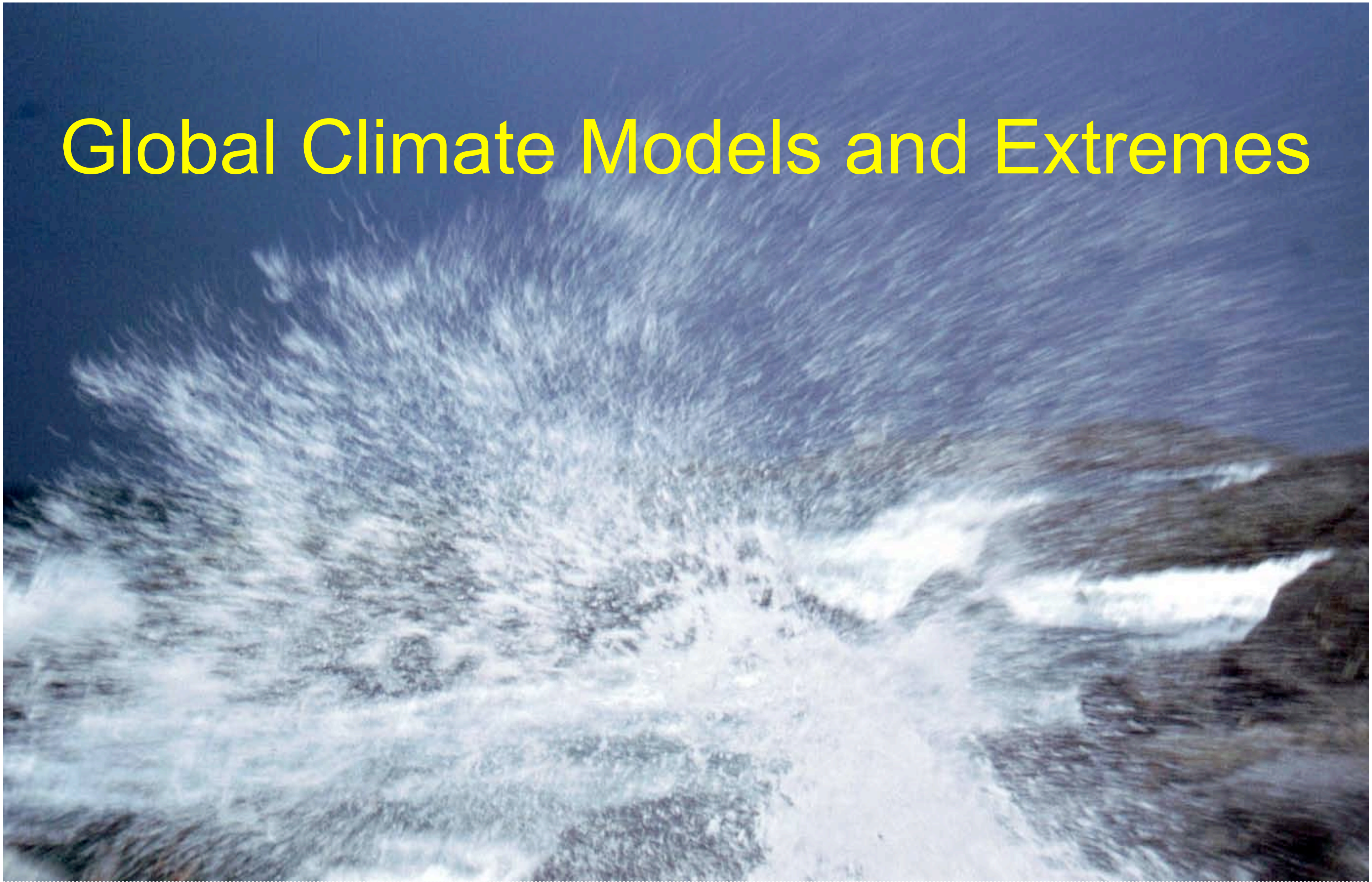
Global Climate Models and Extremes

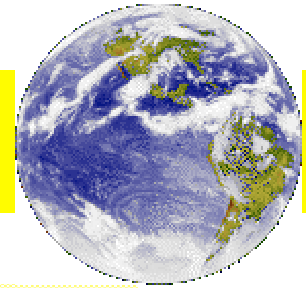


Francis Zwiers[1], Slava Kharin[1], Xuebin Zhang[1], Gabi Hegerl[2]

[1]Environment Canada, [2]Duke University

Photo: F. Zwiers

Outline



- AMIP2 simulations (subtopic 2)
- IPCC AR4 inter-comparisons (subtopic 2)
- Some musing on methodology (subtopics 1 and 3).

Suggested Question IV Subtopics:

(1) Can extremes be used in detection/attribution studies?

(2) Which variables are known with the most confidence when discussing extremes?

(3) How can we achieve better quantification using the statistical theory of extremes?

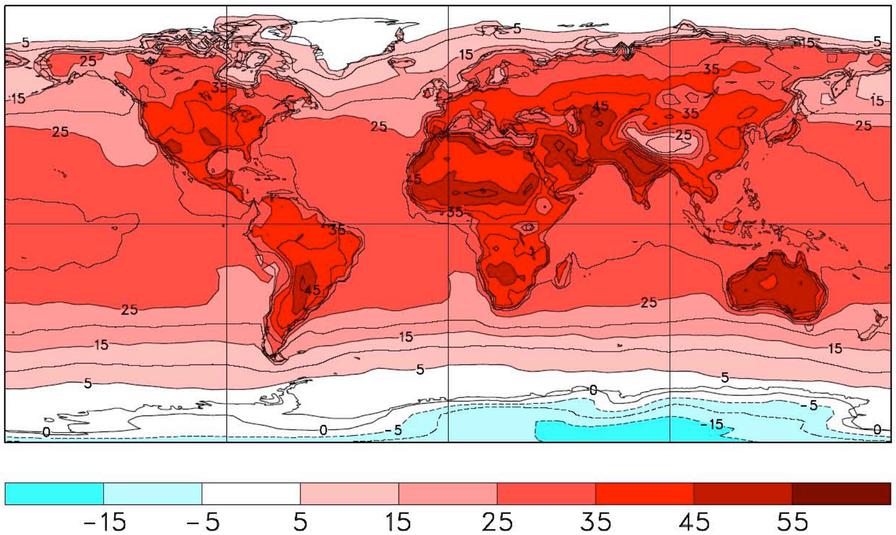
AMIP2 inter-comparison: How well do atmospheric models perform?

- AMIP2
  - 17 year simulations (1979-1996)
  - Prescribed observed SSTs (time evolving)
  - 30 models participating
- We have
  - Daily TAS data from 12 models
  - Daily PCP data from 16 models

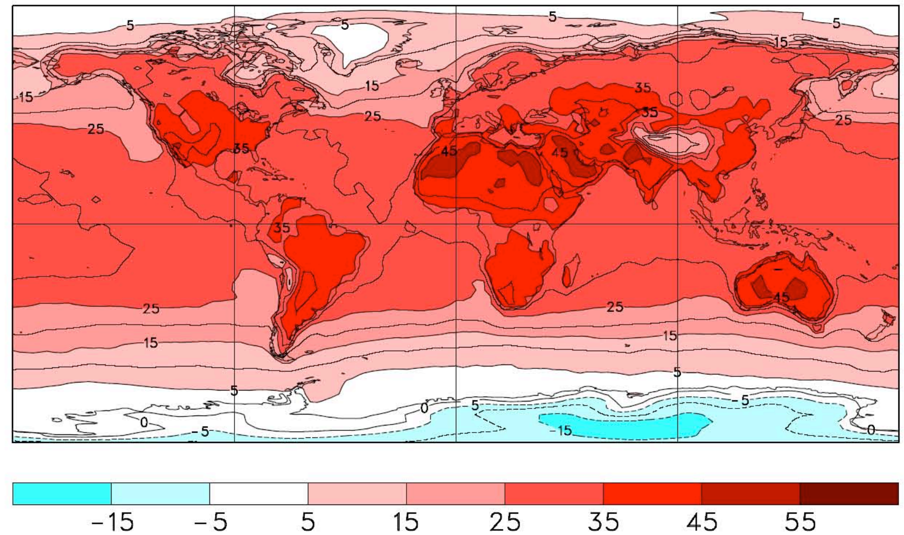
Kharin et al, J. Climate, in press

20-year T_{max} extremes

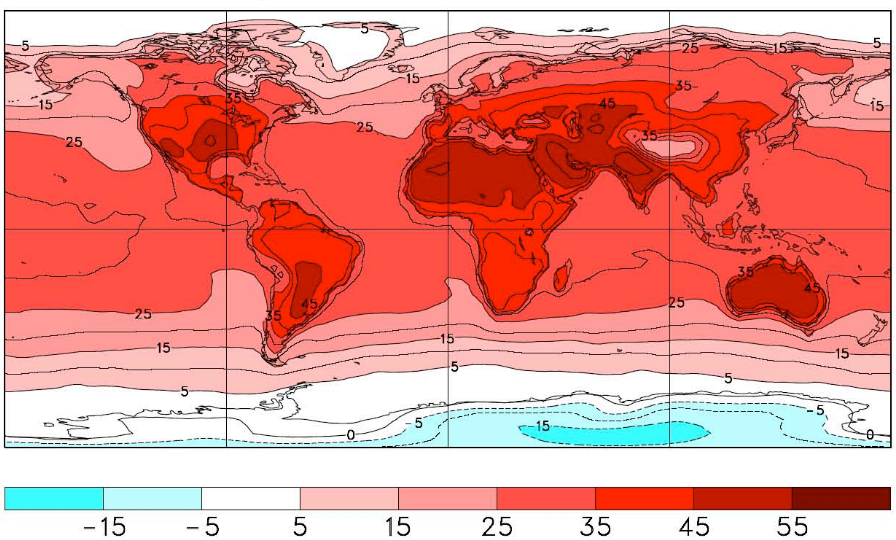
$T_{max,20}$, 1979-95 NCEP2 reanalysis



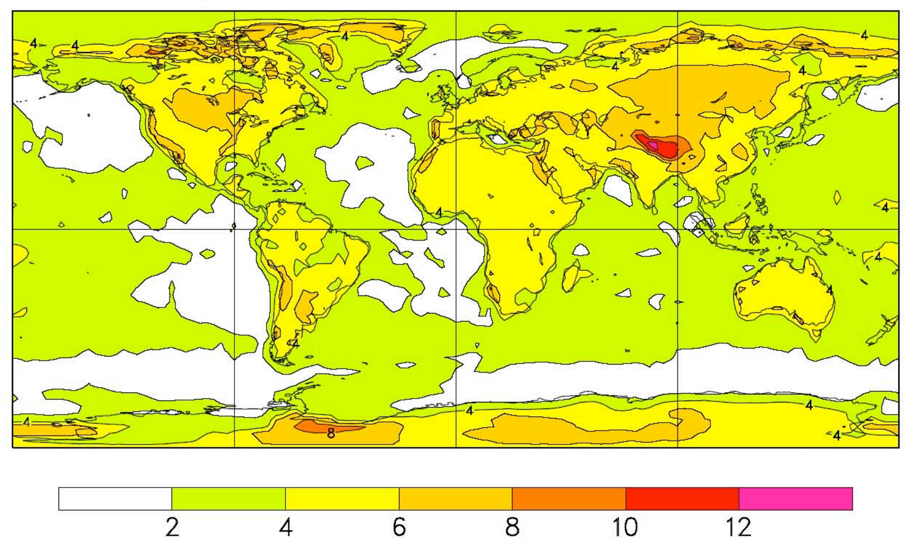
$T_{max,20}$, 1979-95 ERA-40 reanalysis



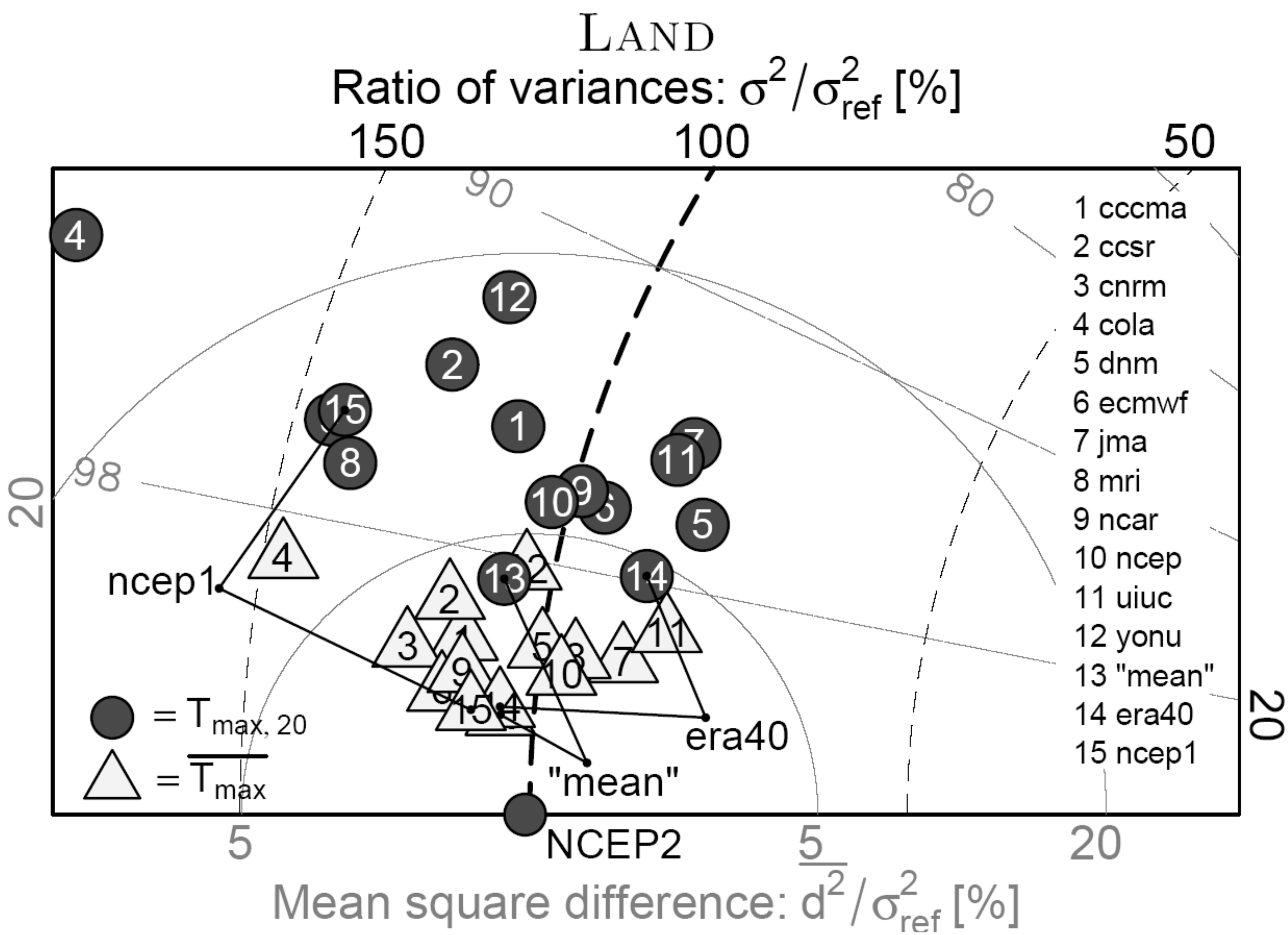
$T_{max,20}$, AMIP-2 "mean model"



$T_{max,20}$, AMIP-2 standard deviation

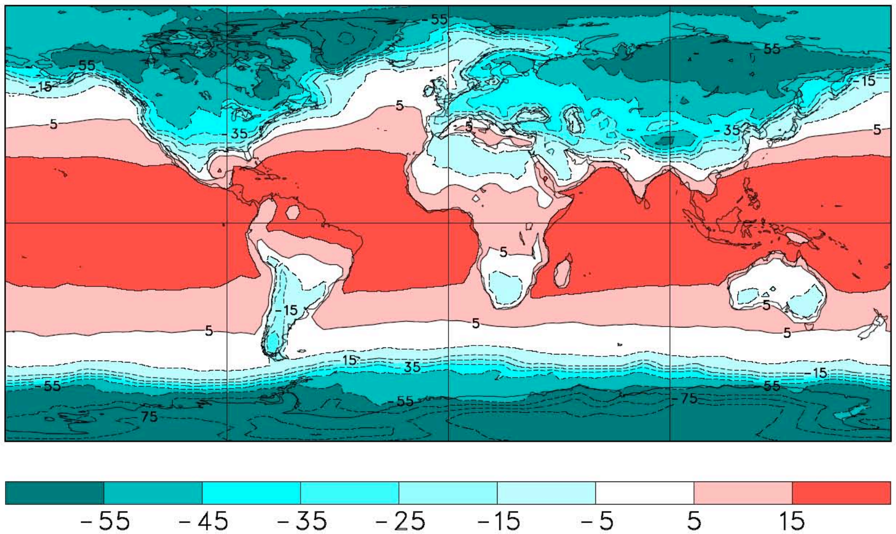


AMIP2 T_{max} performance relative to NCEP2

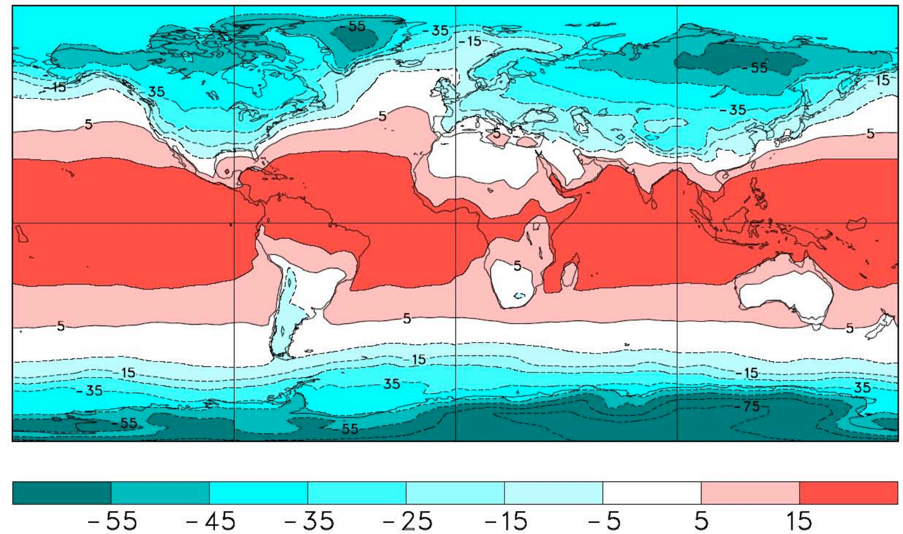


20-year T_{min} extremes

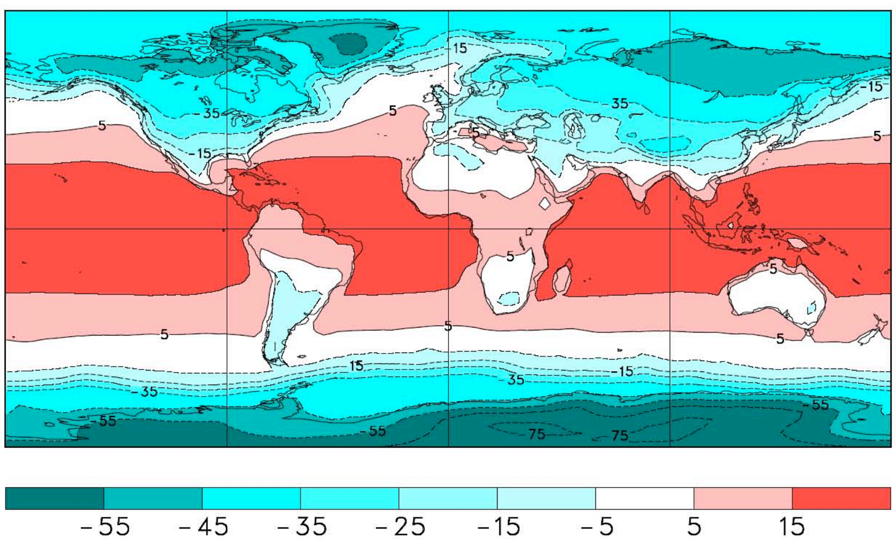
$T_{min,20}$, 1979-95 NCEP2 reanalysis



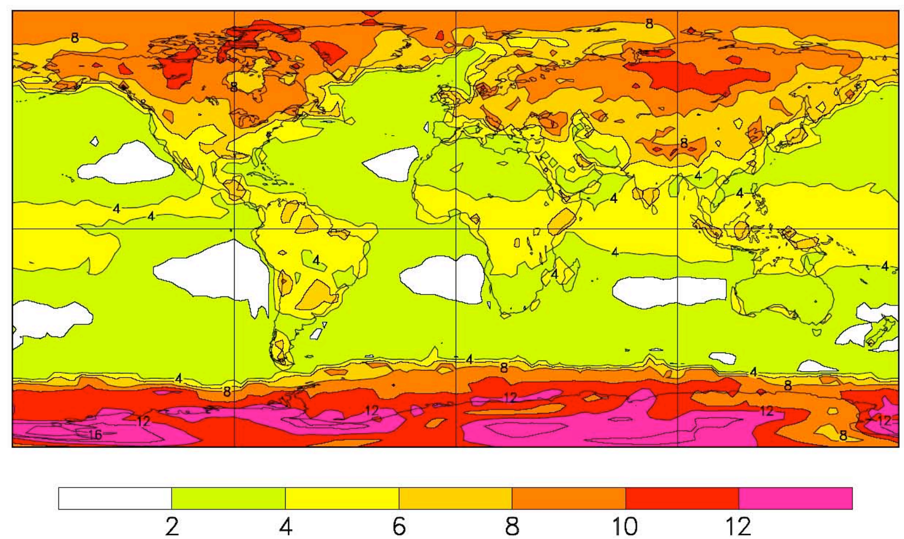
$T_{min,20}$, 1979-95 ERA-40 reanalysis



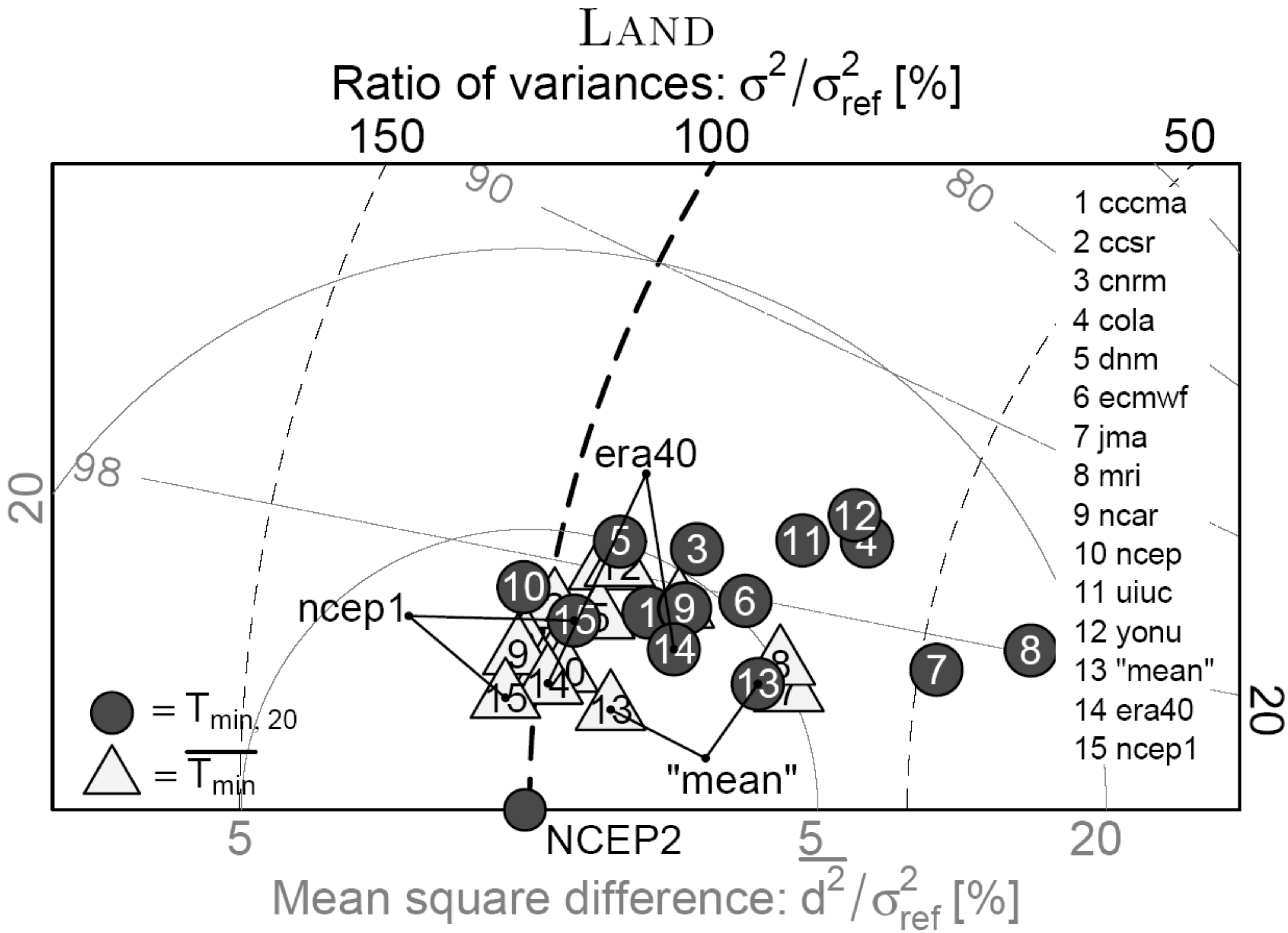
$T_{min,20}$, AMIP-2 "mean model"



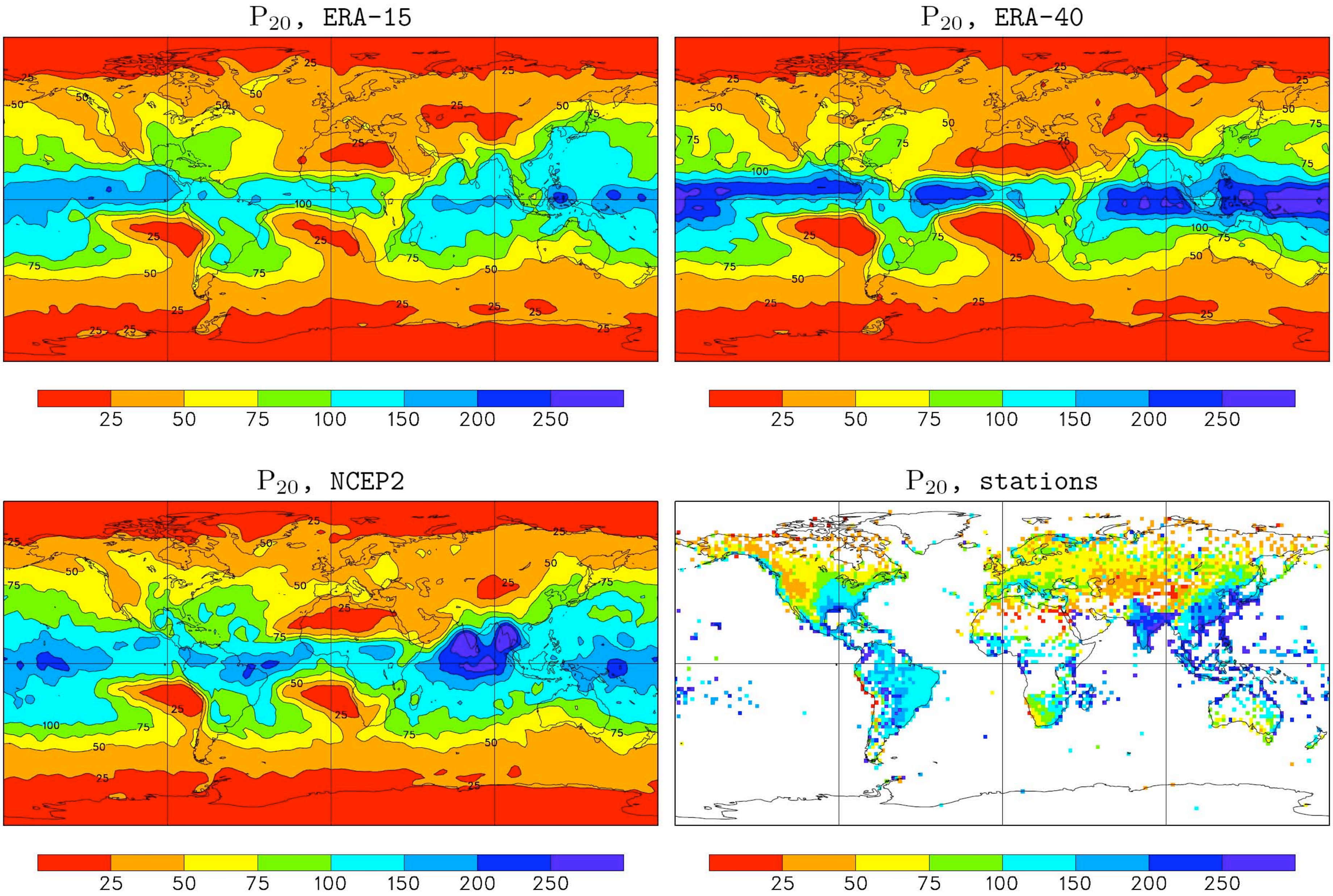
$T_{min,20}$, AMIP-2 standard deviation



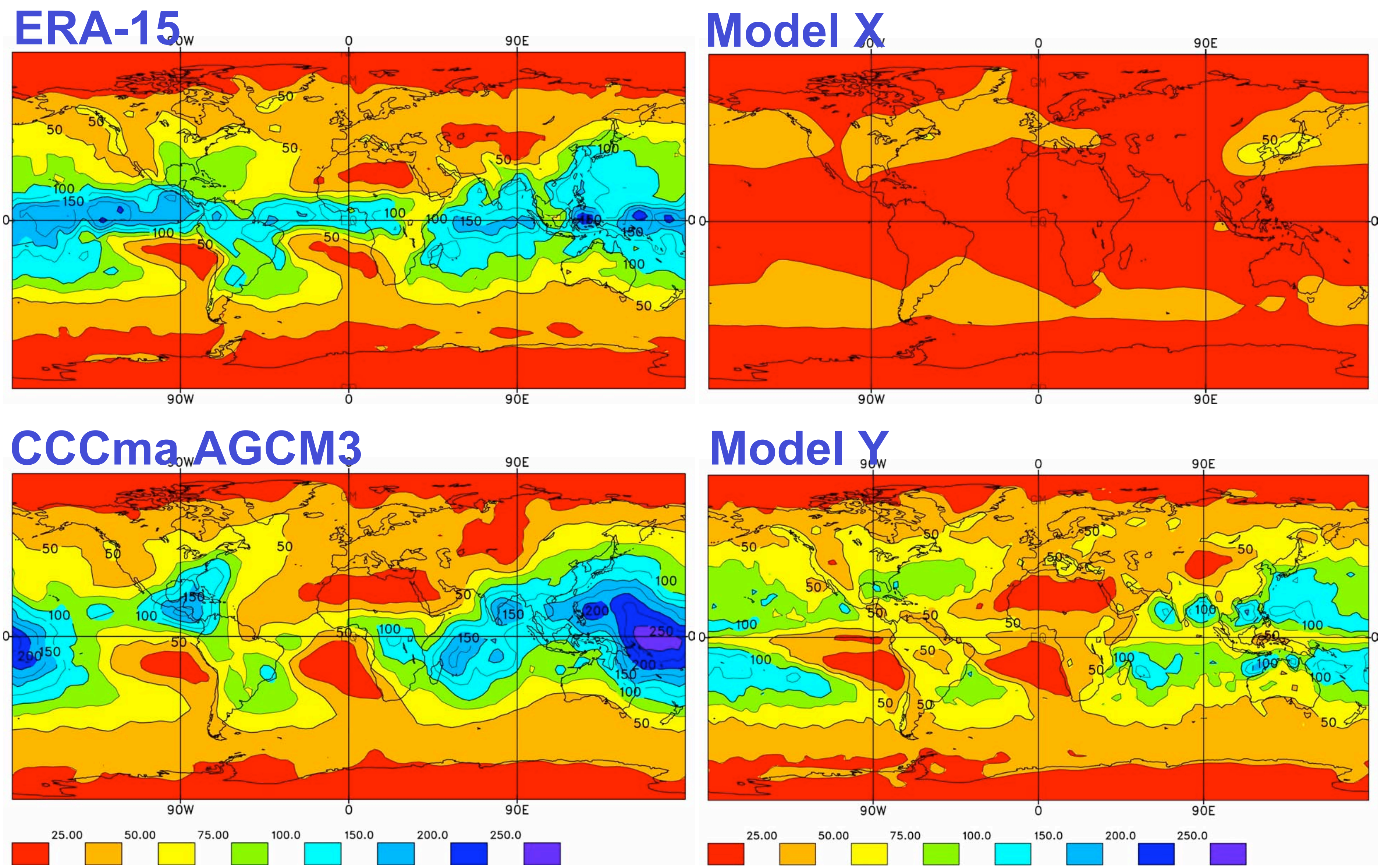
AMIP2 T_{min} performance relative to NCEP2



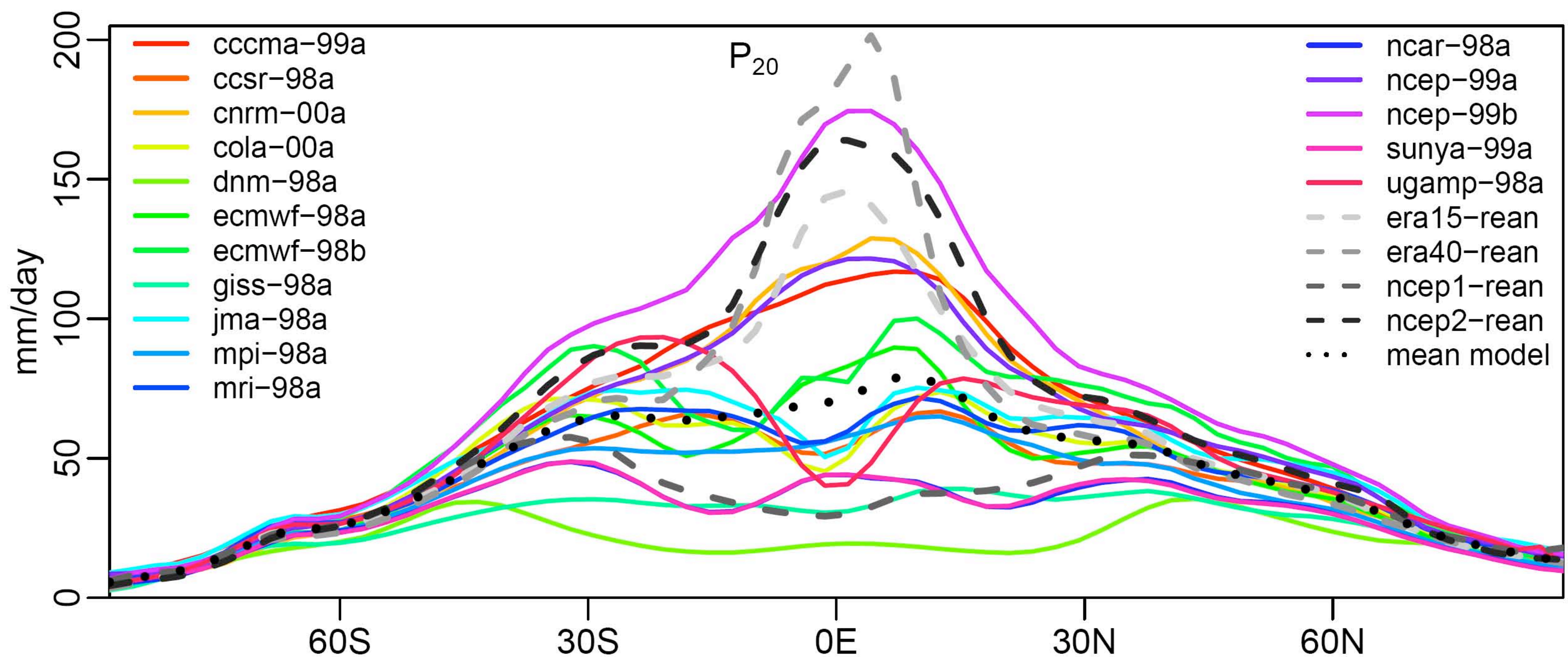
20-year 24-hour PCP extremes – from "obs"



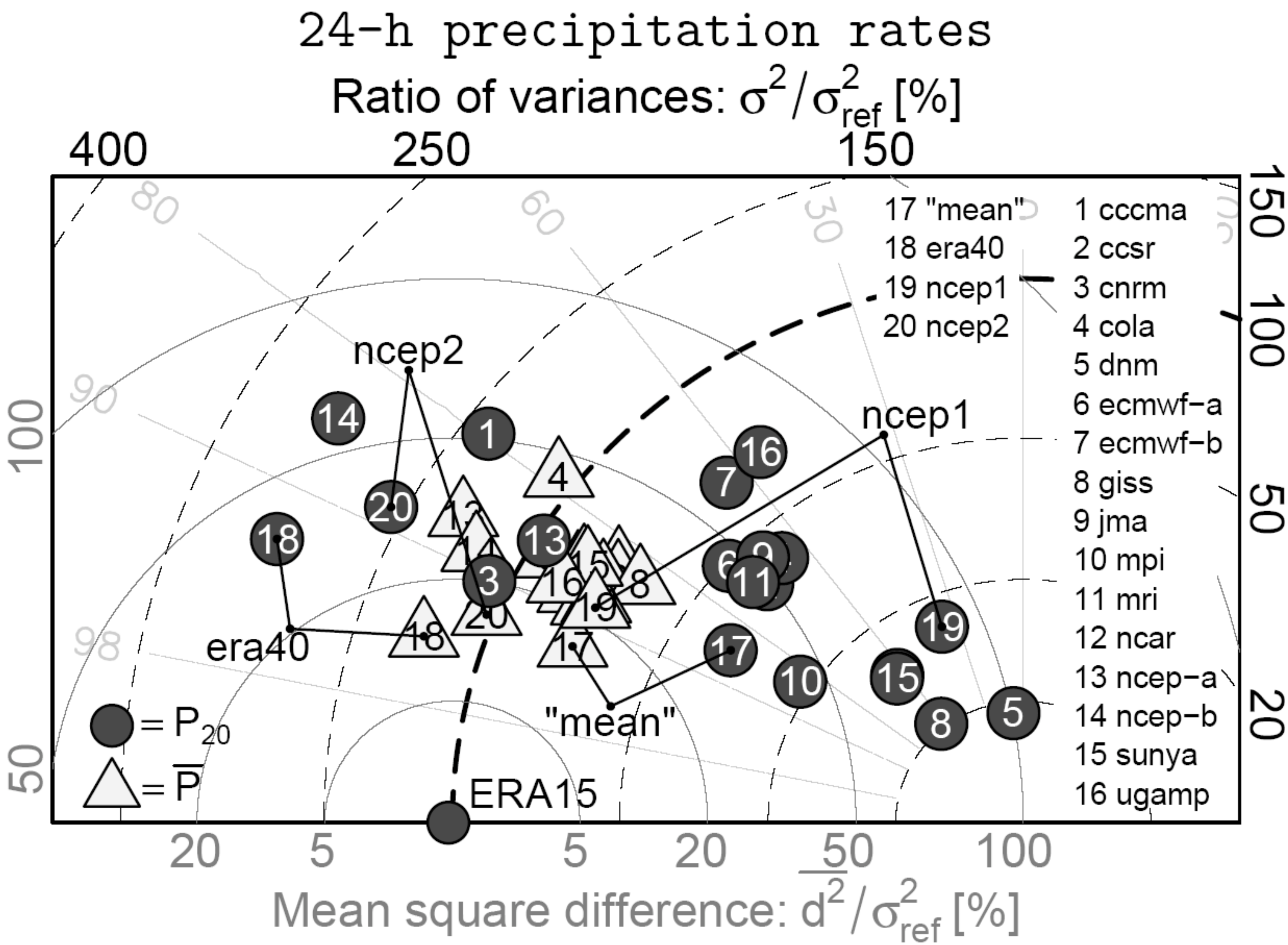
20-year 24-hour PCP extremes – models



20-year 24-hour PCP extremes



AMIP2 PCP performance relative to ERA15

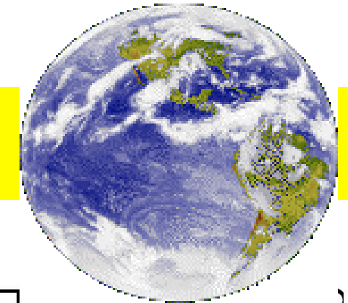


AMIP2 extremes

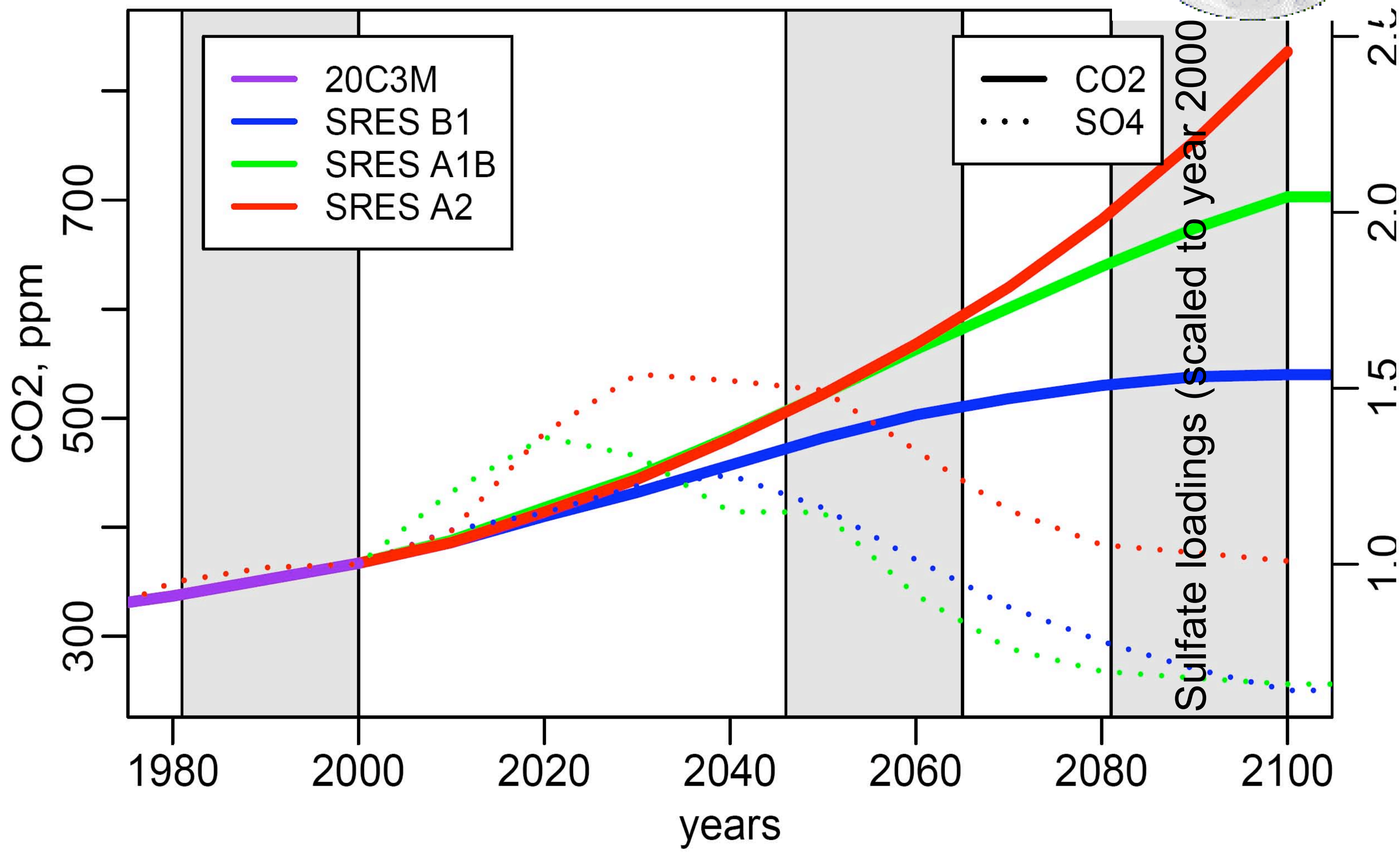
- Temperature
  - “Plausible” when evaluated with global metrics
  - Warm extremes tend to be cooler than NCEP
  - Cold extremes tend to be warmer than NCEP
  - Clustering at zero apparent in several models
    - Land surface issue?
- Precipitation
  - Large differences between station data, reanalyses and models
  - Reanalyses as different from each other as models from a reanalysis
  - Several models have insufficient variability in tropics
  - Split ITCZ also apparent in several models
  - Sensitivity to parameterization of precip producing processes

Environment Canada
Environnement Canada

Meteorological Service of Canada
Service météorologique du Canada



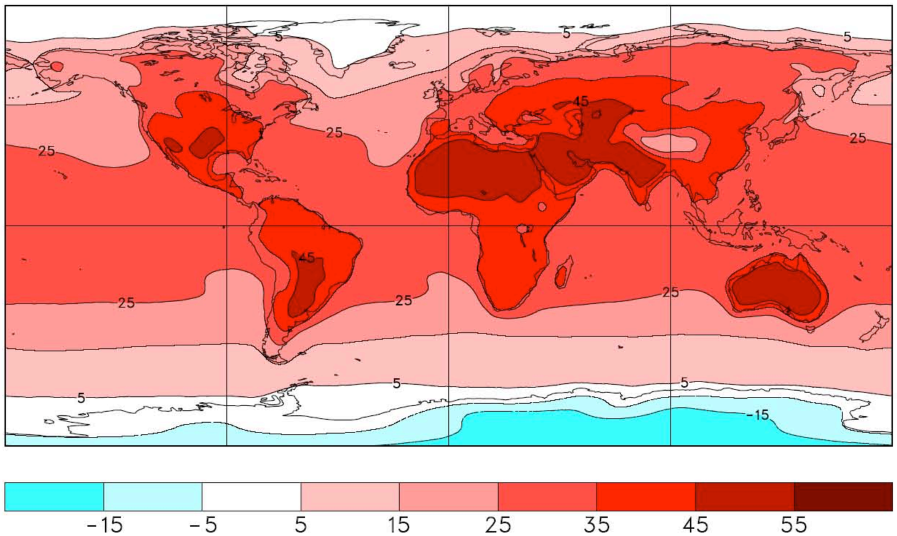
IPCC AR4



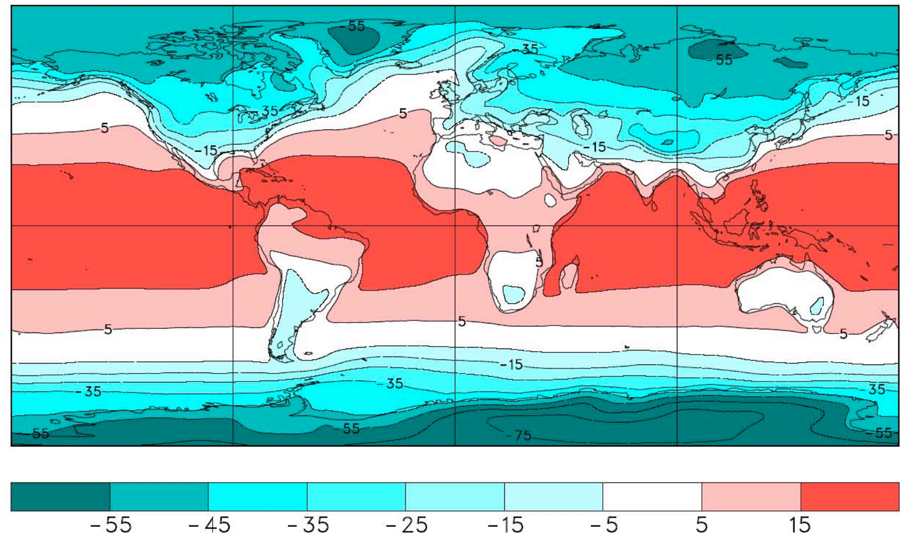
Kharin et al, in prep

20-yr T extremes – current climate (multi-model)

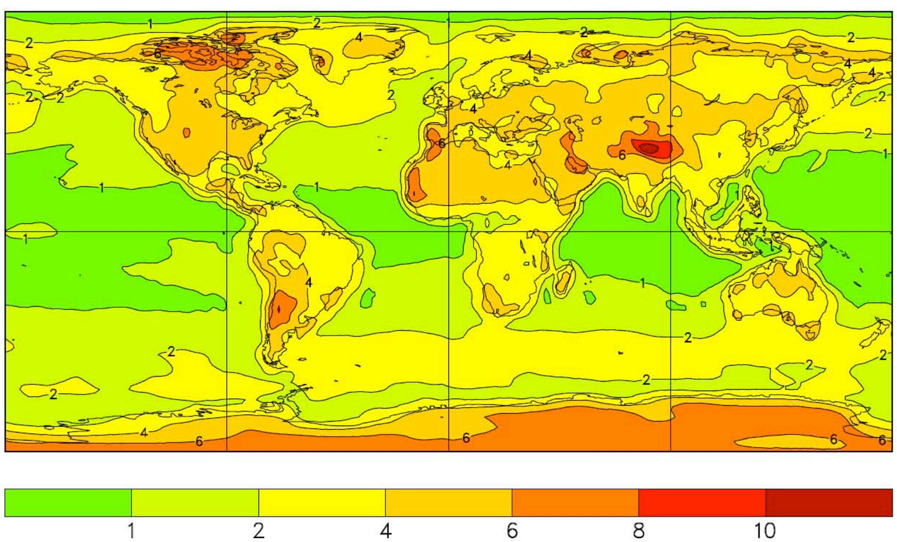
$T_{max,20}$, 1981–2000, 20C3M



$T_{min,20}$, 1981–2000, 20C3M



$\sigma(T_{max,20})$, 1981–2000, 20C3M



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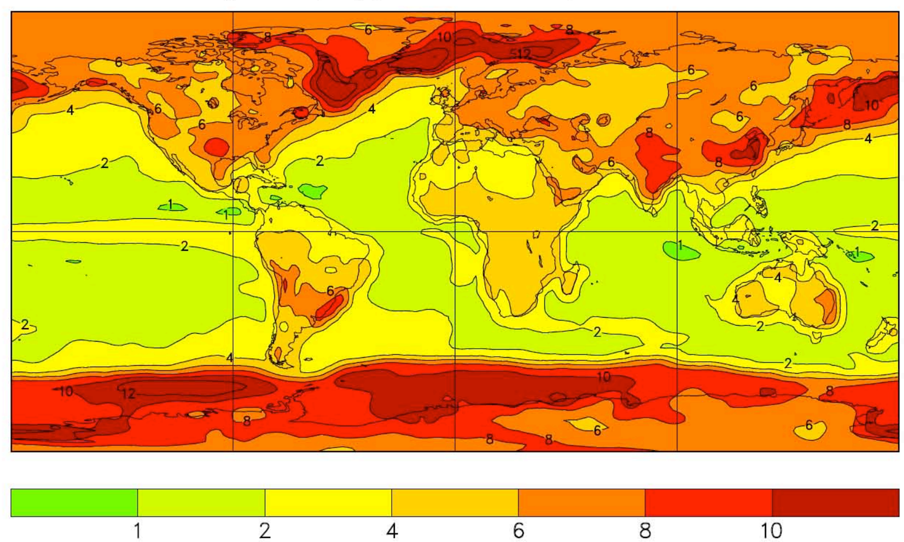
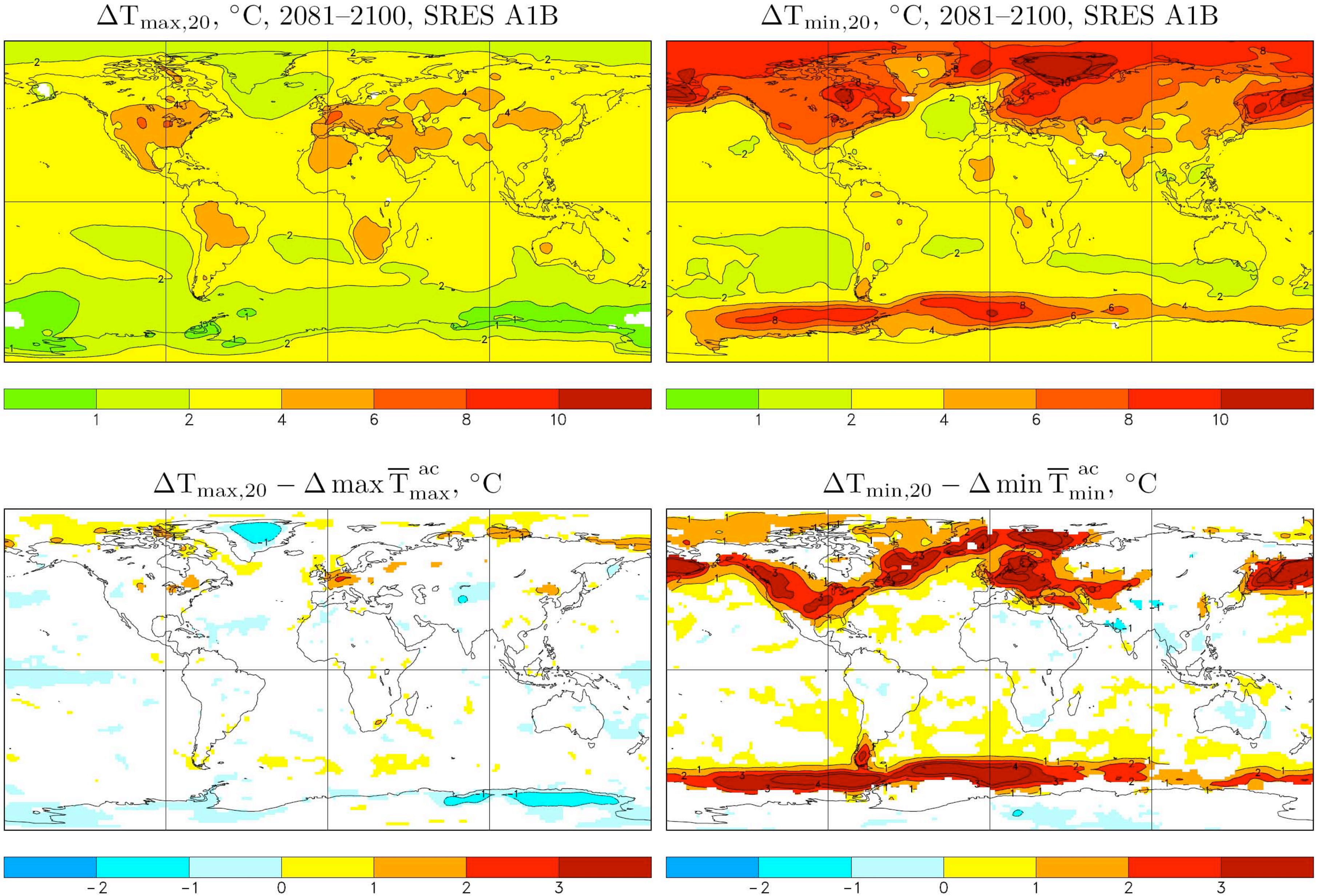
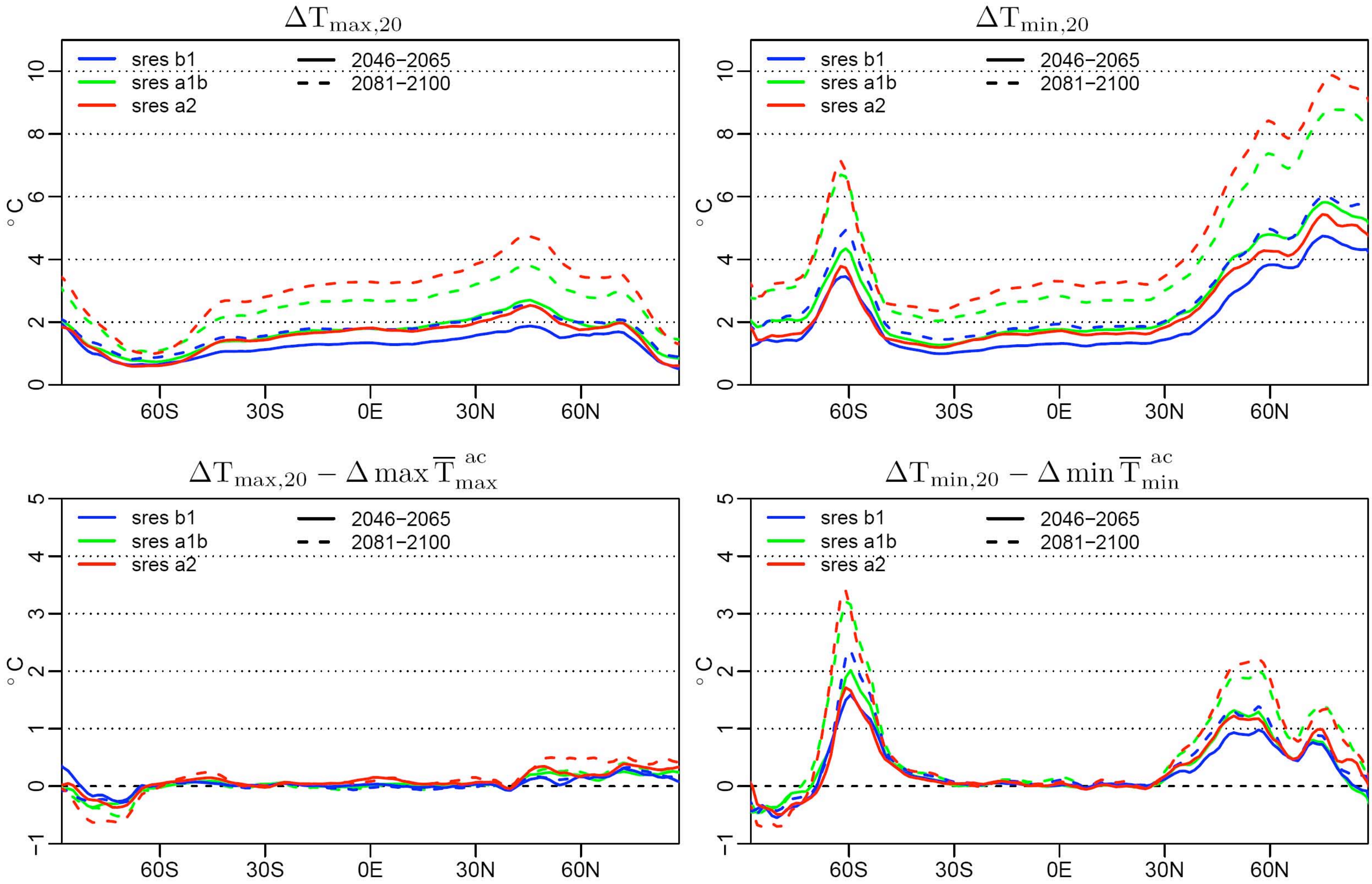


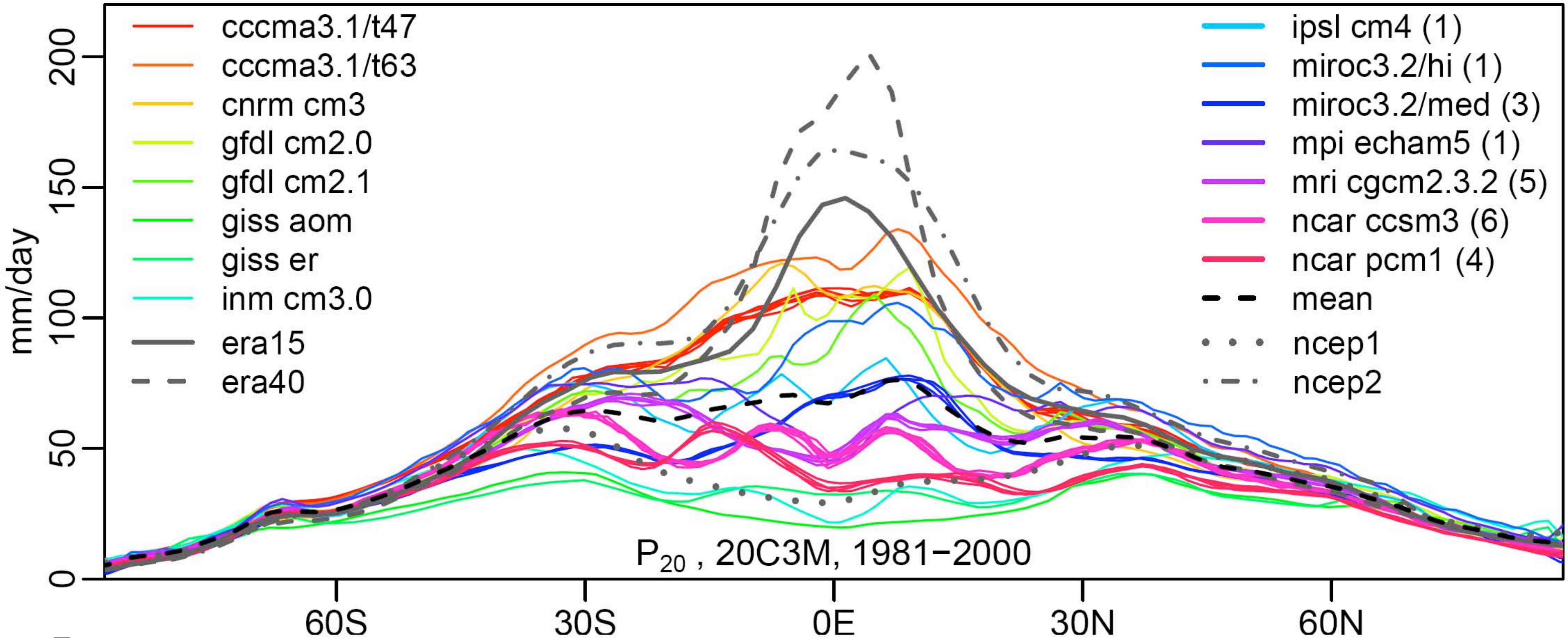
20-yr T extremes – projected change (multi-model)



20-yr T extremes – projected change (multi-model)

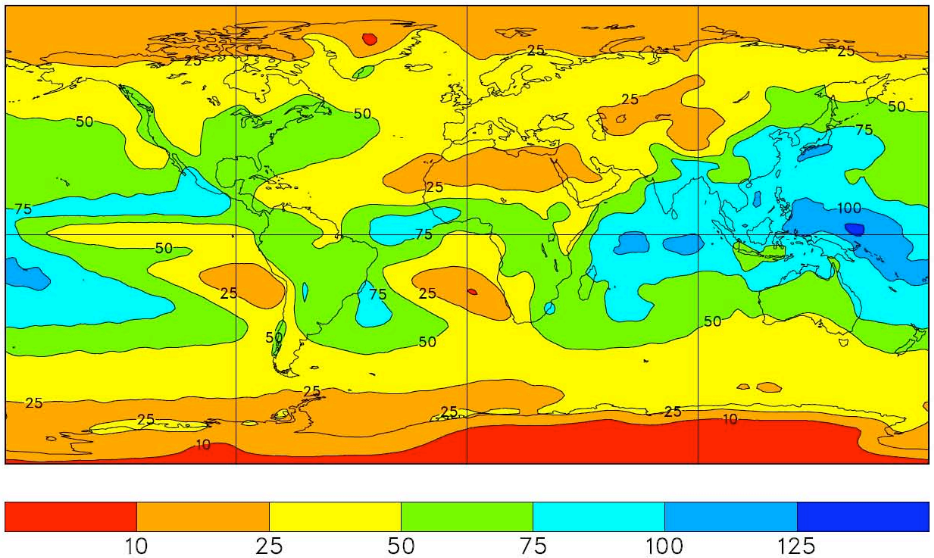


20-yr 24-hr PCP extremes – current climate

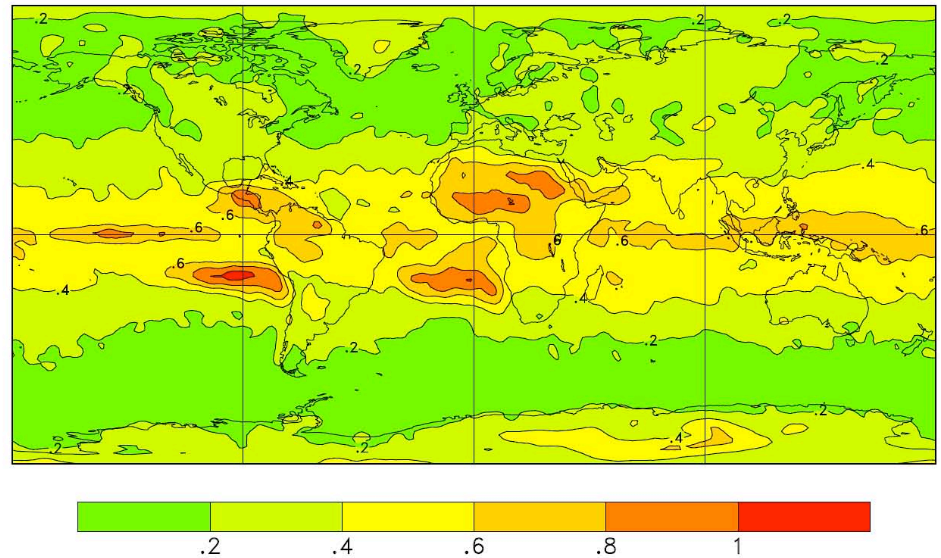


20-yr 24-hr PCP extremes current climate (multi-model)

Multi-model mean P_{20}, 1981–2000, 20C3M

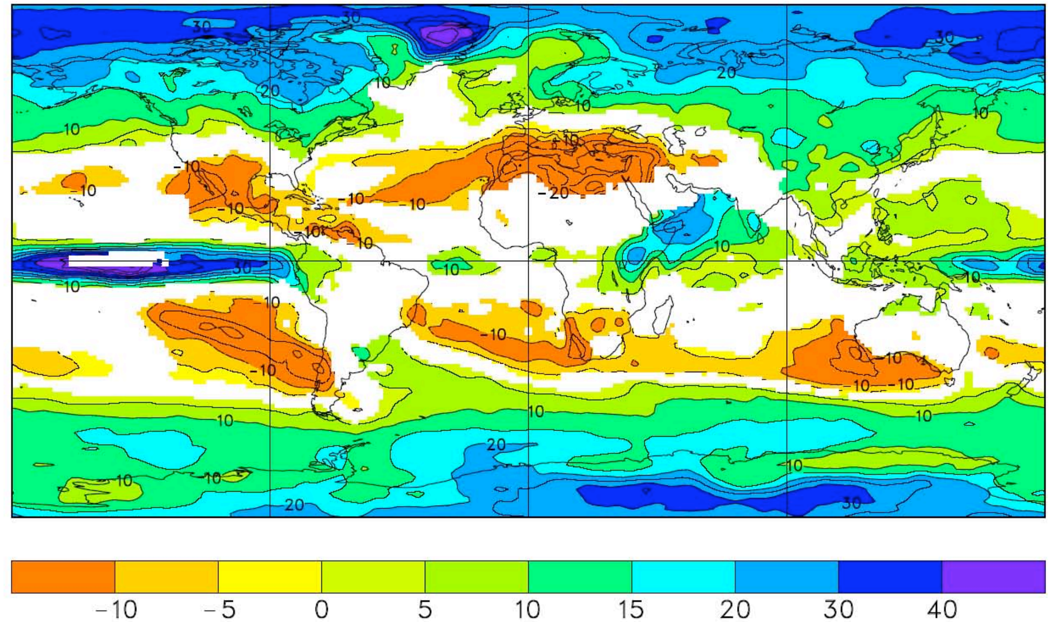


P_{20} coefficient of variation, 1981–2000, 20C3M



Daily mean PCP median projected relative change (multi-model)

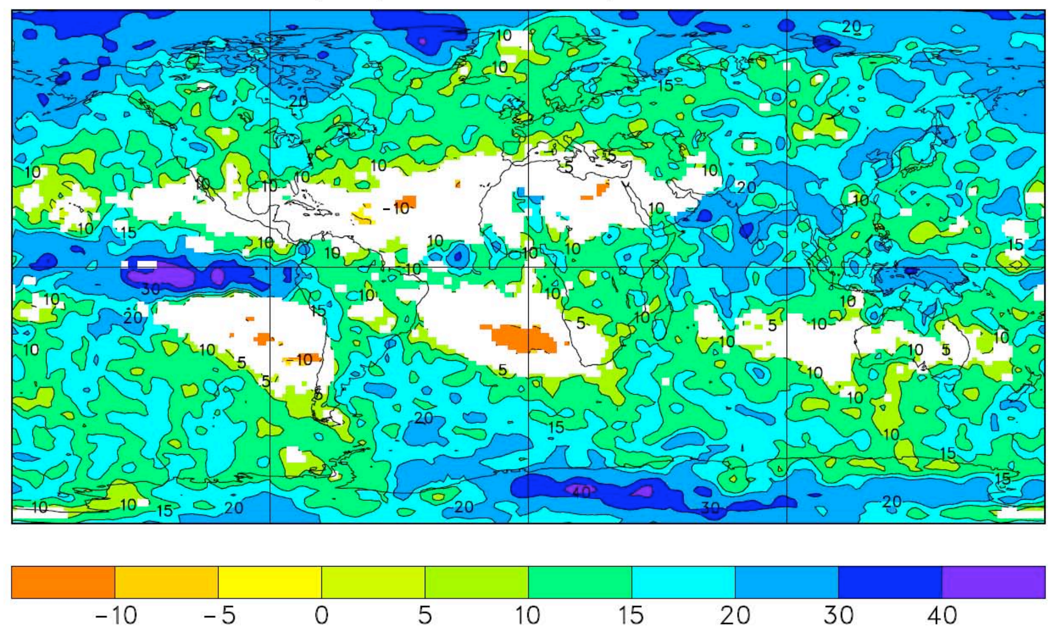
$\Delta\overline{P}$, %, 2081–2100, SRES A1B



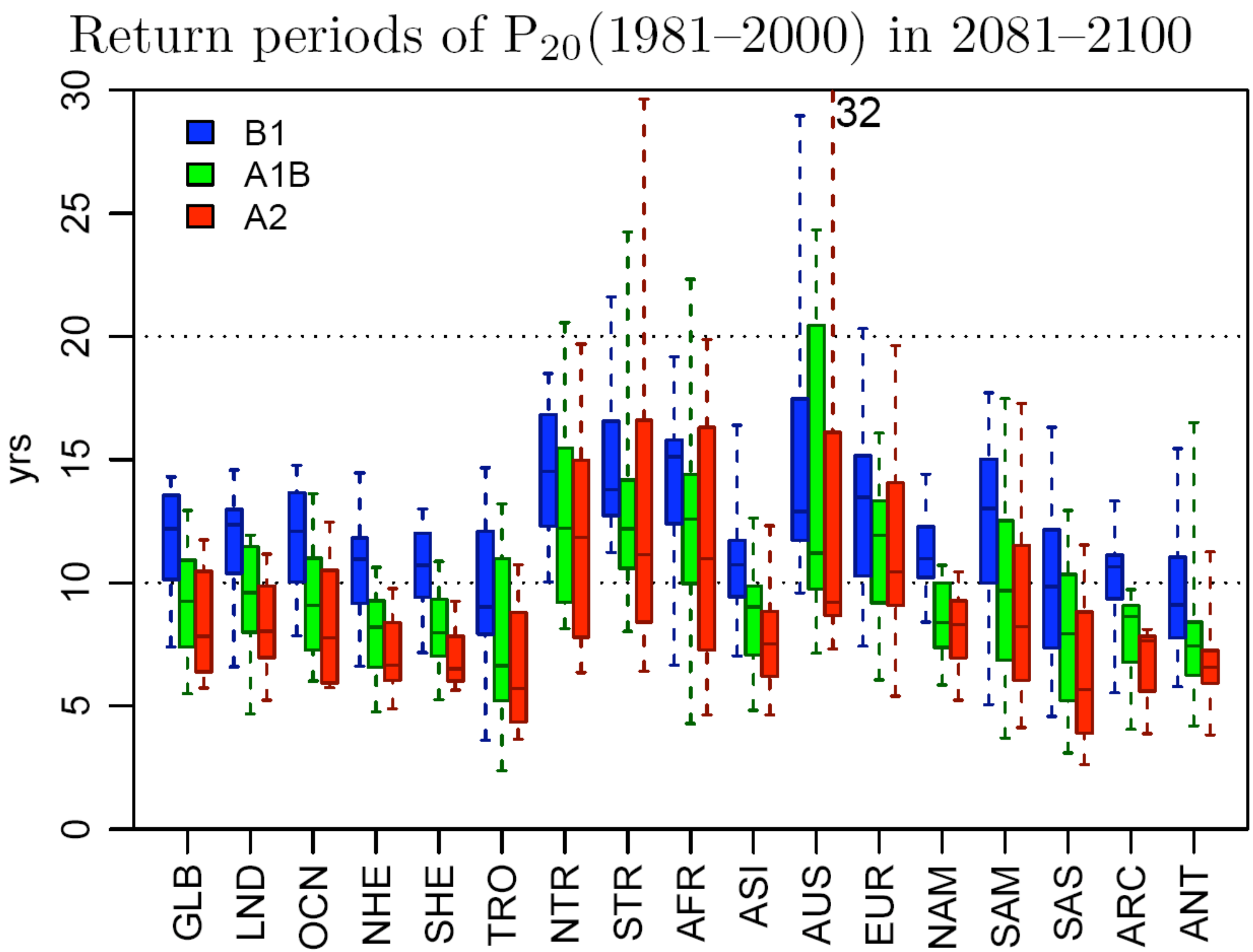
Change significant at 10% level is shaded

20-yr 24-hr PCP extremes median projected relative change (multi-model)

ΔP_{20}, %, 2081–2100, SRES A1B



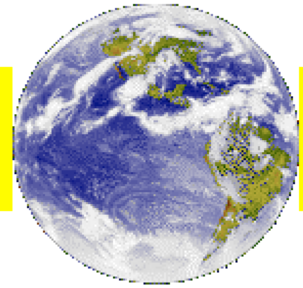
Projected waiting time for current climate 20-yr 24-hr PCP event (regional medians)



AR4 extremes

- Model performance as in AMIP2
  - But, there is general consensus on nature of projected changes
- Extreme warm temperatures
  - generally follow change in the mean
- Extreme cold temperatures
  - Moderate considerably
  - Change faster than the mean (left hand tail becomes shorter) in some regions
- Extreme precipitation
  - Waiting time for current climate events reduced in all regions (regardless of whether mean increases).

Methodological Issues



- Consider only short duration events
- Do indices of, eg, 90th percentile crossing frequency, really measure things that are extreme?
- Perhaps it would be better to refer to
  - *Intense events*
    - Recur at least once per year
    - Risk can be estimated by counting events per unit time
  - *Extreme events*
    - Recur less than once per year
    - Need extreme value theory to estimate risk

Analysis of *Extreme* events

- What methods are appropriate?
  - Two powerful statistical approaches
    - POT and analysis of annual extremes (GEV)
    - Both rely on asymptotic statistical theory
    - Both assume stationarity
  - POT approach arguable more powerful
    - It uses the available data more efficiently
    - But it might be more sensitive to departures from assumptions
  - r-largest approaches are an alternative (Zhang et al, 2004)

Methods of detection of external influences

- Approach depends upon whether the climate becomes more “extreme” (Wallace, pers. comm.)
  - i.e., does the shape of the distribution change under external forcing?
  - If not, optimal detection on mean fields is adequate

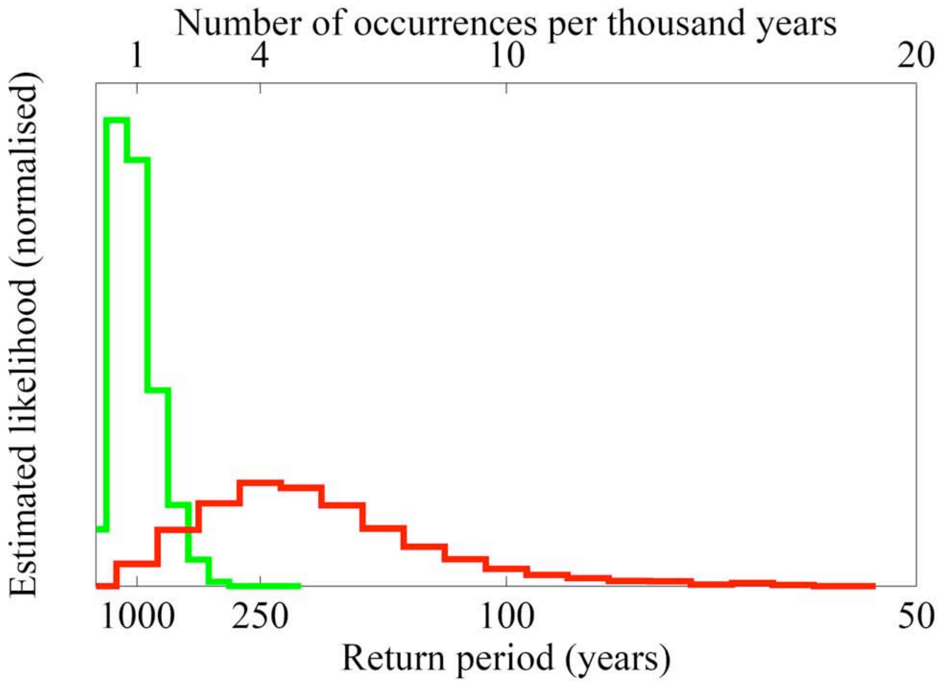
Detection of change in *intense* events

- Based on Frich et al indices (Hegerl et al, 2004; Christidis et al, 2005)
- Indices that count threshold crossings in essence estimate risk of an *intense event*
- Standard optimal detection methods probably okay
- Information needed from models includes
  - Natural internal variability of the risk
  - Change in risk (over time and space) due to influence of external forcing
- Cautions
  - Scaling issues
  - Indices not really simple to estimate – easy to induce inhomogeneity (Zhang et al, 2005)

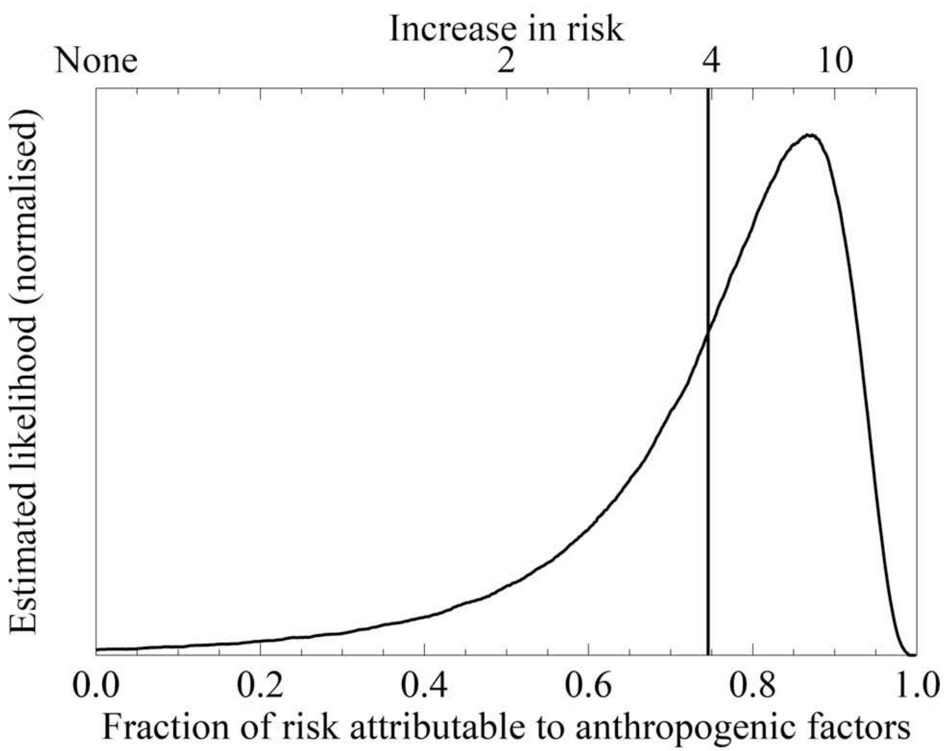
Detection of change in *extreme* events

- Questions of interest often provoked by one-off events
  - European 2003 heat-wave
  - Inadequate observational data to estimate change of risk over time from observations
  - Formal detection not possible
- Approach taken by Stott et al (2004)
  - Determine whether external conditions have contributed to observed long-term change in ambient conditions associated with the *extreme* event
    - regional summer mean temperatures (i.e., regional detection and attribution)
  - If an external influence is detected …
    - use a climate model to determine change in risk (of an warm summer) associated with the historical change in external forcing

Likelihood of European summer mean temperature more than 1.6°C above normal



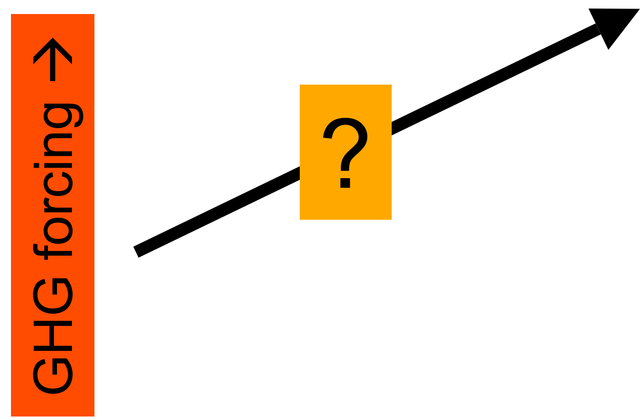
Likelihood of fraction of risk in late 1990s due to anthropogenic forcing



Stott et al, 2004

Double attribution problem

Variation in PDO → variation in risk of extremes



$f(x/y)$ - Distribution on extreme value x given factor y

$f(y/f_{anthro})$ - Distribution on factor y given forcing f_{anthro}

→

$$f(x\,|\,y)f(y\,|\,f_{anthro}) = f(x,y\,|\,f_{anthro})$$
$$\neq f(x\,|\,f_{anthro})$$


The End
Photo: F. Zwiers