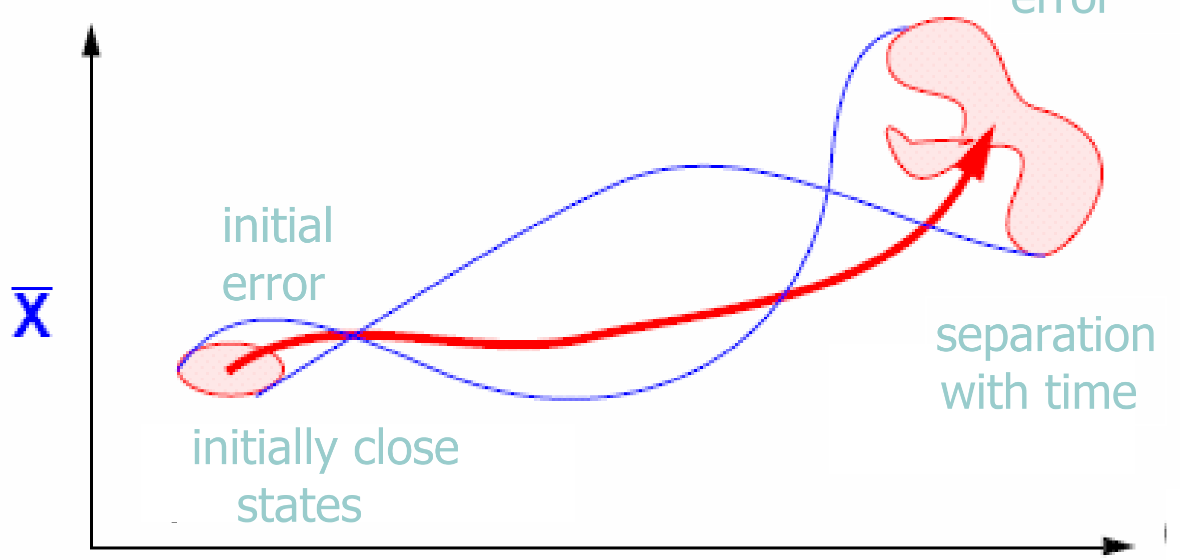
Changes in the decadal potential predictability of the coupled system with global warming

G.J. Boer
Canadian Centre for Climate Modelling and Analysis
Environment Canada
University of Victoria

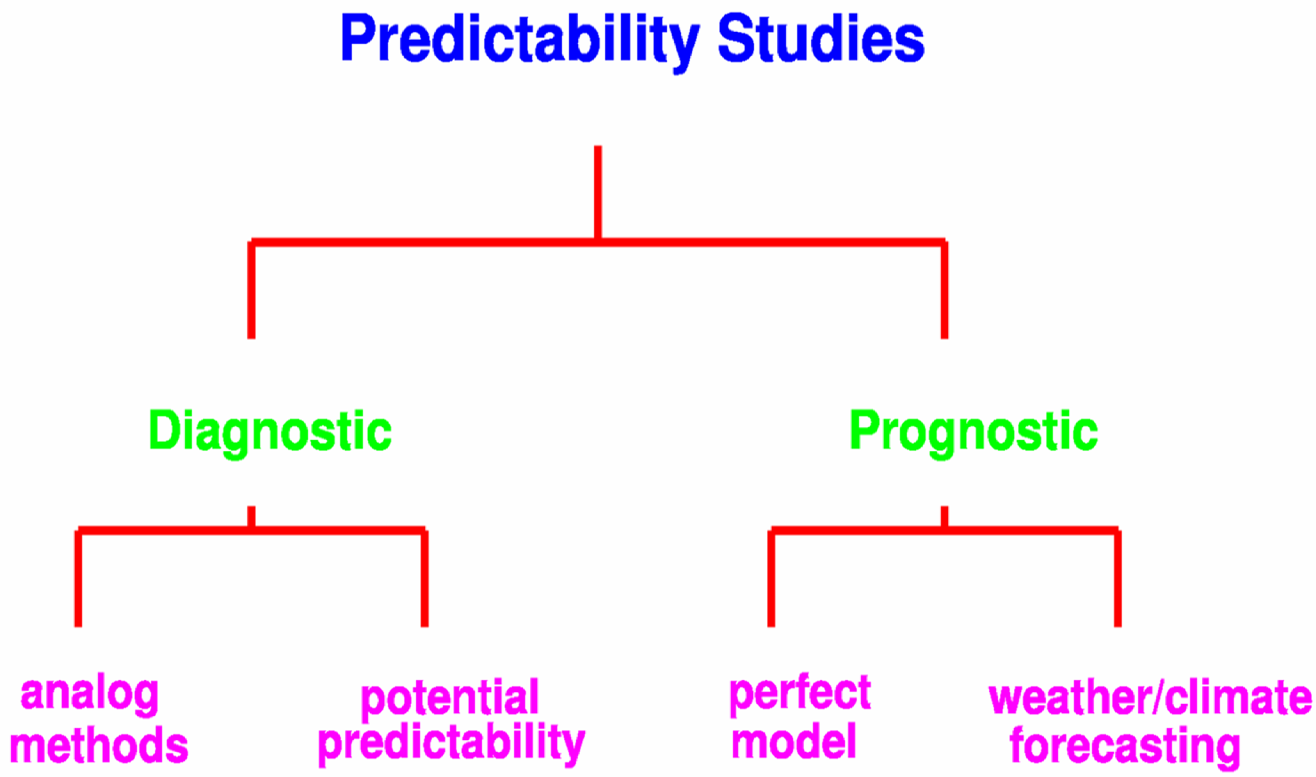
Topics

- Approaches to long-timescale predictability
- MIPs and multi-model ensembles (MMEs)
- Decadal potential predictability results for temperature and precipitation
- Potential predictability change in a warmer world
- Summary

Classical predictability



Sensitive dependence on initial conditions


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

Predictability approaches

- *Classical predictability*

  - measures the average rate of separation of initially close states

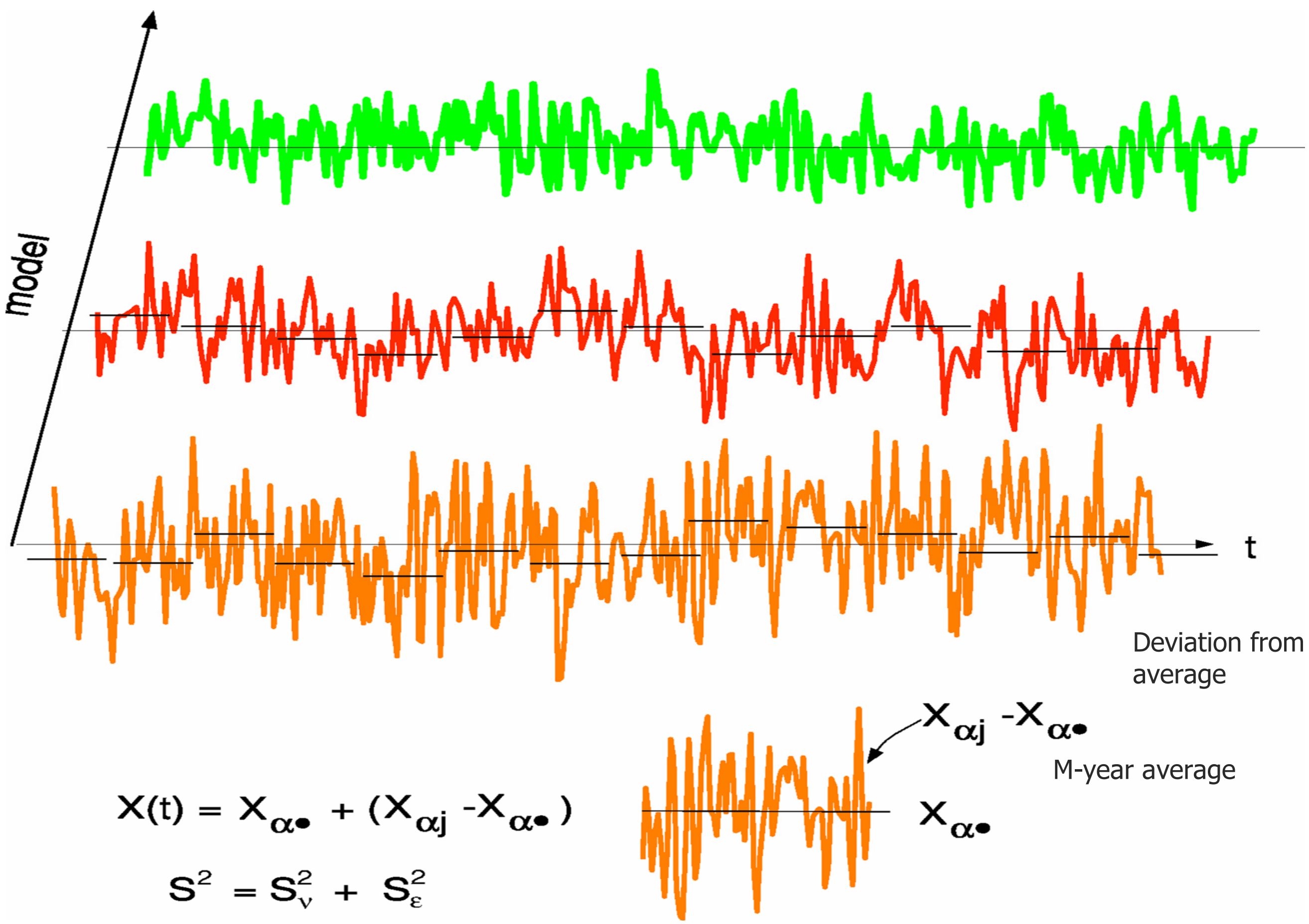
  - prognostic or diagnostic

- *Potential* predictability

  - looks for the existence of deterministic long timescale variability

  - presumes this variability is "potentially" predictable with enough knowledge

Long timescale variability



Potential predictability

- Analysis looks for:
  - long timescale variability at each point
  - not simply the residue of averaging
  - of sufficient magnitude to be of interest
- Presumption is that this variability is at least "potentially" predictable with enough knowledge
- Location and nature of the potential predictability should suggest mechanisms and processes

Approach

- Need suitable statistical tests and approaches
- Require lots of “observations” for statistical confidence
- Aim for geographic distribution of the *potential predictability variance fractions* (ppvf)
- We take a *multi-model ensemble approach* using CMIP3 data (IPCC AR4)

CMIP3 MME Approach

- Consider CMIP3 results as a sample from the population of models "produced with current knowledge"
- Ensemble approach – pool the statistics
  - provides more data
  - allows better estimation of population parameters
  - provides an "expert" consensus
- Simulations include:
  - unforced control simulations
  - A1B and B1 climate change scenarios
  - stabilization integrations

Statistical model

- Statistical model is

$$X = \Omega + \nu + \varepsilon$$

with associated variances

$$\sigma^2 = \sigma^2_\Omega + \sigma^2_\nu + \sigma^2_\varepsilon$$

– Ω is long timescale *externally forced* variability *if present* (we generally *don't* consider now)

- ν is long timescale *internally generated* variability (*this* is what we are interested in)

- ε is short timescale *unpredictable "noise"* variability

- Potential predictability variance fraction is

$$p = (\sigma^2_\Omega + \sigma^2_\nu)/\sigma^2 = p_\Omega + p_\nu$$

Statistics

$$X_i = X_{(\alpha - 1)M + j} = X_{\alpha j}$$

i = 1 …. NM
α = 1 …. N
j = 1 …. M

$$X_{\alpha j} = P_\alpha + (X_{\alpha \bullet} - P_\alpha) + (X_{\alpha \bullet} - X_{\alpha j})$$

$$X_{\alpha \bullet} = \frac{1}{M}\sum_{j=1}^{M} X_{\alpha j}$$

is M-year average

$$S^2 = S_\Omega^2 + S_\nu^2 + S_\varepsilon^2 = \overline{X^2}$$

$$= \overline{P_\alpha^2} + \overline{(X_{\alpha \bullet} - P_\alpha)^2} + \overline{(X_{\alpha \bullet} - X_{\alpha j})^2}$$

$$P_\alpha = \sum_{k=1}^{K} a_k p_k(\alpha)$$

is orthogonal polynomial fit

Long TS forced (if present)

Long TS internally generated

Short TS noise

Statistics are pooled across models in multi-model case

Variance estimates

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

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

$$\hat{\sigma}_{\Omega}^{2} = S_{\Omega}^{2} - \left(\frac{K}{N-K}\right)S_{\nu}^{2}$$

Potential predictability variance fraction (*ppvf*)

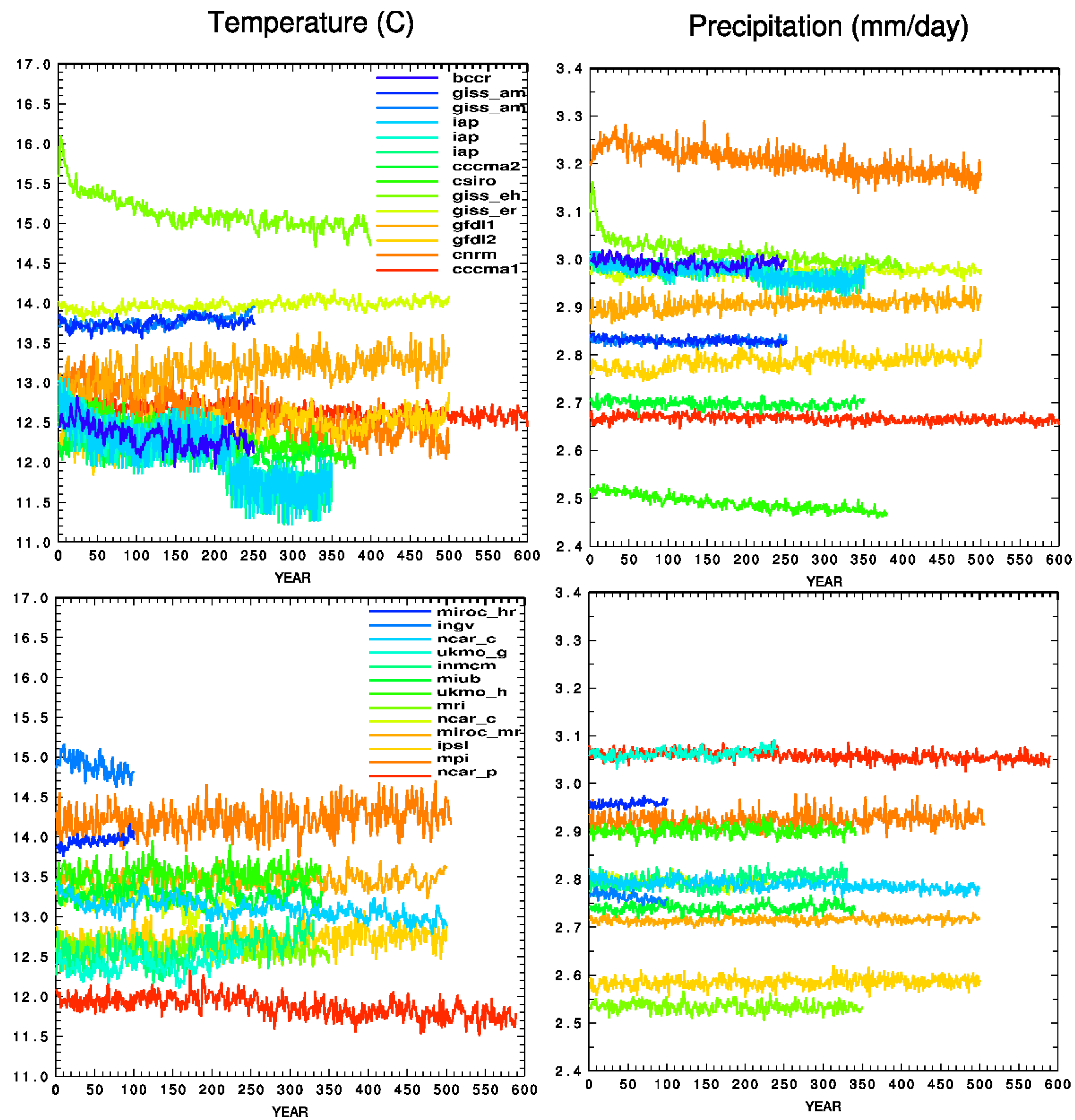
- we *consider here* the internally generated component $p_\nu = \sigma^2_\nu / \sigma^2$
- test for hypothesis

  $p_\nu = 0$, hope to reject - i.e. potential predictability is *not* zero
- estimate confidence interval $p_l < p_\nu < p_u$
- is $p_\nu = \sigma^2_\nu / \sigma^2$ big enough to be of interest?
  - ratio of variances *makes sense*
  - but small p_ν *due to large* σ^2 allows correlation skill to exist

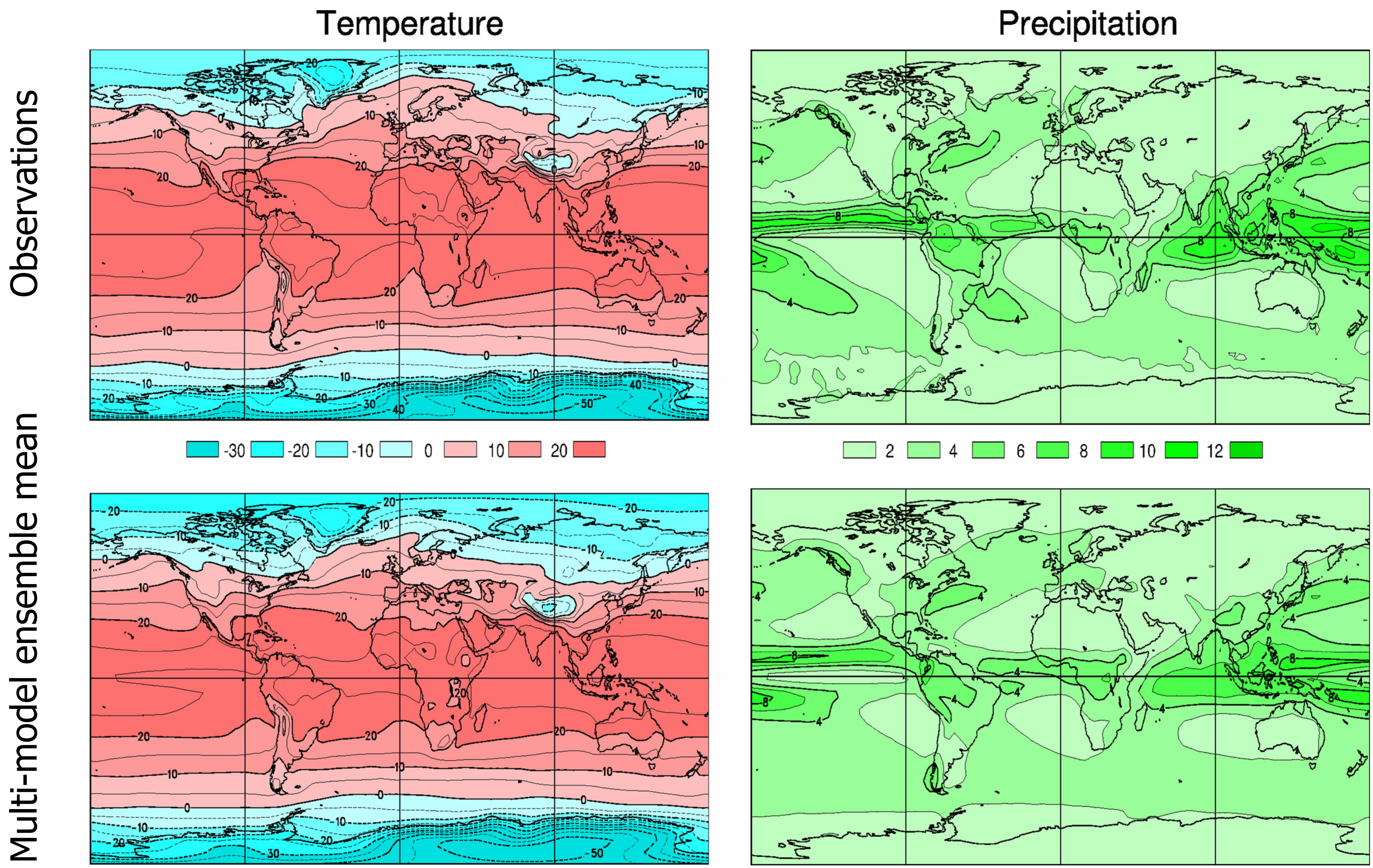
Apply to CMIP3 control climates

- (intended to be) equilibrium climate
- no external forcing – then *internally generated* ppvf is $p_\nu = \sigma^2_\nu / \sigma^2$
- results from 27 models are available
- simulations lengths from 100 to 1000 years
- consider surface air temperature and precipitation (the two main climate parameters)

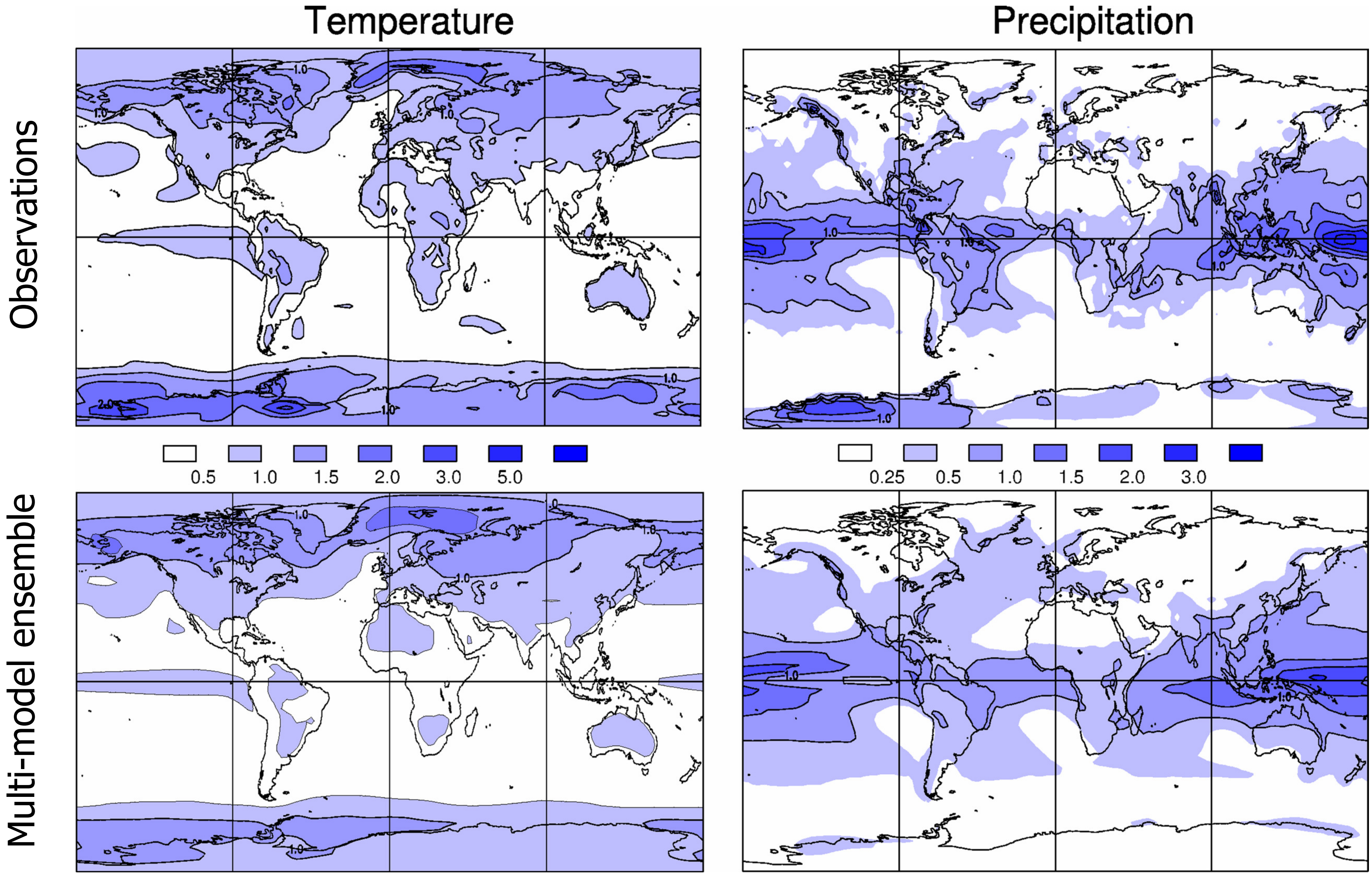
Time series of global annual means



Long-term annual means

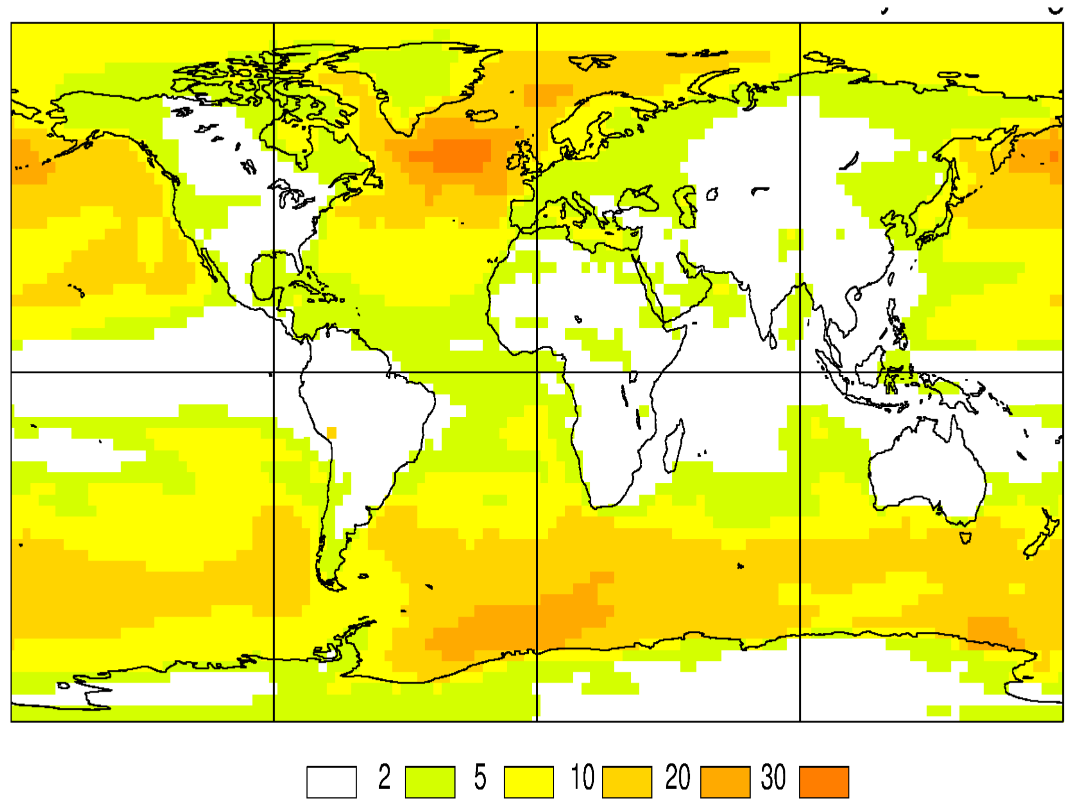


Standard Deviation of annual means



Temperature: potential predictability variance fraction $p_\nu = \sigma^2_\nu/\sigma^2$ (%) for ***decadal*** *means*

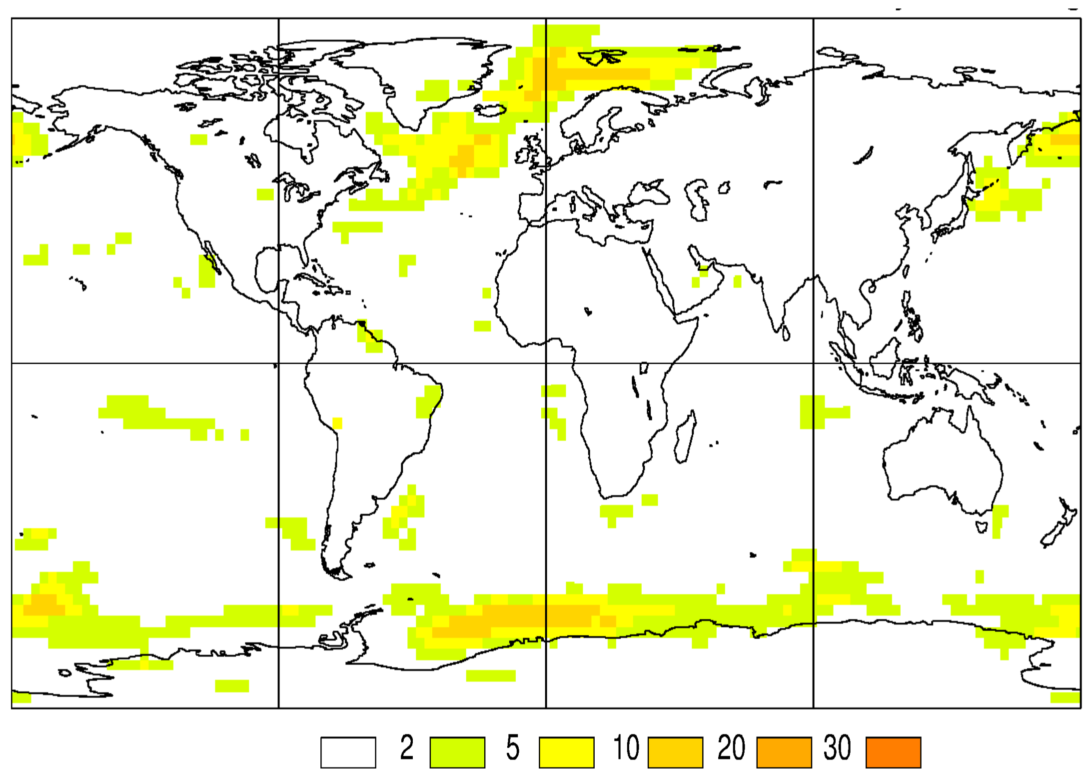
- Ratio of “predictable” to total variance
- MME provides stability of statistics: *ppvf* in white areas <2% and/or not significant at 98% level
- Long timescale predictability found mainly over oceans
- Some incursion into land areas but modest *ppvf*
- Unforced internally generated long timescale variability



Control simulations

Precipitation: potential predictability variance fraction $p_\nu = \sigma^2_\nu/\sigma^2$ (%) for ***decadal*** means

-MME provides "some" significant areas of precipitation
-Much less potentially predictable than temperature
- Little incursion into land areas
- Precipitation predictability a weakened version of temperature predictability at these timescales

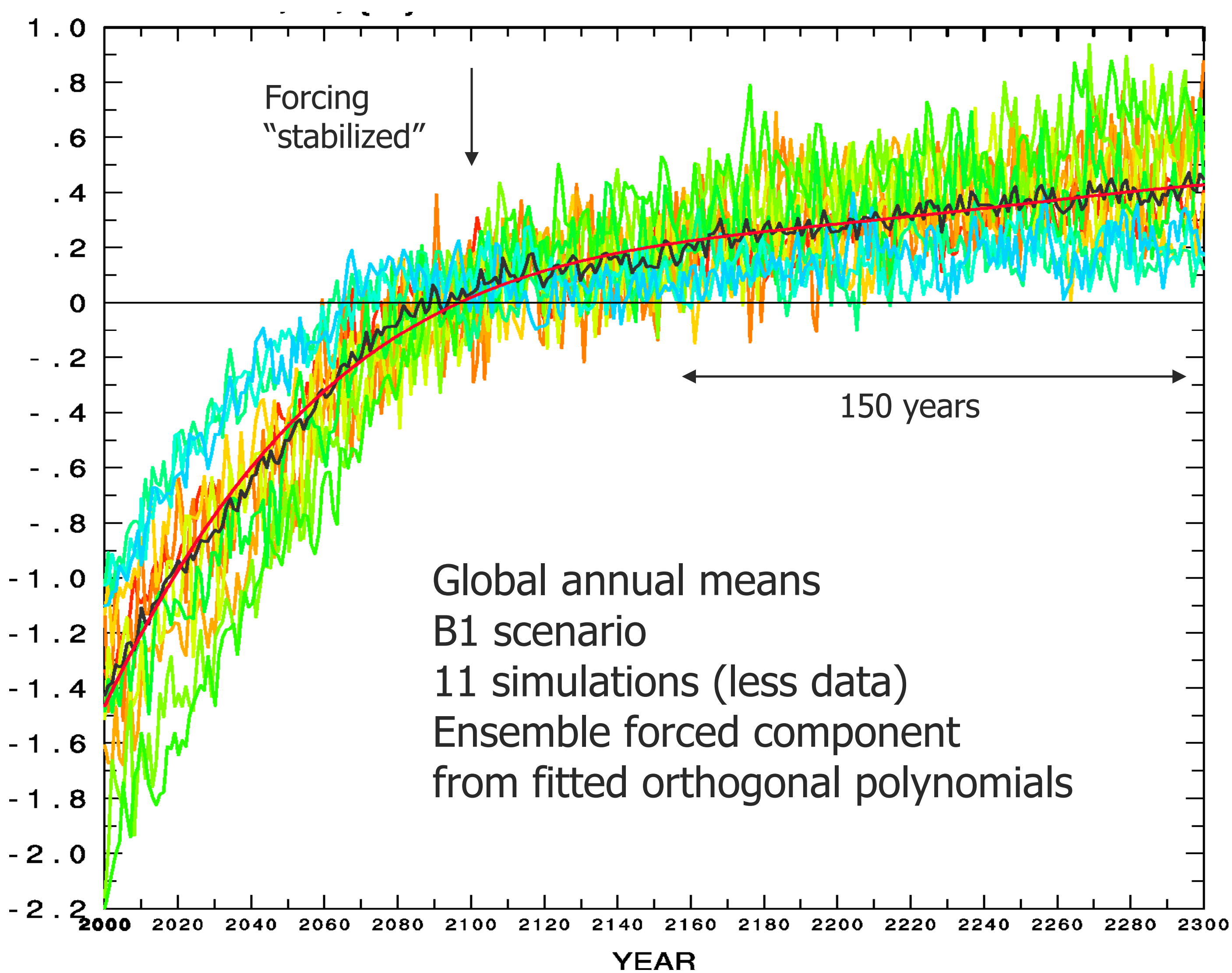


Control simulations

Potential predictability in a warmer world

- B1/Stabilization Scenario
- period is from 2000 to 2300
- GHG concentrations and aerosol loadings increase to 2100 then are constant (stabilized)
- less data: only 11 simulations for full data period

Temperature (C)



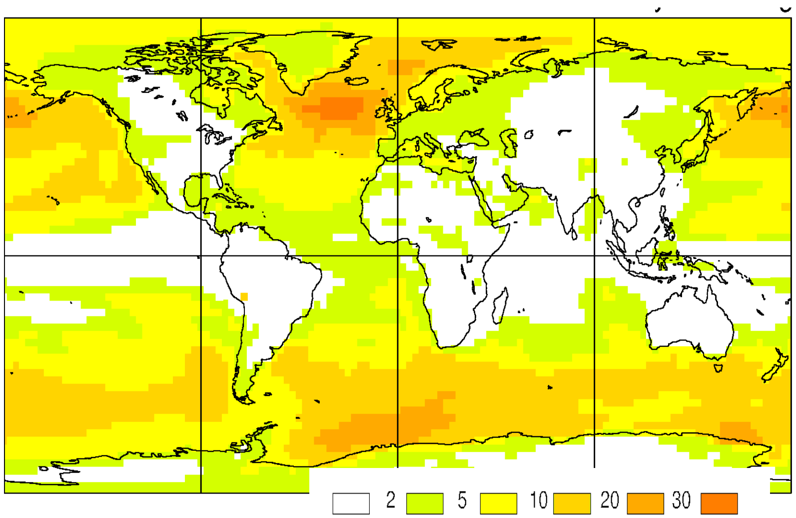
Potential predictability in a warmer world (stabilization case)

- last 150 years of stabilization simulations
- remove *trend* at each point
- estimate *internally generated* potential predictability p_v in warmer world

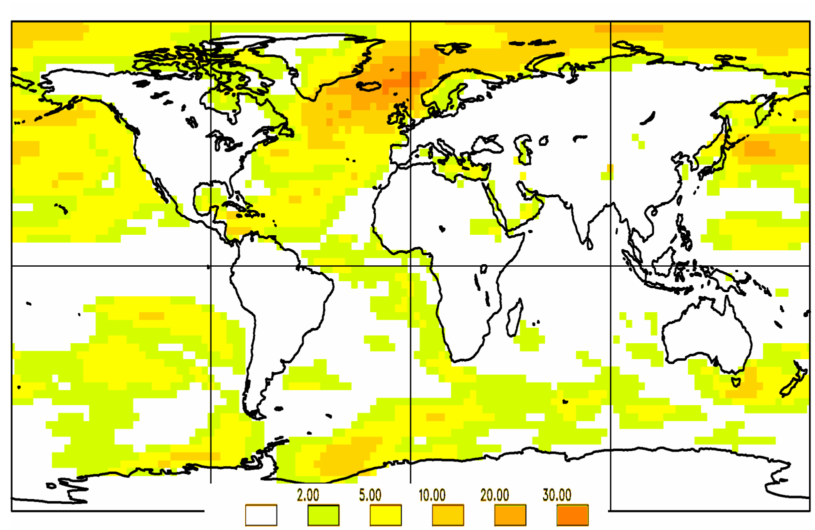
  - estimate *change* from control case

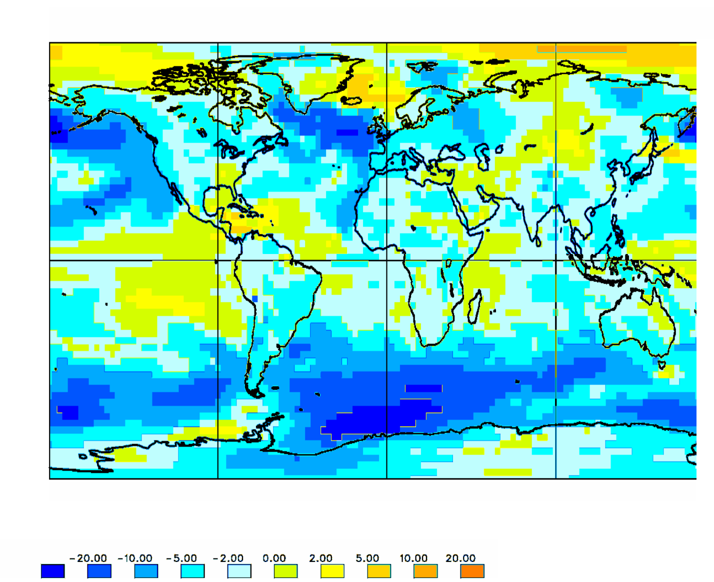
Decadal potential predictability p_v for *Temperature*

Control simulation

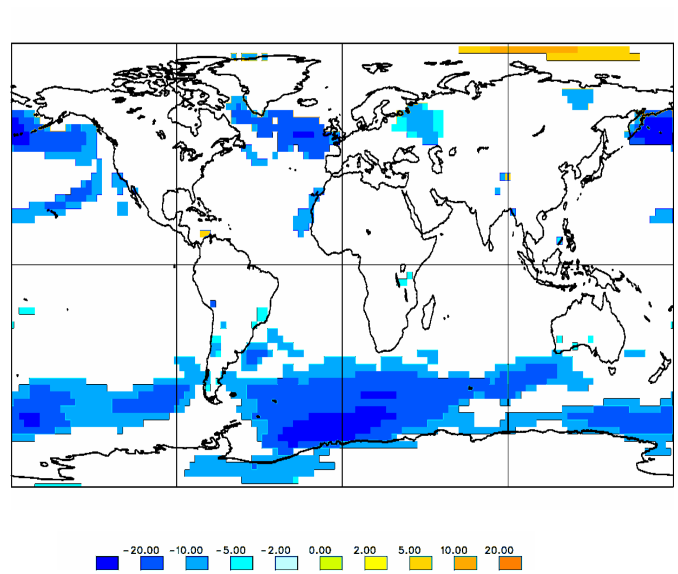


B1 stabilization scenario



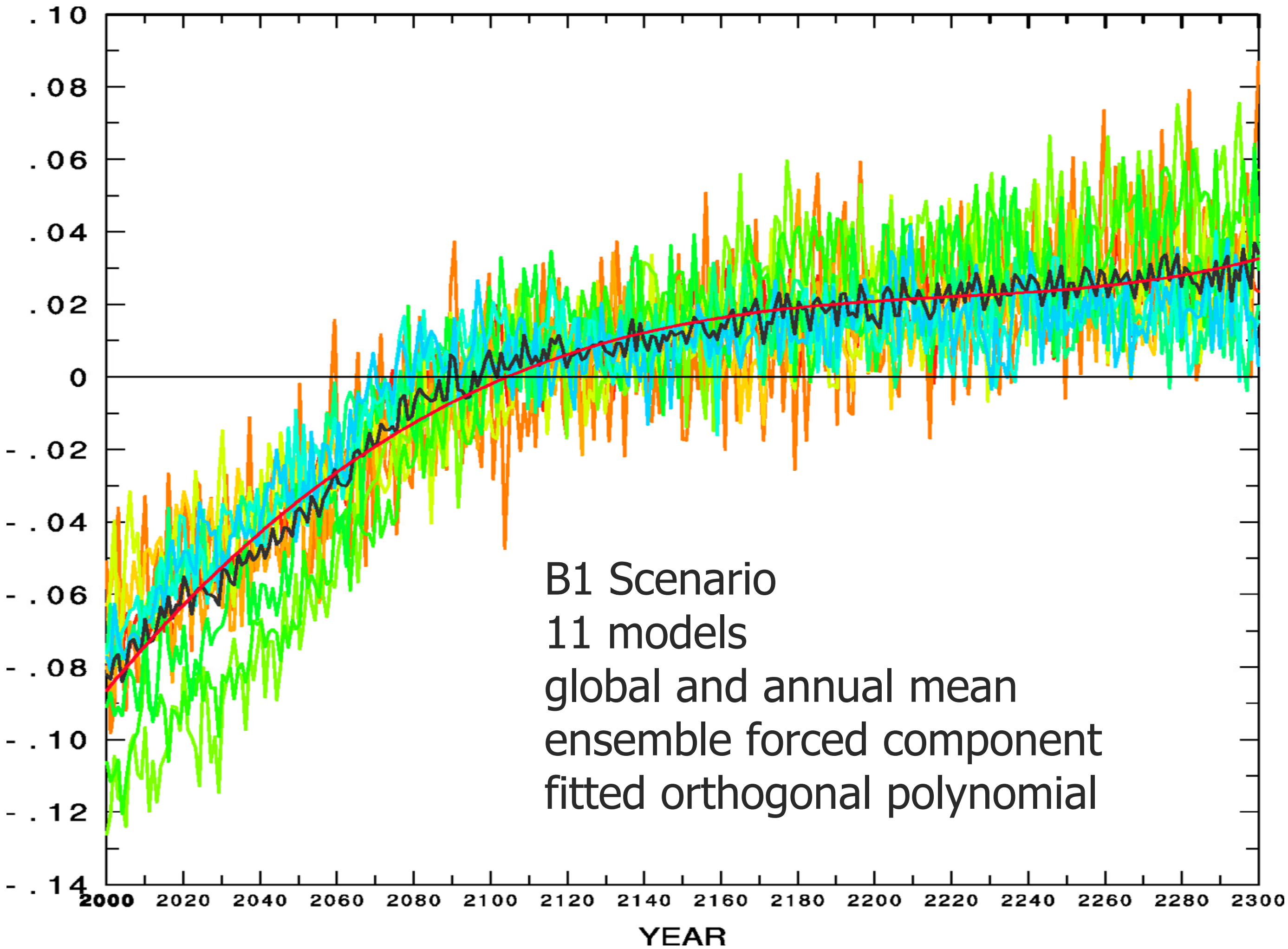


Difference in warmer world



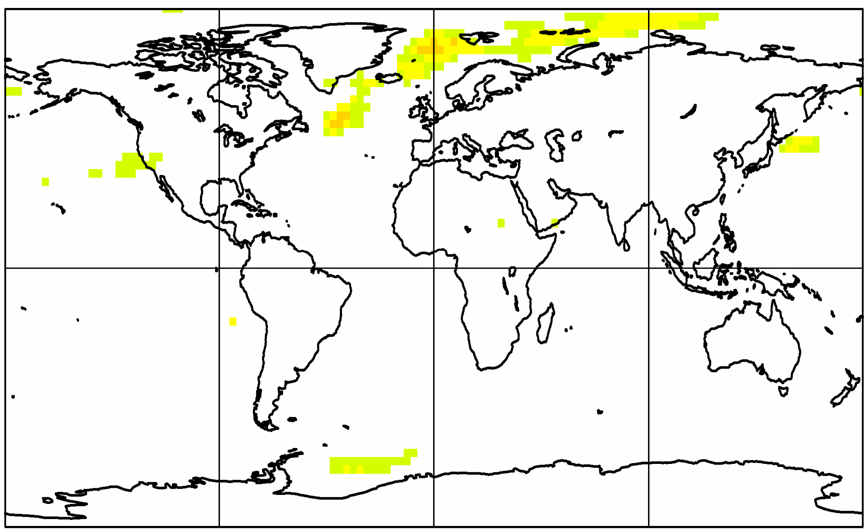
Where confidence bands *don't* overlap

Precipitation (mm/day)

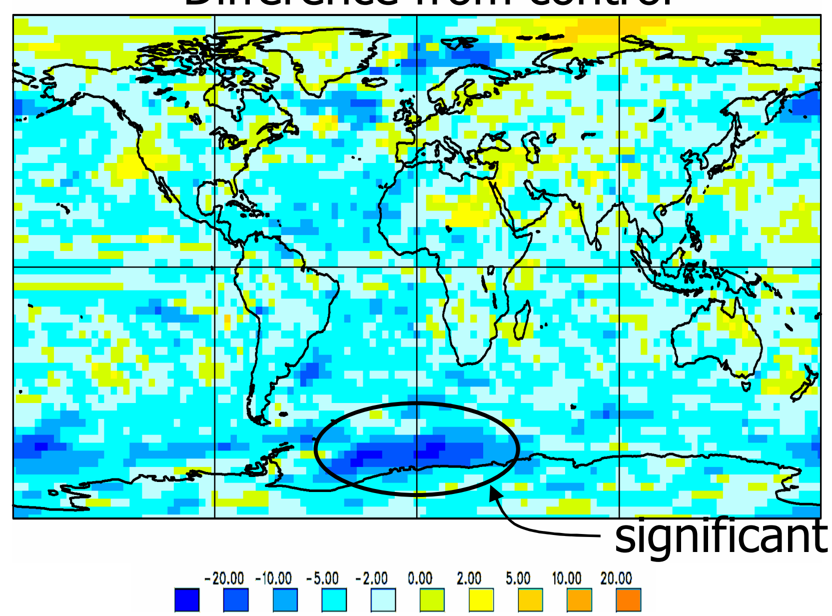


Warmer world: decadal potential predictability for Precipitation

Decadal ppvf



Difference from control



Given the enhanced hydrological cycle, rather an anticlimax

MME *decadal* potential predictability of temperature and precipitation

- "hot spots" over extratropical oceans for both temperature and precipitation
- precipitation considerably less potentially predictable than temperature
- comparatively little potential predictability over land and tropical oceans
- predictability found for regions/processes where surface connects to deeper ocean
- potential decadal predictability *decreases* in warmer world

The challenges of potential predictability

- to identify the mechanisms associated with regions of high potential predictability
- to understand the lack of potential predictability over land and tropical oceans
- to test potential predictability results by means of (multi-model) prognostic decadal predictions

End of presentation