NCAR

NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

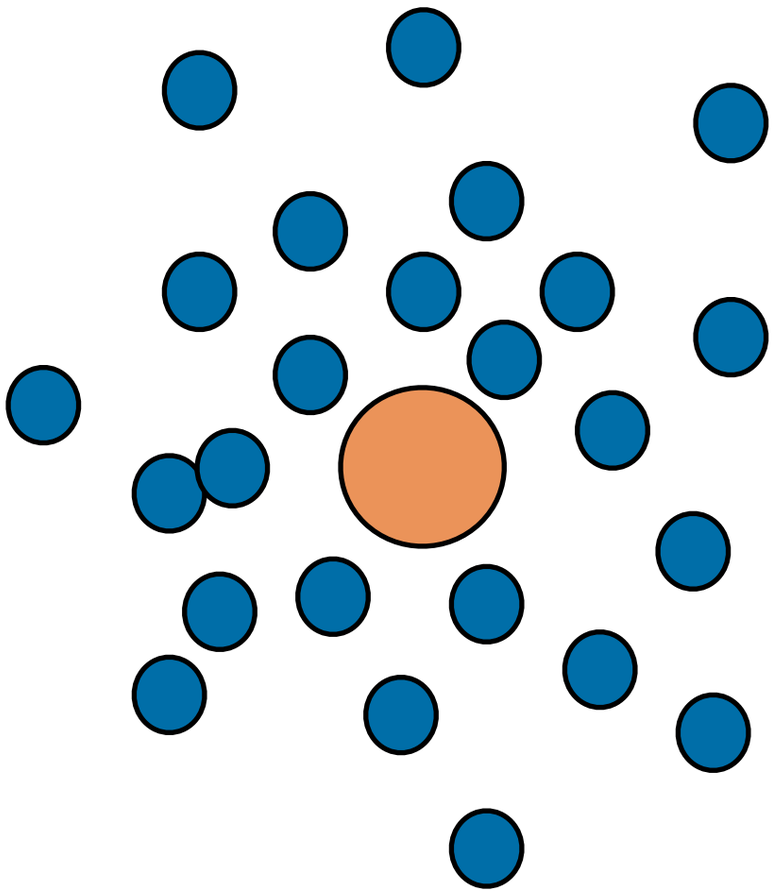
Interpretation of constrained climate model ensembles

Ben Sanderson

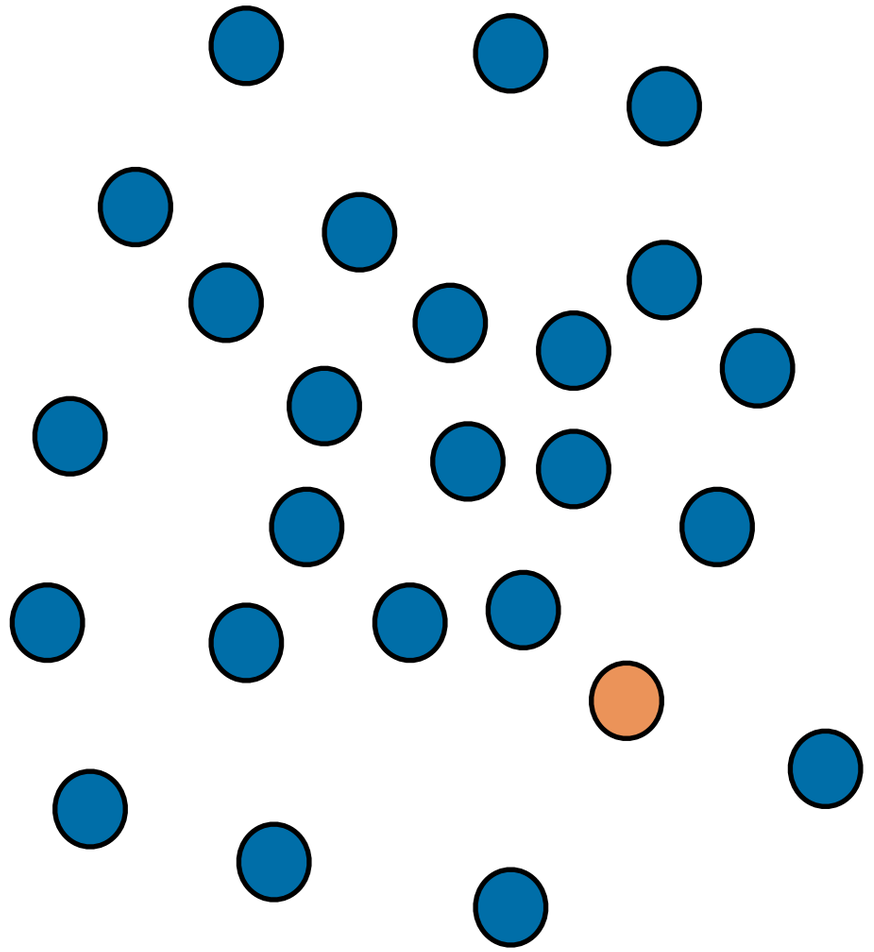
Outline

- A constrained ensemble - indistinguishable, truth plus error or both?
- CMIP mean result: why is it so good?
- Improving confidence in multi-model projections
- A weighting scheme accounting for inter-model similarities

truth + error



indistinguishable



Ensemble Interpretation

indistinguishable

unweighted

- Giorgi 2008
- Murphy et al. 2007
- Ruosteenoja et al. 2007
- Raisanen and Ruokolainen
- Dettinger 2006
- Raisanen and Palmer 2001

- Moise and Hudson 2008
- Palmer et al. 2008
- Min et al. 2007
- Laurent and Cai 2007
- Shukla et al. 2006
- Dessai et al. 2005

- Giorgi and Mearns 2002
- Pierce et al. 2009
- Perkins and Pitman 2009
- Watterson 2008
- Brekke et al. 2008

- Buser et al. 2009
- Smith et al. 2009
- Furrer et al. 2007
- Boulanger et al. 2007
- Greene et al. 2006

weighted

truth + error

cr. Claudia Tebaldi

indistinguishable

unweighted

- model distribution
- space-filling?

- unknown distribution
- weighted by obs
- possibly 0/1 weight

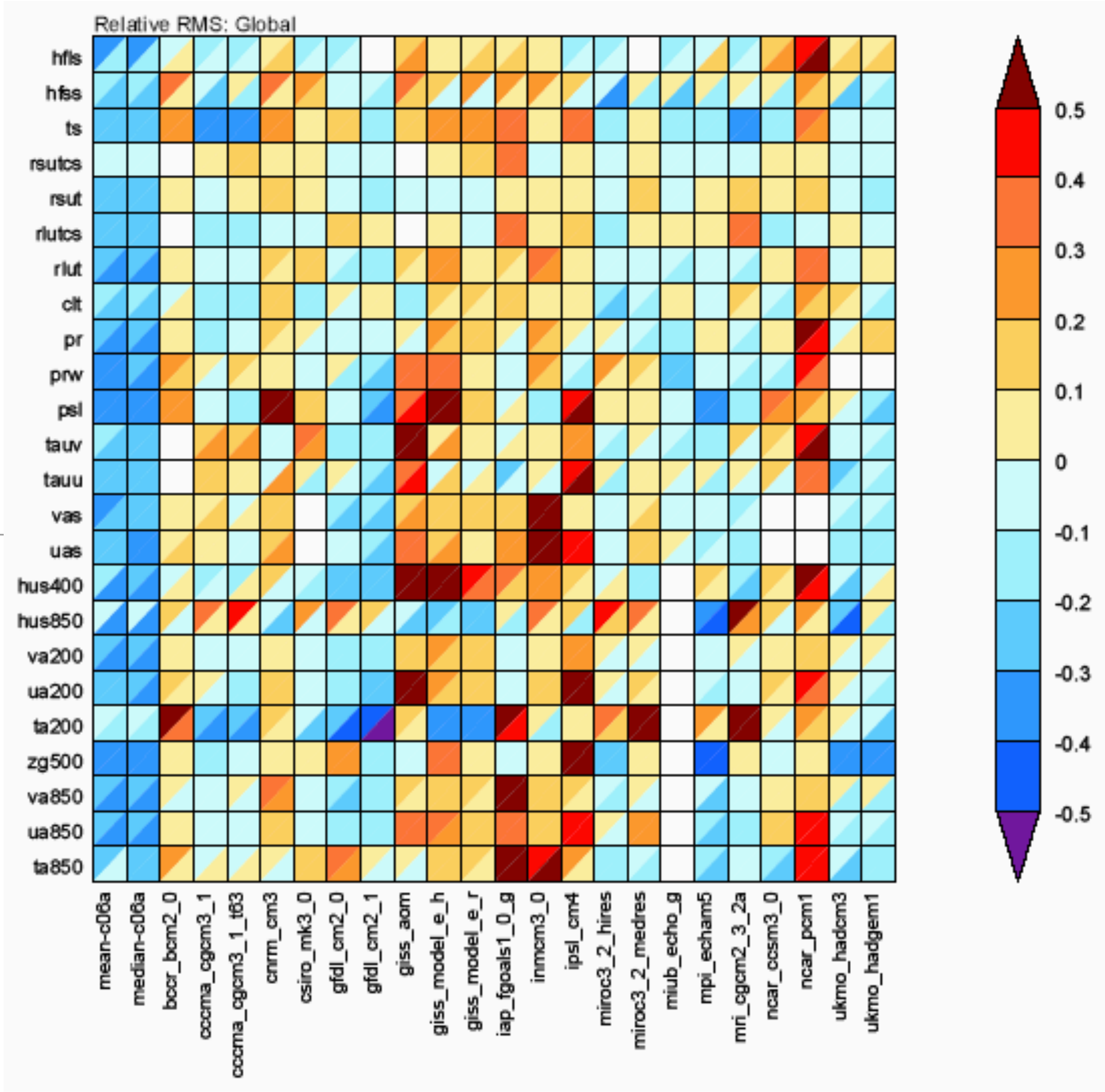
weighted

- unobserved truth
- constrained by obs
- decreasing uncertainty

truth + error

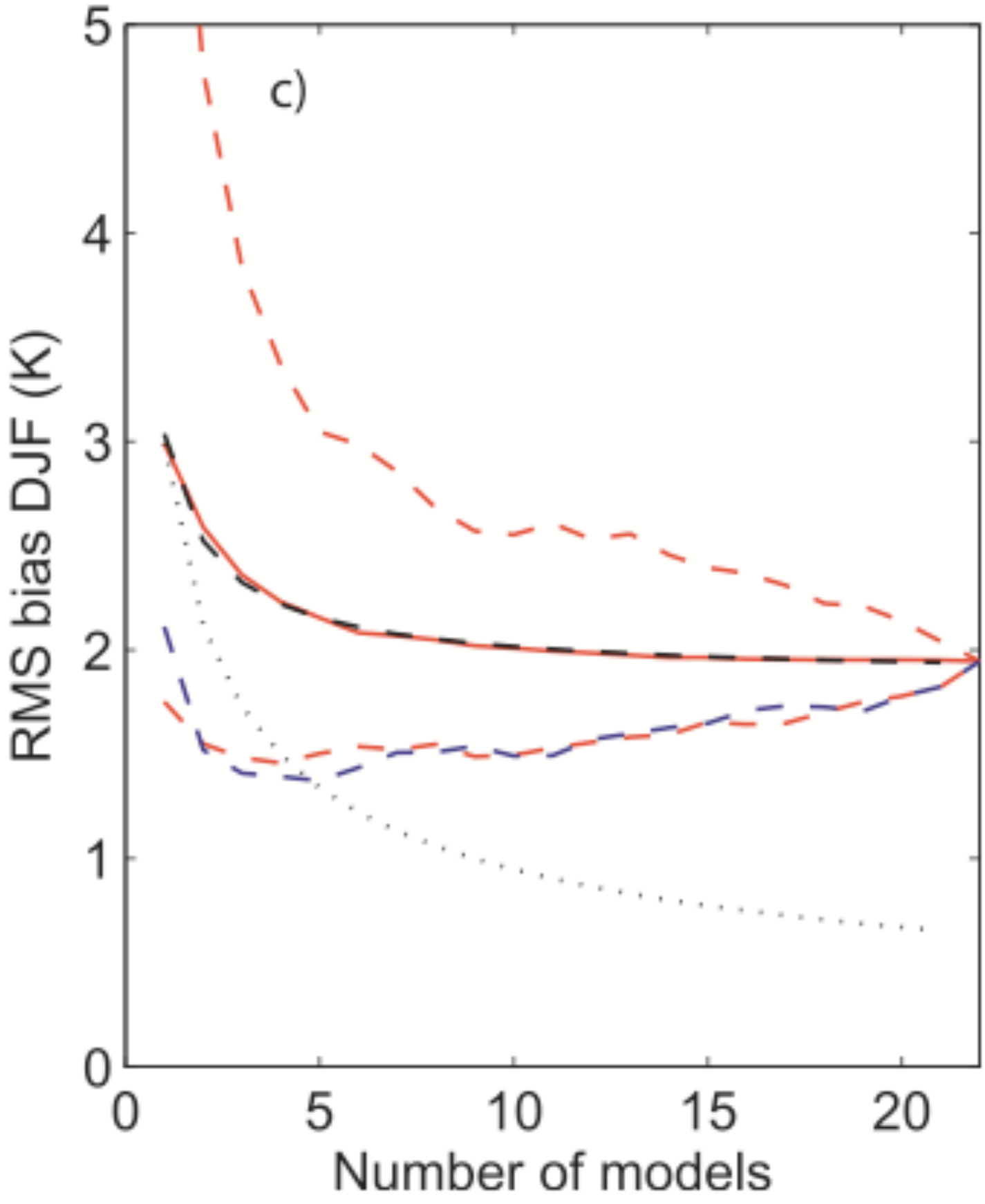
Performance Metrics

Gleckler, P., *et al*,
J. Geophys. Res (2008)



Error of the mean

Knutti et al (2009)

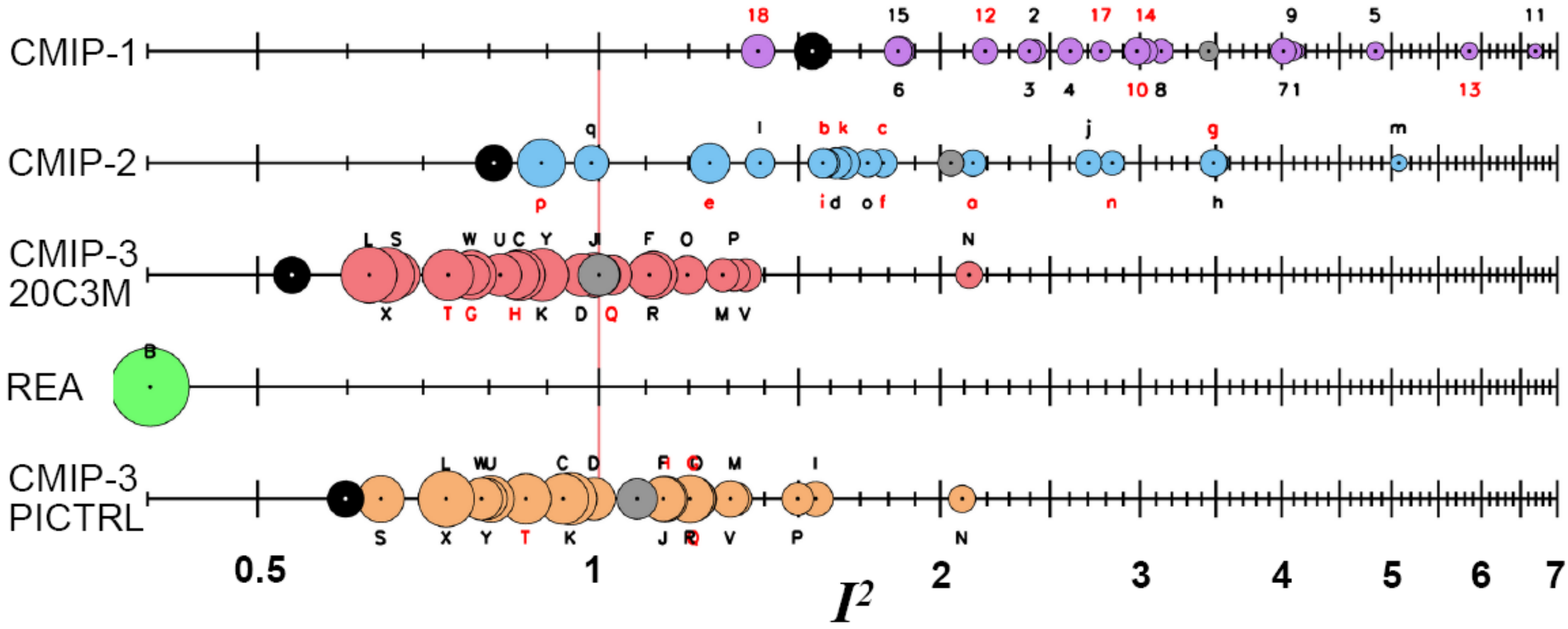


$$\frac{1}{n}\sum \|m_i - O\|^2 = \frac{1}{n}\sum \|m_i - M\|^2 + \|O - M\|^2$$

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

Indistinguishable Mean

Annan *et al.* (2010)



The mean result

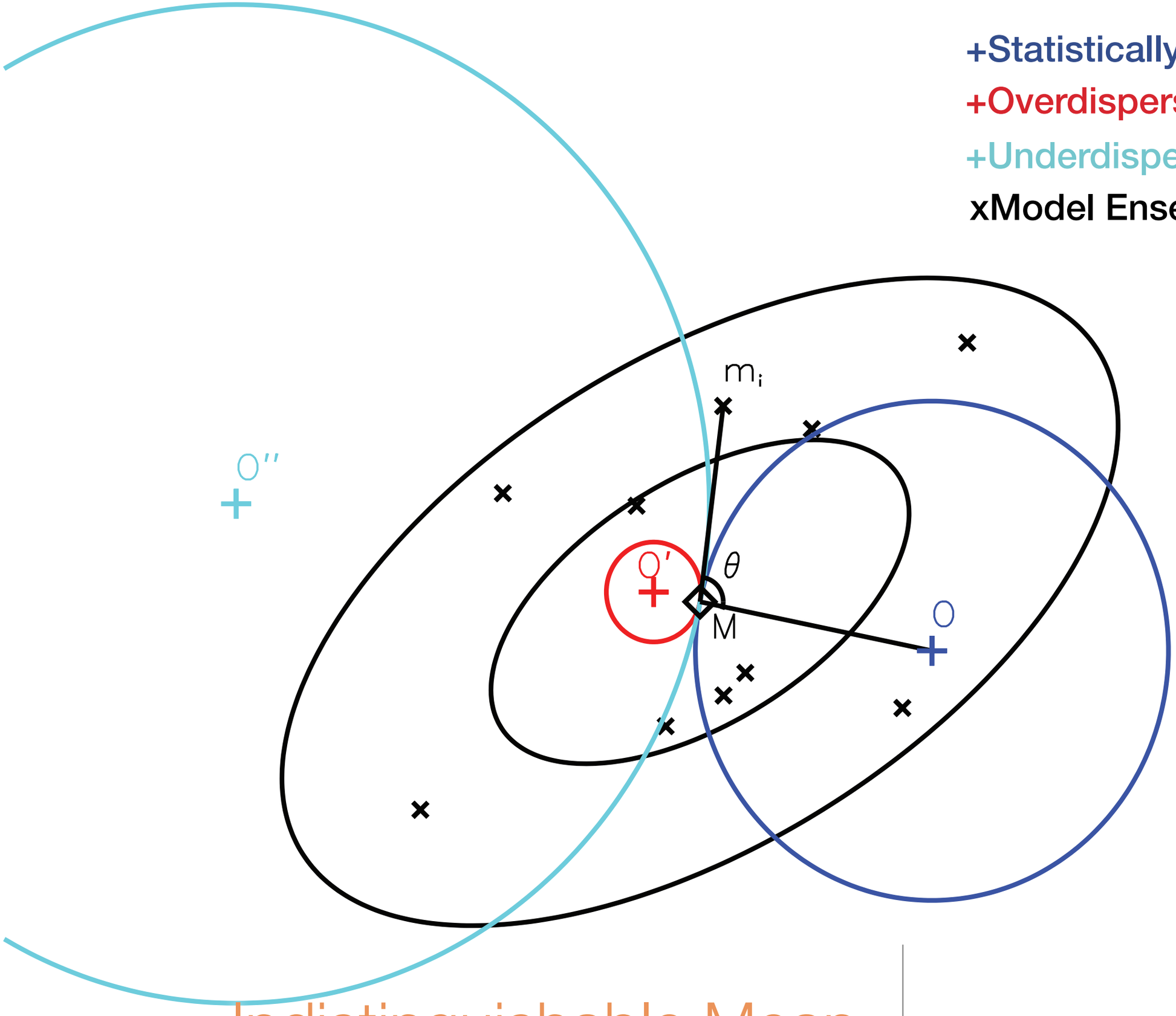
Reichler and Kim (2008)

+Statistically Indistinguishable

+Overdispersive

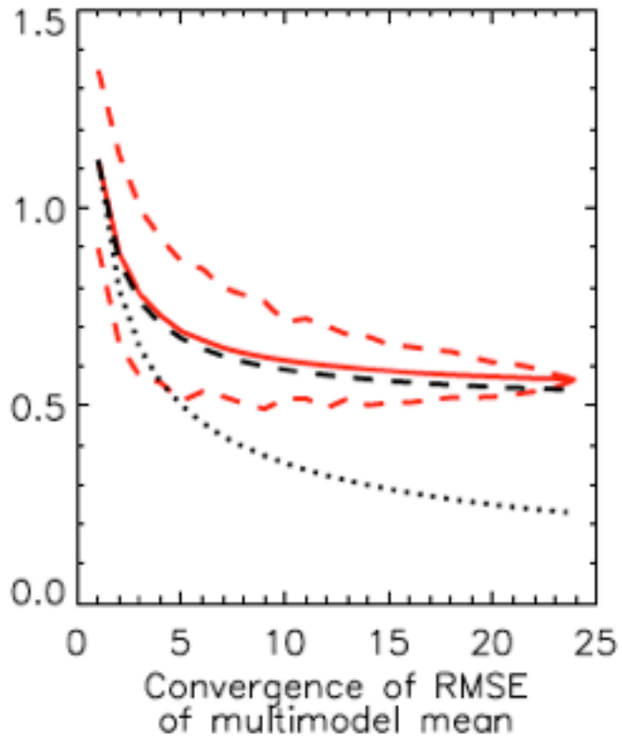
+Underdispersive

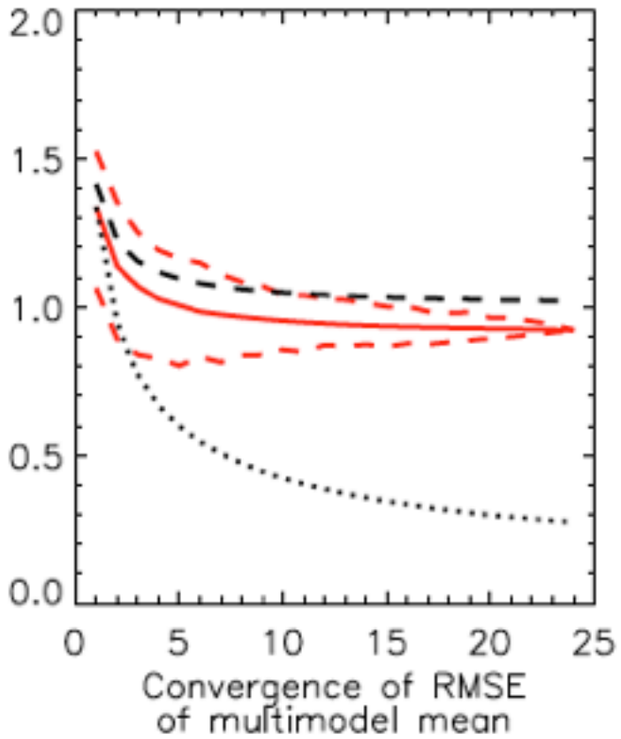
xModel Ensemble

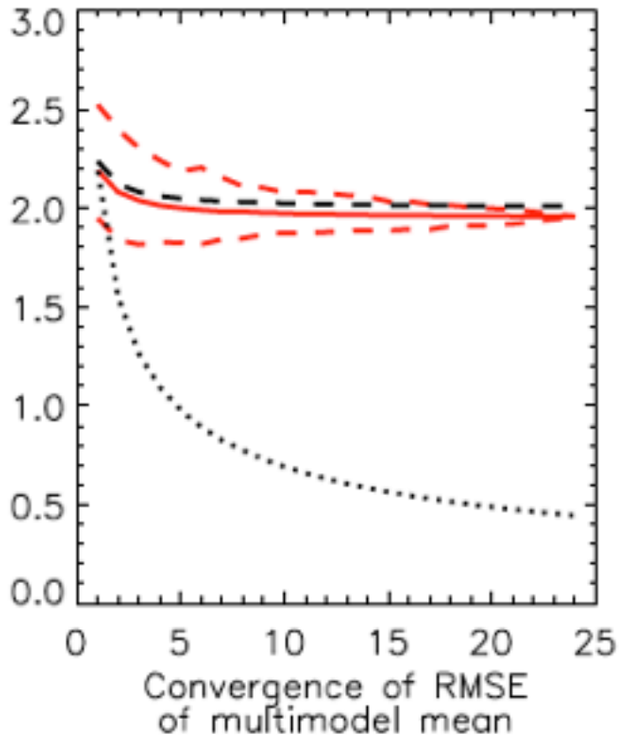


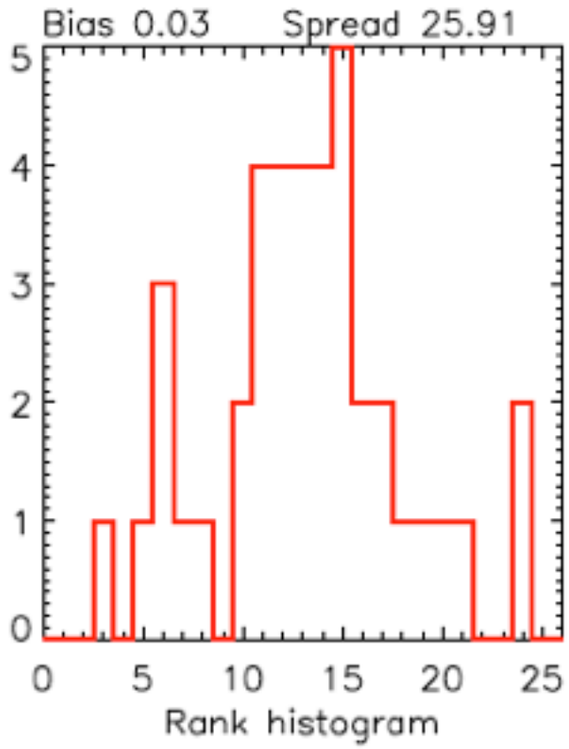
Indistinguishable Mean

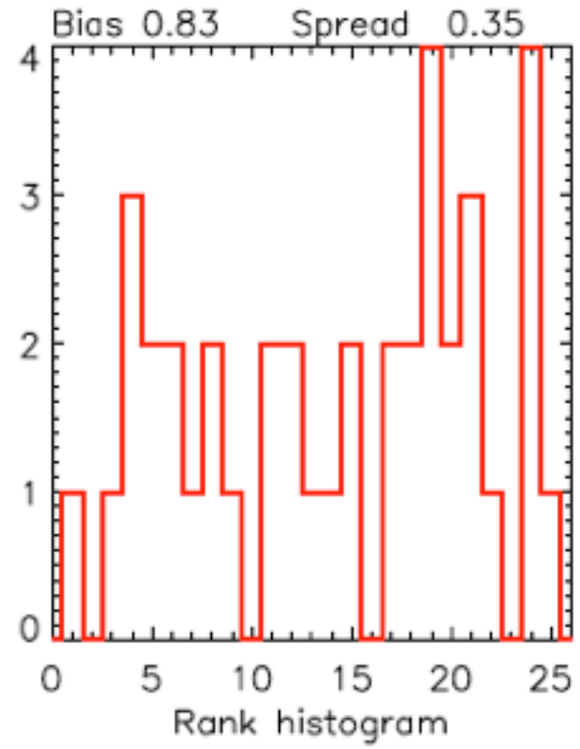
Annan and Hargreaves (2011)

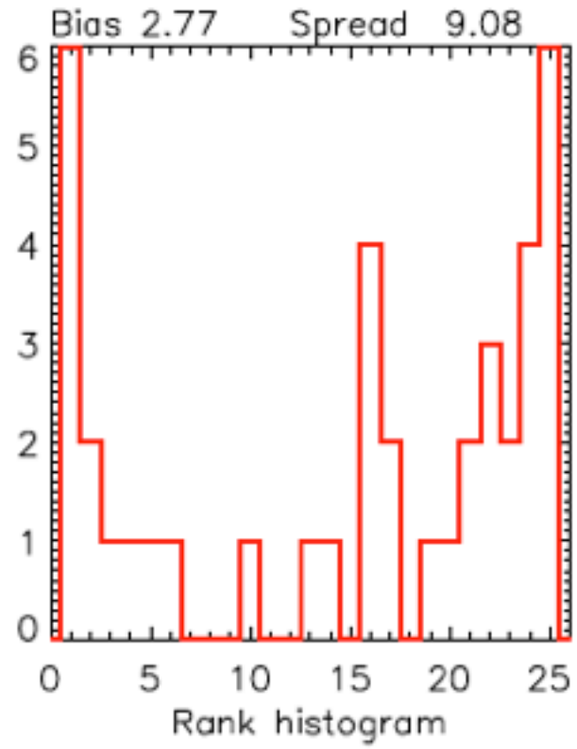






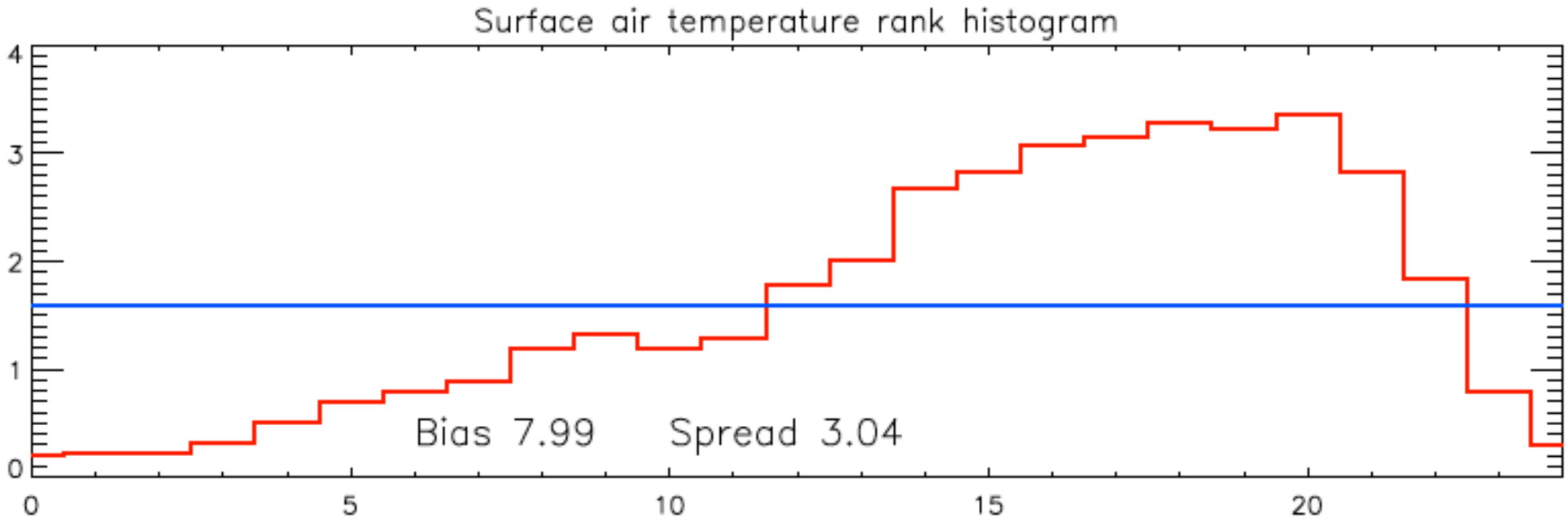






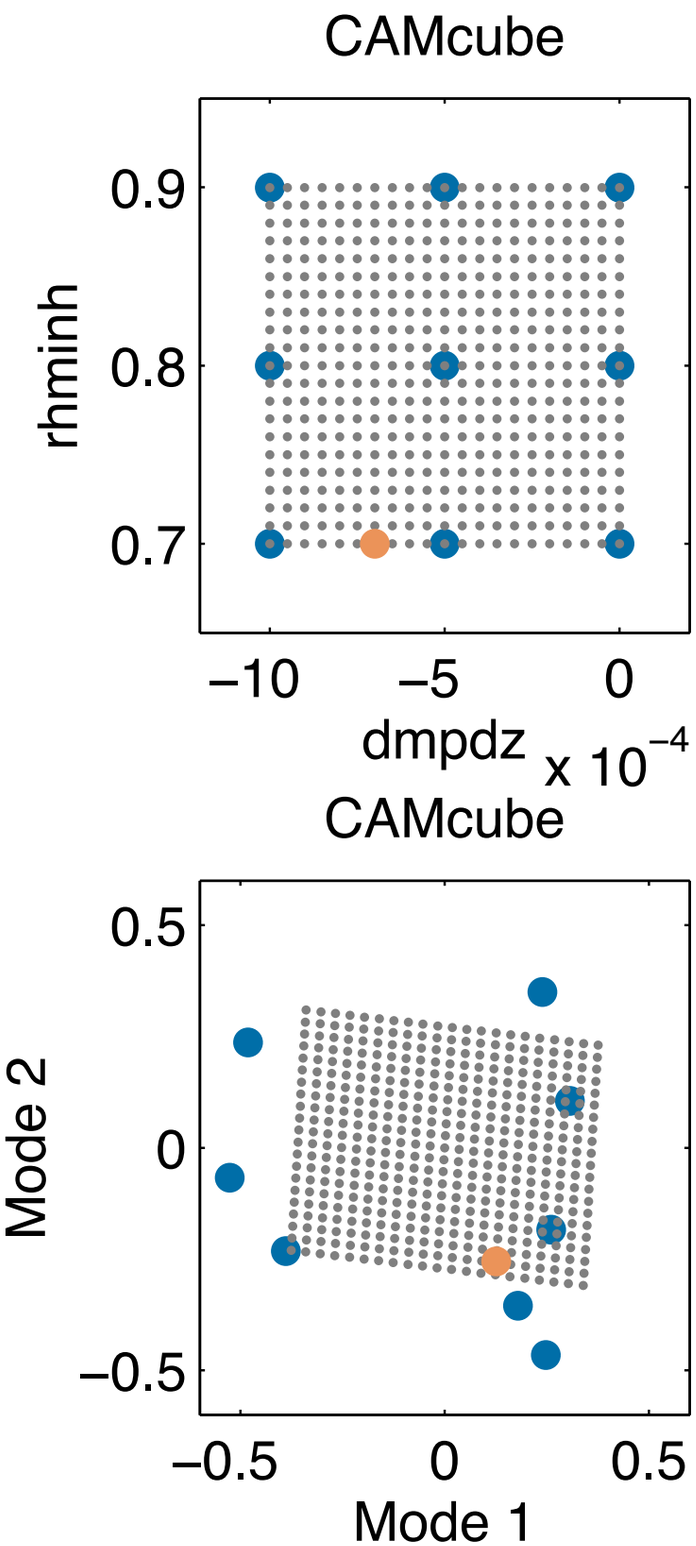
Indistinguishable Mean

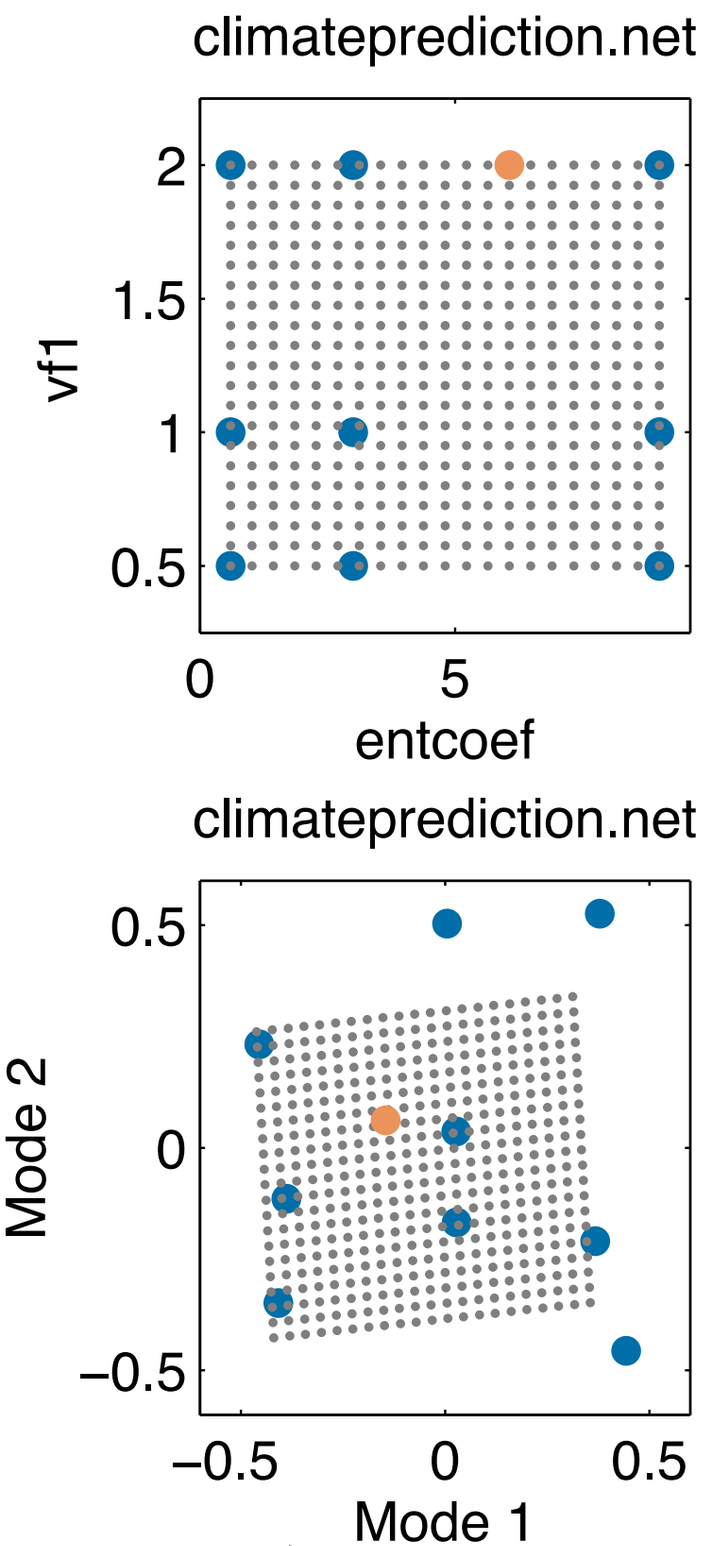
Annan and Hargreaves (2010)



Indistinguishable Mean

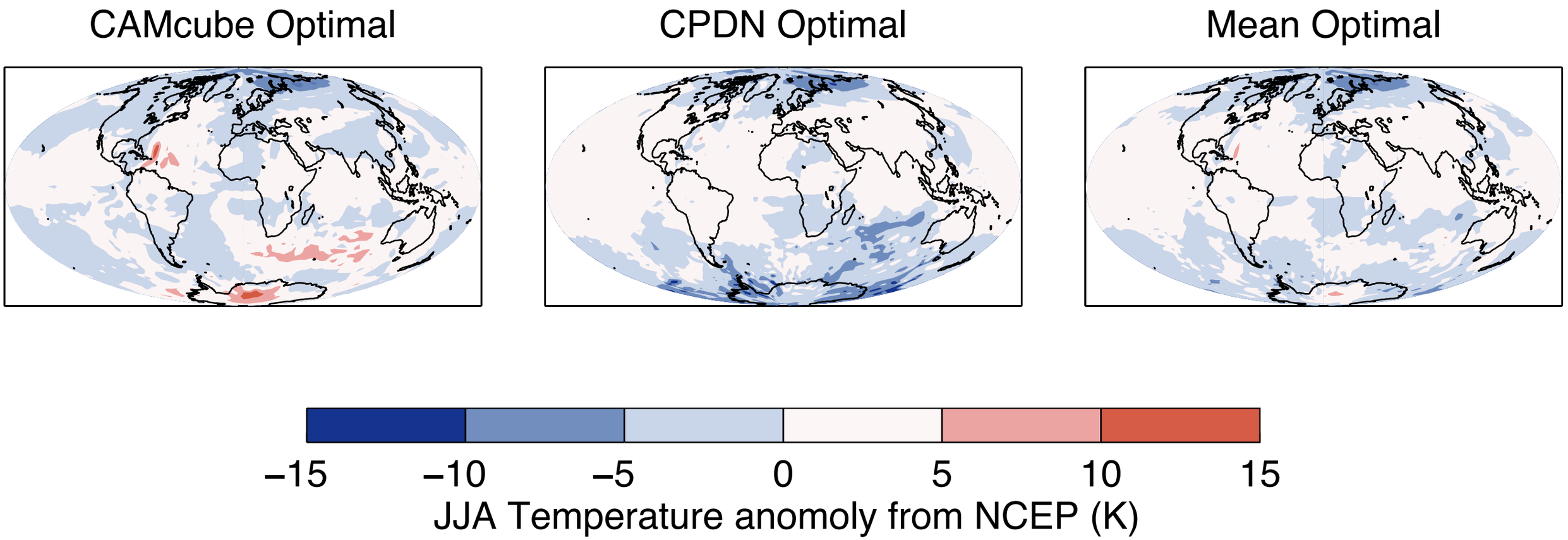
Annan and Hargreaves (2010)





Truth + error by design

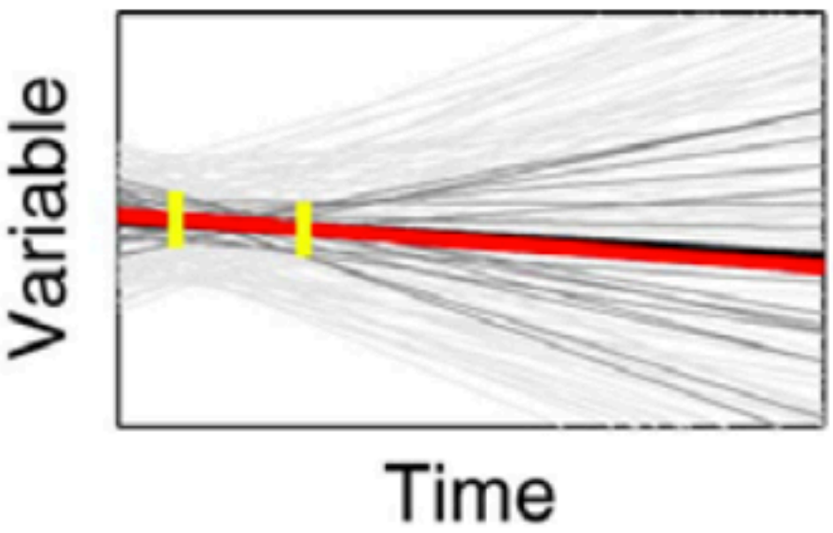
Sanderson & Knutti (in prep)

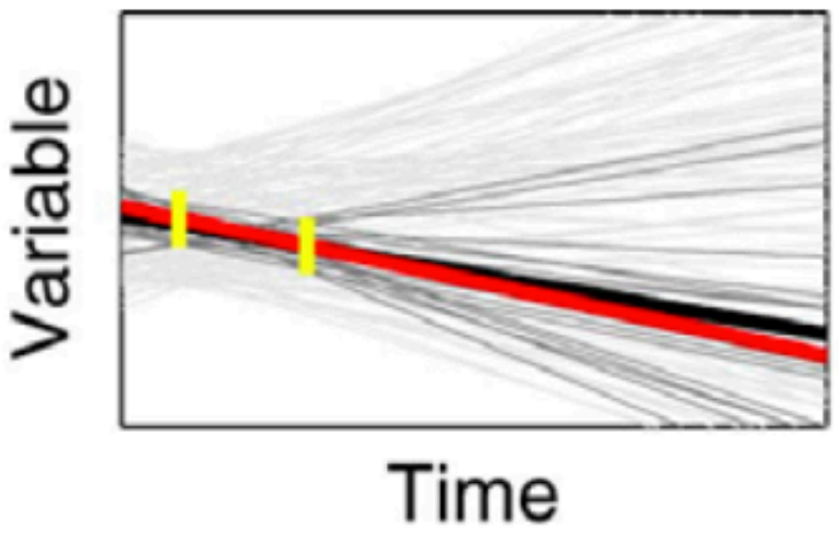


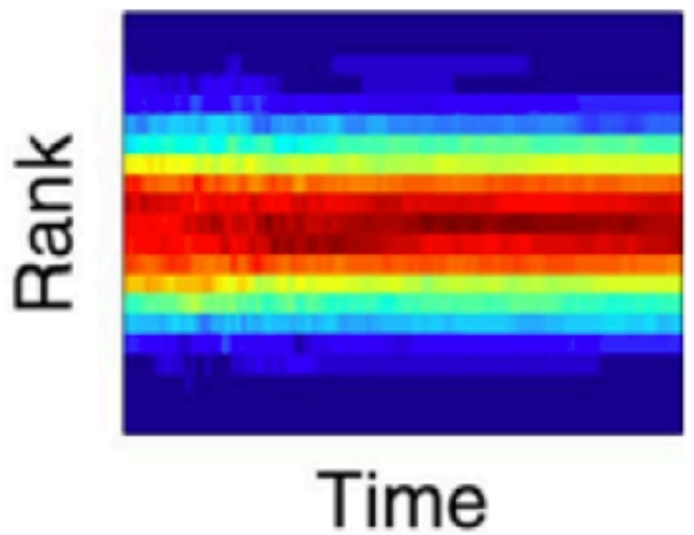
Recipe for a perfect T+E ensemble for the present:

- independent irreducible errors
- sufficiently large ensemble
- perfect calibration

Truth + error by design | Sanderson & Knutti (in prep)

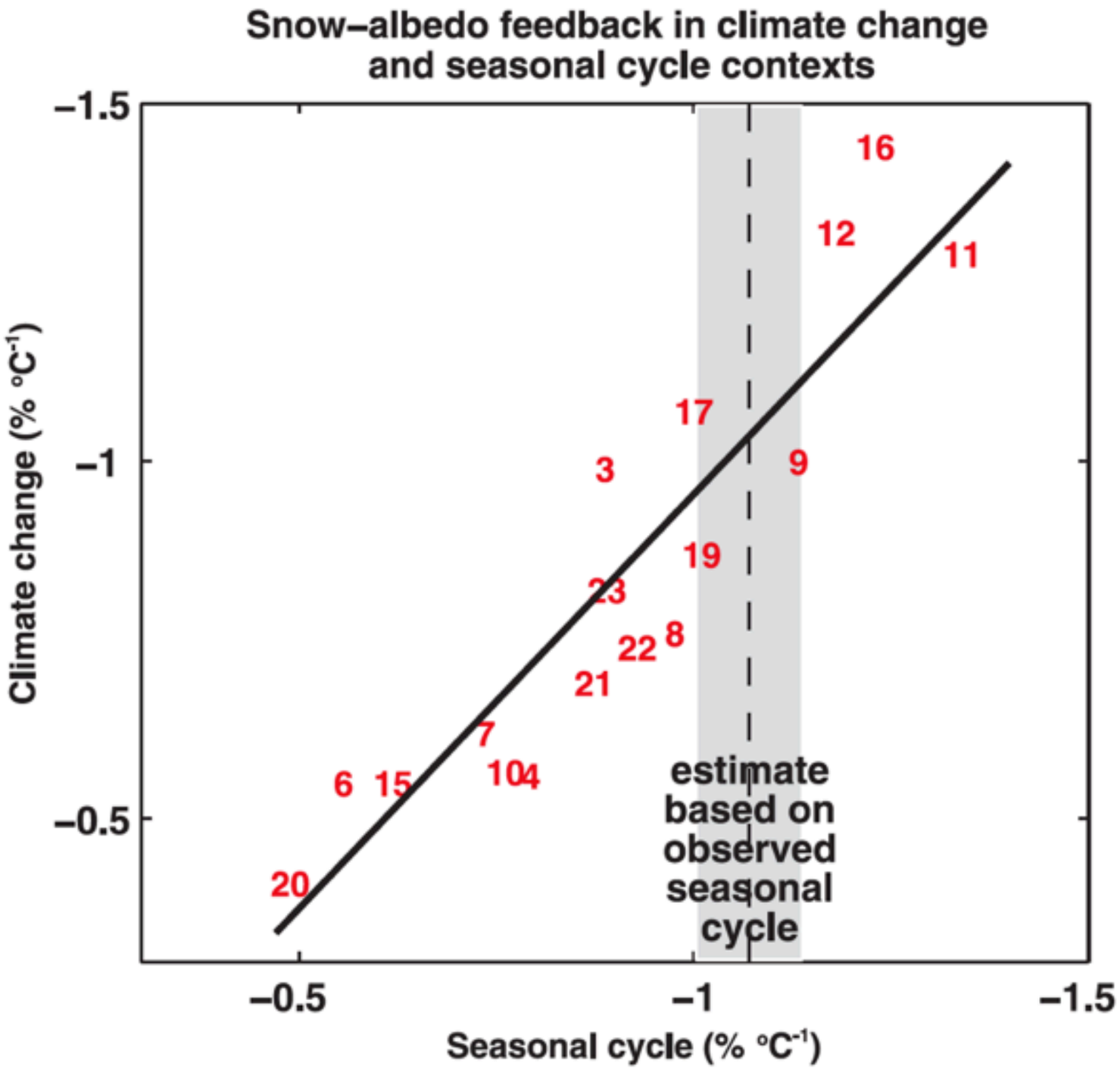




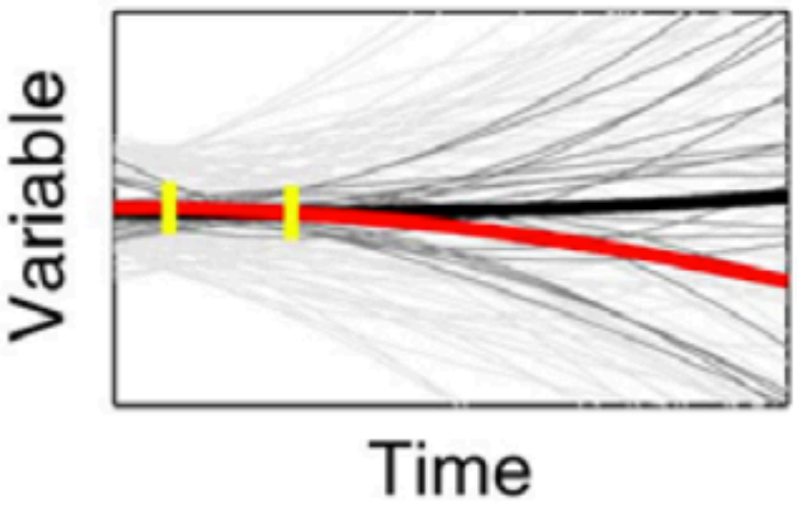


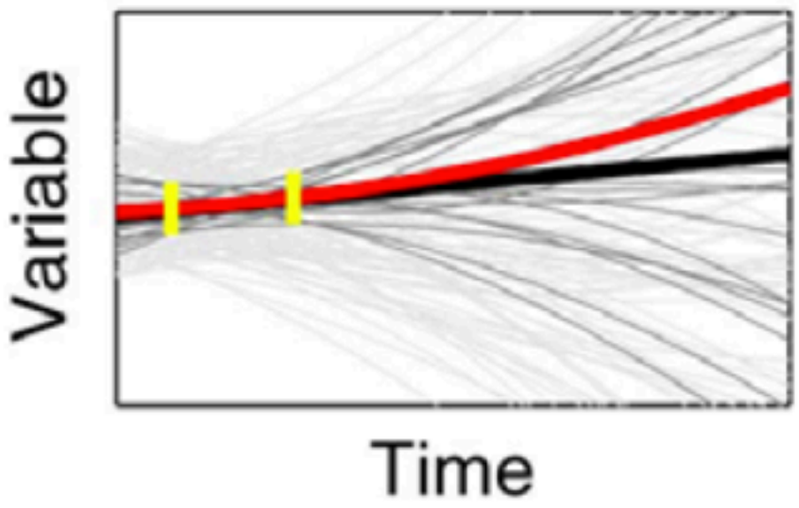
Case 1: A predictable system

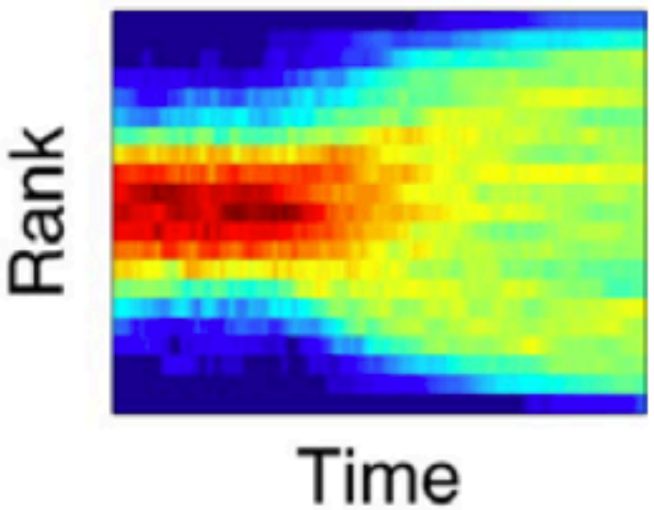
Knutti & Sanderson (submitted)



A predictable system | Qu and Hall (2007)

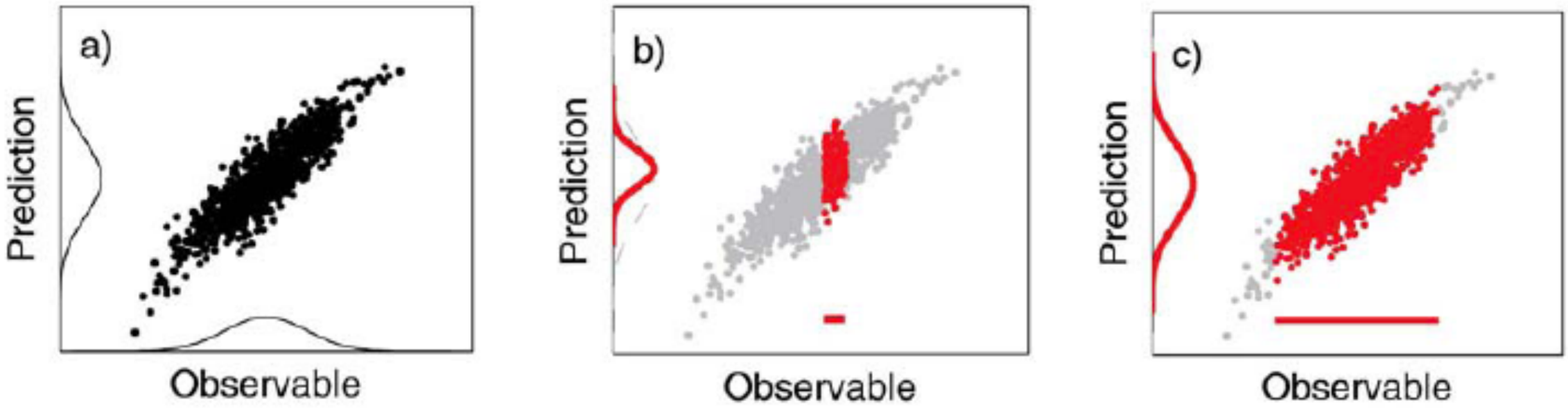






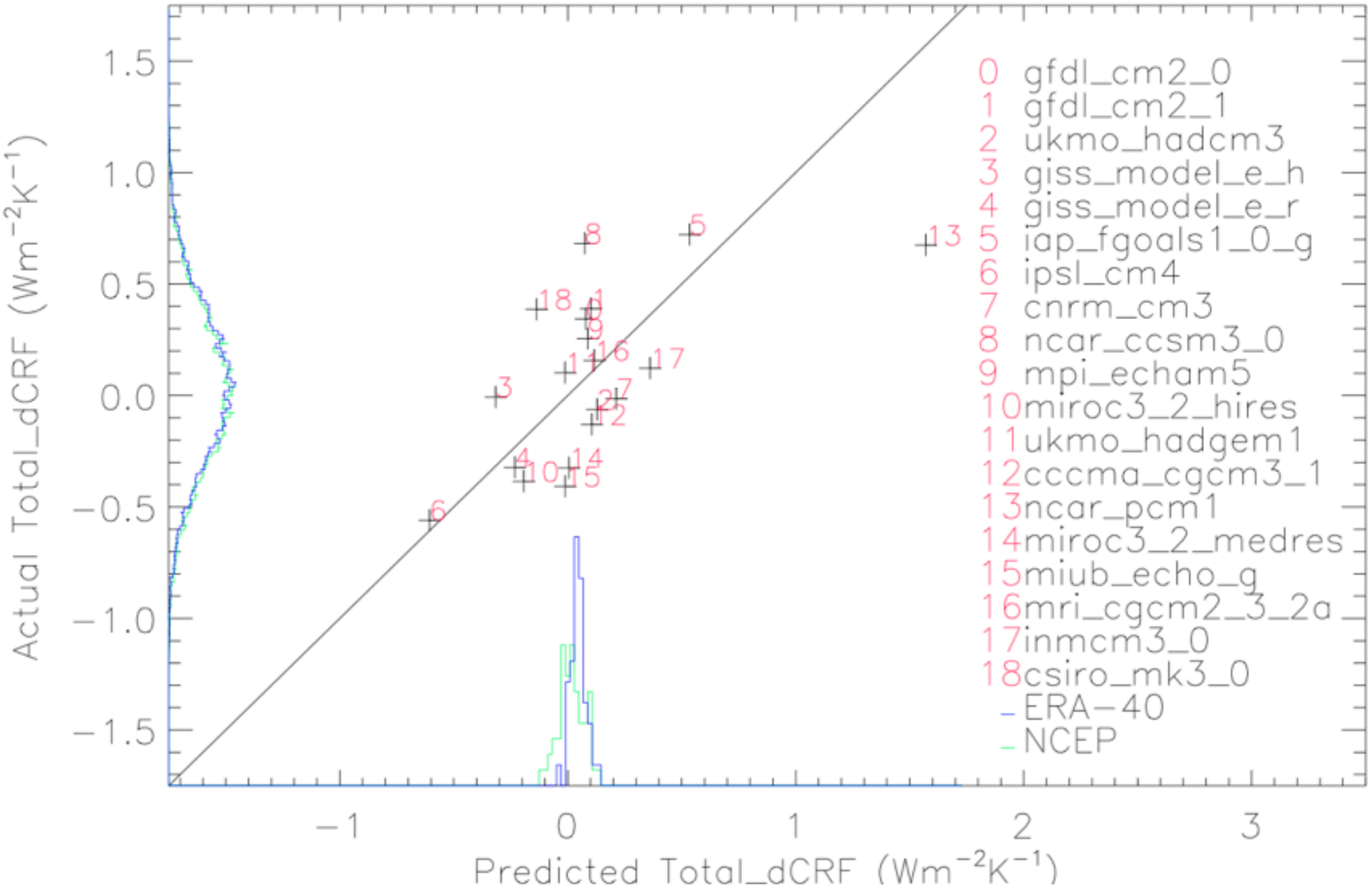
Case II: unconstrained

Knutti & Sanderson (submitted)



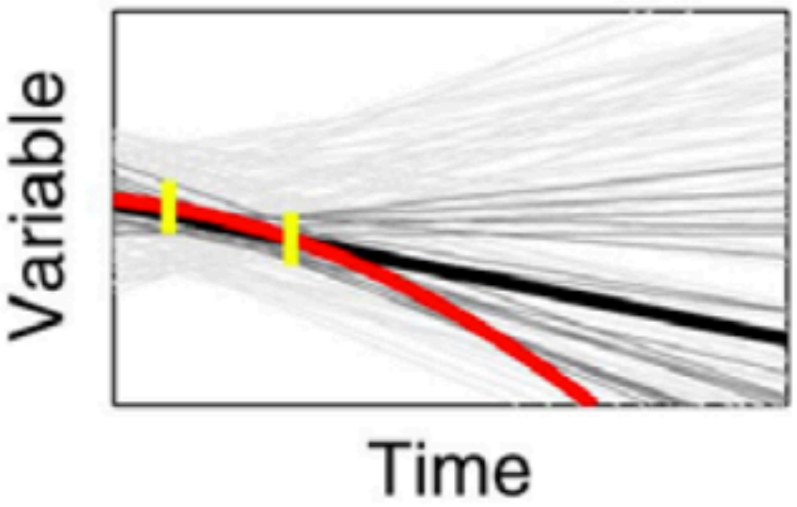
Observable Constraints

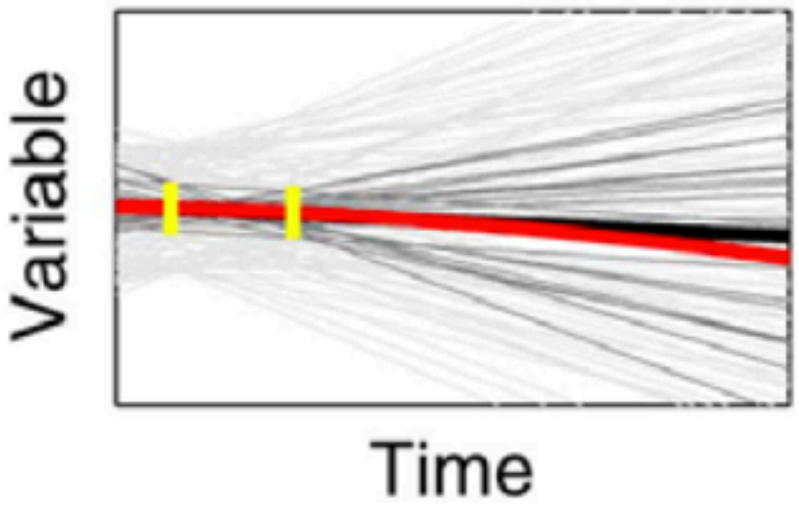
Knutti & Sanderson (submitted)

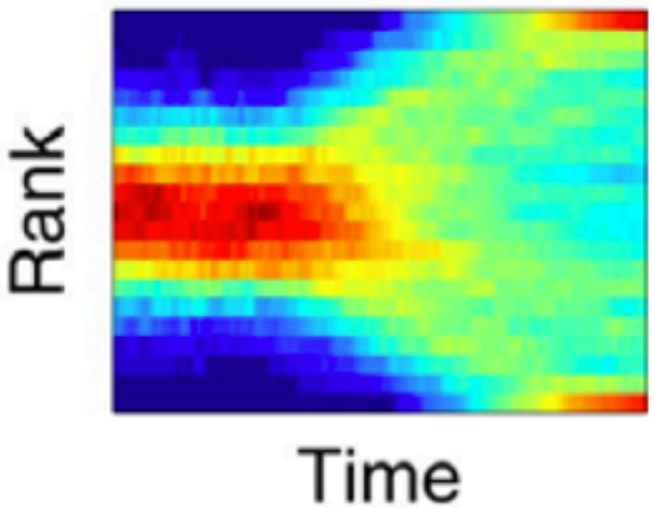


A (less) predictable system

Sanderson (in prep)

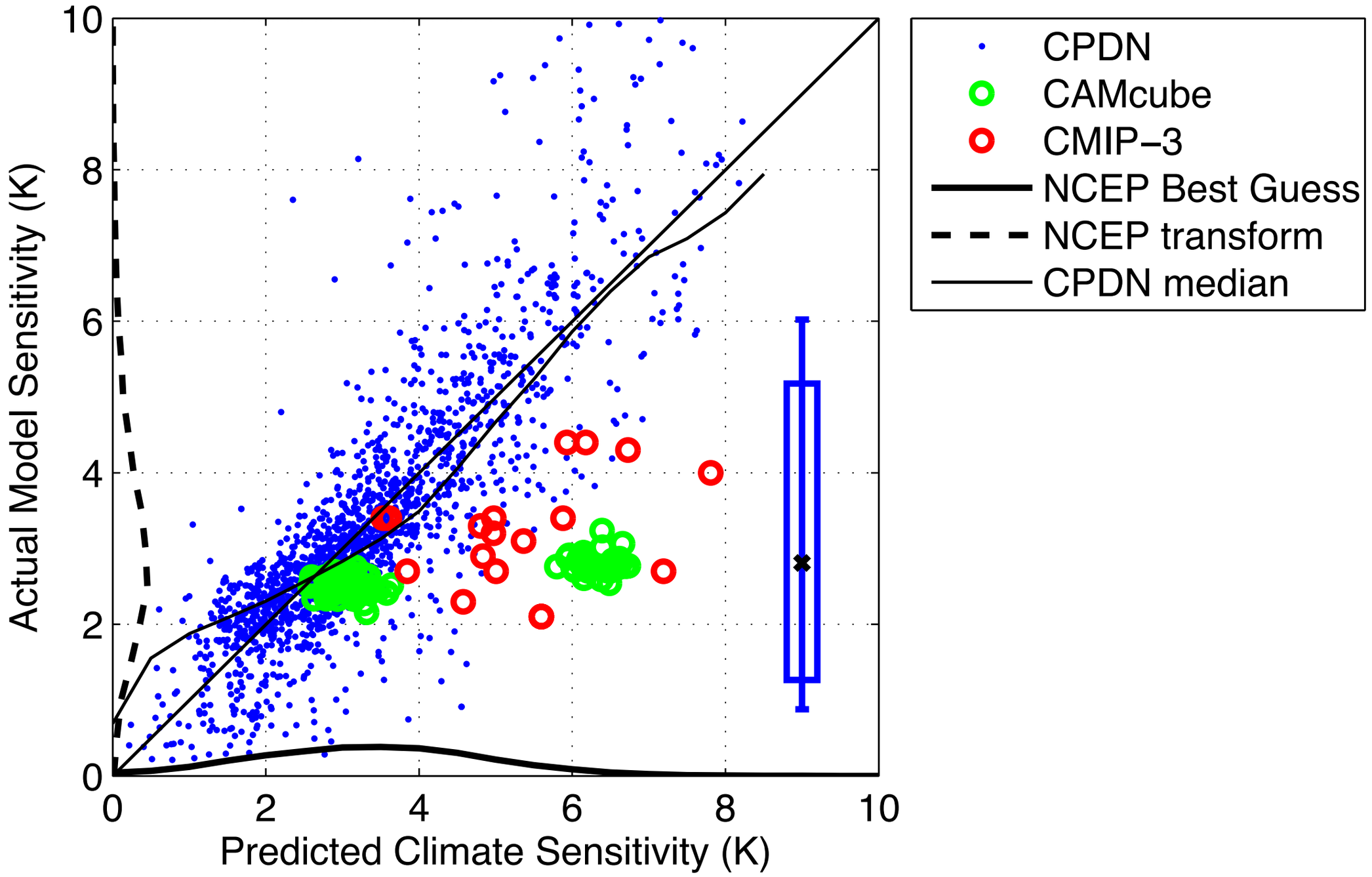






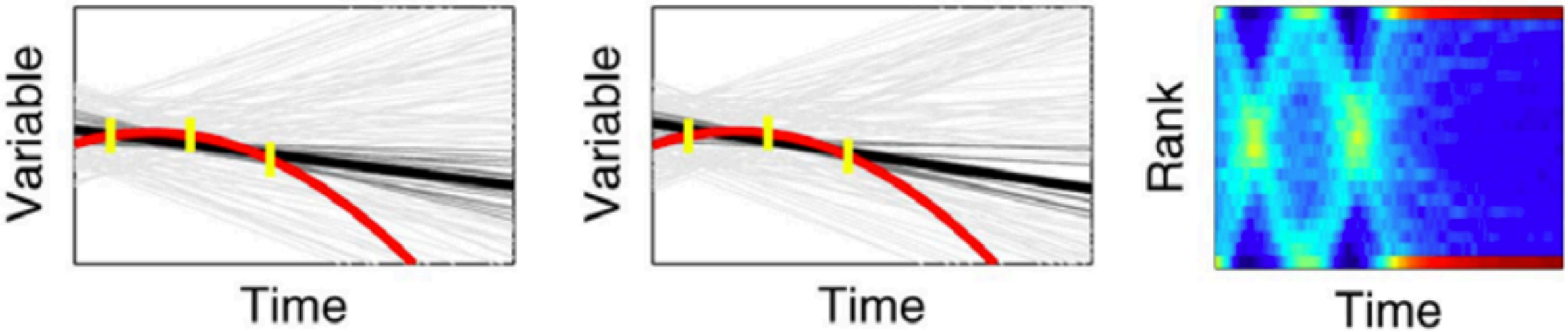
Case III: structurally wrong

Knutti & Sanderson (submitted)



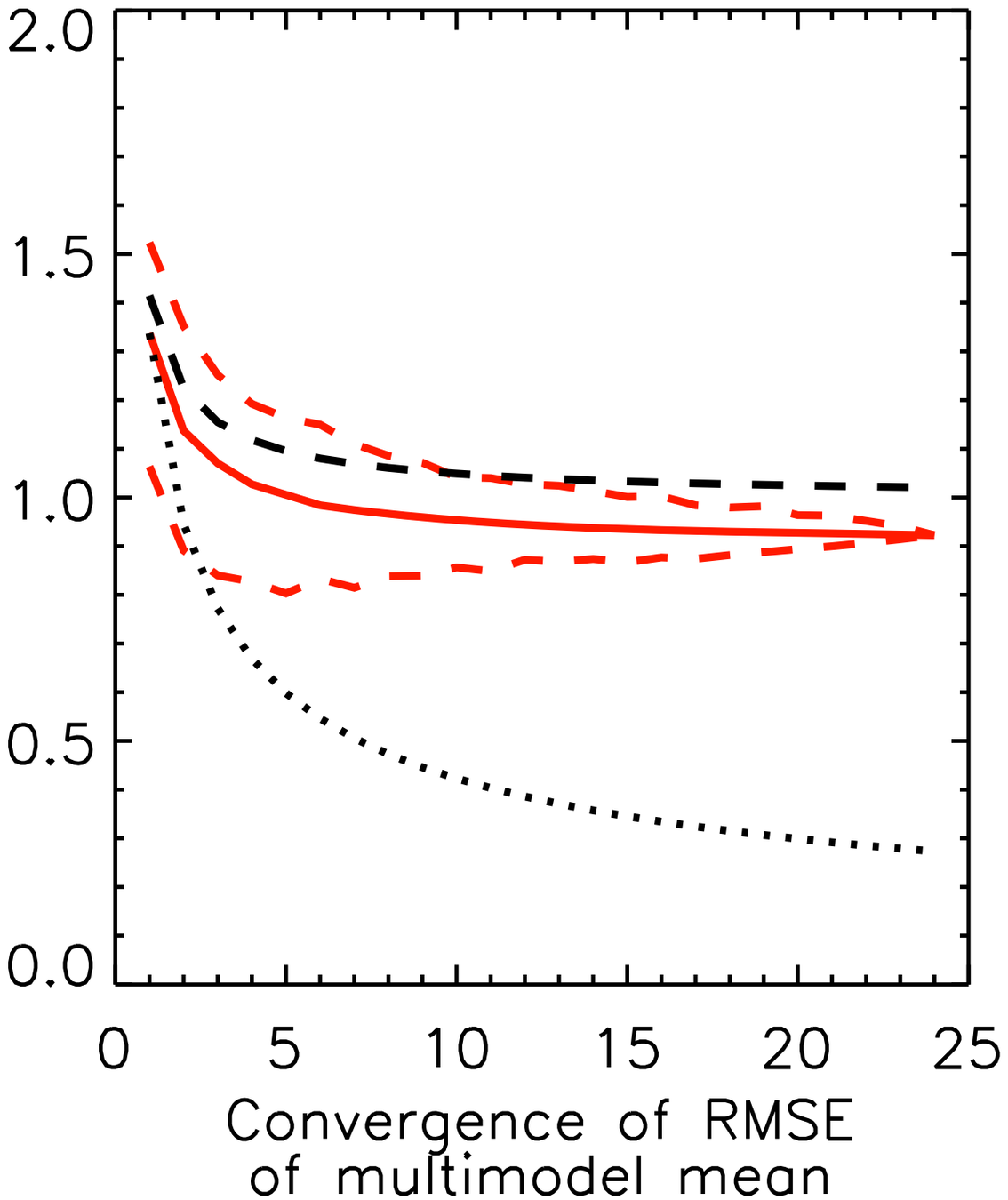
Systematic prediction errors

Sanderson (submitted)



Case IV: impossible constraint

Knutti & Sanderson (submitted)



"Common structural error may be difficult to separate from inter-model differences"

Indistinguishable Mean

Knutti and Sanderson (submitted)

Present

Truth+Error
by design
(with caveats)

-common systematic errors
-imperfect tuning
-small sample

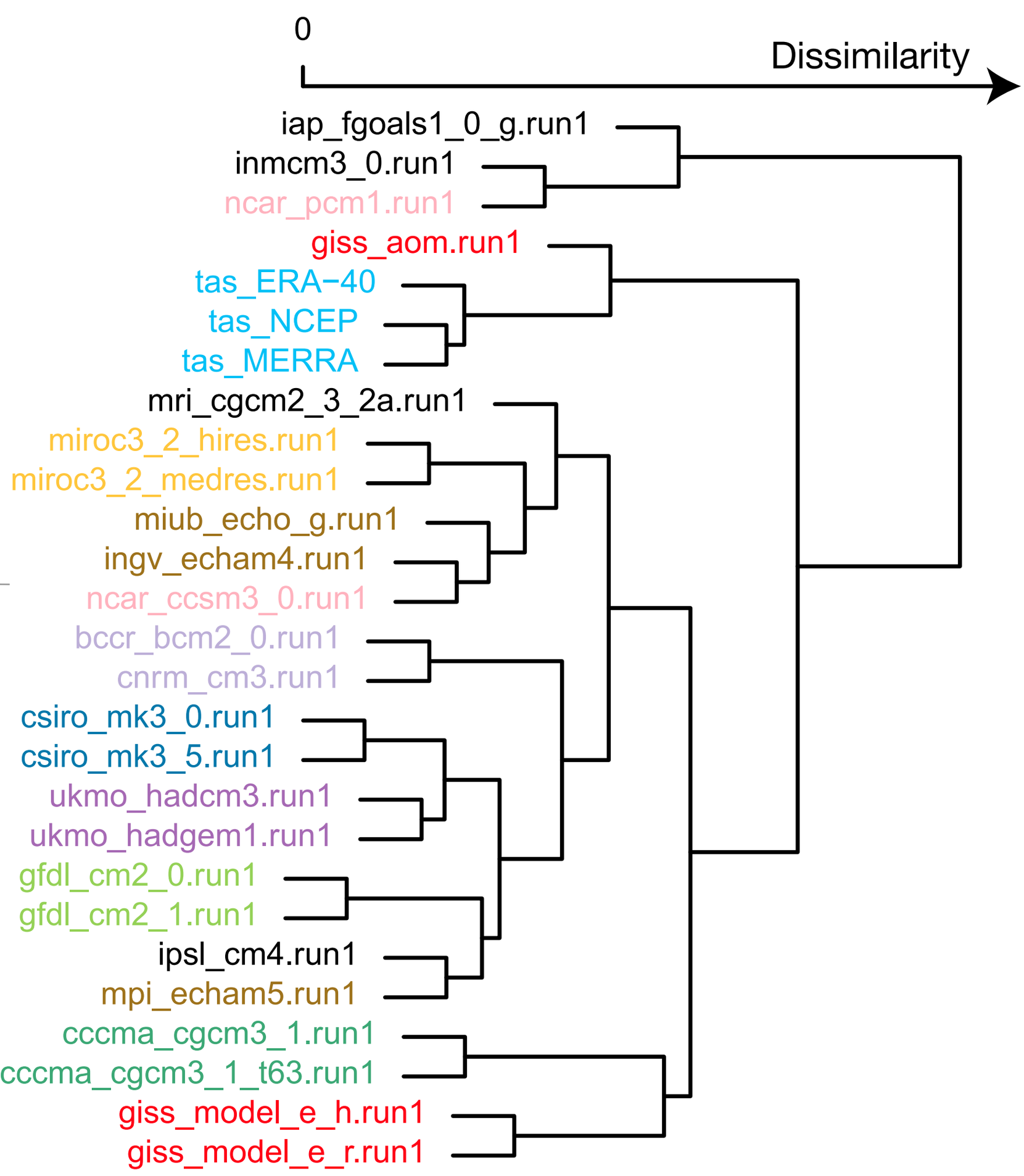
Future

Indistinguishable
(with caveats)

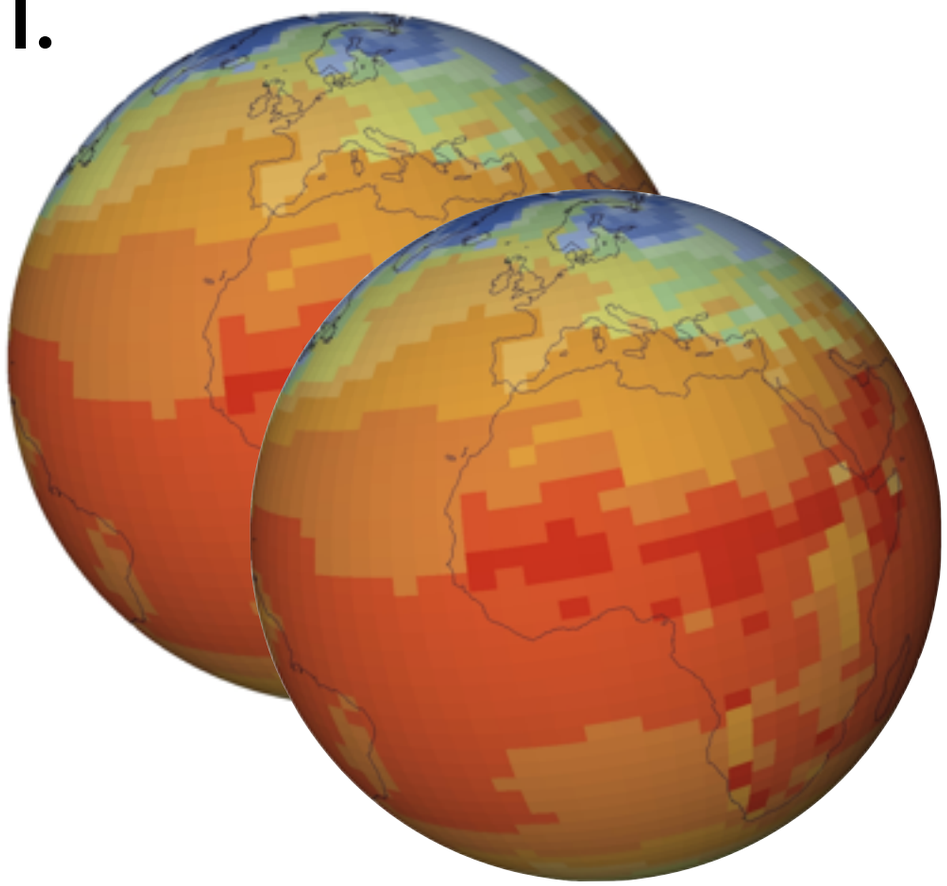
-model interdependency
-feedback constraints
-missing processes

Model Similarity

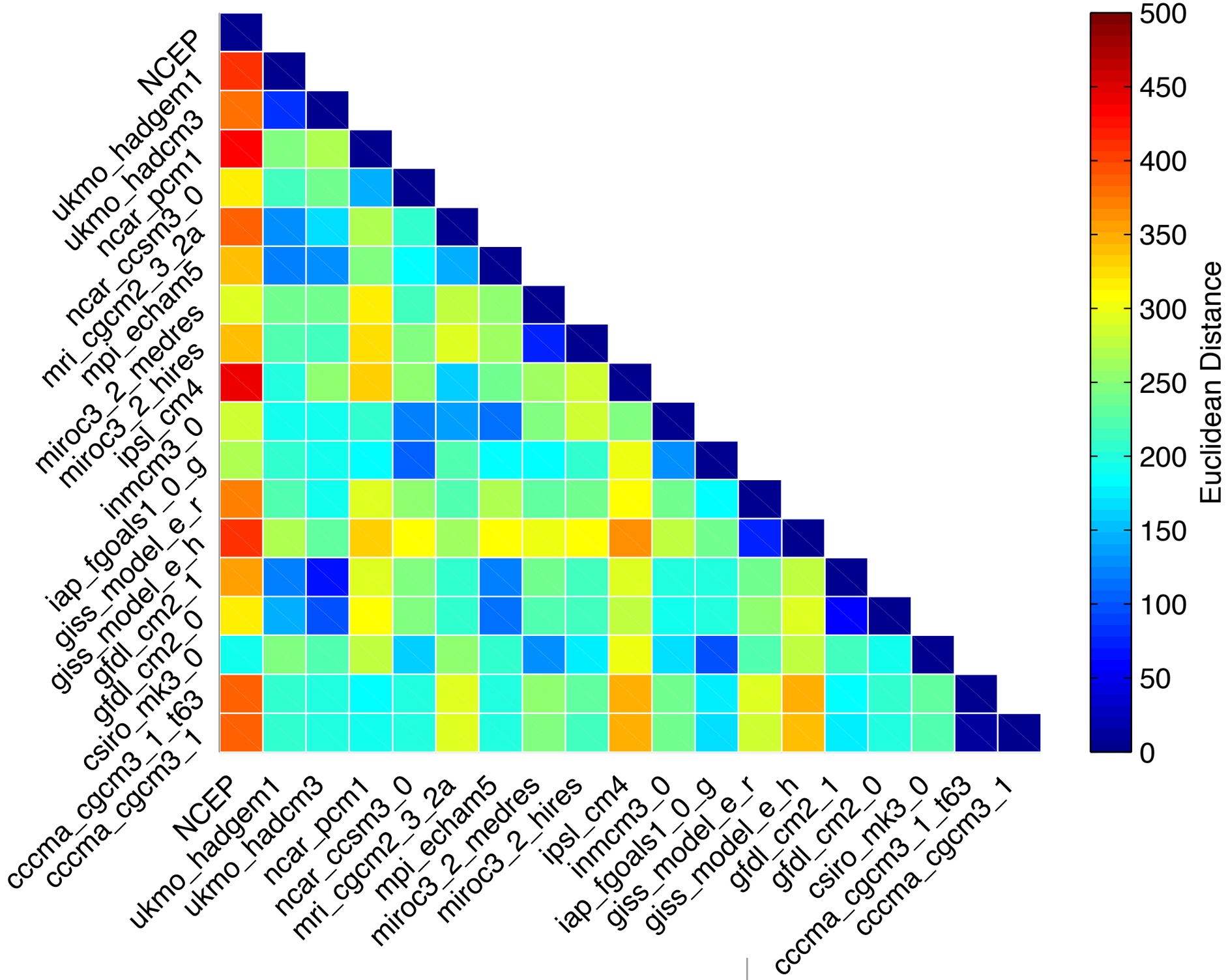
Masson *et al* (2011)



I.



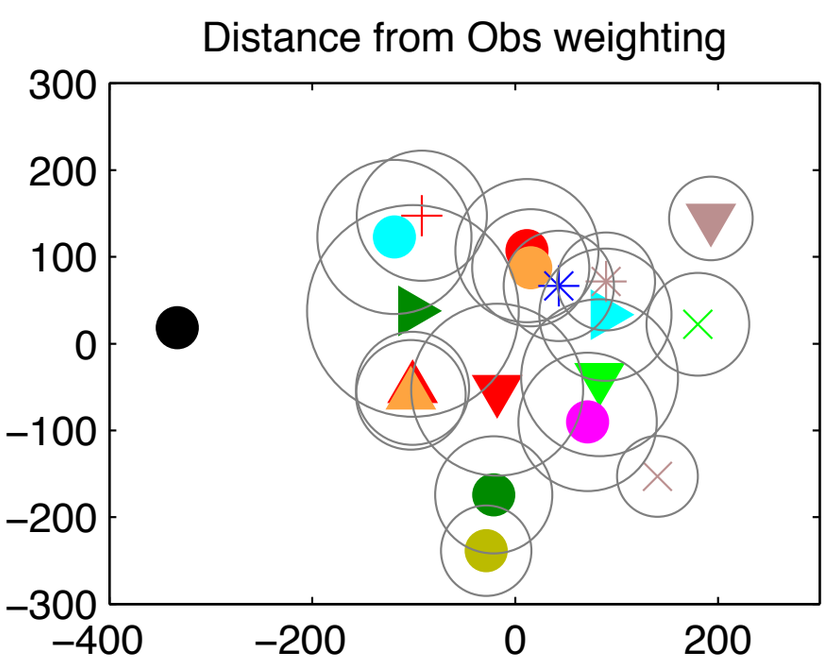
II.

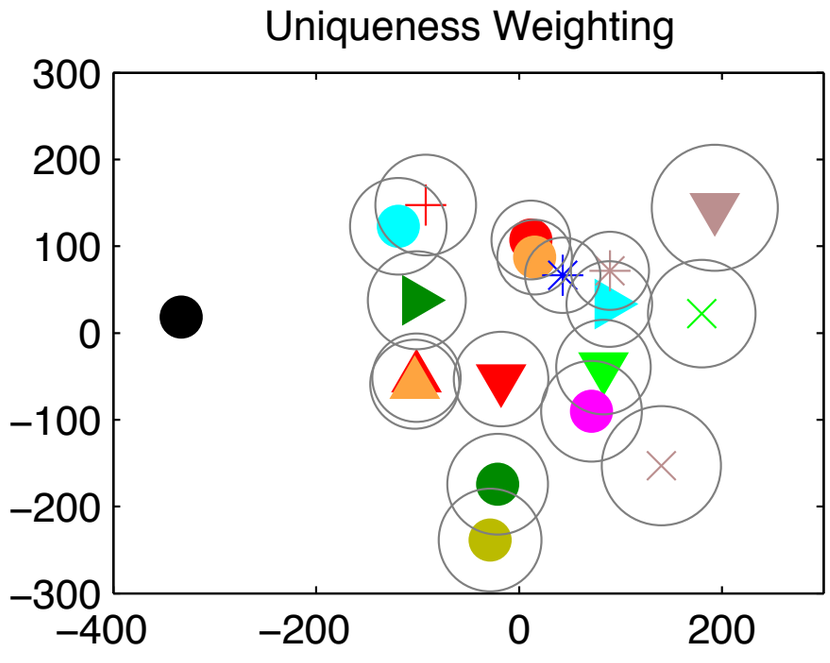


Inter-model Distances

Sanderson & Knutti (in prep.)

CCSM3
GFDL-CM2.0
GFDL-CM2.1
GISS-EH
GISS-ER
MIROC3.2(medres)
MIROC3.2(hires)
MIUB-ECHO/G
MRI-CGCM2.3.2
PCM
UKMO-HadCM3
UKMO-HadGEM1
BCCR-BCM2.0
CGCM3.1(T47)
CGCM3.1(T63)
CNRM-CM4
CSIRO-Mk3.0
ECHAM5/MPI-OM
FGOALS-g1.0
GISS-AOM
INM-CM3.0
IPSL-CM4

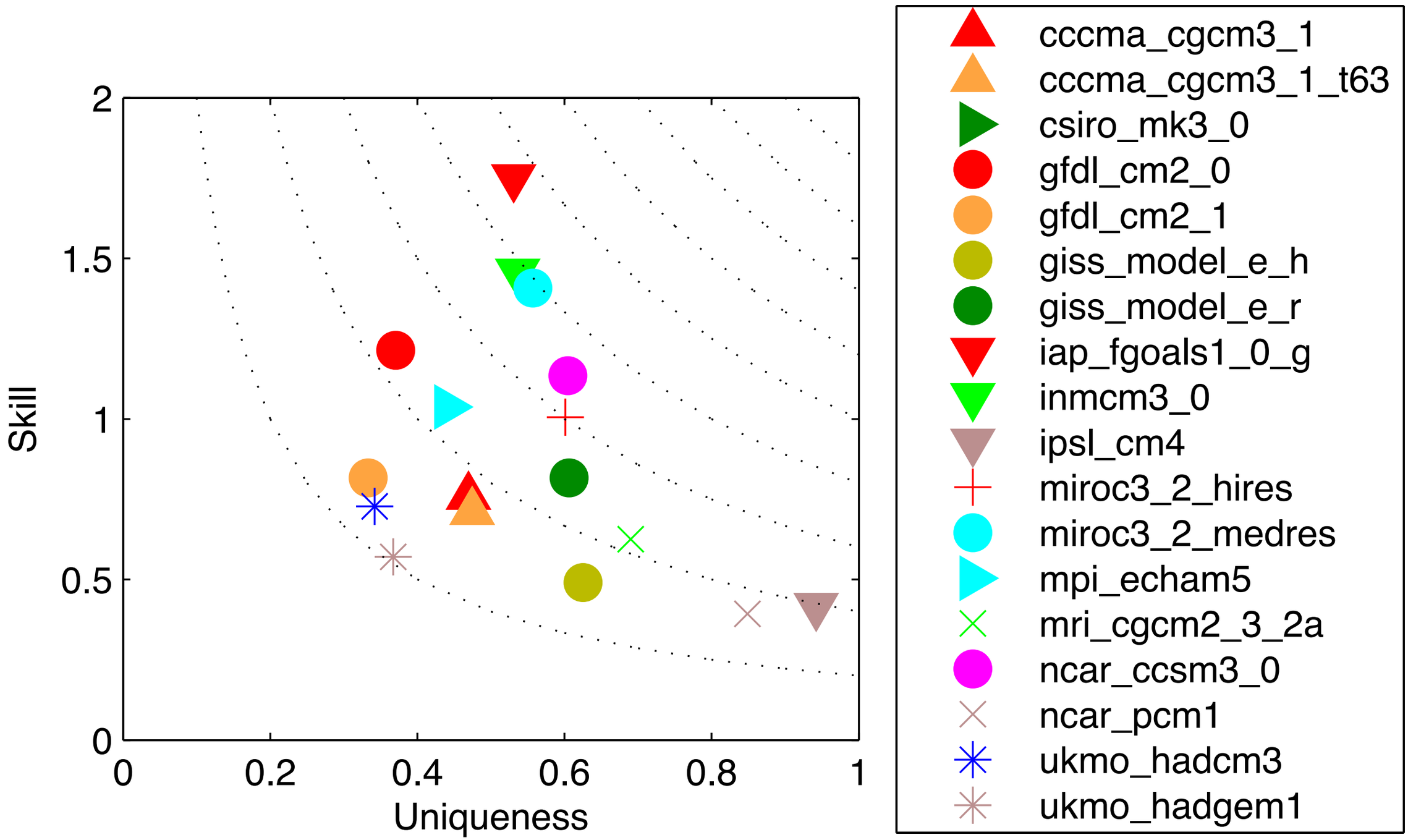




$$W = e^{-\left(\frac{d_{Om}}{\bar{d}}\right)^2} \left(1 + \sum_{n \neq m}^{n} e^{-\left(\frac{d_{nm}}{\bar{d}}\right)^2}\right)^{-1}$$

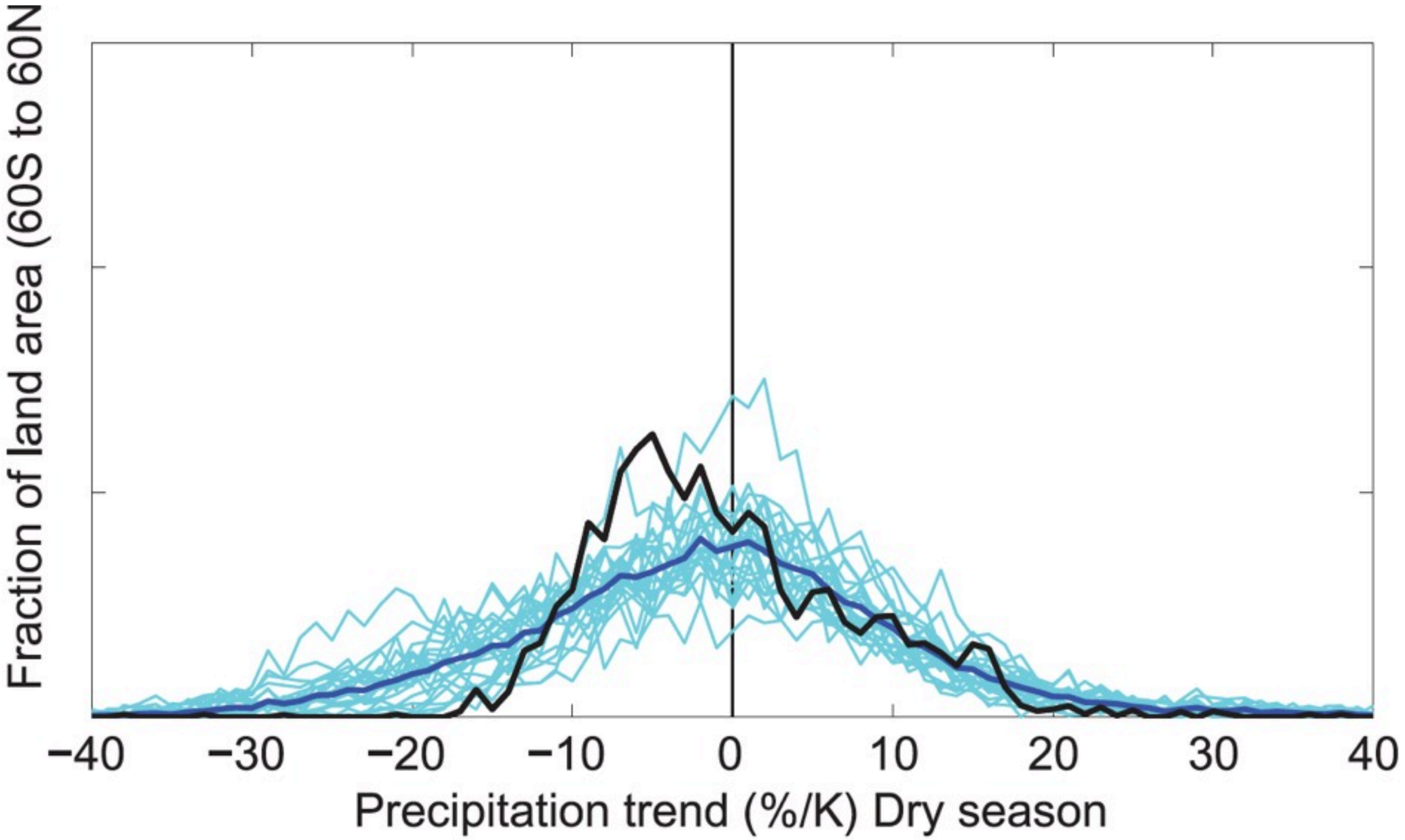
Dimensional Reduction

Sanderson & Knutti (in prep.)



Weighting

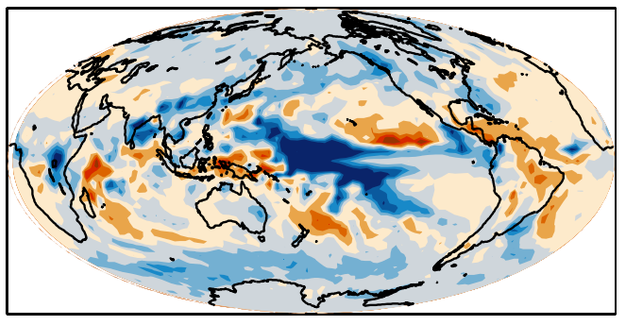
Sanderson & Knutti (in prep.)



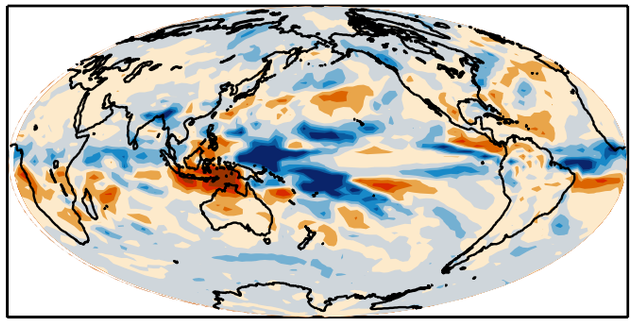
Precipitation Trends

Knutti *et al* (2010)

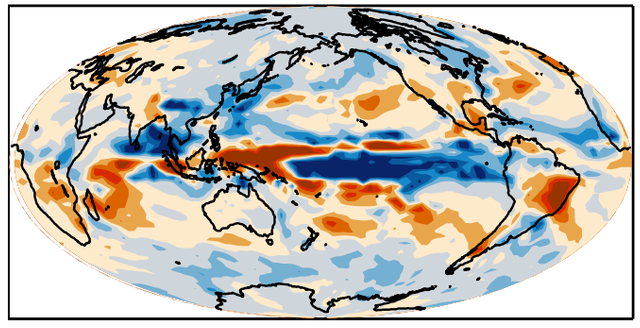
cccma_cgcm3_1_t63



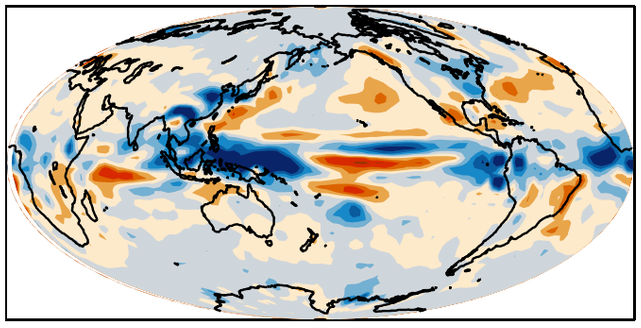
csiro_mk3_0



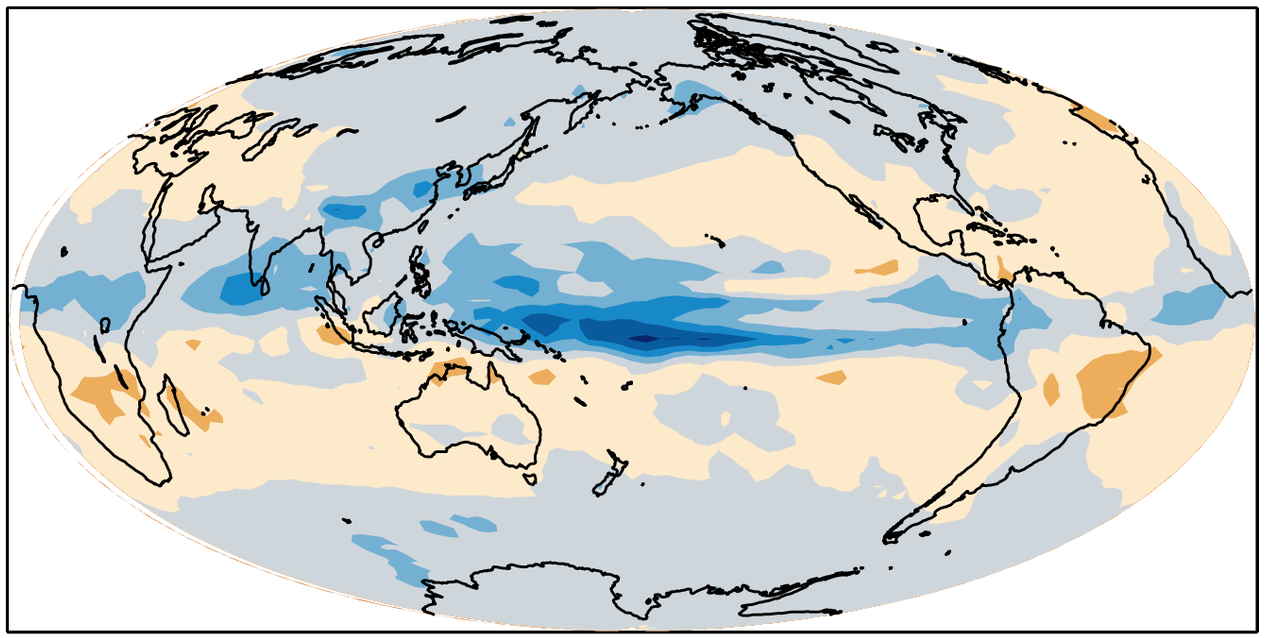
gfdl_cm2_0



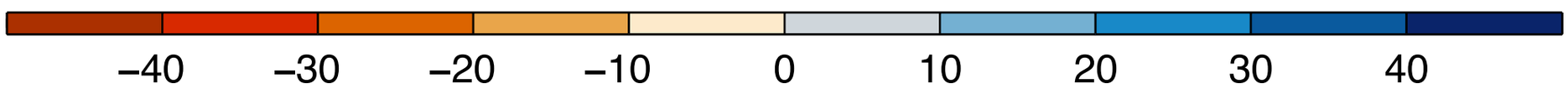
giss_model_e_r



Multi–Model Mean

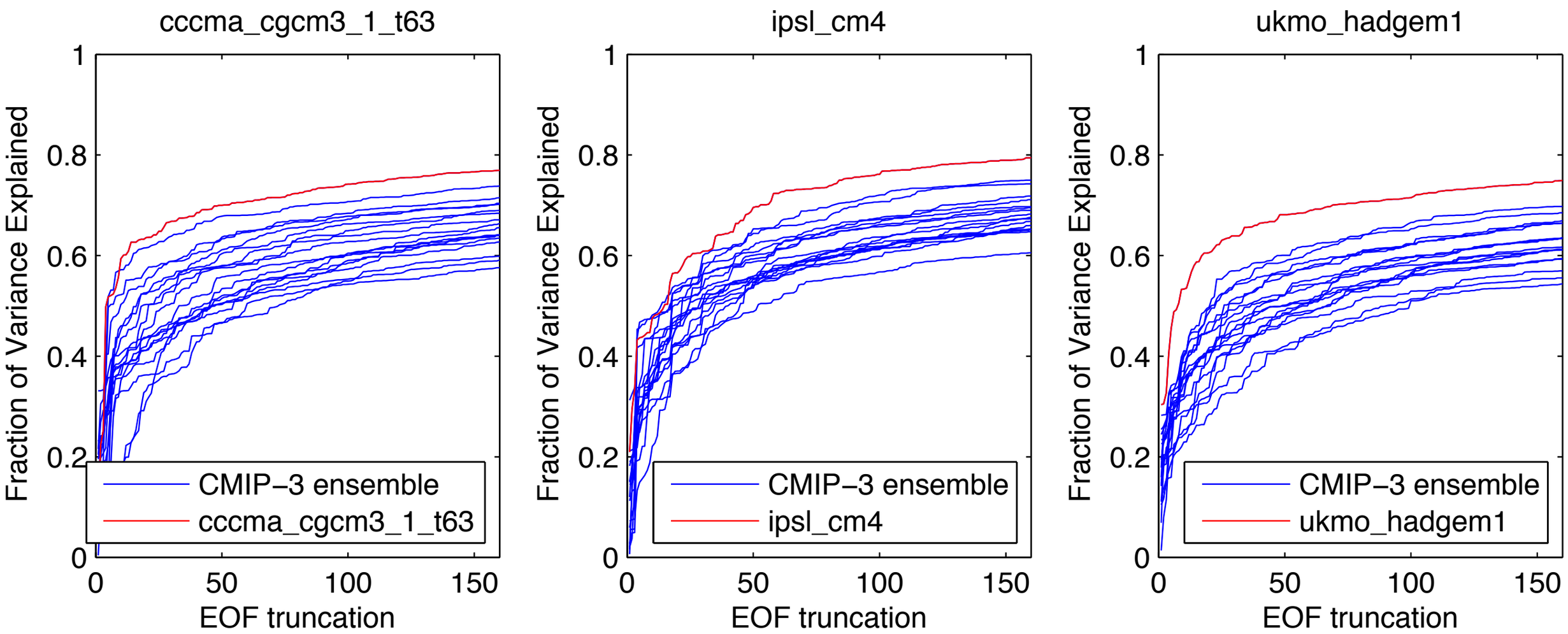


Annual Precipitation Change (cm)



Representative Mean?

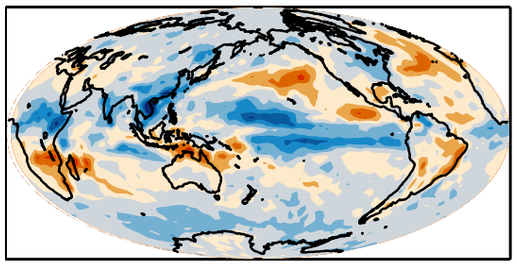
Sanderson (in preparation)



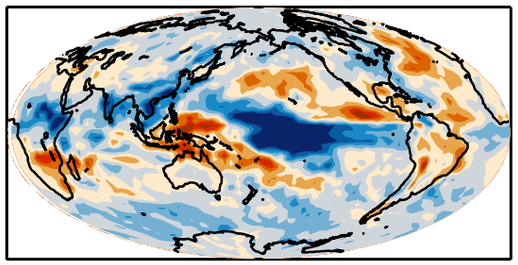
Pattern Projections

Sanderson (in preparation)

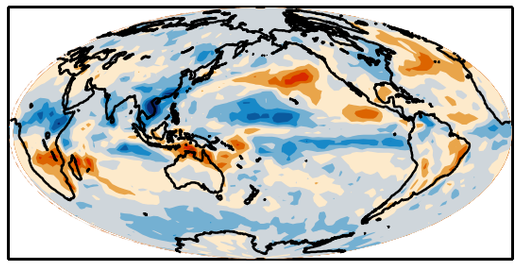
cccma_cgcm3_1



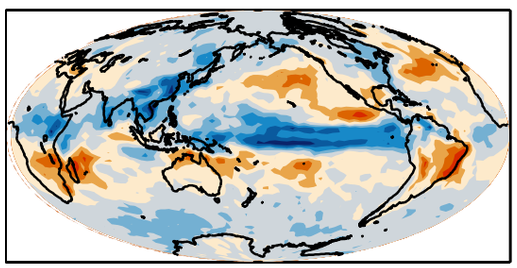
cccma_cgcm3_1_t63



csiro_mk3_0



gfdl_cm2_0



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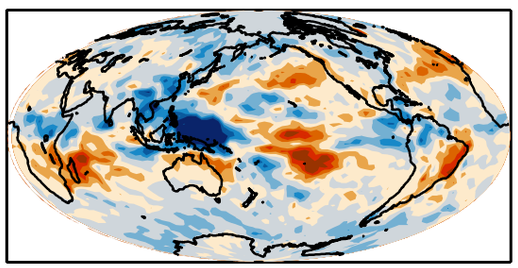
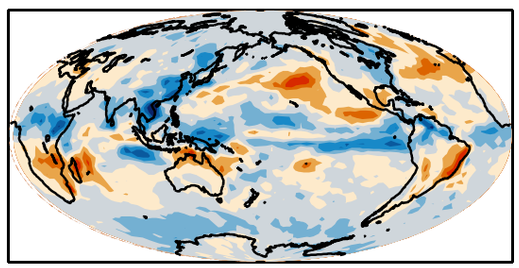
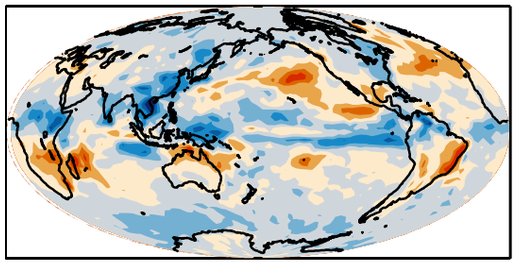


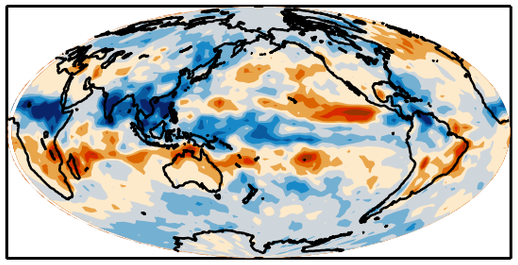
giss_model_e_h



giss_model_e_r



iap_fgoals1_0_g



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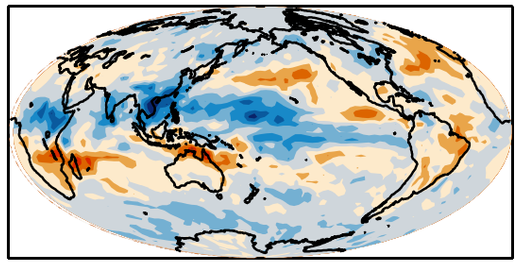
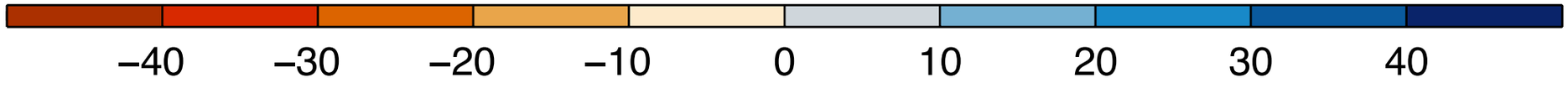


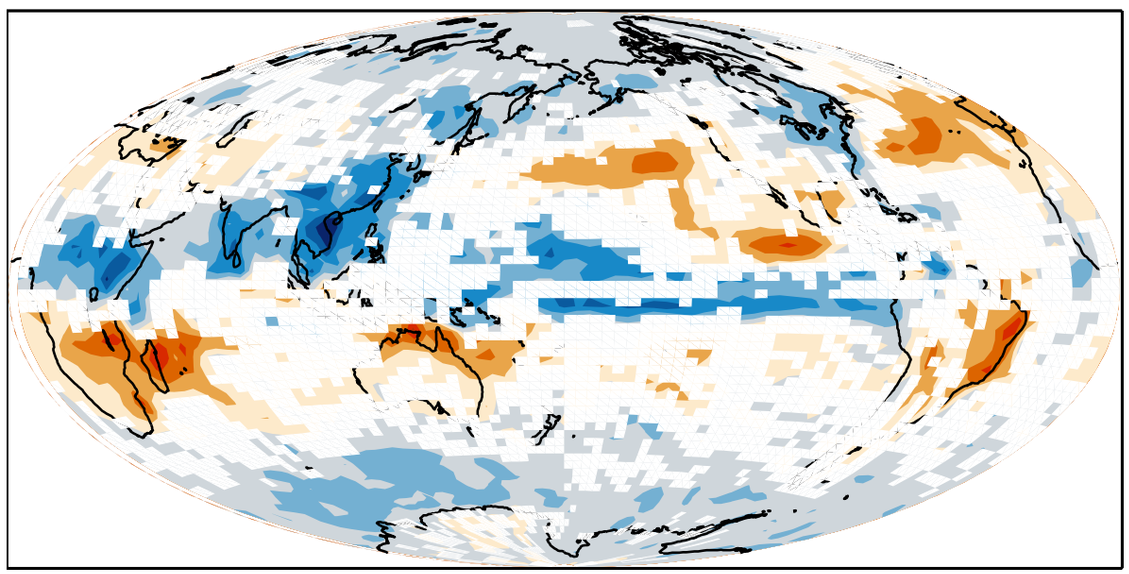
Annual Precipitation Change (cm)



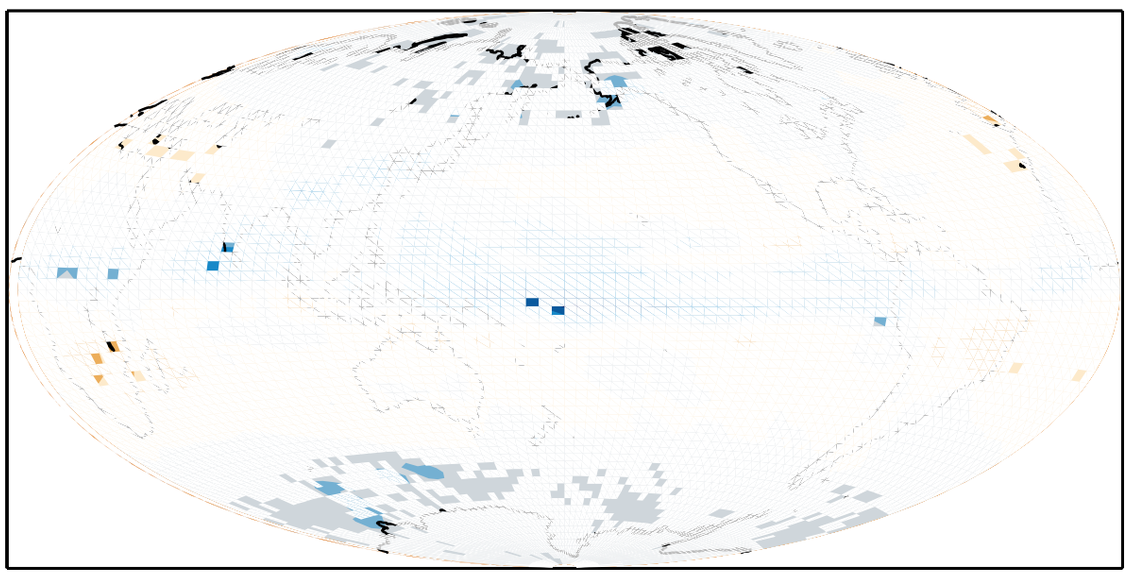
GPCP Reconstruction

Sanderson (in preparation)

Regression from GPCP & CMIP–3 Future temp



Multi–Model Mean

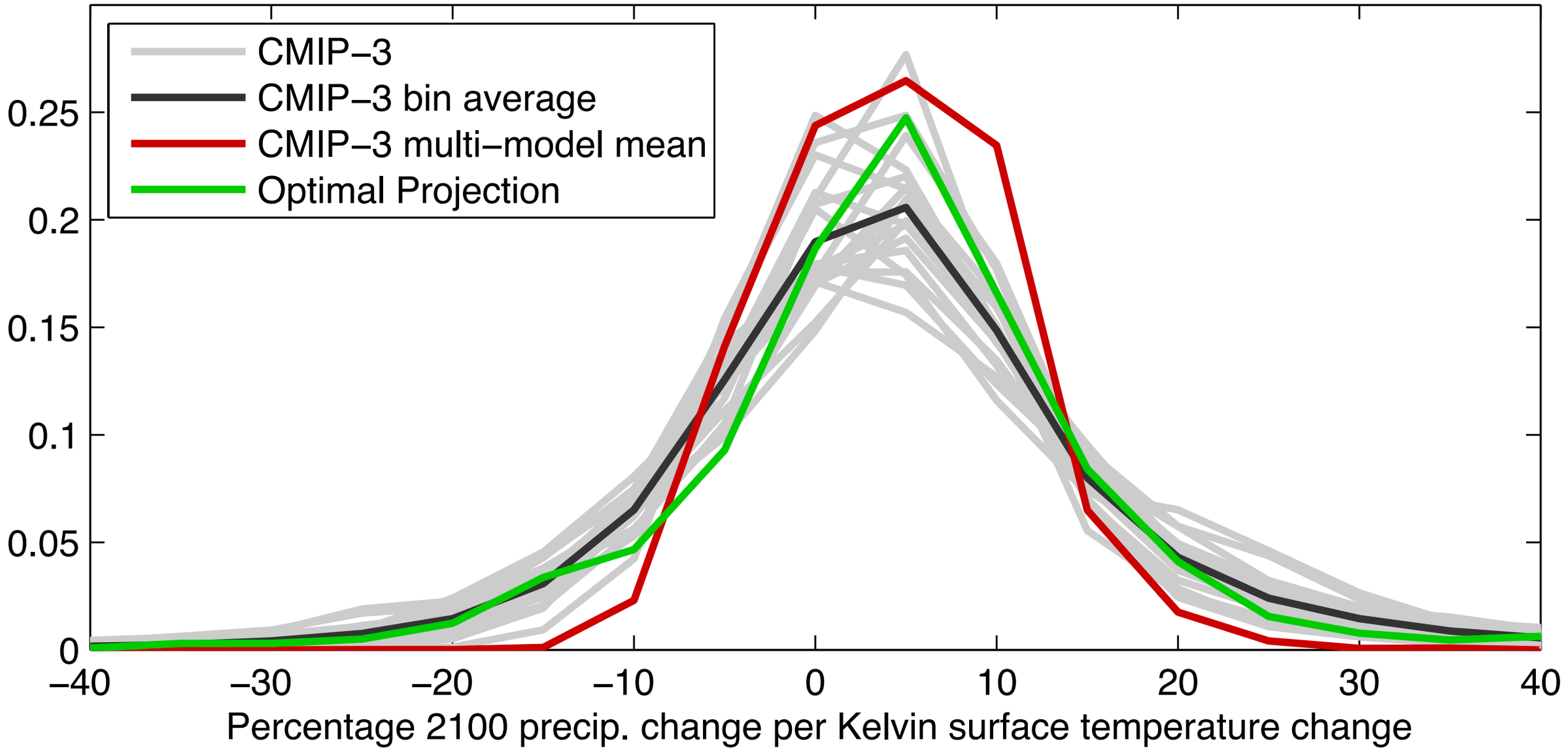


Annual Precipitation Change (cm)

–40 –30 –20 –10 0 10 20 30 40

Model Consistency

Sanderson (in preparation)



Representative estimate

Sanderson (in preparation)

Conclusions

- Constrained ensembles like CMIP may be best understood as imperfect truth+error by design for observed climate periods
- Spread in the present day ensemble is likely due to a combination of systematic errors, tuning limitations and limited degrees of freedom, unlike future predictions which spread due to differences in feedbacks and forced response
- Some aspects of the climate system may be predictable, and will retain truth+error characteristics for a longer lead time
- A complete model weighting should include both aspects of model skill and inter-model similarity