

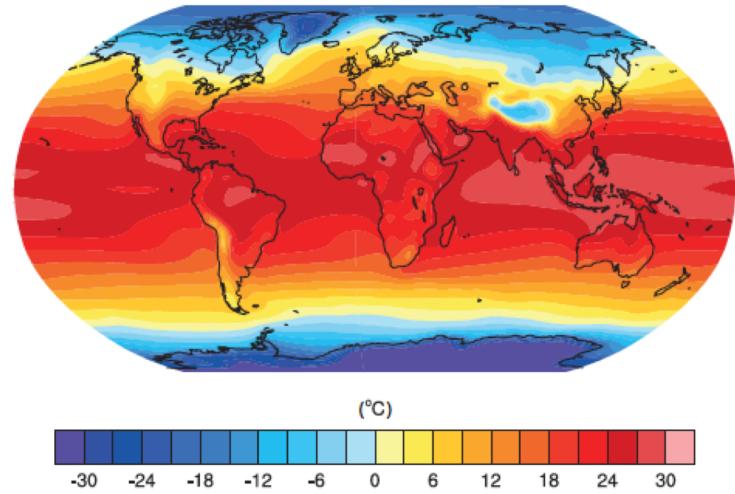
How skillful are climate models?

Key questions to keep in mind:

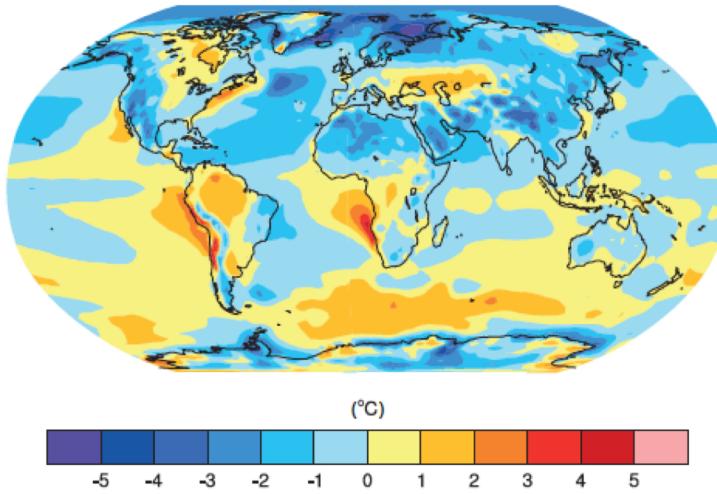
- How do we define skill?
- When is a model adequately skilled for the question at hand?
- Has model skill improved over the last 40 years?
- Can we increase confidence in models with out-of-sample evaluation?

How accurate is the mean state climate in models?

(a) Multi Model Mean Surface Temperature

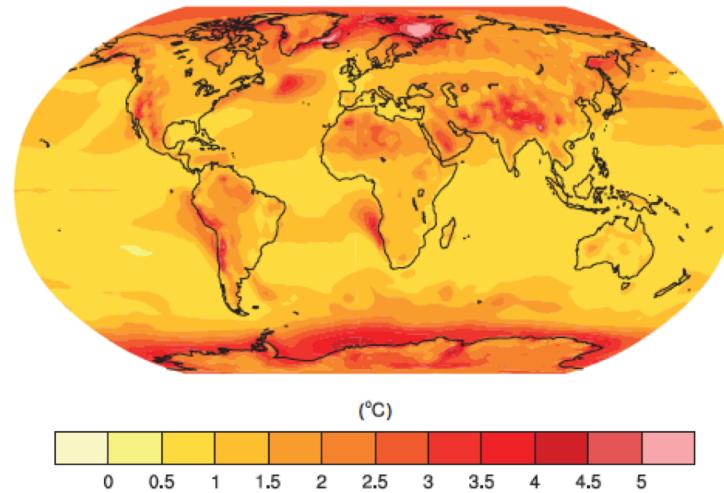


(b) Multi Model Mean Bias

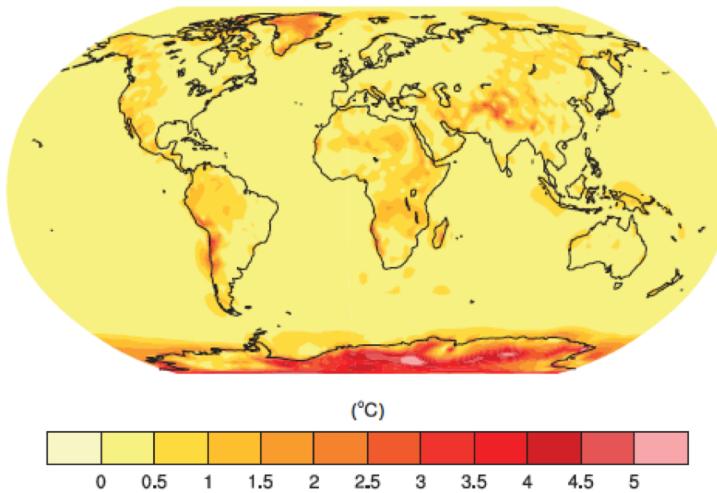


Pretty good for temperature

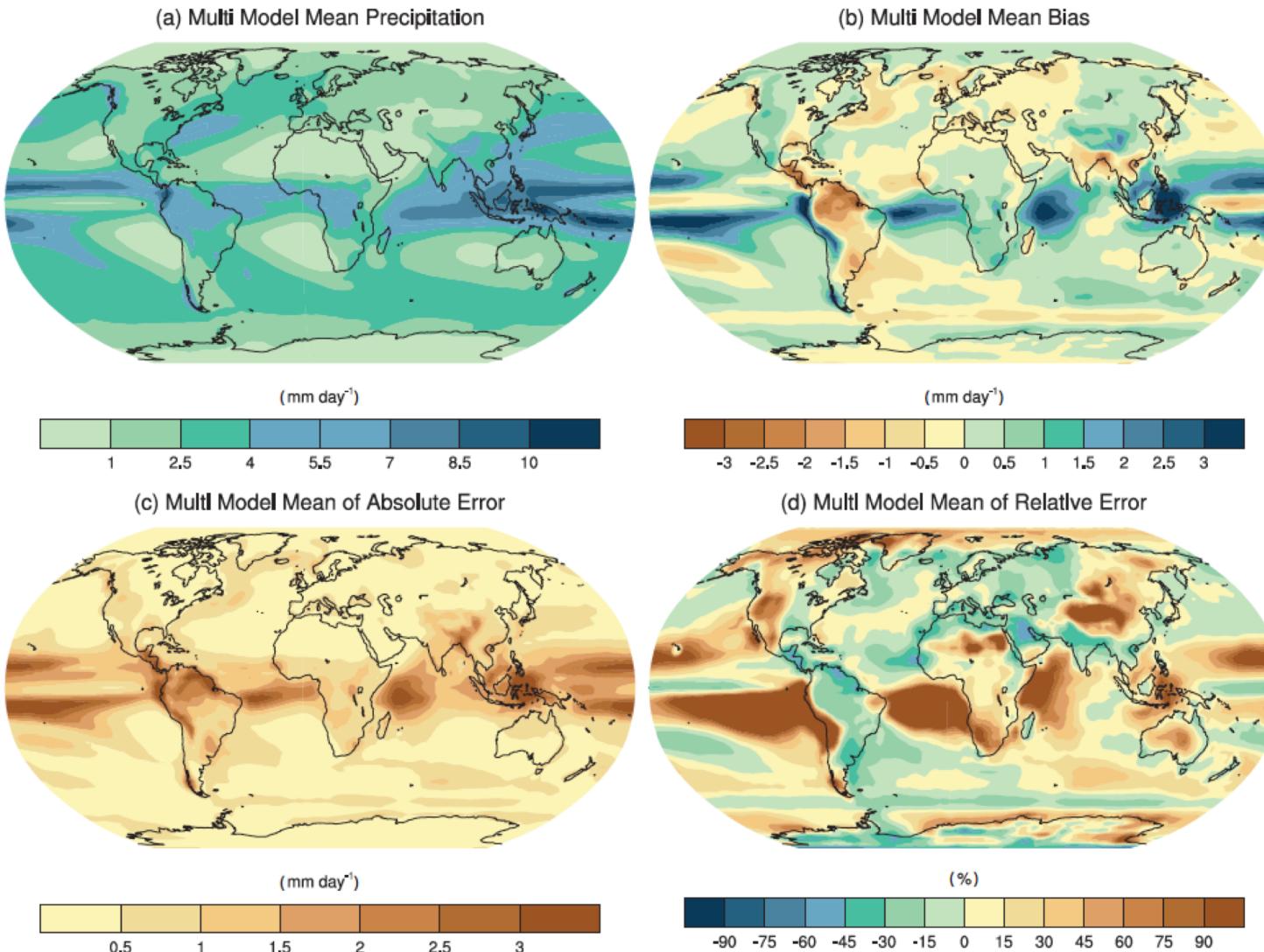
(c) Multi Model Mean of Absolute Error



(d) Mean Reanalysis Inconsistency



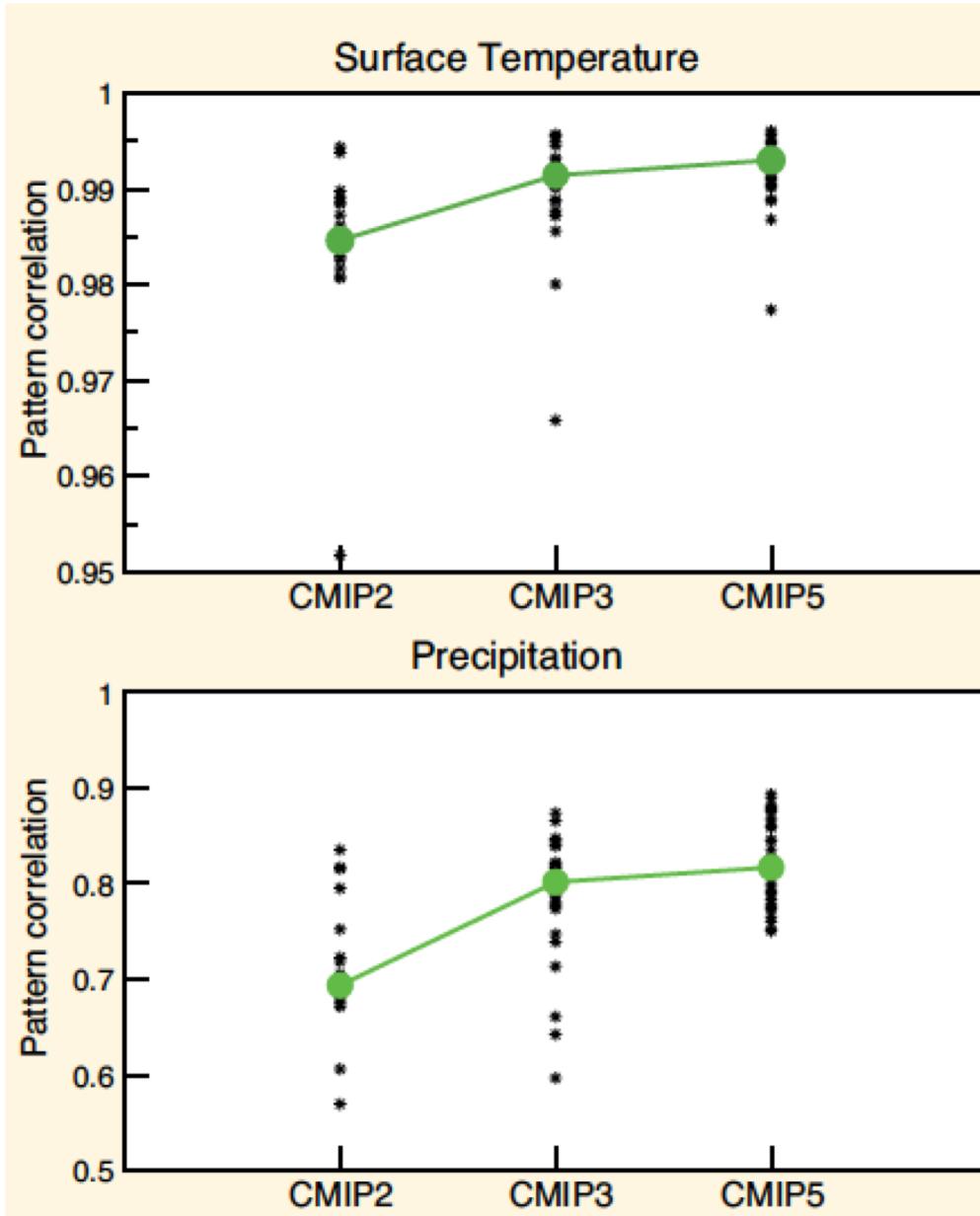
How accurate is the mean state climate in models?



Pretty bad for mean precipitation
(drizzle problem mentioned by
Paul O'Gorman)

Figure 9.4 | Annual-mean precipitation rate (mm day^{-1}) for the period 1980–2005. (a) Multi-model-mean constructed with one realization of all available AOGCMs used in the CMIP5 historical experiment. (b) Difference between multi-model mean and precipitation analyses from the Global Precipitation Climatology Project (Adler et al., 2003). (c) Multi-model-mean absolute error with respect to observations. (d) Multi-model-mean error relative to the multi-model-mean precipitation itself.

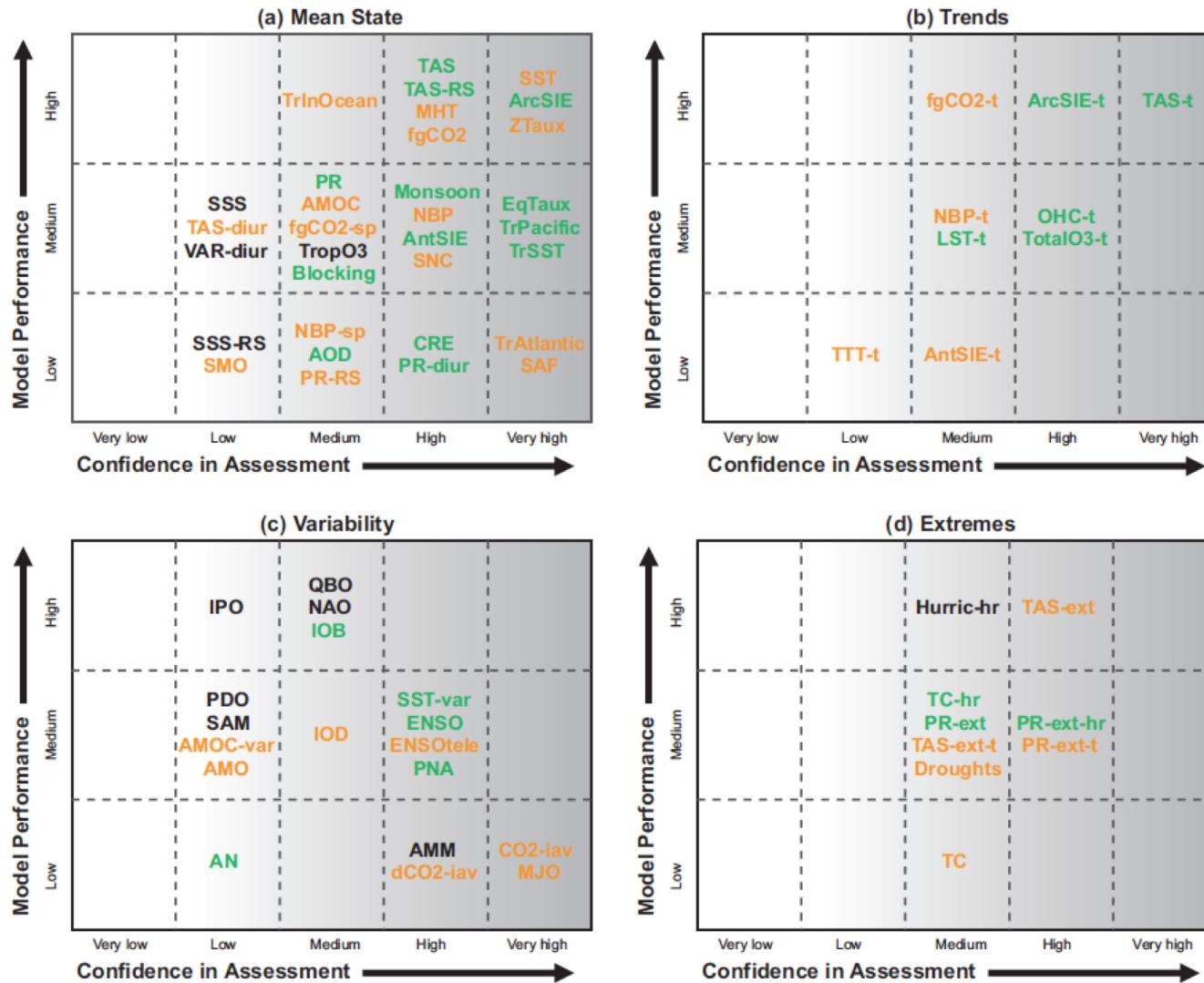
Has the mean climate state in models improved?



Yes! Models are getting better.

The best, median, mean, and worst models all improve every model generation.

Have climate models improved with respect to other metrics?



Yes, climate model skill has improved (or stagnated) by all metrics considered.

Degradation since CMIP3
No changes since CMIP3
Improvements since CMIP3
No relative assessment CMIP3 vs. CMIP5

Potential problem:

Are climate models only skillful / improving because they are being over-fit to historical observations?

Answer 1: No, that's not how model development (and tuning) works. Tuning is mostly guided by physical principles like radiative balance at pre-industrial equilibrium, not by minimizing mismatch between observations and models

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Practice and philosophy of climate model tuning across six U.S. modeling centers

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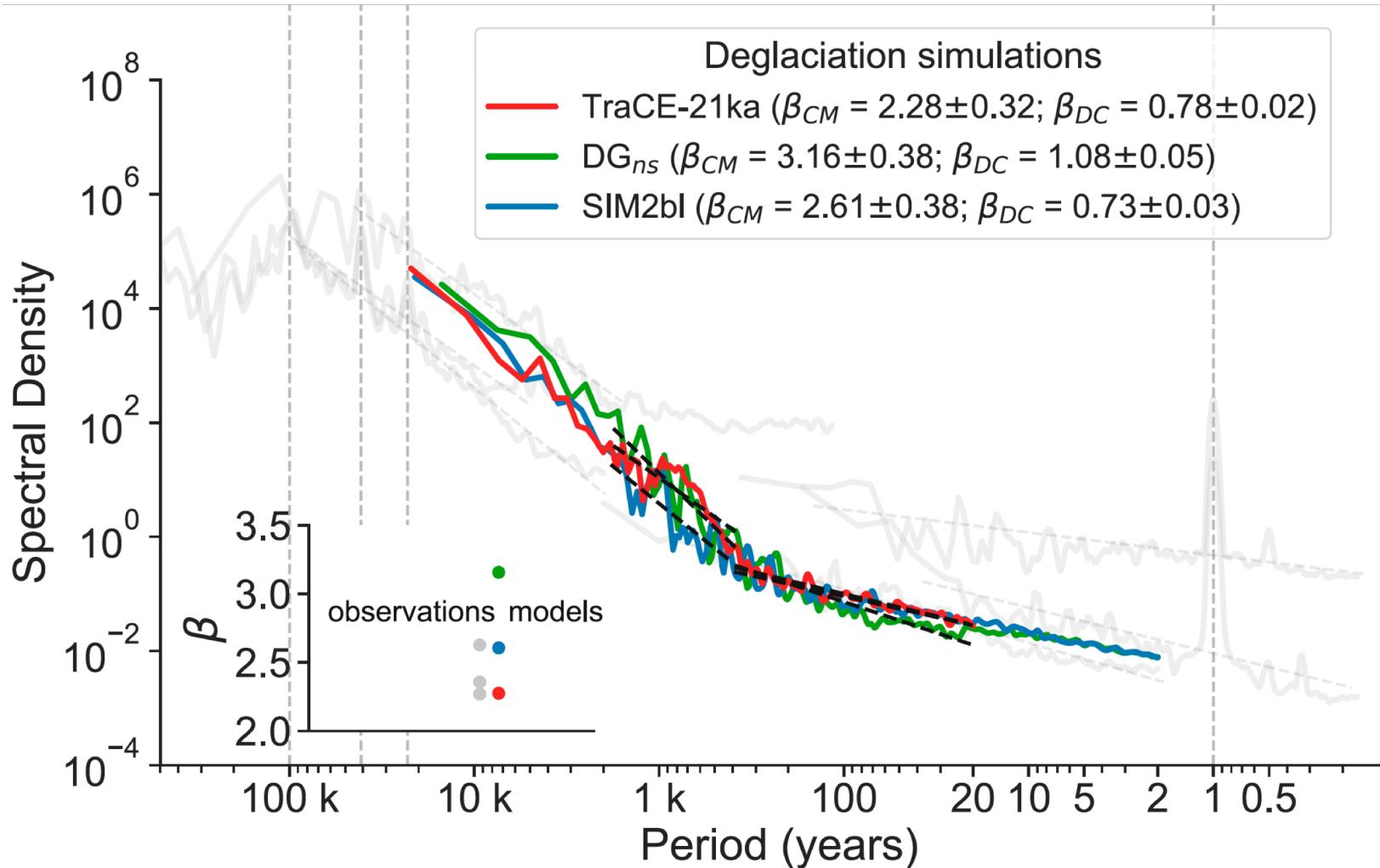
Potential problem:

Are climate models only skillful / improving because they are being over-fit to historical observations?

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Answer 2: No, we can test models with pseudo-out-of-sample comparisons (with paleoclimate proxies) and truly out-of-sample comparisons (retrospective analysis of “future” projections)

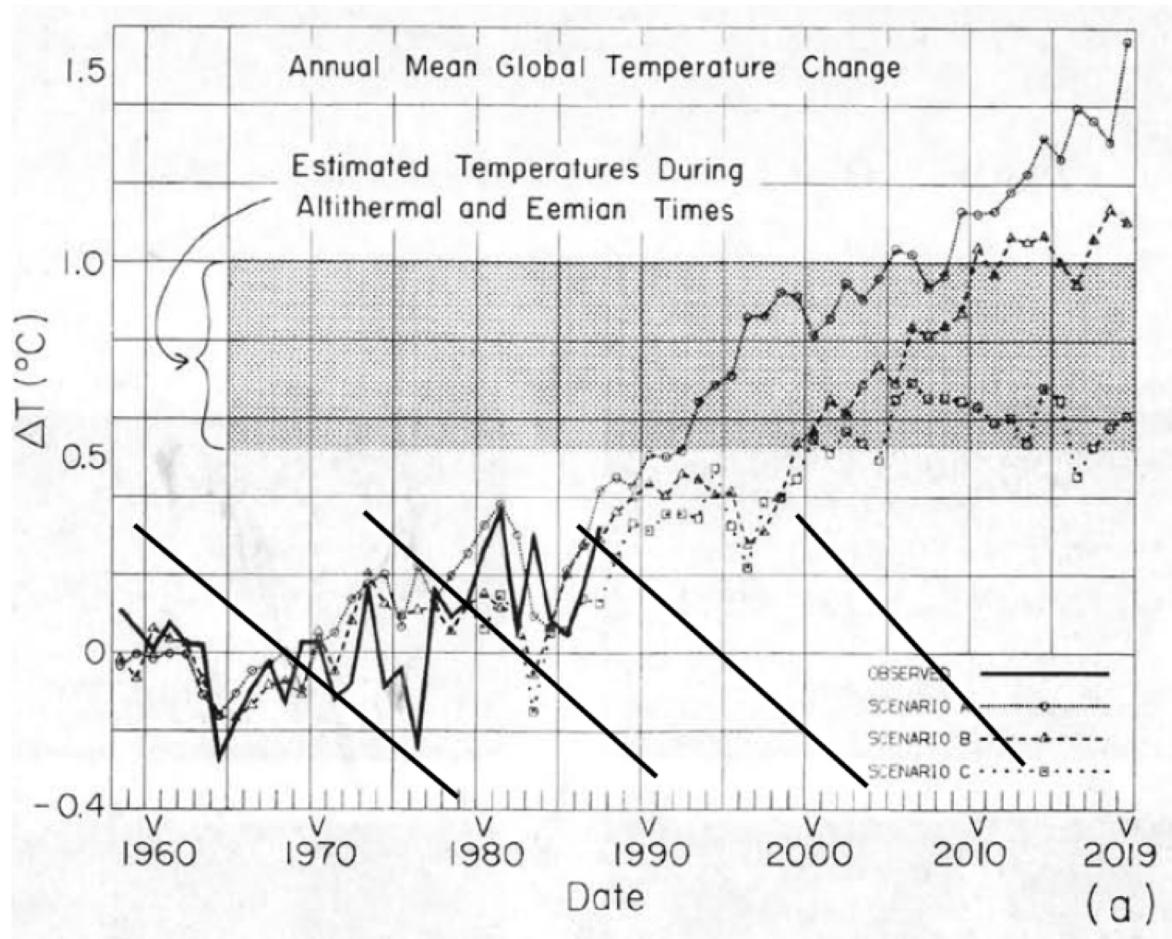
Pseudo-out-of-sample comparison



Models accurately reproduce global-mean temperature variability on all timescales (from combination of direct measurements for < 100 year timescales and paleo-proxies for > 100 year timescales).

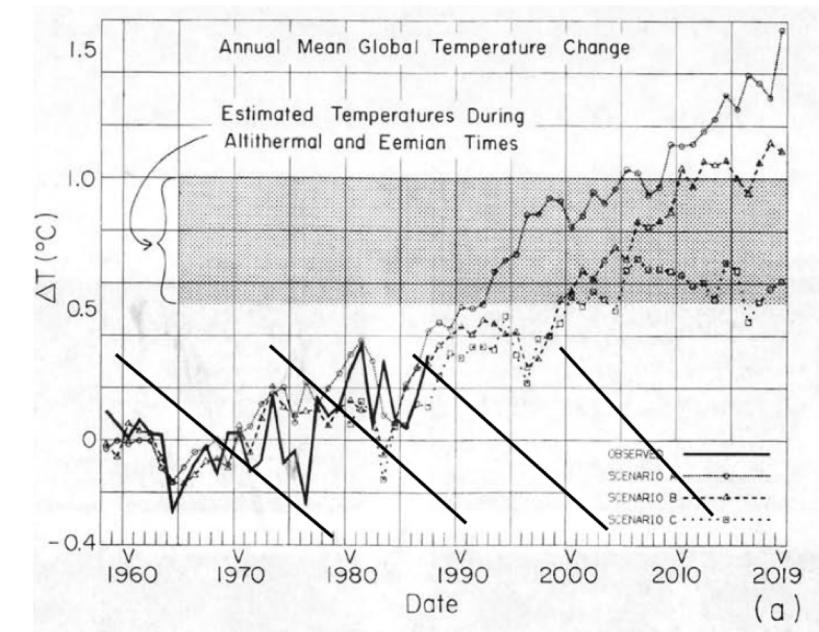
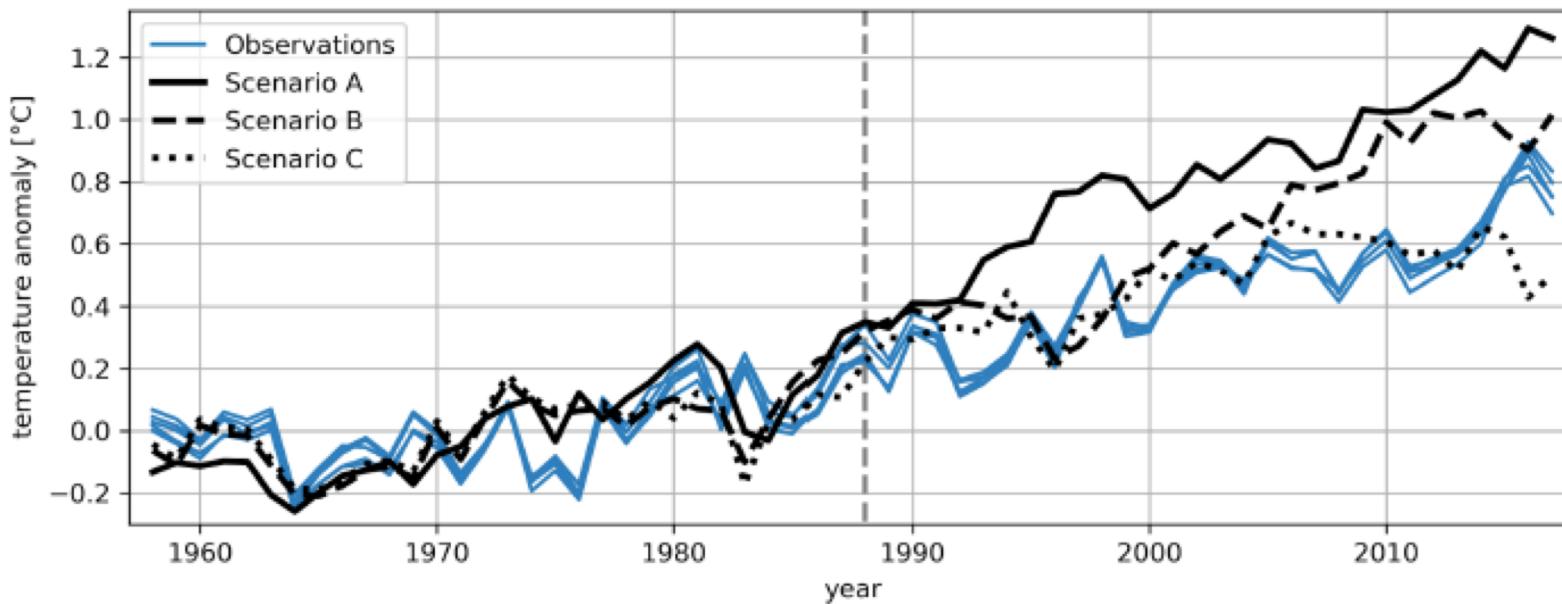
True out-of-sample comparison

Looking back at Hansen et al. 1988

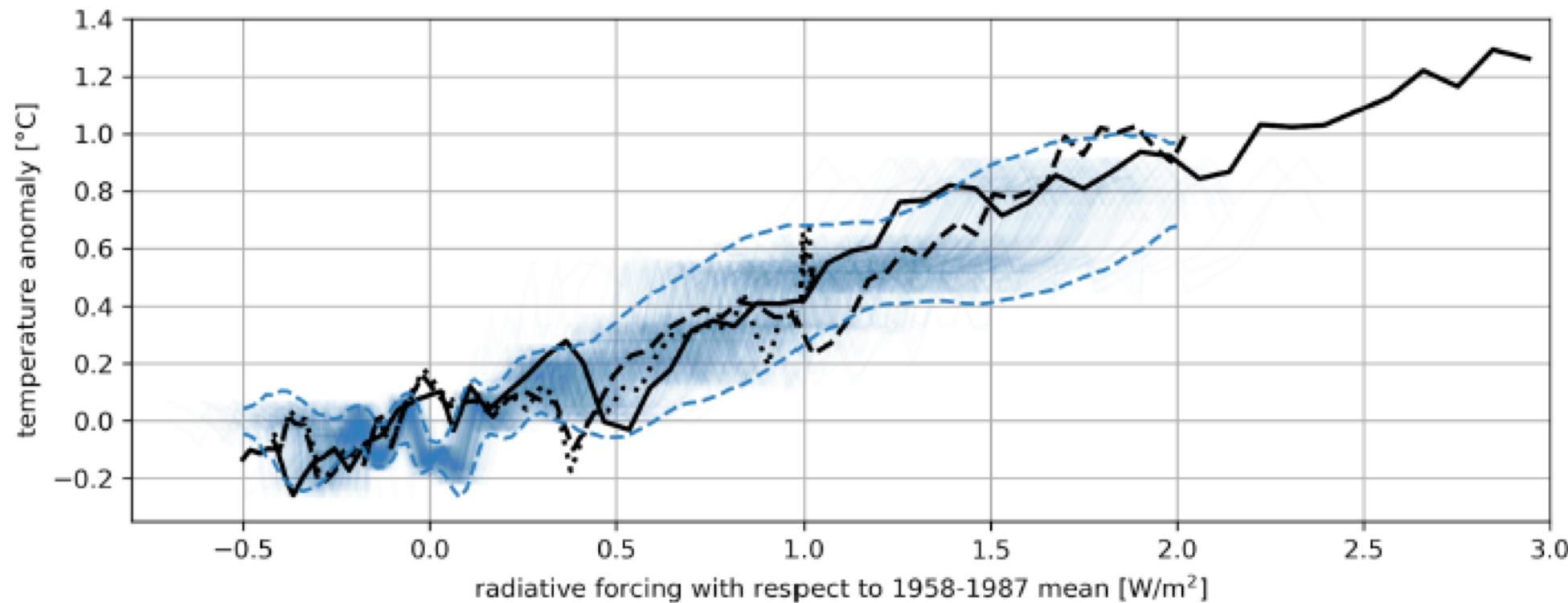


True out-of-sample comparison

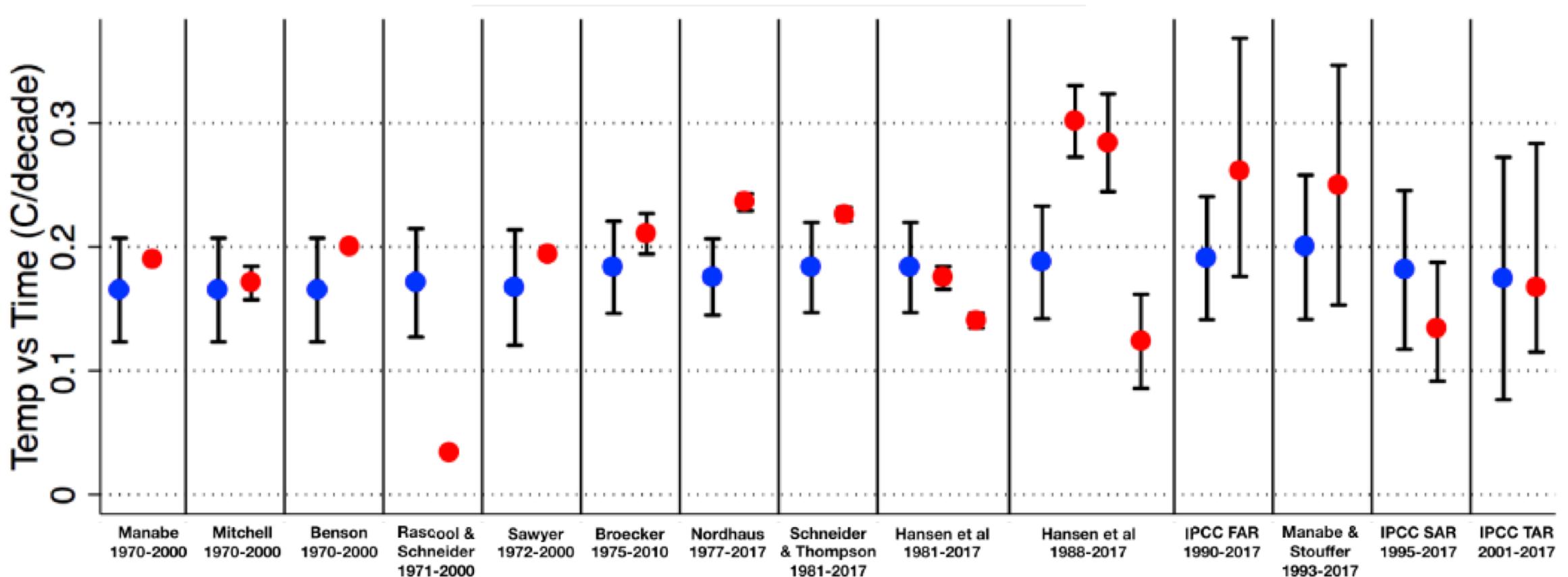
Looking back at Hansen et al. 1988



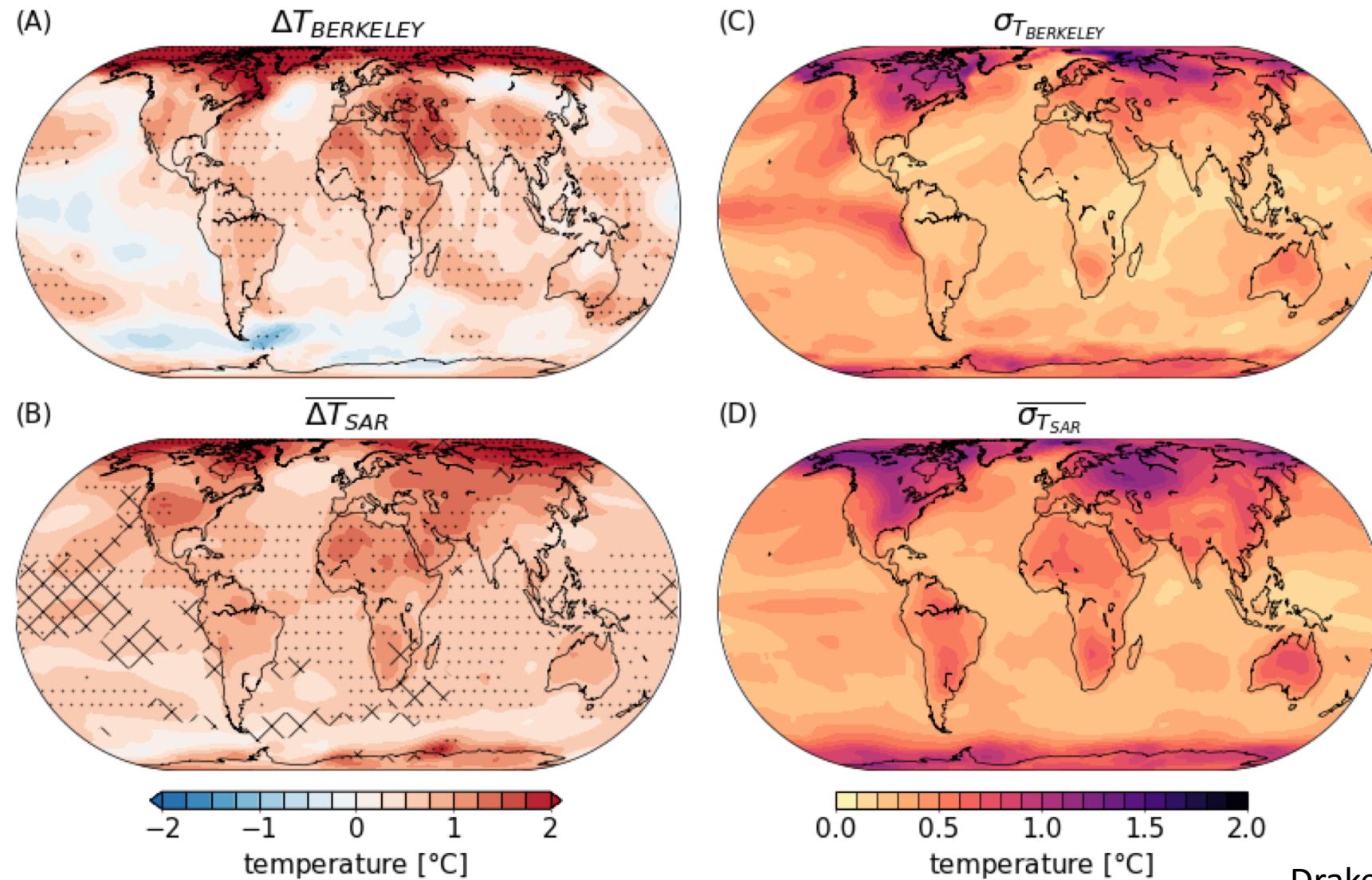
“Apples-to-simulated-apples” comparison



Comprehensive review of all out-of-sample global-warming projections



True out-of-sample comparison of warming patterns



Conclusions

- Models accurately simulate *past* global-mean temperature and variability at all timescales and accurately project *future* global-mean surface temperature
- Models accurately simulate the spatial patterns and magnitudes of mean state temperature and trends, but there is still room for improvement
- Models accurately simulate the general patterns of precipitation and other thermodynamic variables, but struggle with their magnitude, variability, and response to warming.