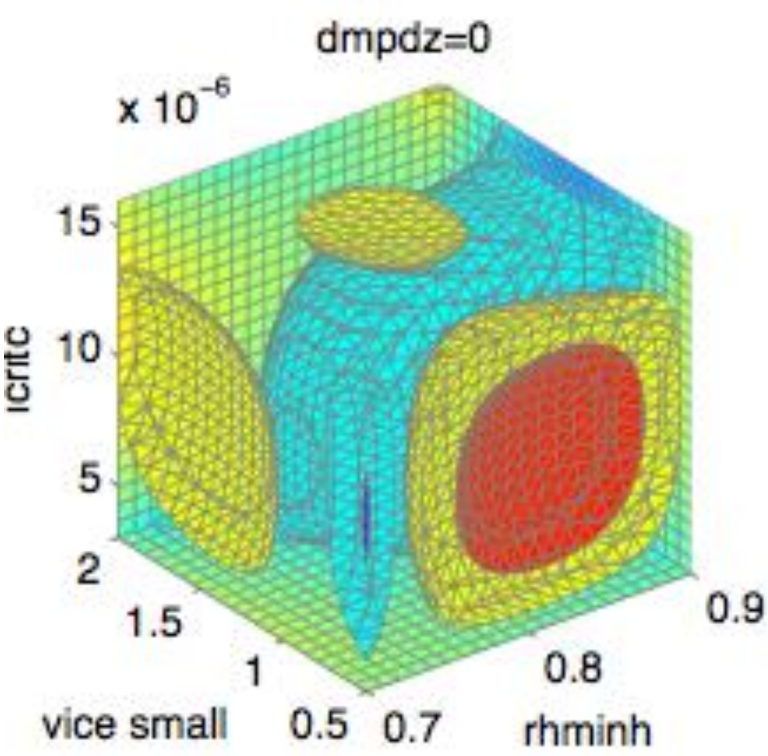
Multi-model uncertainty II

Ben Sanderson

I

Perturbed Physics,
and why
we’re all kidding ourselves

So, you want to build an ensemble?

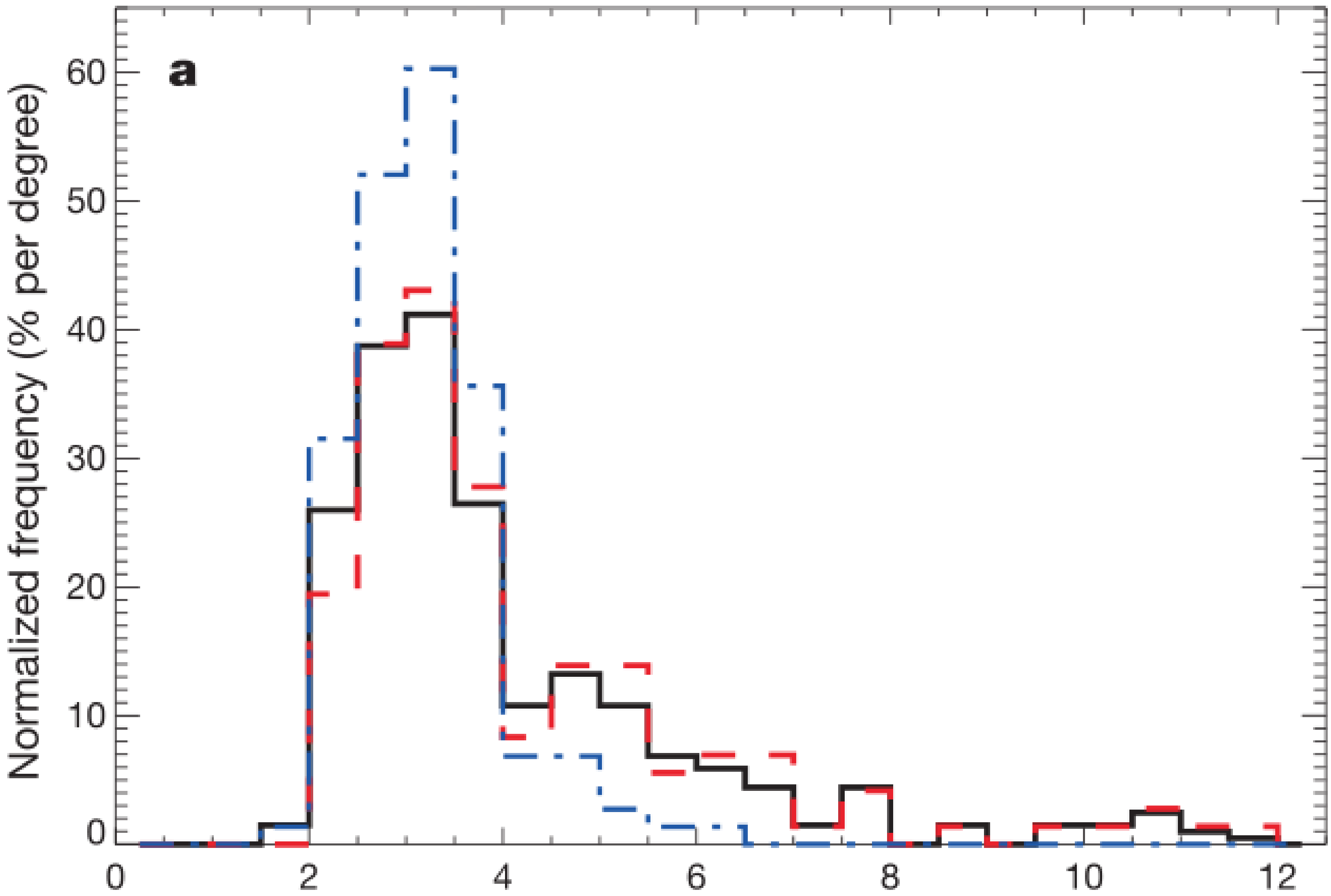


Sanderson(2011)

- 81x3 15yr simulations
- ~2 million hours CPU time
- ~60 MWh (on Jaguar)
- 94 tonnes CO_2 emitted (coal)
- 17 round-the-world flights
- 1/2 million bikes up the Mesa
- 1×10^{-7}K additional warming above RCP4.5 (S=3.5K)

Have a question first.

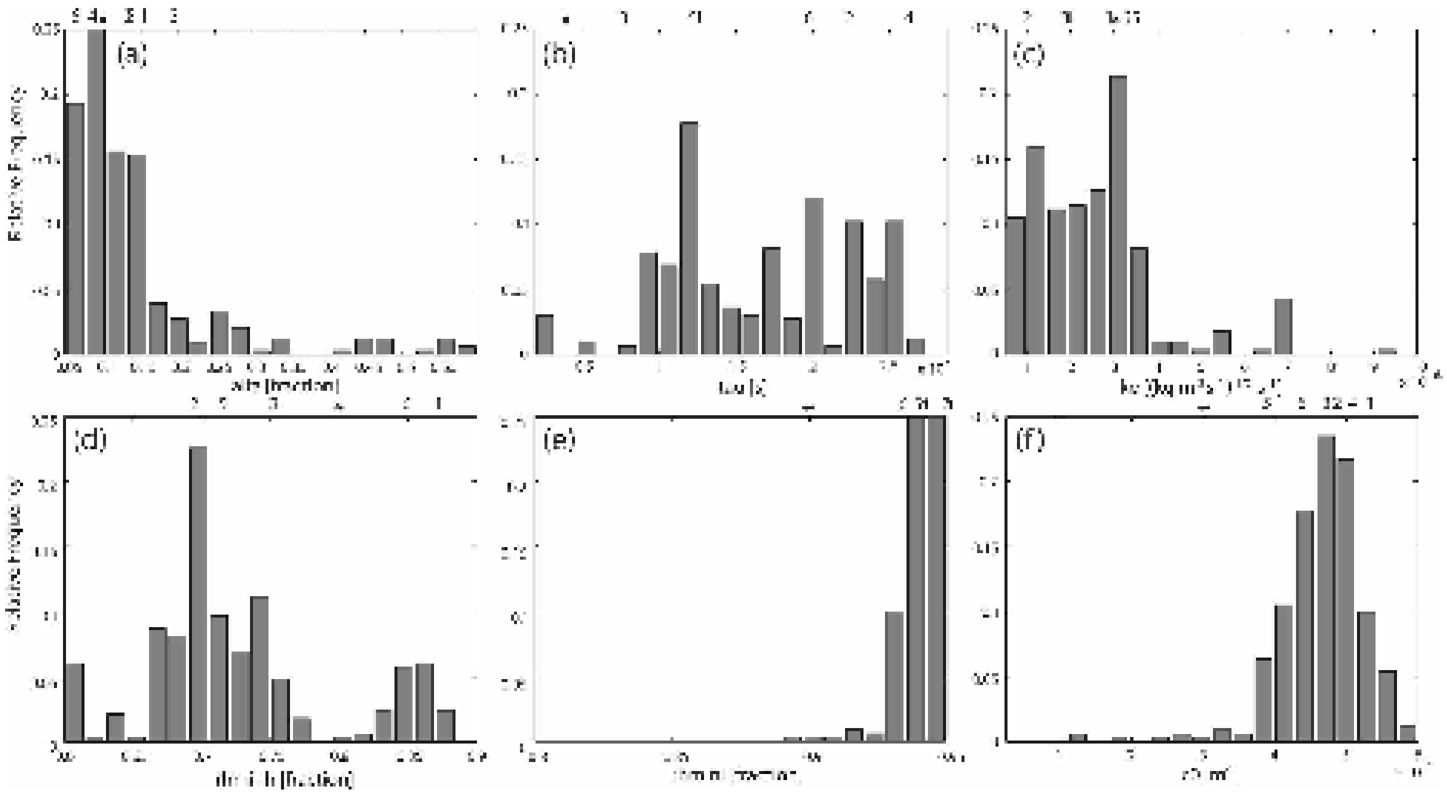
1. Constraint of large scale response variables



Stainforth*et al* (2005)

1. Constraint of large scale response variables

2. Optimal Parameter Search

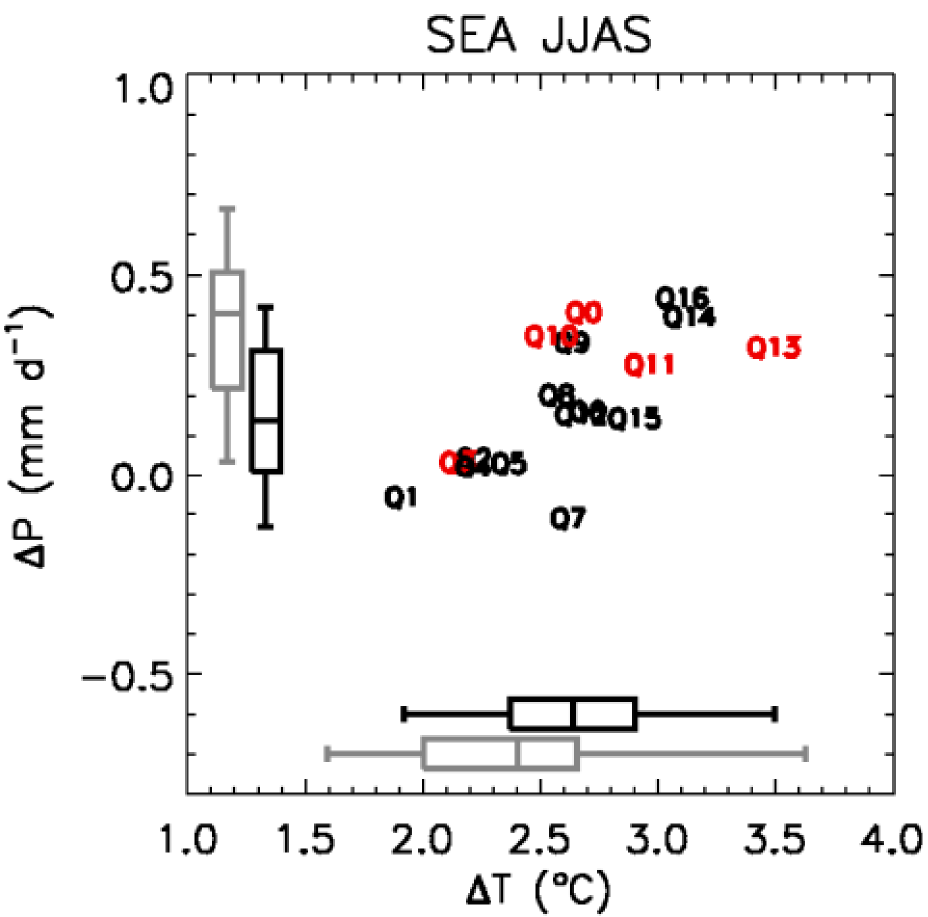


Jackson *et al* (2008)

1. Constraint of large scale response variables

2. Optimal Parameter Search

3. Plausible worlds



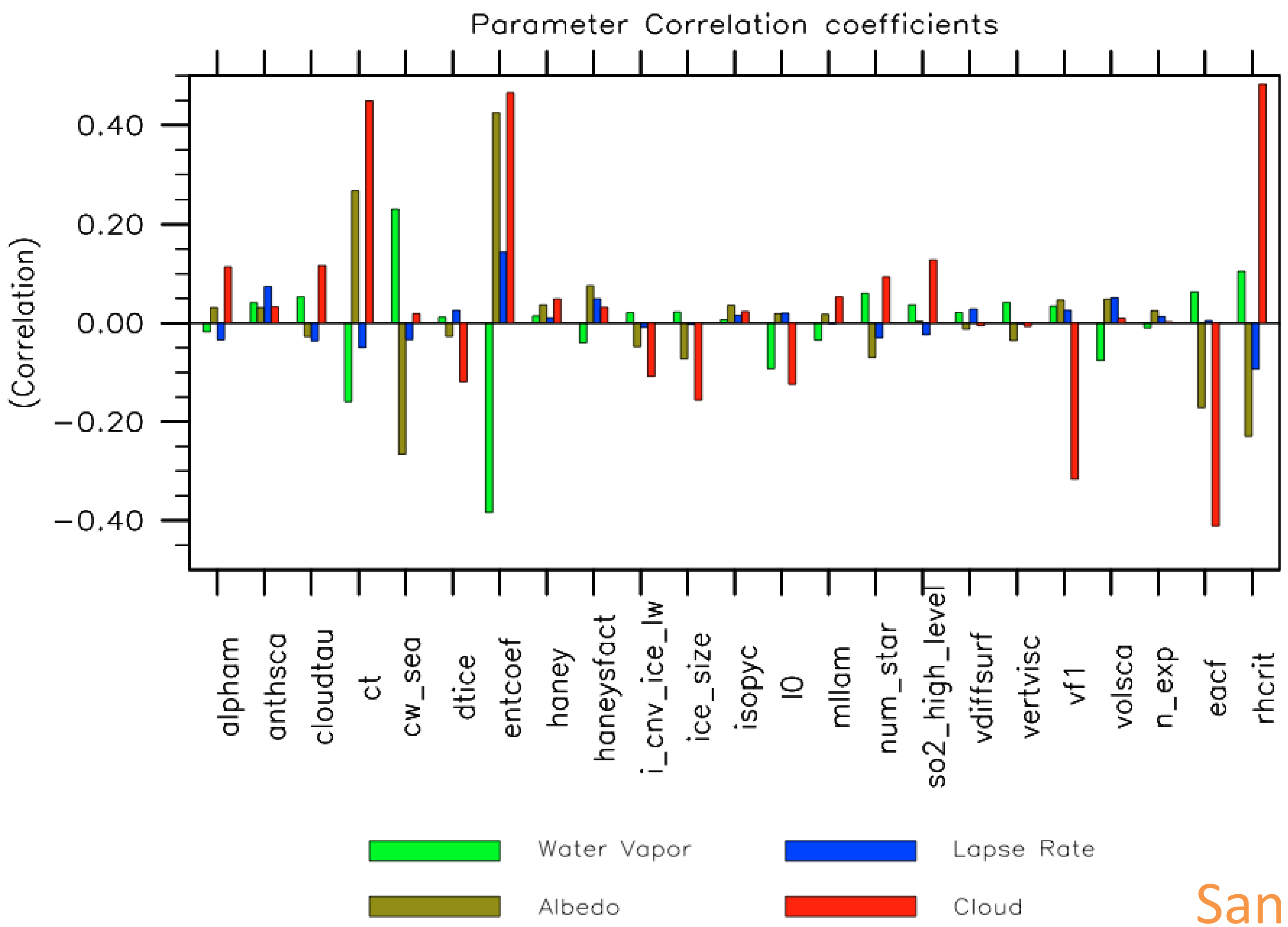
McSweeney and Jones, UKMO press release

1. Constraint of large scale response variables

2. Optimal Parameter Search

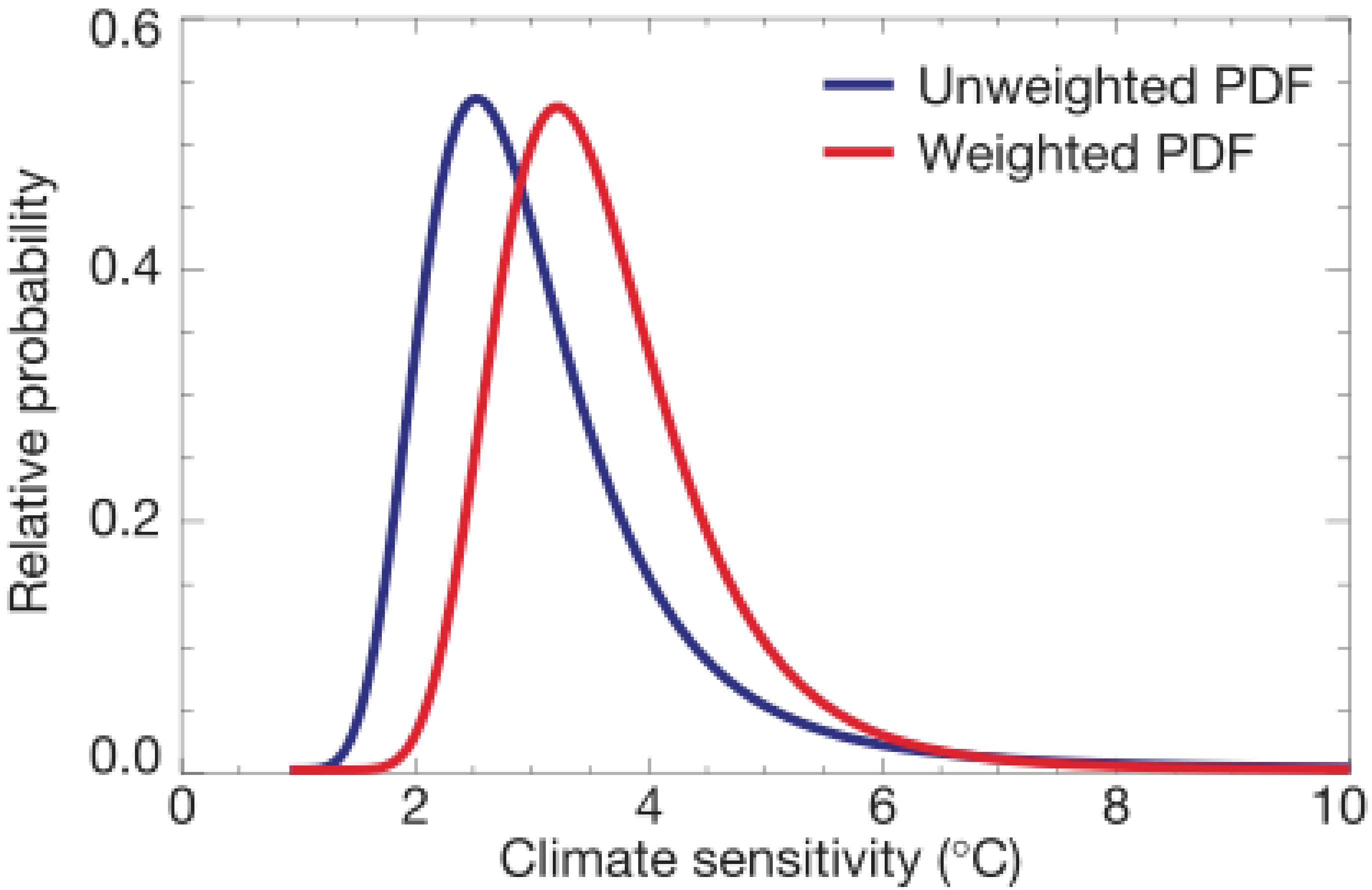
3. Plausible worlds

3. Process understanding



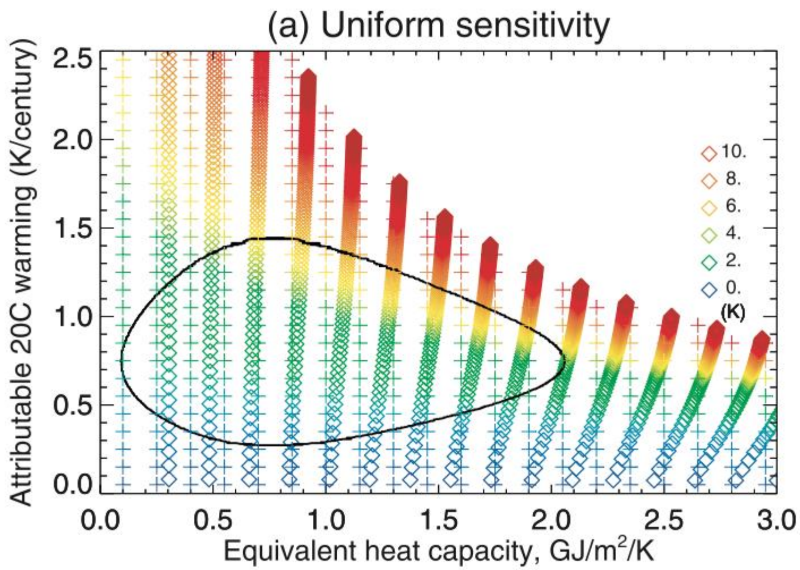
Sanderson et al (2011)

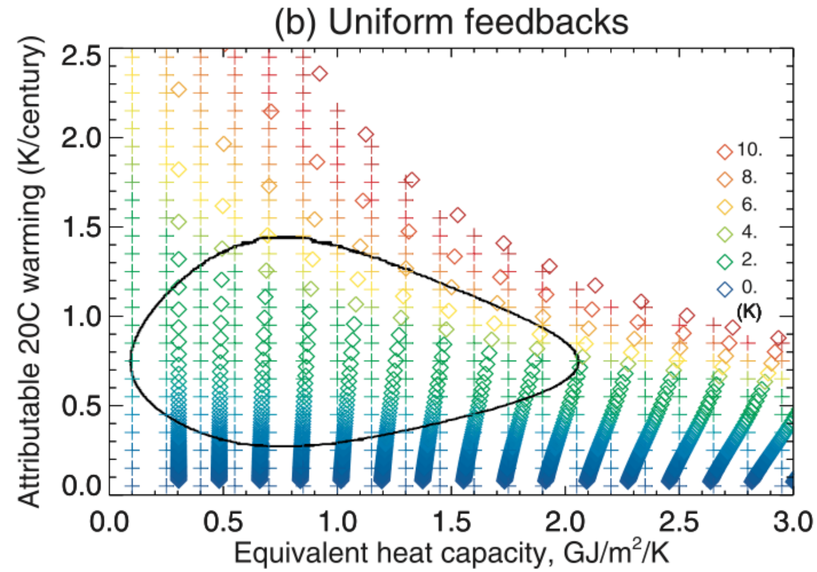
From ensemble to probability

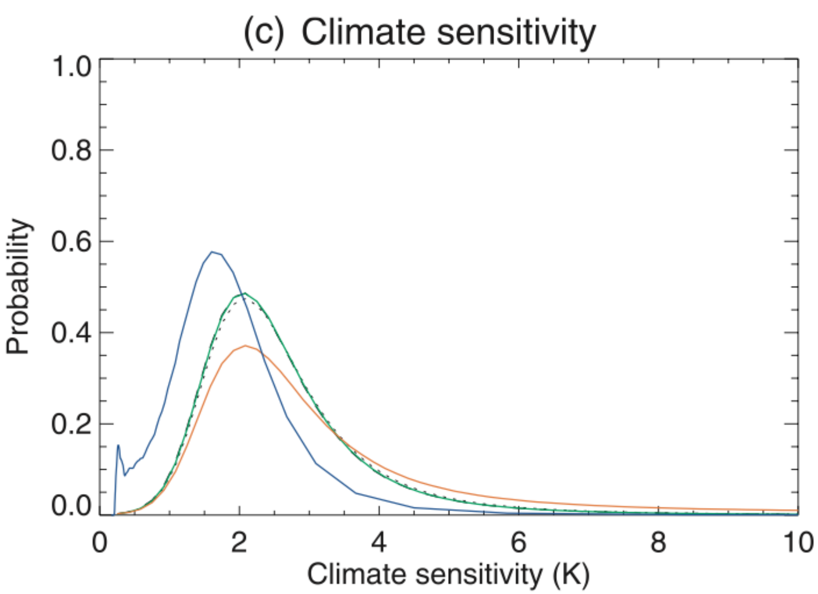


Murphy *et al.* (2004)

Prior Sensitivity







Uniform prior in *S*

Uniform prior in 1/*S*

Uniform prior in TCR

Frame *et al* (2005)

Bayesian Representation

Probability of a future Climate ‘y_f’ given a set of observations ‘o’

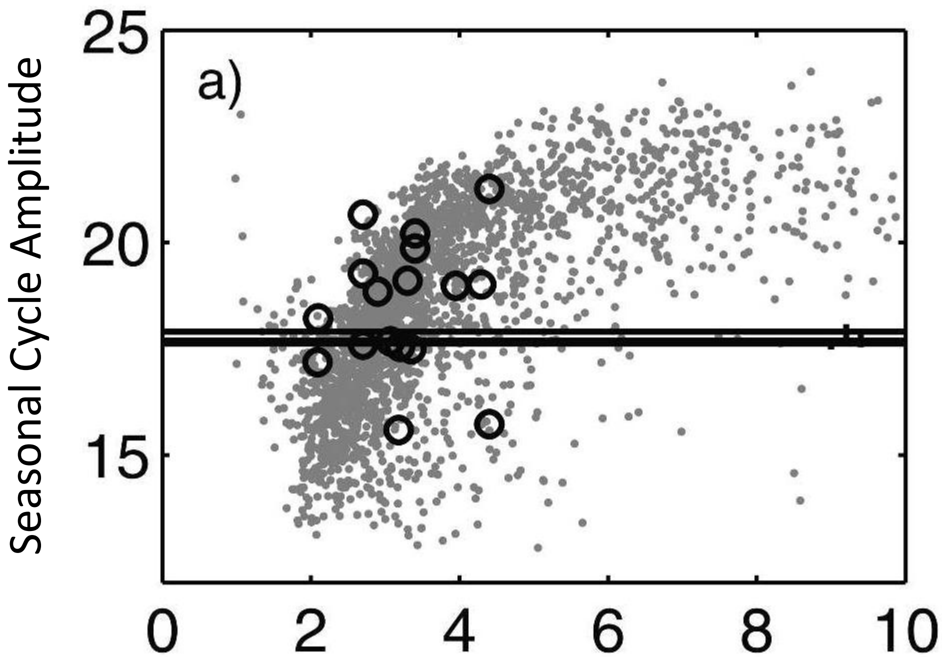
Prior probability of simulating future climate existing at ‘x’

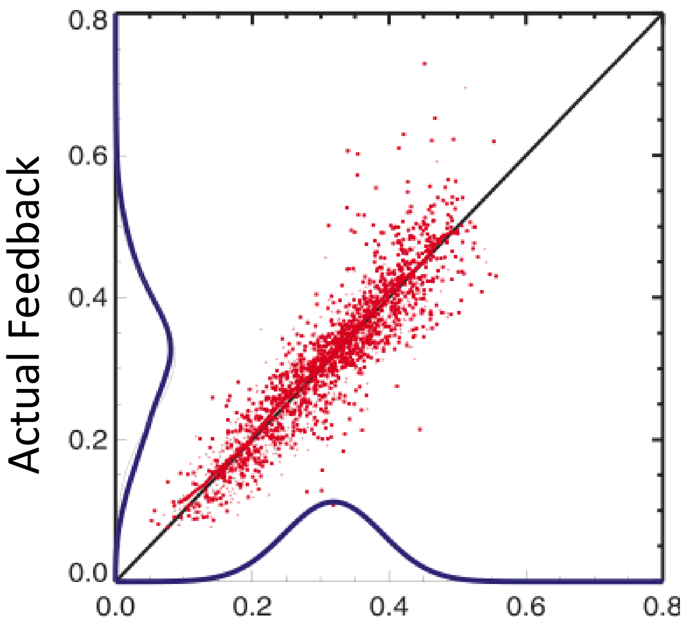
Observational and systematic discrepancy at ‘x’

Expert prior parameter distribution

Murphy *et al.* (2007)

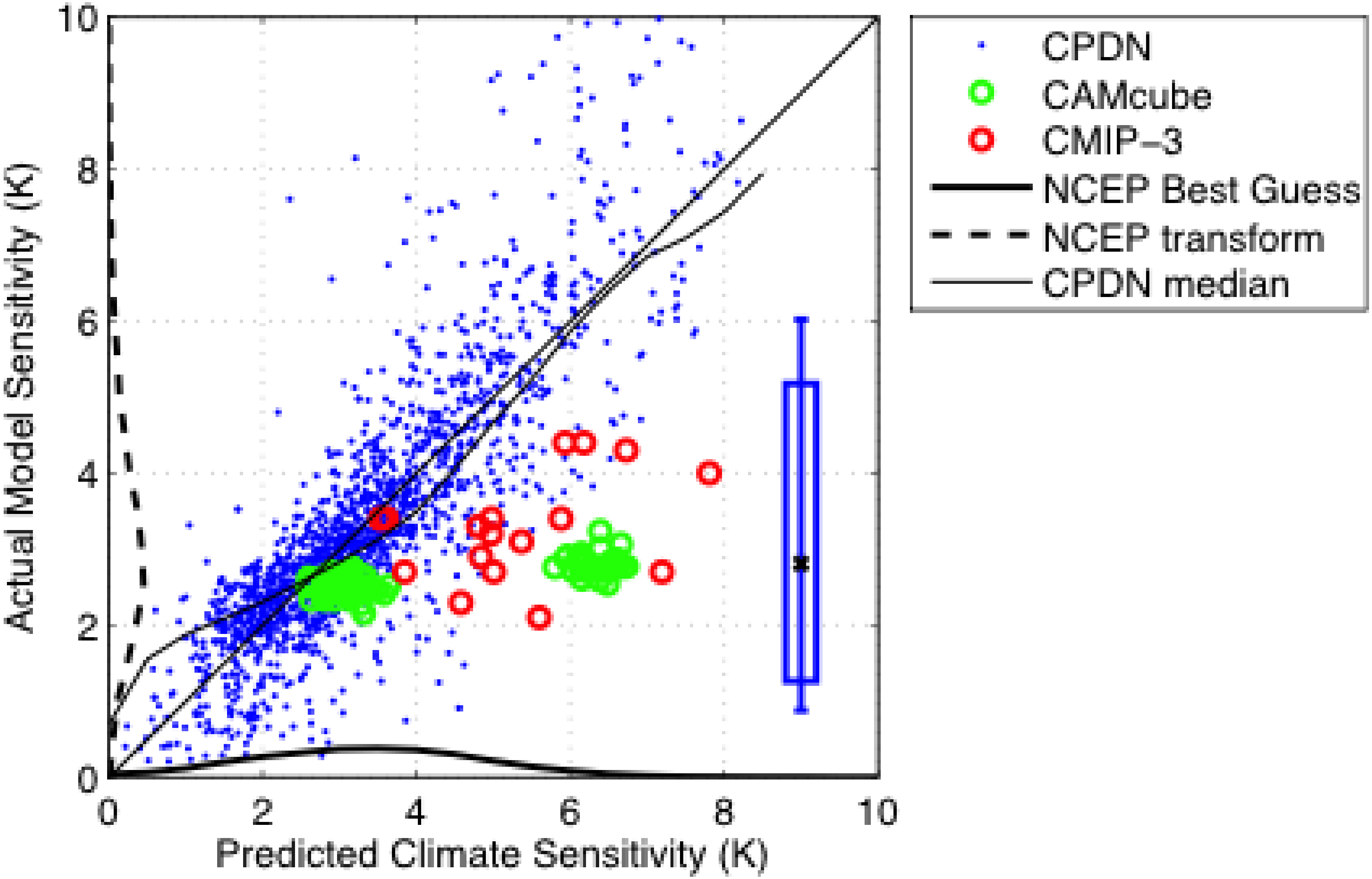
Transfer Function approach





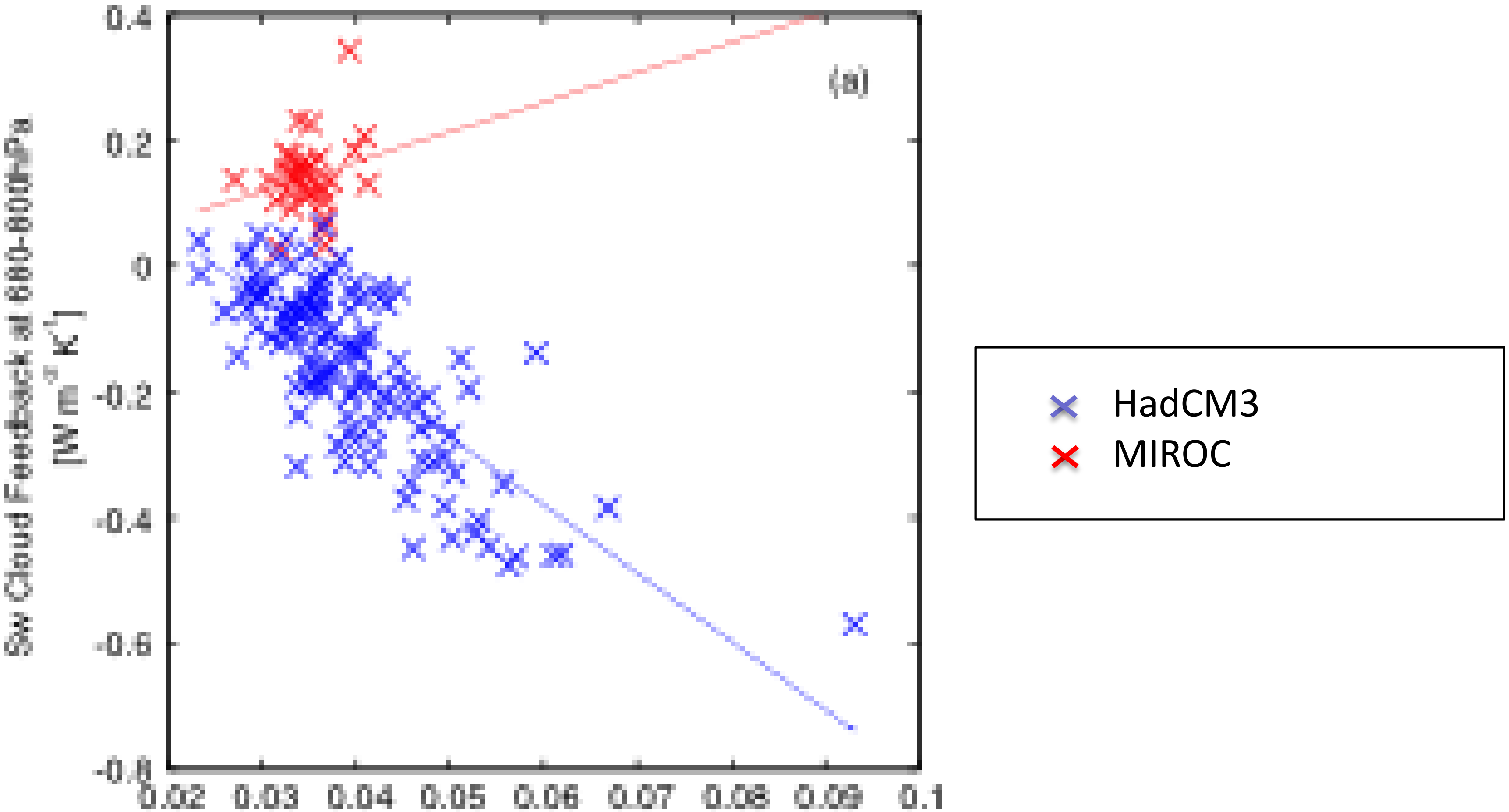
Knutti*et al.* (2006)

Piani*et al.* (2005)



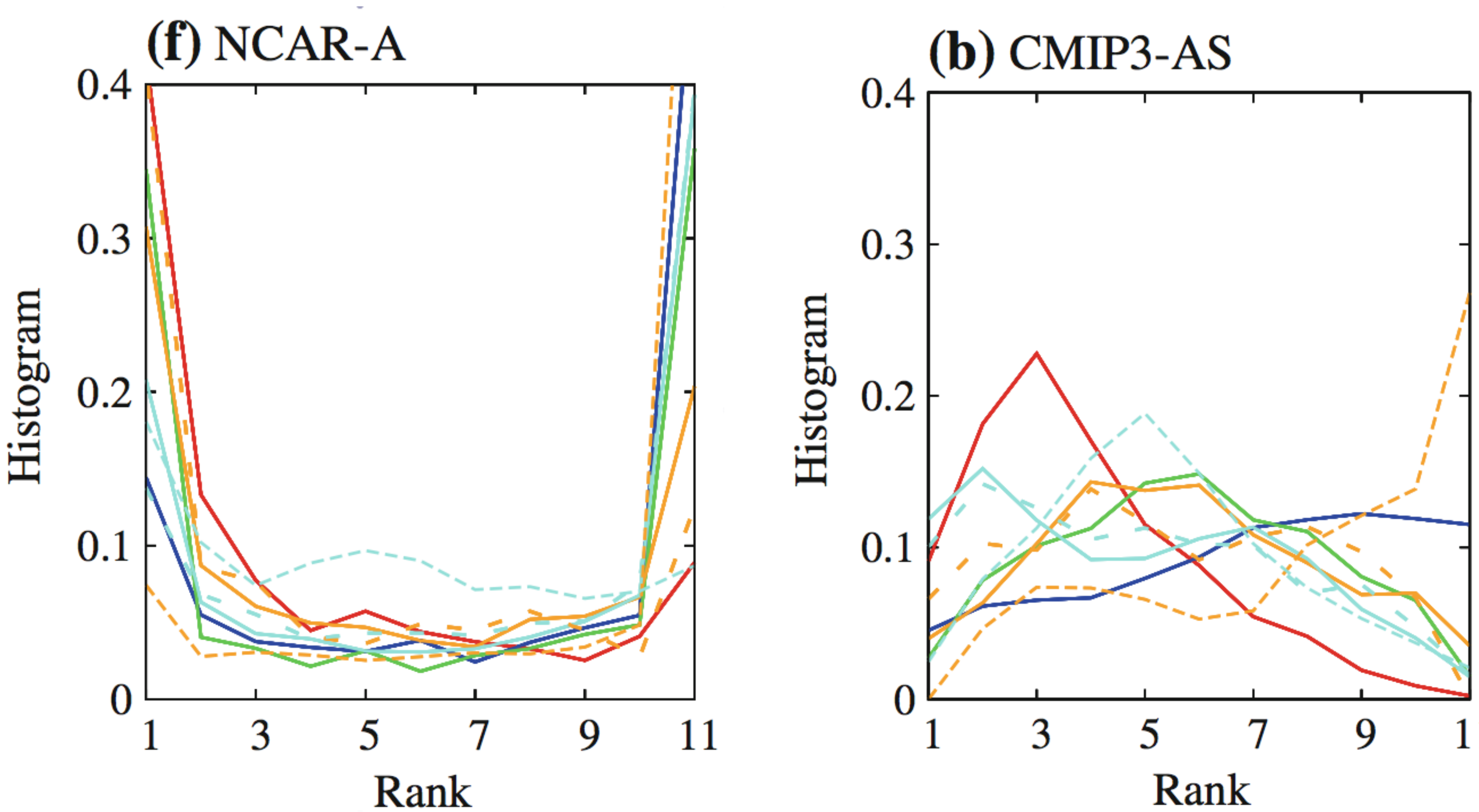
Sanderson (in press)

Systematic Differences



Yokohata et al (2010)

Is one model enough?



Yokohata*et al*, ClimDyn (2011)

II

Multi-model ensembles
(but not as many
as you think)

GCRS

Phillips Charney

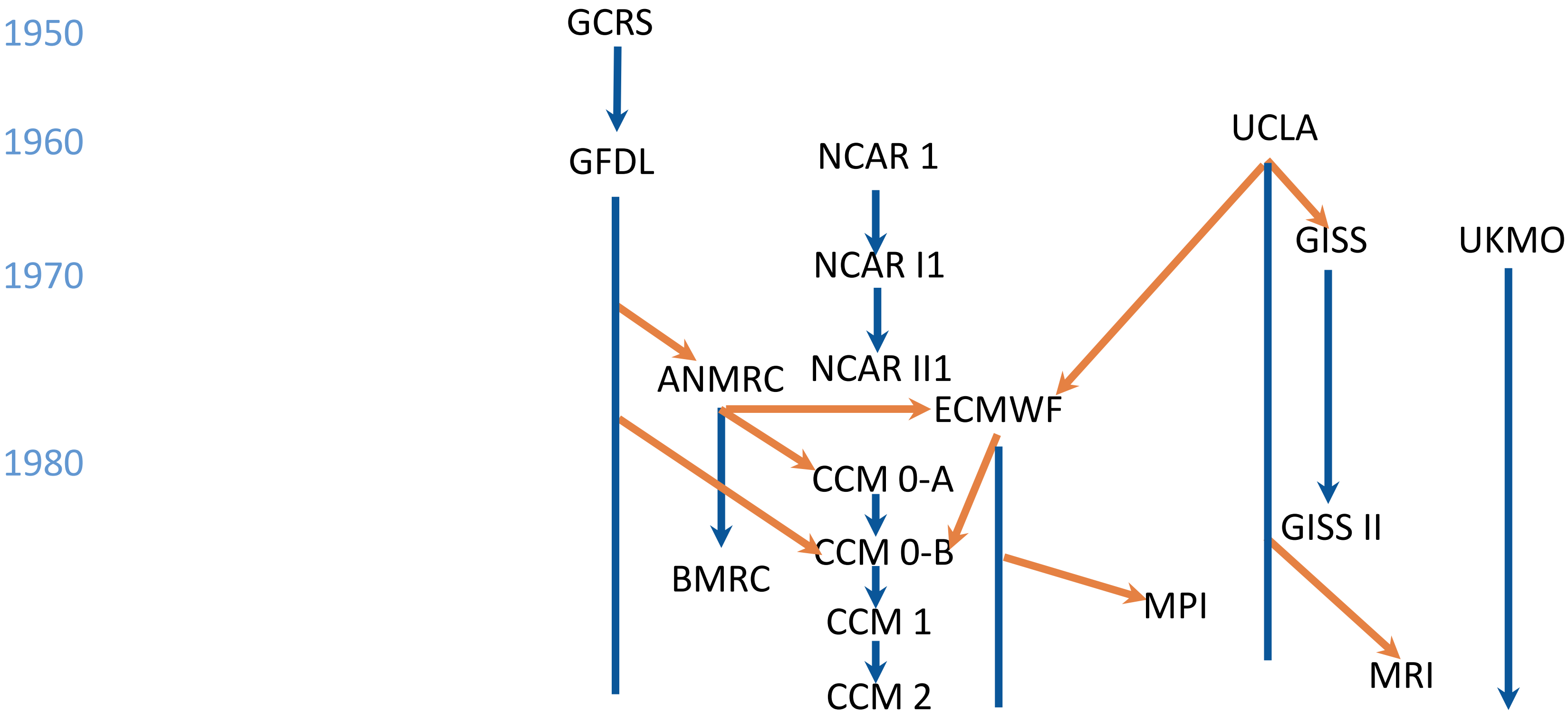
1960

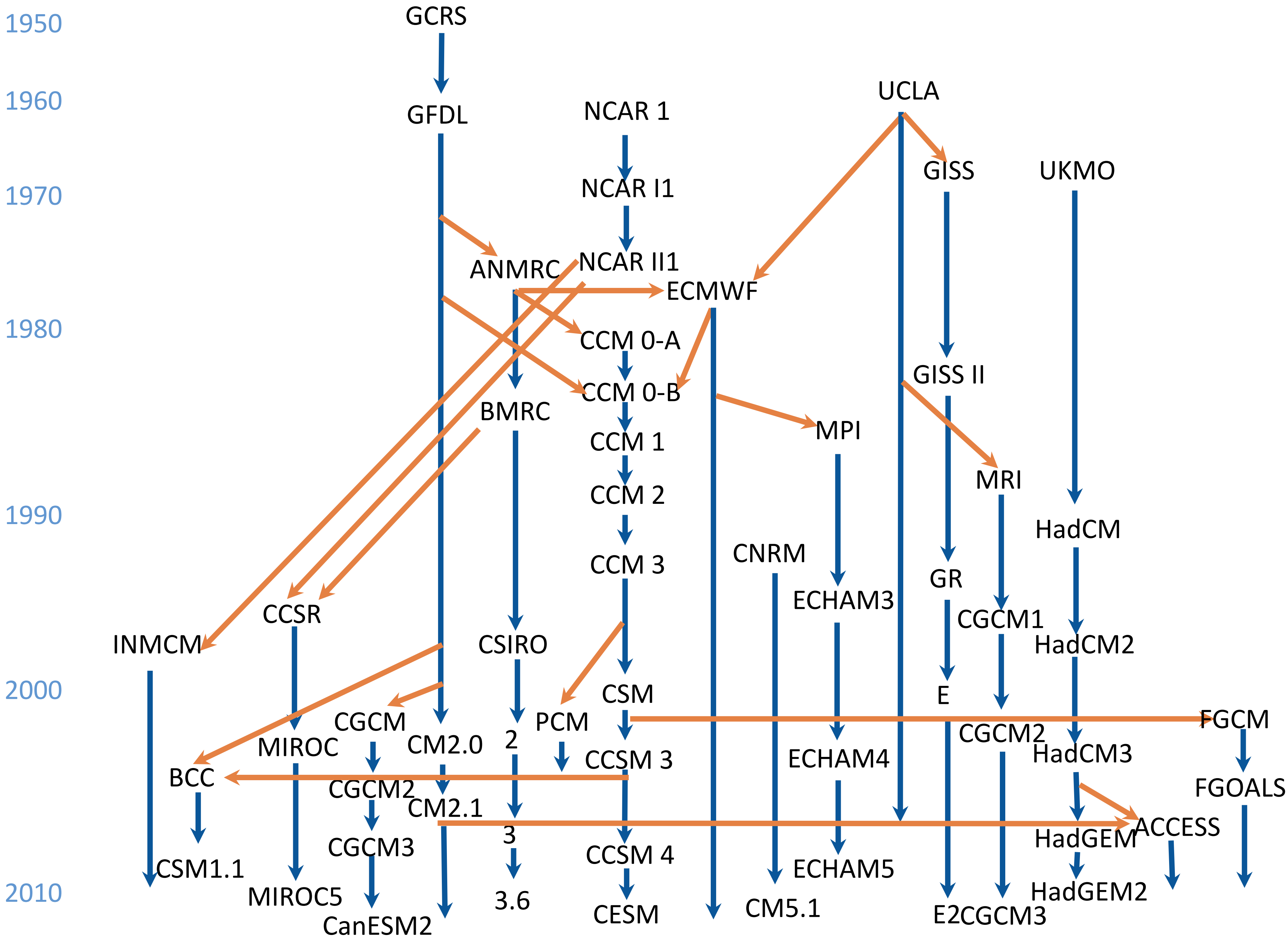
UCLA

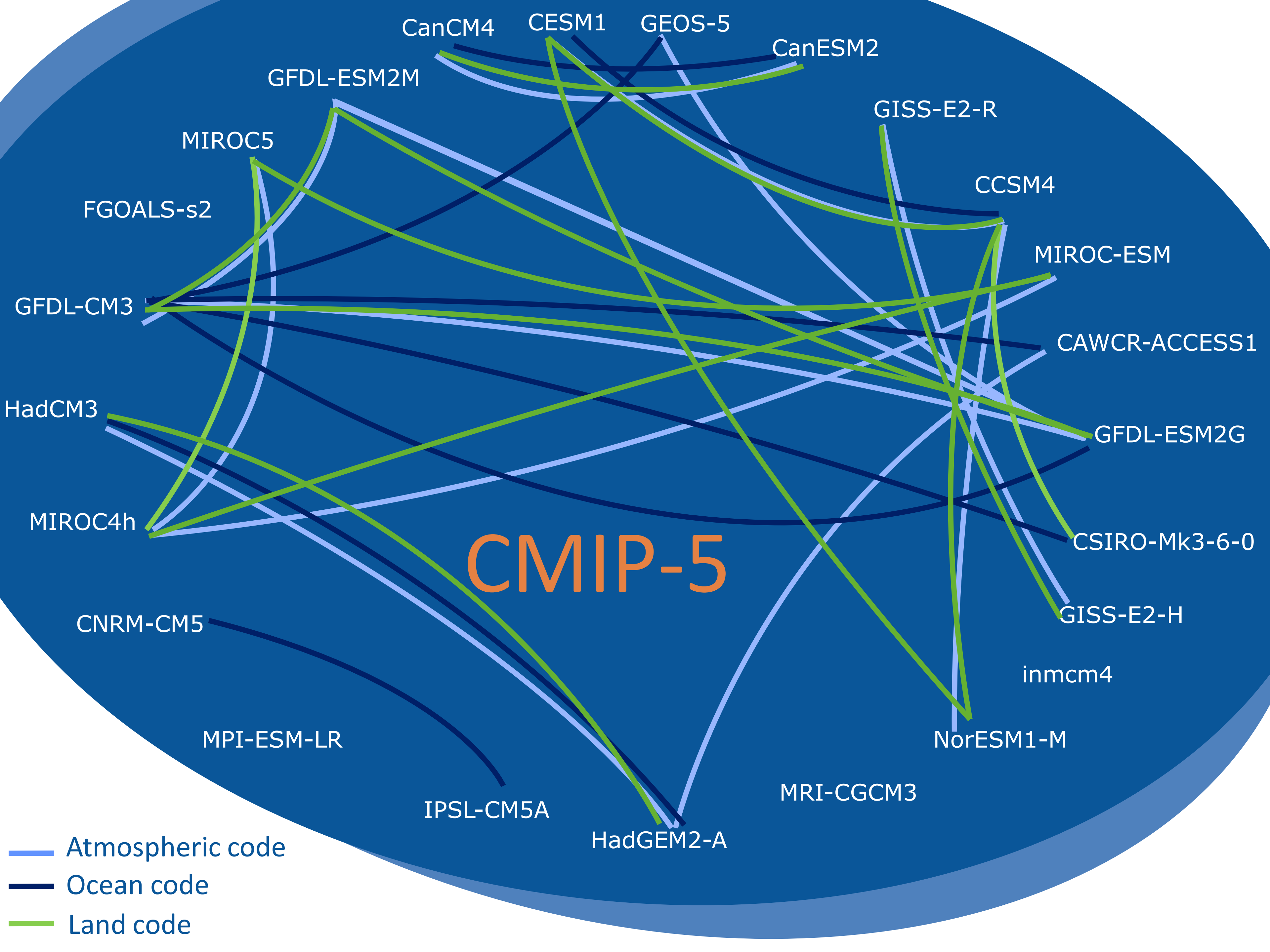
Mintz Arakawa

NCAR 1

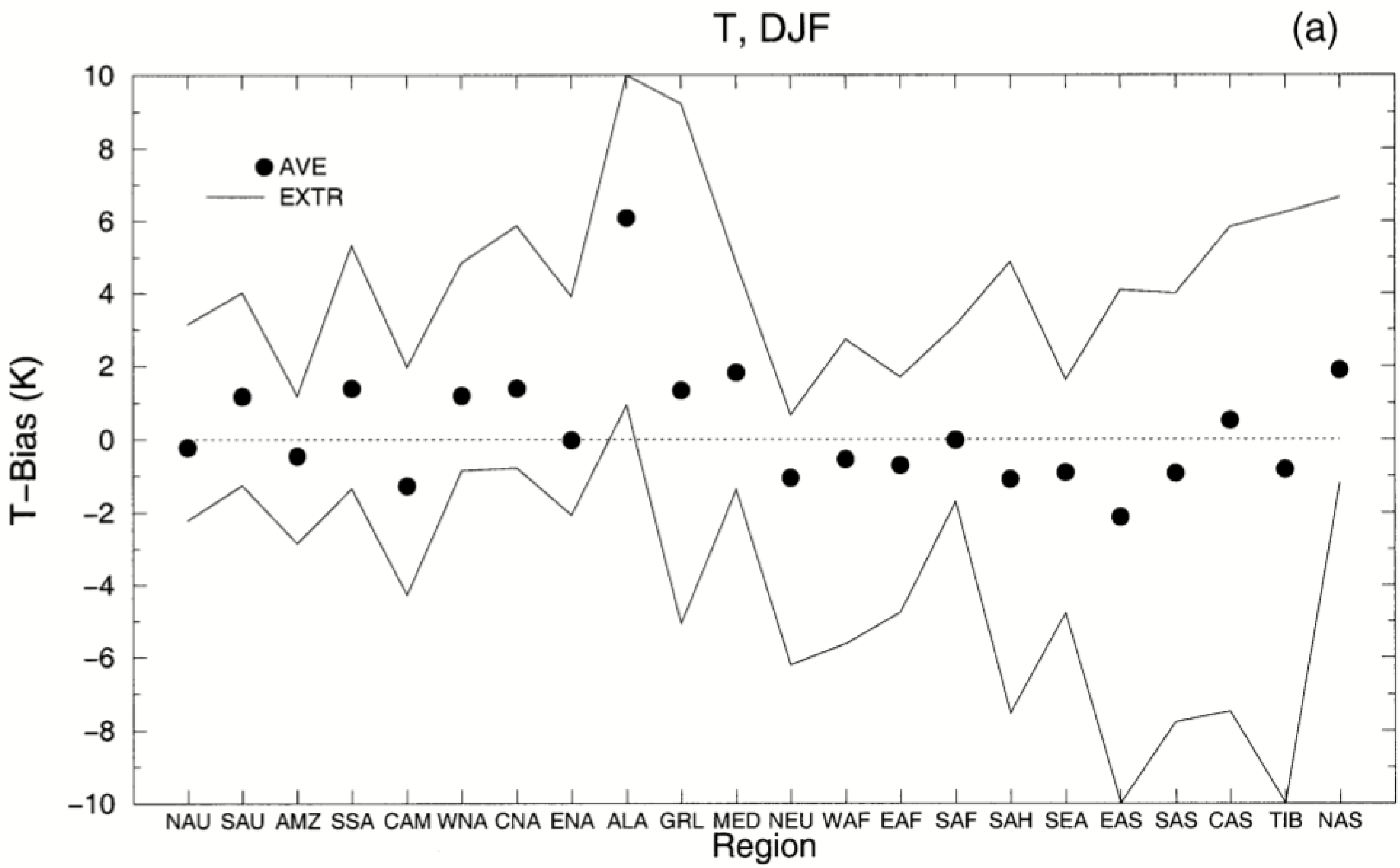
Kasahara Washington


1950
1960
1970
1980
GCRS
GFDL
NCAR 1
NCAR I1
NCAR II1
UCLA
GISS
UKMO
ANMRC
ECMWF
CCM 0-A
CCM 0-B
BMRC
CCM 1
CCM 2
MPI
GISS II
MRI


1950
1960
1970
1980
1990
2000
2010
GCRS
GFDL
NCAR 1
NCAR I1
NCAR II1
UCLA
GISS
UKMO
ANMRC
ECMWF
CCM 0-A
CCM 0-B
GISS II
BMRC
CCM 1
MPI
MRI
CCM 2
HadCM
CNRM
CCM 3
GR
ECHAM3
CCSR
CGCM1
INMCM
CSIRO
HadCM2
CSM
E
CGCM
PCM
FGCM
CM2.0
2
CGCM2
MIROC
ECHAM4
HadCM3
CCSM 3
BCC
FGOALS
CGCM2
CM2.1
3
ACCESS
HadGEM
CGCM3
CCSM 4
CSM1.1
ECHAM5
MIROC5
3.6
HadGEM2
CM5.1
CESM
E2CGCM3
CanESM2

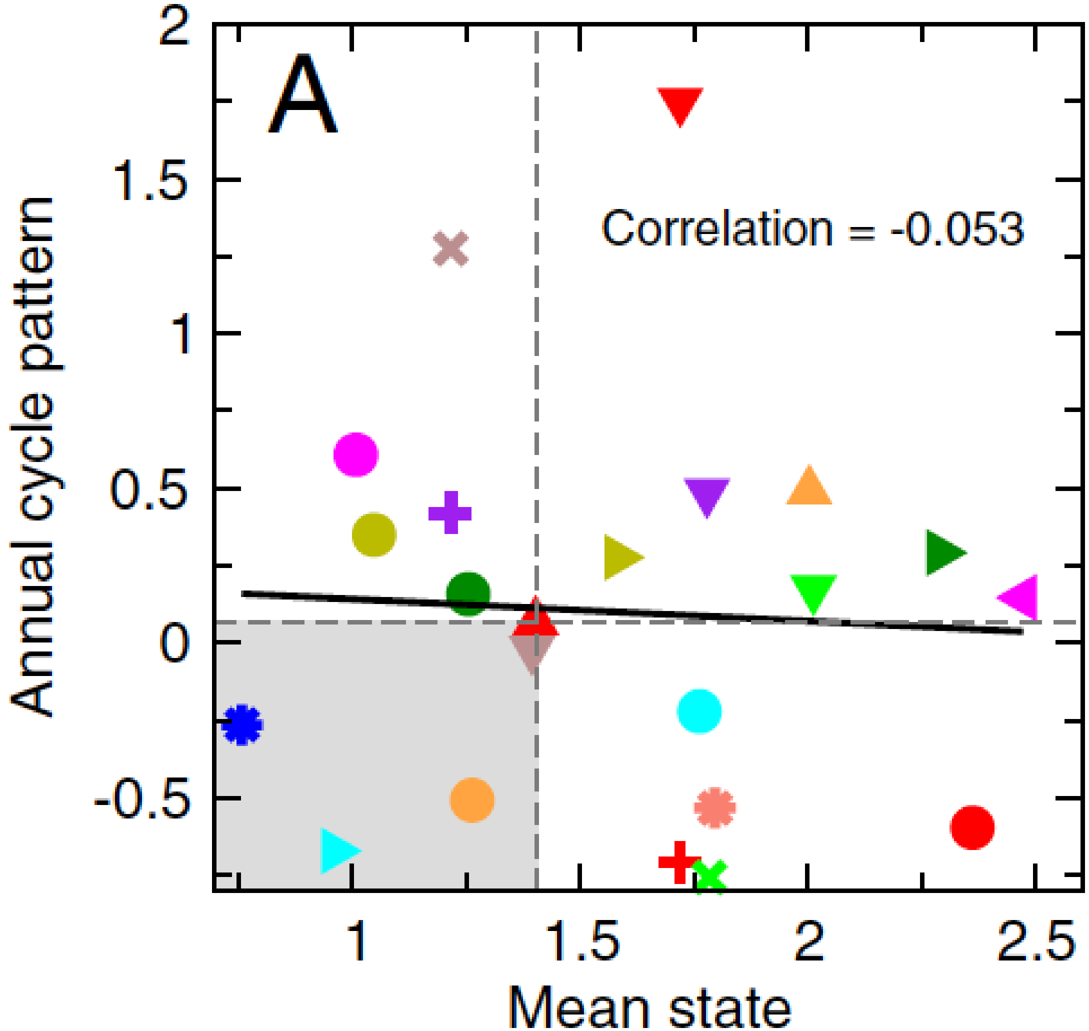

CanCM4
CESM1
GEOS-5
CanESM2
GFDL-ESM2M
GISS-E2-R
MIROC5
CCSM4
FGOALS-s2
MIROC-ESM
GFDL-CM3
CAWCR-ACCESS1
HadCM3
GFDL-ESM2G
MIROC4h
CSIRO-Mk3-6-0
CMIP-5
CNRM-CM5
GISS-E2-H
inmcm4
MPI-ESM-LR
NorESM1-M
MRI-CGCM3
IPSL-CM5A
HadGEM2-A
Atmospheric code
Ocean code
Land code

Just weight them?



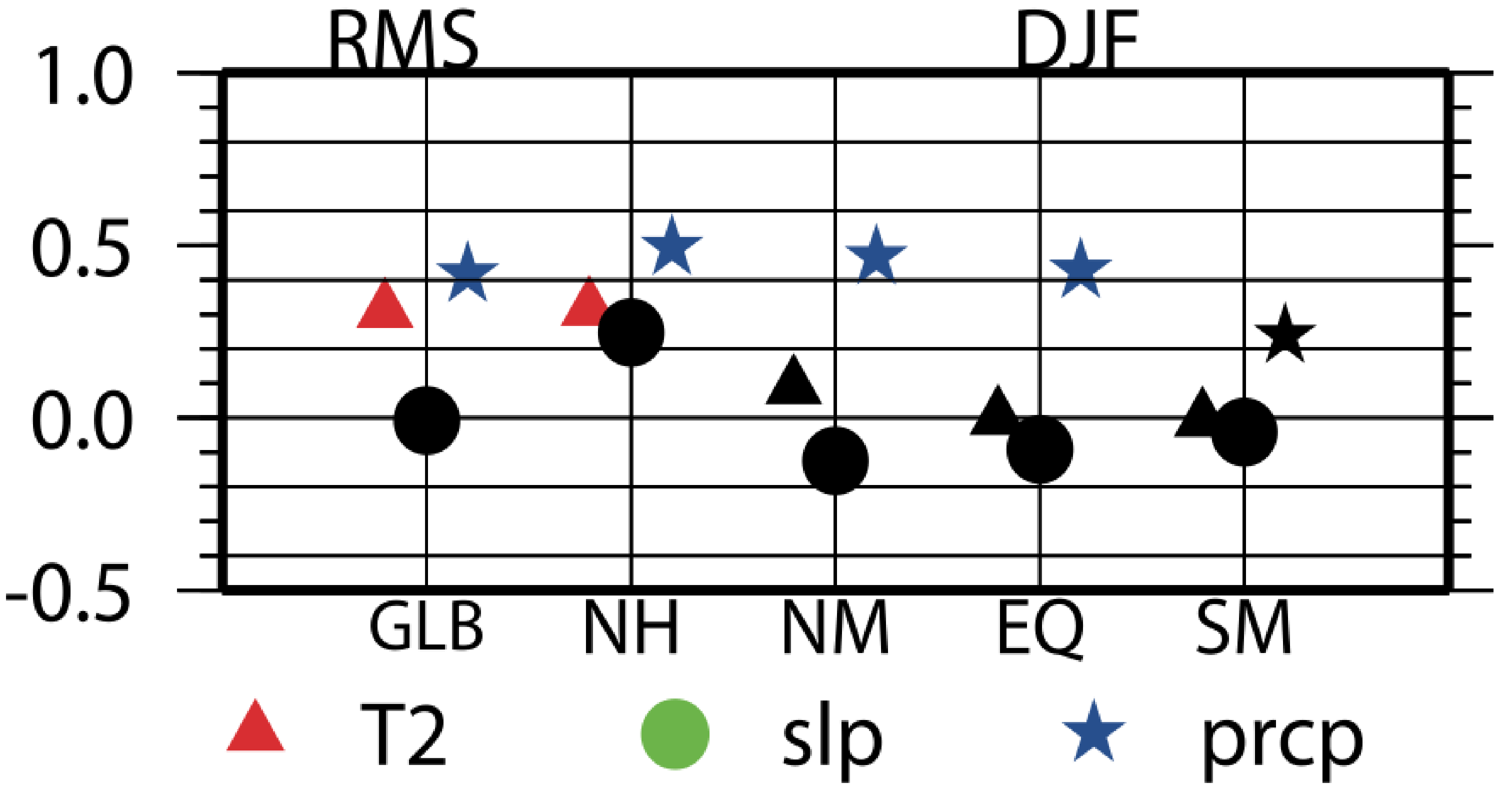
Giorgi and Mearns (2002)

With what?



Santer et al (2009)

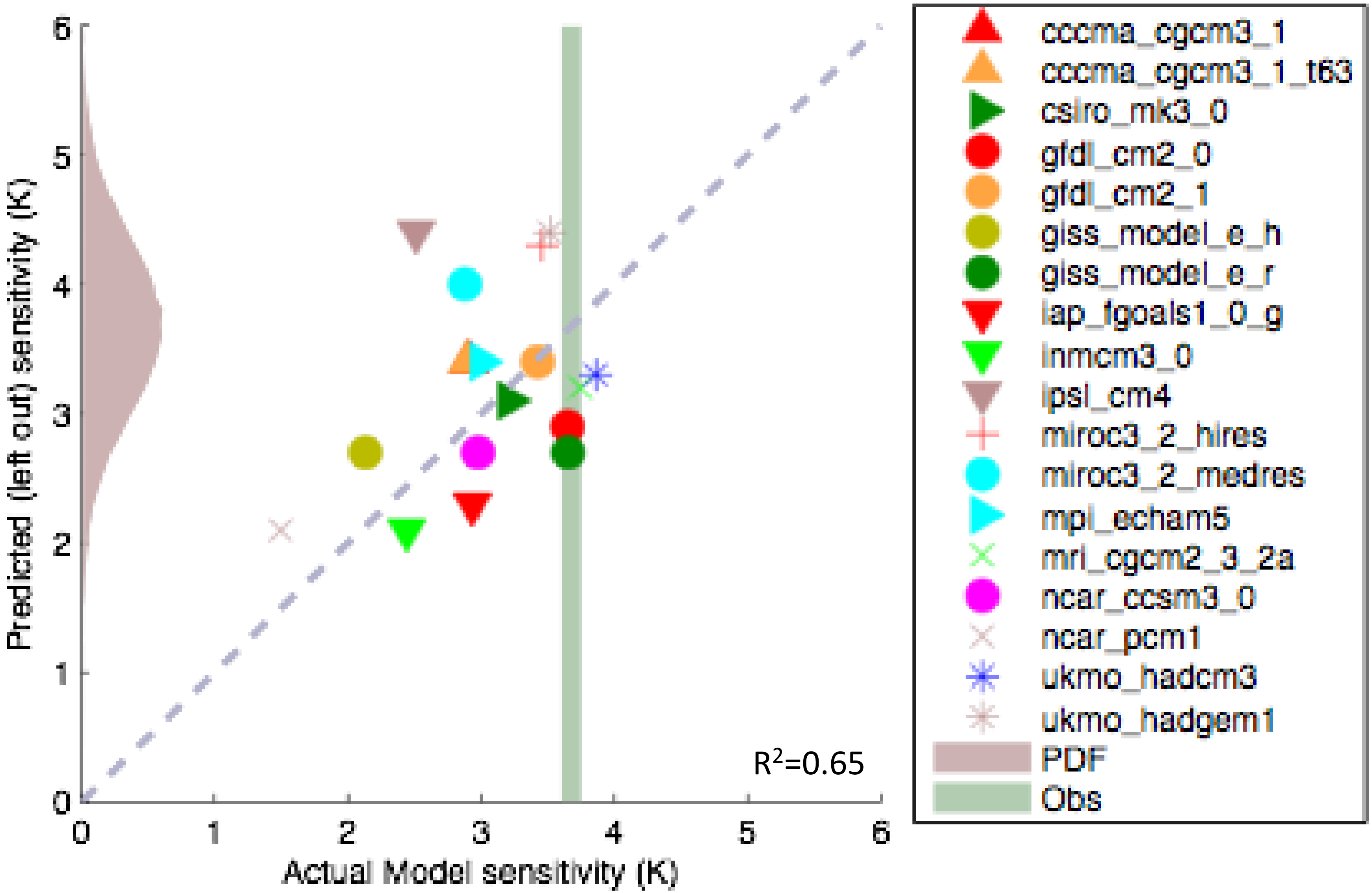
Is the past even relevant?



Abe et al (2009)

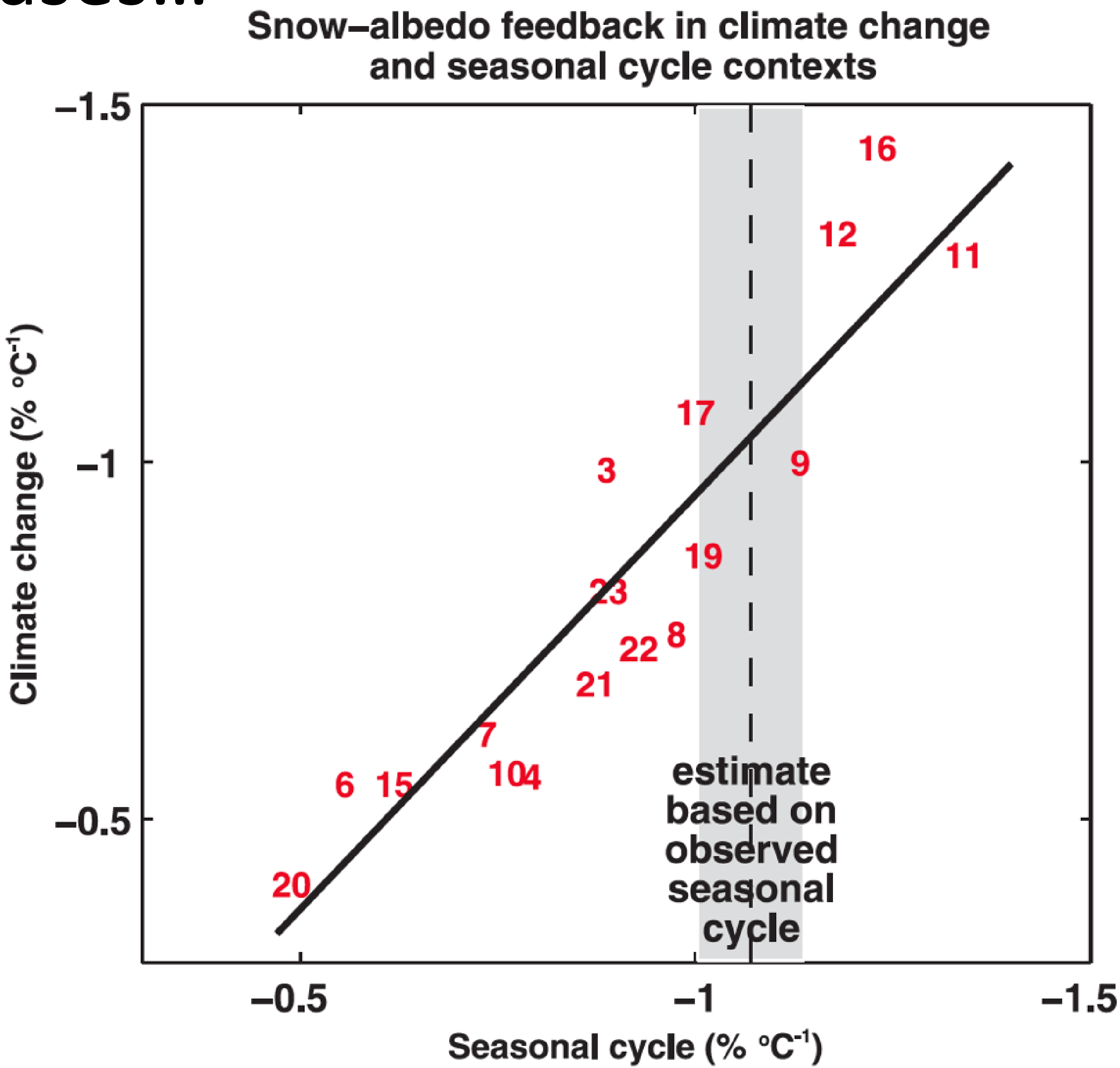
Transfer functions?

Sanderson *et al* (in prep)

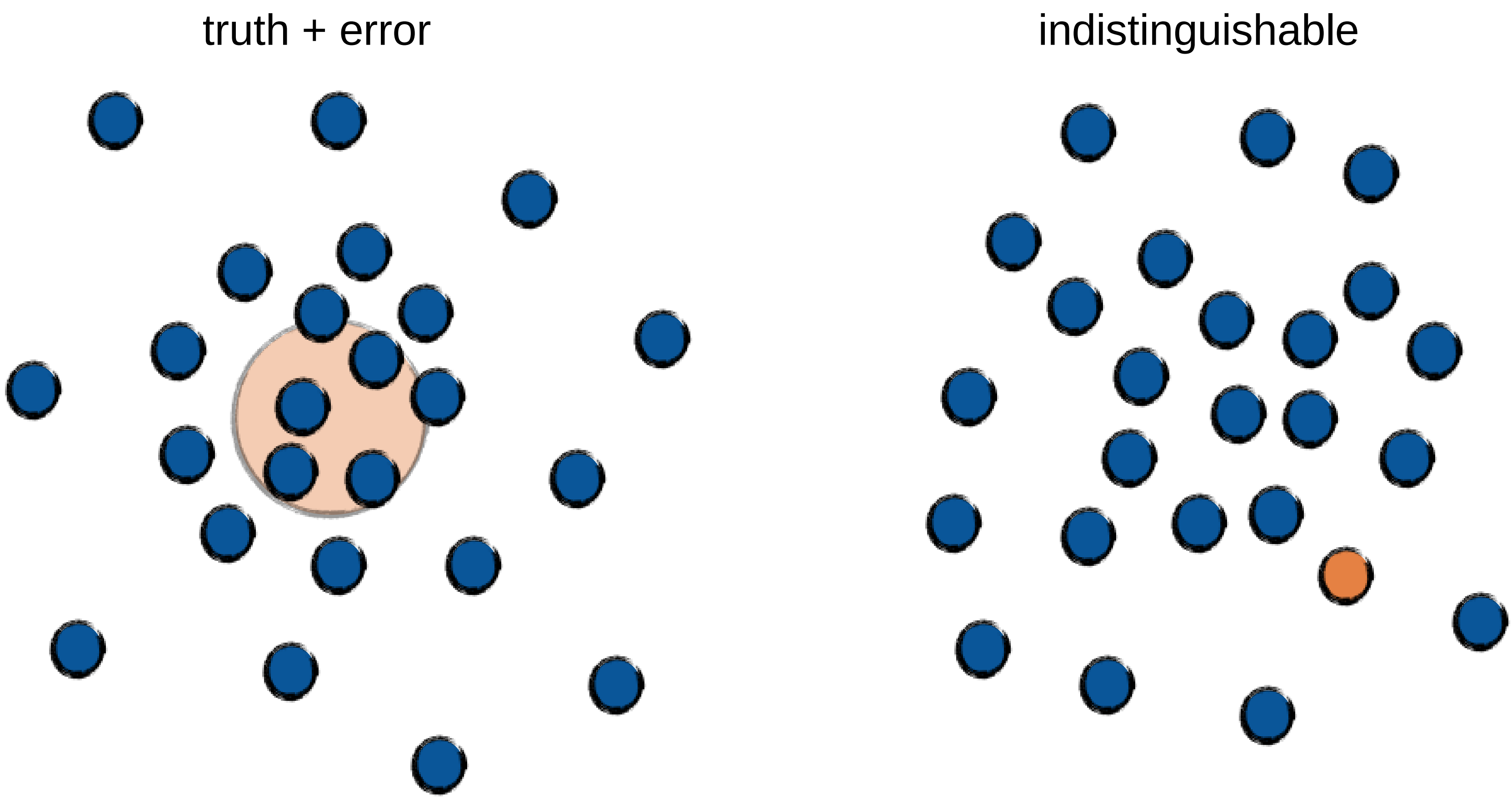


In special cases…

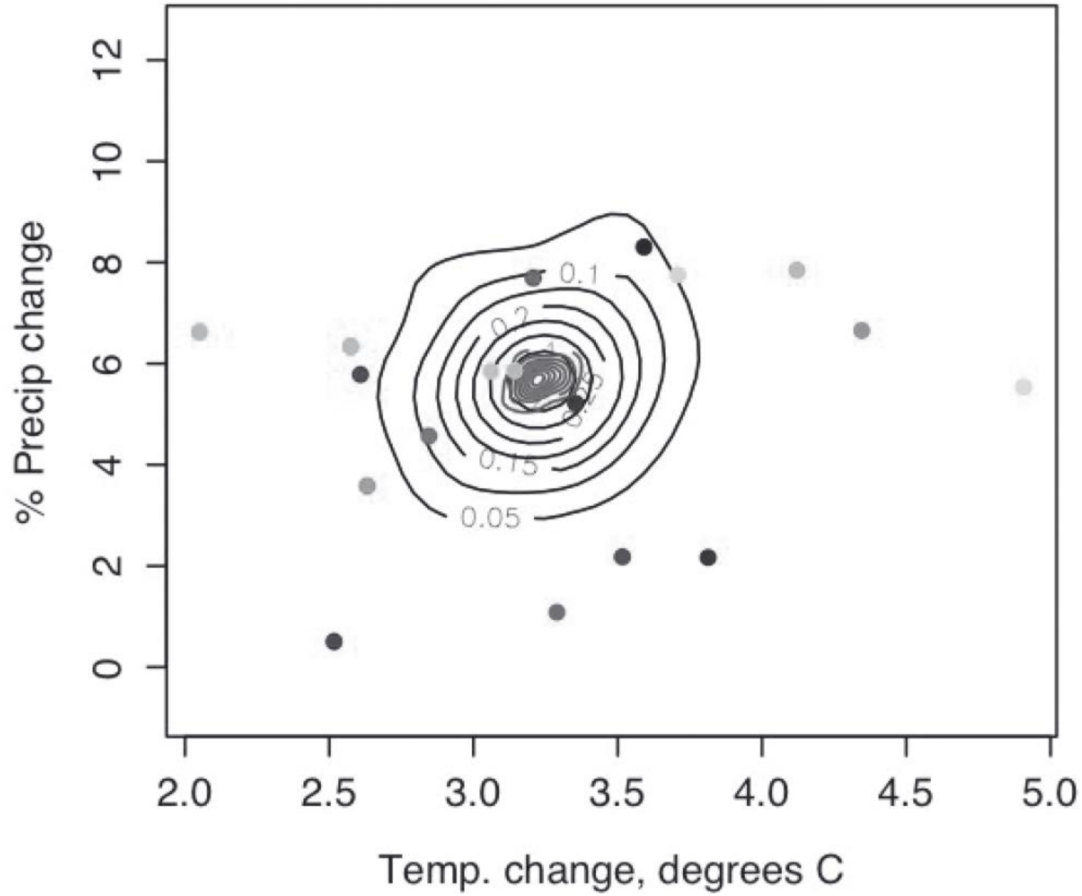
Qu and Hall (2007)



A matter of interpretation

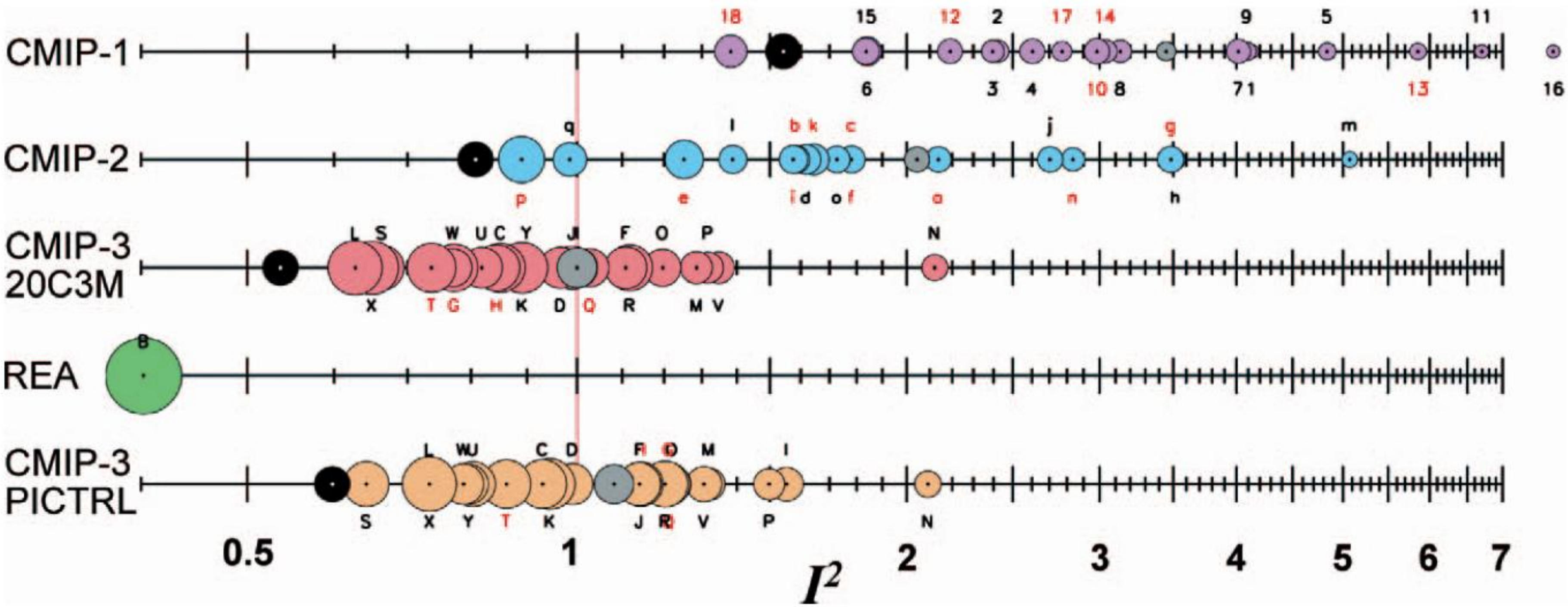


The Bayesian Approach



Tebaldi & Sanso (2009)

The spectacular mean…



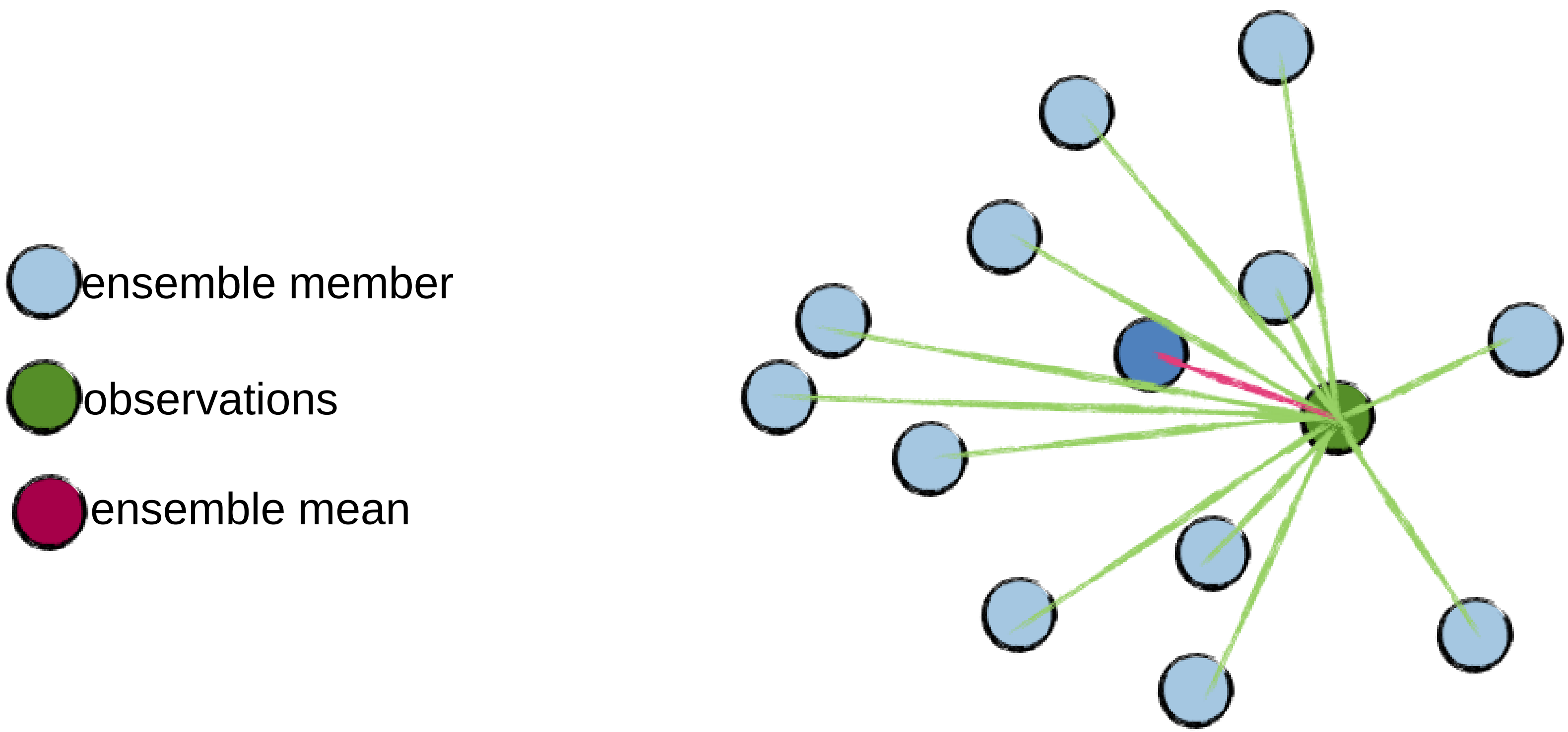
Reichler and Kim, BAMS (2008)

$$\frac{1}{n}\sum\|m_i - O\|^2 = \frac{1}{n}\sum\|m_i - M\|^2 + \|O - M\|^2$$

mean obs-model distance

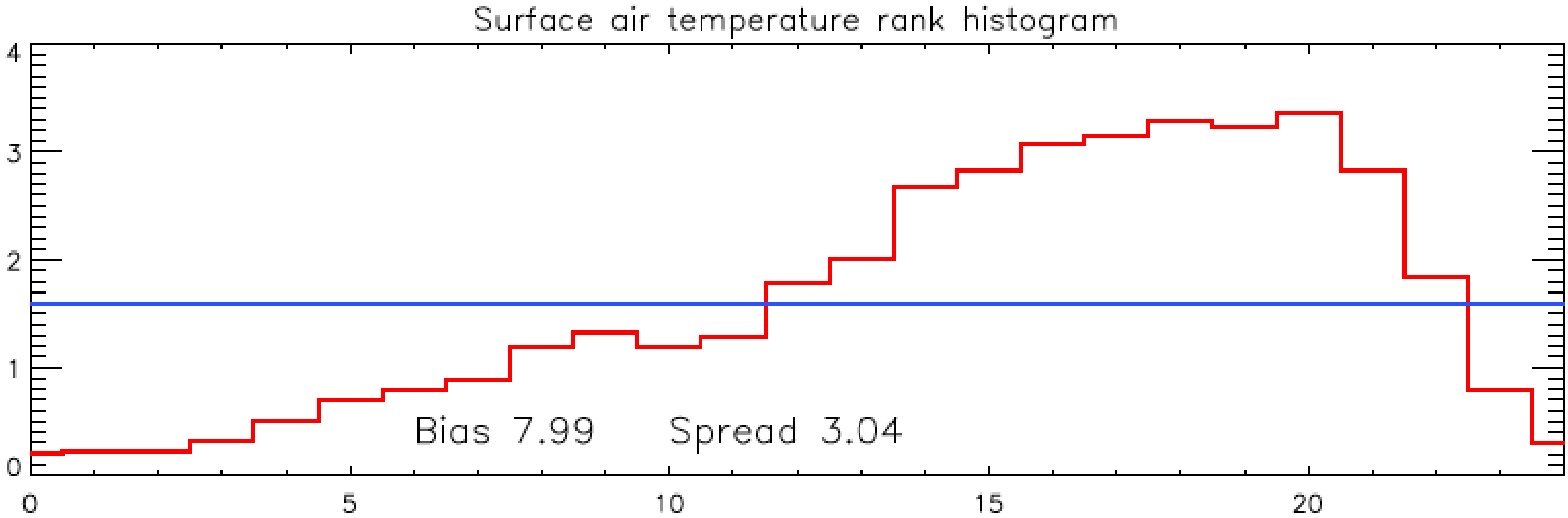
mean model-mean distance

obs-mean distance

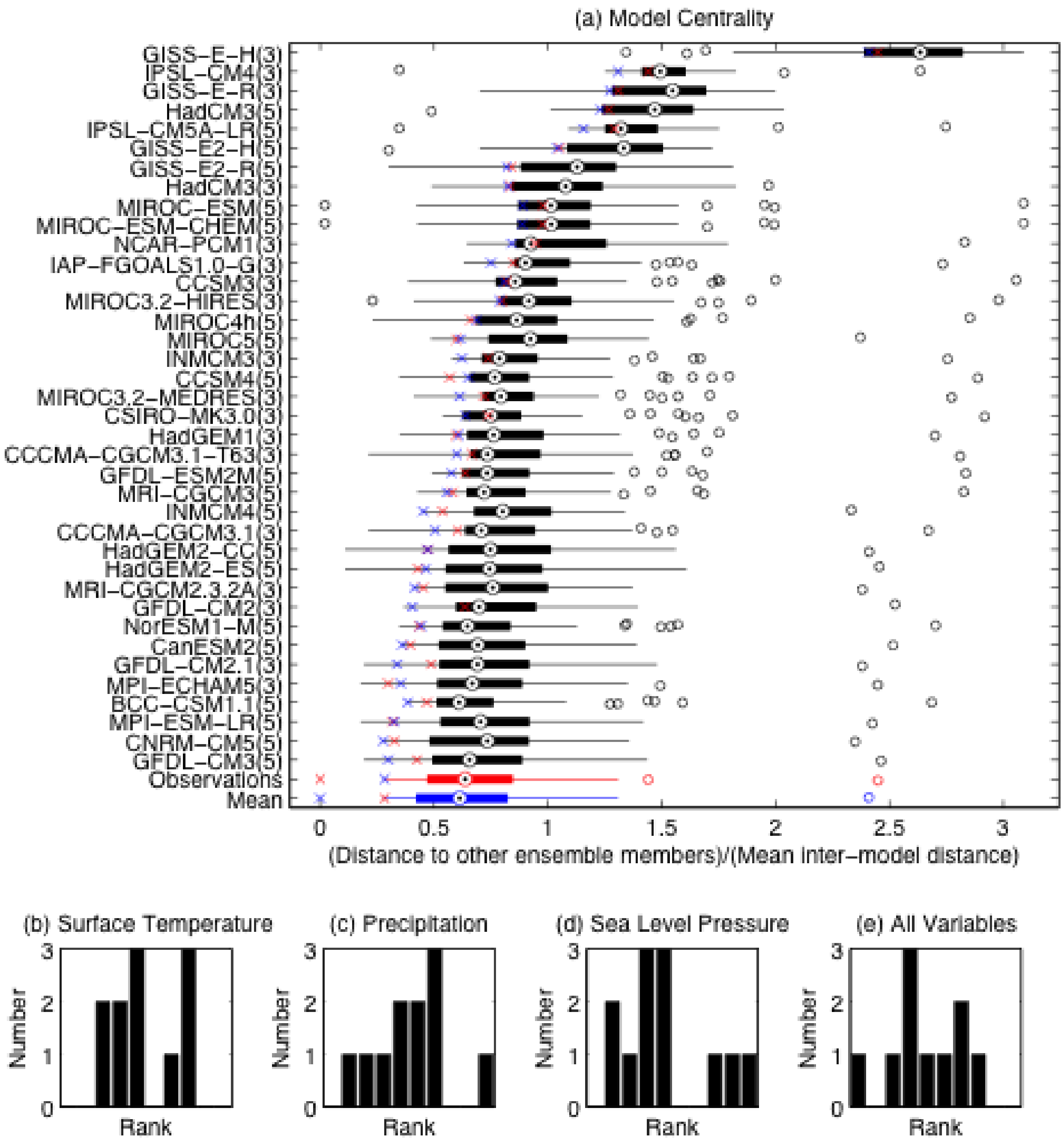


The Cauchy-Schwartz inequality

A reliable ensemble?



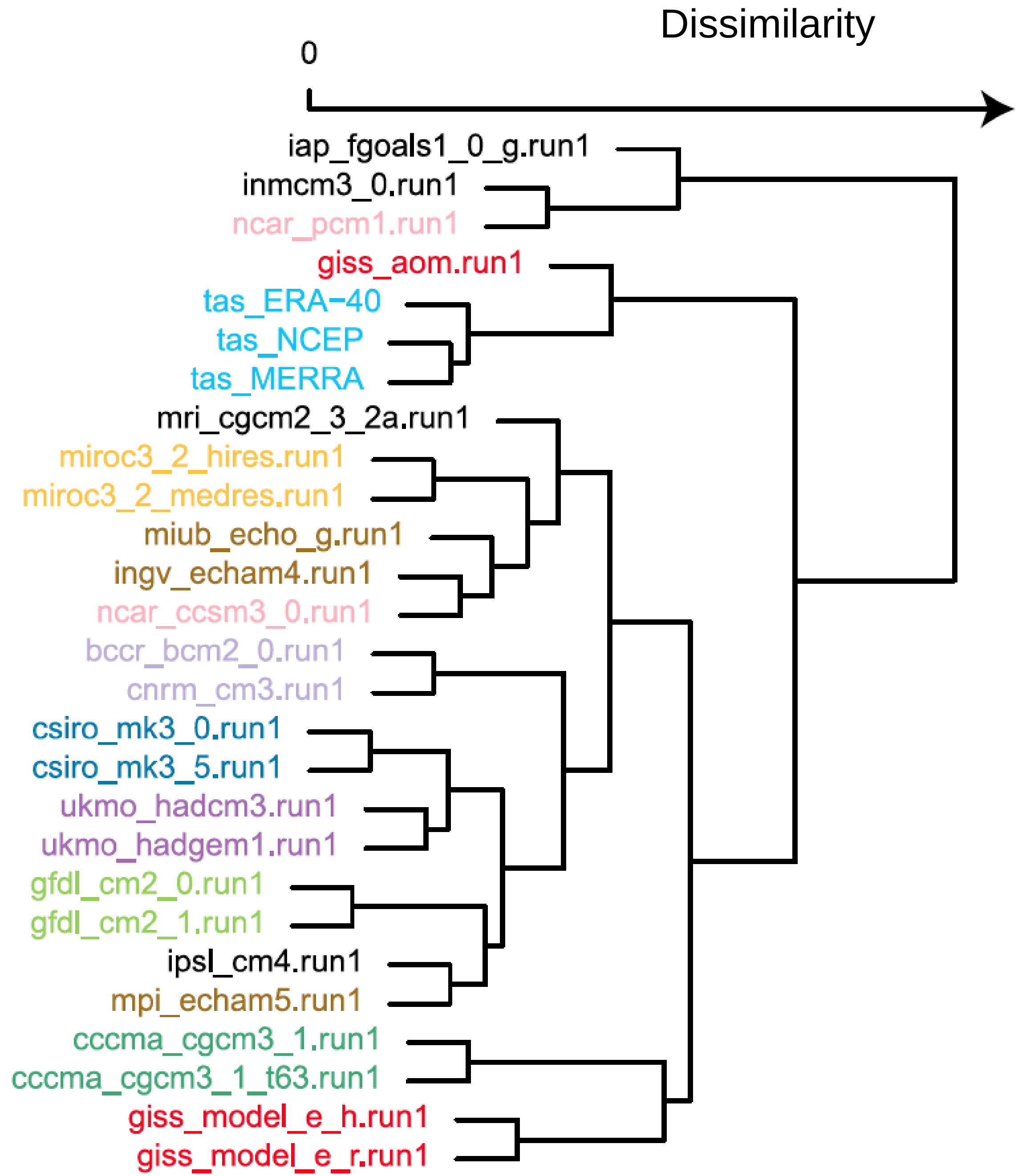
Annan and Hargreaves (2010)

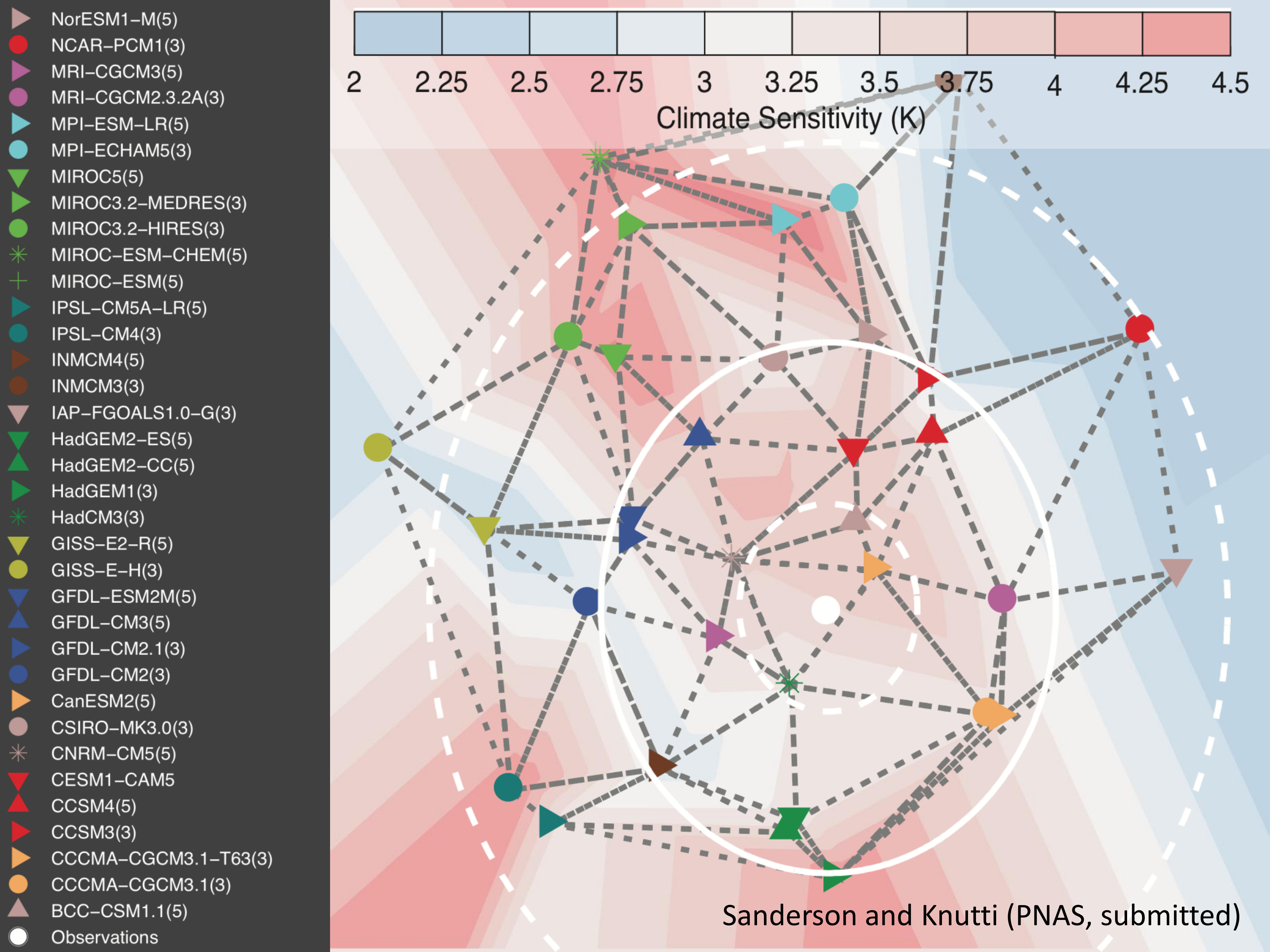


Sanderson and Knutti (in press)

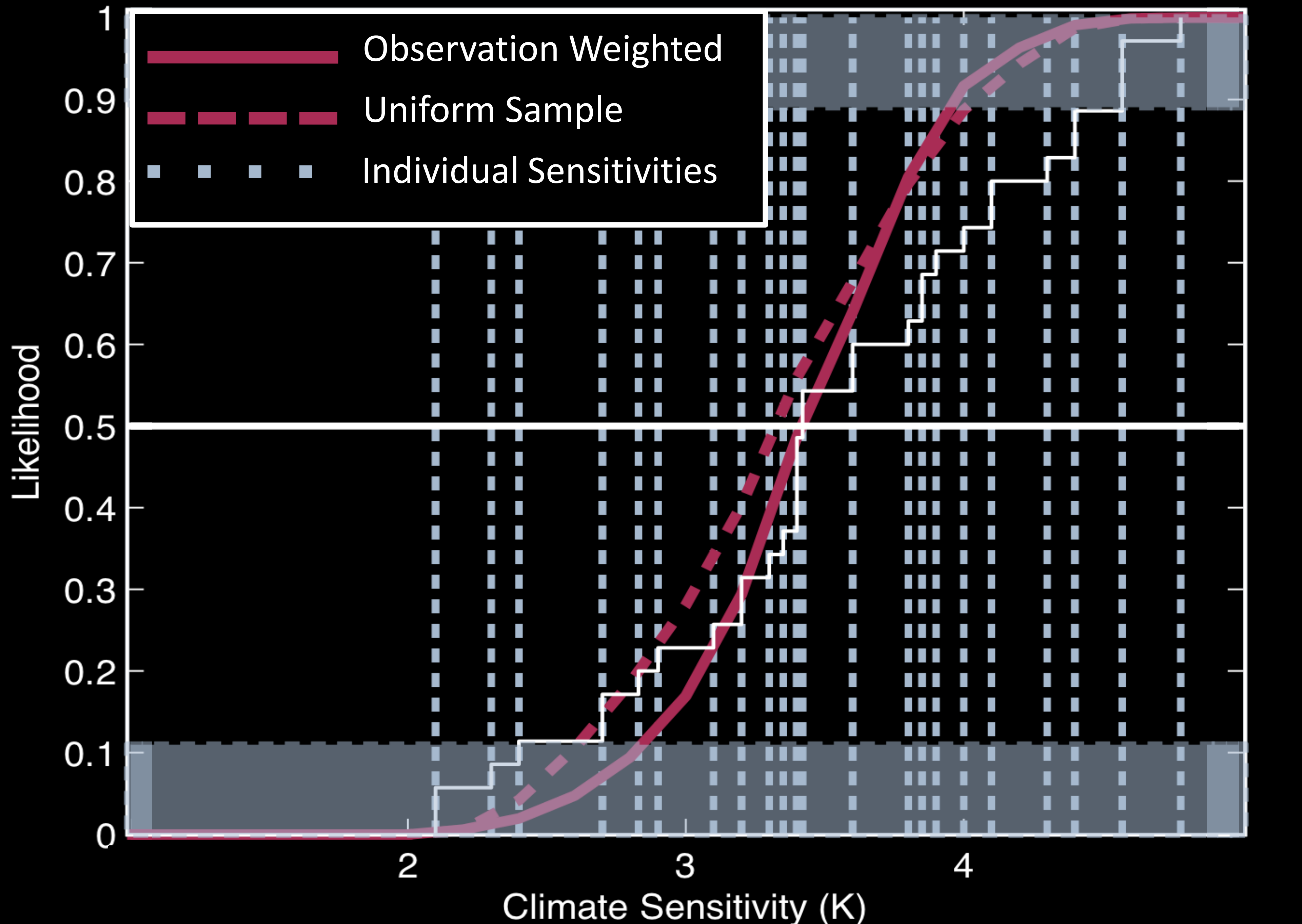
Model Similarity

Masson *et al* (2011)

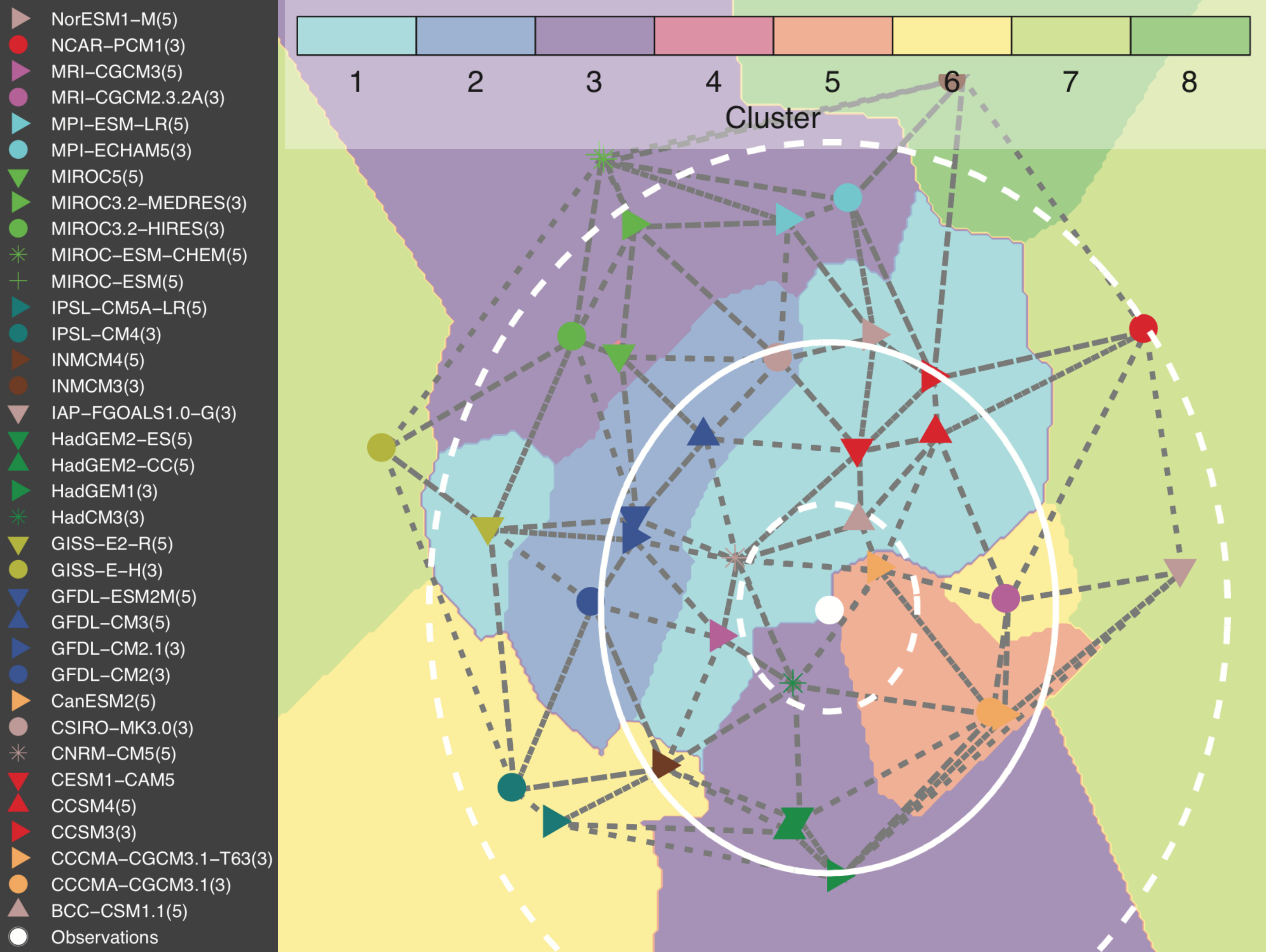




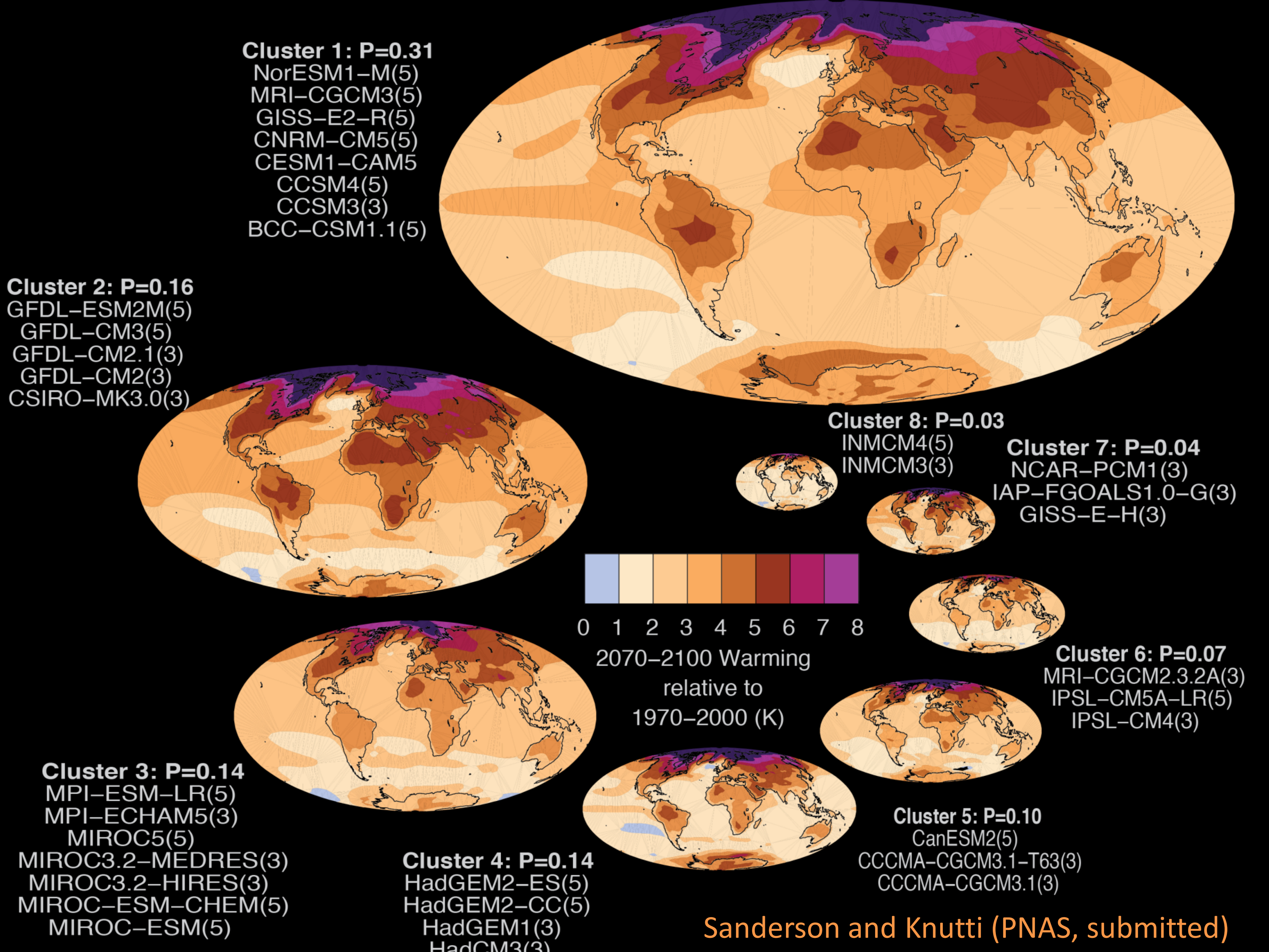
Sanderson and Knutti (PNAS, submitted)



Observation Weighted
Uniform Sample
Individual Sensitivities
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Likelihood
2
3
4
Climate Sensitivity (K)



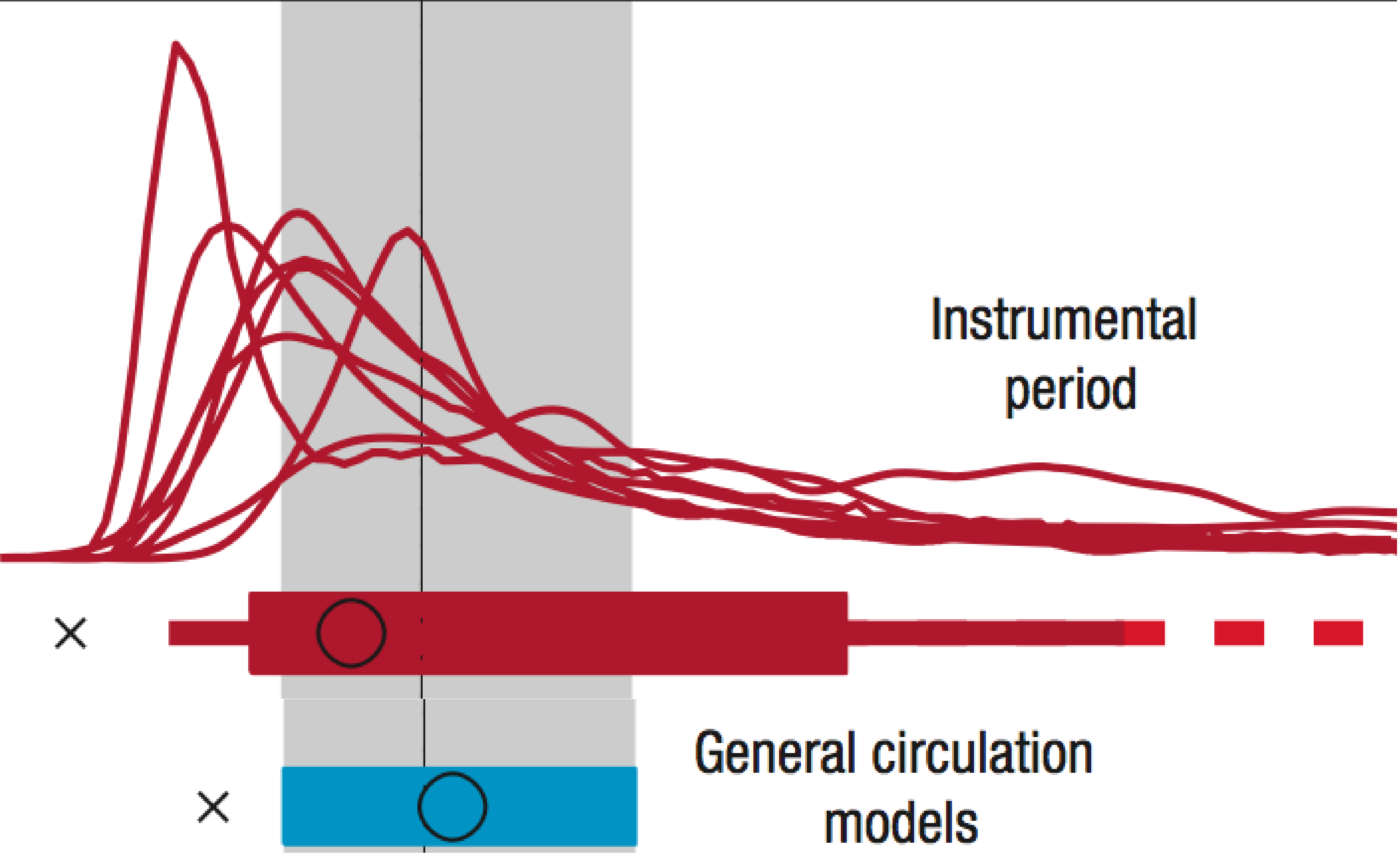
NorESM1–M(5)
NCAR–PCM1(3)
MRI–CGCM3(5)
MRI–CGCM2.3.2A(3)
MPI–ESM–LR(5)
MPI–ECHAM5(3)
MIROC5(5)
MIROC3.2–MEDRES(3)
MIROC3.2–HIRES(3)
MIROC–ESM–CHEM(5)
MIROC–ESM(5)
IPSL–CM5A–LR(5)
IPSL–CM4(3)
INMCM4(5)
INMCM3(3)
IAP–FGOALS1.0–G(3)
HadGEM2–ES(5)
HadGEM2–CC(5)
HadGEM1(3)
HadCM3(3)
GISS–E2–R(5)
GISS–E–H(3)
GFDL–ESM2M(5)
GFDL–CM3(5)
GFDL–CM2.1(3)
GFDL–CM2(3)
CanESM2(5)
CSIRO–MK3.0(3)
CNRM–CM5(5)
CESM1–CAM5
CCSM4(5)
CCSM3(3)
CCCMA–CGCM3.1–T63(3)
CCCMA–CGCM3.1(3)
BCC–CSM1.1(5)
Observations
1
2
3
4
5
6
7
8
Cluster



Sanderson and Knutti (PNAS, submitted)

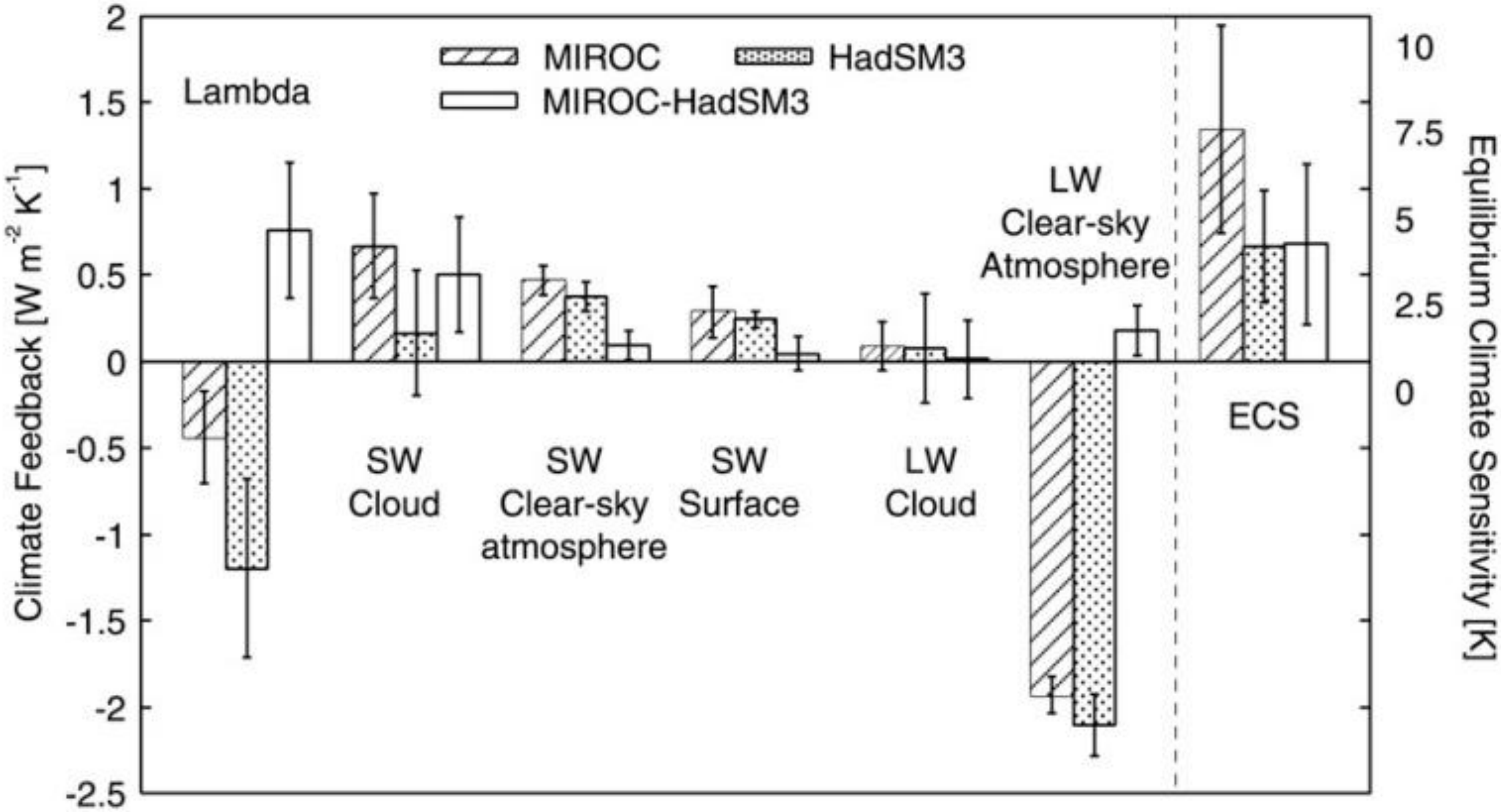
III

Bringing it all together

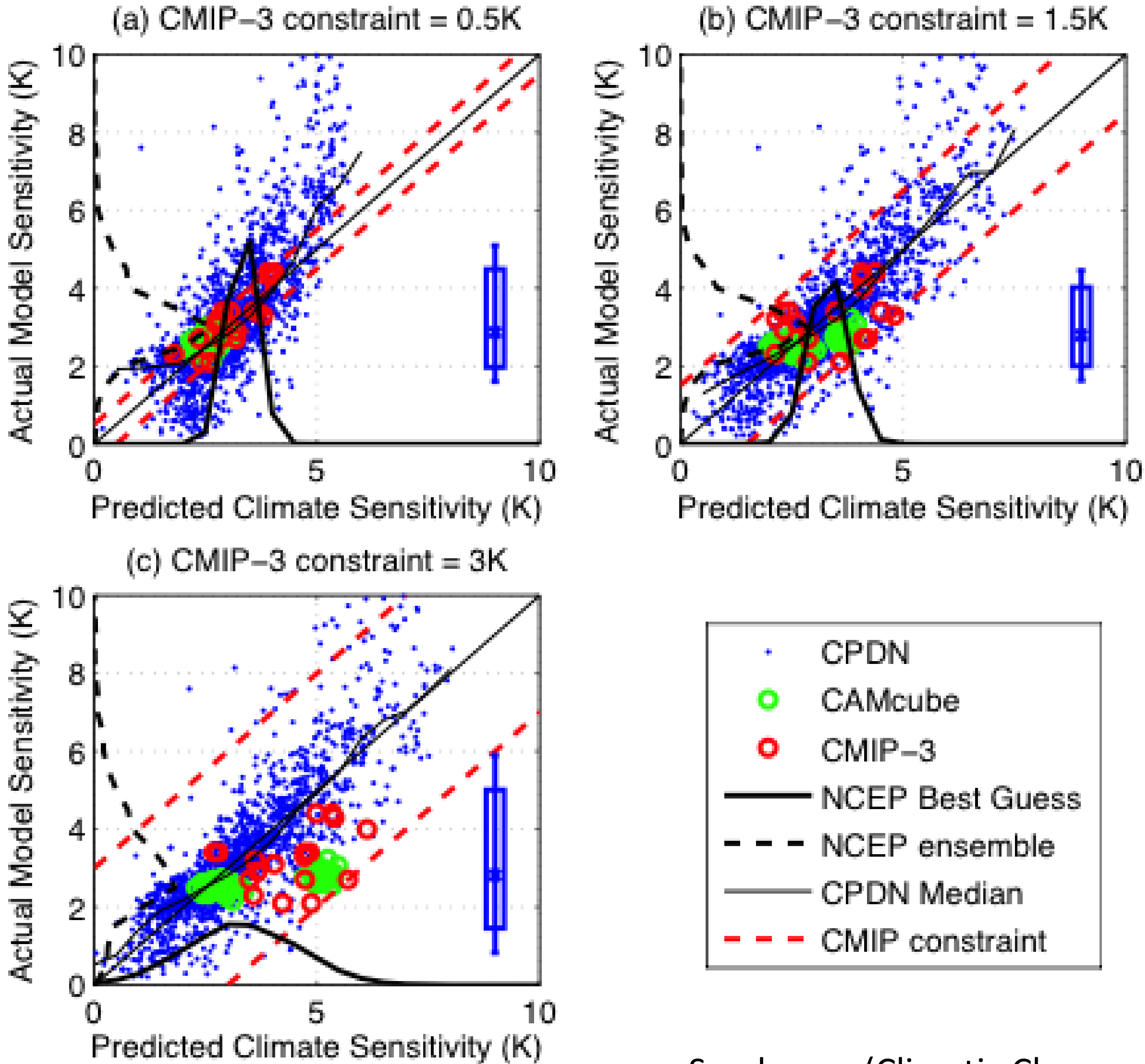


Knutti and Hegerl (2008)

The future is super-ensembles



Yokohata et al (2010)



Sanderson (Climatic Change, in press)

Conclusions

- PPEs – decide on a question first
- Remember your result is dependent on model structure
- PPEs are rarely ‘reliable’
- MMEs have smaller dimensionality than N
- An ensemble of best guesses is not a PDF
- A full uncertainty treatment must consider both parametric & systematic uncertainty