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Role and utility of paleo-simulations in CMIP5

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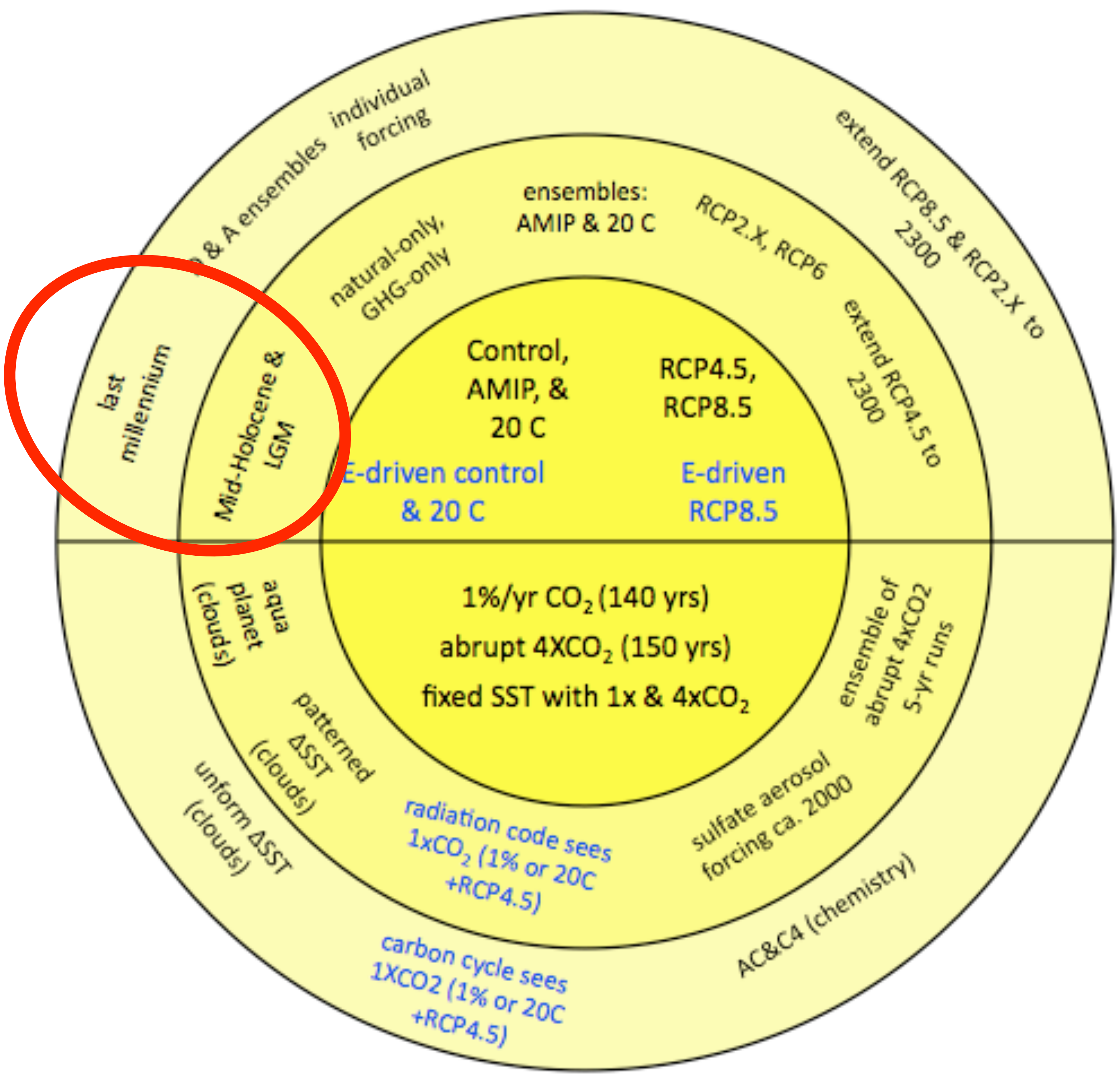
+ contributions

NASA GISS Contributions to CMIP5

Experiment	years/expt	No. of simulations	total model years	archive size (TB)
historical+Ext	162	36	5832	4.5
rcp26	95+200	3	885	0.8
rcp45	95+200	16 (2)	4720 (590)	5.4
rcp60	95+200	3	885	0.3
rcp85	95+200	3	885	0.8
past1000	1000+155	3 (13)	3465 (15015)	2.6 (11)
lgm	100	2	200	0.2
midholocene	100	1 (1)	100 (100)	0.1 (0.1)
historicalMisc +Nat+GHG	155	62 (~40)	9610 (6200)	7.5 (4.8)
amip	155	11 (1)	1705 (155)	2.3 (0.2)
1pctCO2	140	3 (2)	420 (280)	0.3 (0.2)
abrupt4xCO2	150	3 (2)	450 (300)	0.3 (0.2)
Spin-ups	~500	~11	~5500	N/A
Controls	~1000	8	8000	3.7
Total		168 (63)	~43K (22K)	~31 (15)

- 6 basic model configurations:
  2 oceans: GISS-E2-R/H
  3 treatments of atm. chem/ aerosols/indirect effects:
  `physics-versions=1,2,3`
  `NINT, TCAD, TCADI`
- 60,000+ model years
- ~250 distinct simulations
- ~50 TB contributed to CMIP5 archive
- Extensive exploration of forcings - multiple realisations, single forcing runs

Paleo-simulations in CMIP5



Tier 2:
Mid-Holocene
(6000 years ago)
Last Glacial Maximum
(21K years ago)

Tier 3:
Last Millennium
(850 CE- 1850 CE)

Key Factors: ***Same*** models as historical and RCPs, ***Same*** database, ***Same*** diagnostics, ***Same*** formats

Paleo-simulations: Configurations

Mid-Holocene:

Equilibrium (spin-up + 100 years)
orbital change, small GHG change, vegetation
Targets: Green Sahara, sea ice, NH continental seasonality

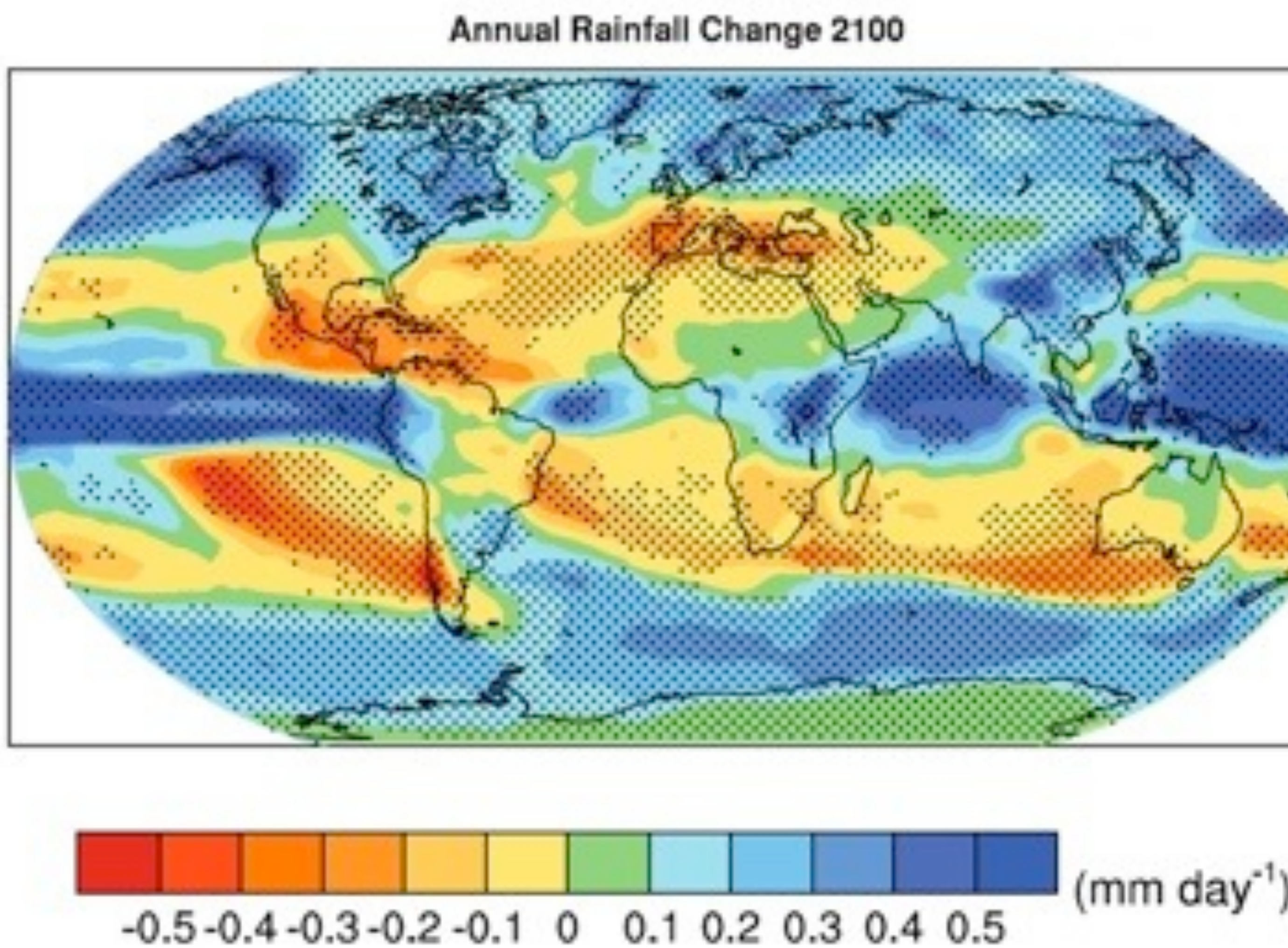
LGM:

Equilibrium (spin-up + 100 years)
ice sheets, GHG changes, orbit, dust, sea level, vegetation
Targets: patterns of cooling, rainfall shifts, ocean circulation

Last Millennium:

Transient (spin-up + 1000 years + 150 years)
volcanic, solar, orbit, anthro. land use/land cover, small GHG
Targets: Hemispheric trends, regional responses, mega-droughts

Relevance to AR4 uncertainties



Precip change multi-model mean, SRES A1B 2080-2099 w.r.t 1980-1999

Stippling denotes 80% of models agree on sign of precip change

Key areas of model divergence:
Sahel, Central US, India, Australia, Amazonia, North Atlantic

Regions of rich history of paleo-climate change:
MH “green sahara”, Medieval US mega-droughts, Holocene trends in Indian monsoon, NADW Abrupt climate change etc...

Why paleo?

- Future climate change is definitely 'out-of-sample'
- Skill metrics based on 20th C climate are insufficient to distinguish projections
- Paleo-climate is not an analog, but many tests of the same machinery
- Tests/quantification of hypotheses for past climate
- Coordinated comparisons require:

    Data synthesis (cf. CLIMAP, MARGO, DUSTMAP)

    Improvements in archives/databases

    More connection of paleo-modelling to CMIP archives

    Greater use of forward models

Paleo-simulations:
Three types of analysis

1) Comparisons to paleo-data/Benchmarking

Q. How well can models simulate past changes?
Q. Can we distinguish between uncertainties in forcings, response or proxies?
Q. Can we explain past climate variability?

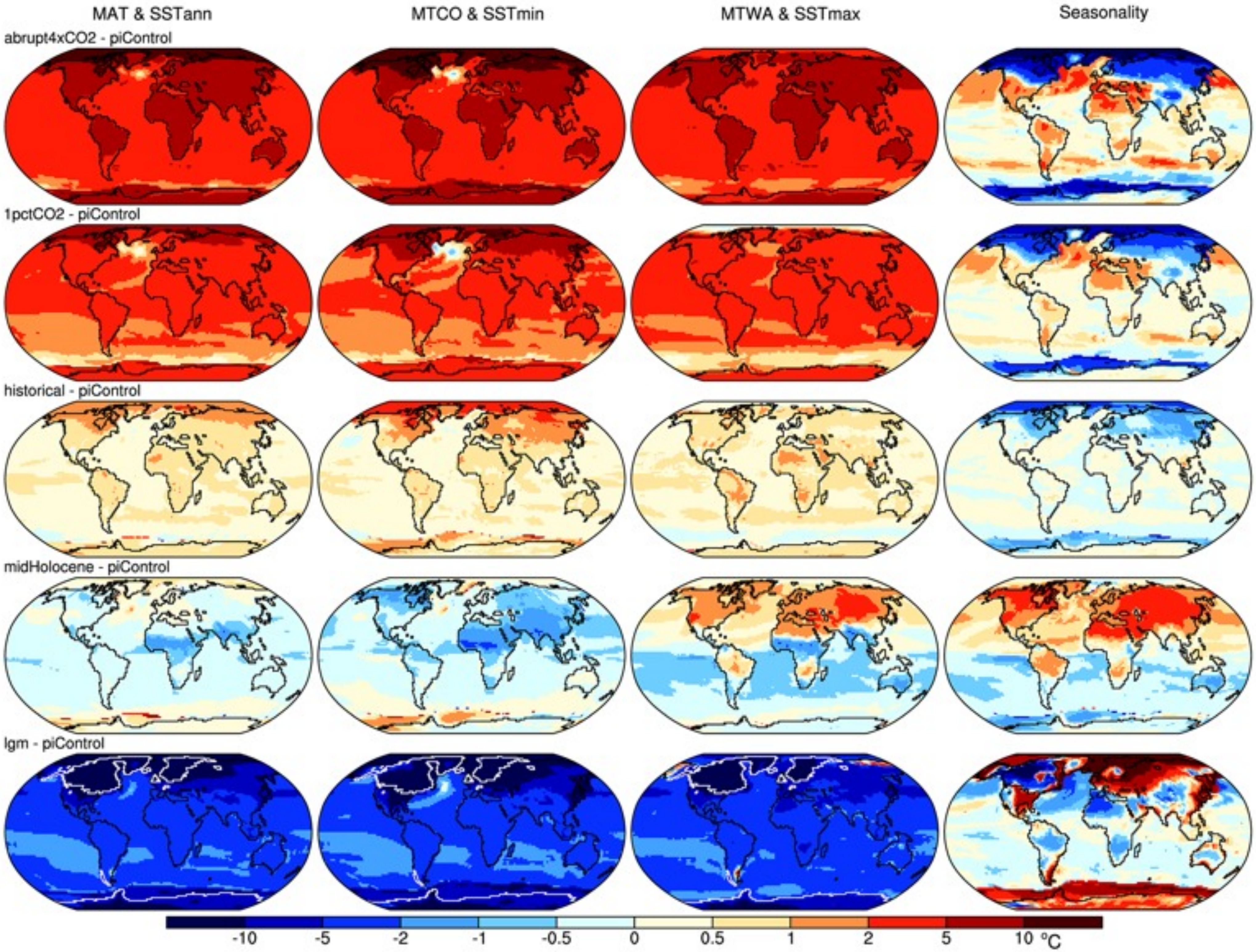
2) Robust metrics for future projections

Q. Coherence of response across experiments

3) Differentiating btw future projections

Q. Can skill metrics with past observations distinguish between differences in future projections with same model?

MME changes across expts. (6 models)



abrupt4xCO2

1%CO2

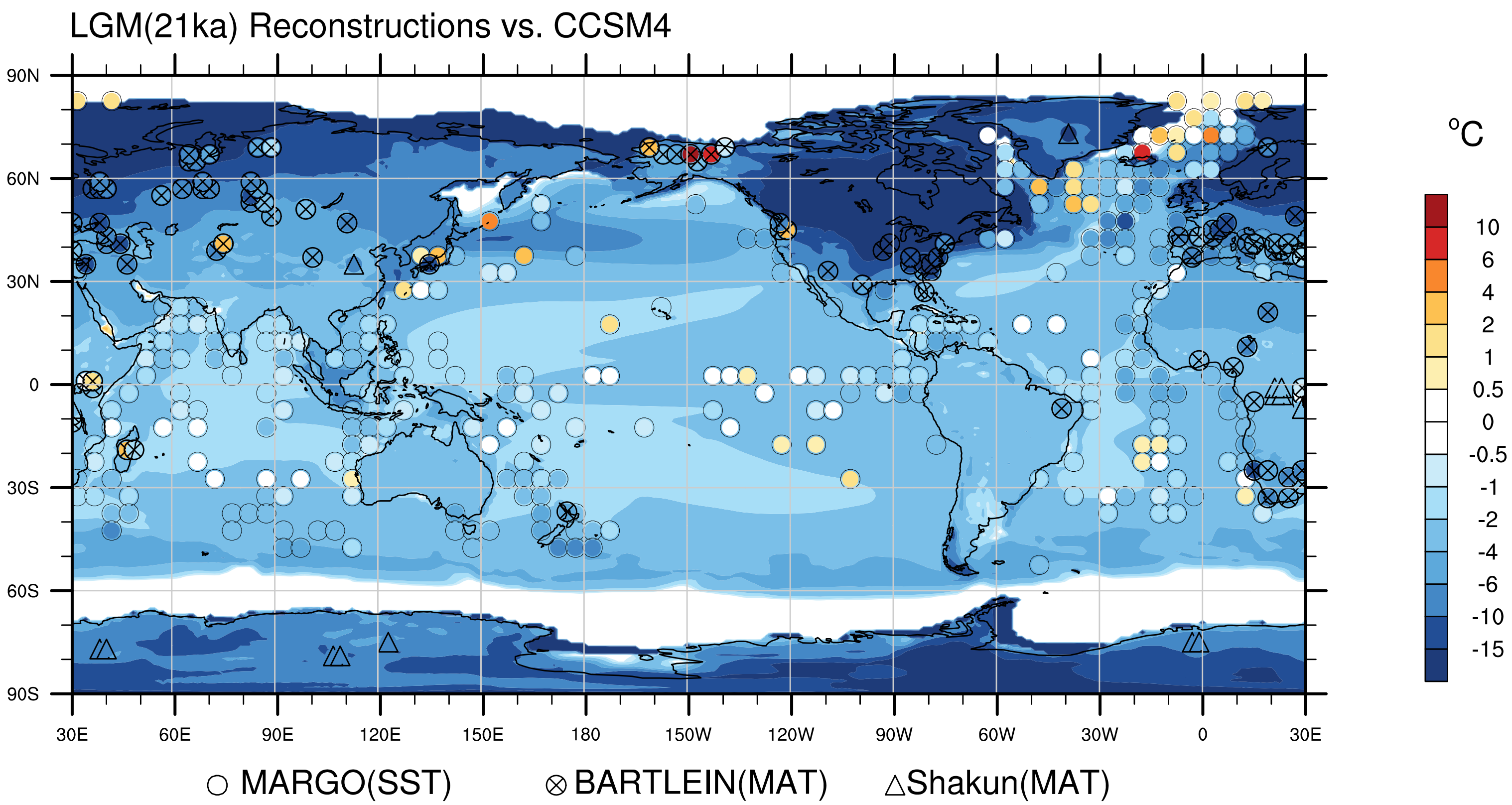
historical

mid-Holocene

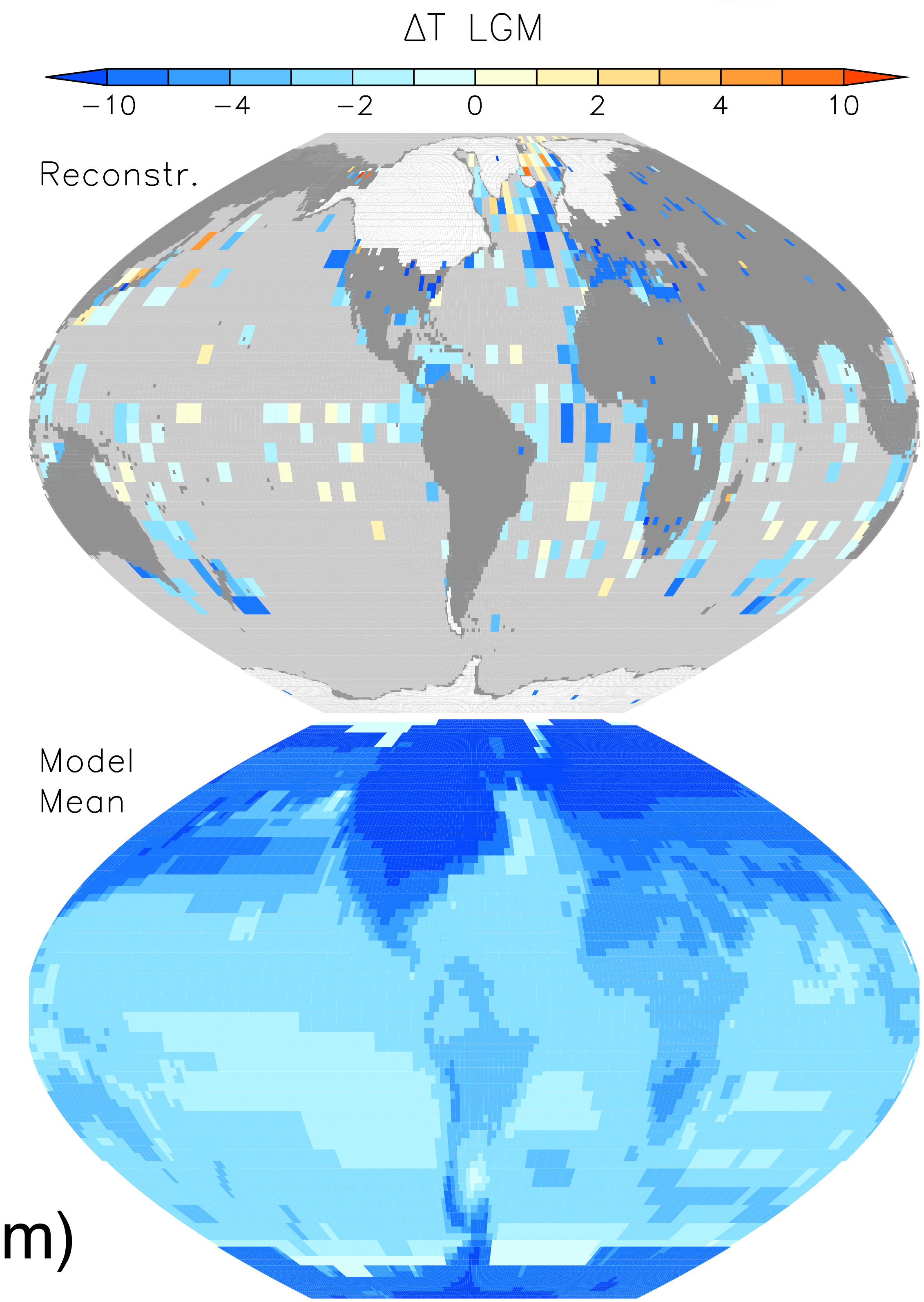
LGM

Izumi, Bartlein & Harrison, subm.

LGM temperature comparisons

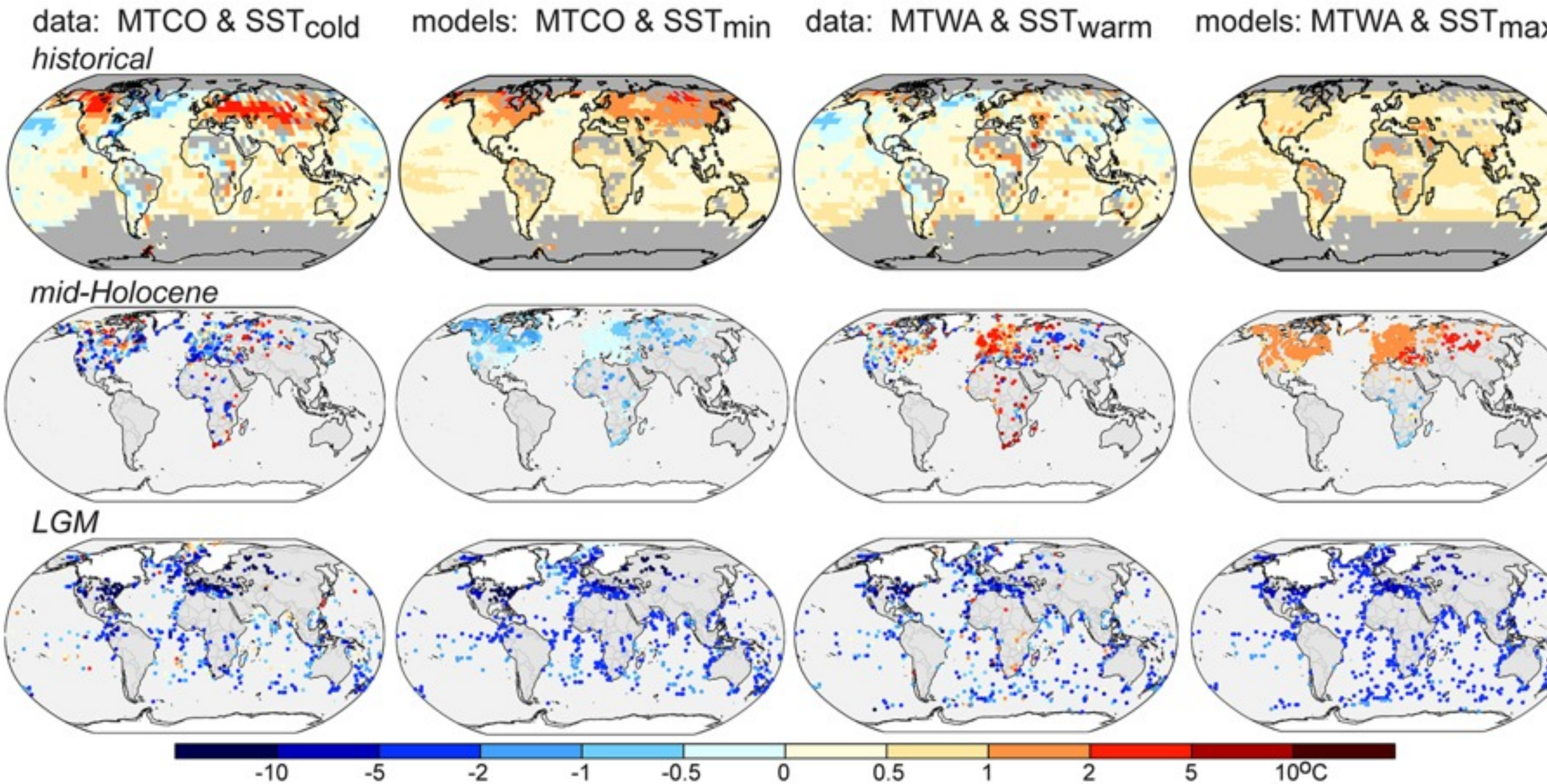


CCSM4 (Brady et al, subm.)



Multi-model Ensemble
(A. Schmittner, pers. comm)

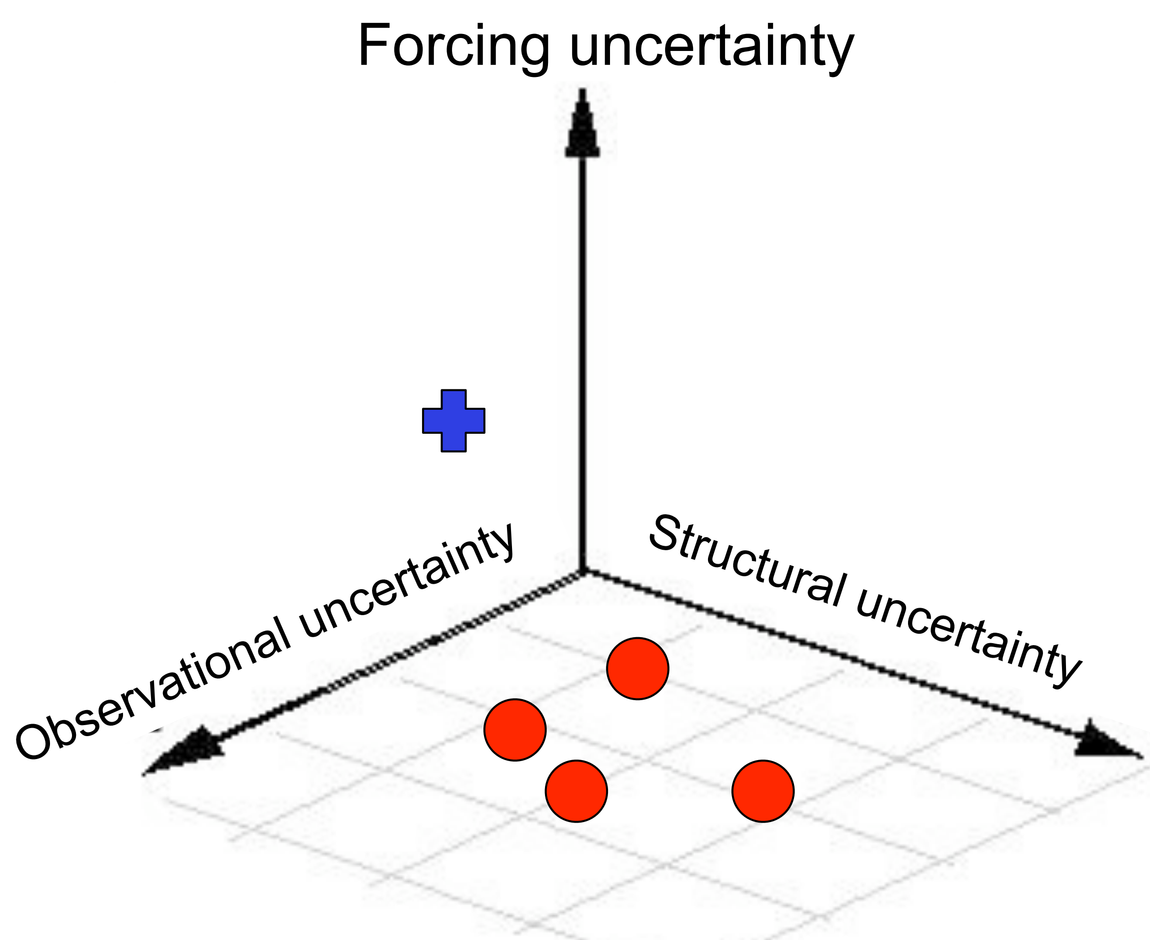
More comparisons of 6-model ensemble

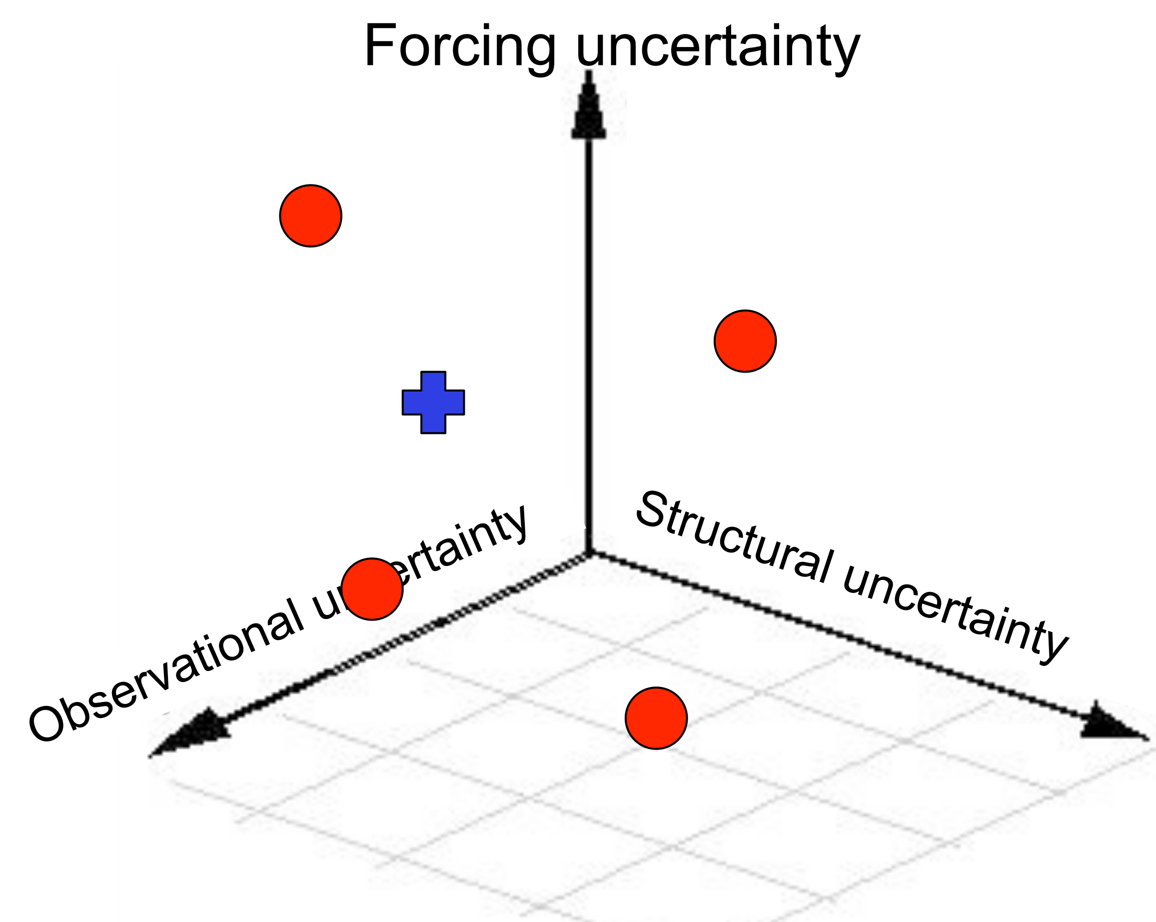


MTCO = Mean Temperature Coldest month
MTWA = Mean Temperature Warmest month

Data from observational syntheses (Izumi et al, subm.)

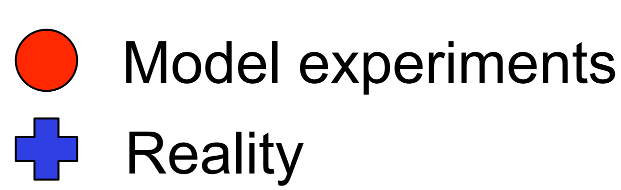
Sampling uncertainty



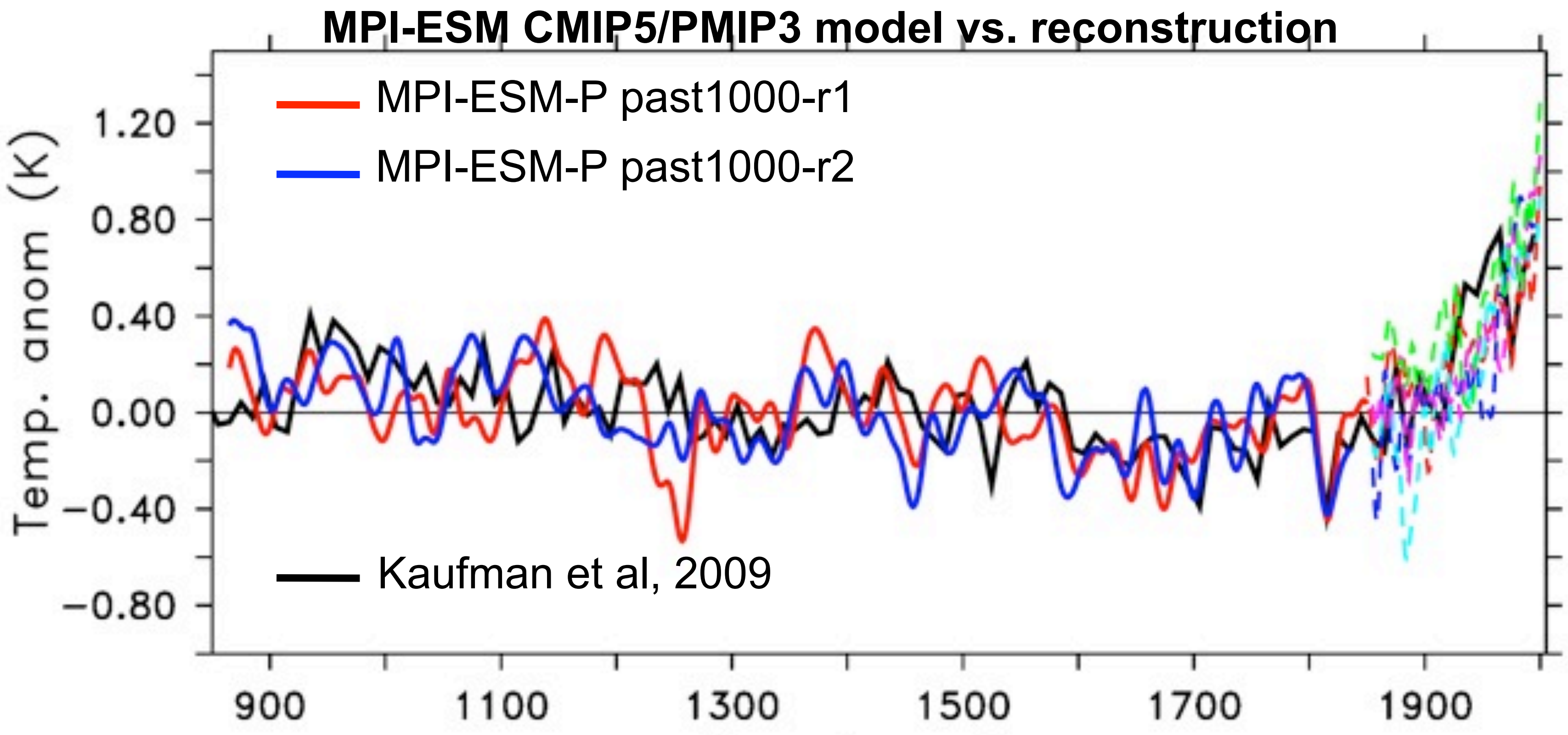


Everyone uses the same forcing

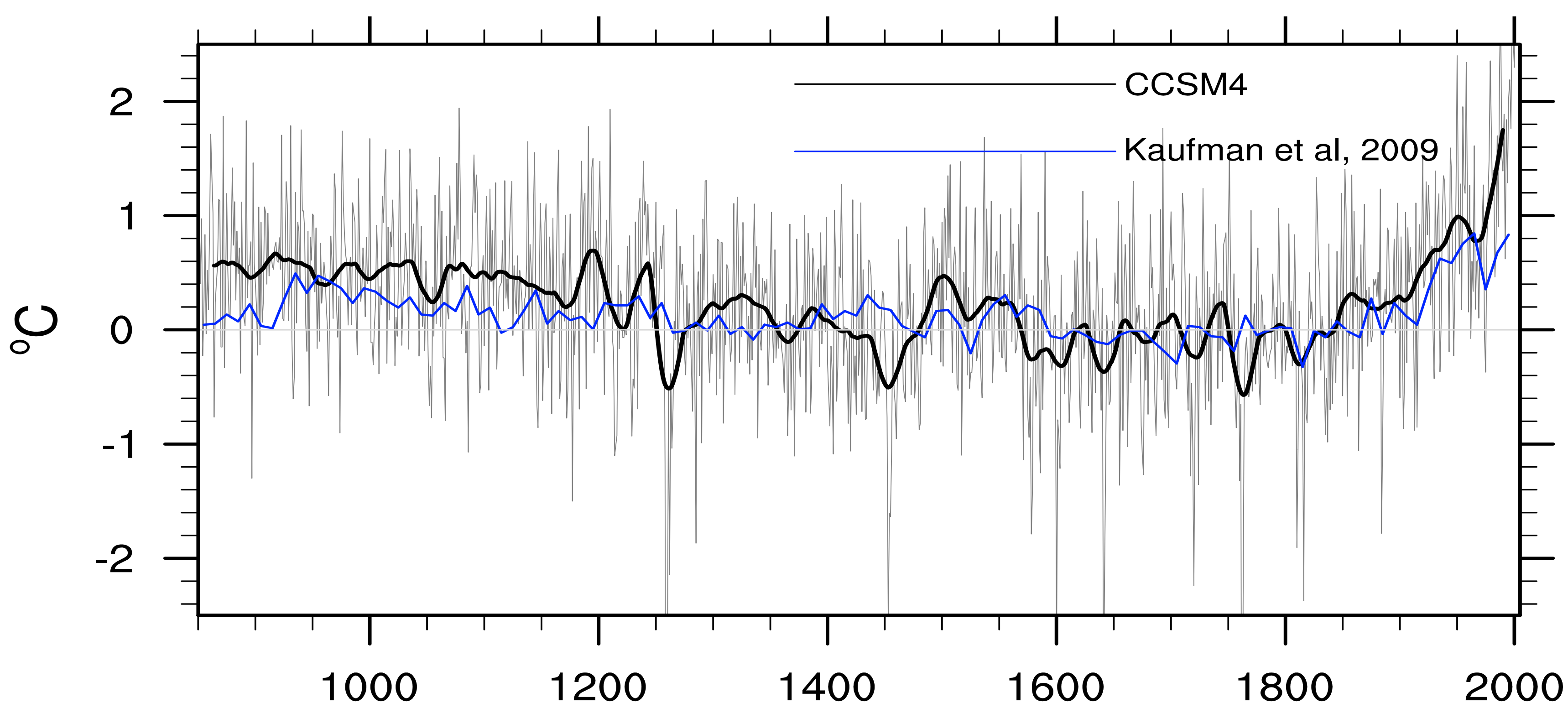
Multiple forcing experiments



Last Millennium: Arctic surface Temp

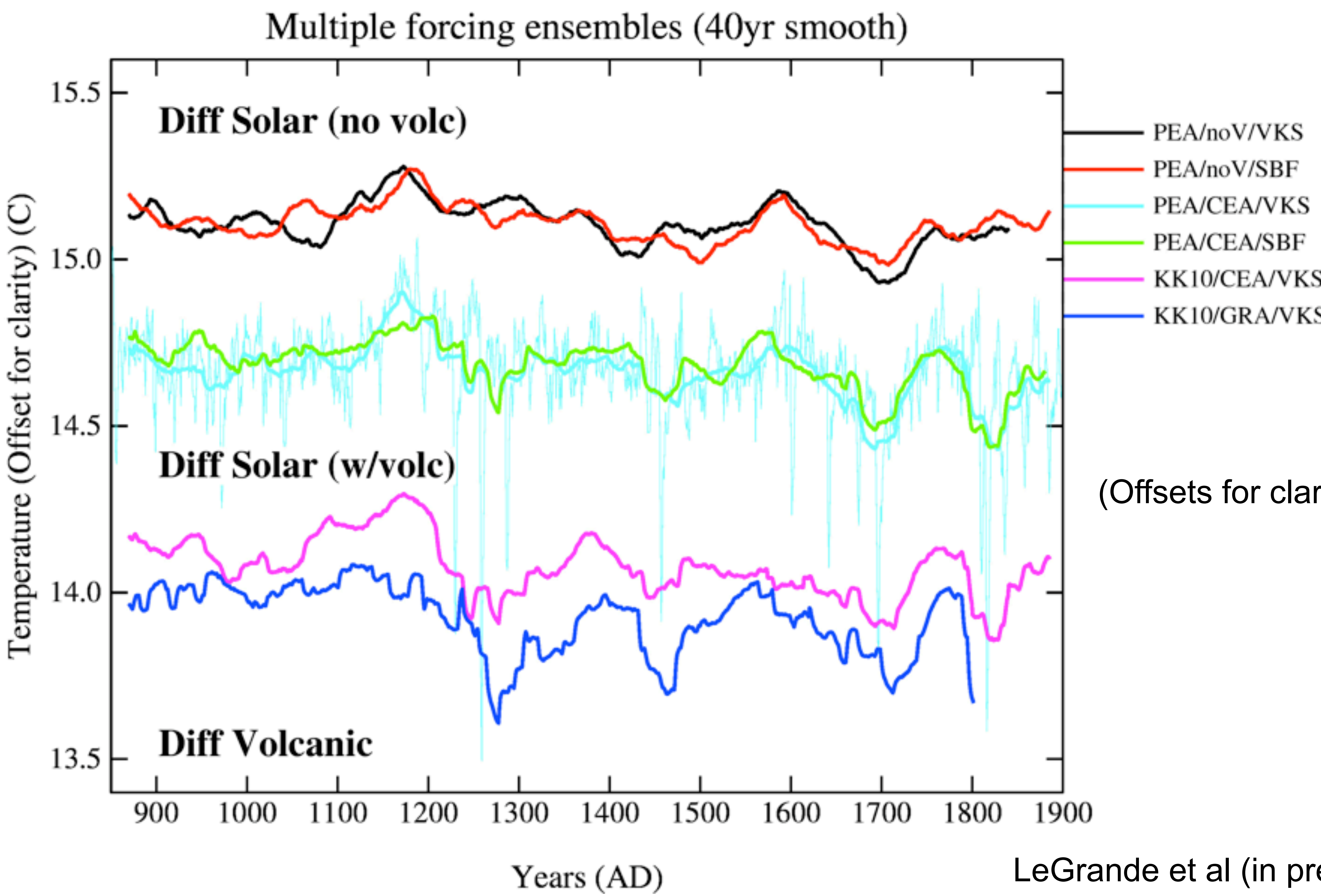


MPI-ESM
(Johann Jungclaus, pers. comm)



CCSM4
(Landrum et al, subm)

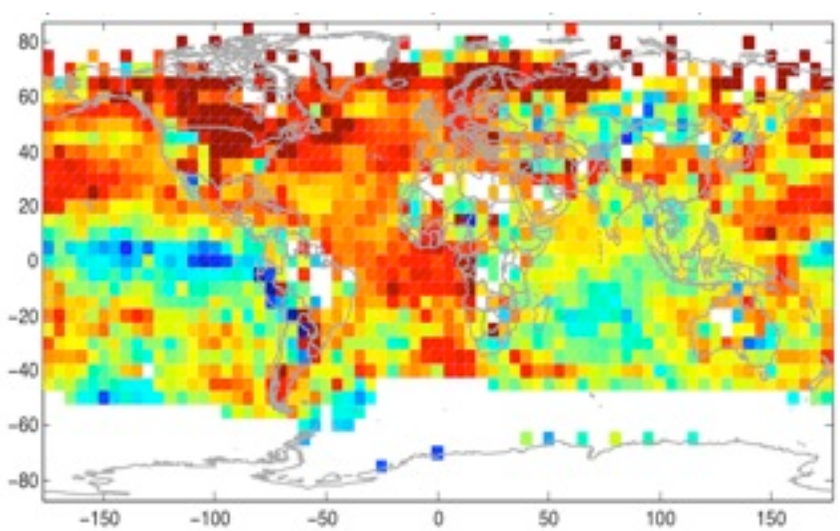
LM: Impacts of forcings



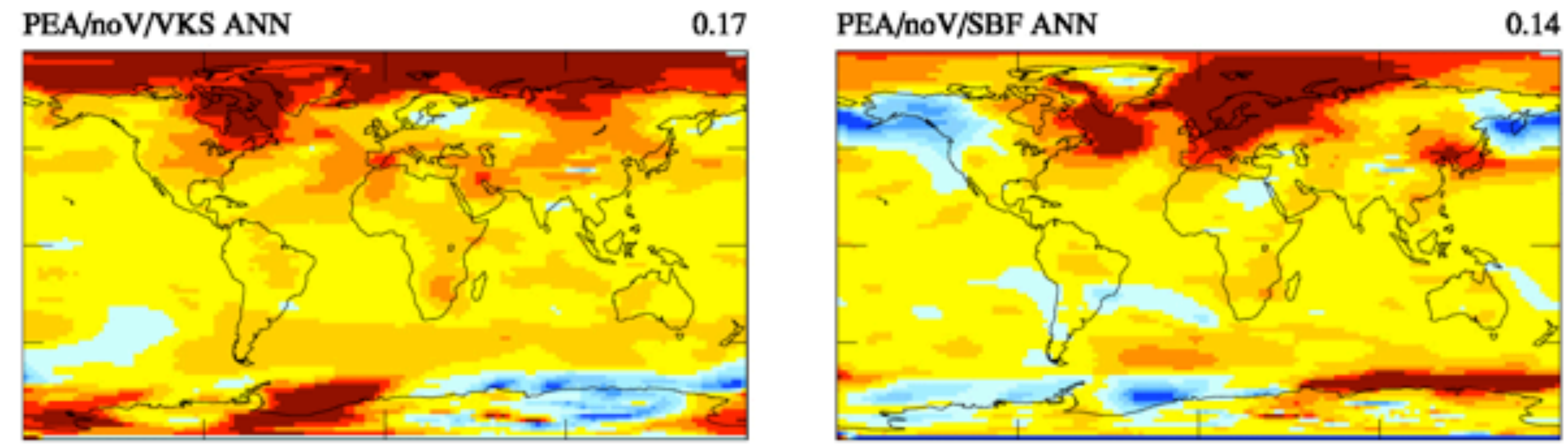
(Offsets for clarity)

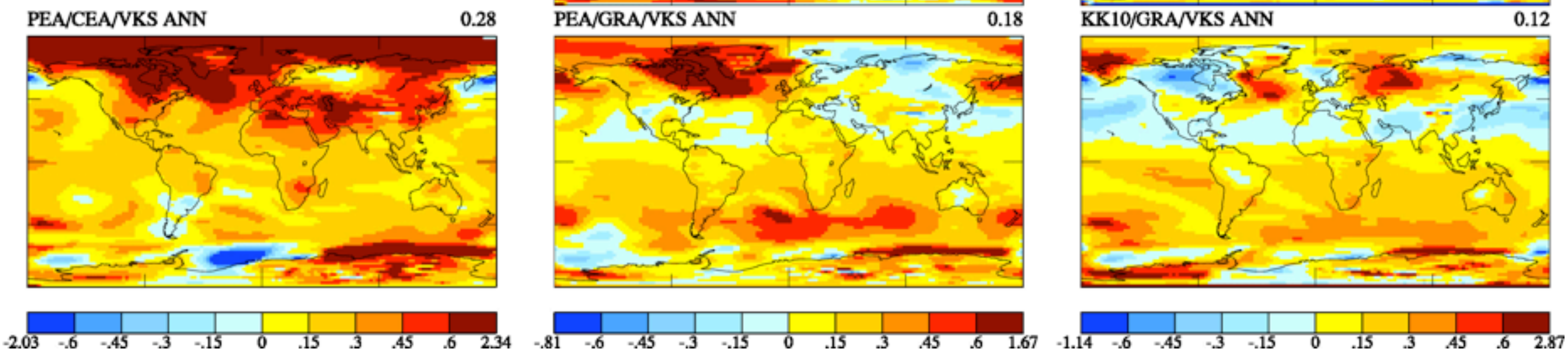
LeGrande et al (in prep)

LM: MCA-LIA in GISS-E2-R



MCA-LIA Reconstruction: Mann et al (2009)





1000-1200 (MCA) minus 1500-1700 (LIA)
Annual Mean Surface Temperature Anomaly

LeGrande et al (in prep)

Paleo-simulations: Summaries

Mid-Holocene:

All models show expected NH summer warming
- more uniform than in data.
Change in seasonality too moderate
Opposite patterns in Southern Africa

LGM:

Overall cooling well captured. Too much cooling in trop. Pac.
Northern N. Atl mismatch - model or proxy problems?

Last Millennium:

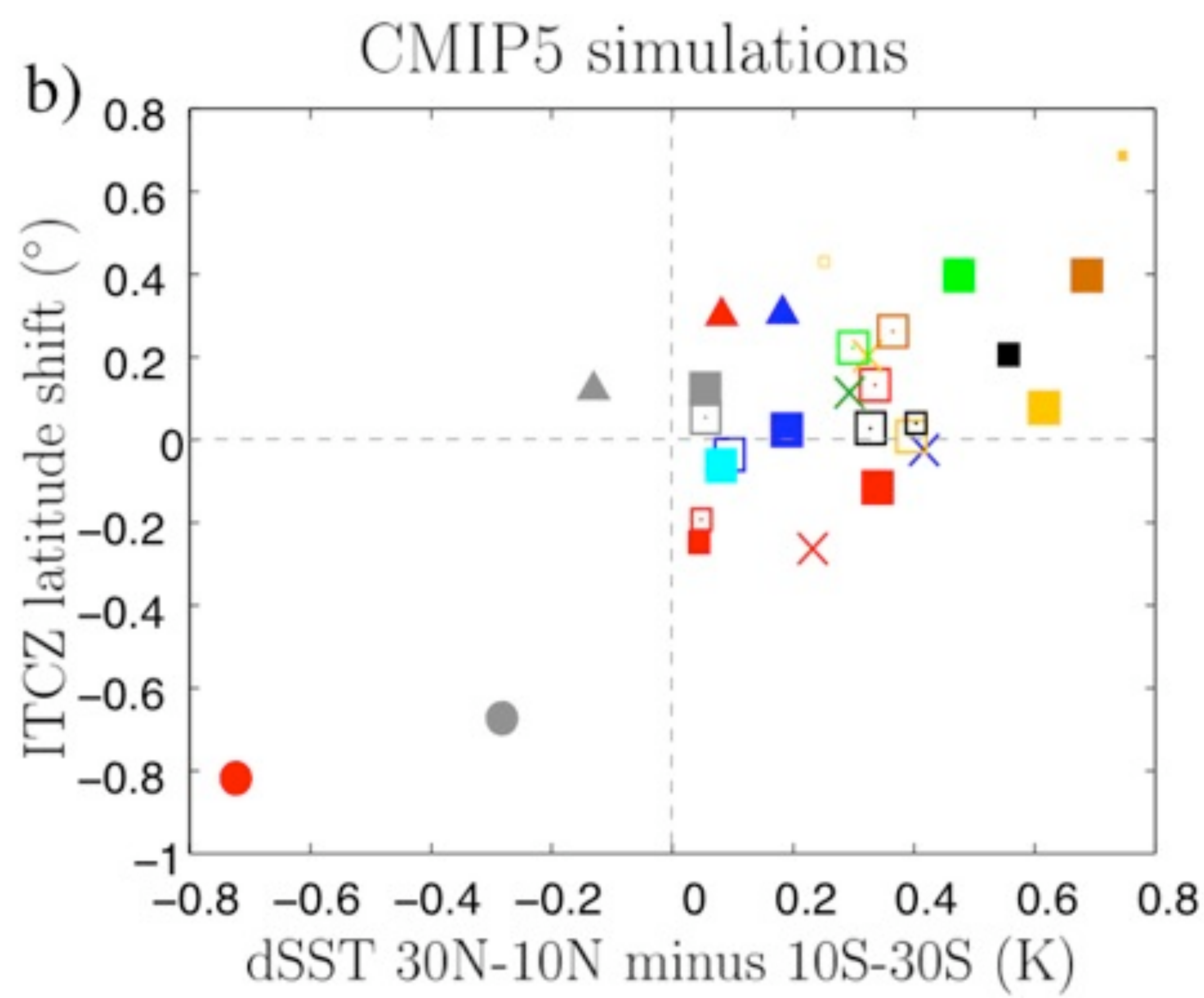
Long term trends small, but reasonable. Clear response to volcanoes, hard to detect response to solar (missing mechanisms?).
Variability strongly tied to choices of forcings (esp. volcanoes)
More analysis needed on patterns of change/internal variabilty

Robust property-property metrics

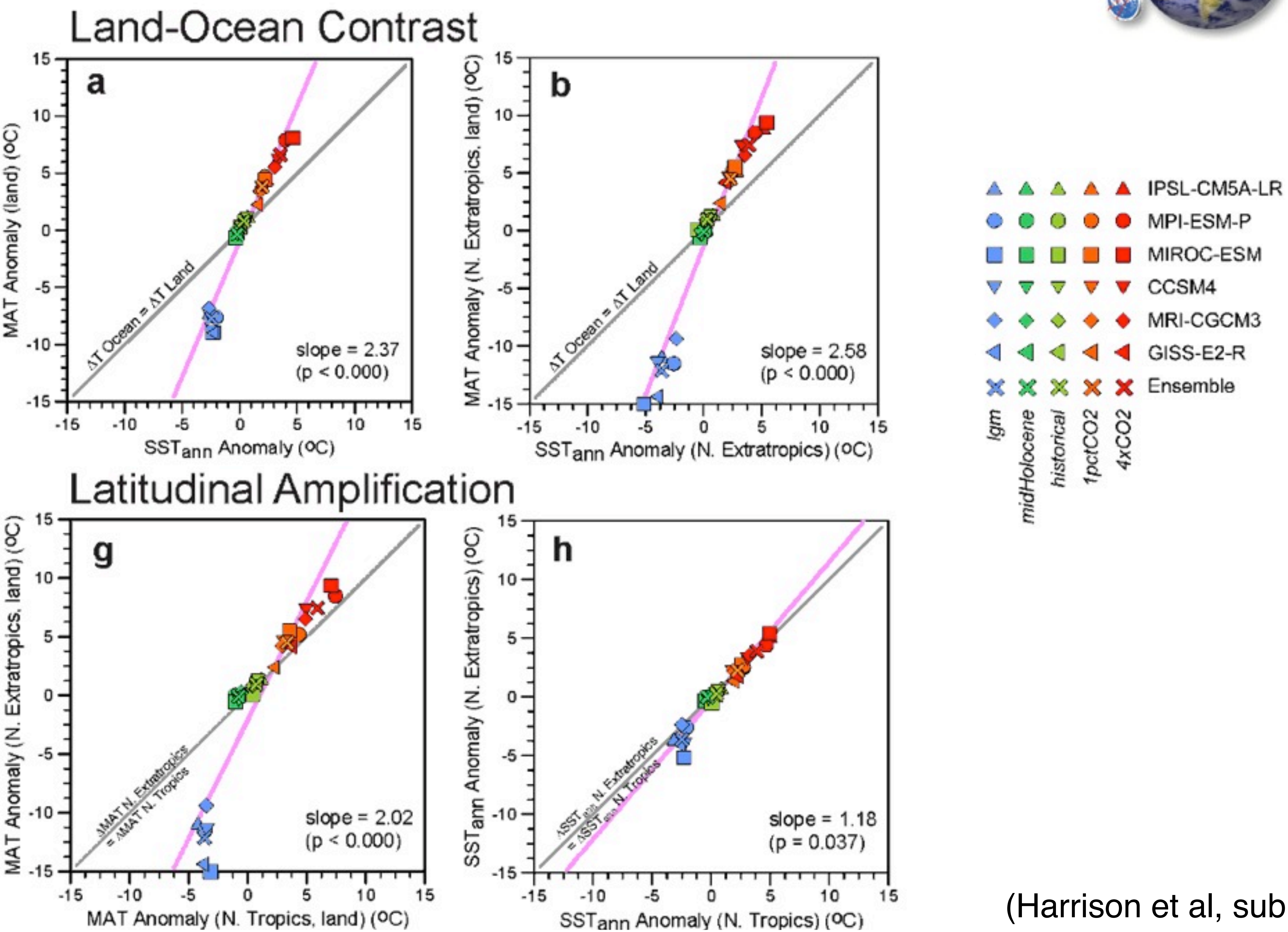
Metrics that show similar behaviour across past and future experiments i.e. not dependent on details of individual models

Matches to paleo-data imply credibility of *relationship* in future projections - (not necessarily magnitude)

e.g. ITCZ shift to change in SST gradient (Camille Risi)

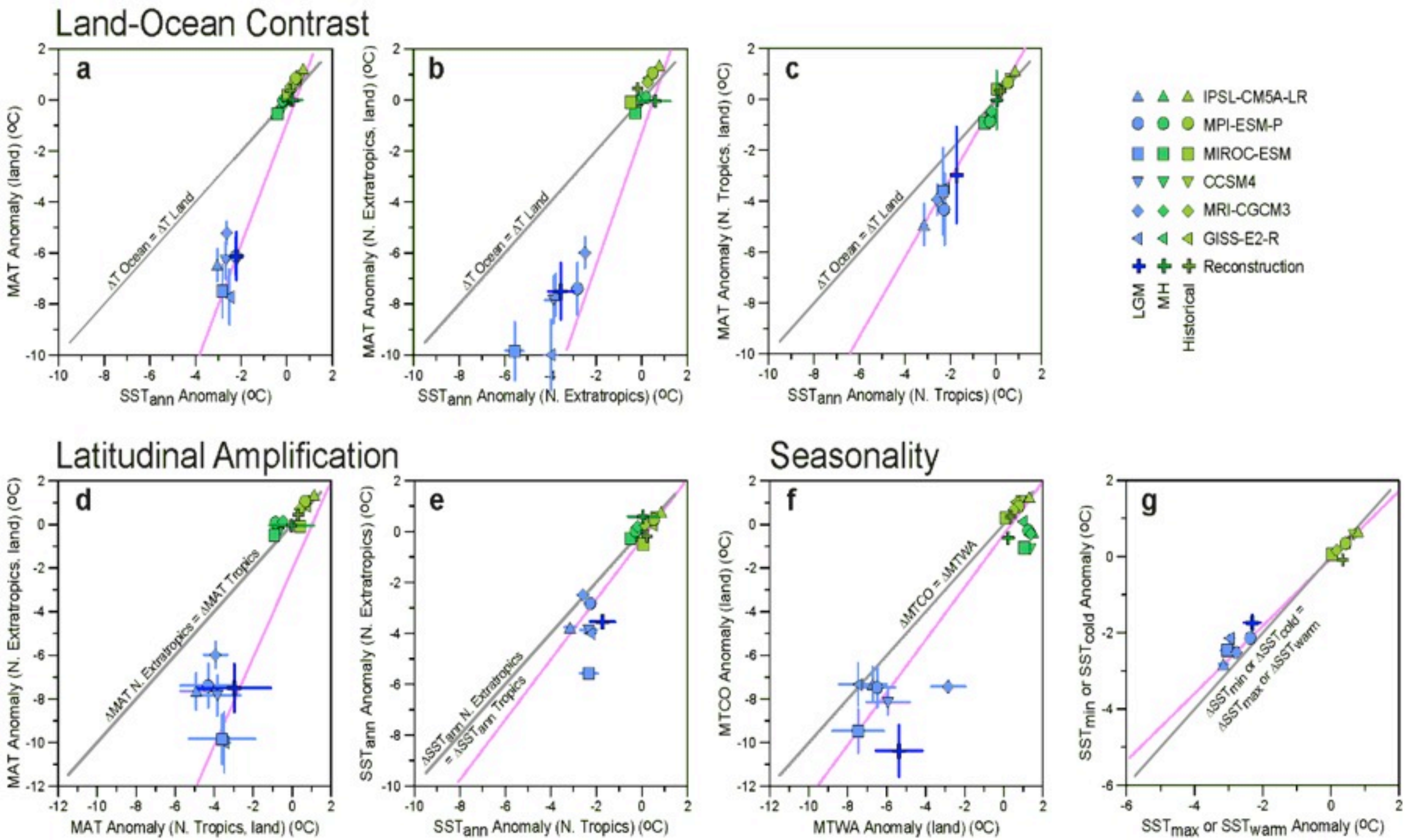


More examples



(Harrison et al, subm.)

With observational constraints...

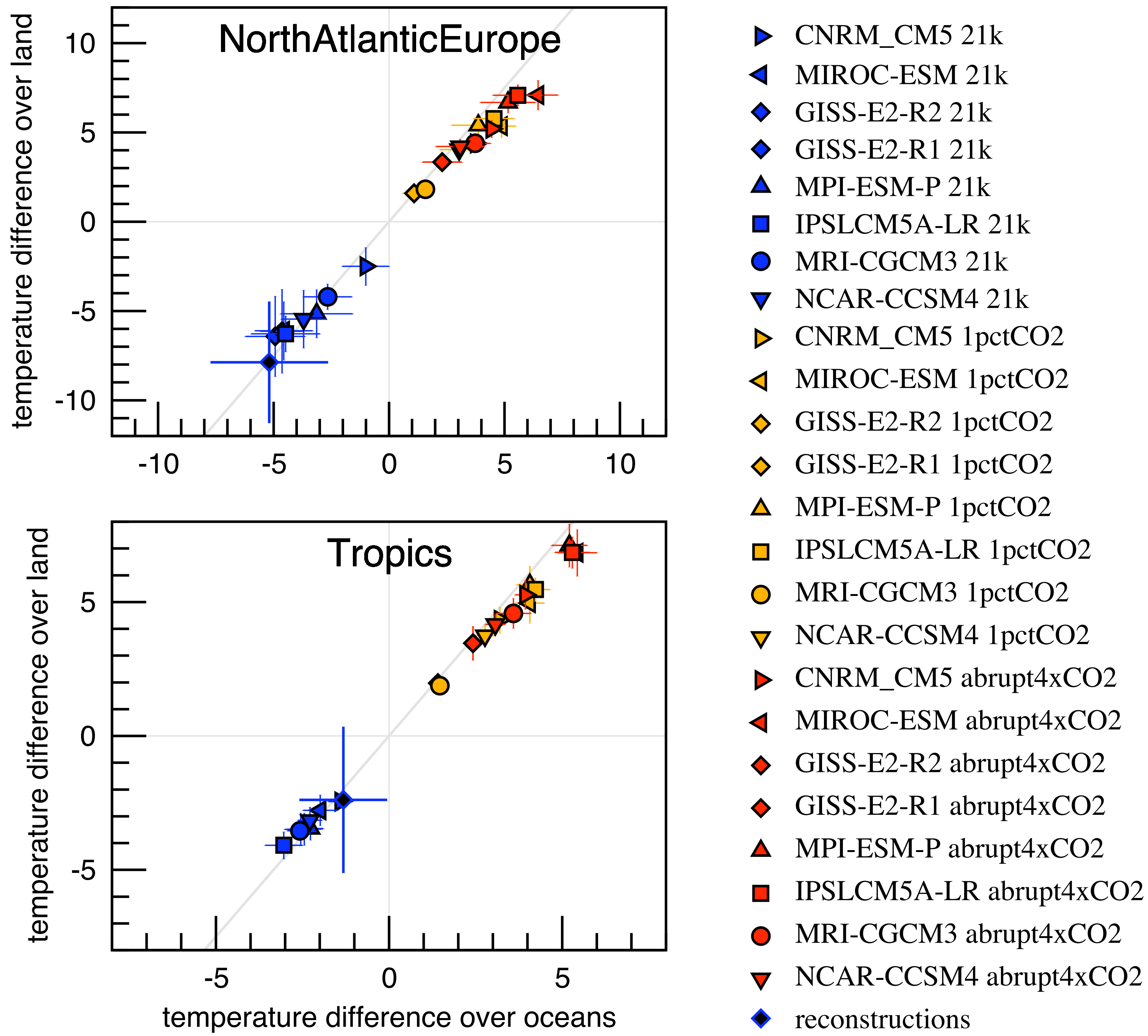


(Harrison et al, subm.)

Regional Land-Ocean contrasts

Relationship btw. land and ocean temperatures in two regions N. Atl/ Europe and the Tropics.

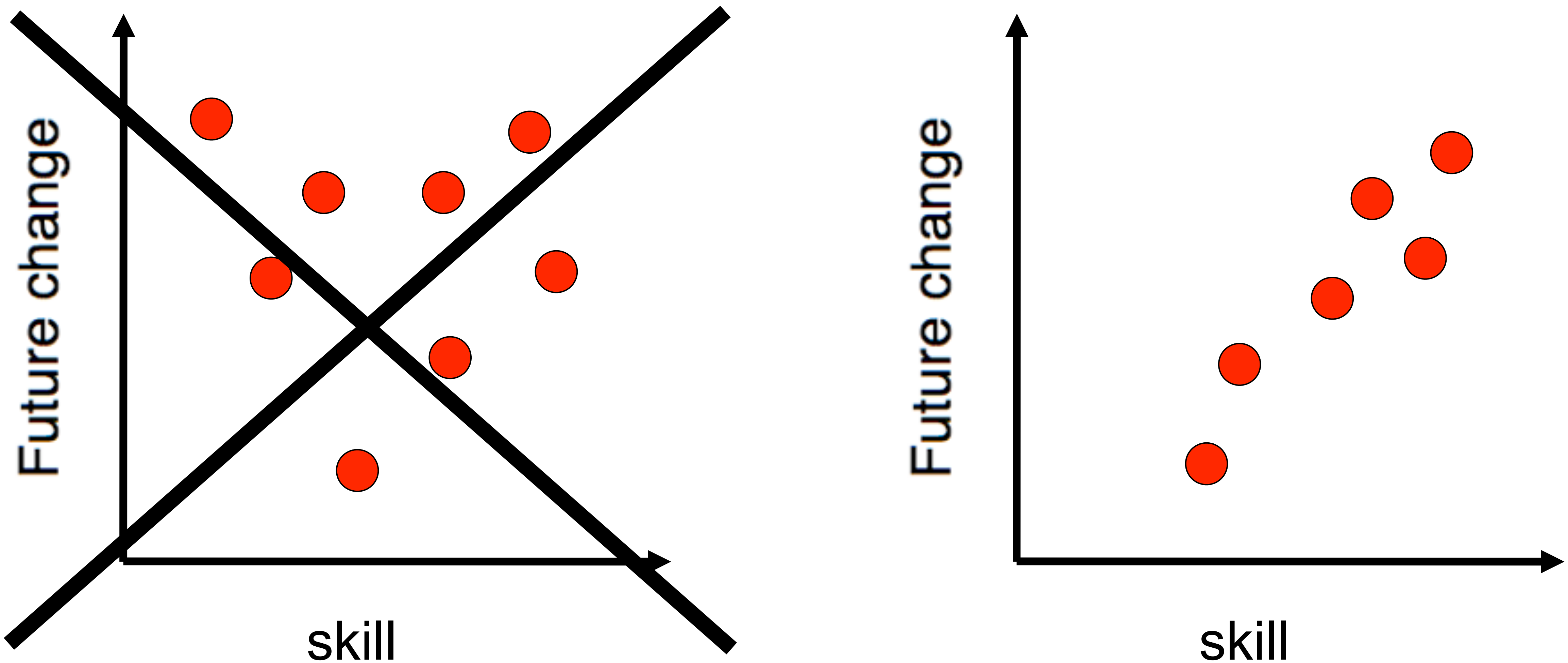
Match to LGM reconstructions



Masa Kageyama (pers. comm)

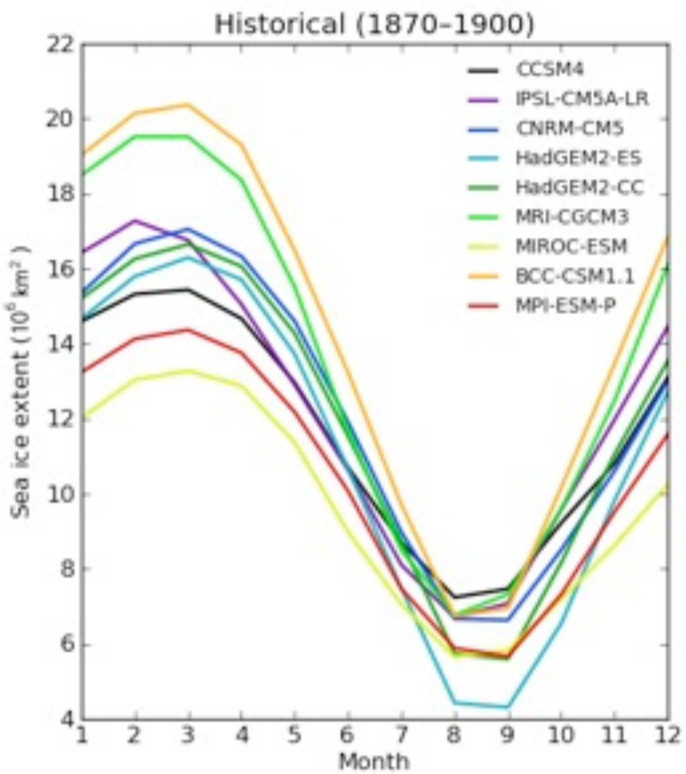
Differentiating projections

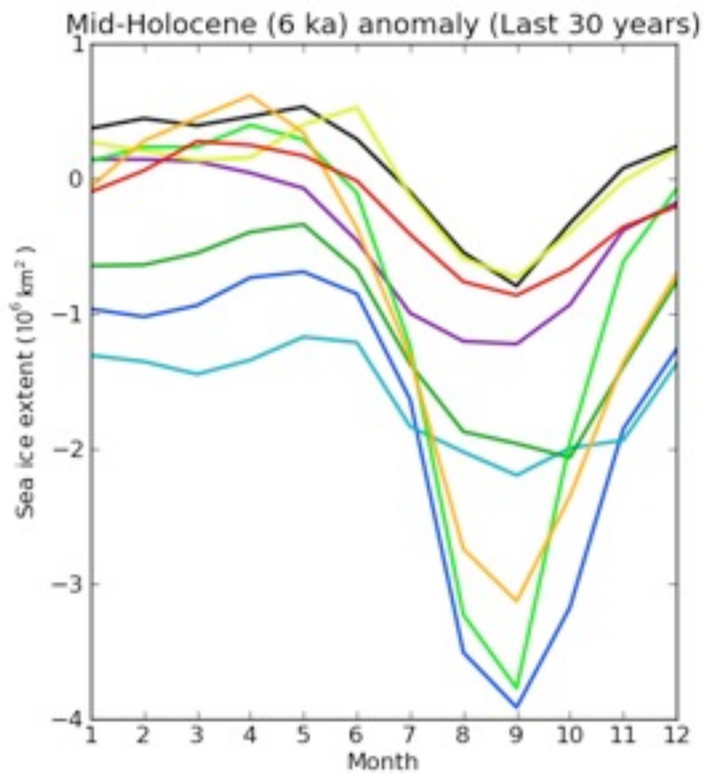
Need correlations of skill scores with future projections...
i.e. does a good simulation of a prior event give any information about future events?

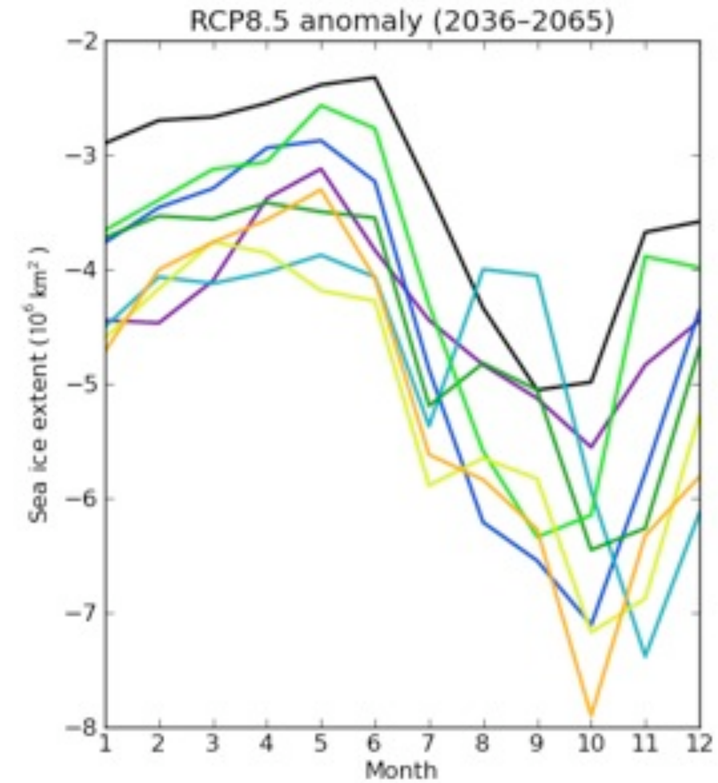


This needs to be demonstrated, not just assumed!

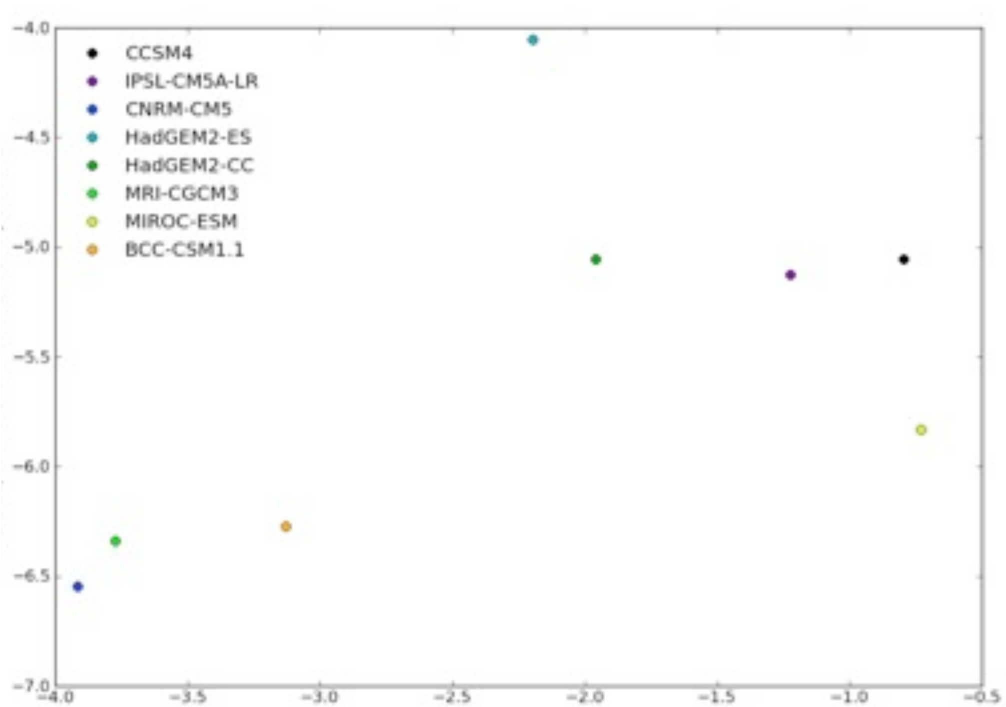
Arctic sea-ice loss constraints from the Mid-Holocene?







RCP8.5



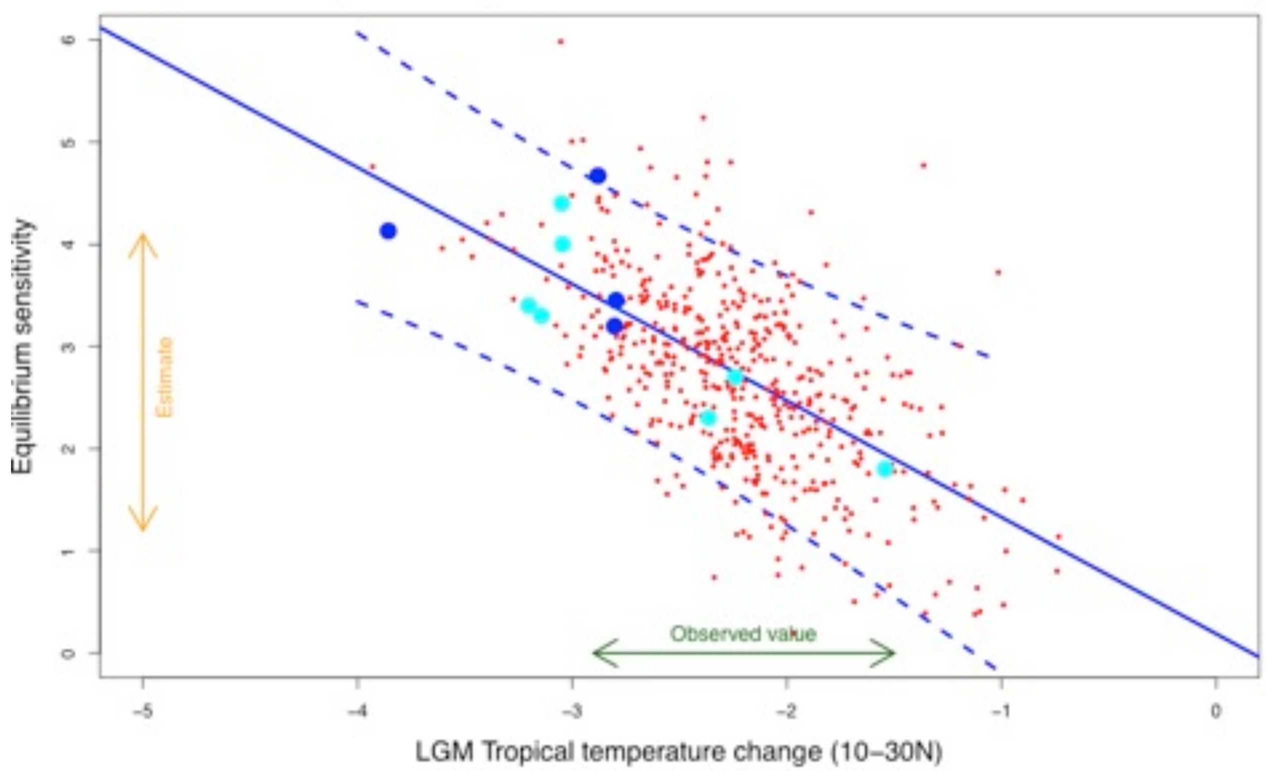
Mid-Holocene

Correlation of Sept sea ice anomaly in MH and RCP8.5 (2036-2065)
(small sample)

(Schmidt et al., in prep)

LGM Climate sensitivity constraints

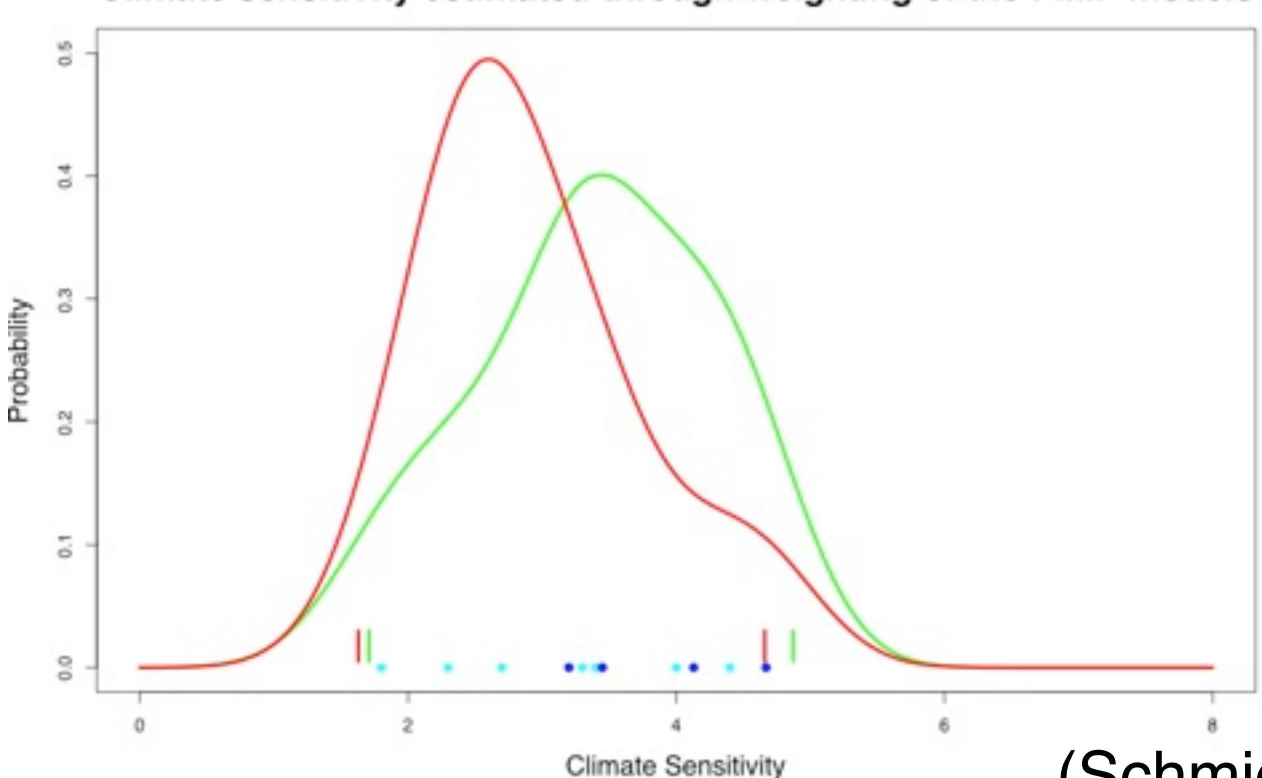
Using LGM Tropical temperature as a constraint on climate sensitivity



Correlation between sensitivity and LGM tropical temperatures

PMIP2+PMIP3+Monte Carlo sample

Climate sensitivity estimated through weighting of the PMIP models

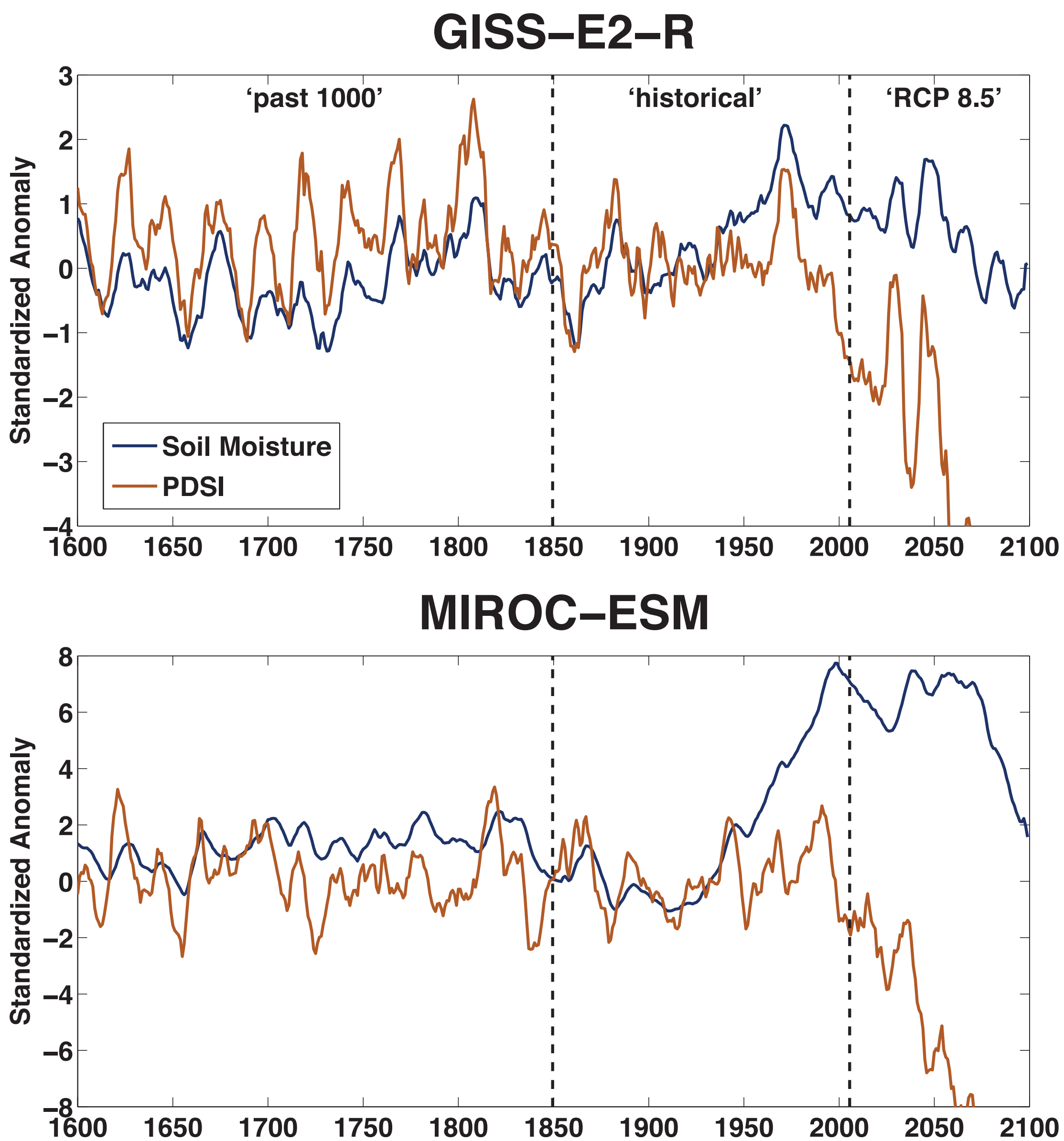


Bayesian weighting of the PMIP models.

Green: prior distribution (equal weighting of the models).
Red: posterior distribution, after weighting according to tropical temperature.

(Schmidt et al, in prep; Annan and Hargreaves, subm.)

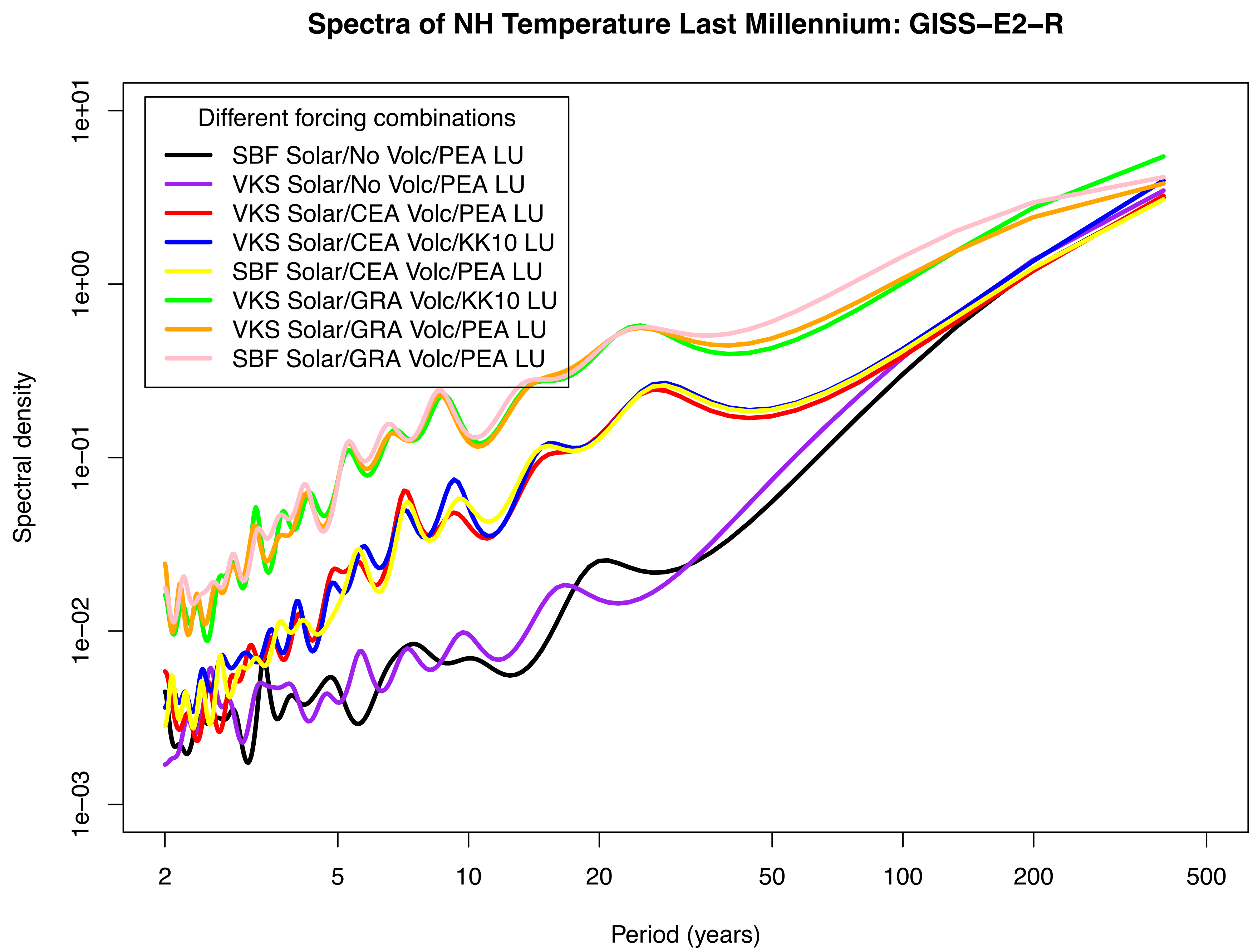
Some metrics are not robust



PDSI and Soil Moisture diverge in periods of strong warming - thus correlations in historical simulations may not continue.

Schmidt et al, in prep

Some metrics too sensitive to uncertain forcing



Last Millennium spectra strongly dependent on uncertain forcings *and* model internal variability - mismatchs not yet attributable.

Conclusions

- Multi-model ensemble does a reasonable job at simulating 3 key periods despite some systematic differences
- Note this is an ‘out-of-sample’ test of these models - important for establishing credibility of projections
- Many climate features are robust across past and future
- Some constraints on future projections but more needs to be done
- Paleo component in CMIP5 very positive development - needs to be expanded (more flexible mechanism for CMIP6?)
    - Other useful periods: Pliocene, last interglacial, 8.2kyr event
- More facilities for process-based diagnostics are required (across all of CMIP5)