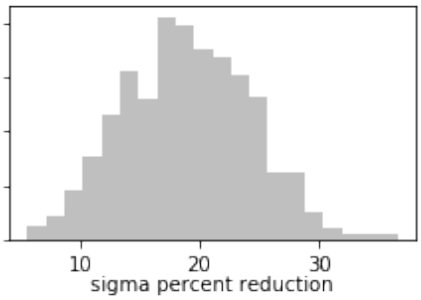
H) sigma change group:grss3, 705 entries
max: 18.2268, min:-0.0486687



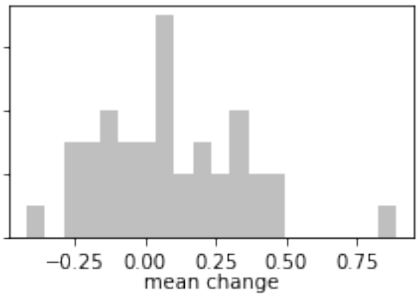
A) mean change group:grhk5, 705 entries
max: 0.326491, min: -0.235445



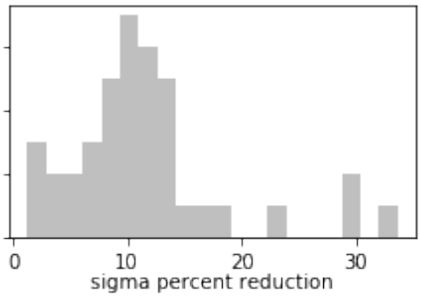
B) sigma change group:grhk5, 705 entries
max: 36.5957, min: 5.56976



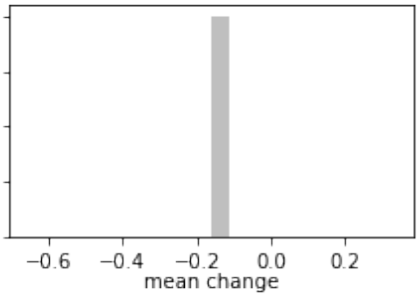
C) mean change group:strk, 40 entries
max: 0.887499, min: -0.418932



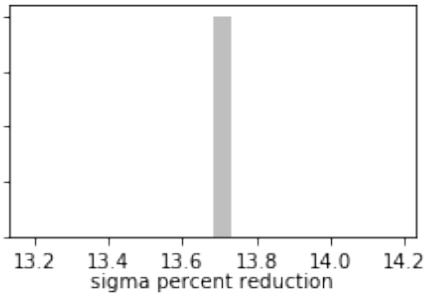
D) sigma change group:strk, 40 entries
max: 33.6005, min: 1.29142



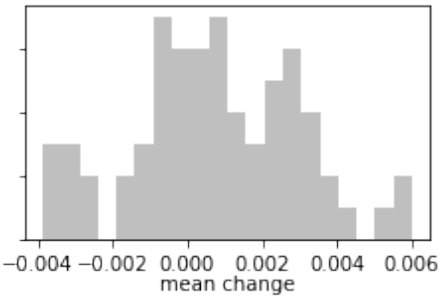
E) mean change group:vka8_cn, 1 entries
max: -0.160681, min: -0.160681



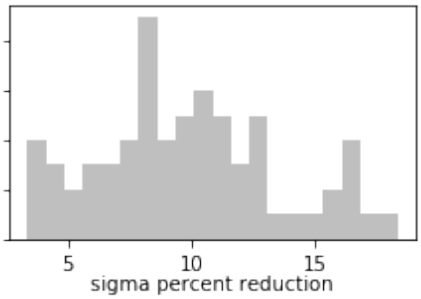
F) sigma change group:vka8_cn, 1 entries
max: 13.6813, min: 13.6813



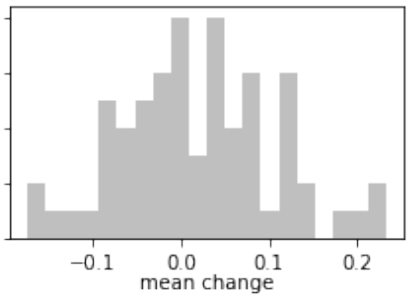
G) mean change group:pp_strt0, 67 entries
max:0.00600315, min:-0.00387314



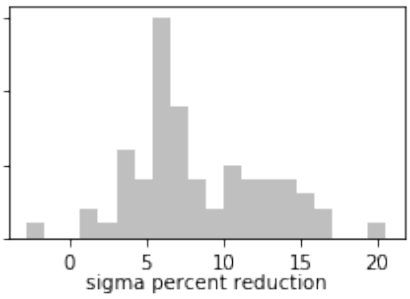
H) sigma change group:pp_strt0, 67 entries
max: 18.3272, min: 3.36293



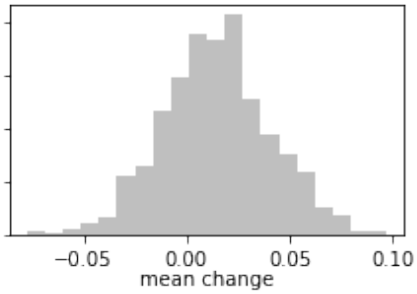
A) mean change group:pp_vka2, 67 entries
max: 0.234138, min: -0.175498



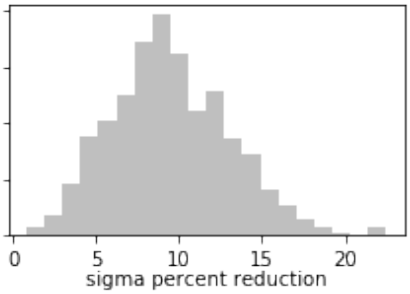
B) sigma change group:pp_vka2, 67 entries
max: 20.574, min: -2.79581



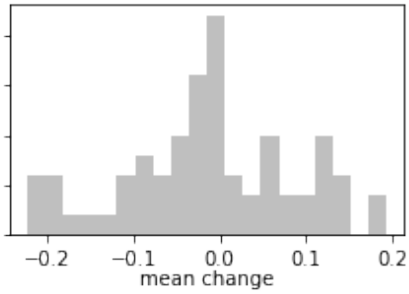
C) mean change group:grsy5, 705 entries
max: 0.0971963, min:-0.0775899



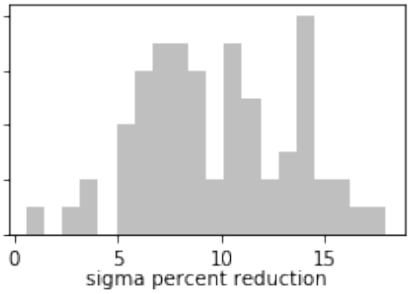
D) sigma change group:grsy5, 705 entries
max: 22.4869, min: 0.791827



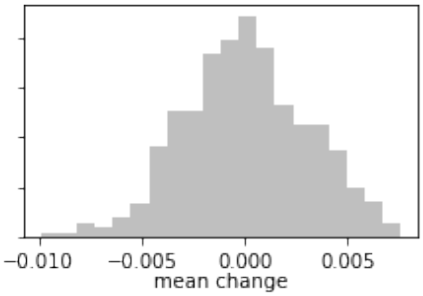
E) mean change group:pp_hk0, 67 entries
max: 0.193773, min: -0.223535



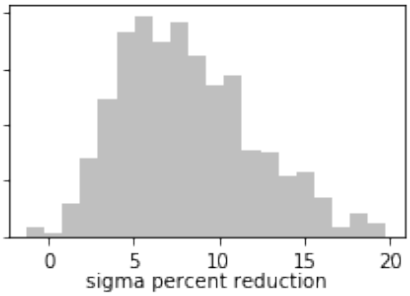
F) sigma change group:pp_hk0, 67 entries
max: 17.9692, min: 0.595834



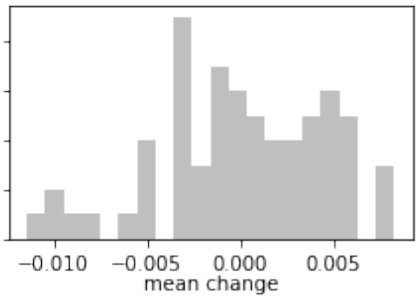
G) mean change group:grrech2, 705 entries
max:0.00757302, min:-0.00989057



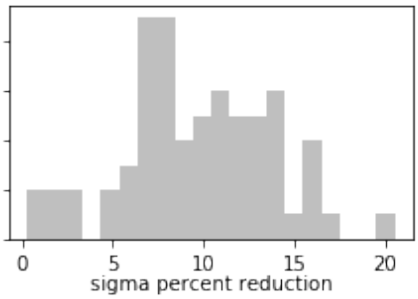
H) sigma change group:grrech2, 705 entries
max: 19.8128, min: -1.30351



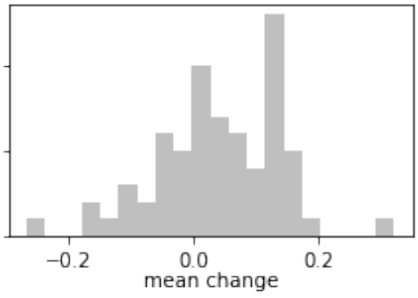
A) mean change group:pp_rech1, 67 entries
max:0.00826768, min:-0.0114644



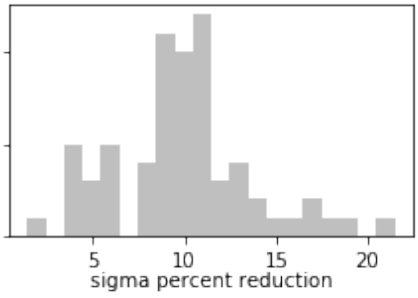
B) sigma change group:pp_rech1, 67 entries
max: 20.5551, min: 0.30667



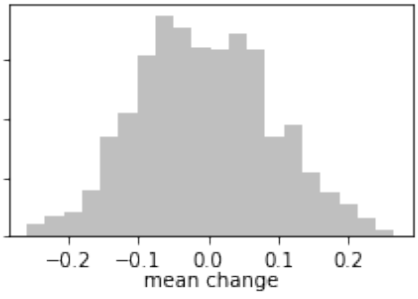
C) mean change group:pp_vka0, 67 entries
max: 0.319861, min: -0.267065



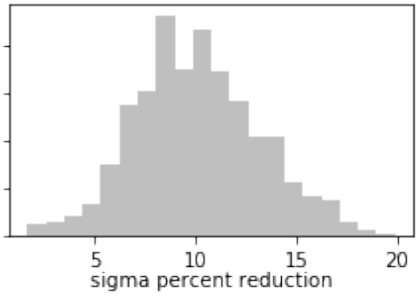
D) sigma change group:pp_vka0, 67 entries
max: 21.4965, min: 1.41393



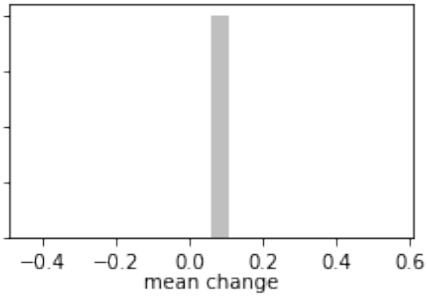
E) mean change group:grvka3, 705 entries
max: 0.265869, min: -0.259629



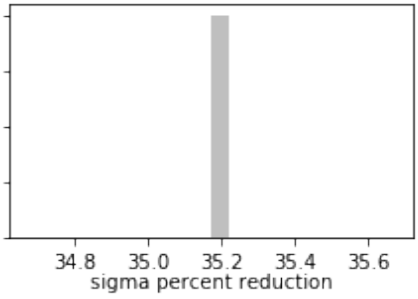
F) sigma change group:grvka3, 705 entries
max: 19.8728, min: 1.68783



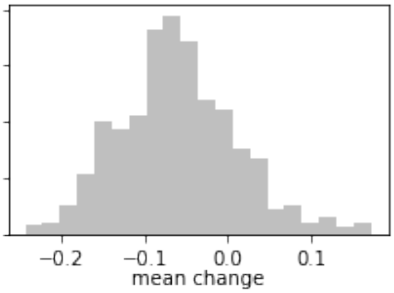
G) mean change group:hk6_cn, 1 entries
max: 0.0580977, min: 0.0580977



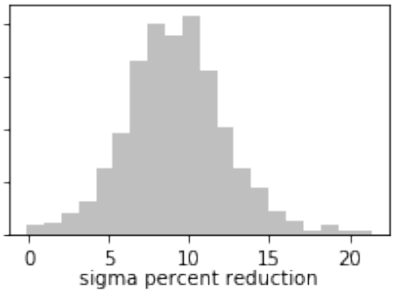
H) sigma change group:hk6_cn, 1 entries
max: 35.1718, min: 35.1718



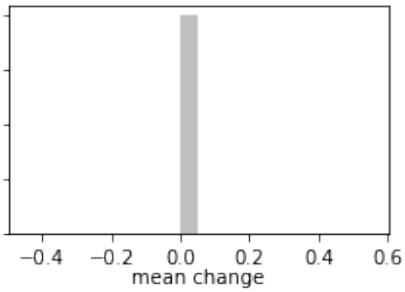
A) mean change group:grhk4, 705 entries
max: 0.172712, min: -0.24388



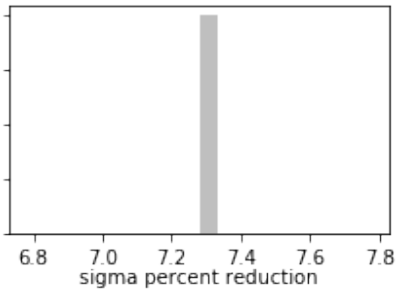
B) sigma change group:grhk4, 705 entries
max: 21.4264, min: -0.131177



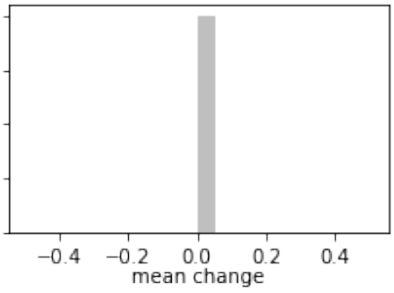
C) mean change group:ss8_cn, 1 entries
max: 0.0515606, min: 0.0515606



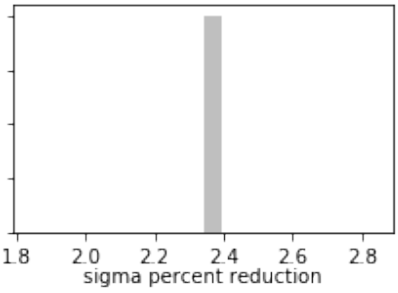
D) sigma change group:ss8_cn, 1 entries
max: 7.28014, min: 7.28014



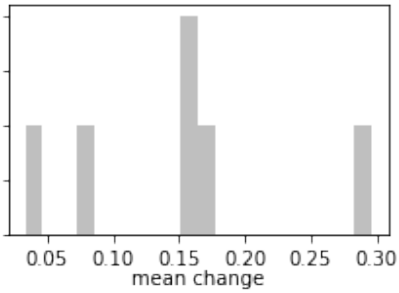
E) mean change group:strt7_cn, 1 entries
max:0.00302895, min:0.00302895



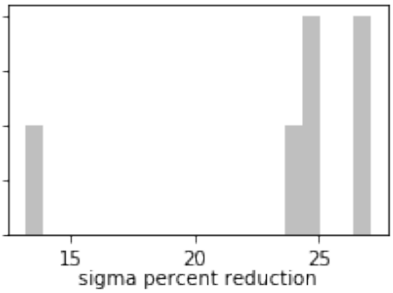
F) sigma change group:strt7_cn, 1 entries
max: 2.34174, min: 2.34174

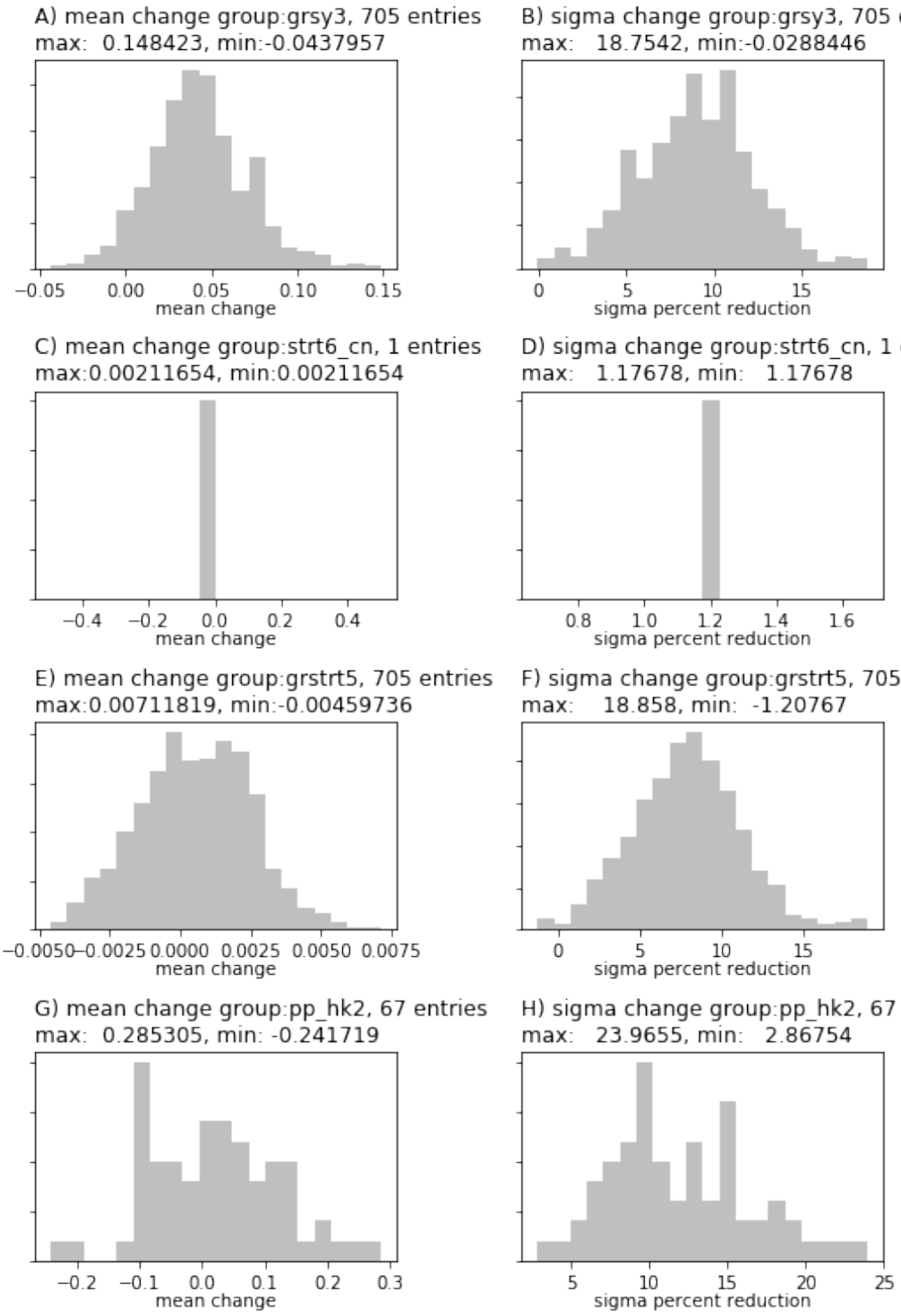


G) mean change group:welflux_k02, 6 entries
max: 0.295879, min: 0.0331856

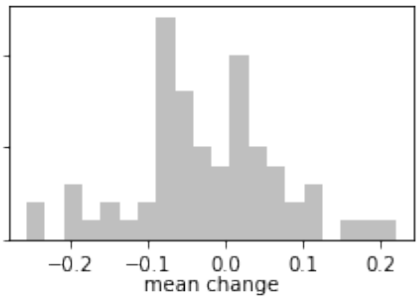


H) sigma change group:welflux_k02, 6 entries
max: 27.1372, min: 13.1679

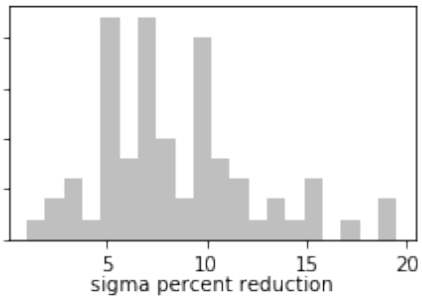



A) mean change group:grsy3, 705 entries
max: 0.148423, min:-0.0437957
mean change
B) sigma change group:grsy3, 705 entries
max: 18.7542, min:-0.0288446
sigma percent reduction
C) mean change group:strt6_cn, 1 entries
max:0.00211654, min:0.00211654
mean change
D) sigma change group:strt6_cn, 1 entries
max: 1.17678, min: 1.17678
sigma percent reduction
E) mean change group:grstrt5, 705 entries
max:0.00711819, min:-0.00459736
mean change
F) sigma change group:grstrt5, 705 entries
max: 18.858, min: -1.20767
sigma percent reduction
G) mean change group:pp_hk2, 67 entries
max: 0.285305, min: -0.241719
mean change
H) sigma change group:pp_hk2, 67 entries
max: 23.9655, min: 2.86754
sigma percent reduction

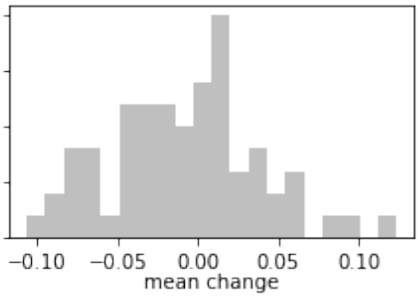
A) mean change group:pp_ss0, 67 entries
max: 0.220002, min: -0.255115



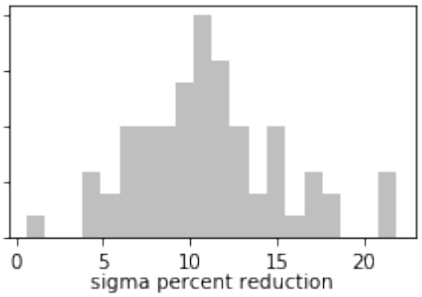
B) sigma change group:pp_ss0, 67 entries
max: 19.4826, min: 1.0153



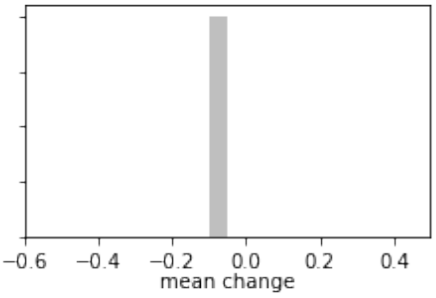
C) mean change group:pp_sy1, 67 entries
max: 0.1233, min: -0.106417



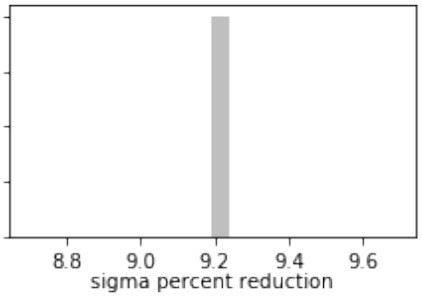
D) sigma change group:pp_sy1, 67 entries
max: 21.8838, min: 0.613913



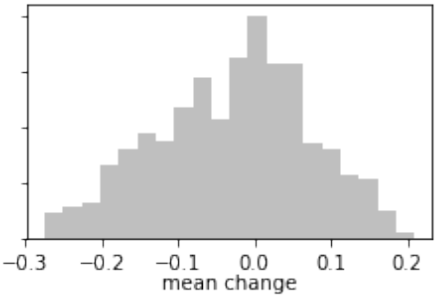
E) mean change group:sy7_cn, 1 entries
max:-0.0493597, min:-0.0493597



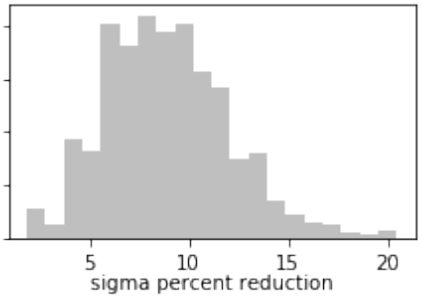
F) sigma change group:sy7_cn, 1 entries
max: 9.19149, min: 9.19149



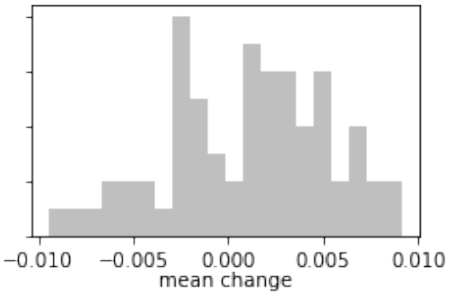
G) mean change group:grvka4, 705 entries
max: 0.209195, min: -0.274577



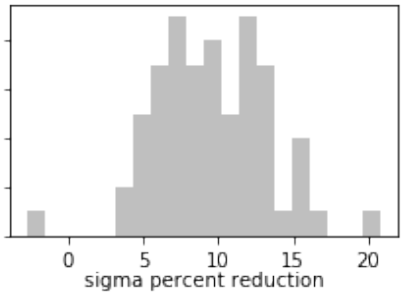
H) sigma change group:grvka4, 705 entries
max: 20.4461, min: 1.84337



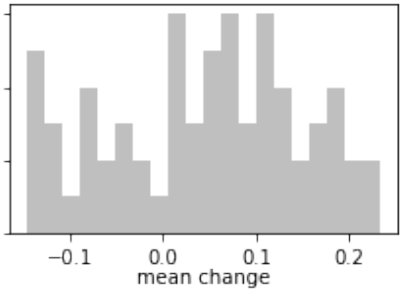
A) mean change group:pp_rech0, 67 entries
max:0.00916587, min:-0.0094705



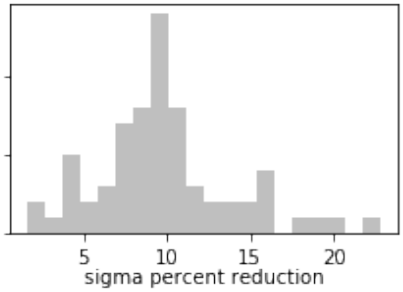
B) sigma change group:pp_rech0, 67 entries
max: 20.8268, min: -2.73944



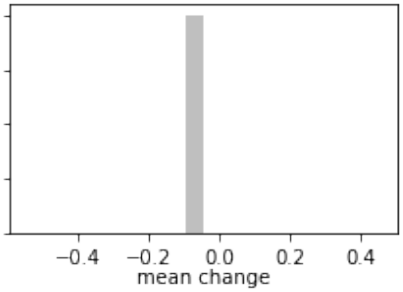
C) mean change group:pp_hk1, 67 entries
max: 0.233375, min: -0.146418



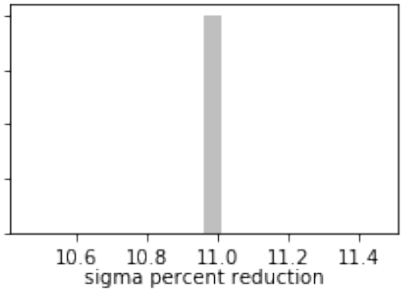
D) sigma change group:pp_hk1, 67 entries
max: 22.8422, min: 1.57942



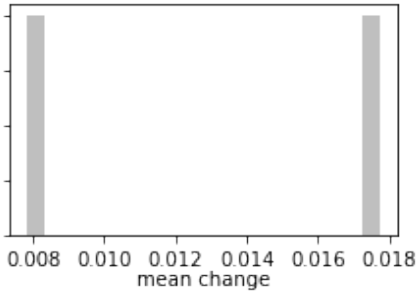
E) mean change group:hk7_cn, 1 entries
max:-0.0453914, min:-0.0453914



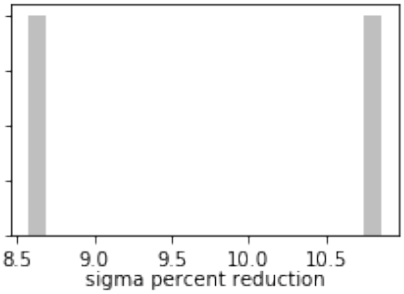
F) sigma change group:hk7_cn, 1 entries
max: 10.9611, min: 10.9611



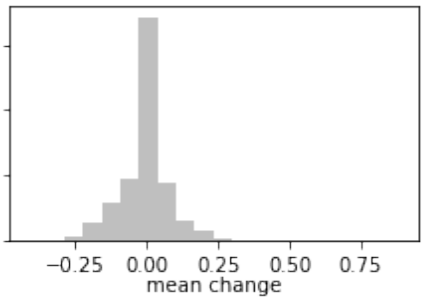
G) mean change group:welflux, 2 entries
max: 0.0177506, min:0.00781415



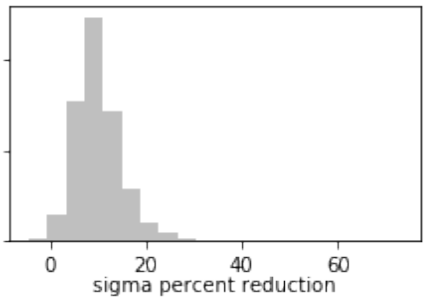
H) sigma change group:welflux, 2 entries
max: 10.8634, min: 8.56582



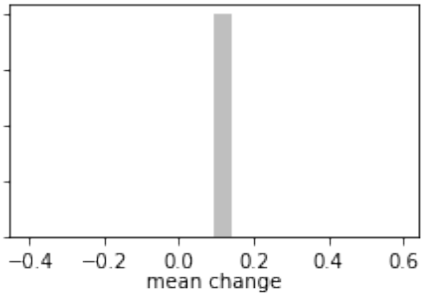
A) mean change group:all, 13200 entries
max: 0.887499, min: -0.418932



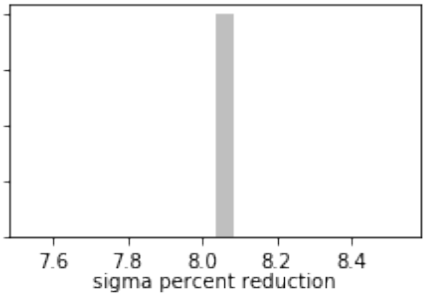
B) sigma change group:all, 13200 entries
max: 73.3261, min: -4.4479



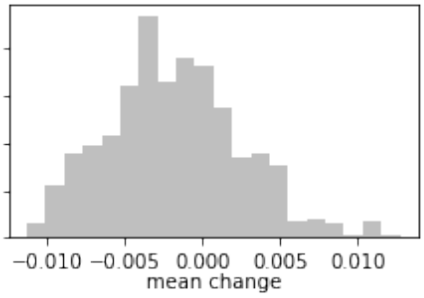
C) mean change group:vka7_cn, 1 entries
max: 0.0924807, min: 0.0924807



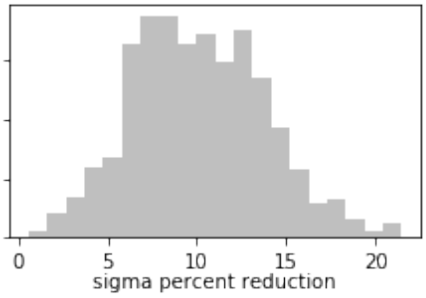
D) sigma change group:vka7_cn, 1 entries
max: 8.03474, min: 8.03474



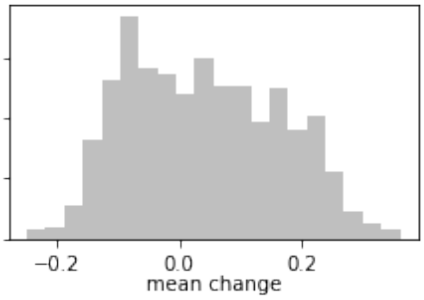
E) mean change group:grrech3, 705 entries
max: 0.0127266, min:-0.0112805



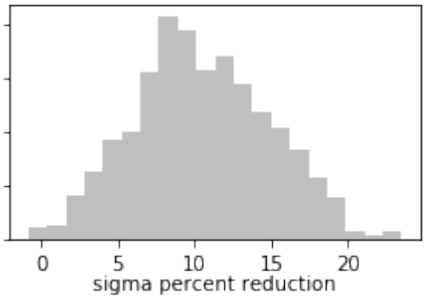
F) sigma change group:grrech3, 705 entries
max: 21.4707, min: 0.584654



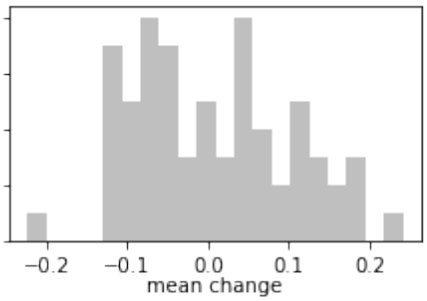
G) mean change group:grss4, 705 entries
max: 0.359907, min: -0.248311



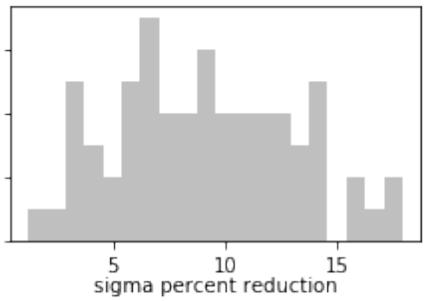
H) sigma change group:grss4, 705 entries
max: 23.5239, min: -0.829862



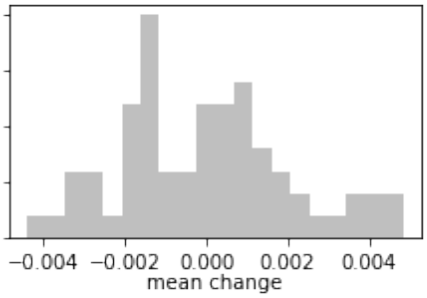
A) mean change group:pp_ss1, 67 entries
max: 0.240781, min: -0.22307



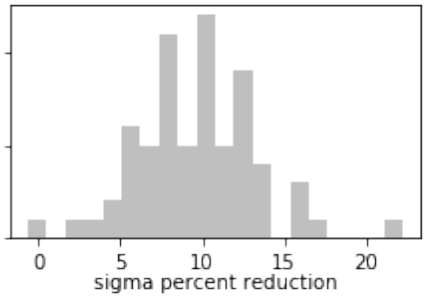
B) sigma change group:pp_ss1, 67 entries
max: 17.9092, min: 1.18892



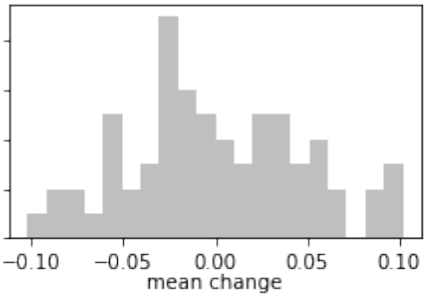
C) mean change group:pp_strt1, 67 entries
max:0.00480947, min:-0.00436778



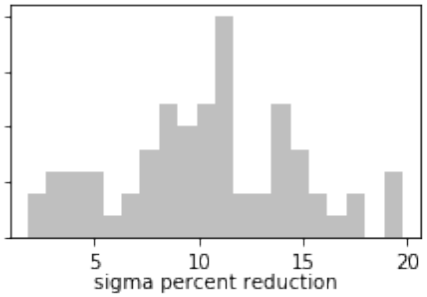
D) sigma change group:pp_strt1, 67 entries
max: 22.2078, min: -0.645749



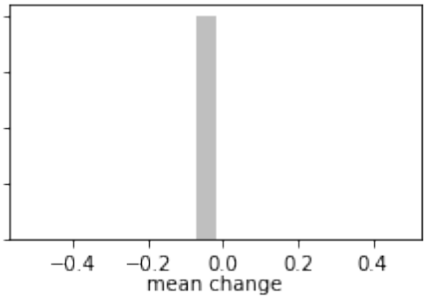
E) mean change group:pp_sy0, 67 entries
max: 0.102167, min: -0.102121



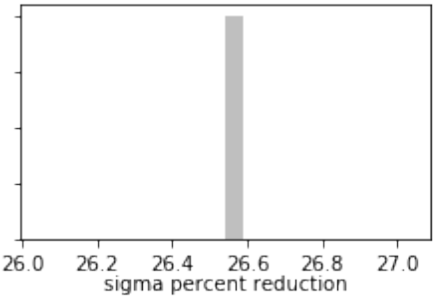
F) sigma change group:pp_sy0, 67 entries
max: 19.7891, min: 1.79239



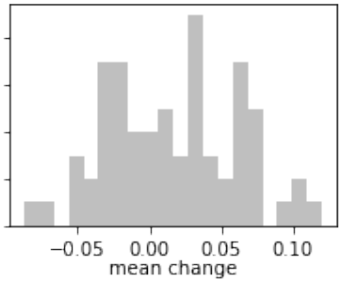
G) mean change group:rech4_cn, 1 entries
max:-0.0205924, min:-0.0205924



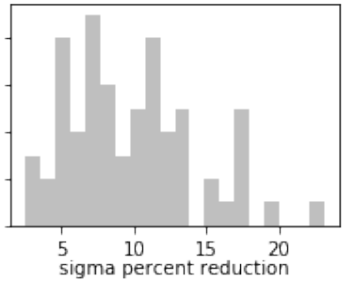
H) sigma change group:rech4_cn, 1 entries
max: 26.5409, min: 26.5409



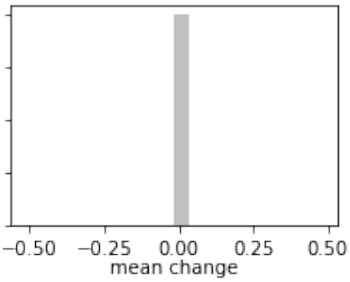
A) mean change group:pp_sy2, 67 entries
max: 0.120147, min:-0.0872637



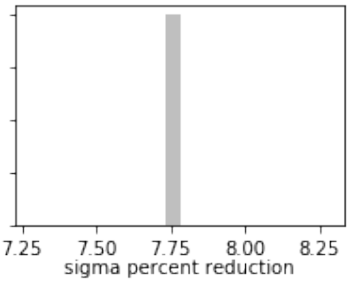
B) sigma change group:pp_sy2, 67 entries
max: 23.1076, min: 2.55649



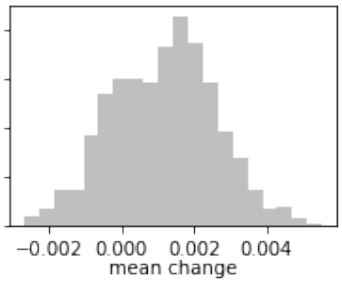
C) mean change group:sy6_cn, 1 entries
max:-0.0154938, min:-0.0154938



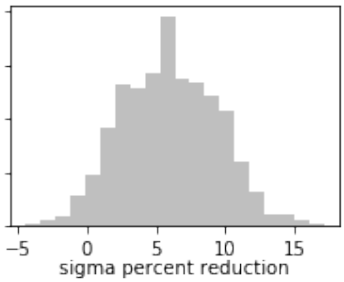
D) sigma change group:sy6_cn, 1 entries
max: 7.77968, min: 7.77968



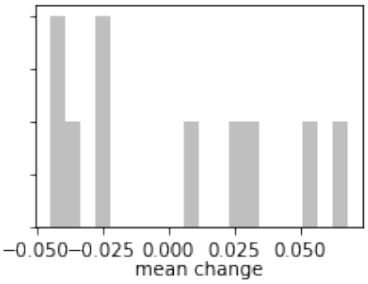
E) mean change group:grstrt4, 705 entries
max:0.00553779, min:-0.0026852



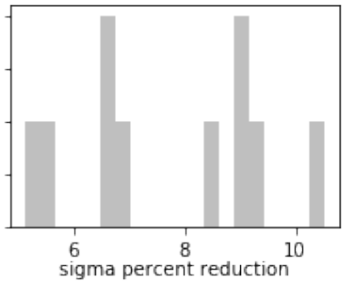
F) sigma change group:grstrt4, 705 entries
max: 17.1211, min: -4.4479



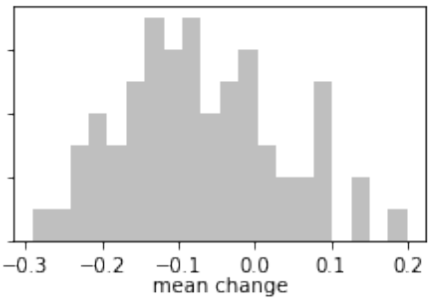
G) mean change group:drncond_k00, 10 entries
max: 0.0679611, min:-0.0447873



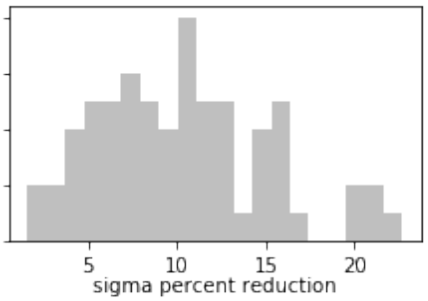
H) sigma change group:drncond_k00, 10 entries
max: 10.51, min: 5.1331



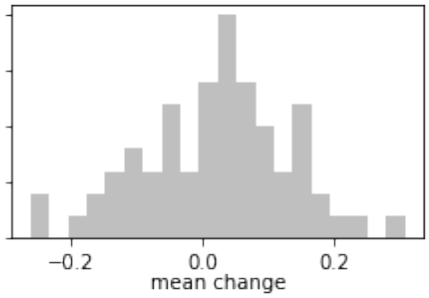
A) mean change group:pp_ss2, 67 entries
max: 0.199418, min: -0.29101



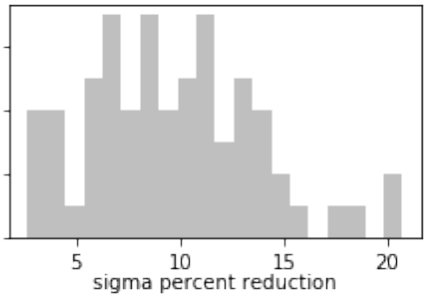
B) sigma change group:pp_ss2, 67 entries
max: 22.6921, min: 1.59979



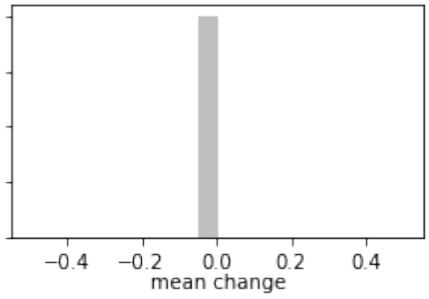
C) mean change group:pp_vka1, 67 entries
max: 0.307447, min: -0.26224



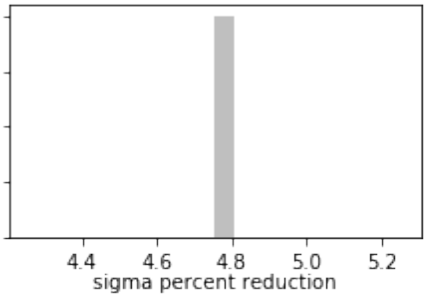
D) sigma change group:pp_vka1, 67 entries
max: 20.7023, min: 2.64517



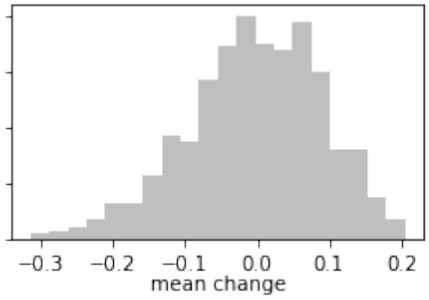
E) mean change group:sy8_cn, 1 entries
max:0.00325204, min:0.00325204



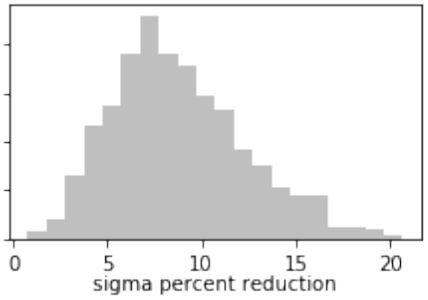
F) sigma change group:sy8_cn, 1 entries
max: 4.75538, min: 4.75538



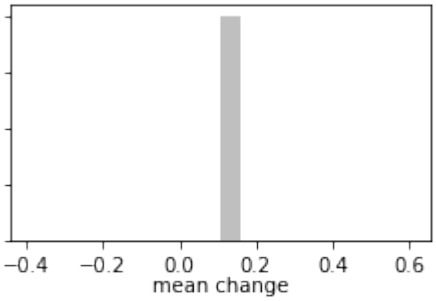
G) mean change group:grvka5, 705 entries
max: 0.205244, min: -0.314772



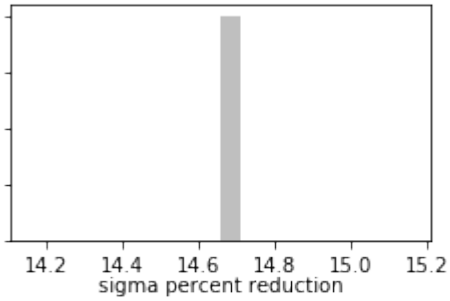
H) sigma change group:grvka5, 705 entries
max: 20.6465, min: 0.767111



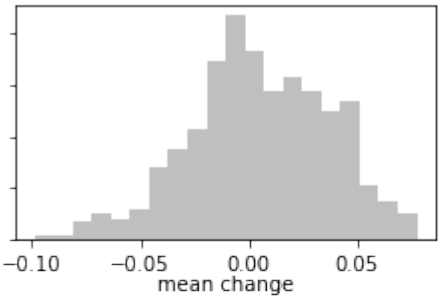
A) mean change group:rech5_cn, 1 entries
max: 0.107673, min: 0.107673



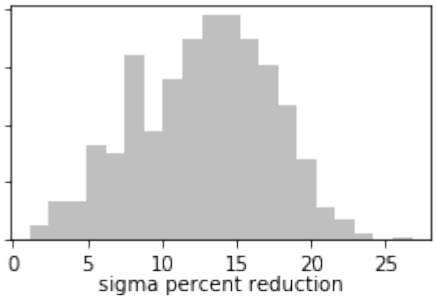
B) sigma change group:rech5_cn, 1 entries
max: 14.6584, min: 14.6584



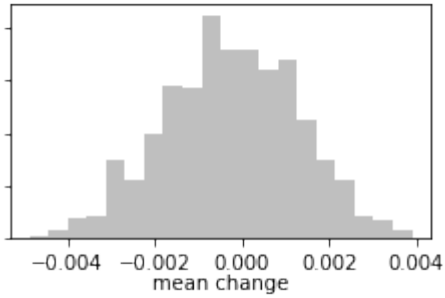
C) mean change group:grsy4, 705 entries
max: 0.077575, min:-0.0989142



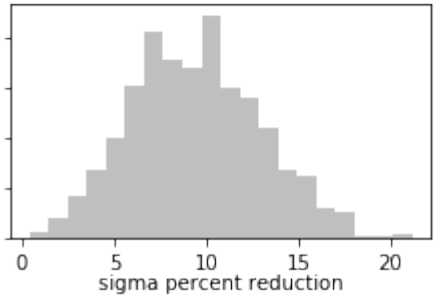
D) sigma change group:grsy4, 705 entries
max: 26.7578, min: 1.08901



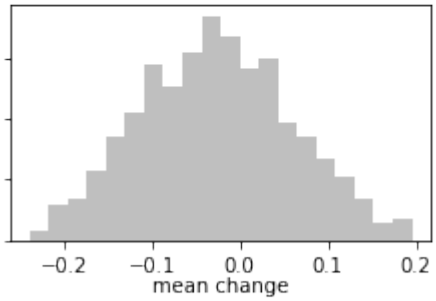
E) mean change group:grstrt3, 705 entries
max:0.00389917, min:-0.00487131



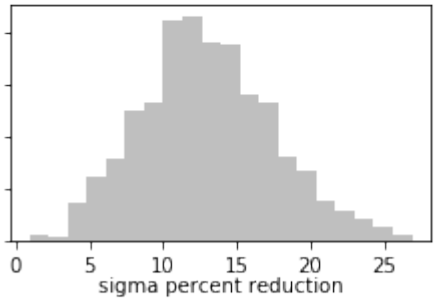
F) sigma change group:grstrt3, 705 entries
max: 21.1745, min: 0.398322



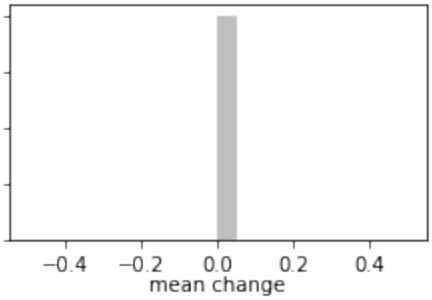
G) mean change group:grhk3, 705 entries
max: 0.195051, min: -0.238493



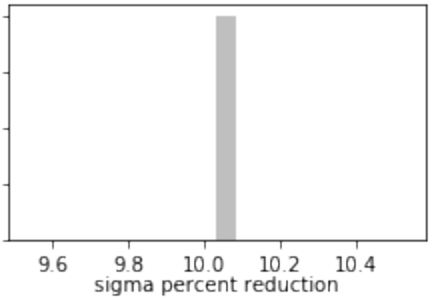
H) sigma change group:grhk3, 705 entries
max: 26.8644, min: 0.924891



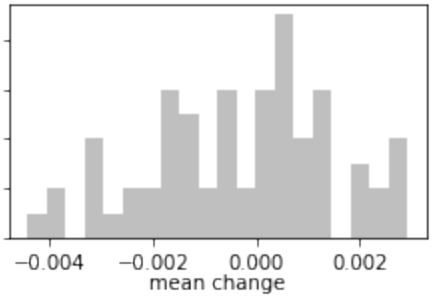
A) mean change group:strt8_cn, 1 entries
max:0.00174037, min:0.00174037



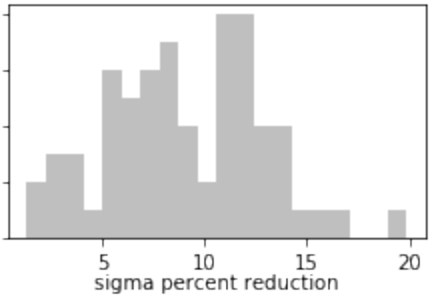
B) sigma change group:strt8_cn, 1 entries
max: 10.0308, min: 10.0308



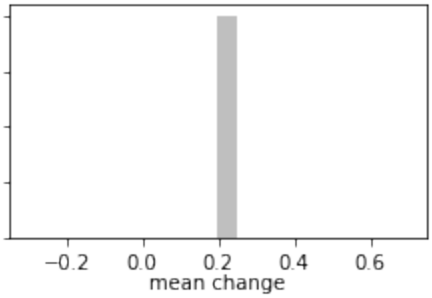
C) mean change group:pp_strt2, 67 entries
max:0.00292313, min:-0.00443698



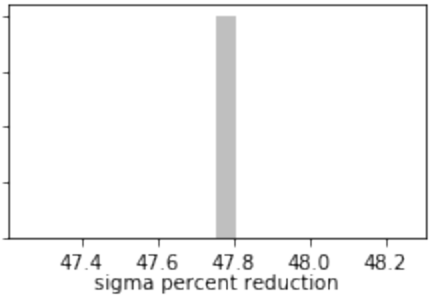
D) sigma change group:pp_strt2, 67 entries
max: 19.8547, min: 1.27937



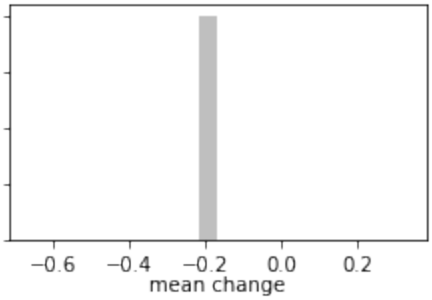
E) mean change group:hk8_cn, 1 entries
max: 0.197241, min: 0.197241



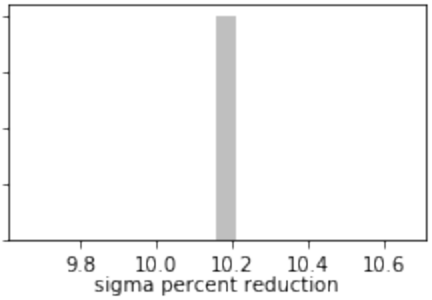
F) sigma change group:hk8_cn, 1 entries
max: 47.7539, min: 47.7539

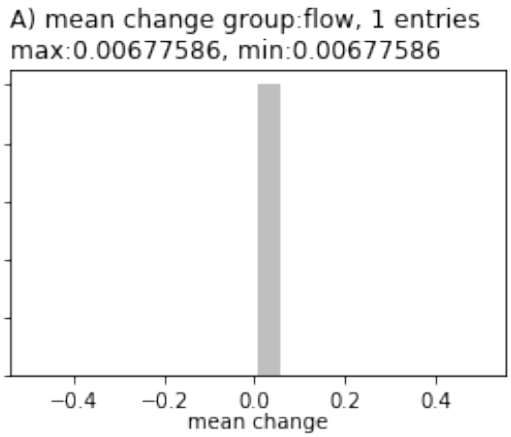


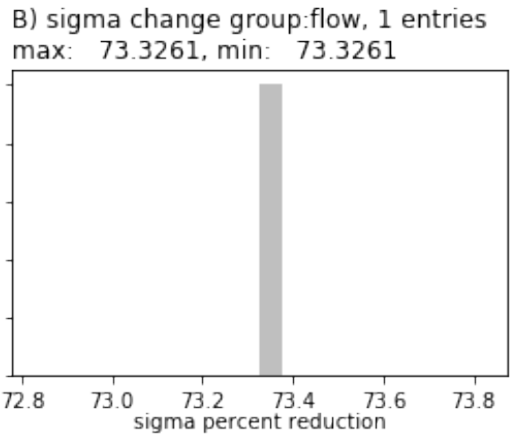
G) mean change group:ss7_cn, 1 entries
max: -0.168241, min: -0.168241



H) sigma change group:ss7_cn, 1 entries
max: 10.1595, min: 10.1595







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

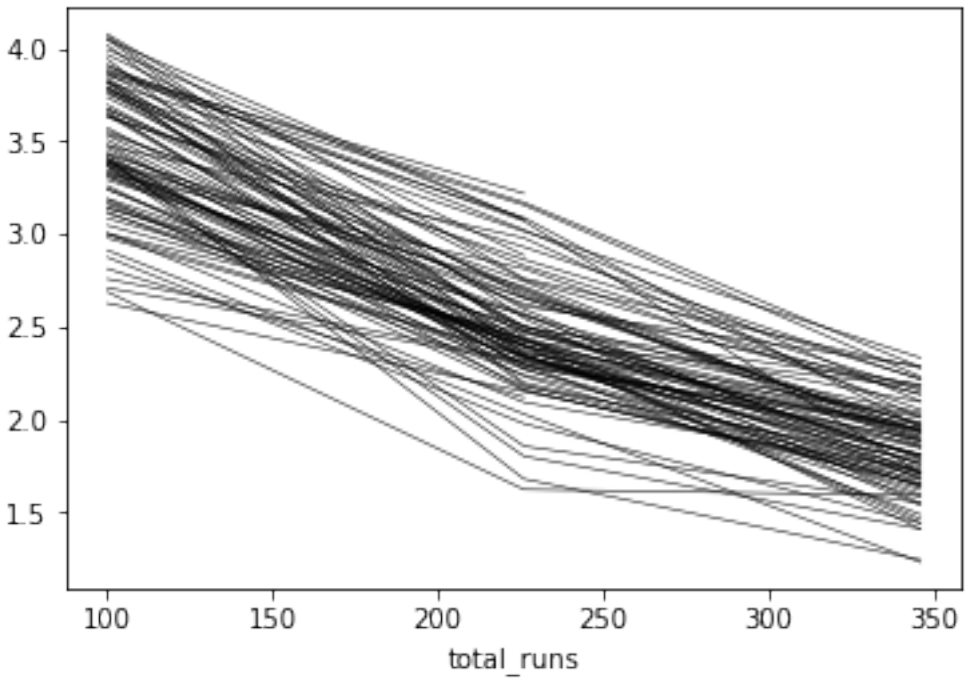
Now let's add some localization. The obvious stuff is temporal - scenario parameters can't influence historic observations (and the inverse is true) so let's tell PESTPP-IES about this:

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

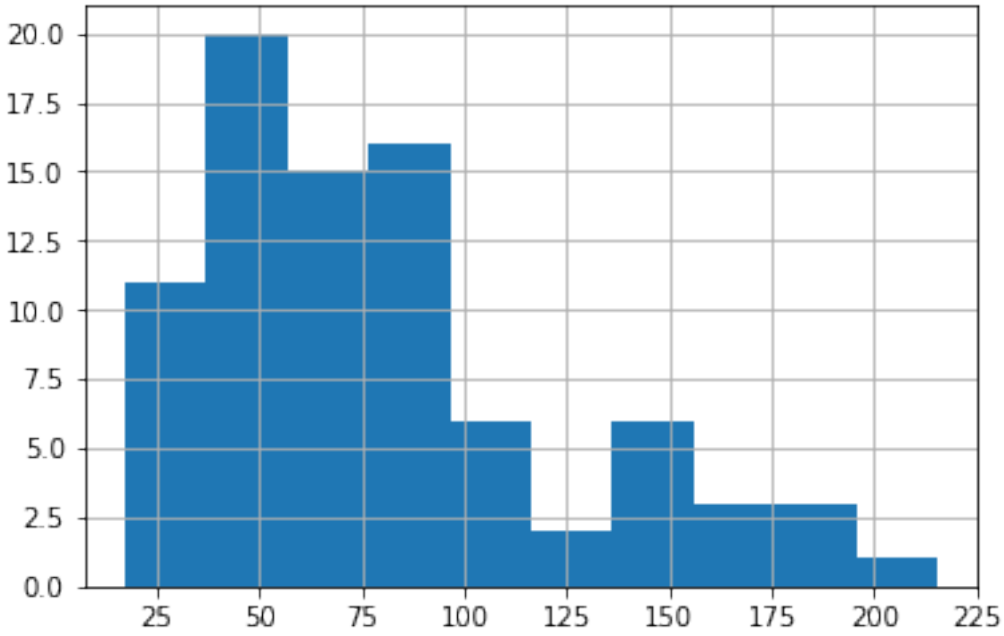
In [13]:
```
loc = pyemu.Matrix.from_names(pst.nnz_obs_names,pst.par_groups).to_dataframe()
loc.loc[:,:]= 1.0
loc.loc[:,scen_groups] = 0.0
pyemu.Matrix.from_dataframe(loc).to_ascii(os.path.join(t_d,"loc.mat"))
```

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_
```

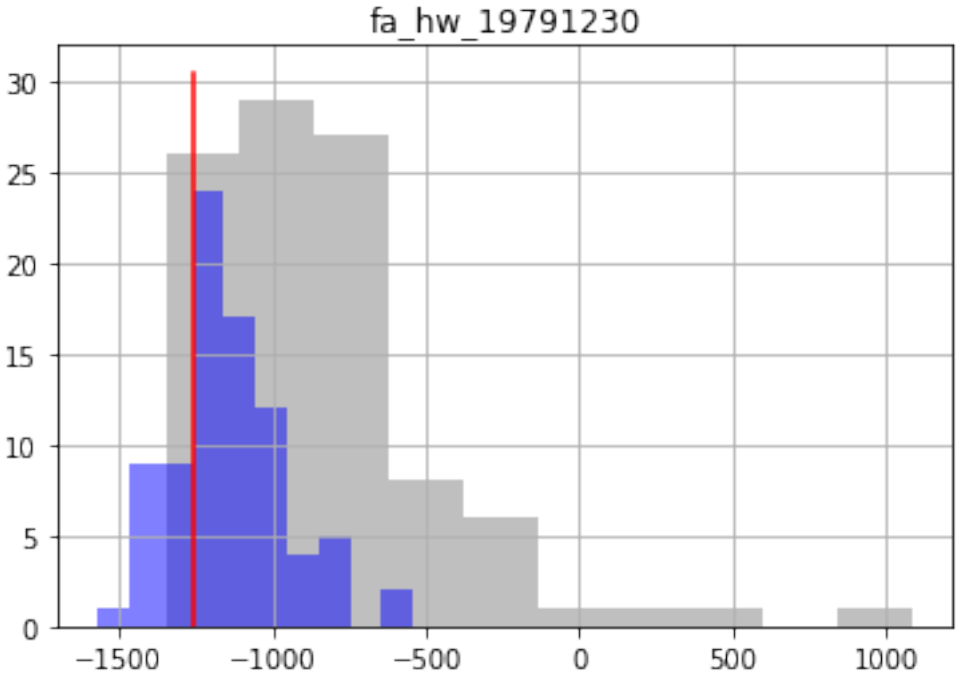
In [15]:
```
phi = pd.read_csv(os.path.join(m_d,"freyberg_ies.phi.actual.csv"),index_col=0)
phi.index = phi.total_runs
phi.iloc[:,6:].apply(np.log10).plot(legend=False,lw=0.5,color='k')
plt.show()
phi.iloc[-1,6:].hist()
```

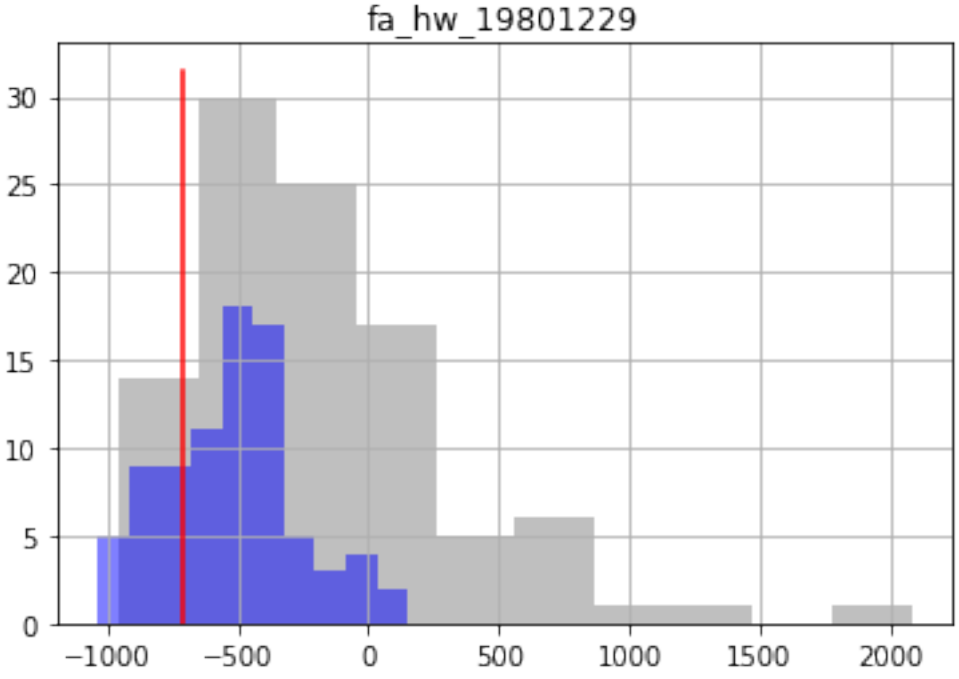


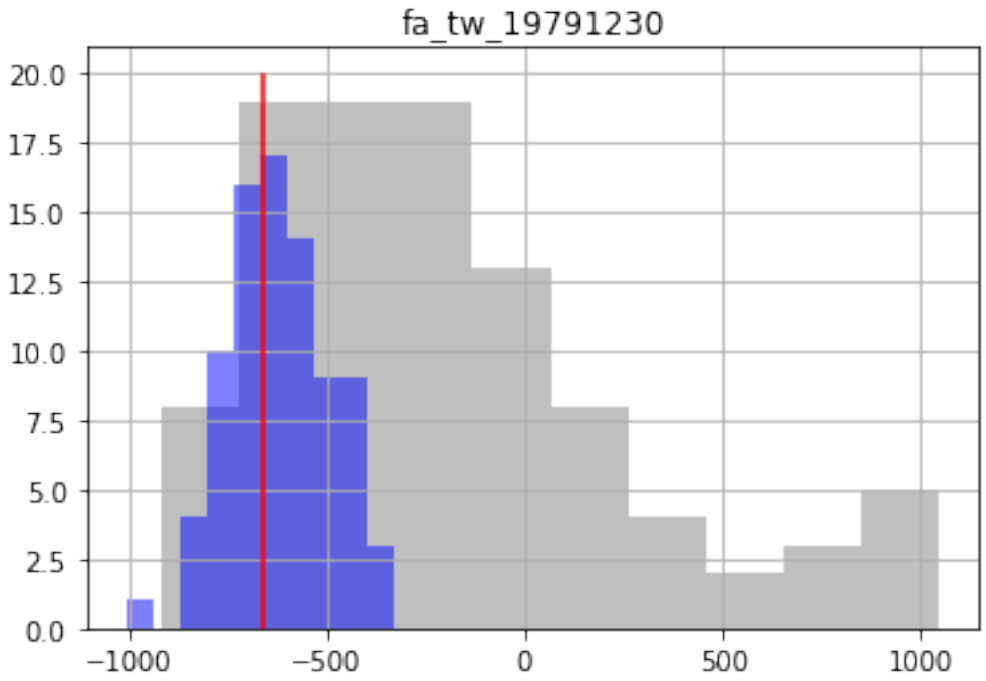
Out[15]: <matplotlib.axes._subplots.AxesSubplot at 0x181aa8c048>

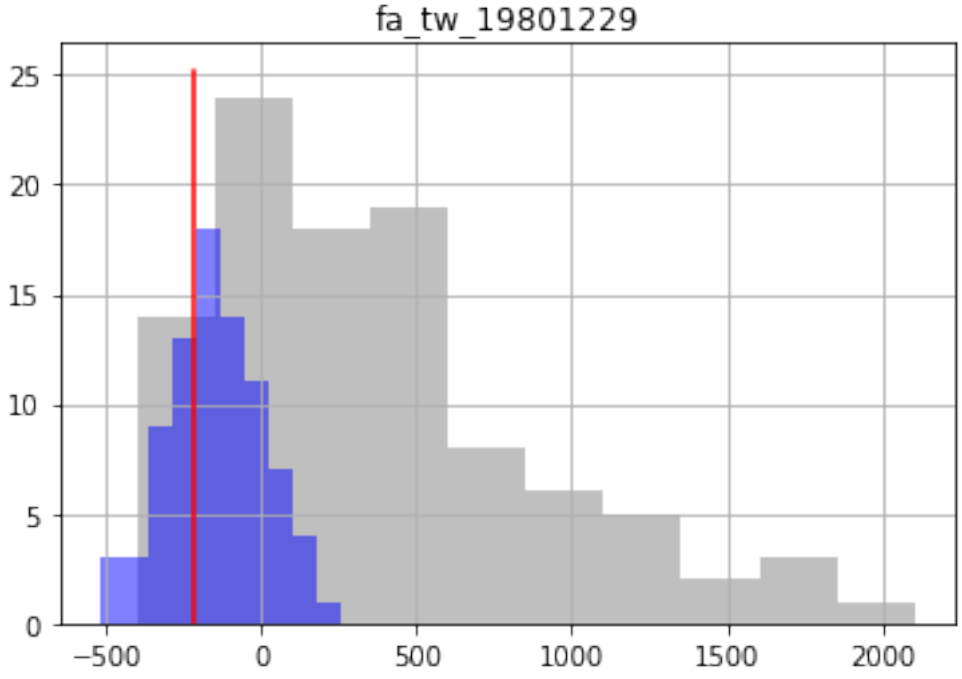


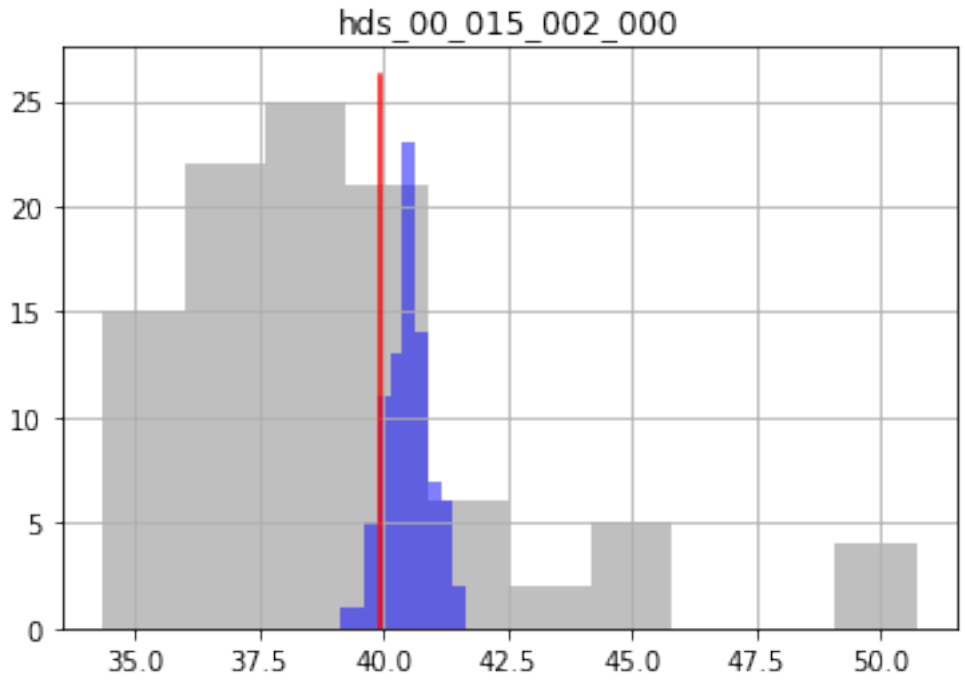
In [16]:
```
oe_pr = pd.read_csv(os.path.join(m_d,"freyberg_ies.0.obs.csv"),index_col=0)
oe_pt = pd.read_csv(os.path.join(m_d,"freyberg_ies.{0}.obs.csv".format(pst.control_dat
obs = pst.observation_data
fnames = pst.pestpp_options["forecasts"].split(",")
for forecast in fnames:
    ax = plt.subplot(111)
    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()
```

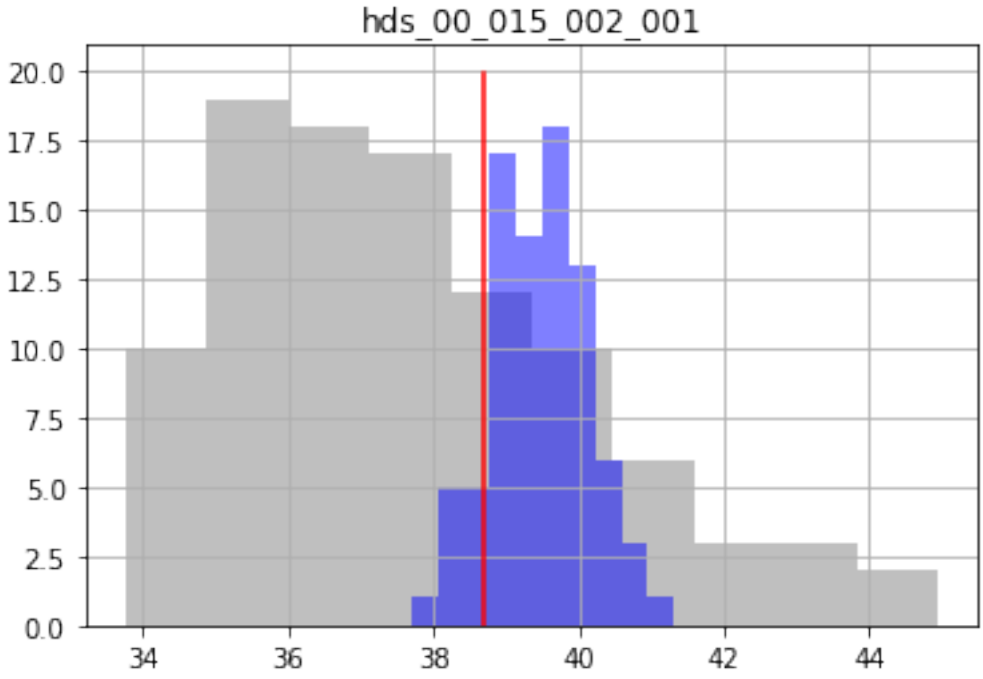

fa_hw_19791230
30
25
20
15
10
5
0
−1500
−1000
−500
0
500
1000


fa_hw_19801229
30
25
20
15
10
5
0
−1000
−500
0
500
1000
1500
2000


fa_tw_19791230
20.0
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0.0
−1000
−500
0
500
1000


fa_tw_19801229
25
20
15
10
5
0
−500
0
500
1000
1500
2000






```
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)
```

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

```
(100, 13200) (83, 13200)
```

```
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>,
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          <Figure size 576x756 with 8 Axes>,
          <Figure size 576x756 with 8 Axes>,
          <Figure size 576x756 with 8 Axes>,
          <Figure size 576x756 with 8 Axes>]
```
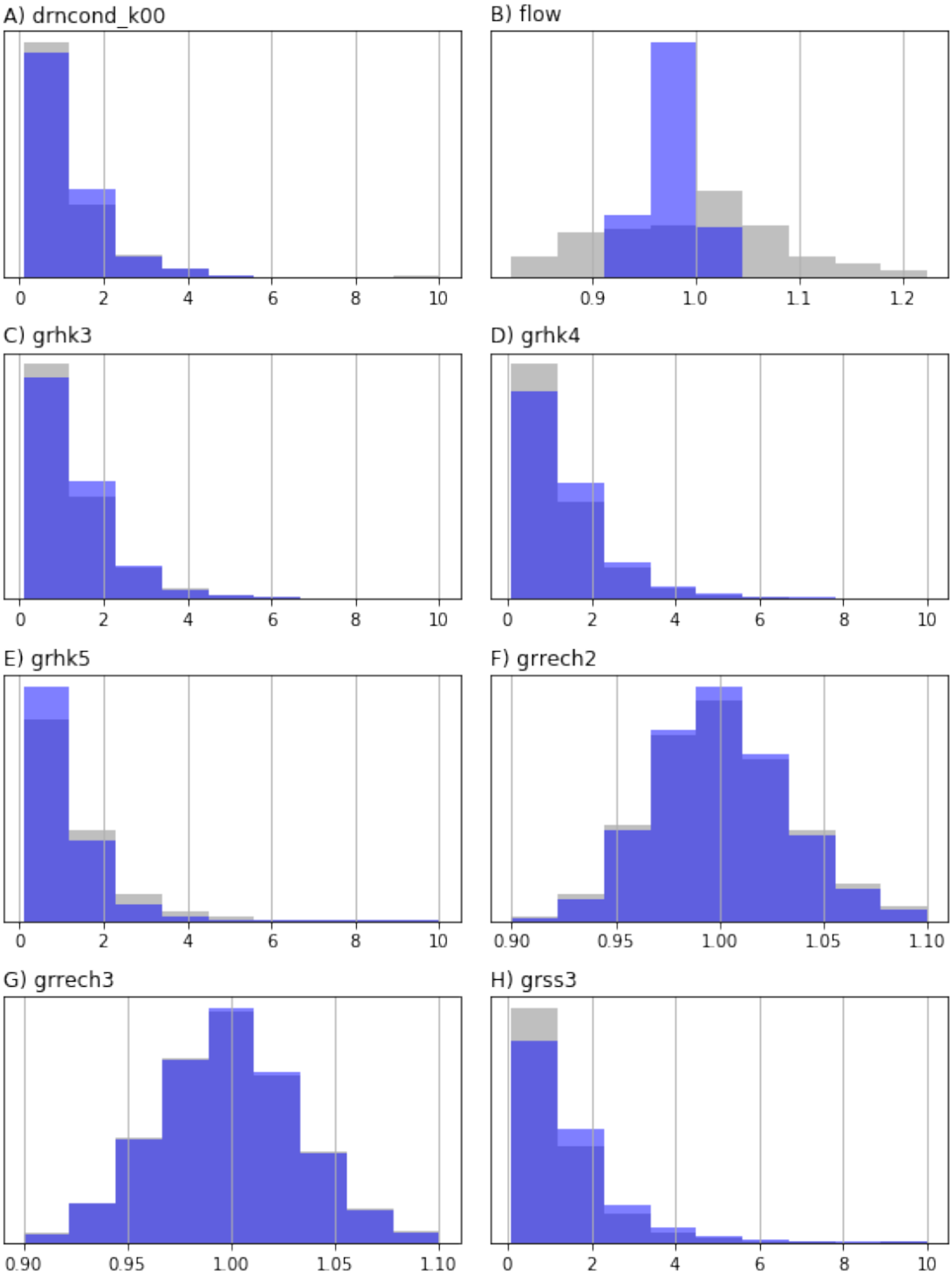
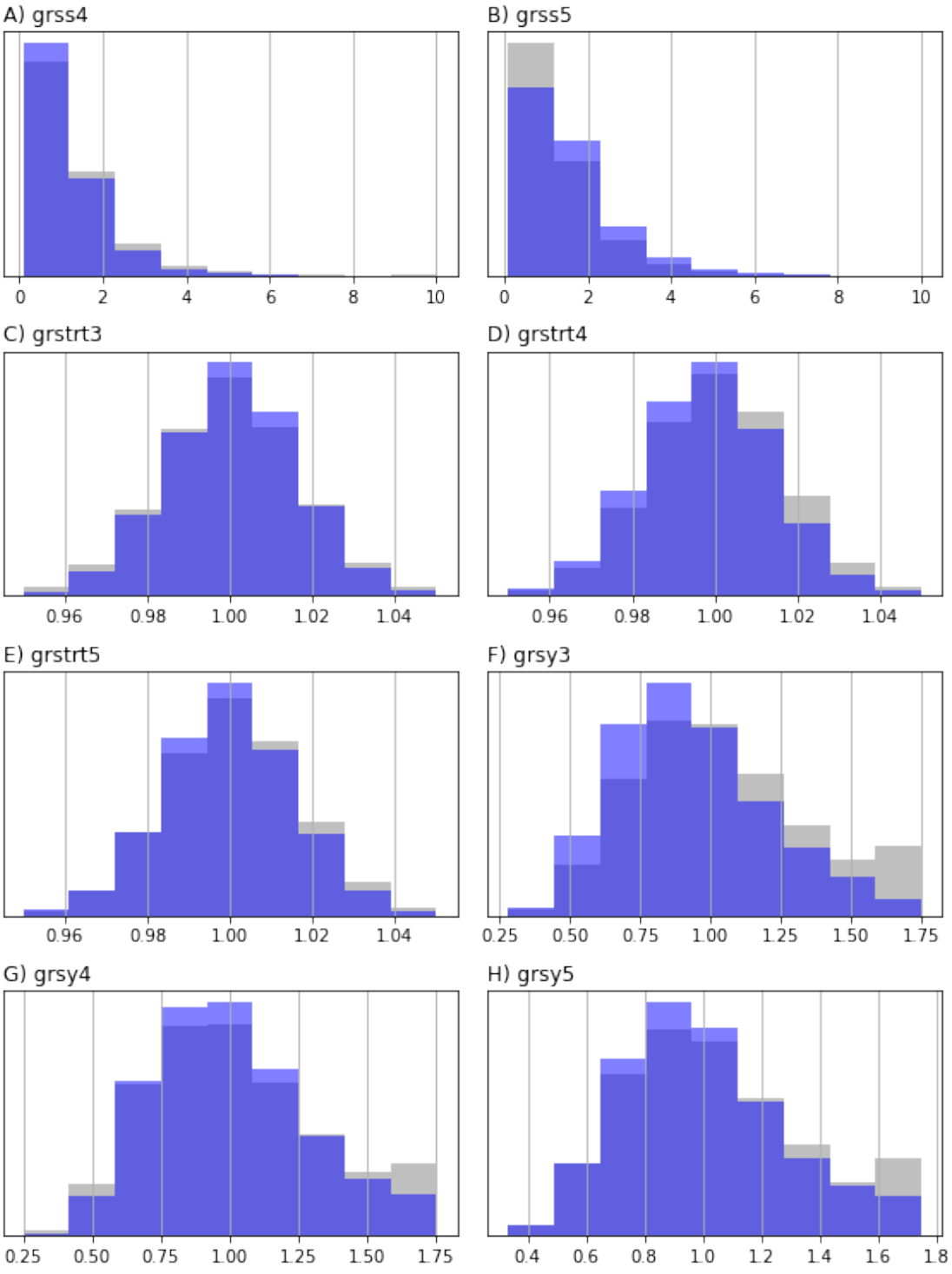
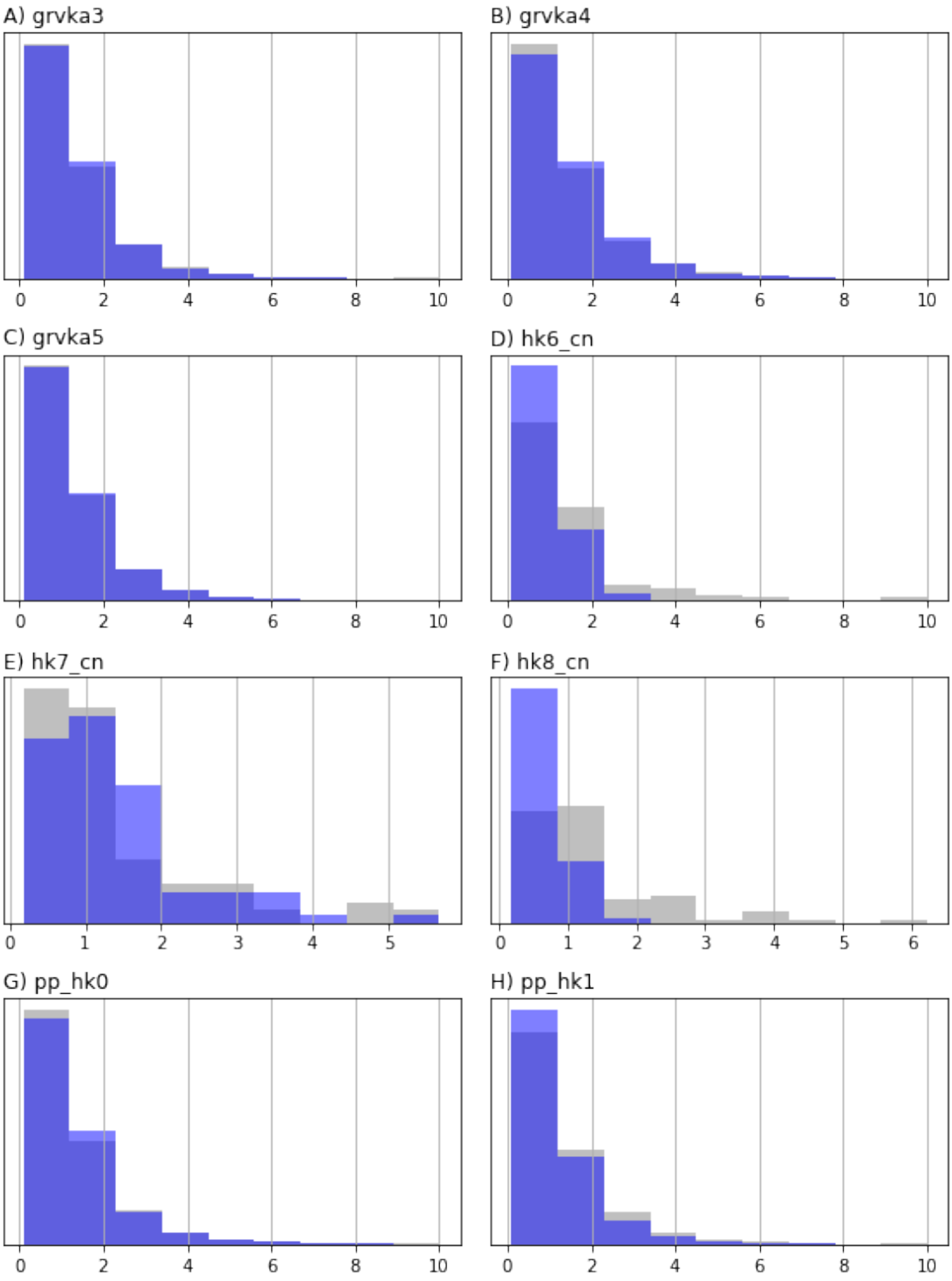
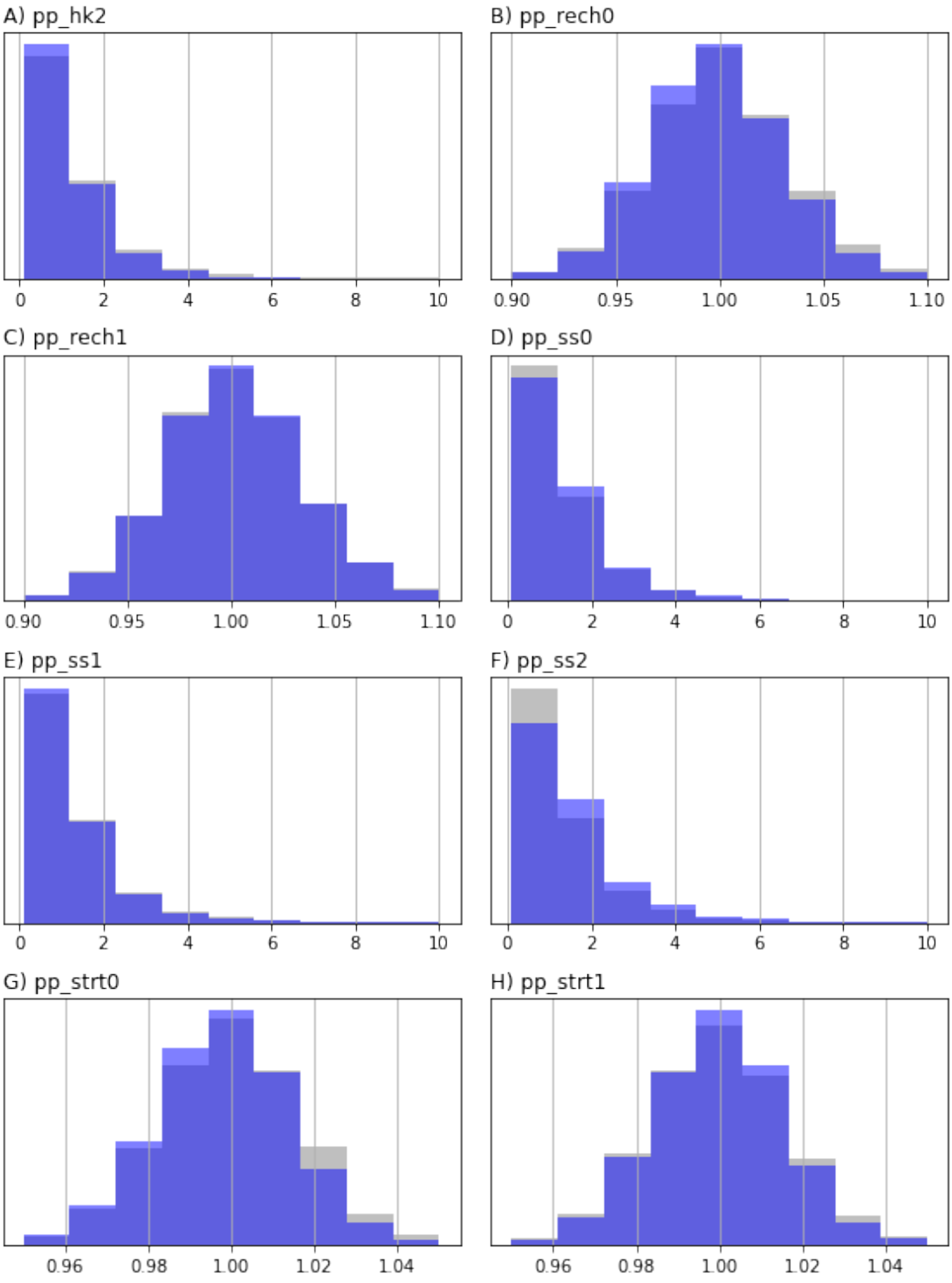
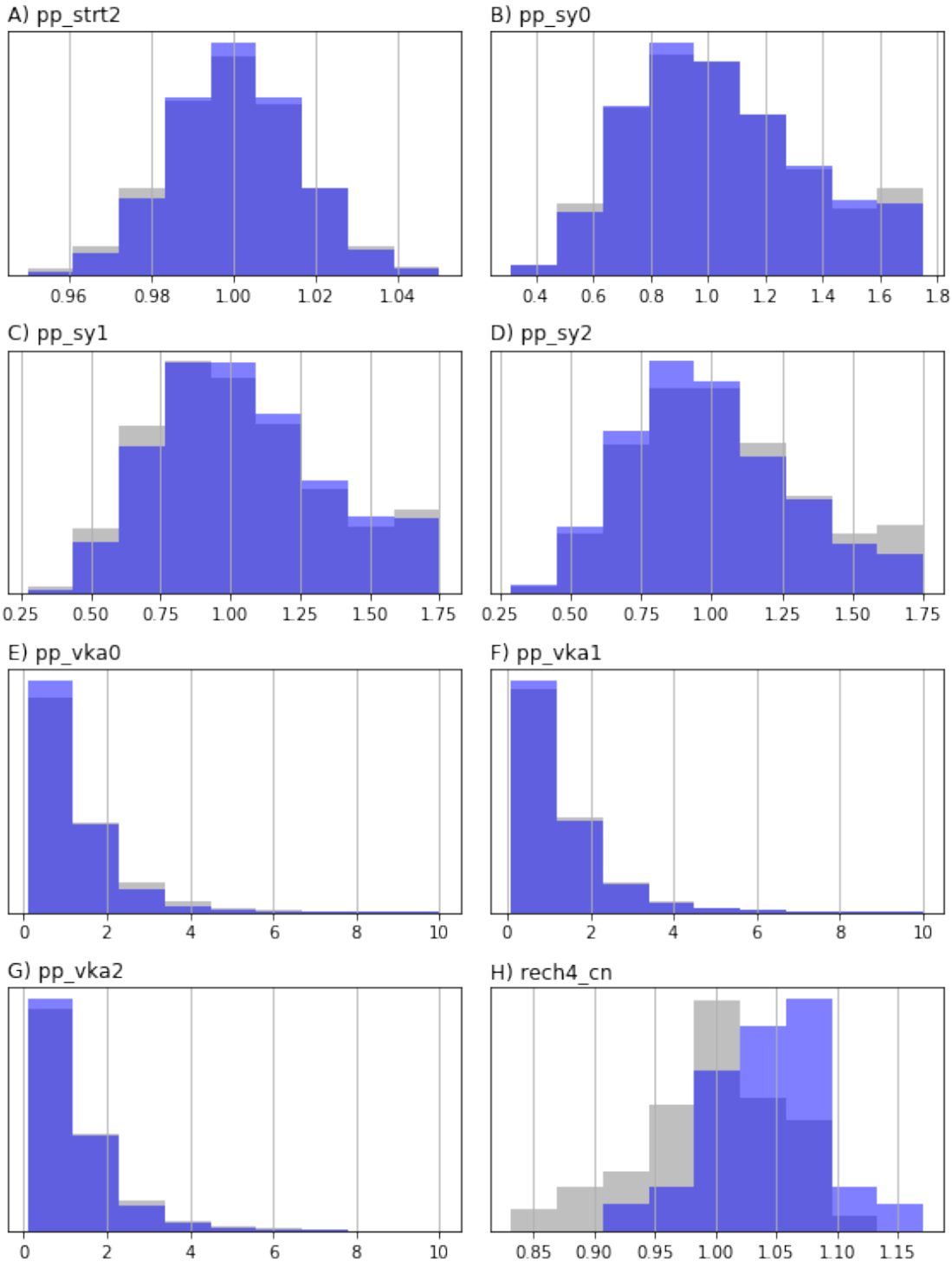

```
<Figure size 576x756 with 0 Axes>
```

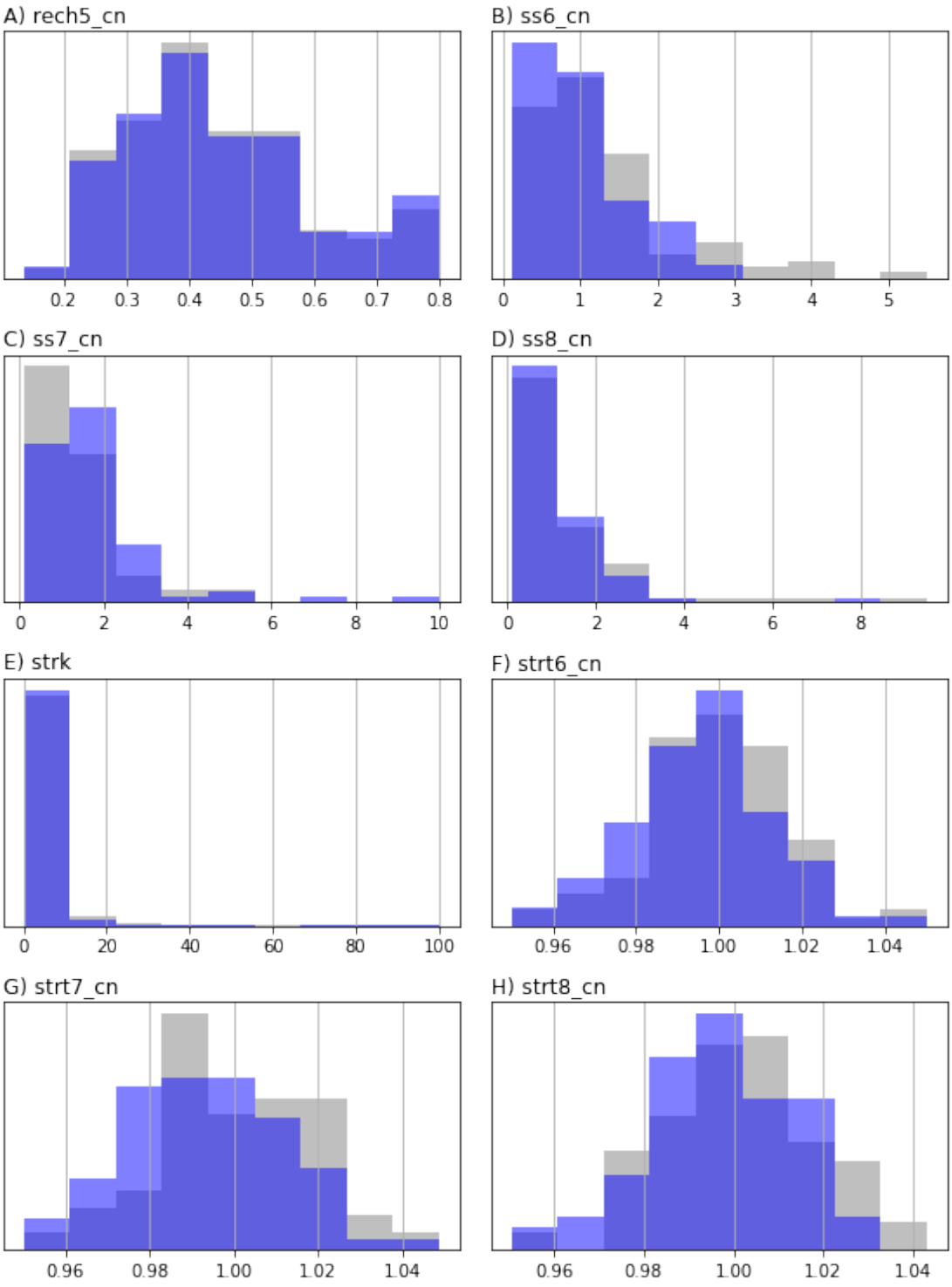

A) drncond_k00
0
2
4
6
8
10
B) flow
0.9
1.0
1.1
1.2
C) grhk3
0
2
4
6
8
10
D) grhk4
0
2
4
6
8
10
E) grhk5
0
2
4
6
8
10
F) grrech2
0.90
0.95
1.00
1.05
1.10
G) grrech3
0.90
0.95
1.00
1.05
1.10
H) grss3
0
2
4
6
8
10

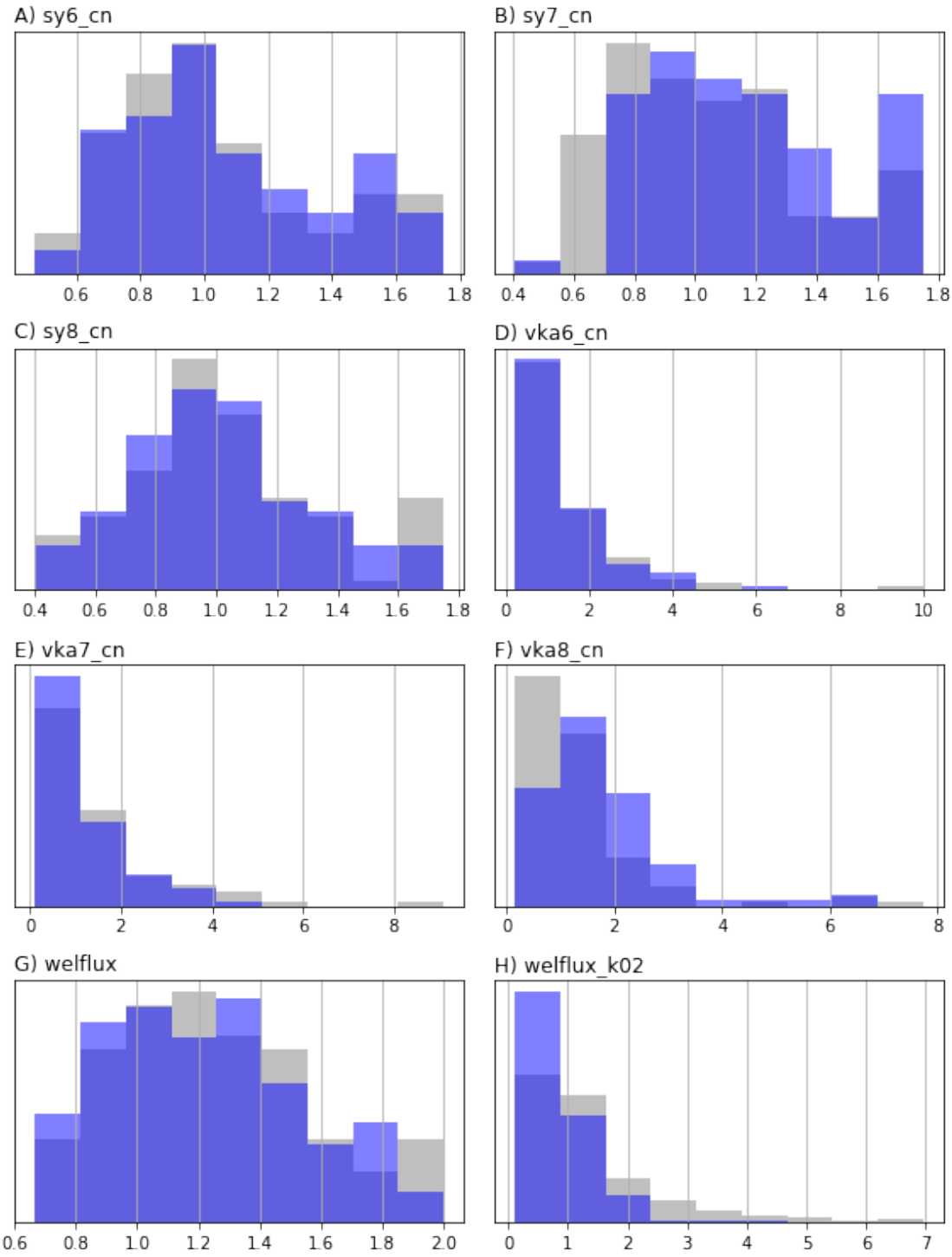

A) grss4
0
2
4
6
8
10
B) grss5
0
2
4
6
8
10
C) grstrt3
0.96
0.98
1.00
1.02
1.04
D) grstrt4
0.96
0.98
1.00
1.02
1.04
E) grstrt5
0.96
0.98
1.00
1.02
1.04
F) grsy3
0.25
0.50
0.75
1.00
1.25
1.50
1.75
G) grsy4
0.25
0.50
0.75
1.00
1.25
1.50
1.75
H) grsy5
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8


A) grvka3
B) grvka4
C) grvka5
D) hk6_cn
E) hk7_cn
F) hk8_cn
G) pp_hk0
H) pp_hk1


A) pp_hk2
0
2
4
6
8
10
B) pp_rech0
0.90
0.95
1.00
1.05
1.10
C) pp_rech1
0.90
0.95
1.00
1.05
1.10
D) pp_ss0
0
2
4
6
8
10
E) pp_ss1
0
2
4
6
8
10
F) pp_ss2
0
2
4
6
8
10
G) pp_strt0
0.96
0.98
1.00
1.02
1.04
H) pp_strt1
0.96
0.98
1.00
1.02
1.04

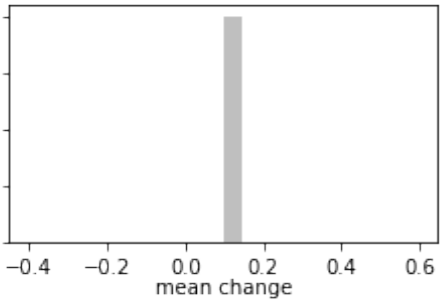

A) pp_strt2
0.96
0.98
1.00
1.02
1.04
B) pp_sy0
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
C) pp_sy1
0.25
0.50
0.75
1.00
1.25
1.50
1.75
D) pp_sy2
0.25
0.50
0.75
1.00
1.25
1.50
1.75
E) pp_vka0
0
2
4
6
8
10
F) pp_vka1
0
2
4
6
8
10
G) pp_vka2
0
2
4
6
8
10
H) rech4_cn
0.85
0.90
0.95
1.00
1.05
1.10
1.15


A) rech5_cn
0.2
0.3
0.4
0.5
0.6
0.7
0.8
B) ss6_cn
0
1
2
3
4
5
C) ss7_cn
0
2
4
6
8
10
D) ss8_cn
0
2
4
6
8
E) strk
0
20
40
60
80
100
F) strt6_cn
0.96
0.98
1.00
1.02
1.04
G) strt7_cn
0.96
0.98
1.00
1.02
1.04
H) strt8_cn
0.96
0.98
1.00
1.02
1.04

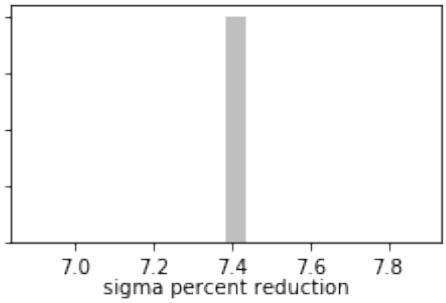


<Figure size 576x756 with 0 Axes>

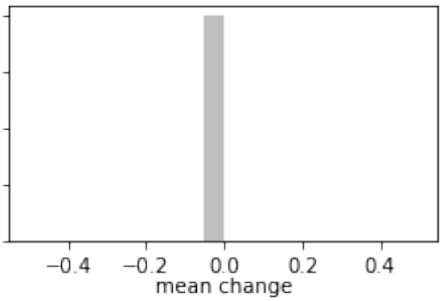
A) mean change group:ss6_cn, 1 entries
max: 0.0971803, min: 0.0971803



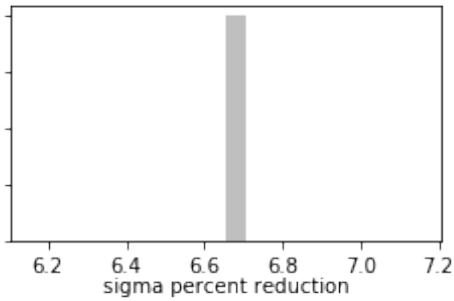
B) sigma change group:ss6_cn, 1 entries
max: 7.3844, min: 7.3844



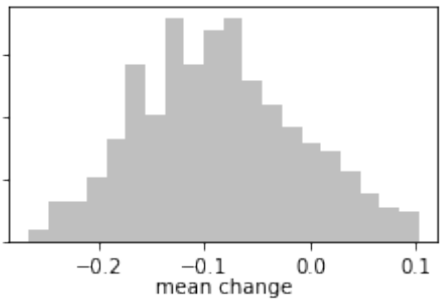
C) mean change group:vka6_cn, 1 entries
max:-0.00205207, min:-0.00205207



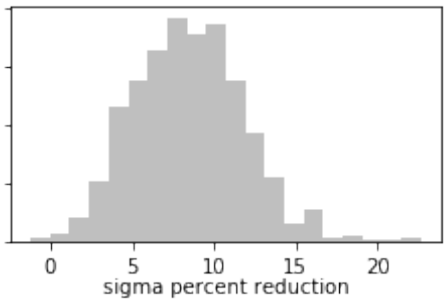
D) sigma change group:vka6_cn, 1 entries
max: 6.65533, min: 6.65533



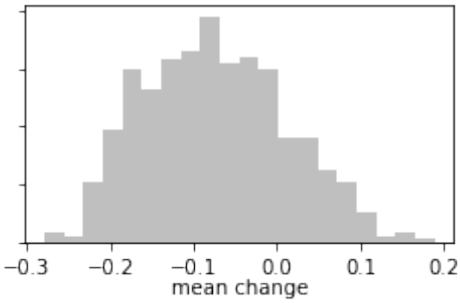
E) mean change group:grss5, 705 entries
max: 0.102548, min: -0.266688



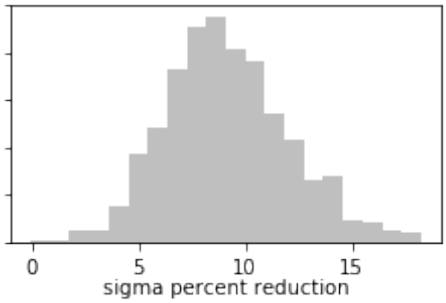
F) sigma change group:grss5, 705 entries
max: 22.6526, min: -1.21124



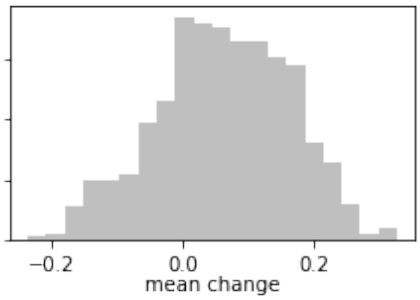
G) mean change group:grss3, 705 entries
max: 0.188897, min: -0.279149



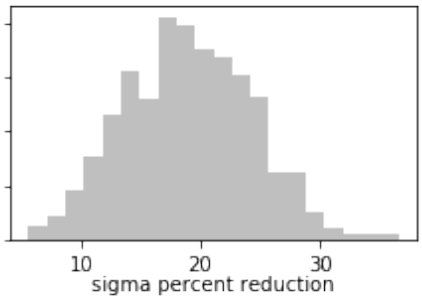
H) sigma change group:grss3, 705 entries
max: 18.2268, min:-0.0486687



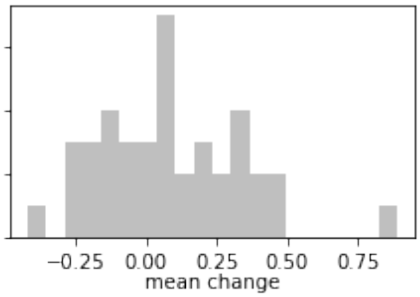
A) mean change group:grhk5, 705 entries
max: 0.326491, min: -0.235445



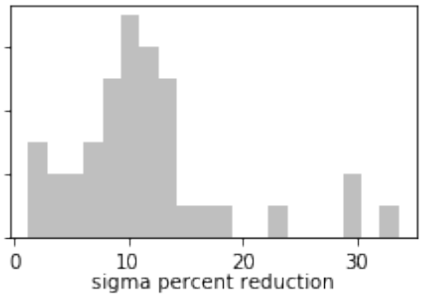
B) sigma change group:grhk5, 705 entries
max: 36.5957, min: 5.56976



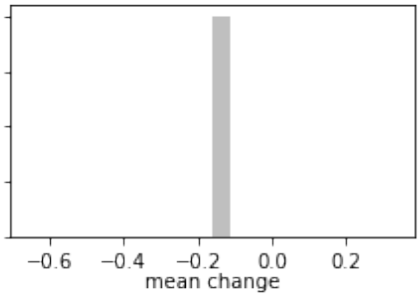
C) mean change group:strk, 40 entries
max: 0.887499, min: -0.418932



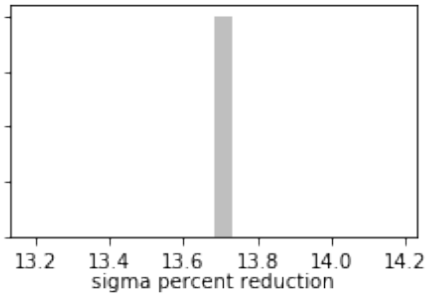
D) sigma change group:strk, 40 entries
max: 33.6005, min: 1.29142



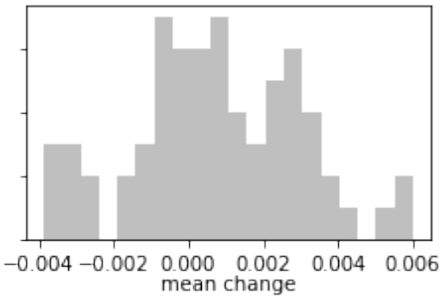
E) mean change group:vka8_cn, 1 entries
max: -0.160681, min: -0.160681



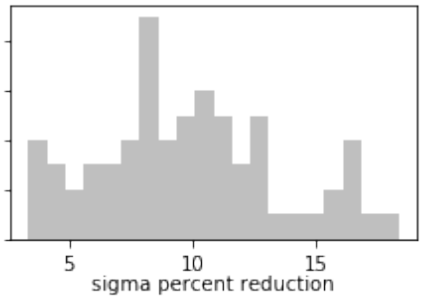
F) sigma change group:vka8_cn, 1 entries
max: 13.6813, min: 13.6813



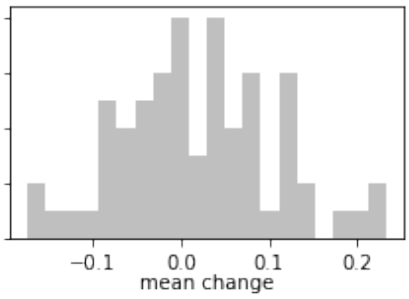
G) mean change group:pp_strt0, 67 entries
max:0.00600315, min:-0.00387314



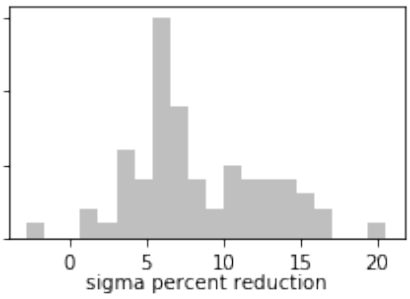
H) sigma change group:pp_strt0, 67 entries
max: 18.3272, min: 3.36293



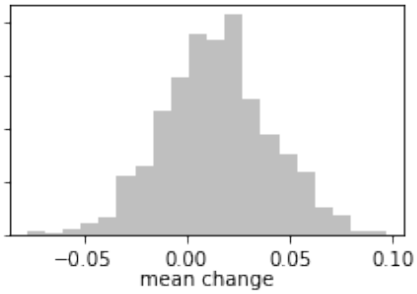
A) mean change group:pp_vka2, 67 entries
max: 0.234138, min: -0.175498



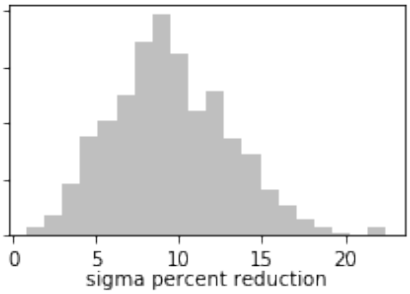
B) sigma change group:pp_vka2, 67 entries
max: 20.574, min: -2.79581



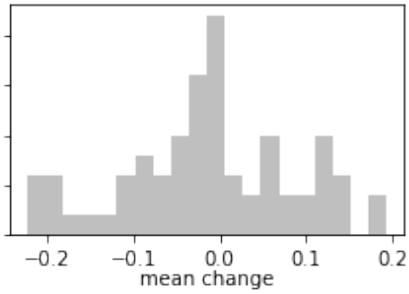
C) mean change group:grsy5, 705 entries
max: 0.0971963, min:-0.0775899



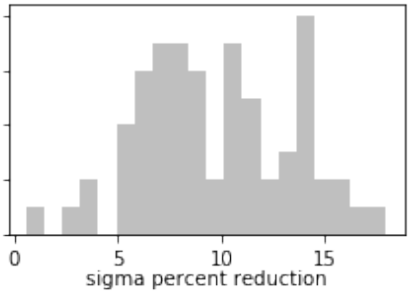
D) sigma change group:grsy5, 705 entries
max: 22.4869, min: 0.791827



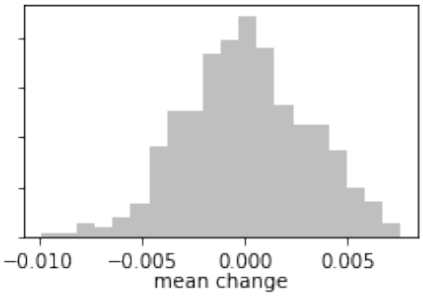
E) mean change group:pp_hk0, 67 entries
max: 0.193773, min: -0.223535



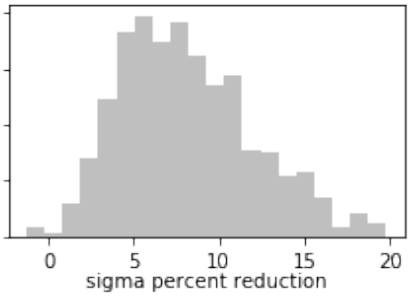
F) sigma change group:pp_hk0, 67 entries
max: 17.9692, min: 0.595834



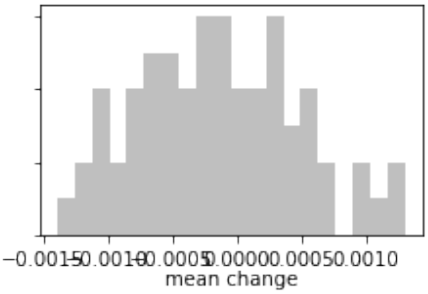
G) mean change group:grrech2, 705 entries
max:0.00757302, min:-0.00989057



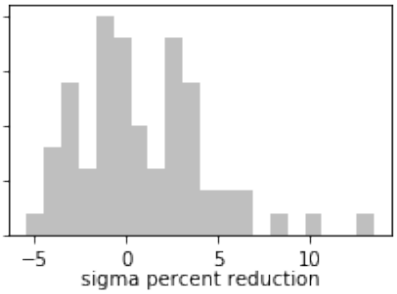
H) sigma change group:grrech2, 705 entries
max: 19.8128, min: -1.30351



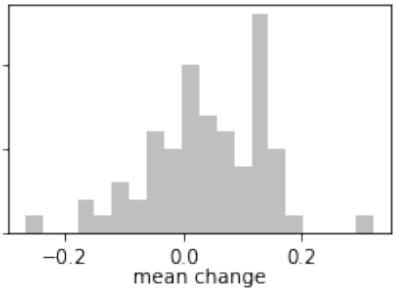
A) mean change group:pp_rech1, 67 entries
max:0.00130674, min:-0.00139261



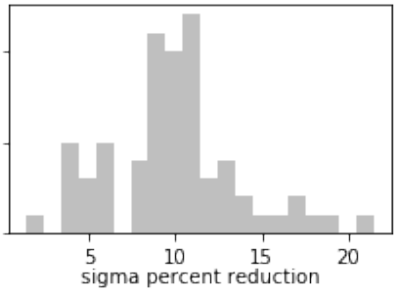
B) sigma change group:pp_rech1, 67 entries
max: 13.5348, min: -5.44046



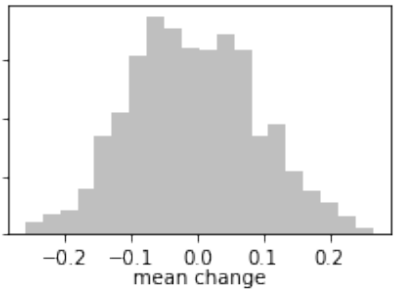
C) mean change group:pp_vka0, 67 entries
max: 0.319861, min: -0.267065



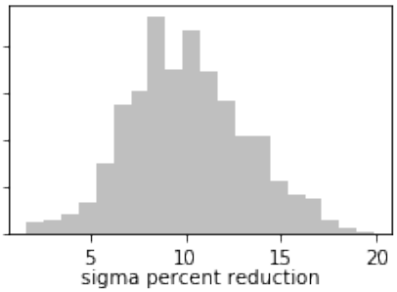
D) sigma change group:pp_vka0, 67 entries
max: 21.4965, min: 1.41393



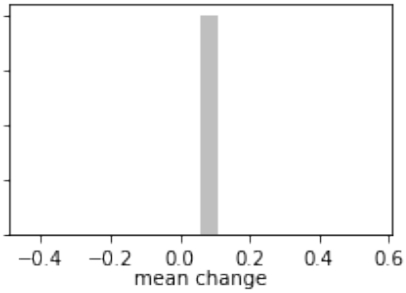
E) mean change group:grvka3, 705 entries
max: 0.265869, min: -0.259629



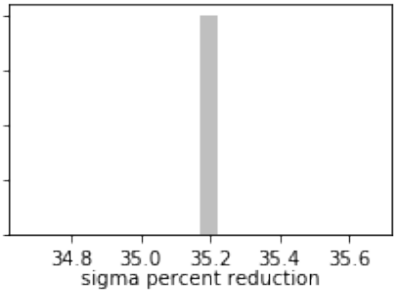
F) sigma change group:grvka3, 705 entries
max: 19.8728, min: 1.68783



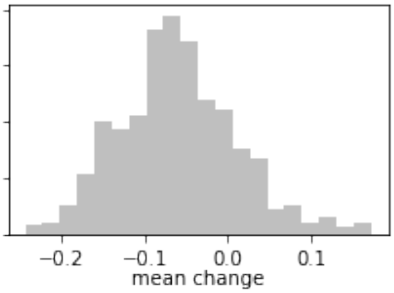
G) mean change group:hk6_cn, 1 entries
max: 0.0580977, min: 0.0580977



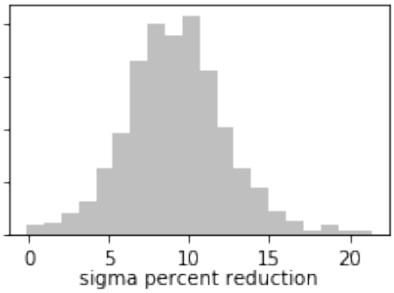
H) sigma change group:hk6_cn, 1 entries
max: 35.1718, min: 35.1718



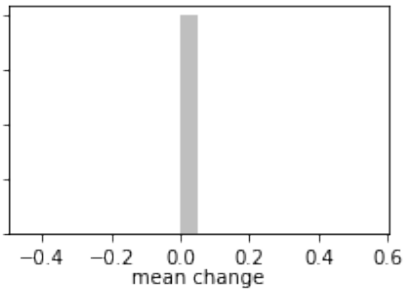
A) mean change group:grhk4, 705 entries
max: 0.172712, min: -0.24388



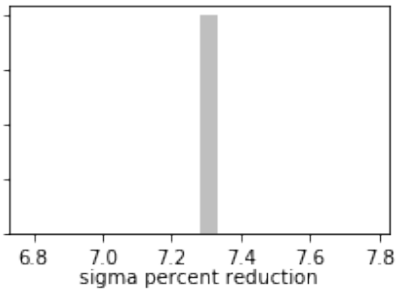
B) sigma change group:grhk4, 705 entries
max: 21.4264, min: -0.131177



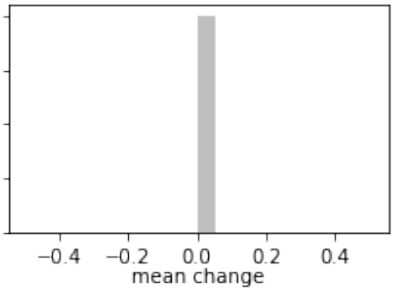
C) mean change group:ss8_cn, 1 entries
max: 0.0515606, min: 0.0515606



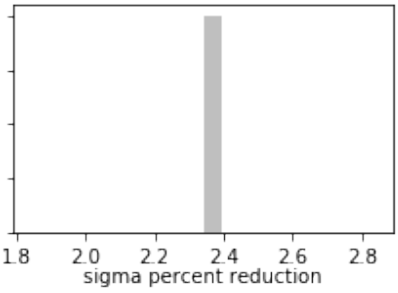
D) sigma change group:ss8_cn, 1 entries
max: 7.28014, min: 7.28014



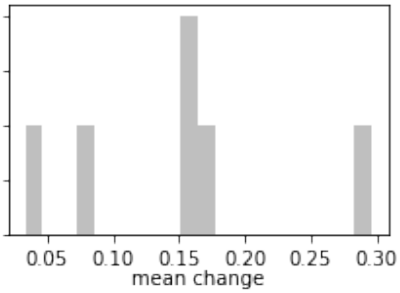
E) mean change group:strt7_cn, 1 entries
max:0.00302895, min:0.00302895



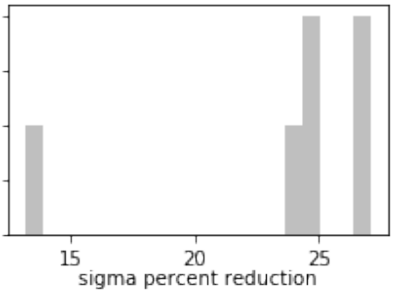
F) sigma change group:strt7_cn, 1 entries
max: 2.34174, min: 2.34174

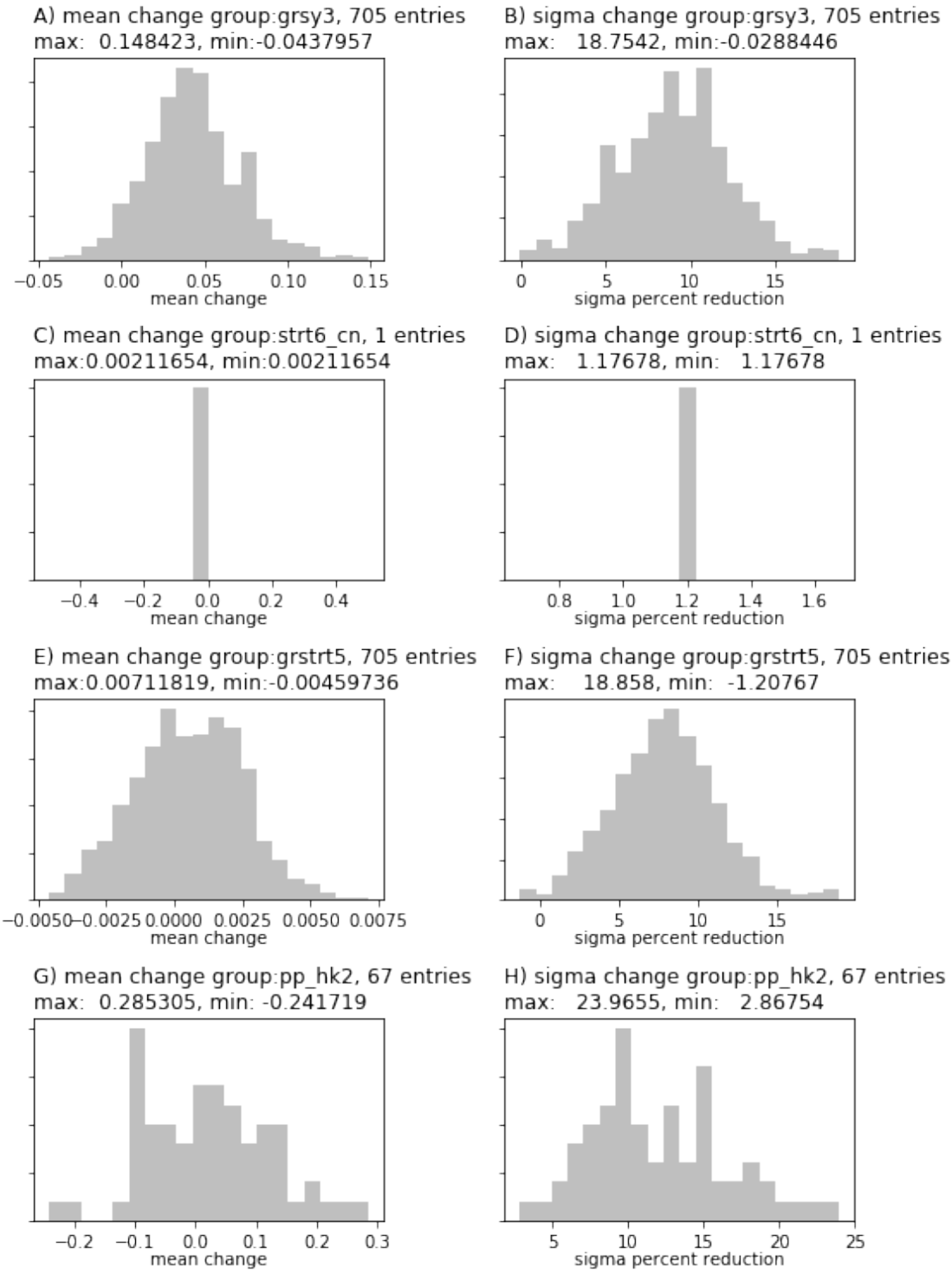


G) mean change group:welflux_k02, 6 entries
max: 0.295879, min: 0.0331856

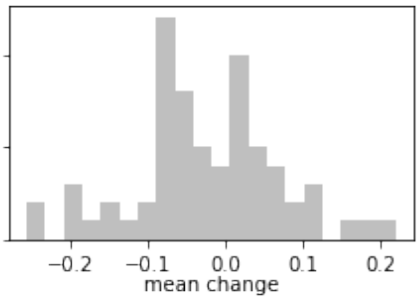


H) sigma change group:welflux_k02, 6 entries
max: 27.1372, min: 13.1679

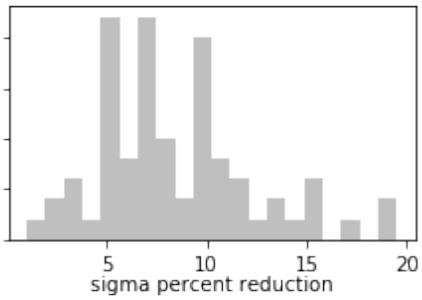



A) mean change group:grsy3, 705 entries
max: 0.148423, min:-0.0437957
mean change
B) sigma change group:grsy3, 705 entries
max: 18.7542, min:-0.0288446
sigma percent reduction
C) mean change group:strt6_cn, 1 entries
max:0.00211654, min:0.00211654
mean change
D) sigma change group:strt6_cn, 1 entries
max: 1.17678, min: 1.17678
sigma percent reduction
E) mean change group:grstrt5, 705 entries
max:0.00711819, min:-0.00459736
mean change
F) sigma change group:grstrt5, 705 entries
max: 18.858, min: -1.20767
sigma percent reduction
G) mean change group:pp_hk2, 67 entries
max: 0.285305, min: -0.241719
mean change
H) sigma change group:pp_hk2, 67 entries
max: 23.9655, min: 2.86754
sigma percent reduction

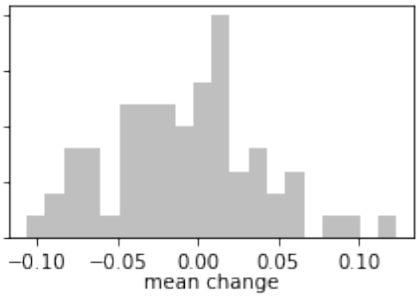
A) mean change group:pp_ss0, 67 entries
max: 0.220002, min: -0.255115



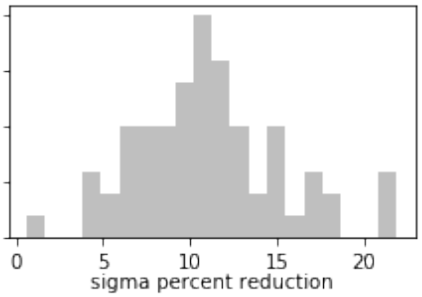
B) sigma change group:pp_ss0, 67 entries
max: 19.4826, min: 1.0153



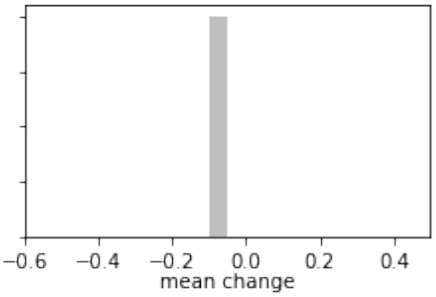
C) mean change group:pp_sy1, 67 entries
max: 0.1233, min: -0.106417



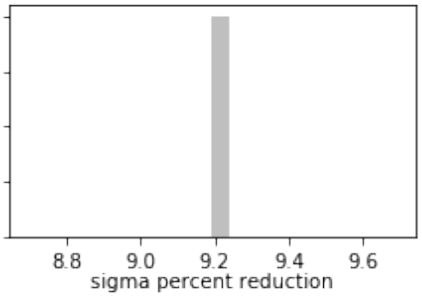
D) sigma change group:pp_sy1, 67 entries
max: 21.8838, min: 0.613913



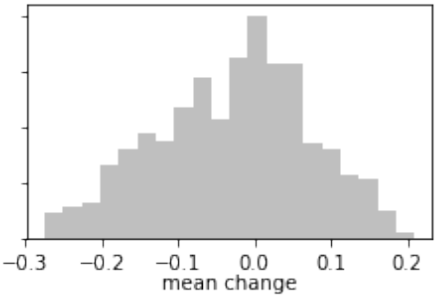
E) mean change group:sy7_cn, 1 entries
max:-0.0493597, min:-0.0493597



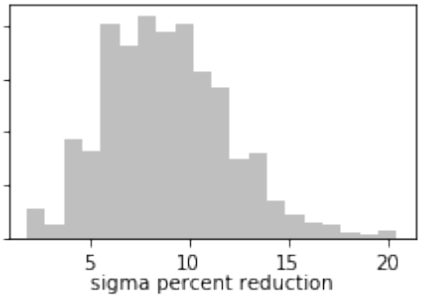
F) sigma change group:sy7_cn, 1 entries
max: 9.19149, min: 9.19149



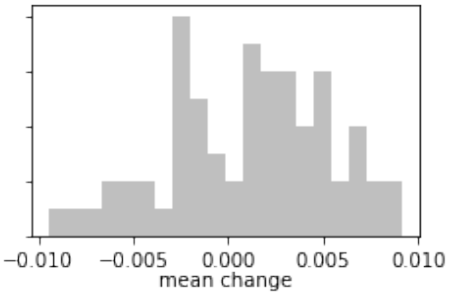
G) mean change group:grvka4, 705 entries
max: 0.209195, min: -0.274577



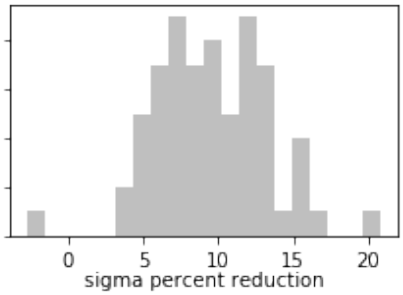
H) sigma change group:grvka4, 705 entries
max: 20.4461, min: 1.84337



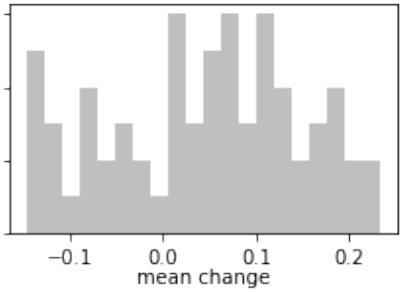
A) mean change group:pp_rech0, 67 entries
max:0.00916587, min:-0.0094705



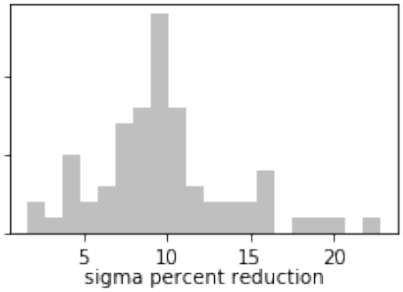
B) sigma change group:pp_rech0, 67 entries
max: 20.8268, min: -2.73944



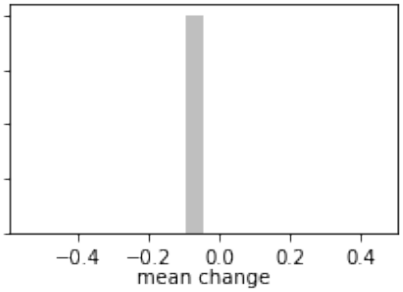
C) mean change group:pp_hk1, 67 entries
max: 0.233375, min: -0.146418



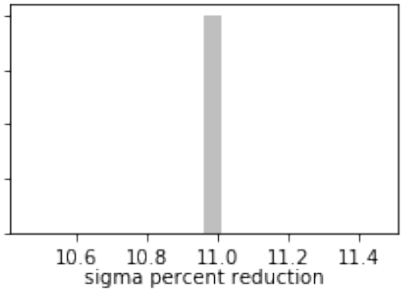
D) sigma change group:pp_hk1, 67 entries
max: 22.8422, min: 1.57942



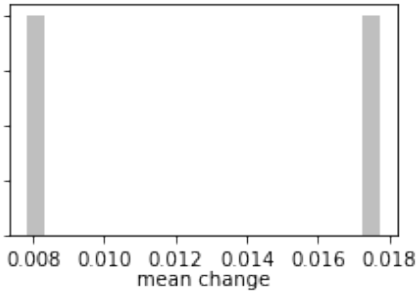
E) mean change group:hk7_cn, 1 entries
max:-0.0453914, min:-0.0453914



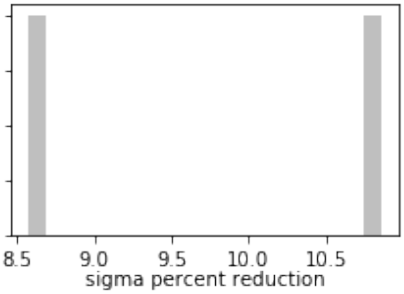
F) sigma change group:hk7_cn, 1 entries
max: 10.9611, min: 10.9611



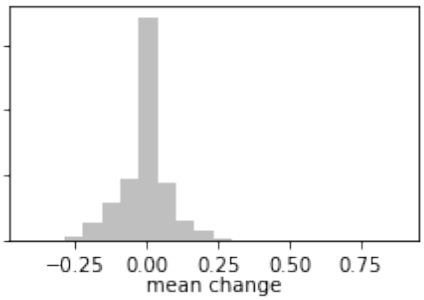
G) mean change group:welflux, 2 entries
max: 0.0177506, min:0.00781415



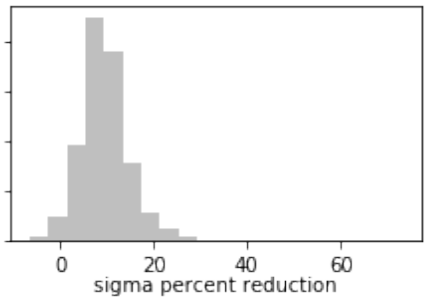
H) sigma change group:welflux, 2 entries
max: 10.8634, min: 8.56582



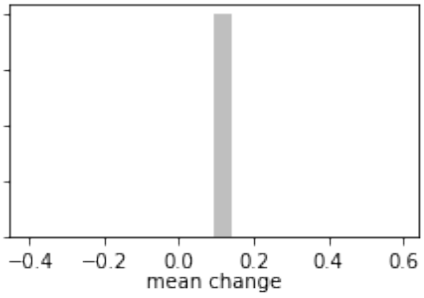
A) mean change group:all, 13200 entries
max: 0.887499, min: -0.418932



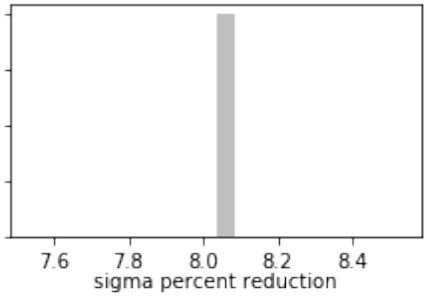
B) sigma change group:all, 13200 entries
max: 73.3261, min: -6.57774



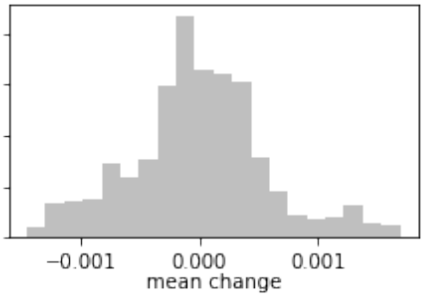
C) mean change group:vka7_cn, 1 entries
max: 0.0924807, min: 0.0924807



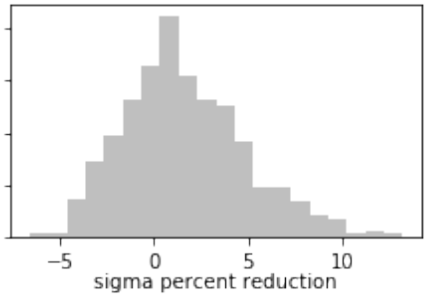
D) sigma change group:vka7_cn, 1 entries
max: 8.03474, min: 8.03474



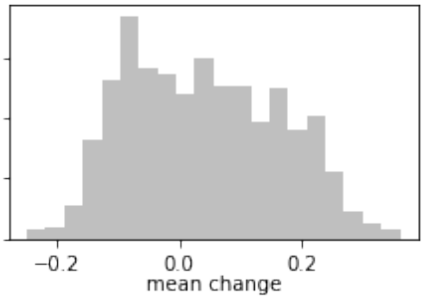
E) mean change group:grrech3, 705 entries
max:0.00168952, min:-0.00145647



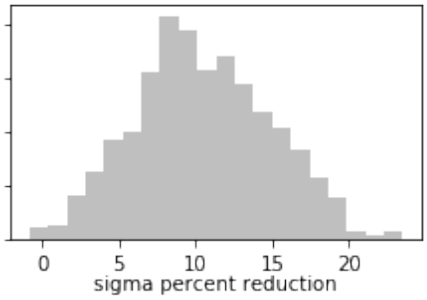
F) sigma change group:grrech3, 705 entries
max: 13.2203, min: -6.57774



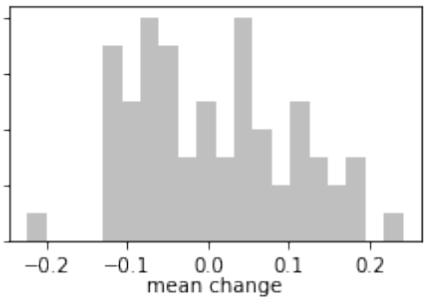
G) mean change group:grss4, 705 entries
max: 0.359907, min: -0.248311



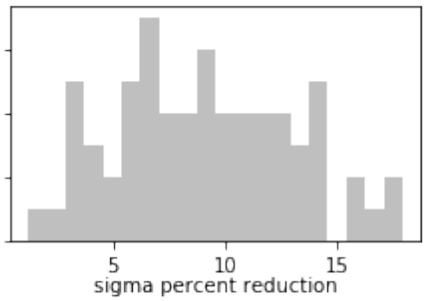
H) sigma change group:grss4, 705 entries
max: 23.5239, min: -0.829862



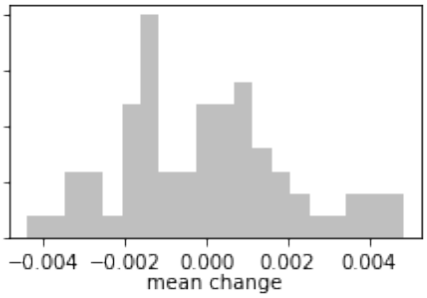
A) mean change group:pp_ss1, 67 entries
max: 0.240781, min: -0.22307



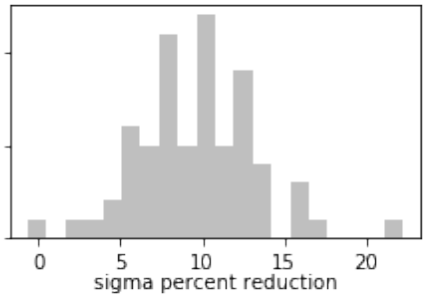
B) sigma change group:pp_ss1, 67 entries
max: 17.9092, min: 1.18892



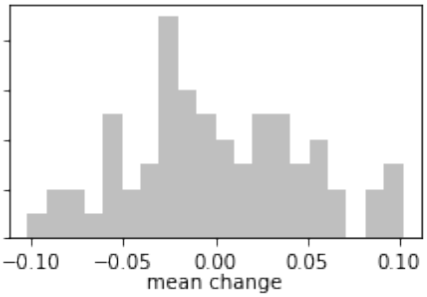
C) mean change group:pp_strt1, 67 entries
max:0.00480947, min:-0.00436778



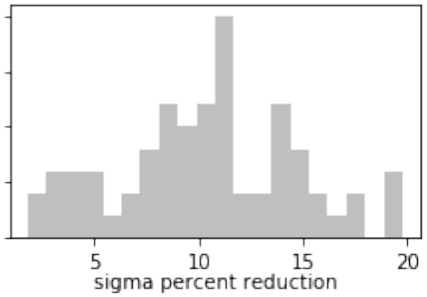
D) sigma change group:pp_strt1, 67 entries
max: 22.2078, min: -0.645749



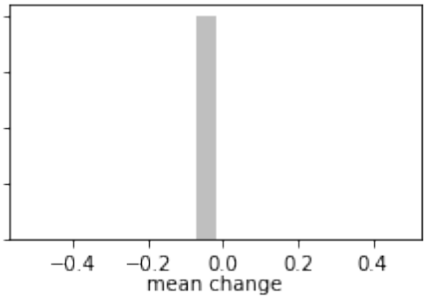
E) mean change group:pp_sy0, 67 entries
max: 0.102167, min: -0.102121



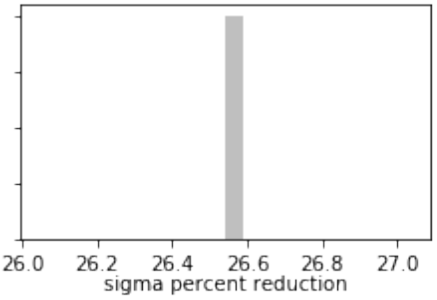
F) sigma change group:pp_sy0, 67 entries
max: 19.7891, min: 1.79239



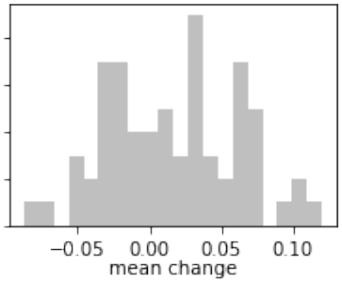
G) mean change group:rech4_cn, 1 entries
max:-0.0205924, min:-0.0205924



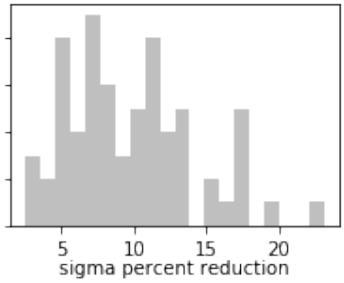
H) sigma change group:rech4_cn, 1 entries
max: 26.5409, min: 26.5409



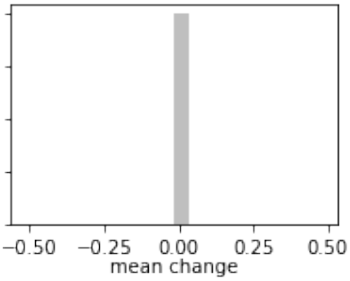
A) mean change group:pp_sy2, 67 entries
max: 0.120147, min:-0.0872637



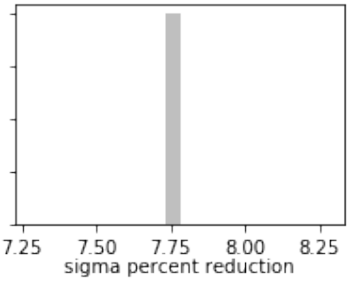
B) sigma change group:pp_sy2, 67 entries
max: 23.1076, min: 2.55649



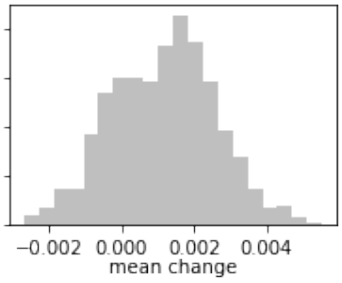
C) mean change group:sy6_cn, 1 entries
max:-0.0154938, min:-0.0154938



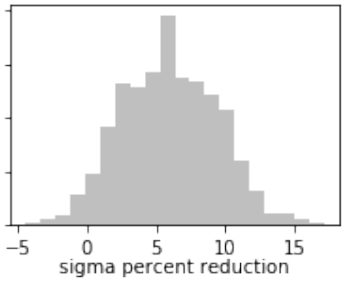
D) sigma change group:sy6_cn, 1 entries
max: 7.77968, min: 7.77968



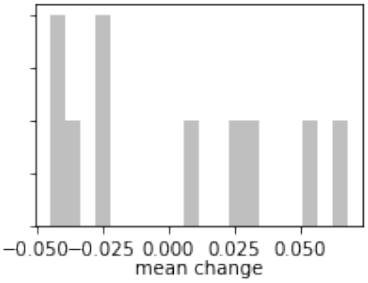
E) mean change group:grstrt4, 705 entries
max:0.00553779, min:-0.0026852



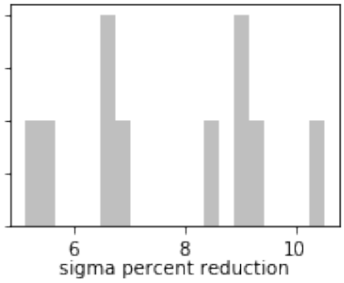
F) sigma change group:grstrt4, 705 entries
max: 17.1211, min: -4.4479



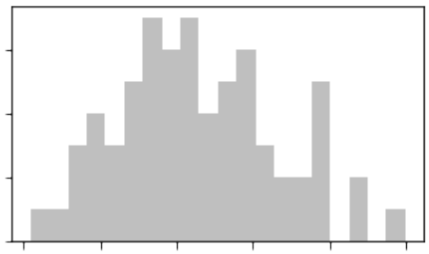
G) mean change group:drncond_k00, 10 entries
max: 0.0679611, min:-0.0447873



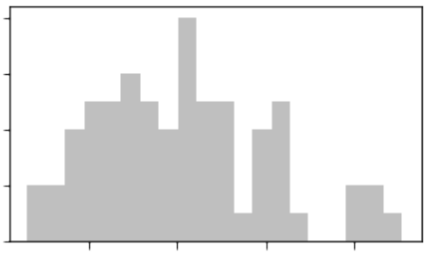
H) sigma change group:drncond_k00, 10 entries
max: 10.51, min: 5.1331



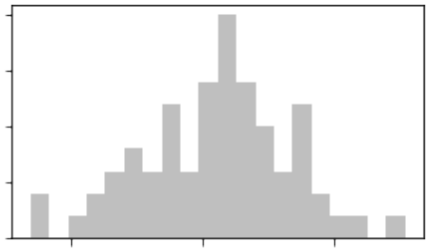
A) mean change group:pp_ss2, 67 entries
max: 0.199418, min: -0.29101



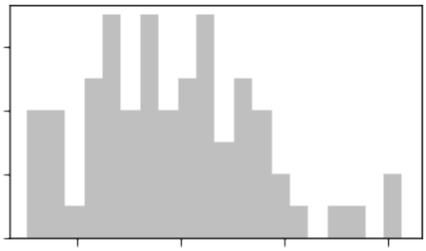
B) sigma change group:pp_ss2, 67 entries
max: 22.6921, min: 1.59979



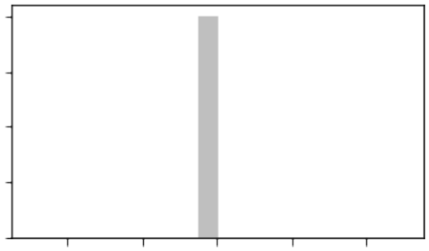
C) mean change group:pp_vka1, 67 entries
max: 0.307447, min: -0.26224



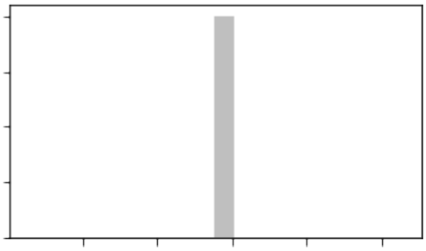
D) sigma change group:pp_vka1, 67 entries
max: 20.7023, min: 2.64517



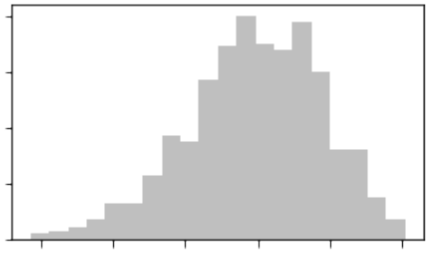
E) mean change group:sy8_cn, 1 entries
max:0.00325204, min:0.00325204



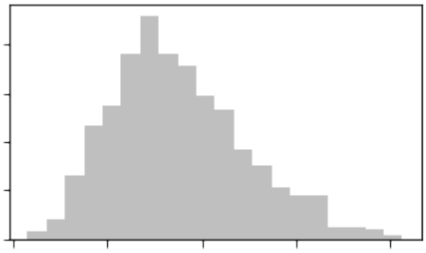
F) sigma change group:sy8_cn, 1 entries
max: 4.75538, min: 4.75538



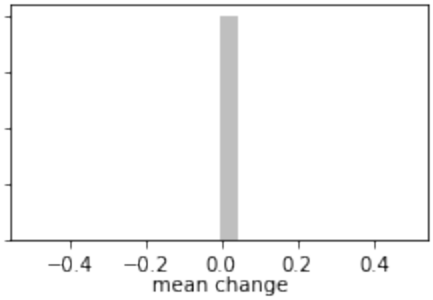
G) mean change group:grvka5, 705 entries
max: 0.205244, min: -0.314772



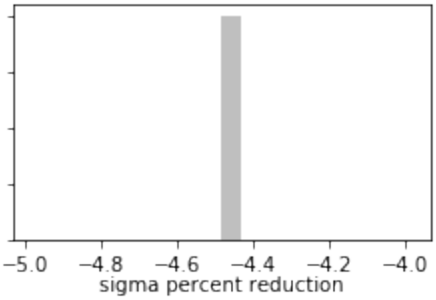
H) sigma change group:grvka5, 705 entries
max: 20.6465, min: 0.767111



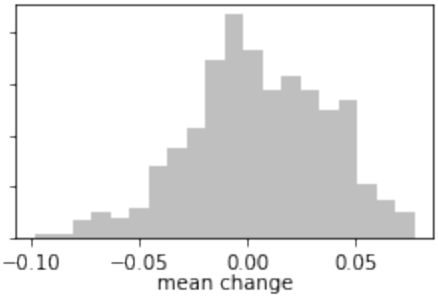
A) mean change group:rech5_cn, 1 entries
max:-0.00484726, min:-0.00484726



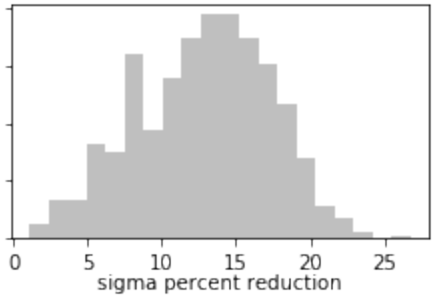
B) sigma change group:rech5_cn, 1 entries
max: -4.48154, min: -4.48154



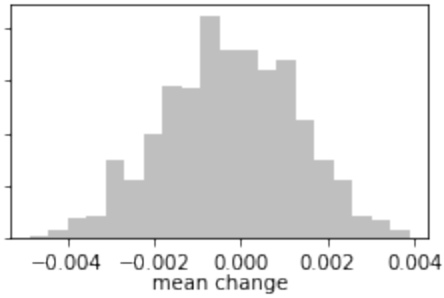
C) mean change group:grsy4, 705 entries
max: 0.077575, min:-0.0989142



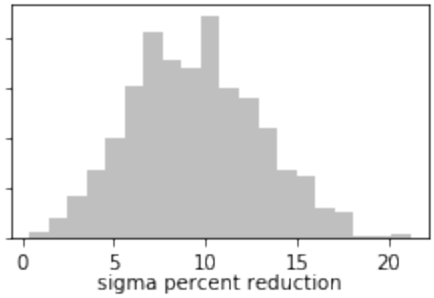
D) sigma change group:grsy4, 705 entries
max: 26.7578, min: 1.08901



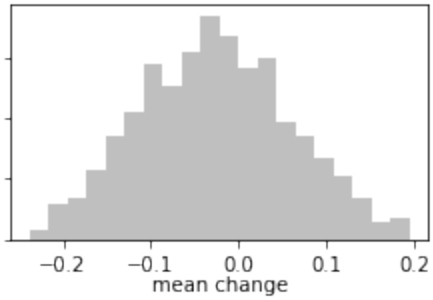
E) mean change group:grstrt3, 705 entries
max:0.00389917, min:-0.00487131



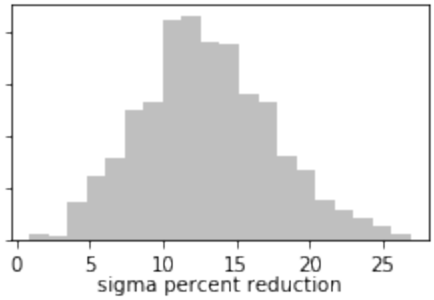
F) sigma change group:grstrt3, 705 entries
max: 21.1745, min: 0.398322



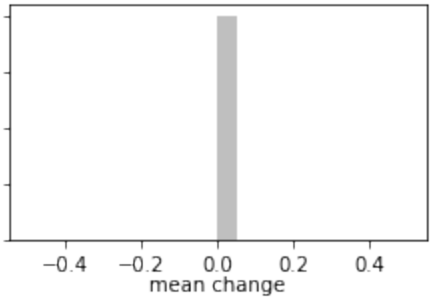
G) mean change group:grhk3, 705 entries
max: 0.195051, min: -0.238493



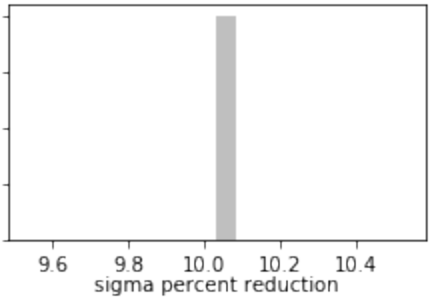
H) sigma change group:grhk3, 705 entries
max: 26.8644, min: 0.924891



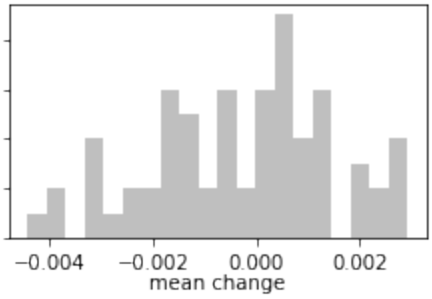
A) mean change group:strt8_cn, 1 entries
max:0.00174037, min:0.00174037



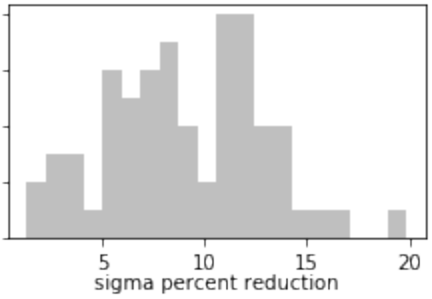
B) sigma change group:strt8_cn, 1 entries
max: 10.0308, min: 10.0308



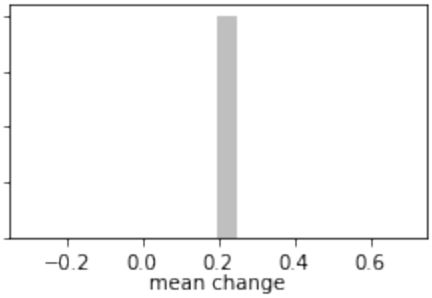
C) mean change group:pp_strt2, 67 entries
max:0.00292313, min:-0.00443698



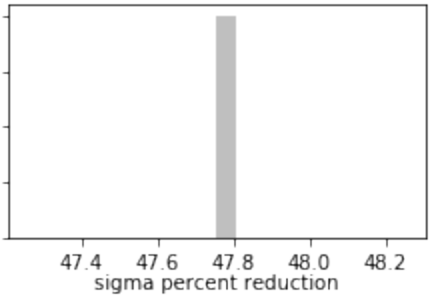
D) sigma change group:pp_strt2, 67 entries
max: 19.8547, min: 1.27937



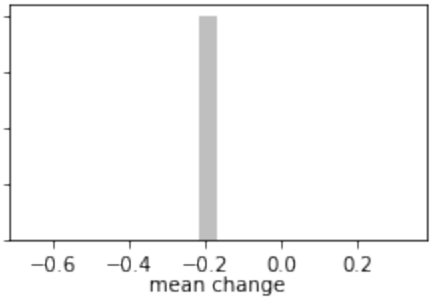
E) mean change group:hk8_cn, 1 entries
max: 0.197241, min: 0.197241



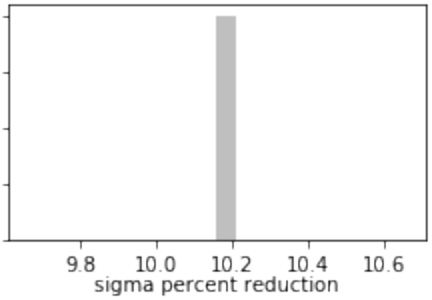
F) sigma change group:hk8_cn, 1 entries
max: 47.7539, min: 47.7539

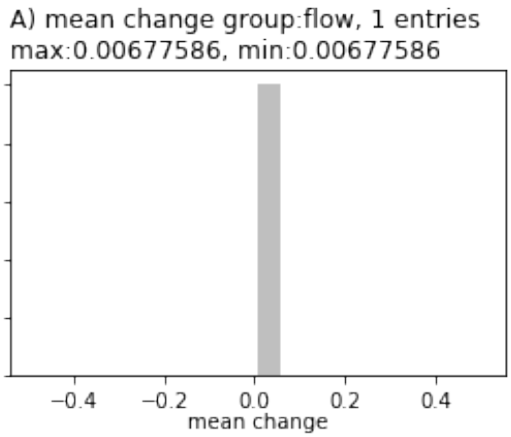


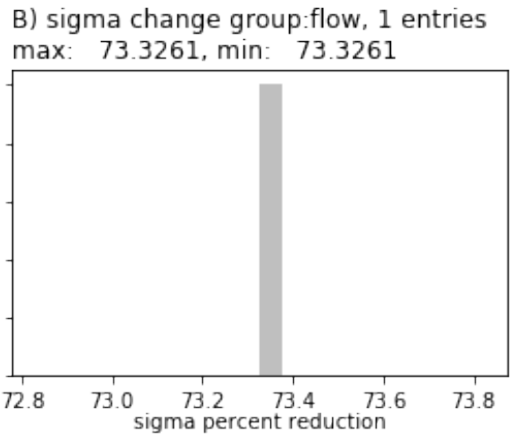
G) mean change group:ss7_cn, 1 entries
max: -0.168241, min: -0.168241



H) sigma change group:ss7_cn, 1 entries
max: 10.1595, min: 10.1595




A) mean change group:flow, 1 entries
max:0.00677586, min:0.00677586
−0.4
−0.2
0.0
0.2
0.4
mean change


B) sigma change group:flow, 1 entries
max: 73.3261, min: 73.3261
72.8
73.0
73.2
73.4
73.6
73.8
sigma percent reduction

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.par_names).to_dataframe()
         loc.loc[:,:] = 1.0
         loc_dist = 5000.0
         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"]
             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"]
             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 0.4925373134328358
hds_00_002_015_000 0.4794326241134752 0.5074626865671642
```

```
hds_00_003_008_000 0.43829787234042555 0.43283582089552236
hds_00_009_001_000 0.3304964539007092 0.2835820895522388
hds_00_013_010_000 0.15319148936170213 0.14925373134328357
hds_00_015_016_000 0.13900709219858157 0.11940298507462686
hds_00_021_010_000 0.06950354609929078 0.07462686567164178
hds_00_022_015_000 0.12198581560283688 0.13432835820895522
hds_00_024_004_000 0.17872340425531916 0.1791044776119403
hds_00_026_006_000 0.2198581560283688 0.208955223880597
hds_00_029_015_000 0.29929078014184396 0.29850746268656714
hds_00_033_007_000 0.3829787234042553 0.3880597014925373
hds_00_034_010_000 0.4 0.40298507462686567
```

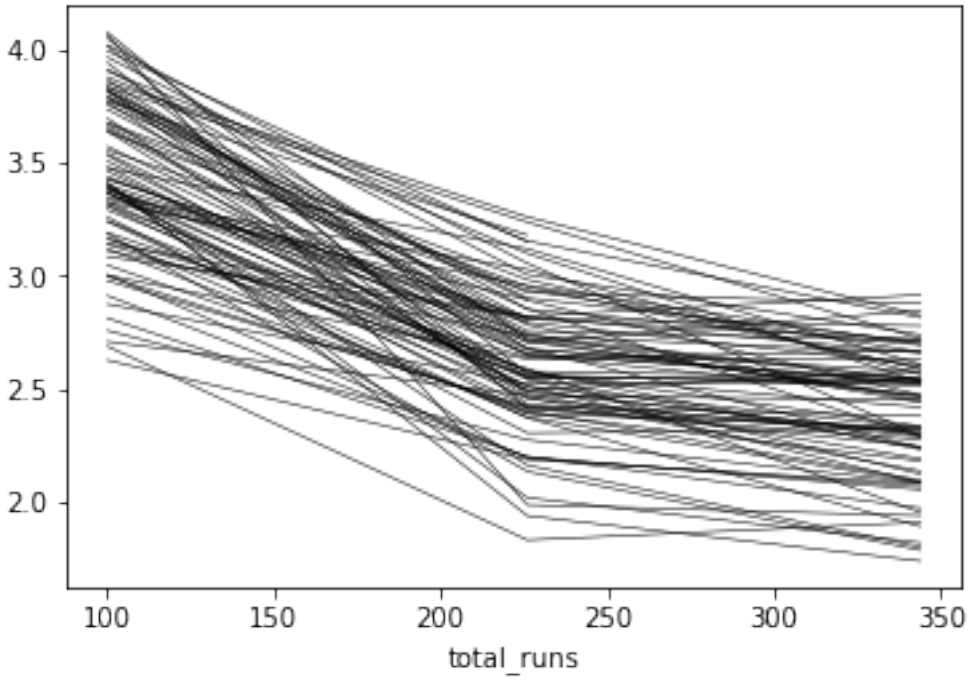
```
Out[20]: fo_39_19791230        2346.0
         hds_00_002_009_000    1818.0
         hds_00_002_015_000    1802.0
         hds_00_003_008_000    1882.0
         hds_00_009_001_000    2042.0
         hds_00_013_010_000    2186.0
         hds_00_015_016_000    2218.0
         hds_00_021_010_000    2266.0
         hds_00_022_015_000    2202.0
         hds_00_024_004_000    2154.0
         hds_00_026_006_000    2122.0
         hds_00_029_015_000    2026.0
         hds_00_033_007_000    1930.0
         hds_00_034_010_000    1914.0
         dtype: float64
```

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

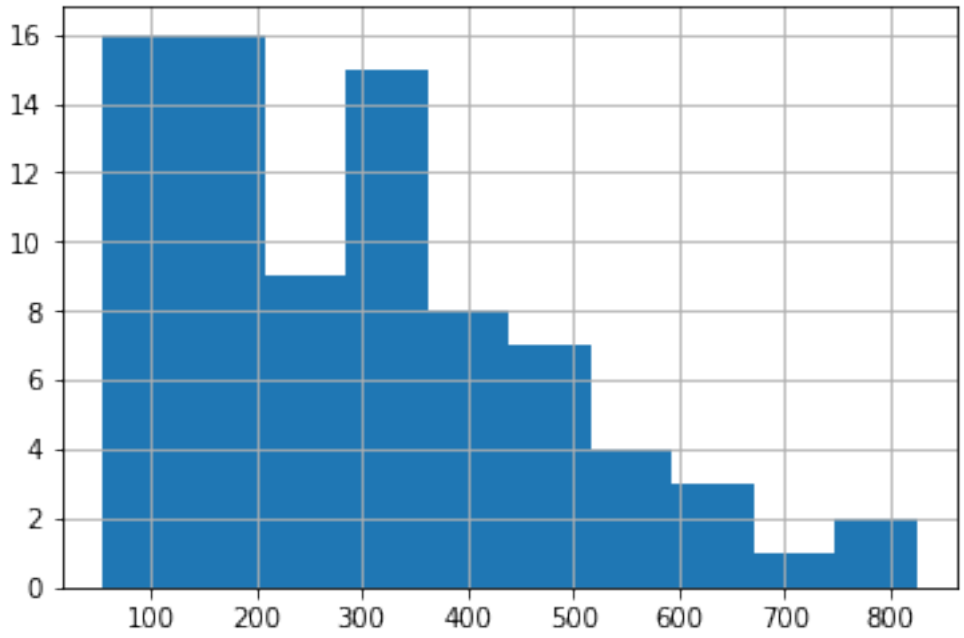
```
[[1. 1. 1. ... 1. 1. 1.]
 [1. 1. 1. ... 1. 1. 1.]
 [1. 1. 1. ... 1. 1. 1.]
 ...
 [1. 1. 1. ... 1. 1. 1.]
 [1. 1. 1. ... 1. 1. 1.]
 [1. 1. 1. ... 1. 1. 1.]]
<class 'numpy.ndarray'>
```

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

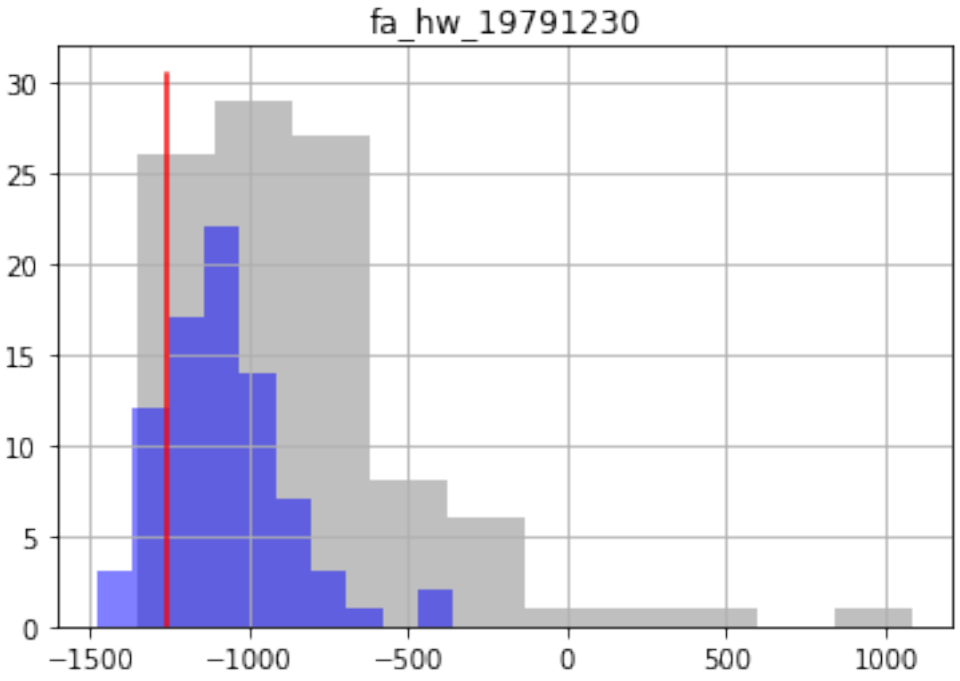
```
In [23]: phi = pd.read_csv(os.path.join(m_d,"freyberg_ies.phi.actual.csv"),index_col=0)
         phi.index = phi.total_runs
         phi.iloc[:,6:].apply(np.log10).plot(legend=False,lw=0.5,color='k')
         plt.show()
         phi.iloc[-1,6:].hist()
```

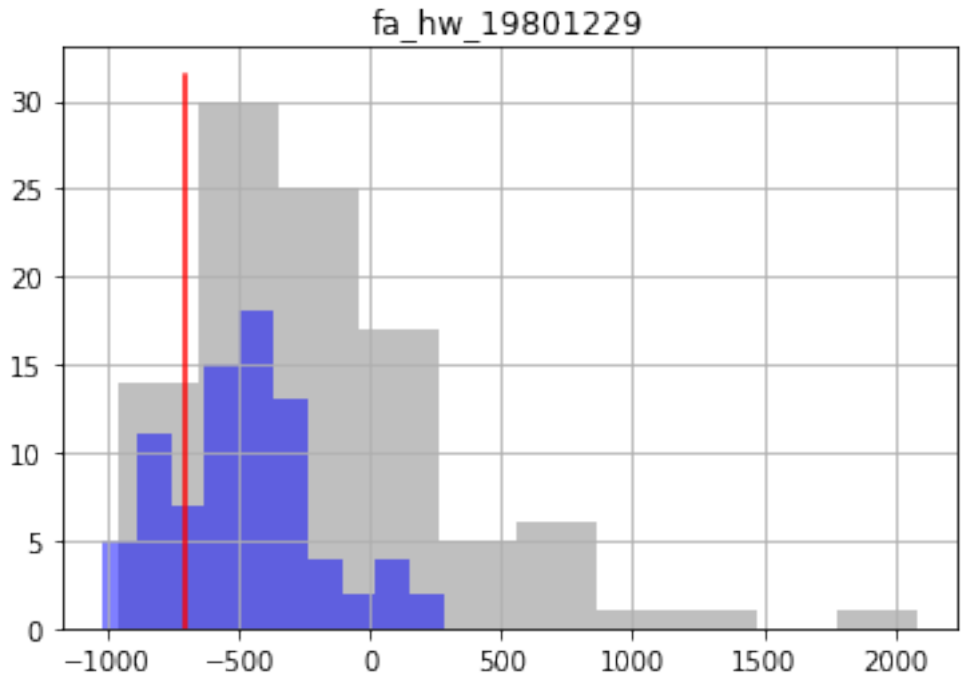


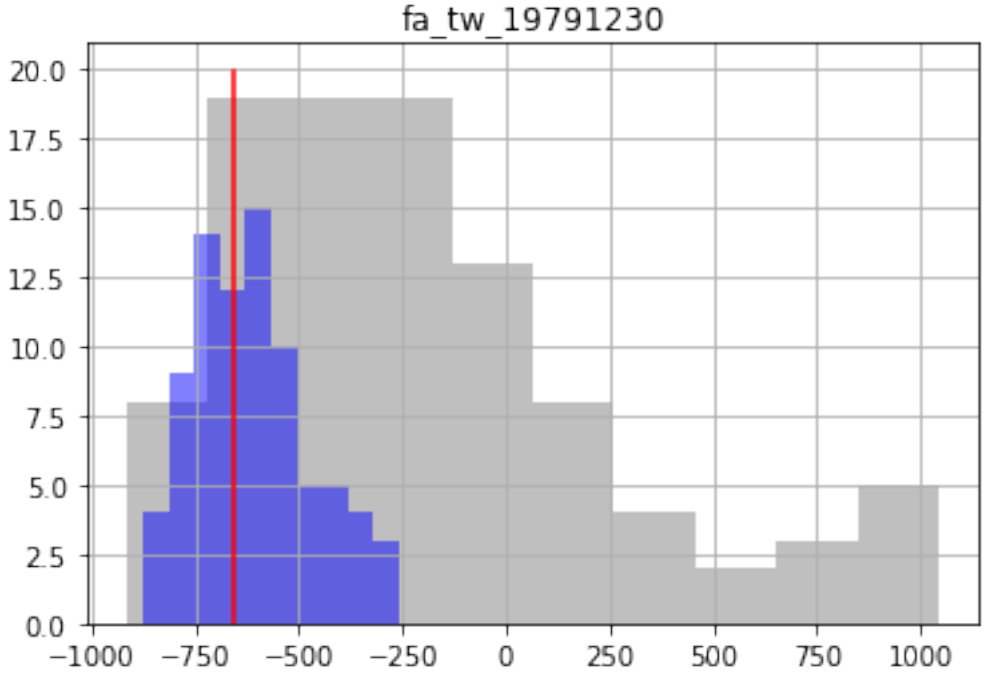
Out[23]: <matplotlib.axes._subplots.AxesSubplot at 0x181f09d748>

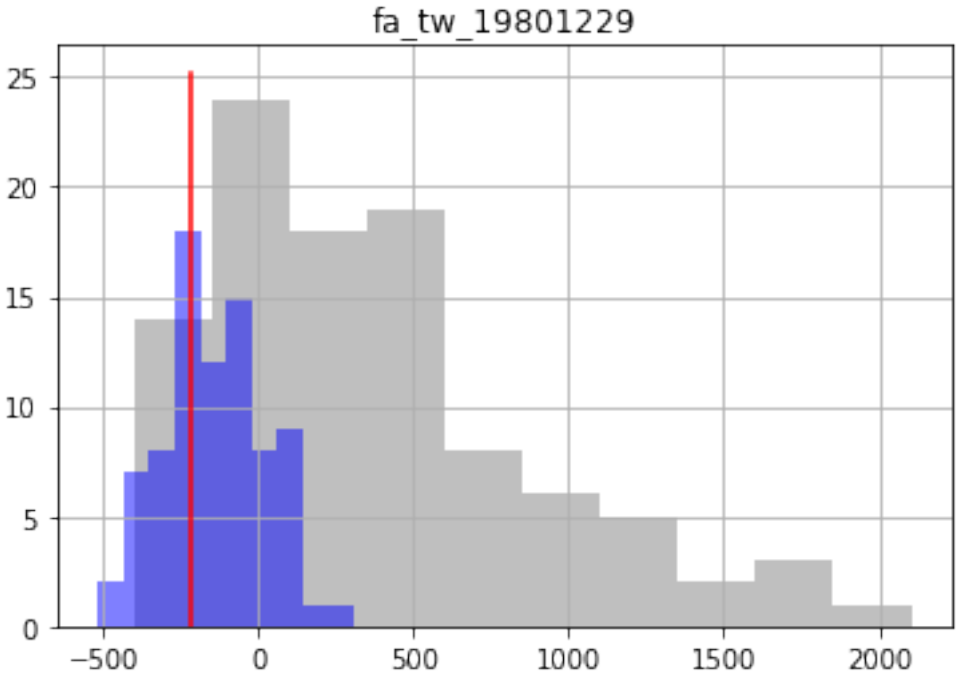


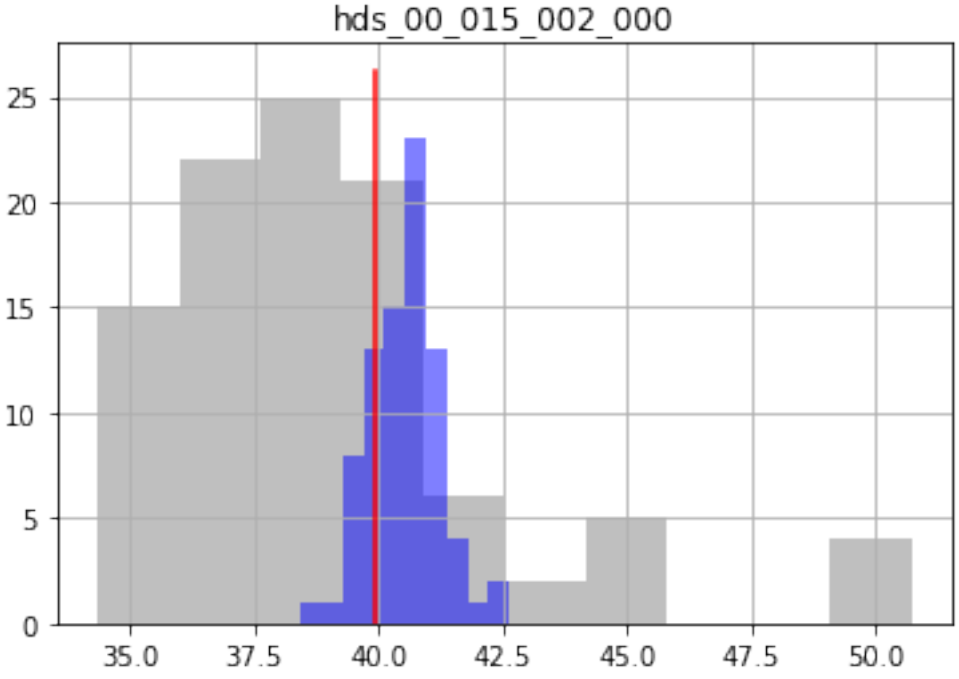
In [24]:
```
oe_pr = pd.read_csv(os.path.join(m_d,"freyberg_ies.0.obs.csv"),index_col=0)
oe_pt = pd.read_csv(os.path.join(m_d,"freyberg_ies.{0}.obs.csv".format(pst.control_dat
obs = pst.observation_data
fnames = pst.pestpp_options["forecasts"].split(",")
for forecast in fnames:
    ax = plt.subplot(111)
    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()
```

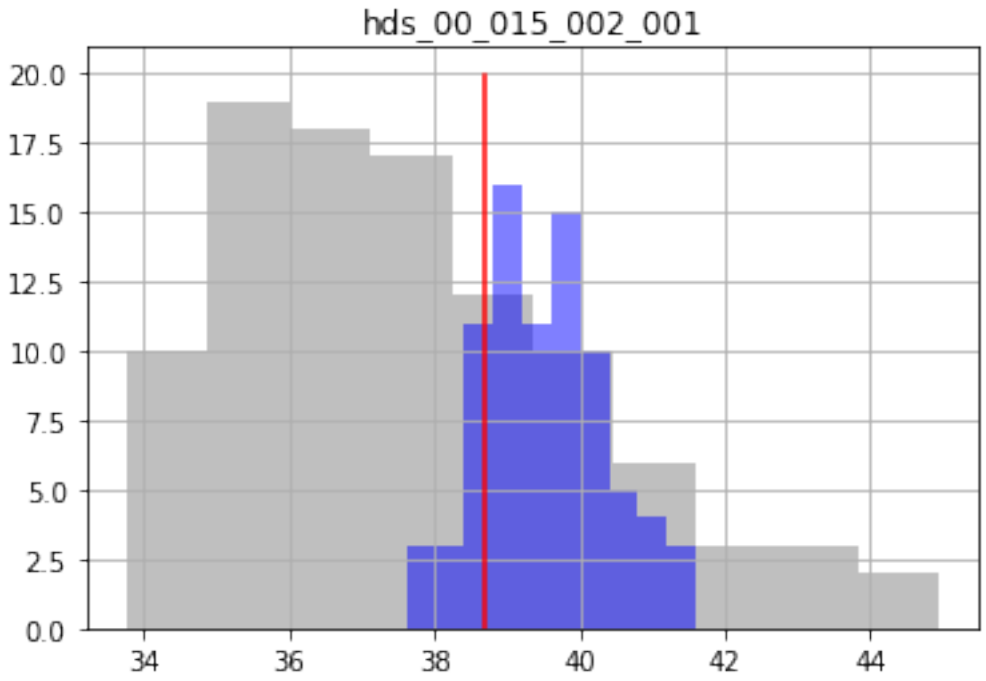



fa_hw_19801229
30
25
20
15
10
5
0
−1000
−500
0
500
1000
1500
2000


fa_tw_19791230
20.0
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0.0
−1000
−750
−500
−250
0
250
500
750
1000

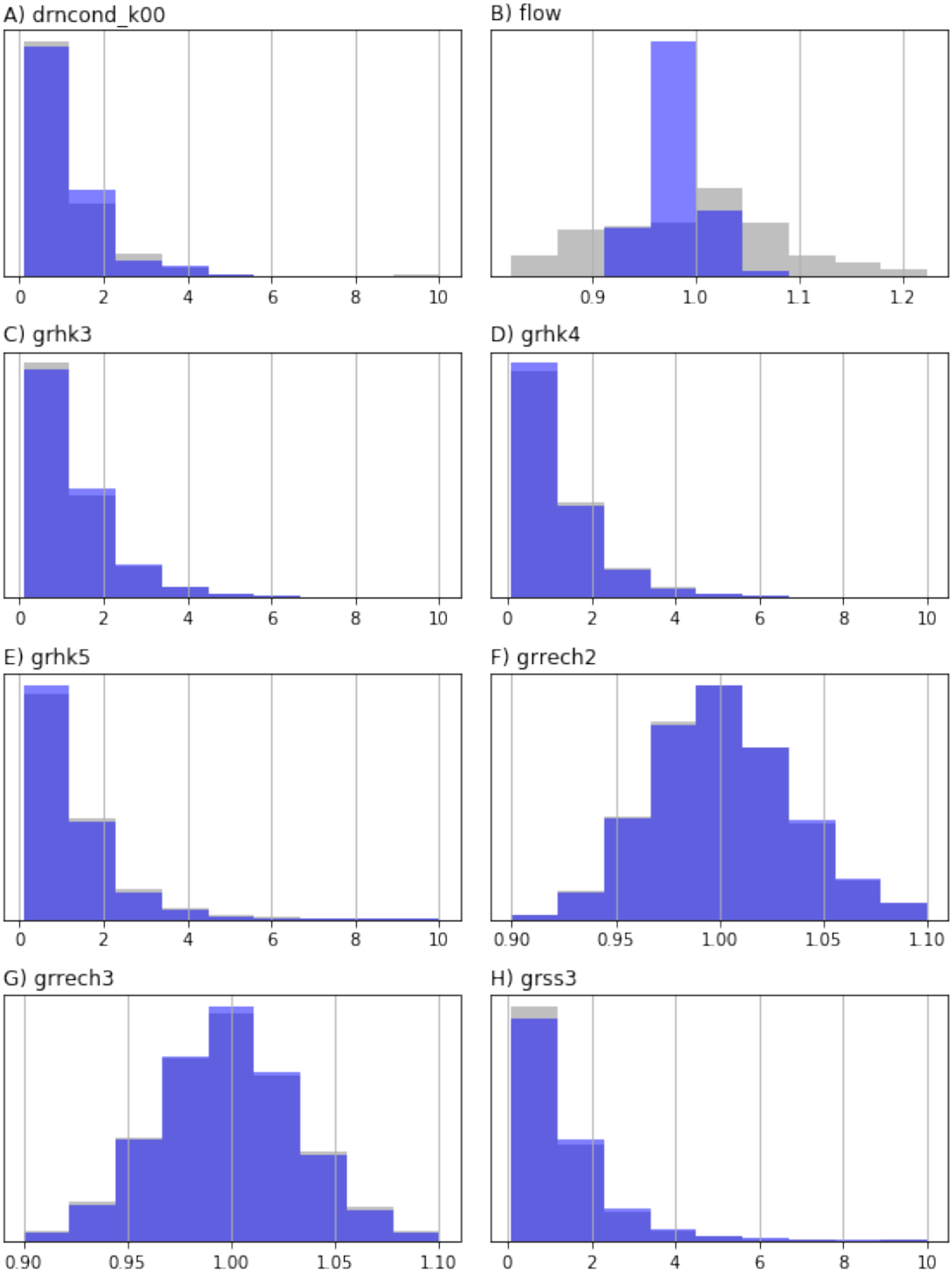

fa_tw_19801229
25
20
15
10
5
0
−500
0
500
1000
1500
2000

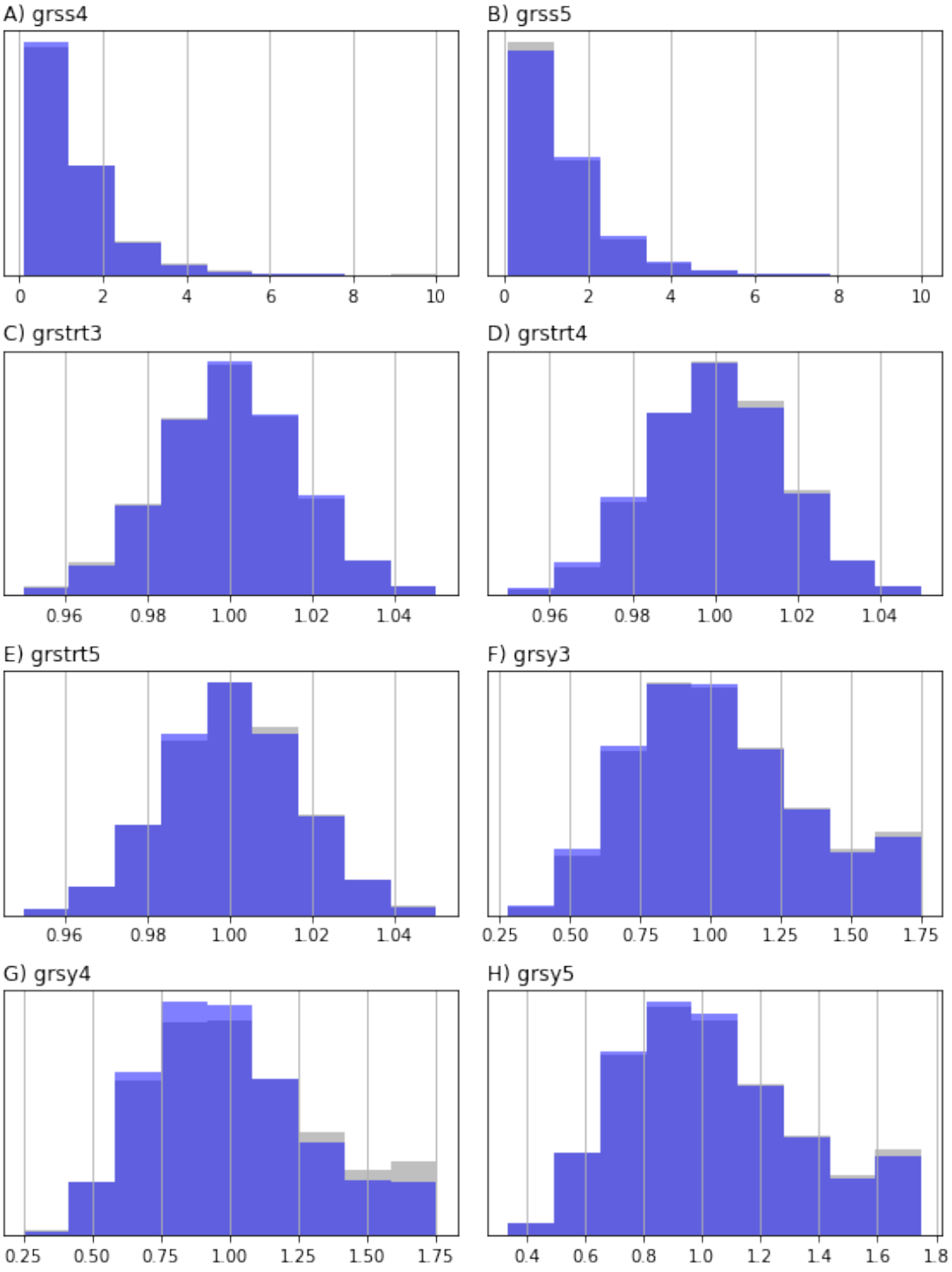

hds_00_015_002_000
25
20
15
10
5
0
35.0
37.5
40.0
42.5
45.0
47.5
50.0

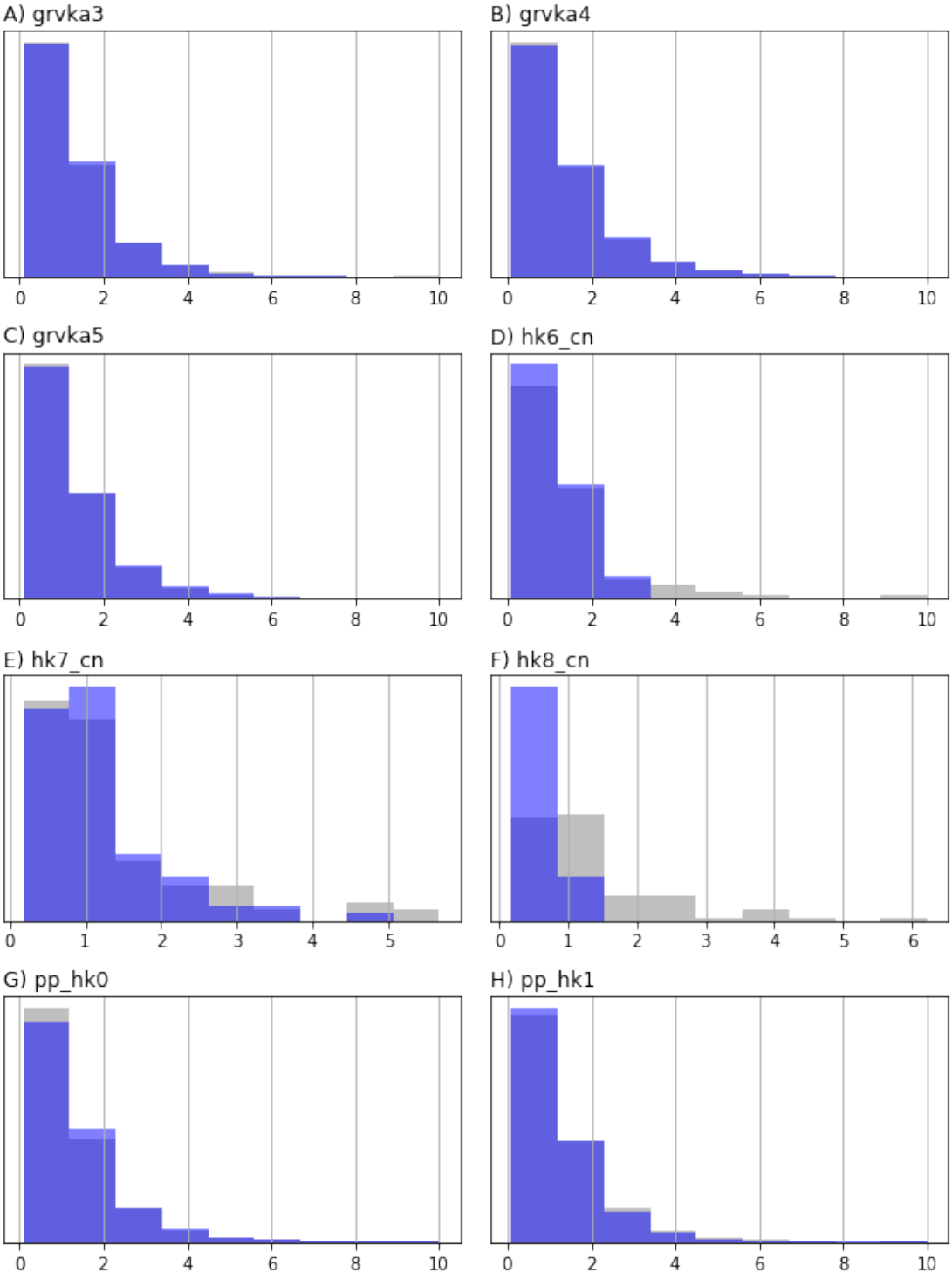


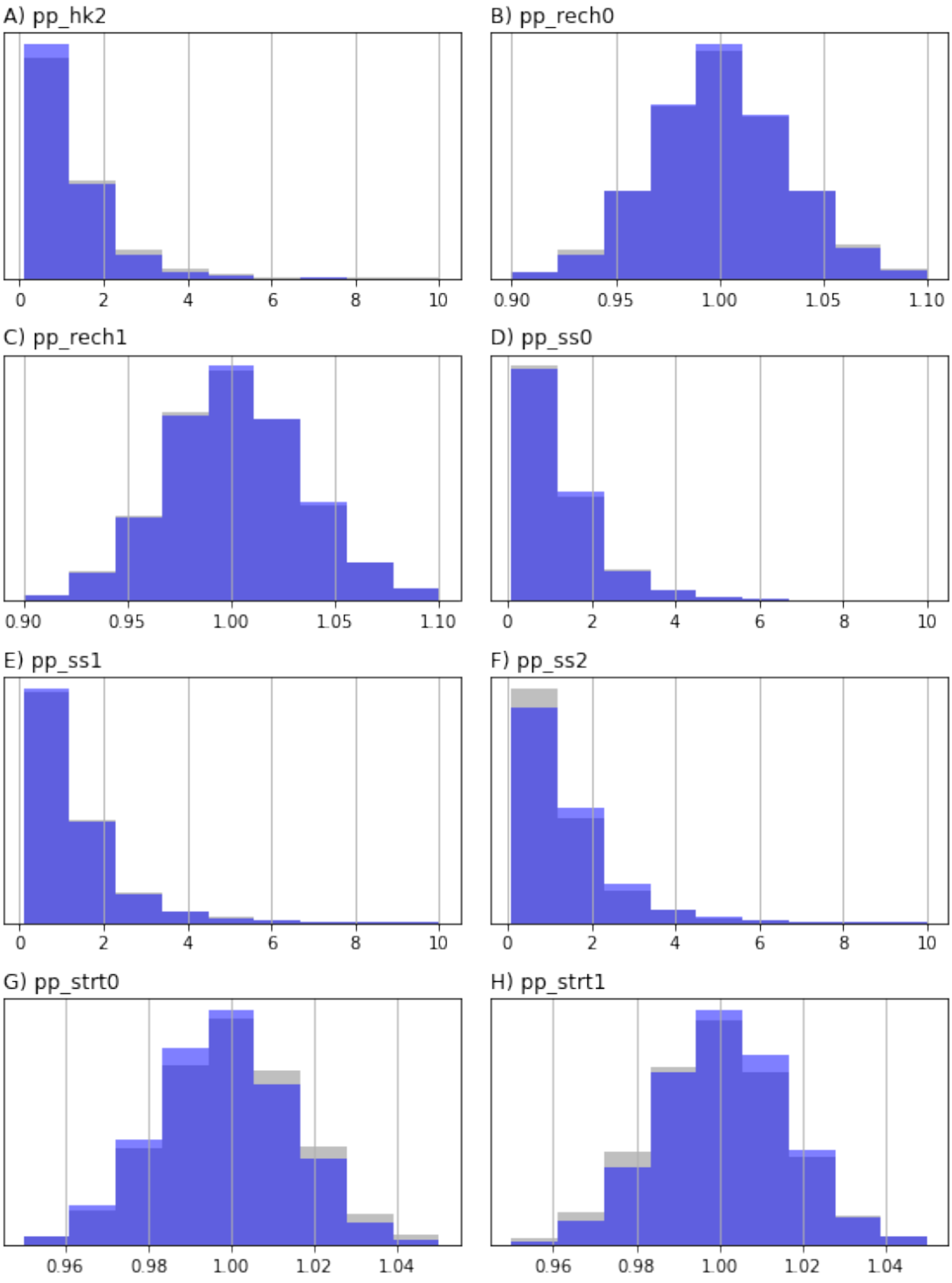

```
In [25]: pe_pr = pd.read_csv(os.path.join(m_d,"freyberg_ies.0.par.csv"),index_col=0)
         pe_pt = pd.read_csv(os.path.join(m_d,"freyberg_ies.{0}.par.csv".format(pst.control_dat
         par = pst.parameter_data
         pdict = par.groupby("pargp").groups
         pyemu.plot_utils.ensemble_helper({"0.5":pe_pr,"b":pe_pt},plot_cols=pdict)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

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


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 8 Axes>,
          <Figure size 576x756 with 8 Axes>,
          <Figure size 576x756 with 8 Axes>,
          <Figure size 576x756 with 8 Axes>,
```

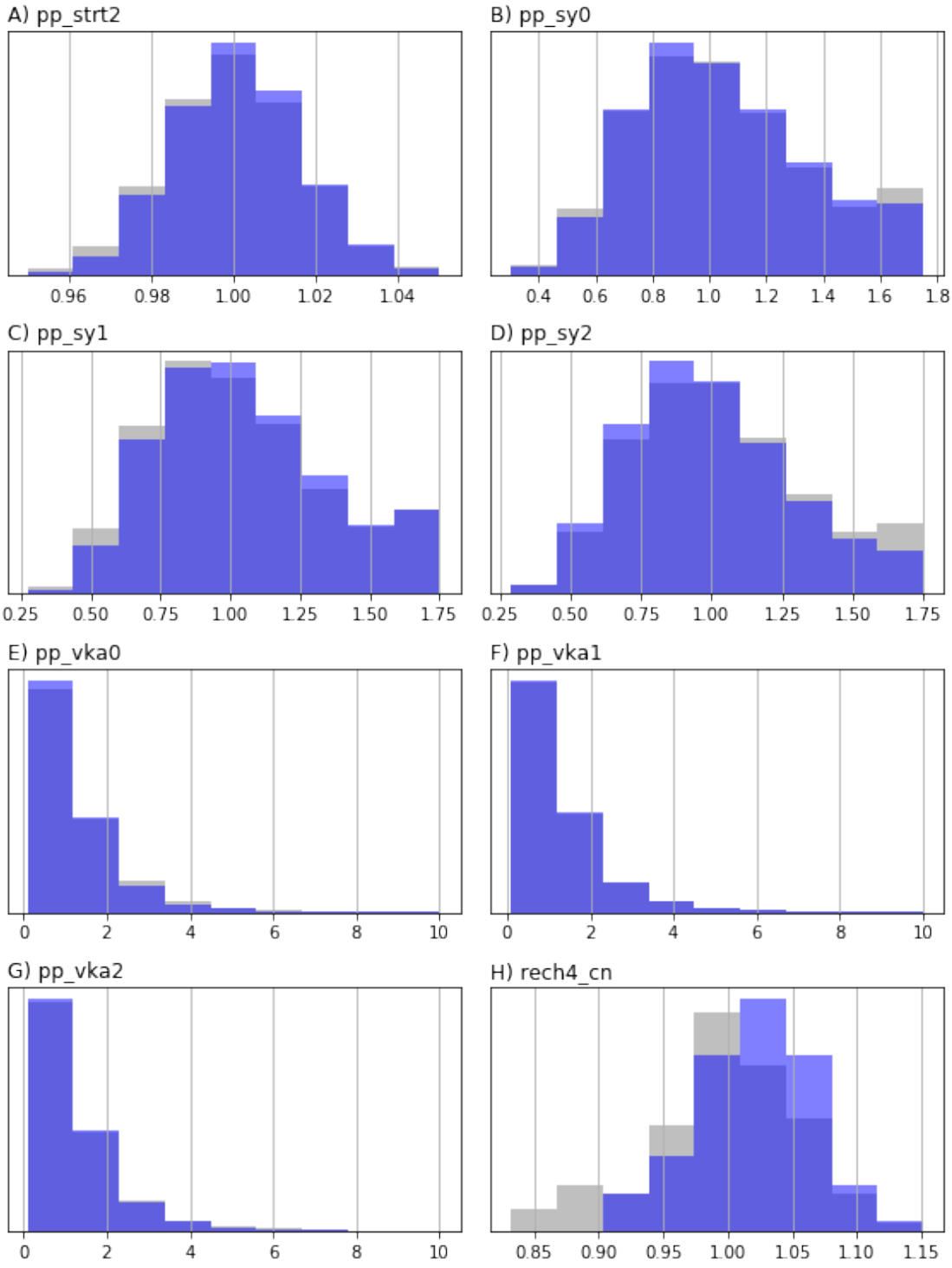
```
        <Figure size 576x756 with 8 Axes>,
        <Figure size 576x756 with 8 Axes>]

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

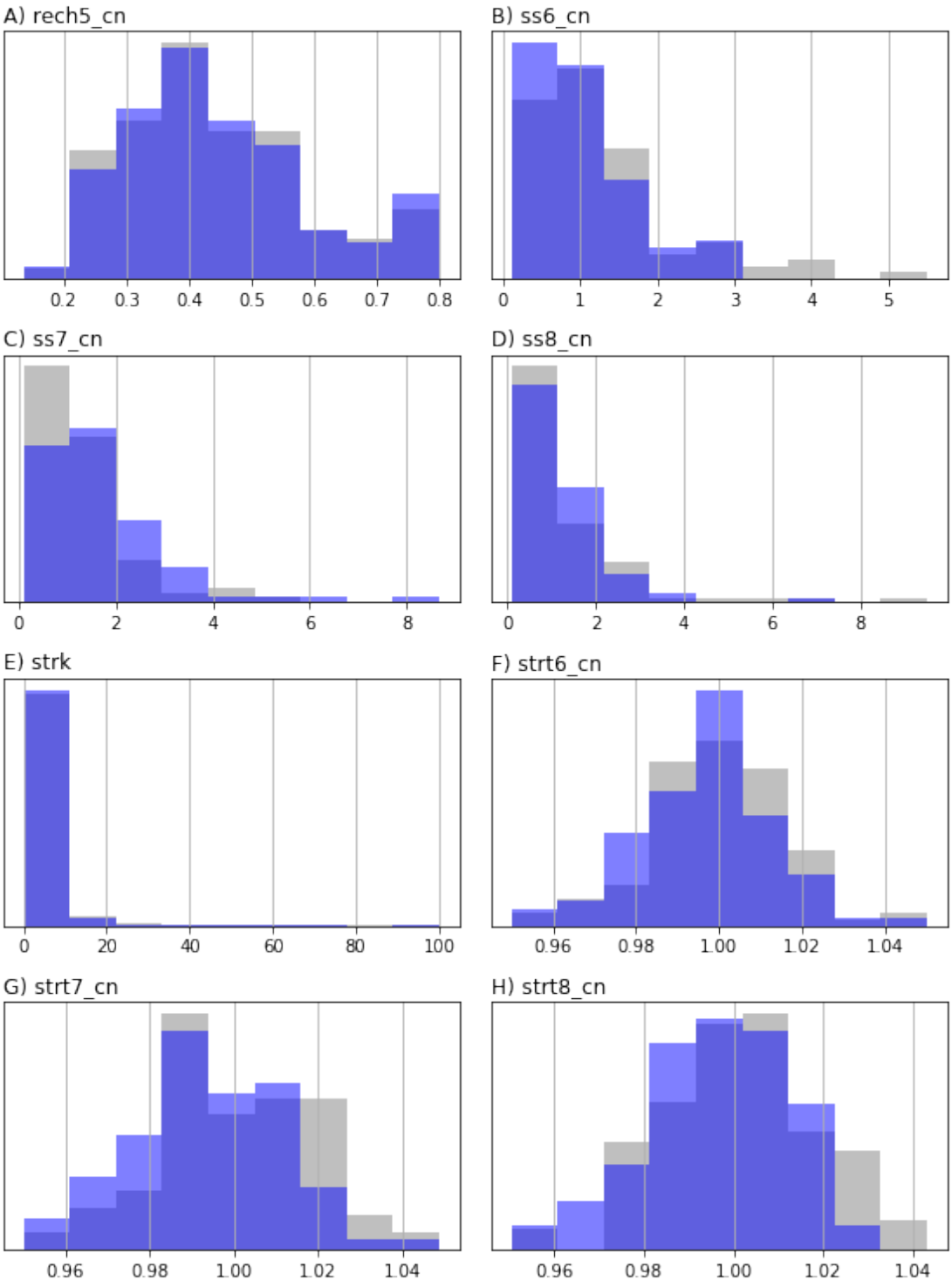


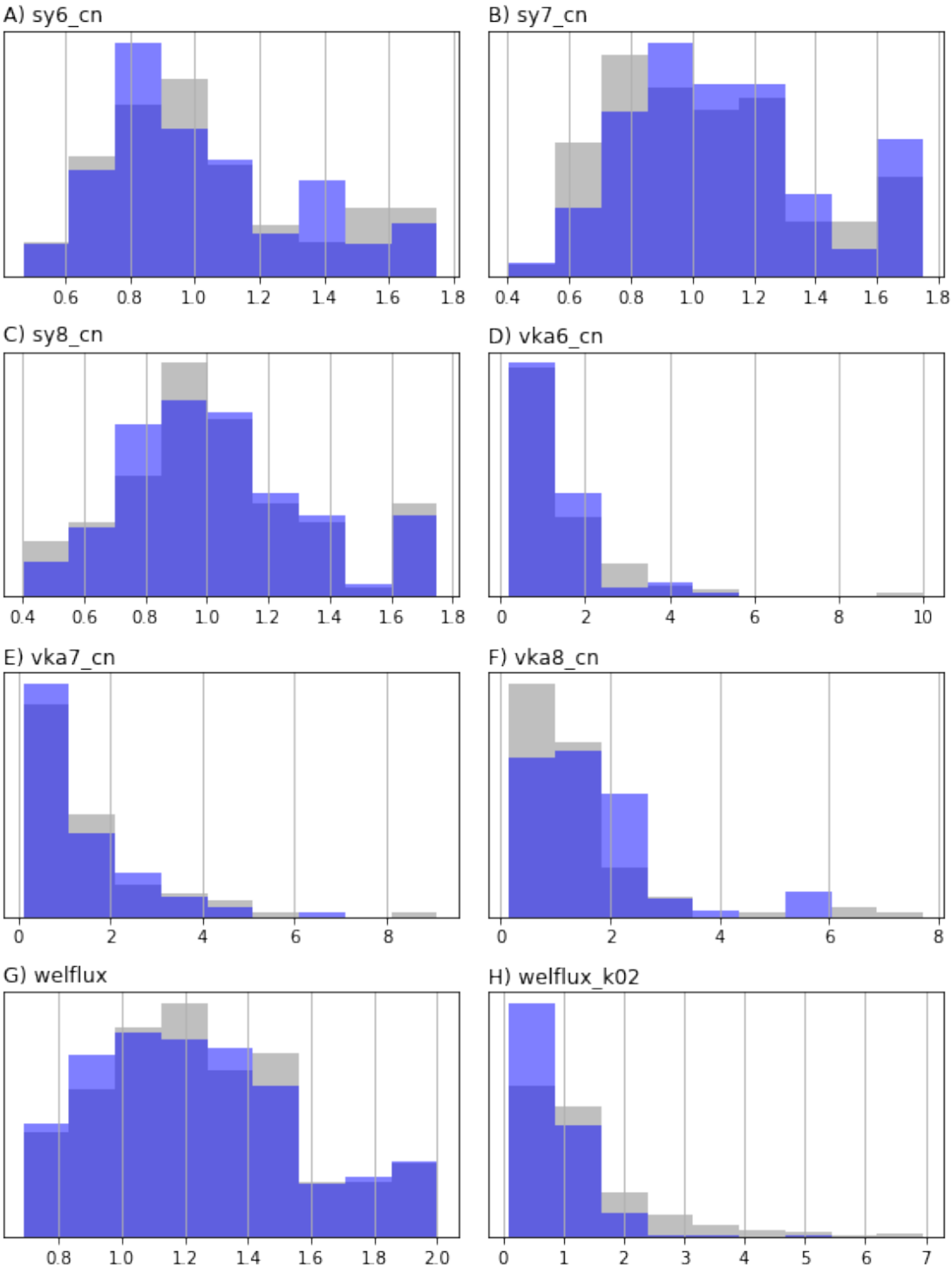

A) grss4
0
2
4
6
8
10
B) grss5
0
2
4
6
8
10
C) grstrt3
0.96
0.98
1.00
1.02
1.04
D) grstrt4
0.96
0.98
1.00
1.02
1.04
E) grstrt5
0.96
0.98
1.00
1.02
1.04
F) grsy3
0.25
0.50
0.75
1.00
1.25
1.50
1.75
G) grsy4
0.25
0.50
0.75
1.00
1.25
1.50
1.75
H) grsy5
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8


A) grvka3
B) grvka4
C) grvka5
D) hk6_cn
E) hk7_cn
F) hk8_cn
G) pp_hk0
H) pp_hk1


A) pp_hk2
0
2
4
6
8
10
B) pp_rech0
0.90
0.95
1.00
1.05
1.10
C) pp_rech1
0.90
0.95
1.00
1.05
1.10
D) pp_ss0
0
2
4
6
8
10
E) pp_ss1
0
2
4
6
8
10
F) pp_ss2
0
2
4
6
8
10
G) pp_strt0
0.96
0.98
1.00
1.02
1.04
H) pp_strt1
0.96
0.98
1.00
1.02
1.04

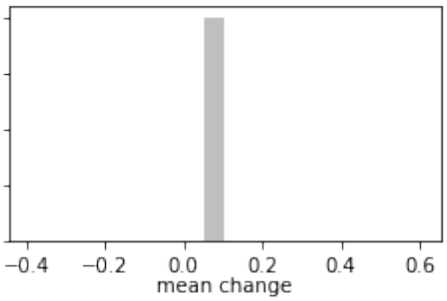

A) pp_strt2
0.96
0.98
1.00
1.02
1.04
B) pp_sy0
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
C) pp_sy1
0.25
0.50
0.75
1.00
1.25
1.50
1.75
D) pp_sy2
0.25
0.50
0.75
1.00
1.25
1.50
1.75
E) pp_vka0
0
2
4
6
8
10
F) pp_vka1
0
2
4
6
8
10
G) pp_vka2
0
2
4
6
8
10
H) rech4_cn
0.85
0.90
0.95
1.00
1.05
1.10
1.15


A) rech5_cn
0.2
0.3
0.4
0.5
0.6
0.7
0.8
B) ss6_cn
0
1
2
3
4
5
C) ss7_cn
0
2
4
6
8
D) ss8_cn
0
2
4
6
8
E) strk
0
20
40
60
80
100
F) strt6_cn
0.96
0.98
1.00
1.02
1.04
G) strt7_cn
0.96
0.98
1.00
1.02
1.04
H) strt8_cn
0.96
0.98
1.00
1.02
1.04

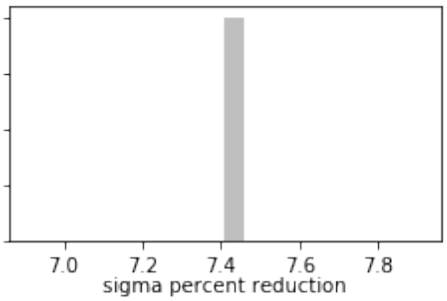


<Figure size 576x756 with 0 Axes>

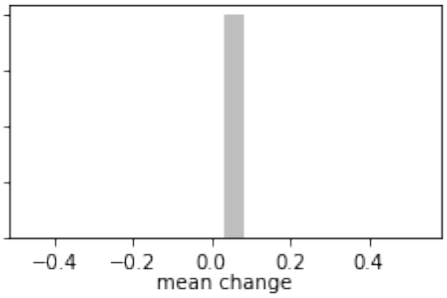
A) mean change group:ss6_cn, 1 entries
max: 0.104407, min: 0.104407



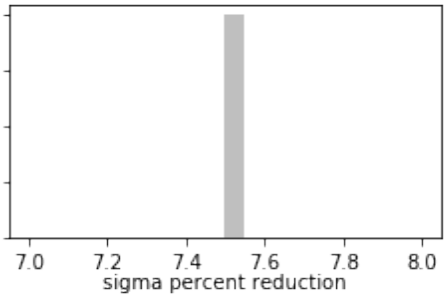
B) sigma change group:ss6_cn, 1 entries
max: 7.40928, min: 7.40928



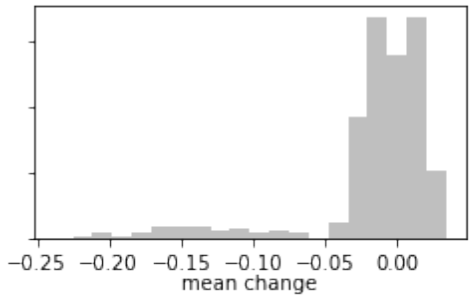
C) mean change group:vka6_cn, 1 entries
max: 0.0334883, min: 0.0334883



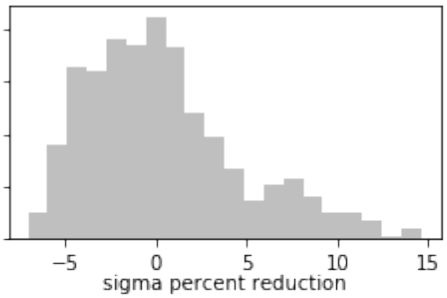
D) sigma change group:vka6_cn, 1 entries
max: 7.49861, min: 7.49861



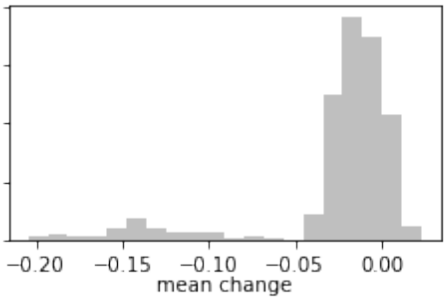
E) mean change group:grss5, 705 entries
max: 0.0344673, min: -0.238627



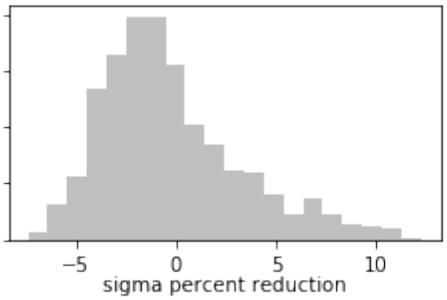
F) sigma change group:grss5, 705 entries
max: 14.6004, min: -7.0577



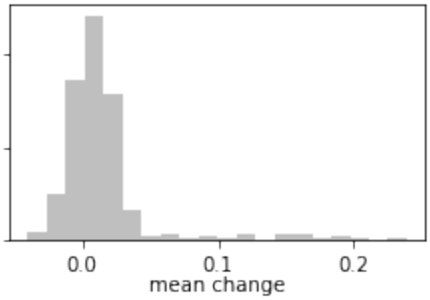
G) mean change group:grss3, 705 entries
max: 0.022985, min: -0.204499



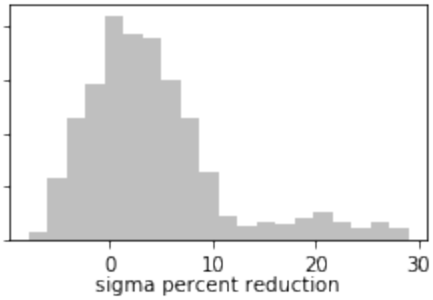
H) sigma change group:grss3, 705 entries
max: 12.2283, min: -7.39208



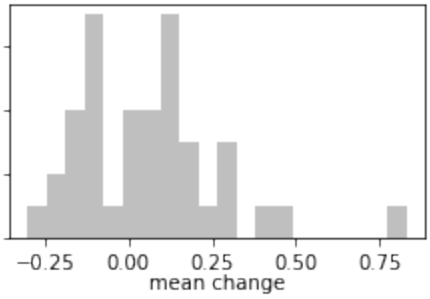
A) mean change group:grhk5, 705 entries
max: 0.2391, min:-0.0403956



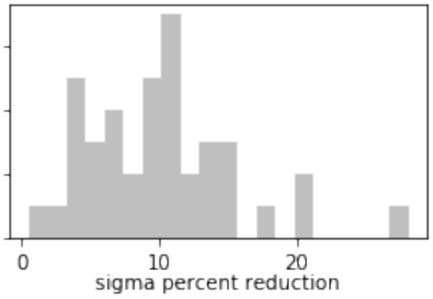
B) sigma change group:grhk5, 705 entries
max: 28.9497, min: -7.88686



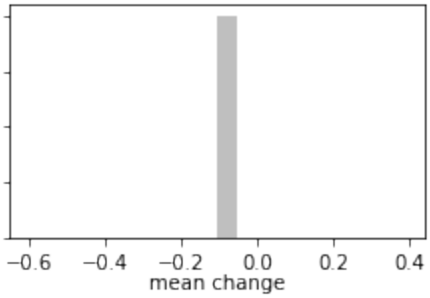
C) mean change group:strk, 40 entries
max: 0.831749, min: -0.302757



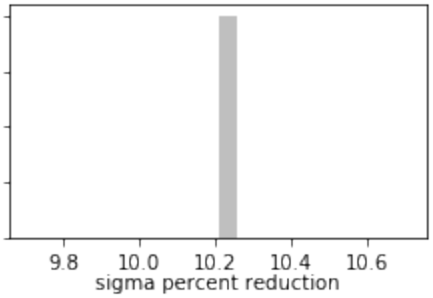
D) sigma change group:strk, 40 entries
max: 28.098, min: 0.507801



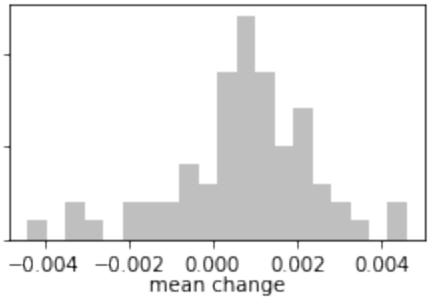
E) mean change group:vka8_cn, 1 entries
max: -0.106331, min: -0.106331



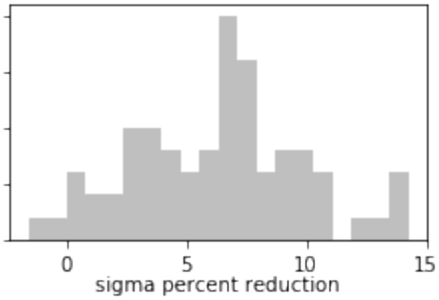
F) sigma change group:vka8_cn, 1 entries
max: 10.2083, min: 10.2083



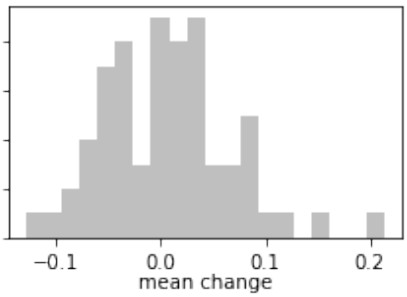
G) mean change group:pp_strt0, 67 entries
max:0.00459681, min:-0.00439708



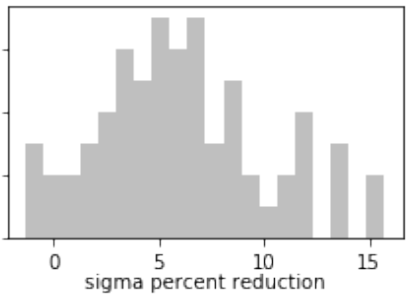
H) sigma change group:pp_strt0, 67 entries
max: 14.2416, min: -1.58329



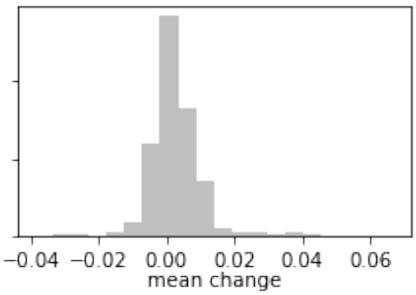
A) mean change group:pp_vka2, 67 entries
max: 0.213576, min: -0.129684



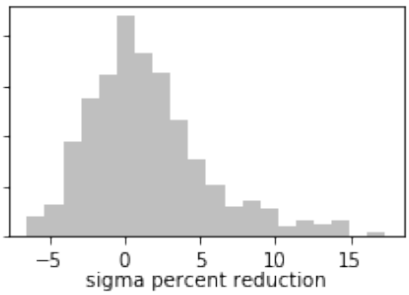
B) sigma change group:pp_vka2, 67 entries
max: 15.7396, min: -1.3092



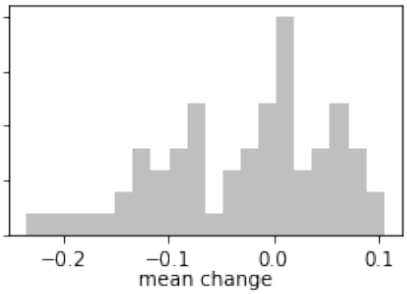
C) mean change group:grsy5, 705 entries
max: 0.0667668, min:-0.0389877



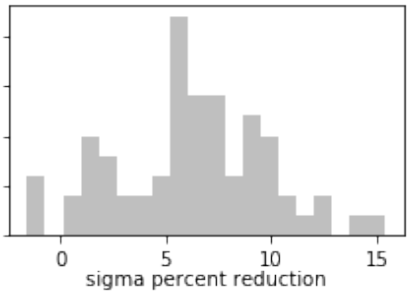
D) sigma change group:grsy5, 705 entries
max: 17.3278, min: -6.48078



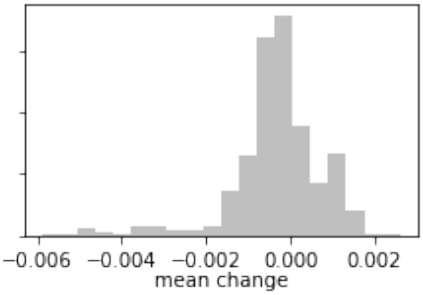
E) mean change group:pp_hk0, 67 entries
max: 0.105524, min: -0.236437



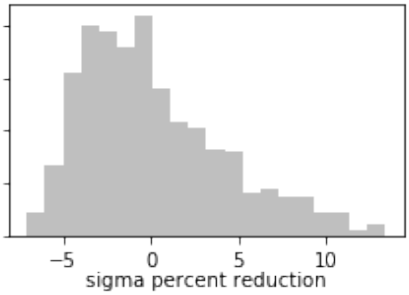
F) sigma change group:pp_hk0, 67 entries
max: 15.44, min: -1.57007



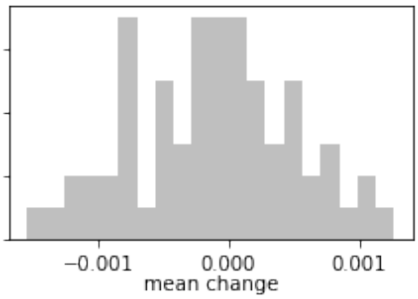
G) mean change group:grrech2, 705 entries
max:0.00259577, min:-0.00590362



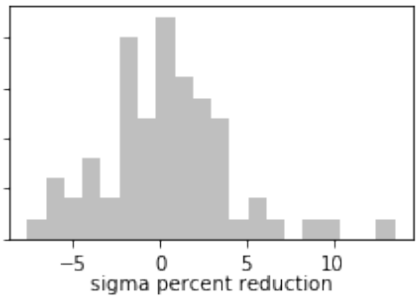
H) sigma change group:grrech2, 705 entries
max: 13.4277, min: -7.05396



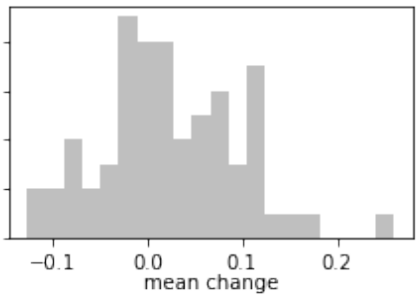
A) mean change group:pp_rech1, 67 entries
max:0.00126261, min:-0.00154338



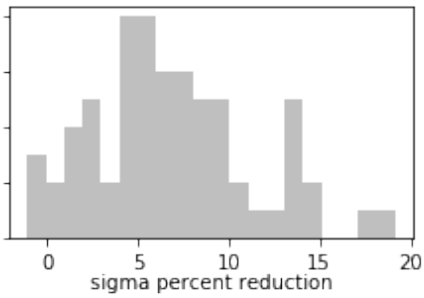
B) sigma change group:pp_rech1, 67 entries
max: 13.5441, min: -7.6021



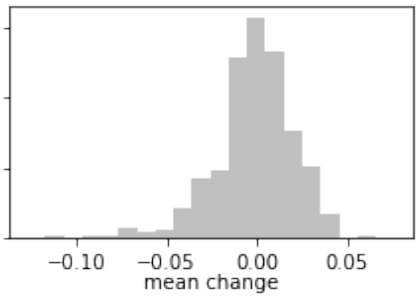
C) mean change group:pp_vka0, 67 entries
max: 0.260098, min: -0.127154



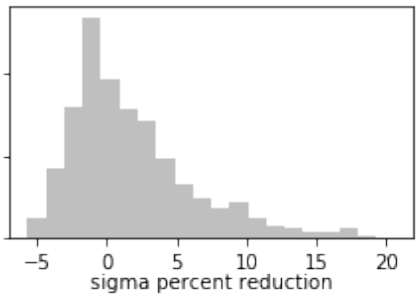
D) sigma change group:pp_vka0, 67 entries
max: 19.1454, min: -1.06341



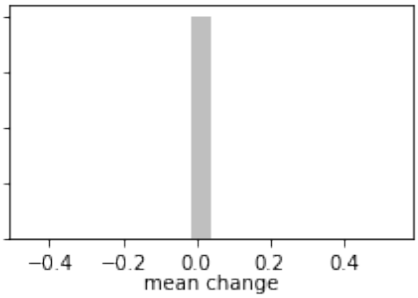
E) mean change group:grvka3, 705 entries
max: 0.0760281, min: -0.127542



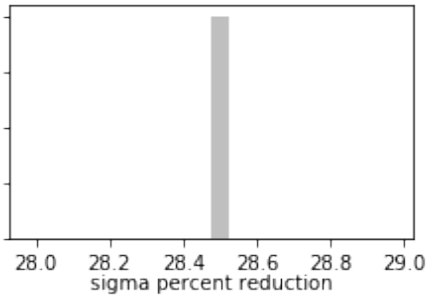
F) sigma change group:grvka3, 705 entries
max: 20.6302, min: -5.69223



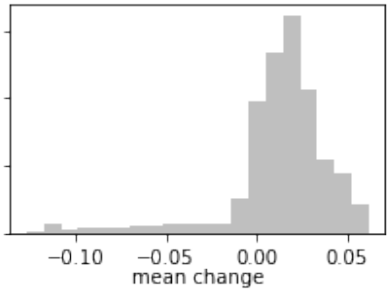
G) mean change group:hk6_cn, 1 entries
max: 0.0377975, min: 0.0377975



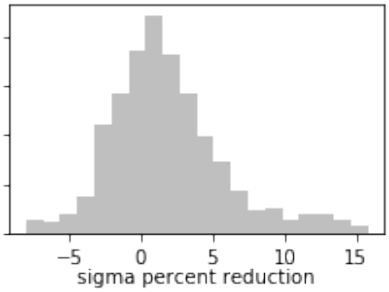
H) sigma change group:hk6_cn, 1 entries
max: 28.4767, min: 28.4767



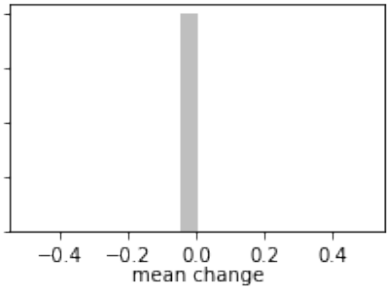
A) mean change group:grhk4, 705 entries
max: 0.0616574, min: -0.126817



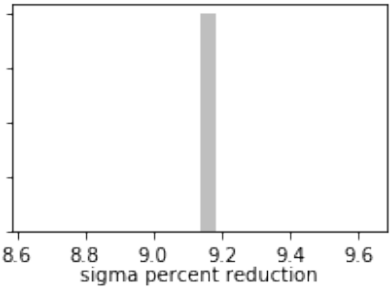
B) sigma change group:grhk4, 705 entries
max: 15.7909, min: -7.96538



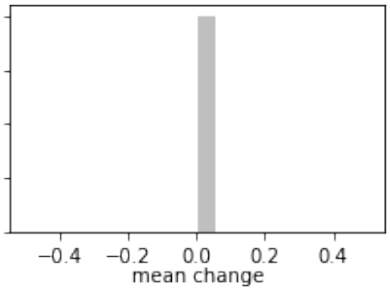
C) mean change group:ss8_cn, 1 entries
max:0.00495796, min:0.00495796



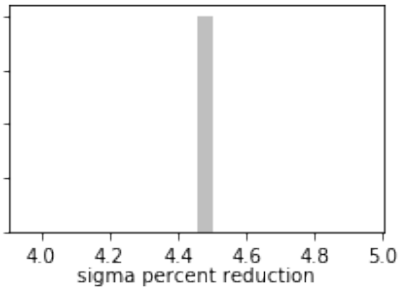
D) sigma change group:ss8_cn, 1 entries
max: 9.13613, min: 9.13613



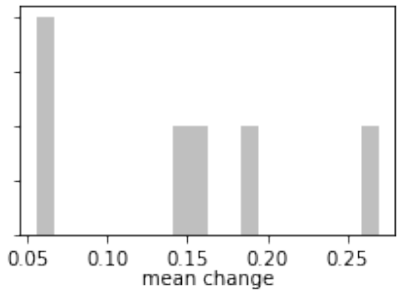
E) mean change group:strt7_cn, 1 entries
max:0.00297486, min:0.00297486



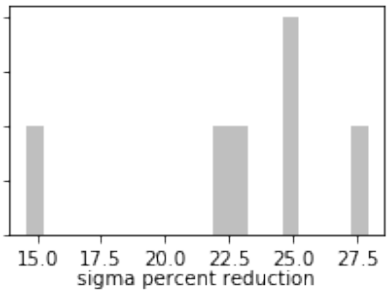
F) sigma change group:strt7_cn, 1 entries
max: 4.45487, min: 4.45487



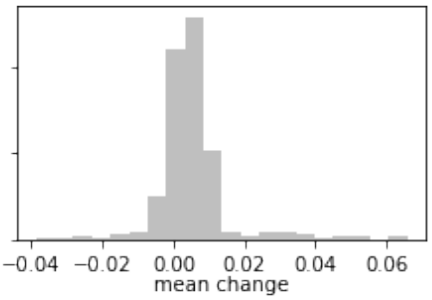
G) mean change group:welflux_k02, 6 entries
max: 0.269501, min: 0.0557287



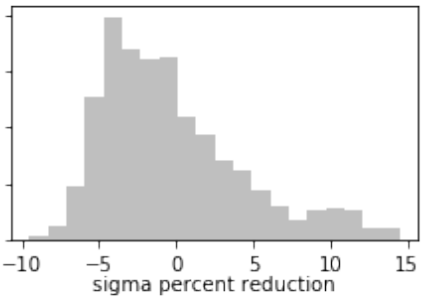
H) sigma change group:welflux_k02, 6 entries
max: 27.9191, min: 14.5705



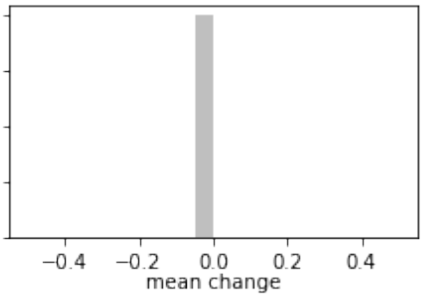
A) mean change group:grsy3, 705 entries
max: 0.0658301, min:-0.0386137



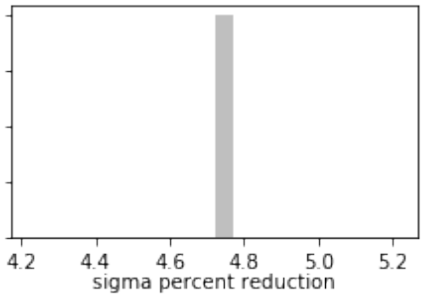
B) sigma change group:grsy3, 705 entries
max: 14.5451, min: -9.52666



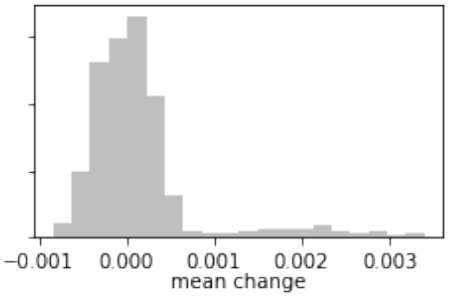
C) mean change group:strt6_cn, 1 entries
max:0.00184101, min:0.00184101



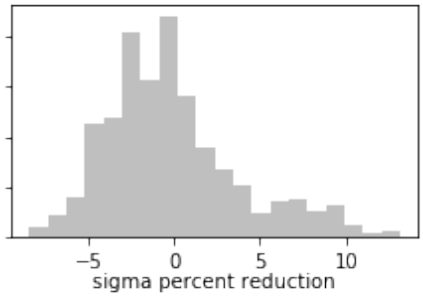
D) sigma change group:strt6_cn, 1 entries
max: 4.72113, min: 4.72113



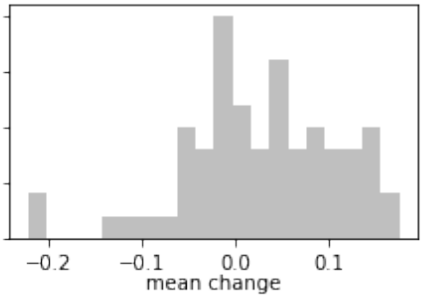
E) mean change group:grstrt5, 705 entries
max:0.00340053, min:-0.000836881



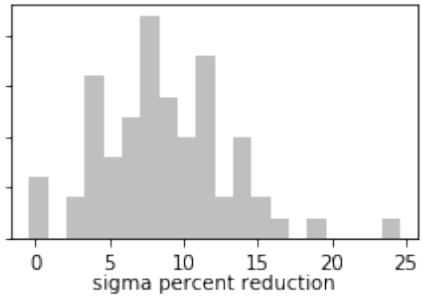
F) sigma change group:grstrt5, 705 entries
max: 13.1687, min: -8.42812



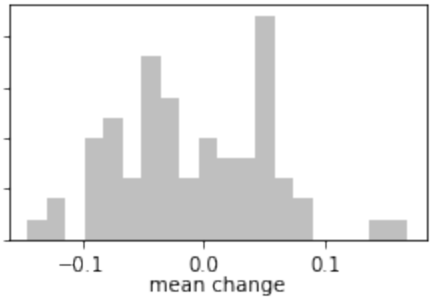
G) mean change group:pp_hk2, 67 entries
max: 0.174616, min: -0.22118



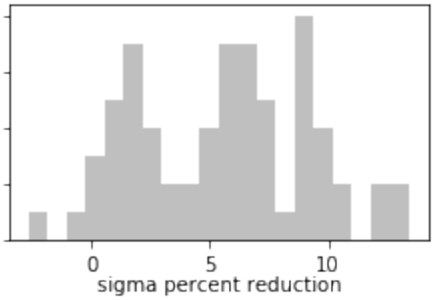
H) sigma change group:pp_hk2, 67 entries
max: 24.6298, min: -0.432601



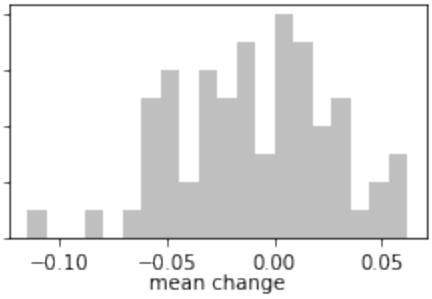
A) mean change group:pp_ss0, 67 entries
max: 0.168351, min: -0.144946



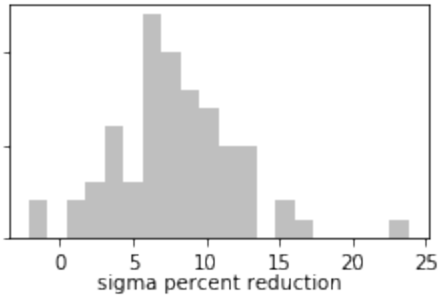
B) sigma change group:pp_ss0, 67 entries
max: 13.4103, min: -2.65724



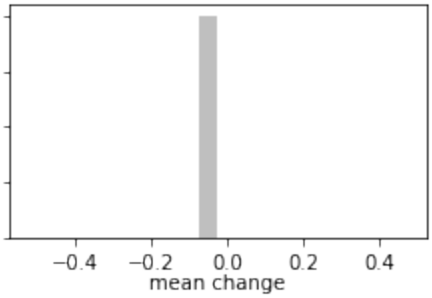
C) mean change group:pp_sy1, 67 entries
max: 0.0623299, min: -0.115064



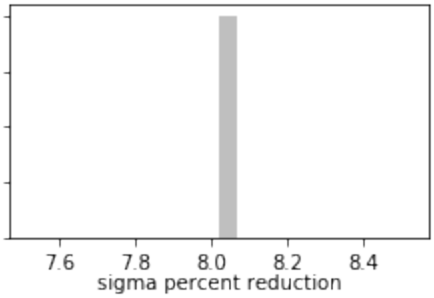
D) sigma change group:pp_sy1, 67 entries
max: 23.8601, min: -2.13517



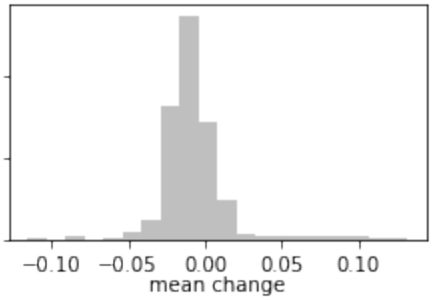
E) mean change group:sy7_cn, 1 entries
max:-0.0250412, min:-0.0250412



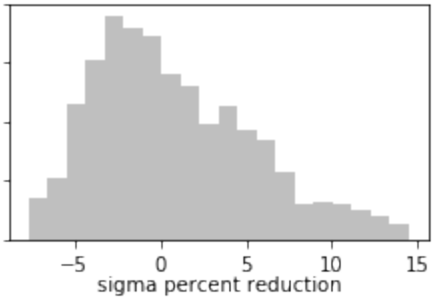
F) sigma change group:sy7_cn, 1 entries
max: 8.01955, min: 8.01955



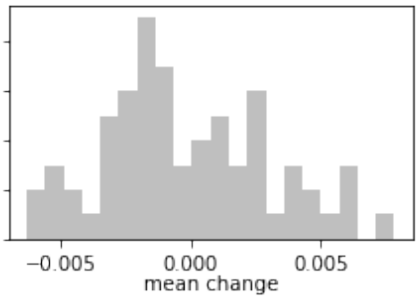
G) mean change group:grvka4, 705 entries
max: 0.13217, min: -0.115621



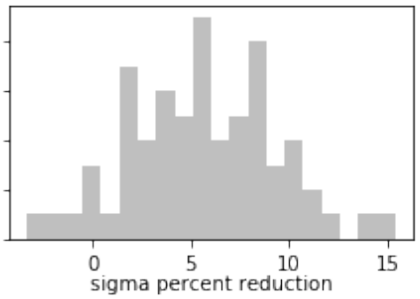
H) sigma change group:grvka4, 705 entries
max: 14.4839, min: -7.67333



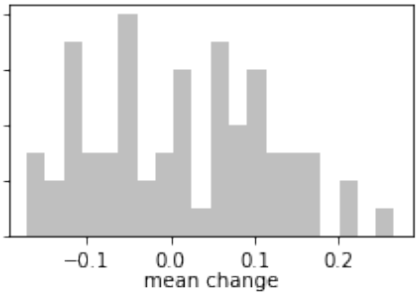
A) mean change group:pp_rech0, 67 entries
max:0.00782899, min:-0.00629393



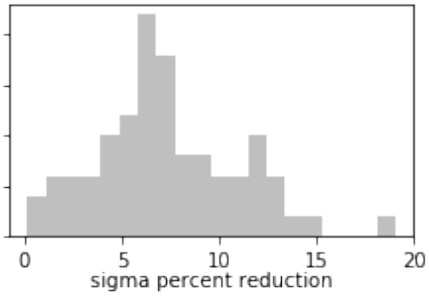
B) sigma change group:pp_rech0, 67 entries
max: 15.397, min: -3.31558



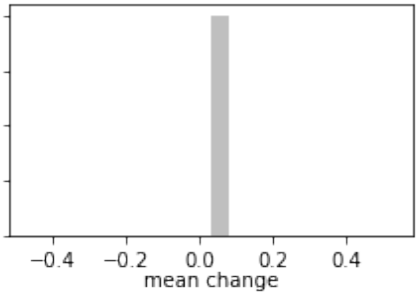
C) mean change group:pp_hk1, 67 entries
max: 0.266335, min: -0.171874



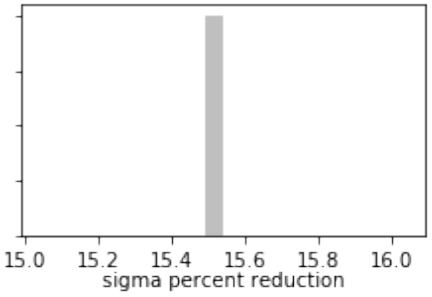
D) sigma change group:pp_hk1, 67 entries
max: 19.0522, min: 0.156923



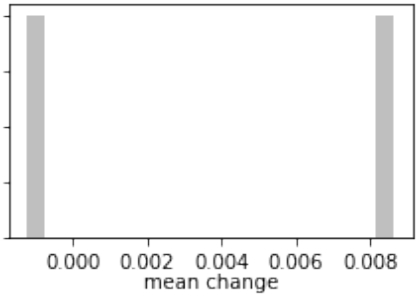
E) mean change group:hk7_cn, 1 entries
max: 0.0304892, min: 0.0304892



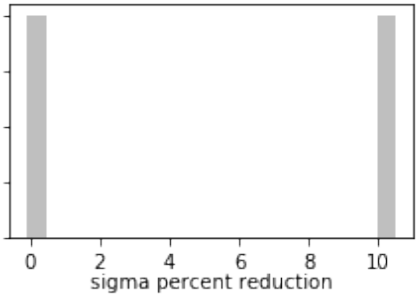
F) sigma change group:hk7_cn, 1 entries
max: 15.5409, min: 15.5409



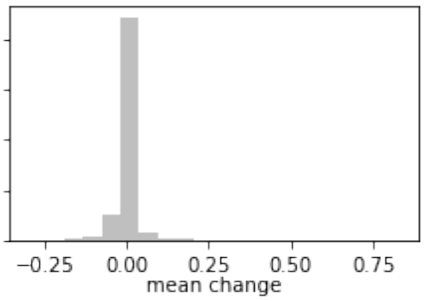
G) mean change group:welflux, 2 entries
max:0.00863885, min:-0.00124156



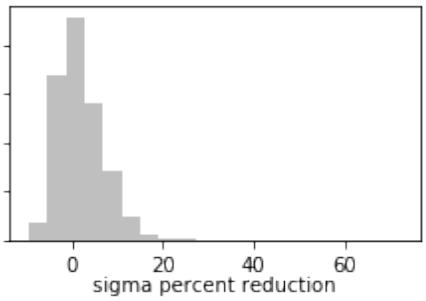
H) sigma change group:welflux, 2 entries
max: 10.4834, min:-0.0736556



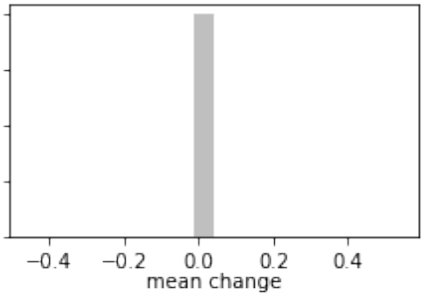
A) mean change group:all, 13200 entries
max: 0.831749, min: -0.302757



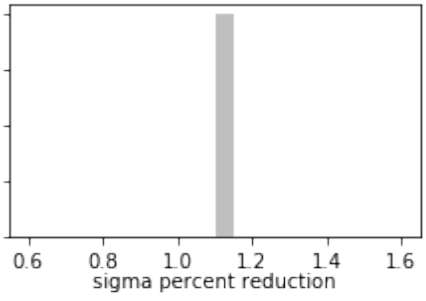
B) sigma change group:all, 13200 entries
max: 72.4741, min: -9.52666



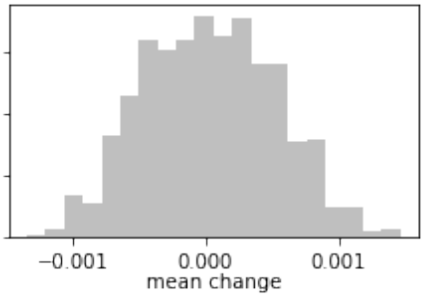
C) mean change group:vka7_cn, 1 entries
max: 0.039501, min: 0.039501



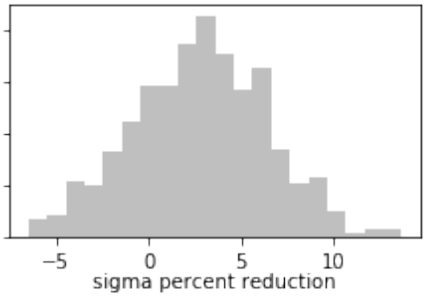
D) sigma change group:vka7_cn, 1 entries
max: 1.10168, min: 1.10168



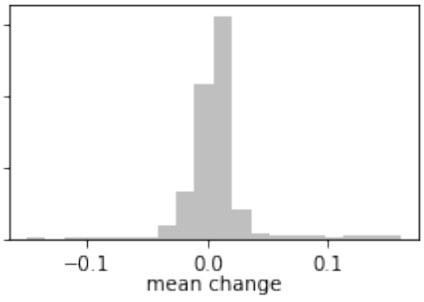
E) mean change group:grrech3, 705 entries
max:0.00146476, min:-0.00133942



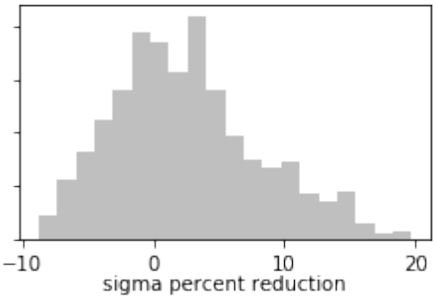
F) sigma change group:grrech3, 705 entries
max: 13.7137, min: -6.49541



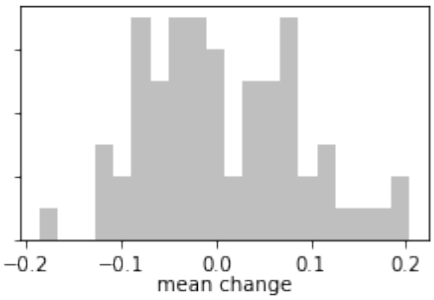
G) mean change group:grss4, 705 entries
max: 0.160323, min: -0.150123



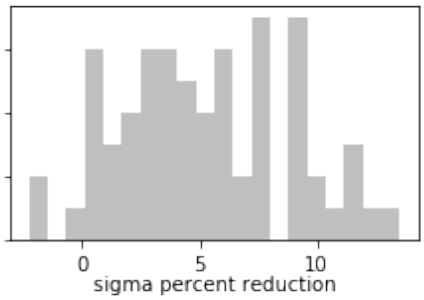
H) sigma change group:grss4, 705 entries
max: 19.7372, min: -8.78613



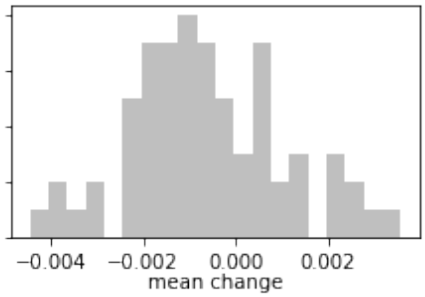
A) mean change group:pp_ss1, 67 entries
max: 0.204035, min: -0.186558



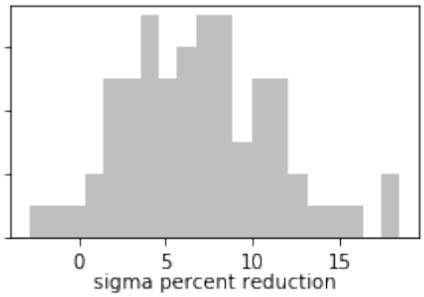
B) sigma change group:pp_ss1, 67 entries
max: 13.5249, min: -2.27045



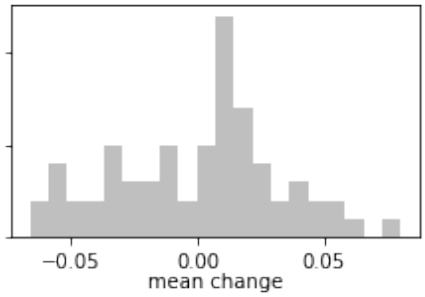
C) mean change group:pp_strt1, 67 entries
max:0.00355915, min:-0.00442933



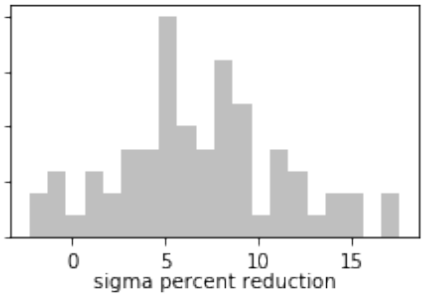
D) sigma change group:pp_strt1, 67 entries
max: 18.4832, min: -2.85007



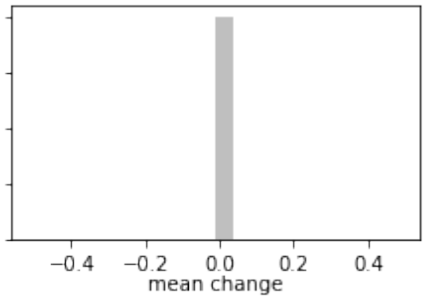
E) mean change group:pp_sy0, 67 entries
max: 0.0801693, min:-0.0660824



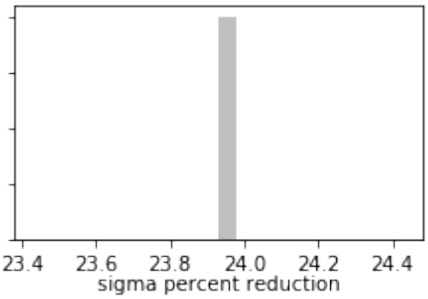
F) sigma change group:pp_sy0, 67 entries
max: 17.5758, min: -2.32871



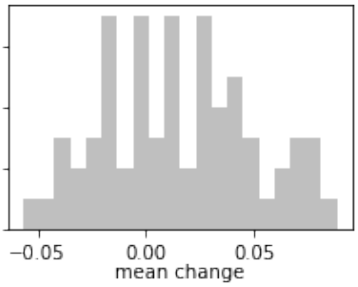
G) mean change group:rech4_cn, 1 entries
max:-0.0109736, min:-0.0109736



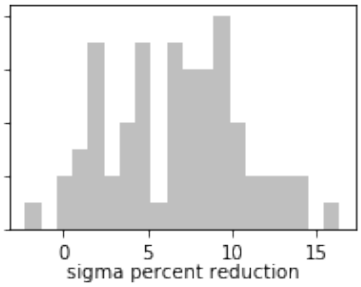
H) sigma change group:rech4_cn, 1 entries
max: 23.9304, min: 23.9304



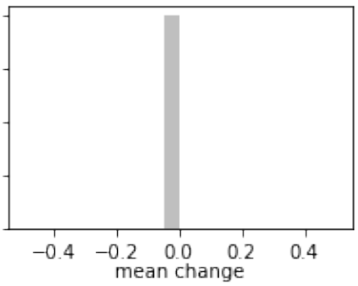
A) mean change group:pp_sy2, 67 entries
max: 0.0883762, min:-0.0567242



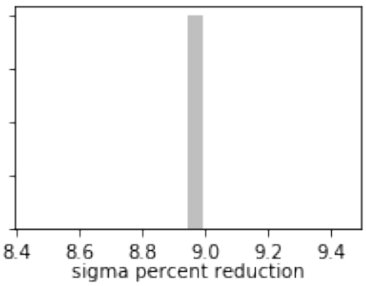
B) sigma change group:pp_sy2, 67 entries
max: 16.3452, min: -2.22



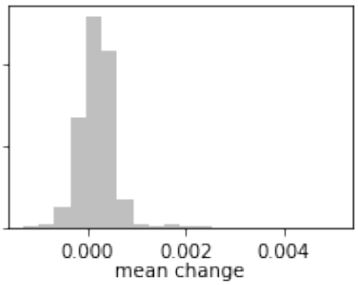
C) mean change group:sy6_cn, 1 entries
max:0.00412569, min:0.00412569



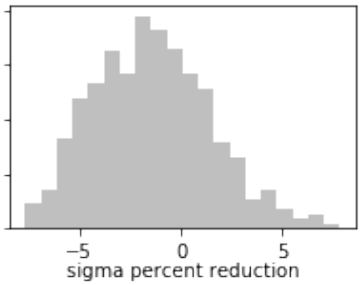
D) sigma change group:sy6_cn, 1 entries
max: 8.94291, min: 8.94291



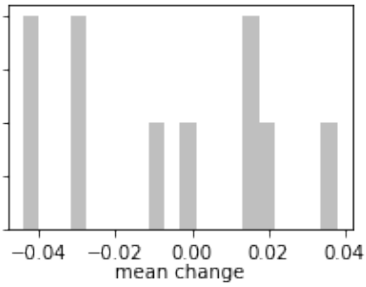
E) mean change group:grstrt4, 705 entries
max:0.00508507, min:-0.00130209



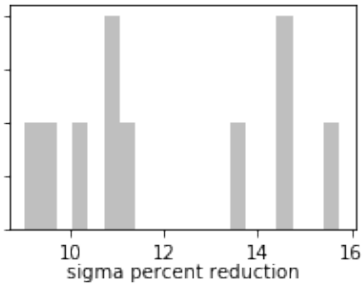
F) sigma change group:grstrt4, 705 entries
max: 7.78594, min: -7.63388



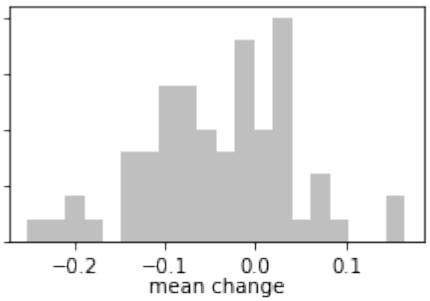
G) mean change group:drncond_k00, 10 entries
max: 0.0379495, min:-0.0441847



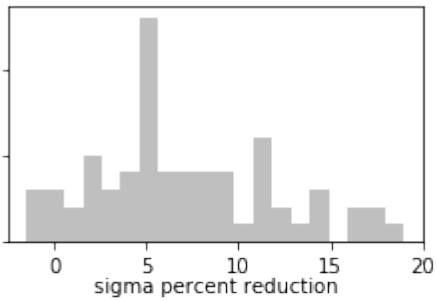
H) sigma change group:drncond_k00, 10 entries
max: 15.7435, min: 9.03991



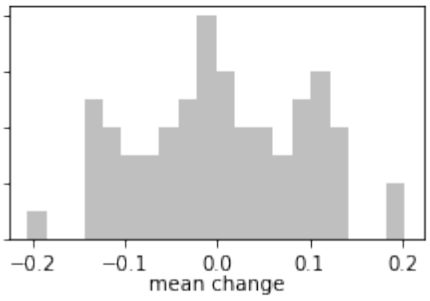
A) mean change group:pp_ss2, 67 entries
max: 0.16505, min: -0.251512



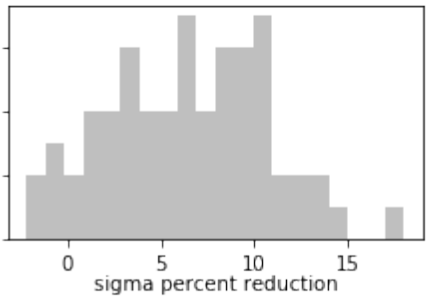
B) sigma change group:pp_ss2, 67 entries
max: 18.9791, min: -1.5158



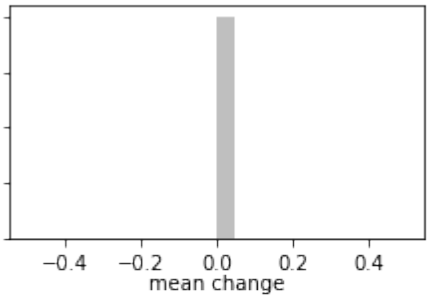
C) mean change group:pp_vka1, 67 entries
max: 0.202925, min: -0.205906



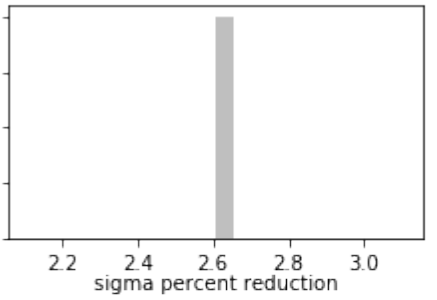
D) sigma change group:pp_vka1, 67 entries
max: 18.0203, min: -2.22949



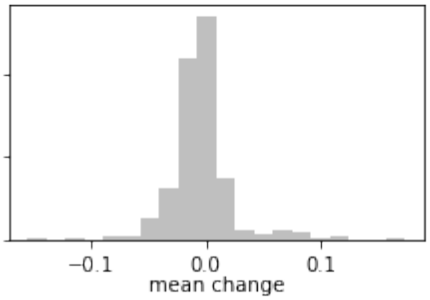
E) mean change group:sy8_cn, 1 entries
max:-0.00157664, min:-0.00157664



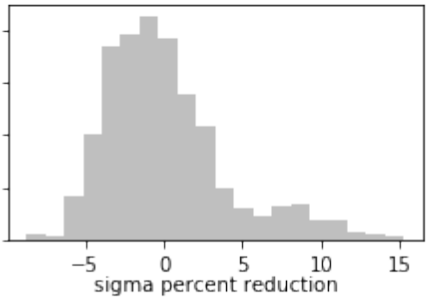
F) sigma change group:sy8_cn, 1 entries
max: 2.60569, min: 2.60569



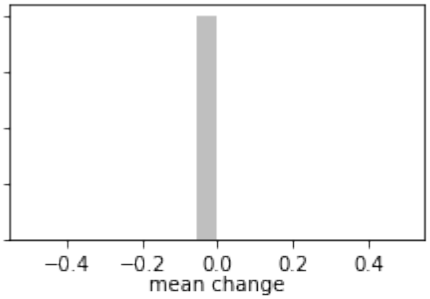
G) mean change group:grvka5, 705 entries
max: 0.174119, min: -0.155643



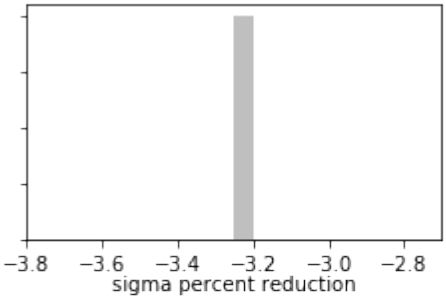
H) sigma change group:grvka5, 705 entries
max: 15.2552, min: -8.72668



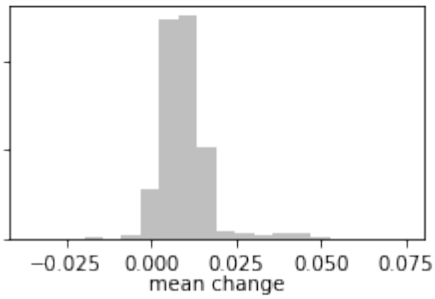
A) mean change group:rech5_cn, 1 entries
max:-0.00323902, min:-0.00323902



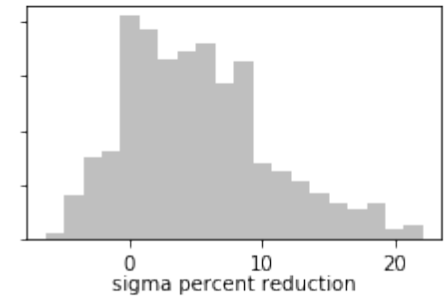
B) sigma change group:rech5_cn, 1 entries
max: -3.25, min: -3.25



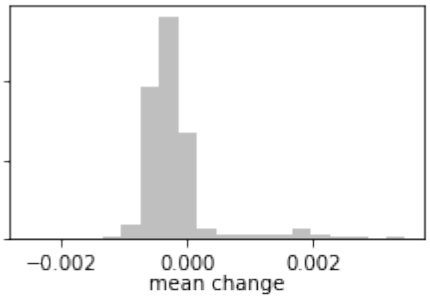
C) mean change group:grsy4, 705 entries
max: 0.0746875, min:-0.0364017



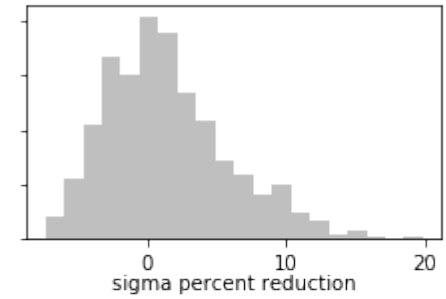
D) sigma change group:grsy4, 705 entries
max: 22.1728, min: -6.39421



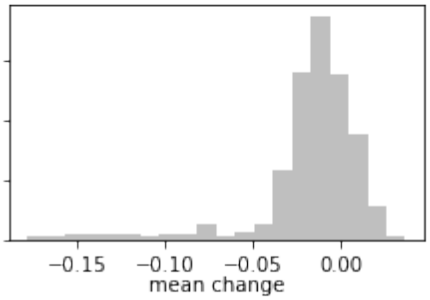
E) mean change group:grstrt3, 705 entries
max:0.00346015, min:-0.00254454



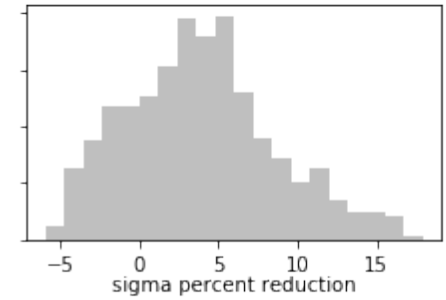
F) sigma change group:grstrt3, 705 entries
max: 19.9095, min: -7.37513



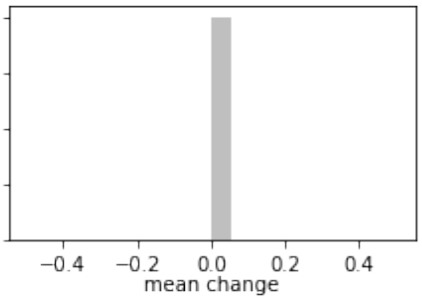
G) mean change group:grhk3, 705 entries
max: 0.0363641, min: -0.178624



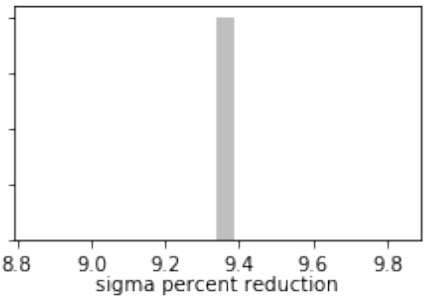
H) sigma change group:grhk3, 705 entries
max: 17.9554, min: -5.97684



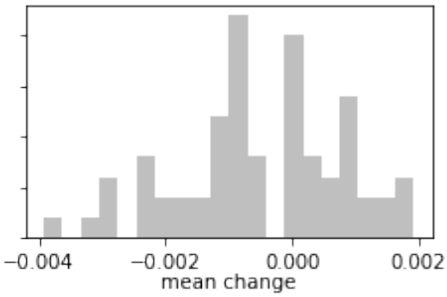
A) mean change group:strt8_cn, 1 entries
max:0.00207683, min:0.00207683



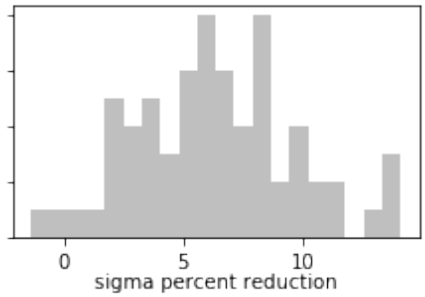
B) sigma change group:strt8_cn, 1 entries
max: 9.33985, min: 9.33985



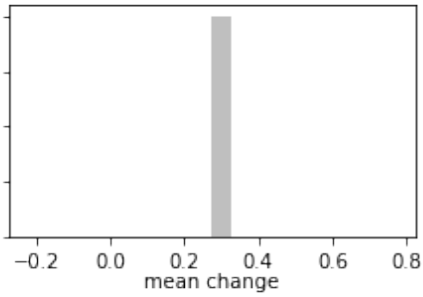
C) mean change group:pp_strt2, 67 entries
max:0.00192465, min:-0.00391615



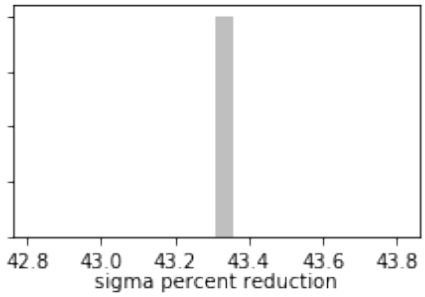
D) sigma change group:pp_strt2, 67 entries
max: 14.1382, min: -1.41581



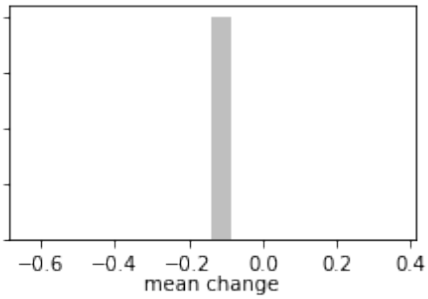
E) mean change group:hk8_cn, 1 entries
max: 0.274171, min: 0.274171



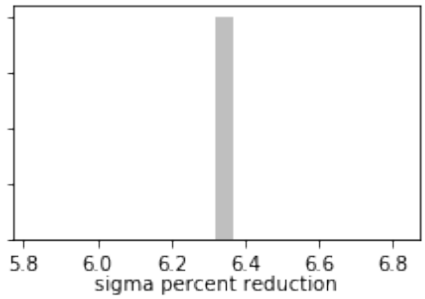
F) sigma change group:hk8_cn, 1 entries
max: 43.3098, min: 43.3098

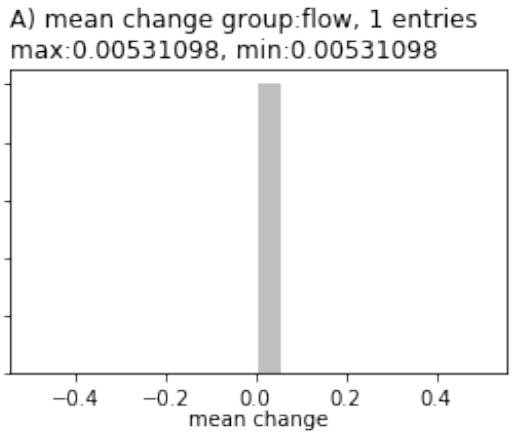


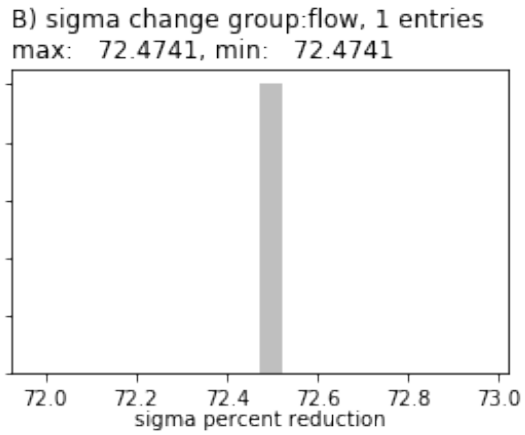
G) mean change group:ss7_cn, 1 entries
max: -0.136729, min: -0.136729



H) sigma change group:ss7_cn, 1 entries
max: 6.32024, min: 6.32024




A) mean change group:flow, 1 entries
max:0.00531098, min:0.00531098
−0.4
−0.2
0.0
0.2
0.4
mean change


B) sigma change group:flow, 1 entries
max: 72.4741, min: 72.4741
72.0
72.2
72.4
72.6
72.8
73.0
sigma percent reduction