Decadal Multi-model Potential Predictability

G.J. Boer
CCCma

Funded by the Canadian Foundation for Climate and Atmospheric Sciences

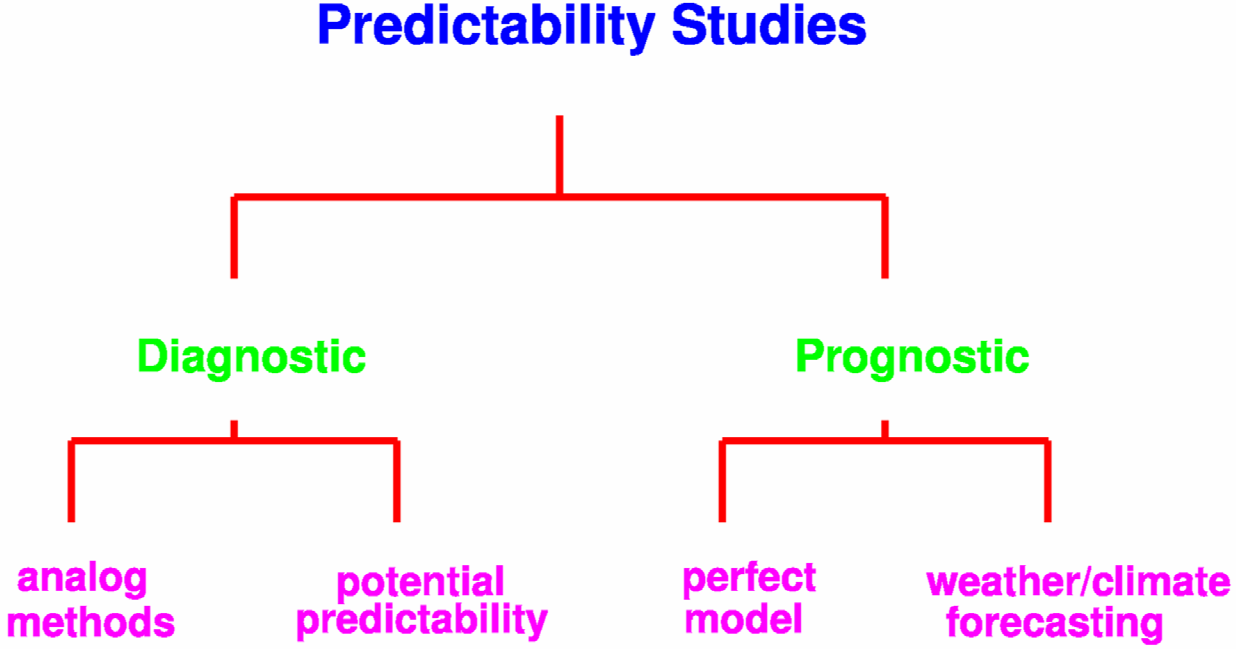
Intro

- Theme II subproject offers to study "decadal" prediction
- How do we convince ourselves that there is hope?
- "Potential predictability" is a diagnostic approach which assumes that:

  - coupled processes introduce long-timescale variability in the system

  - this variability is not simply the residue of averaging unpredictable noise

  - that in a deterministic system this variability could be predicted with enough knowledge


Predictability Studies
Diagnostic
Prognostic
analog methods
potential predictability
perfect model
weather/climate forecasting

Potential predictability

- Diagnostic study from available information
- Analysis looks for:
  - long timescale variability
  - of sufficient magnitude to be of interest
  - in observations (of models in this case)
  - not simply the residue of averaging
- Location and nature of the variability may suggest mechanism/processes

Statistical model

$X_{nm} = \mu + \delta_n + \varepsilon_{nm}$ where

- δ_n represents the long timescale "potentially predictable" variance

- ε_{nm} is the "noise"

- is δ non-zero? Do we see long timescale variability (and hence potential predictability)?

- what fraction of the variance is "potentially predictable"?

- how well do we know this (i.e. what are the confidence bands)?

Variance estimates

- Look for unbiased estimates of variance of:

$$S_\delta^2 = \frac{1}{N}\sum_n (\overline{X}_{n.} - \overline{X}_{..})^2$$ n= number of pentades ...

$$S_\varepsilon^2 = \frac{1}{NM}\sum_n \sum_m (\overline{X}_{nm} - \overline{X}_{n.})^2$$ m= year in pentade ...

- long timescale component
- short timescale noise

$$\hat{\sigma}_\delta^2 = \left(\frac{N}{N-1}\right) S_\delta^2 - \left(\frac{1}{M-1}\right) S_\varepsilon^2$$

$$\hat{\sigma}_\varepsilon^2 = \left(\frac{M}{M-1}\right) S_\varepsilon^2$$

Potential predictability variance fraction (*ppvf*)

- long timescale fraction of total variance
- approximate test for hypothesis

  $\rho = 0$ (hope to reject)
- estimate confidence interval $\rho_l < \rho < \rho_u$
- is ρ big enough to be of interest?

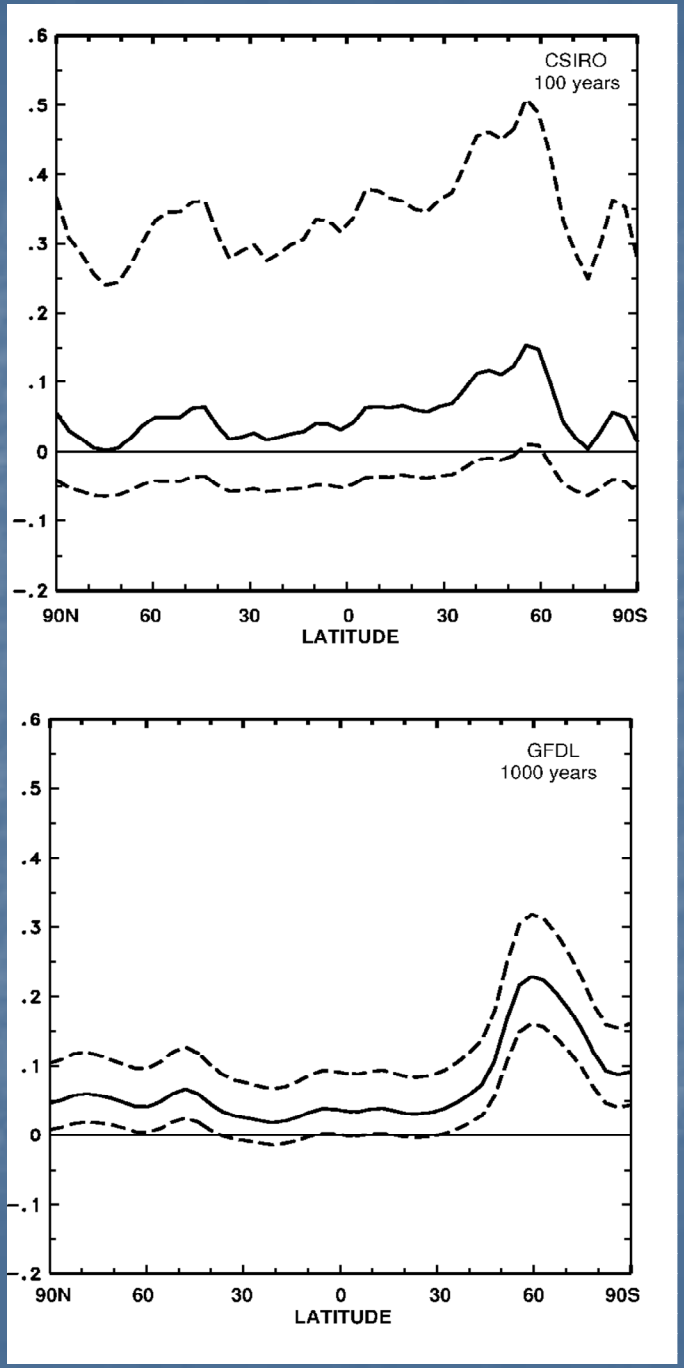
$$\hat{\rho} = \frac{\hat{\sigma}_\delta^2}{\hat{\sigma}_\delta^2 + \hat{\sigma}_\varepsilon^2}$$

- Results from earlier study show data requirements are severe

- large confidence bands

- even with 1000years of data

- Multi-model approach provides lots of data



Multi-model approach

- assumes a random sample from the population of models produced with current knowledge

  - current numerics, parameterizations ...

  - reasonable approaches/researchers ...

- Simulations by different models are take to be independent realizations of the climate system

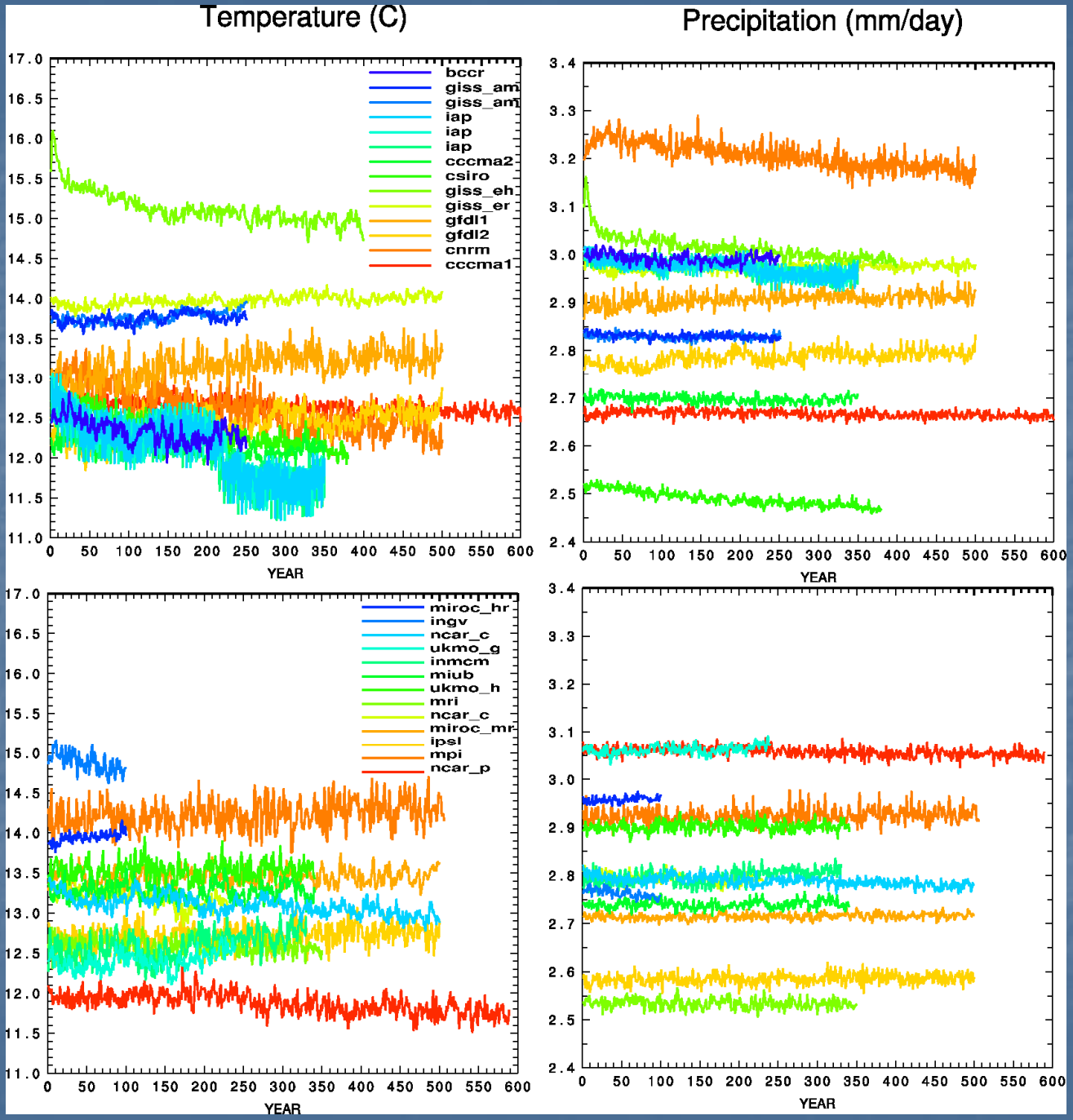
  - ensemble gives information on probabilistic structure of system

  - ensemble allows better estimation of population parameters (hence of *ppvf*)

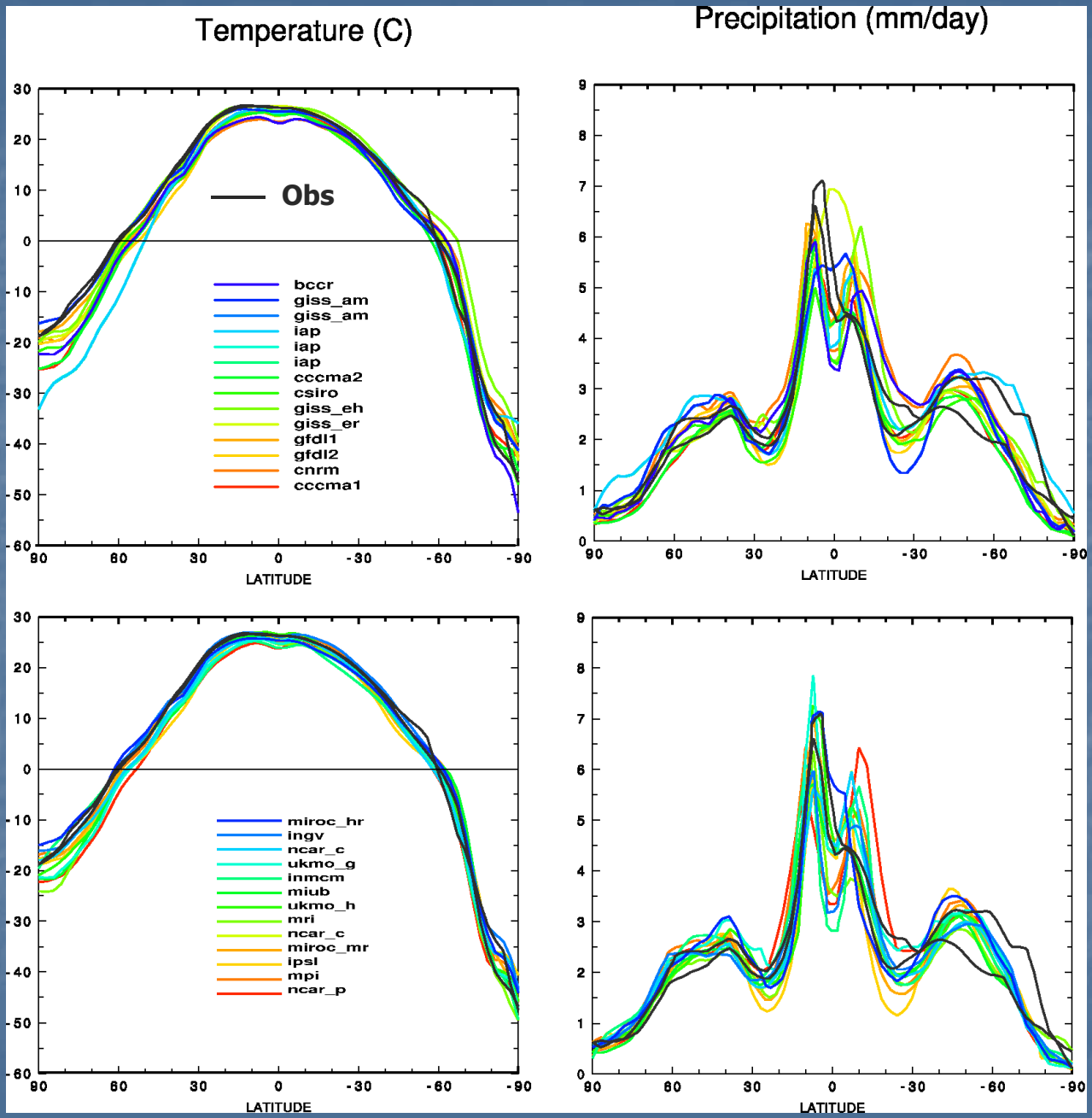
IPCC AR4 data

- consider initially preindustrial Control climate
- (intended to be) equilibrium climate in balance with forcing
- results from 27 models are available
- simulations lengths from 100 to 1000 years
- we consider surface air temperature and precipitation (the two main climate parameters)

Time series of global annual means



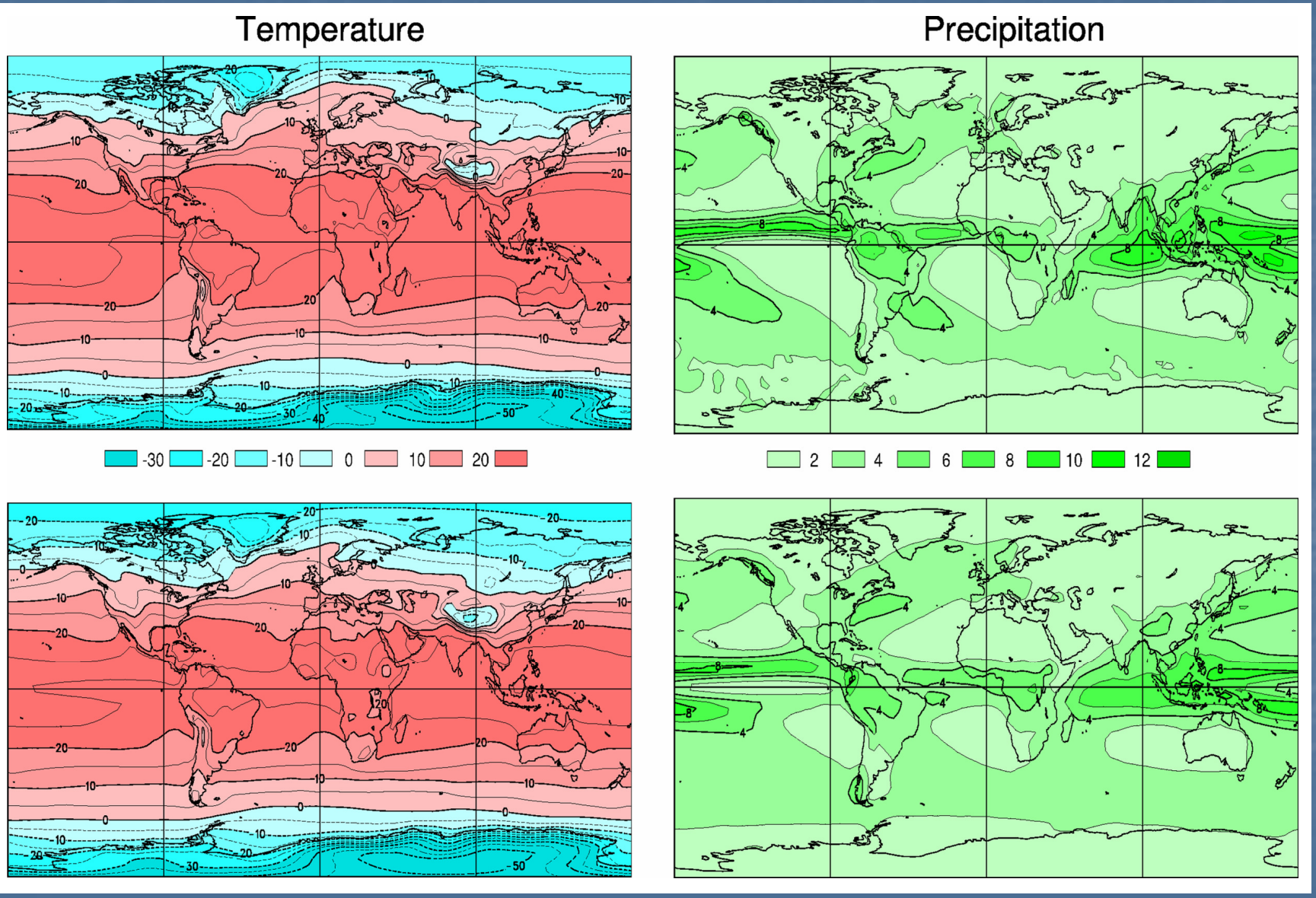
Zonally and annually averaged climate



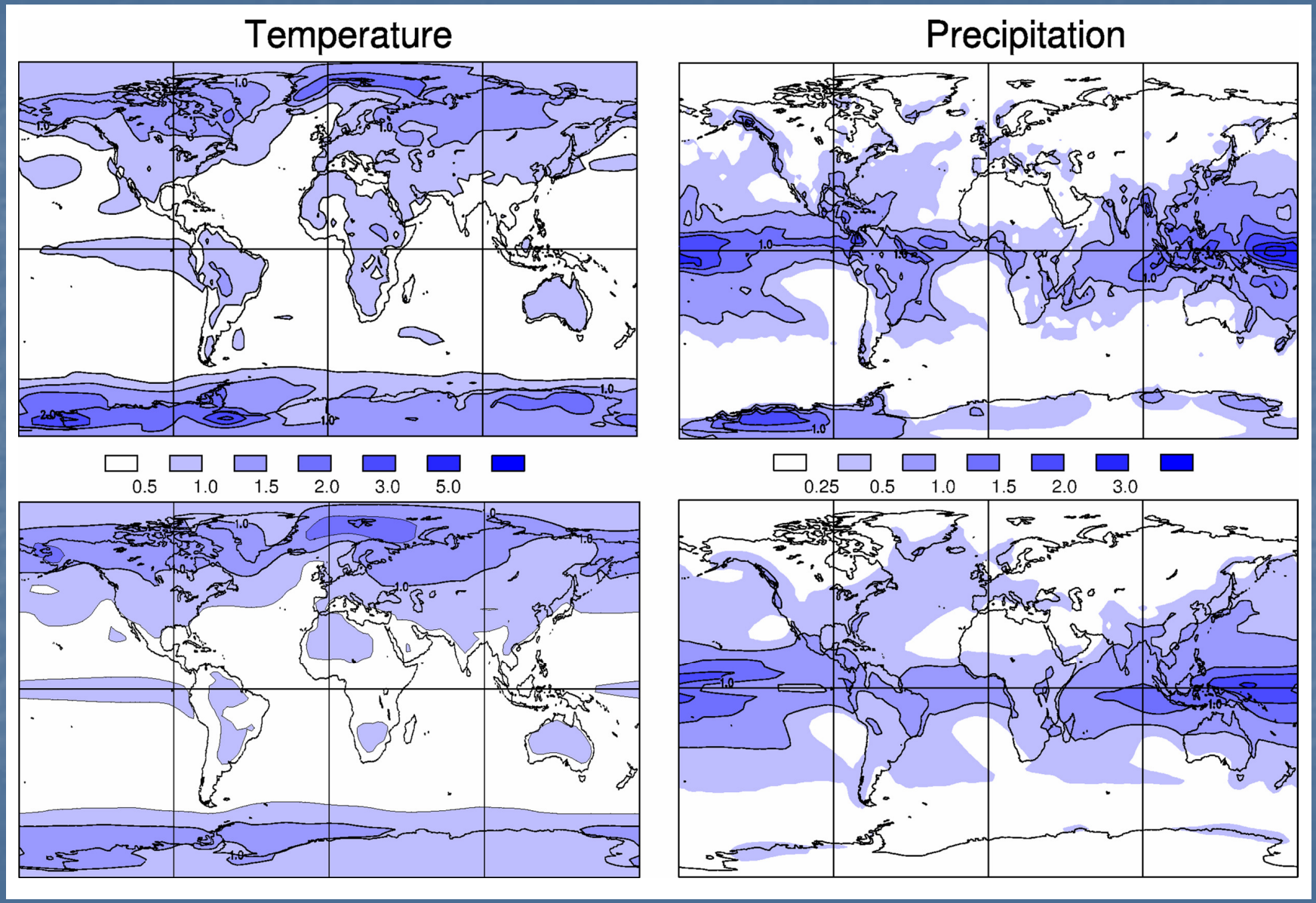
Long-term means

Observations

Multi-model ensemble mean



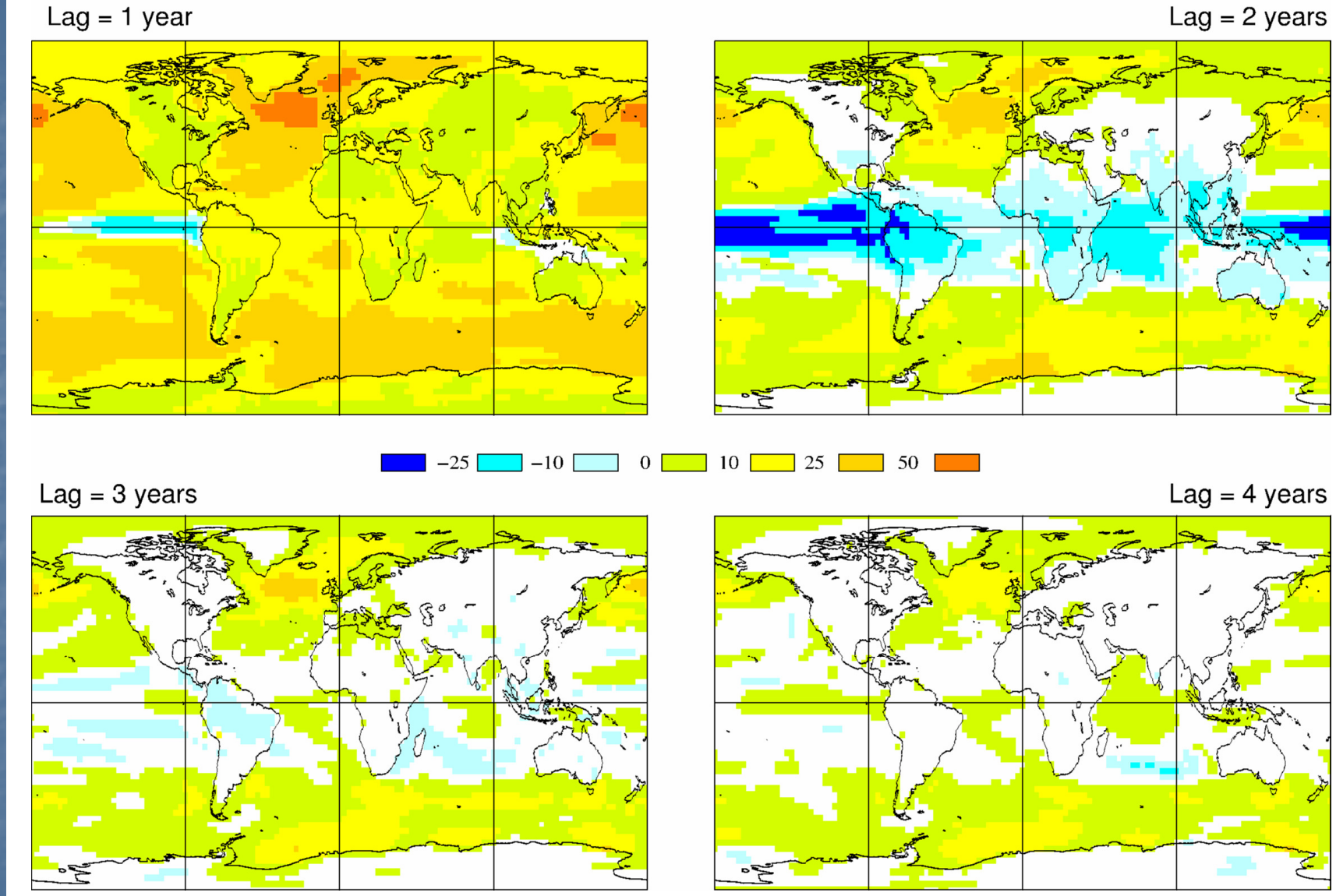
Standard Deviation of annual means



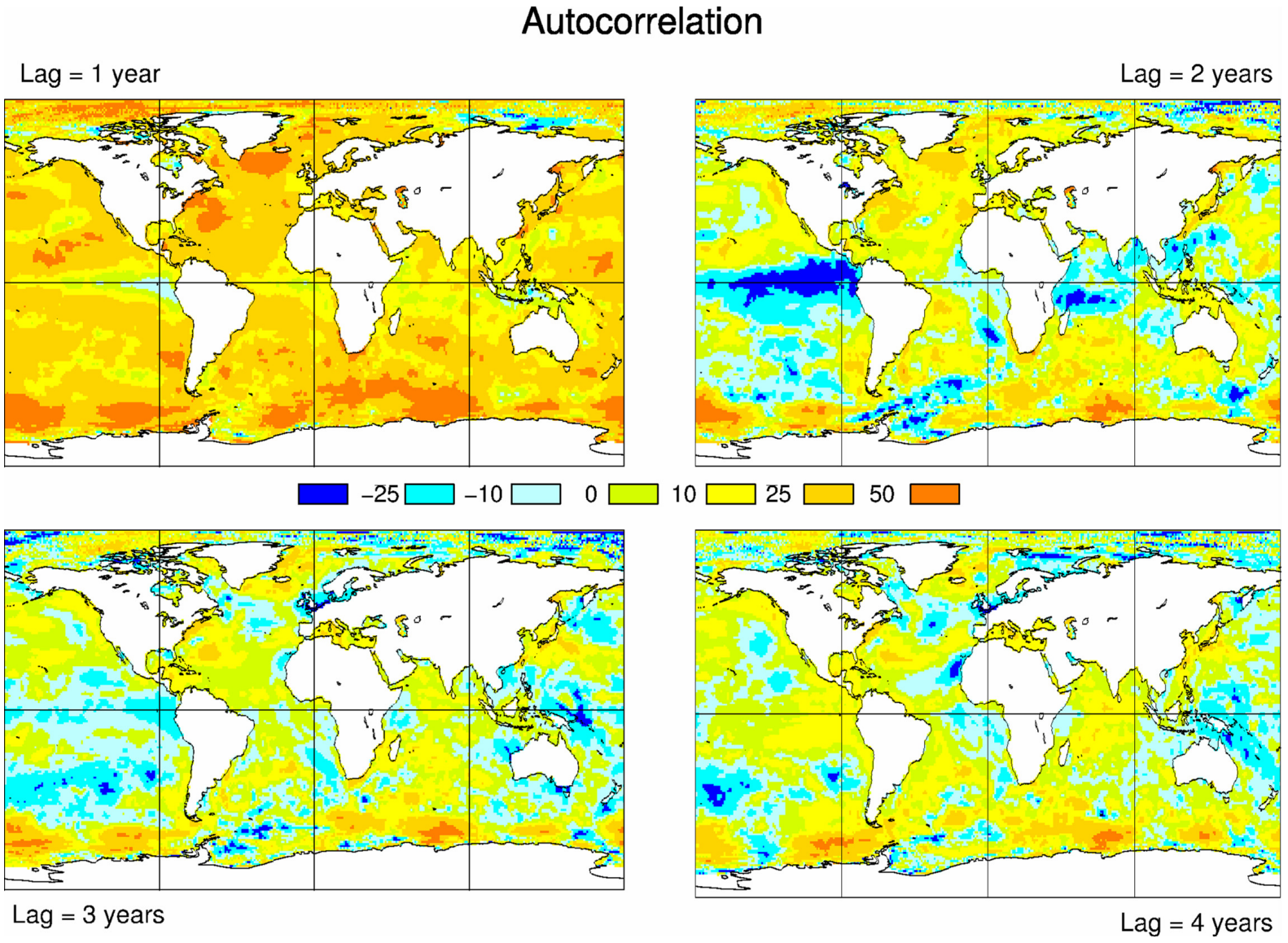
Autocorrelation

- Decorrelation rate gives a sense of timescales
- Can compare with observations for Temp
- Suggests areas with long timescales which are candidates for predictability

Autocorrelation



From Multi-model Ensemble


Autocorrelation
Lag = 1 year
Lag = 2 years
−25
−10
0
10
25
50
Lag = 3 years
Lag = 4 years

From obs SST

Potential predictability

- Fraction of long timescale variability
- Expect connection to autocorrelation
- Earlier efforts included temperature only but MME provides enough data to consider precipitation
- Implication for decadal etc forecasting

Potential predictability: preliminary results

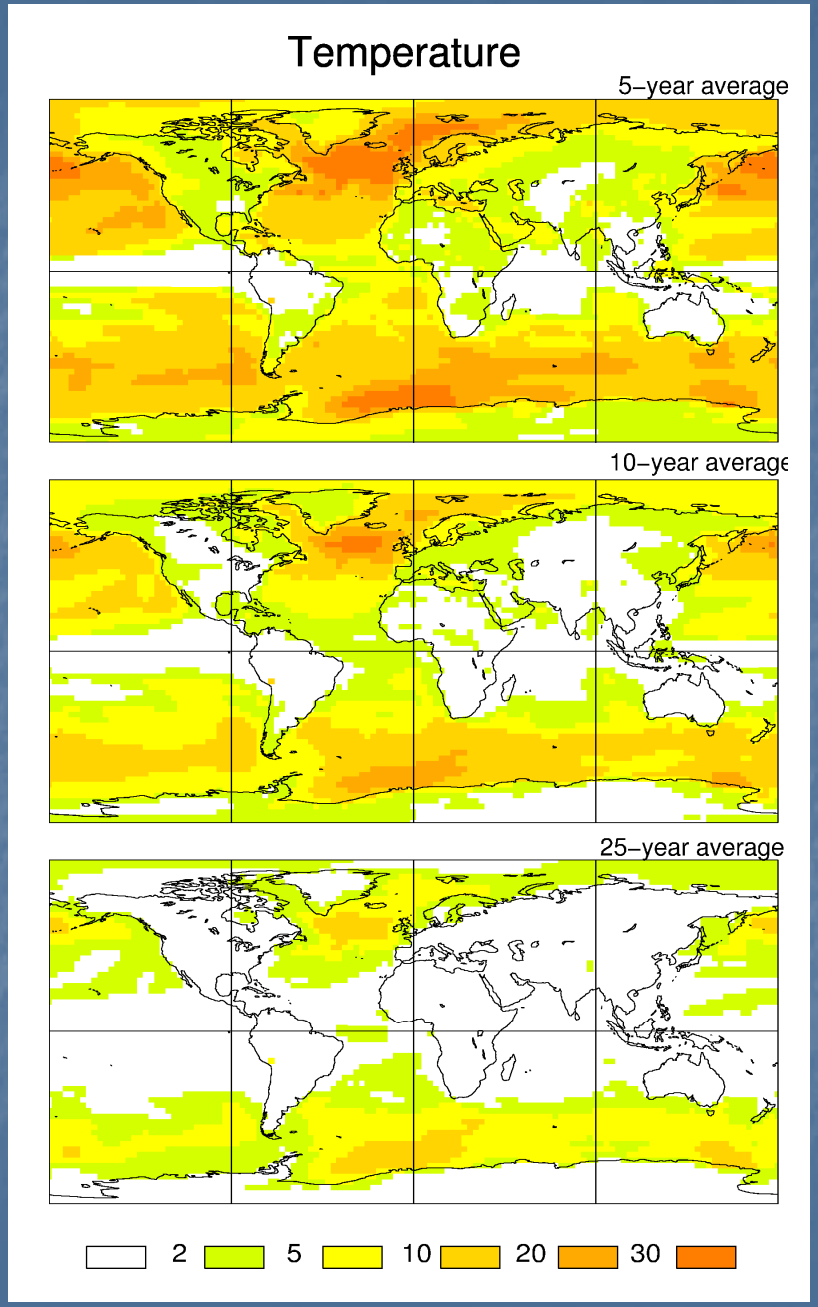
- Ratio of "predictable" to total variance

- MME provides stability of statistics: *ppvf* in white areas <2% and/or not significant at 1% level

- Long timescale predictability found mainly over oceans

- Some incursion into land areas but modest *ppvf*

- Natural and anthropogenic forcing should add predictability expc. over land



Potential predictability: preliminary results

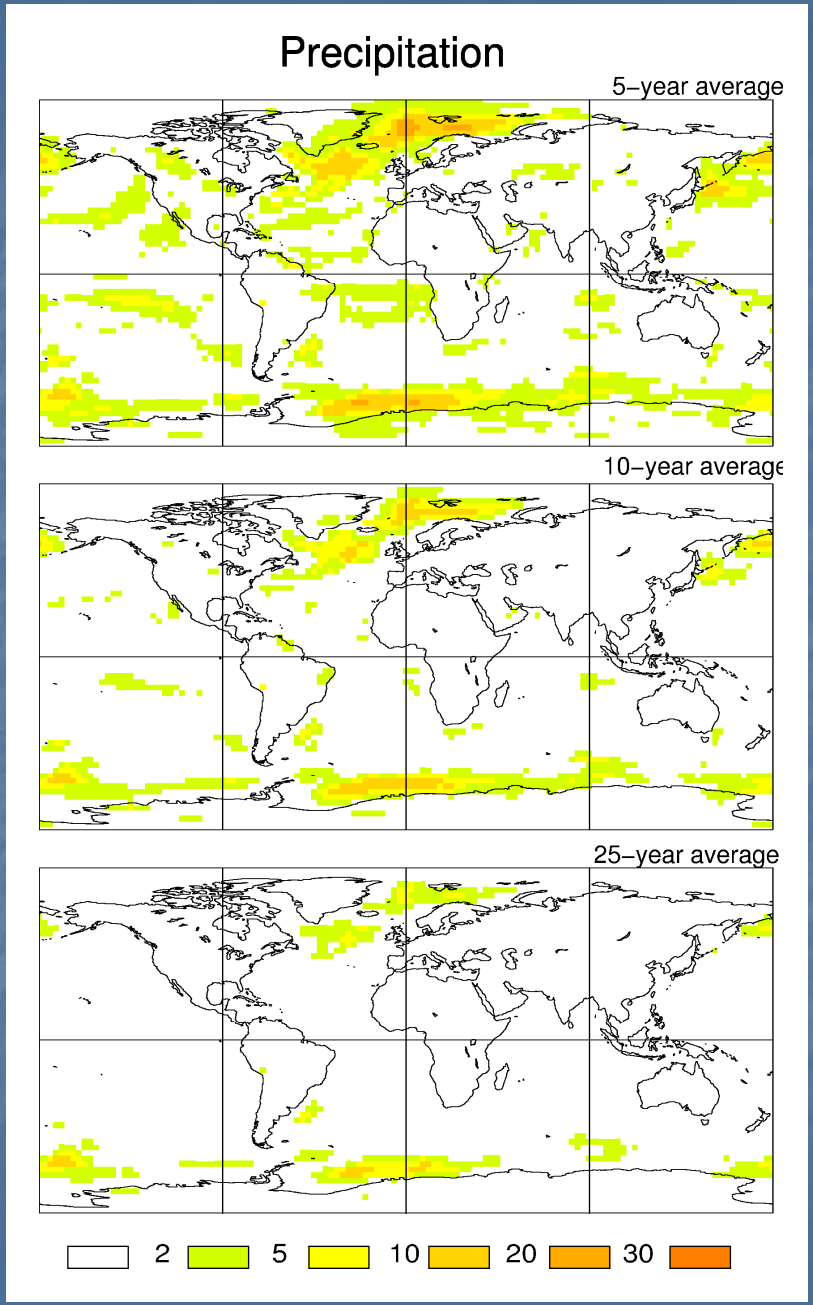
-MME provides "some" significant areas of precipitation

-Much less potentially predictable than temperature

- Predictability over oceans a much weakened version compared to temperature

- Some incursion into land areas but more modest

- Natural and anthropogenic forcing might add predictability perhaps over ocean?



The good and bad of potential predictability

- Potential predictability: bad

  - doesn't necessarily imply actual predictability

  - not enough data to infer for real system so adopt "perfect model" approach

  - need multi-model and/or long simulations for stable statistics

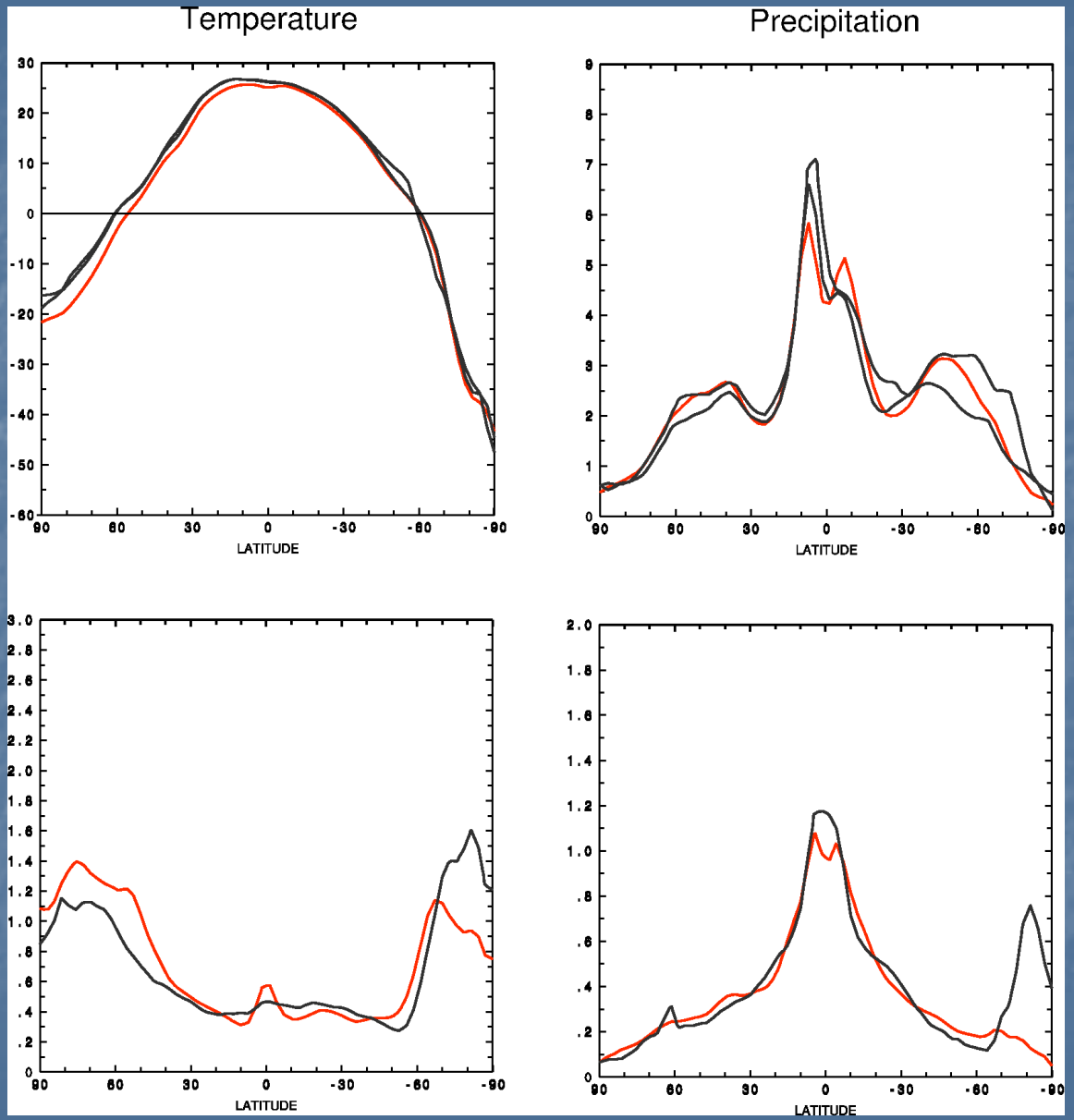
- Potential predictability: good

  - implies the possibility of actual predictability given sufficient information

  - may suggest potential mechanisms

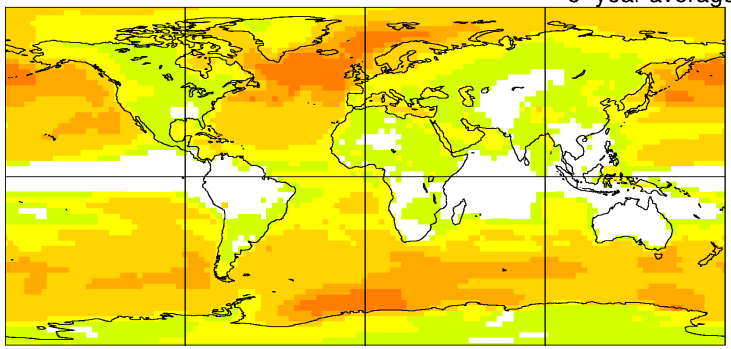
  - motivates decadal prediction efforts – the next big thing in prediction research

End of presentation

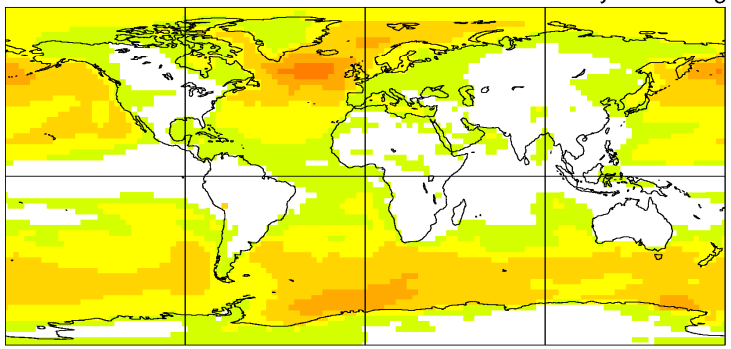

Temperature
Precipitation
LATITUDE
LATITUDE
LATITUDE
LATITUDE

Temperature

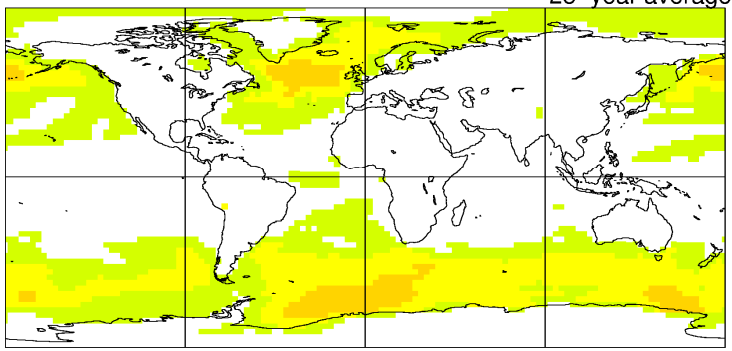
5–year average



10–year average



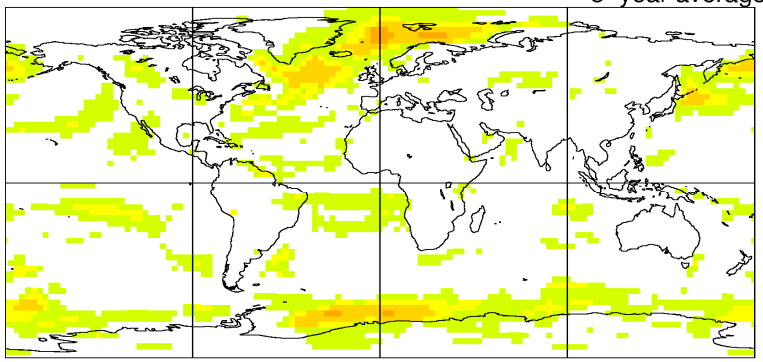
25–year average



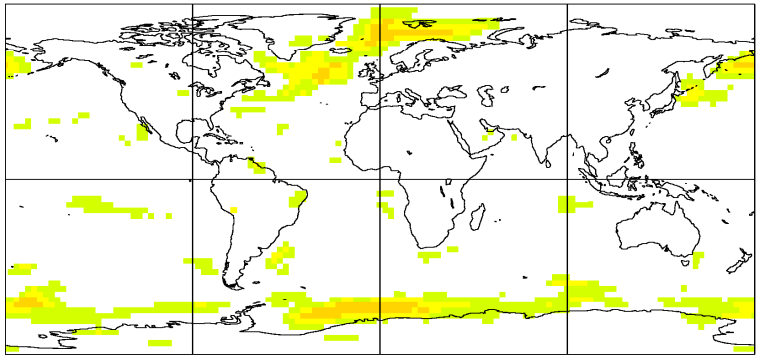
2 5 10 20 30

Precipitation

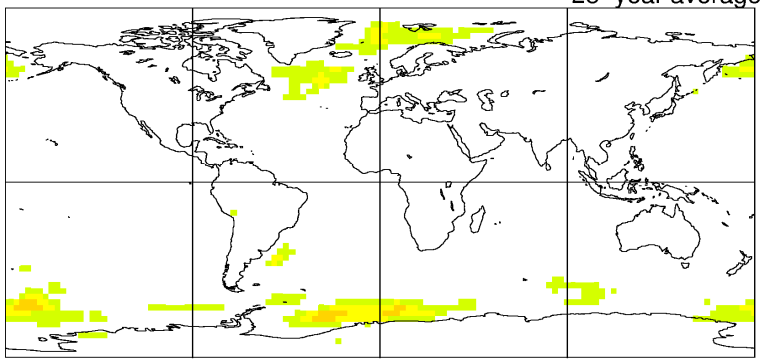
5–year average



10–year average



25–year average



2 5 10 20 30

Potential predictability: preliminary results

- Ratio of "predictable" to natural variance
- MME provides stability of statistics
- Long timescale predictability found mainly over oceans
- Natural and anthropogenic forcing should add predictability expc. over land