Uncertainty in Climate Change Projections over North America: The Role of Natural Variability

Clara Deser

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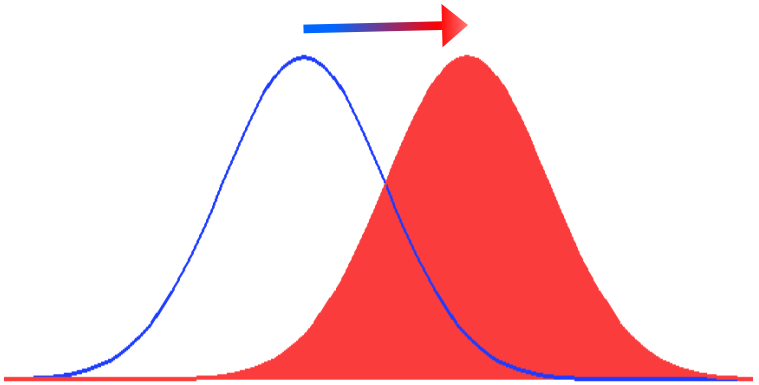
NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

Climate Dynamics, 2012; Nature Climate Change, 2012

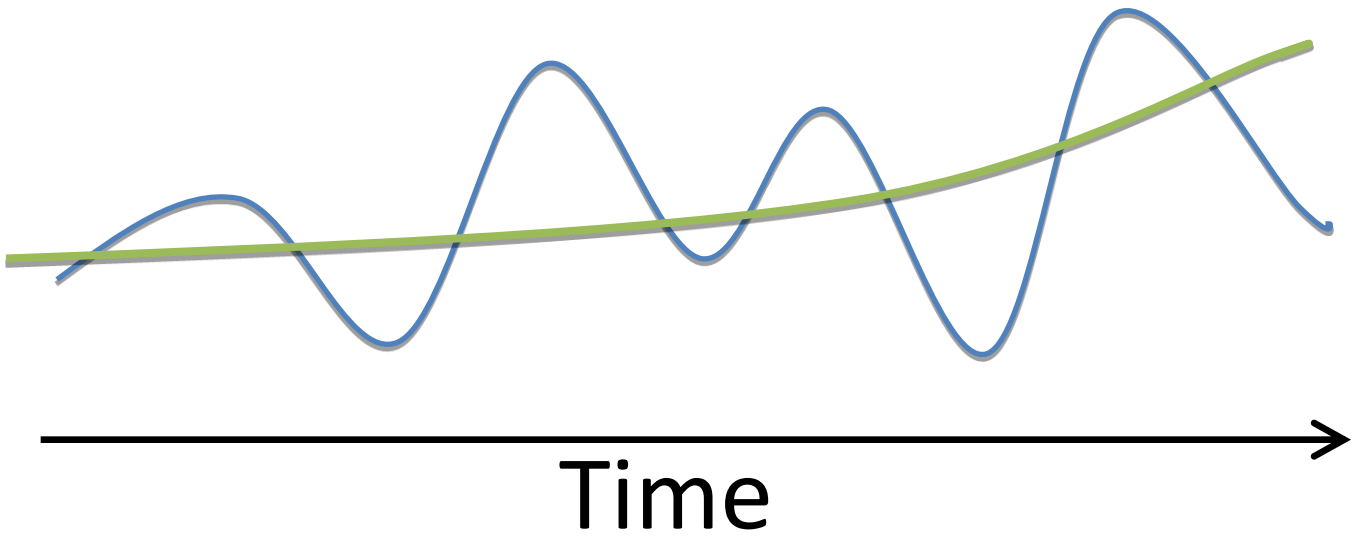


CESM Tutorial

August 2, 2012

Climate Variability

Climate Change



Climate Variability

or

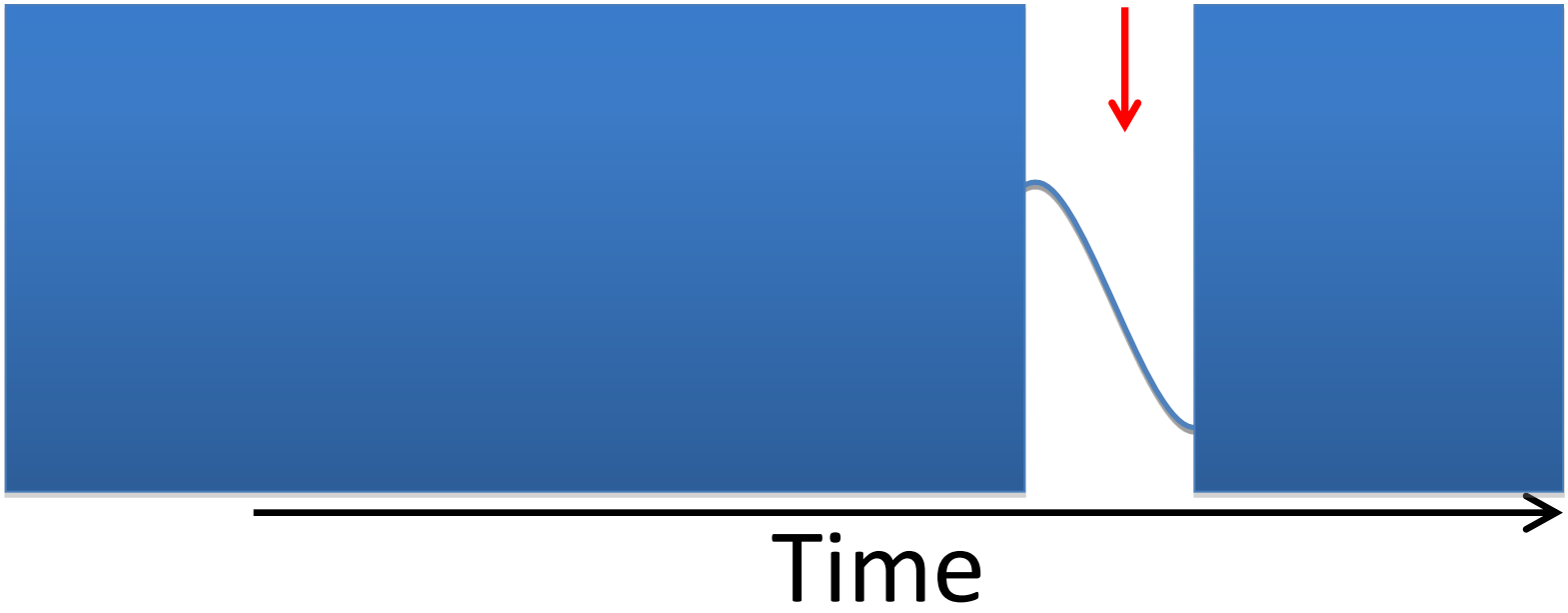
Climate Change

?

Climate Variability

or

Climate Change ?



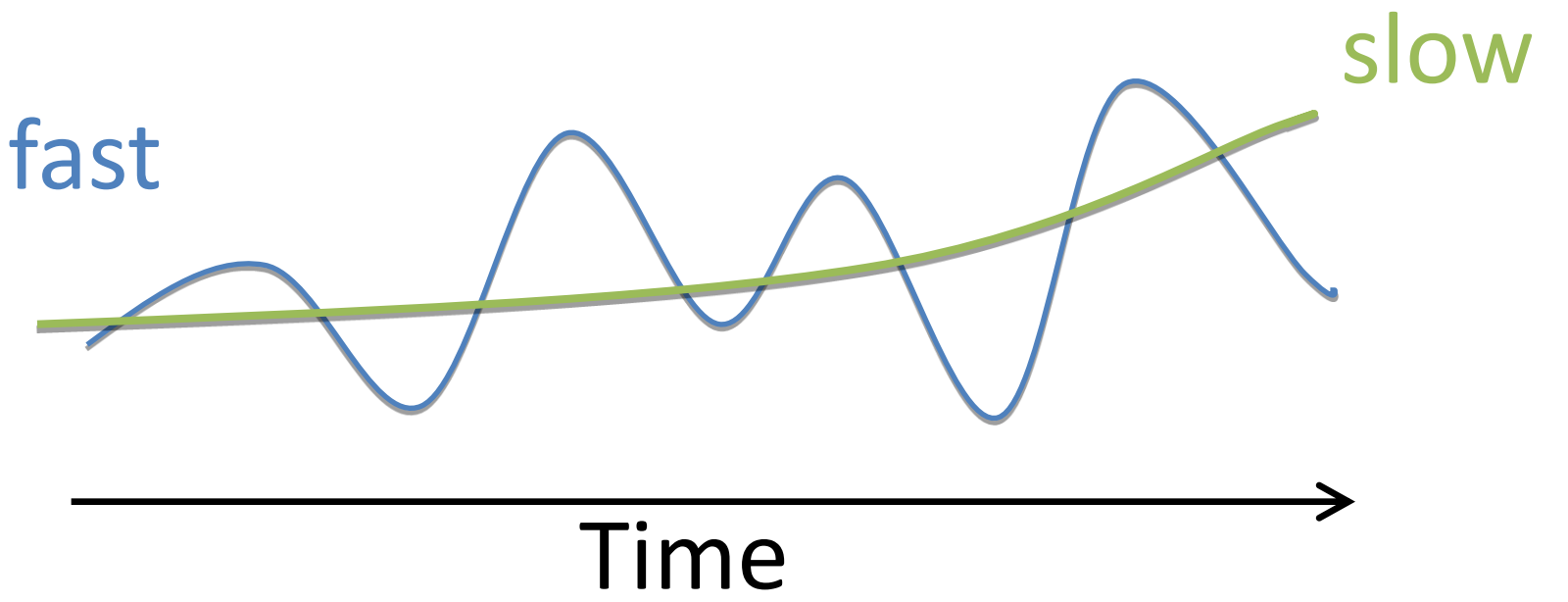
Two Examples of Slow Natural Climate Variations

Climate Variability

and

Climate Change

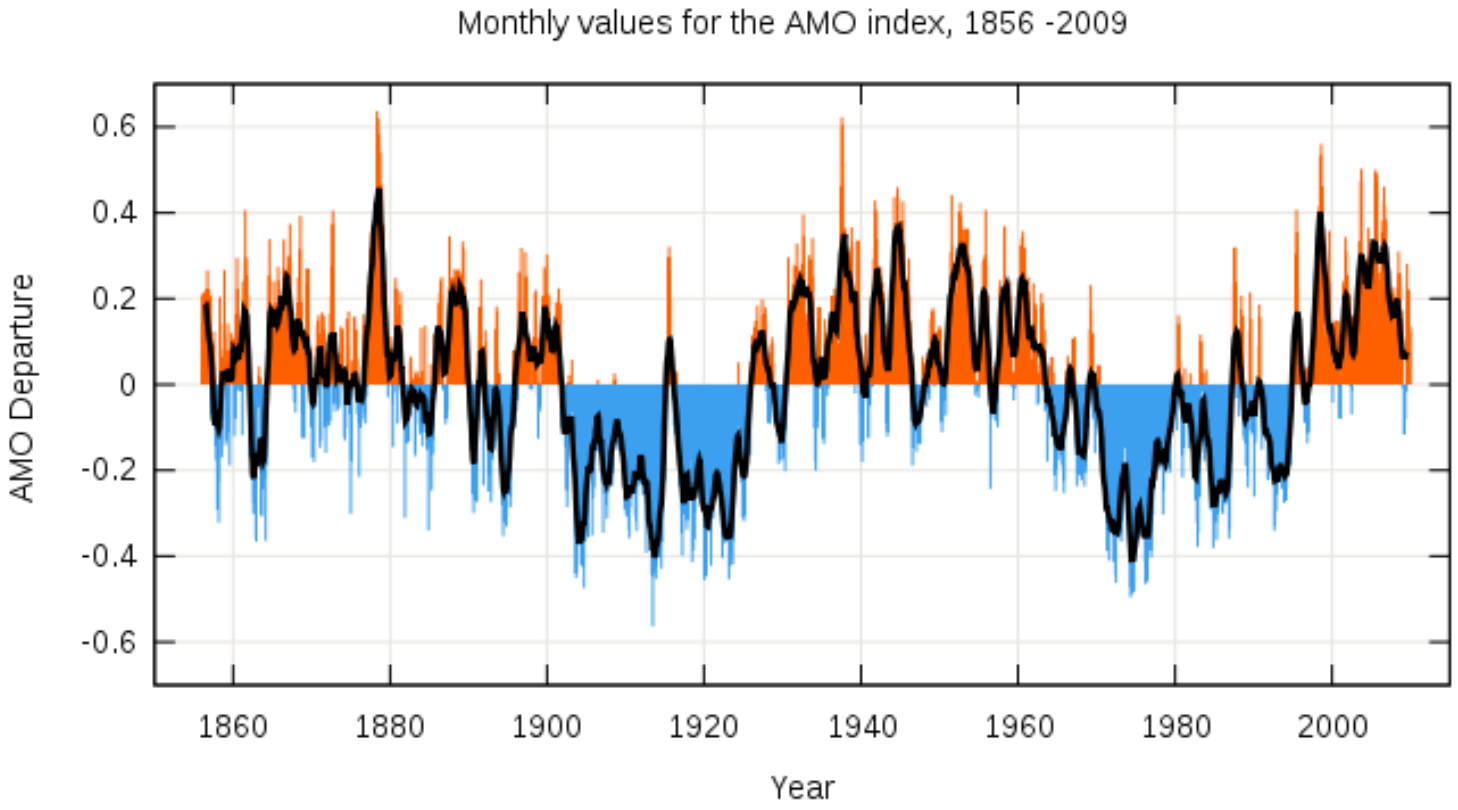
Can be very slow!



Atlantic Multidecadal Oscillation (AMO)

North Atlantic Sea Surface Temperature Anomalies

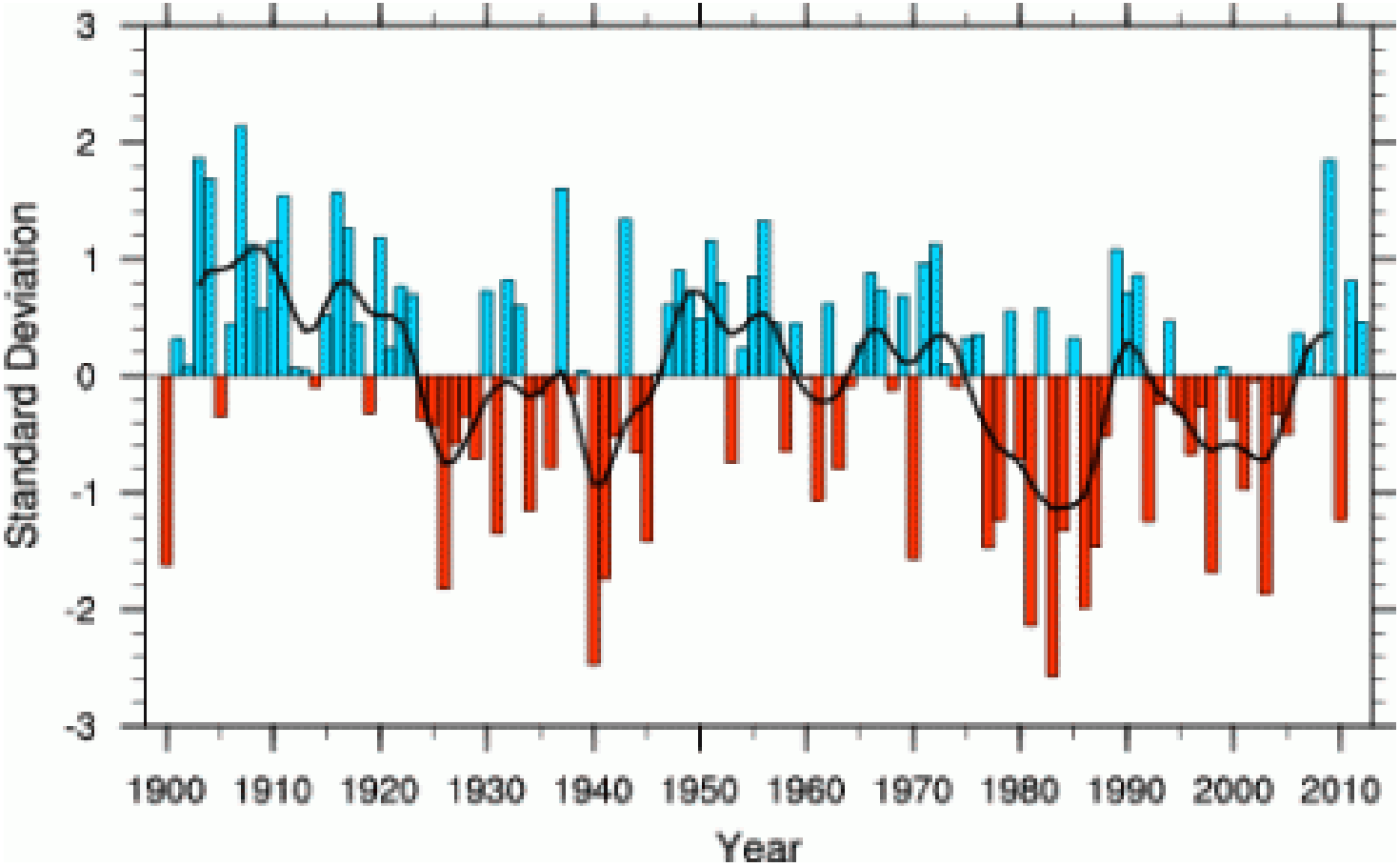
Ocean



North Pacific Sea Level Pressure Index

"PDO/IPO"

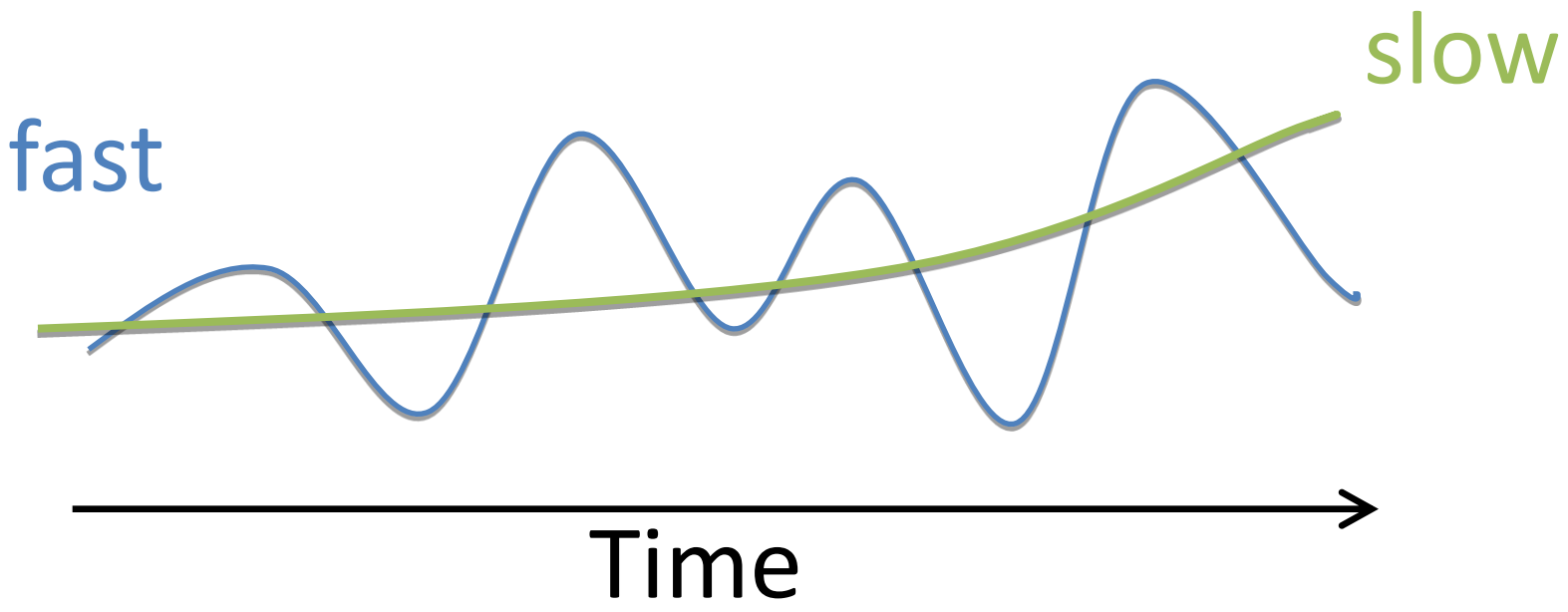
Atmosphere



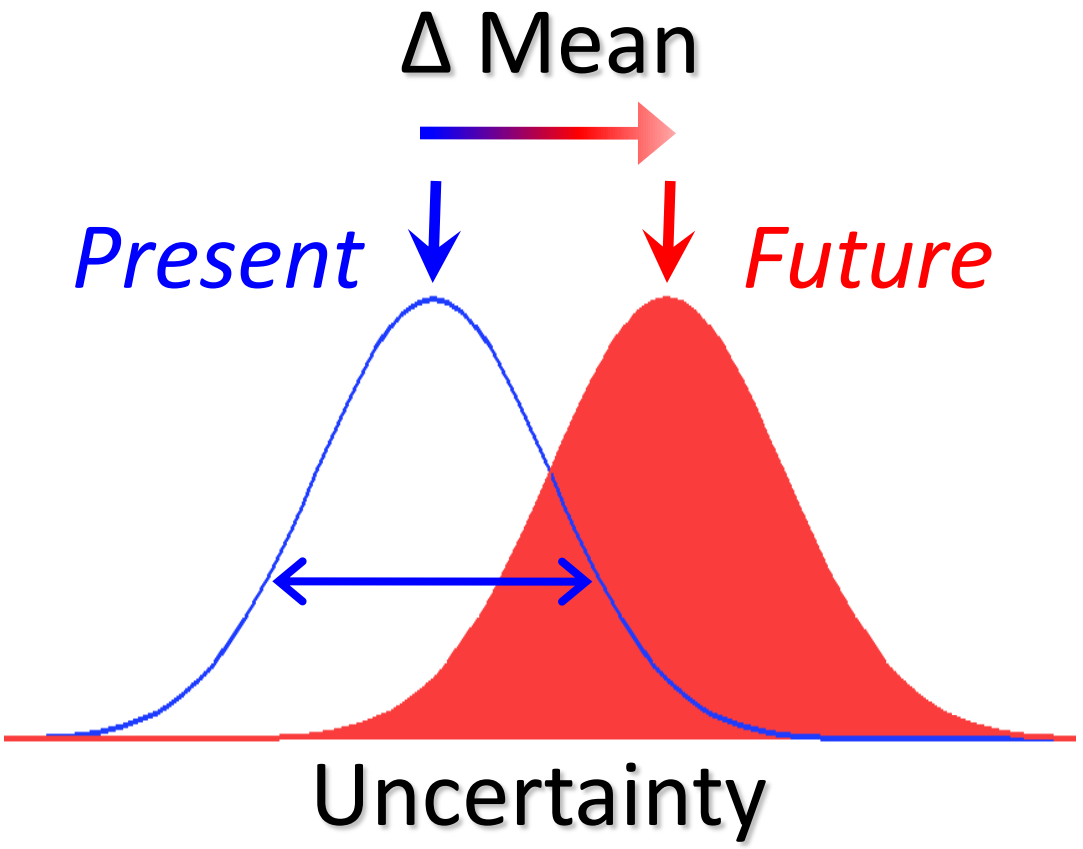
Can be difficult to distinguish with short records

Climate Variability

Climate Change



Climate Change



Signal: Δ Mean/Uncertainty

Climate Change: Sources of Uncertainty

- Forcing

  GHG emissions scenario (e.g., B1, A1B, A2, RCPs)
  ozone, sulfate aerosols, land use, black carbon …

- Response

  Model sensitivity
  (different physics, parameterizations, resolution …)

- Internal (Natural) Variability
  - atmosphere
  - ocean
  - coupled atmosphere-ocean system

IPCC Fourth Assessment Report
Climate Change 2007: The Physical Science Basis

- Forcing

  3 Scenarios for 21st Century (B1, A1B, A2)

- Model Sensitivity

  23 Coupled General Circulation Models

- Internal (Natural) Variability

  Multiple Simulations

IPCC Fourth Assessment Report
Climate Change 2007: The Physical Science Basis

- Forcing

  3 Scenarios for 21st Century (B1, A1B, A2)

- Model Sensitivity

  23 Coupled General Circulation Models

- Internal (Natural) Variability

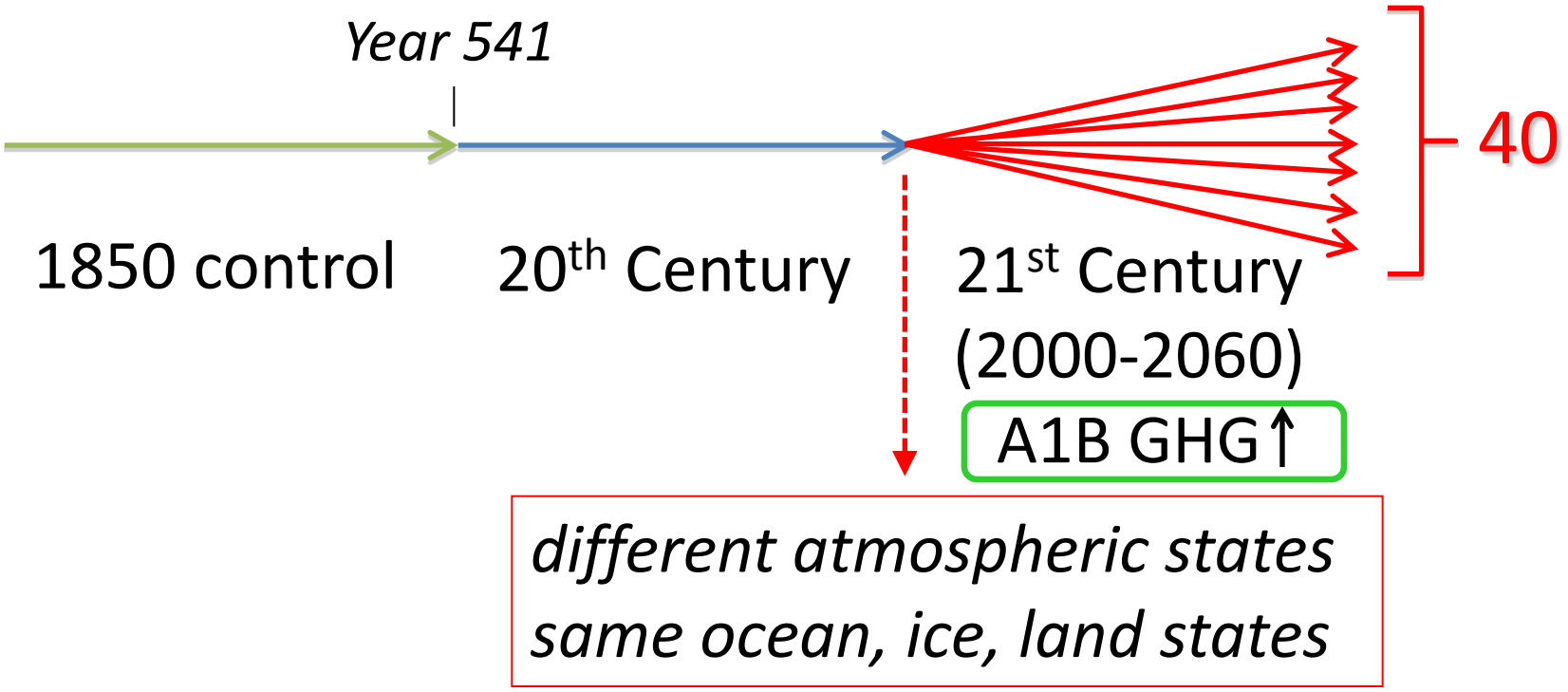
  Multiple Simulations

# Simulations	1	2	3	4	5	6	7
# Models	10	1	3	2	3	0	1

CMIP3; CMIP5 expected to be similar

The Large Ensemble Project:
Uncertainty Due to Natural Variability

40 CCSM3 Integrations

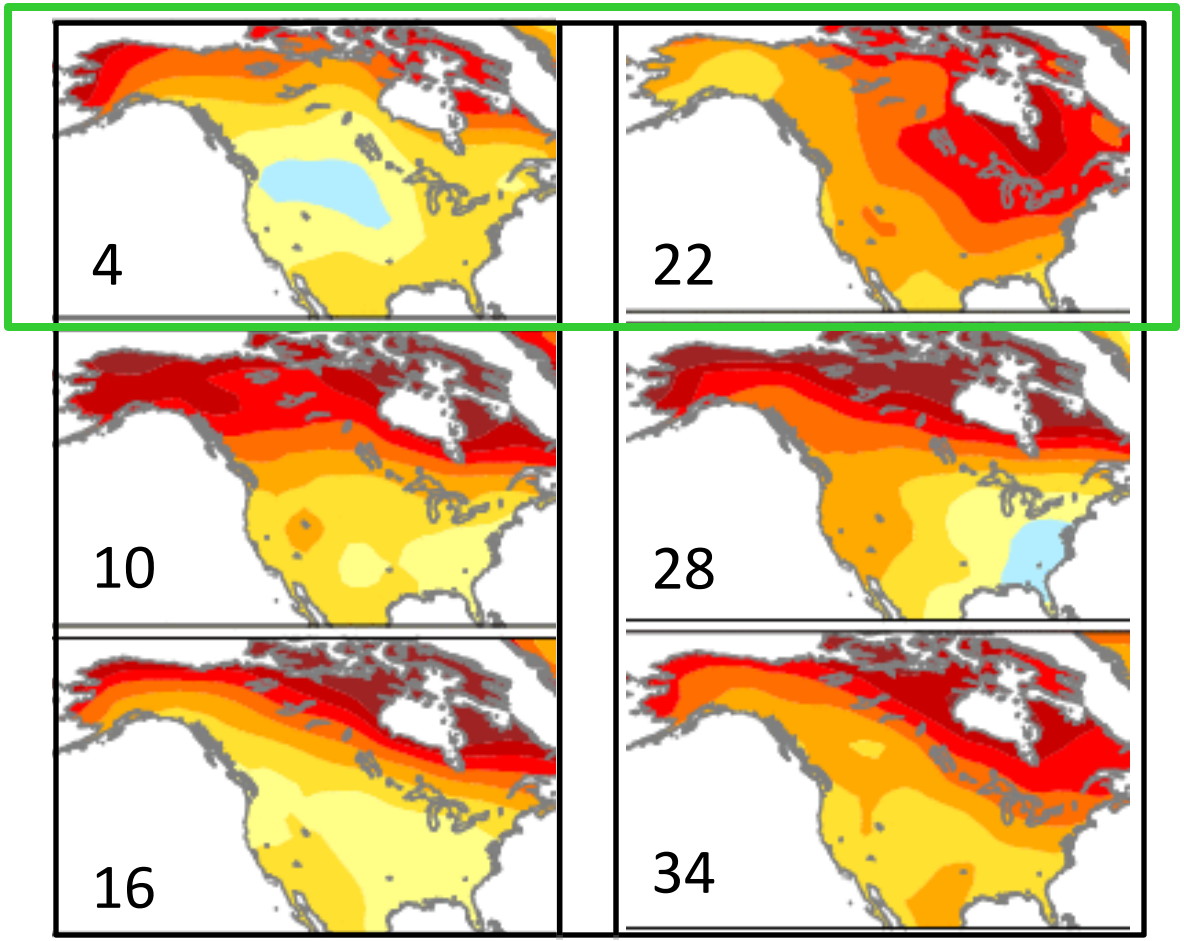


Future Winter Temperature Trends 2005-2060
6 of the 40 CCSM3 Integrations

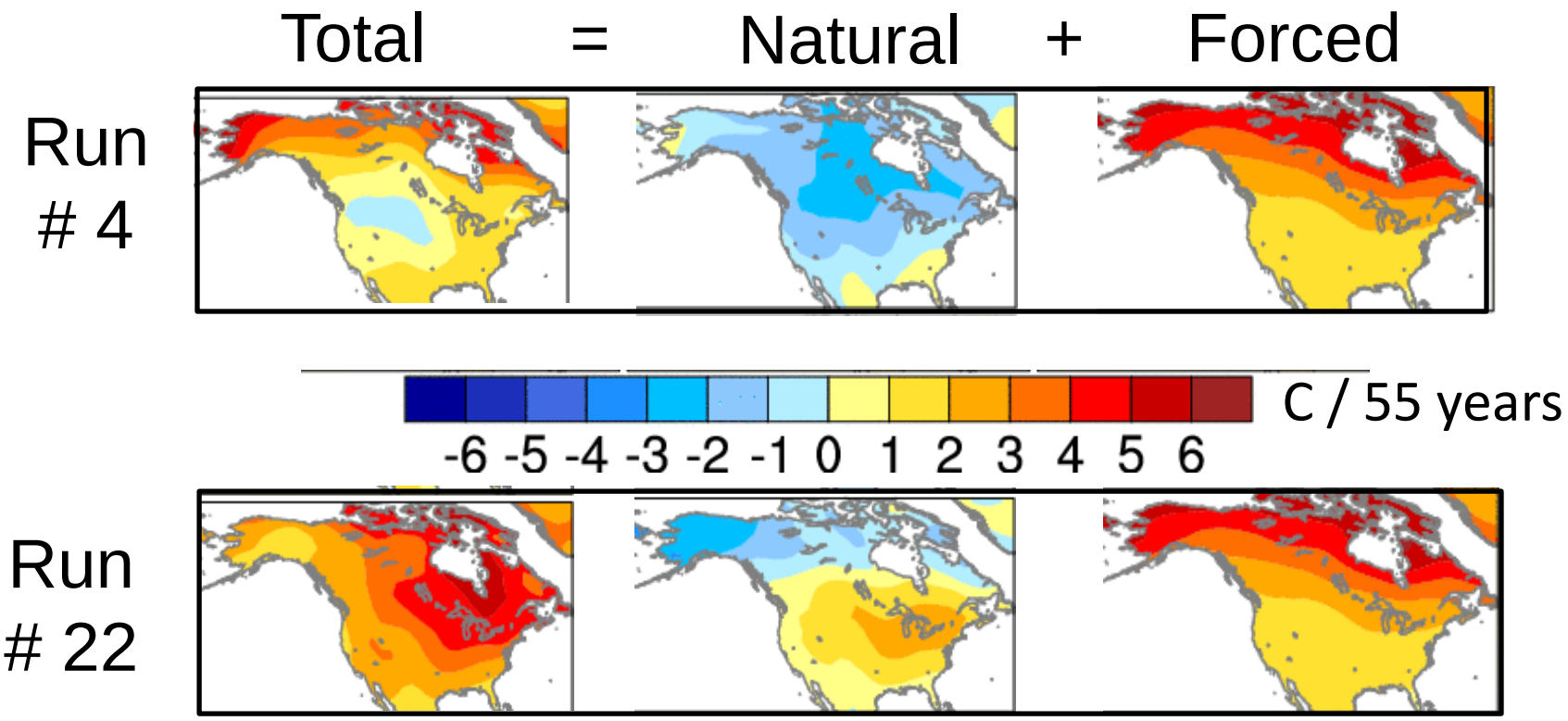
Natural Variability

+

Climate Change



Future Winter Temperature Trends 2005-2060



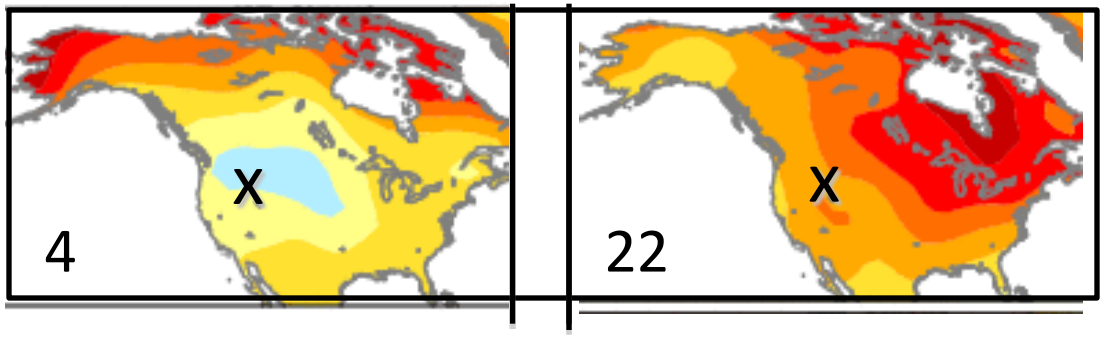
Where does the natural component come from?

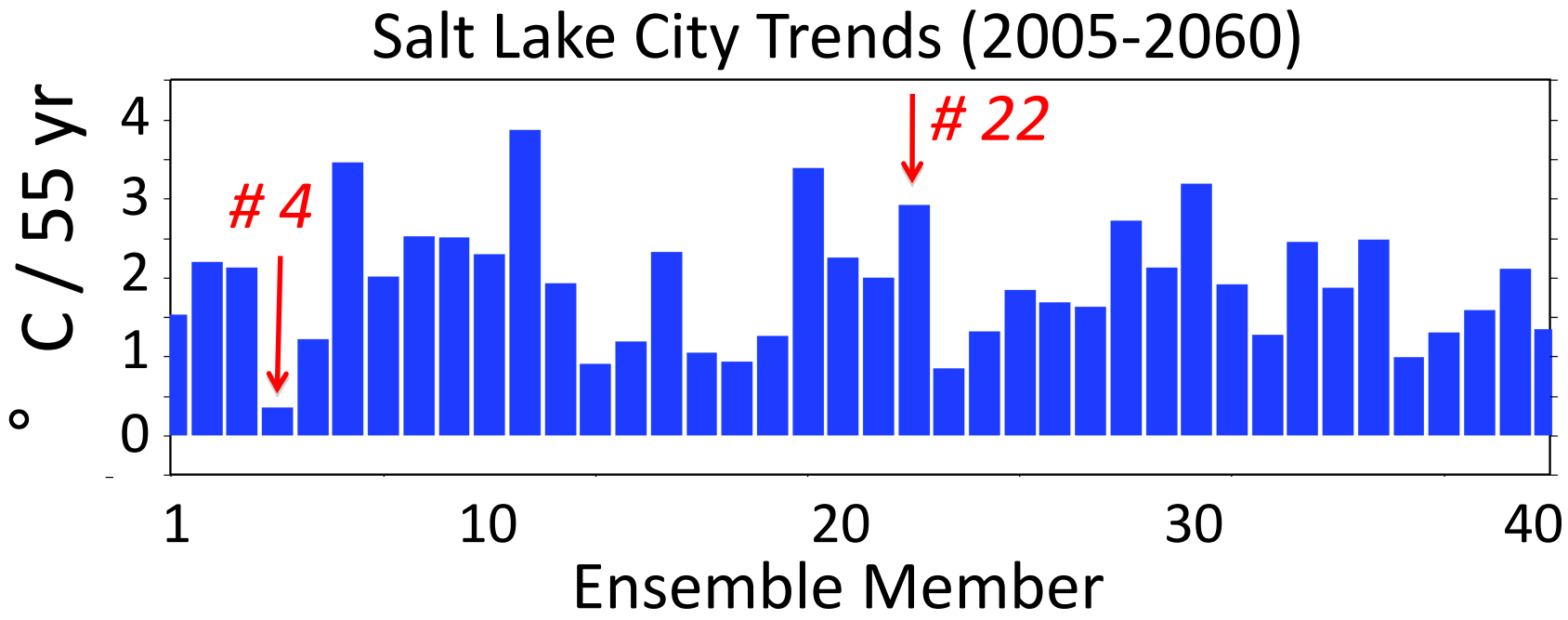
Atmospheric Circulation Variability

Future Winter Temperature Trends 2005-2060

X

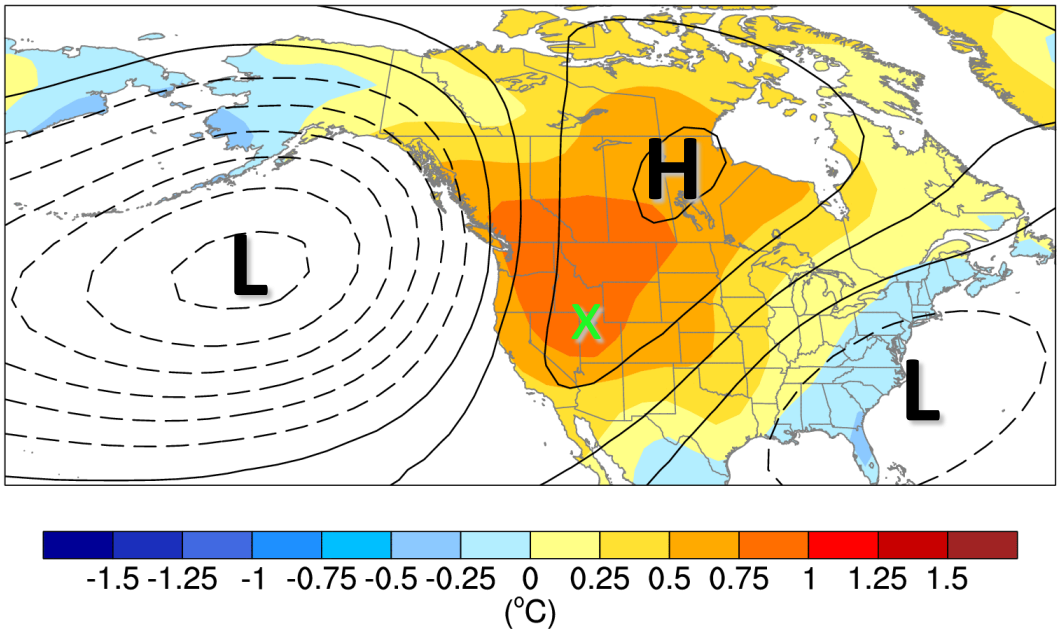
Salt Lake City, Utah

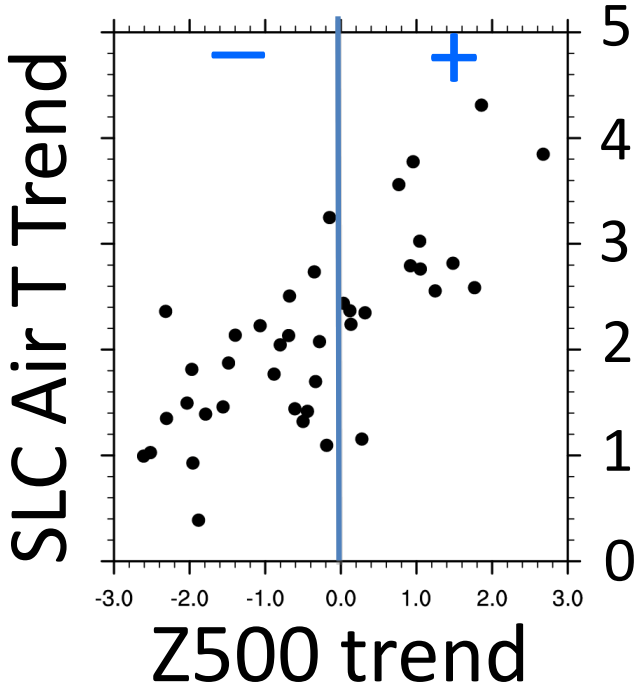




Regress 500mb height trends onto SLC T Trends

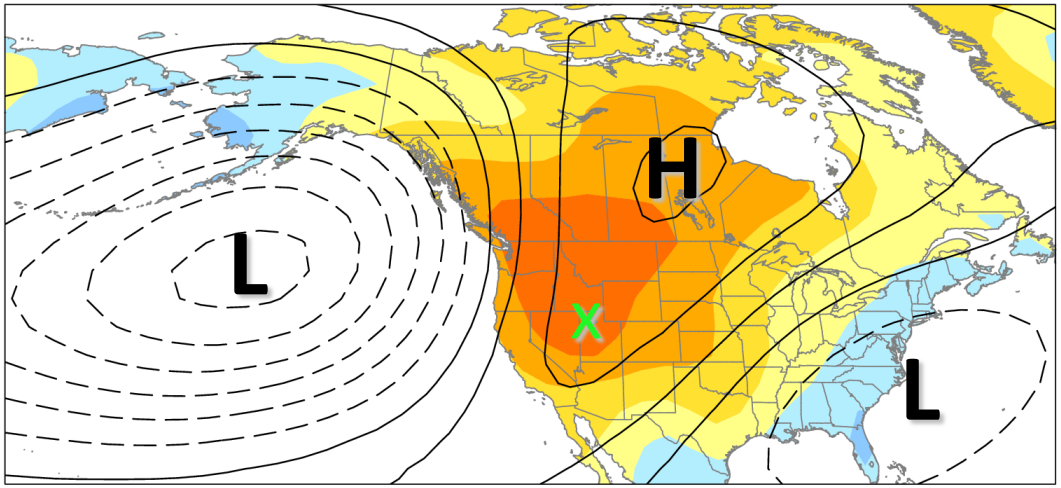
Z500, Temperature Trends (2005-2060)
Regressed onto SLC T Trends X





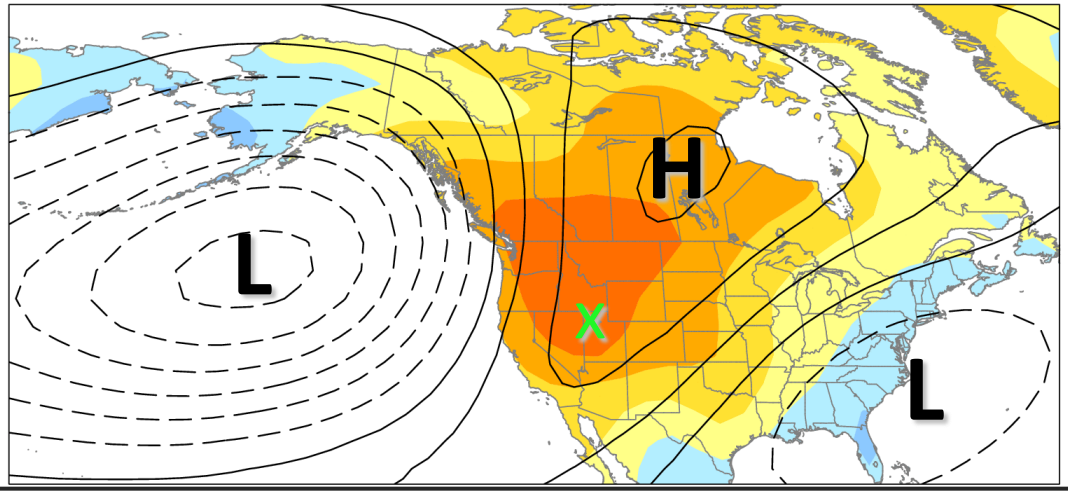
"Pacific-North American Pattern"

Z500, Temperature Trends (2005-2060)
Regressed on SLC T Trends x

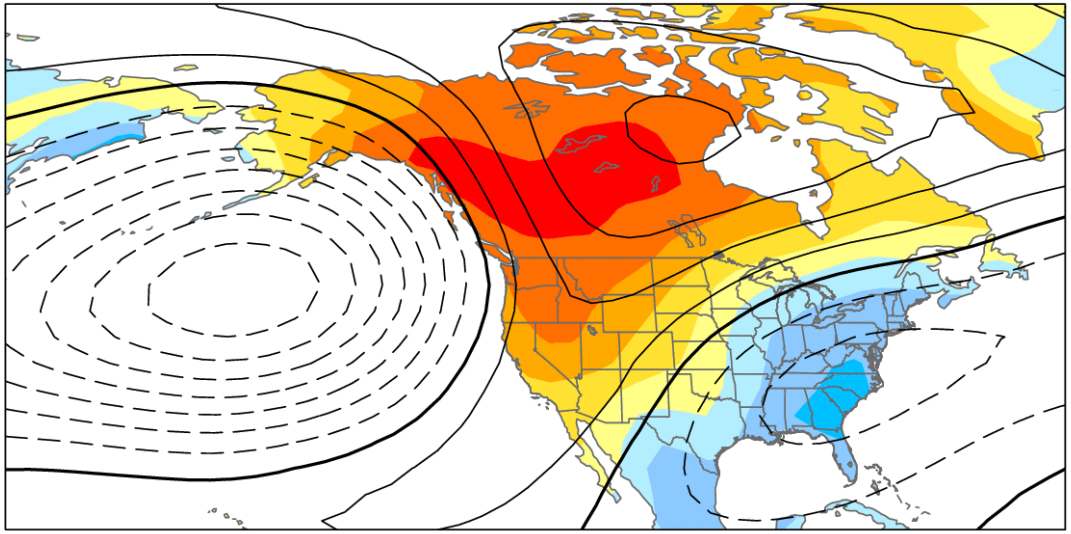


"Pacific-North American Pattern"

Z500, Temperature Trends (2005-2060)
Regressed on SLC T Trends x

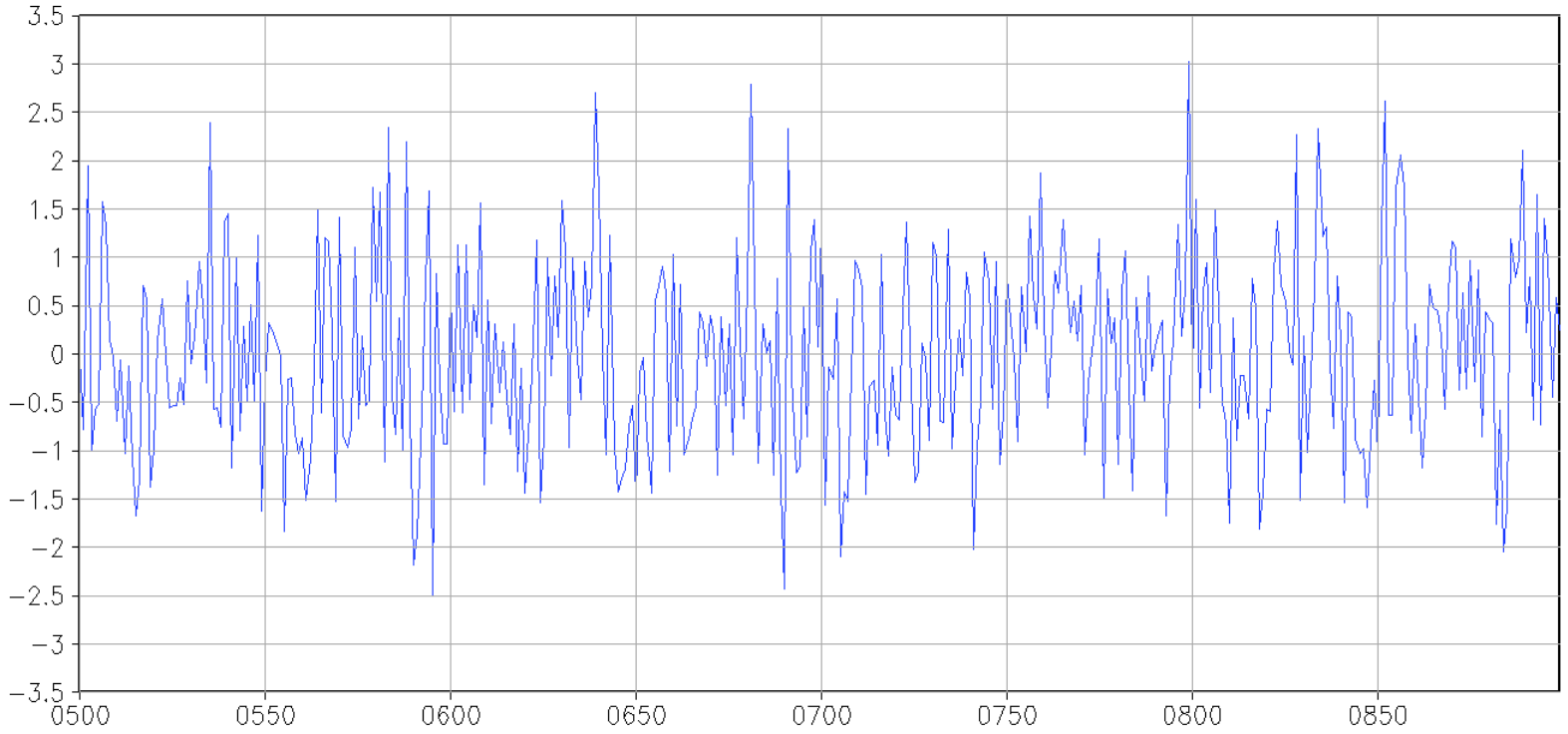


"Pacific-North American Pattern"



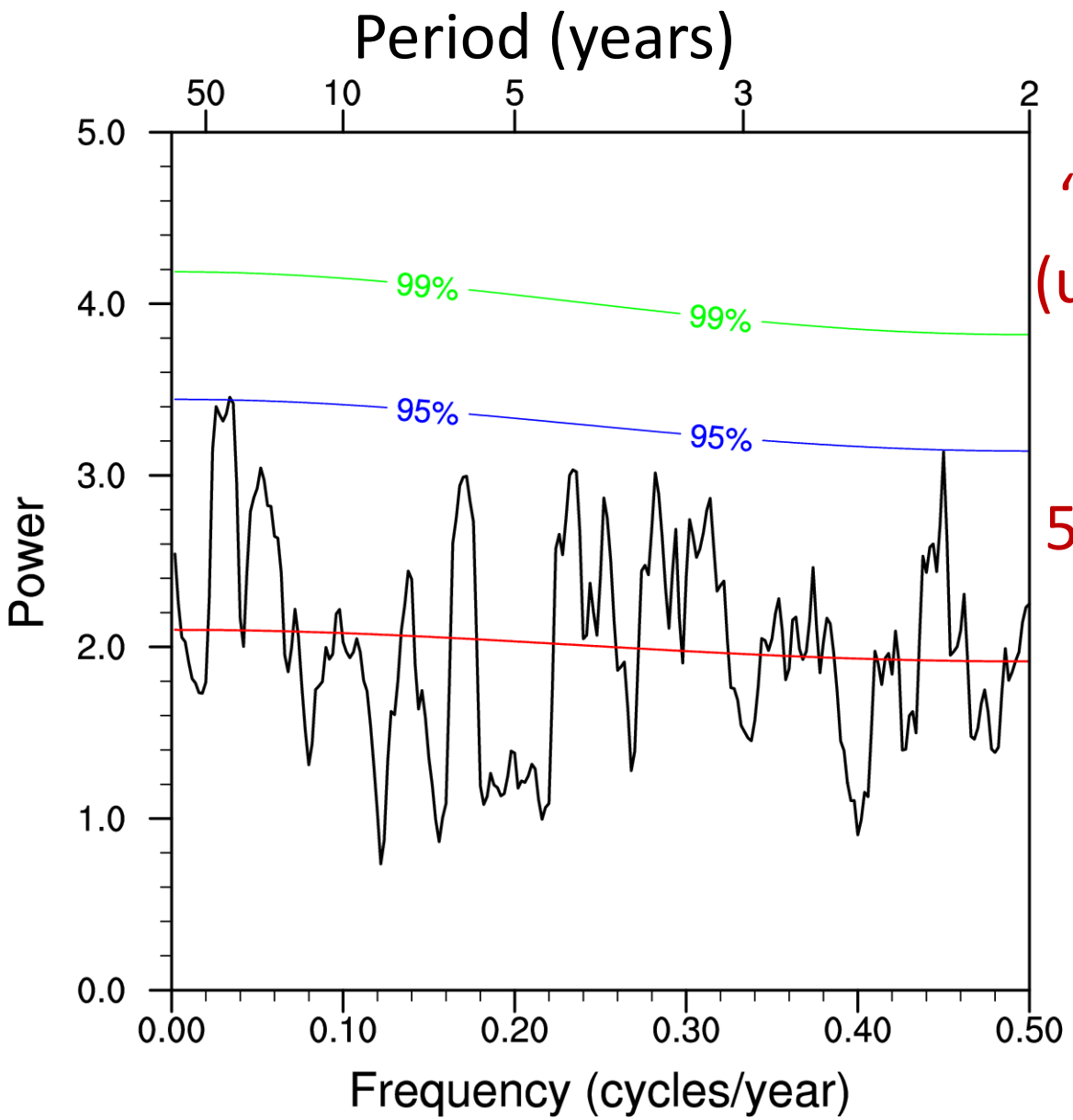
PNA is also the leading pattern of variability (EOF1) in a long CCSM3 control run on interannual time scales (44%) and for 55-year trends (56%)

PNA Pattern: CCSM3 Control Run (400 Years)



Model Year

Power Spectrum of the Pacific-North American Pattern

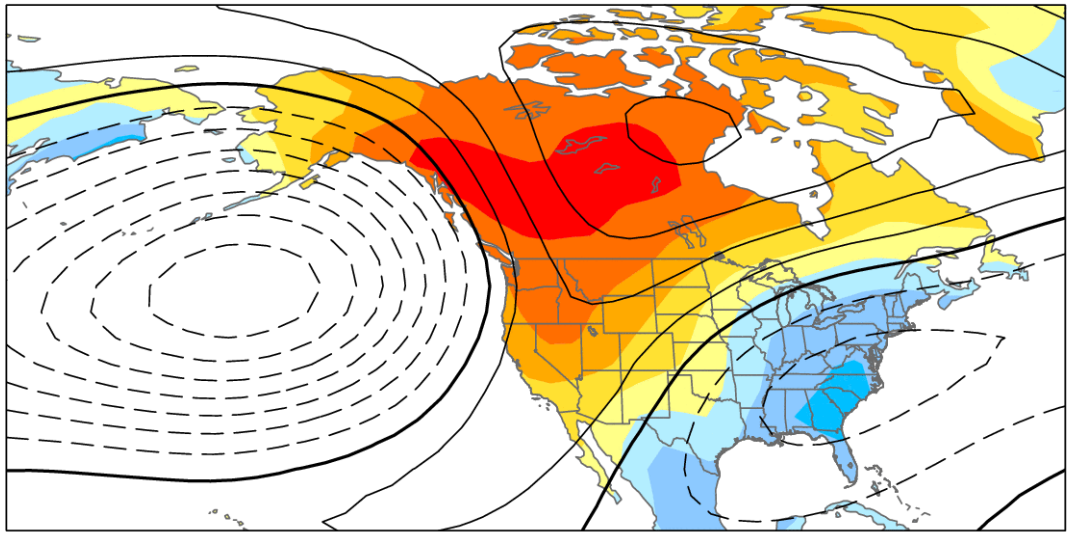


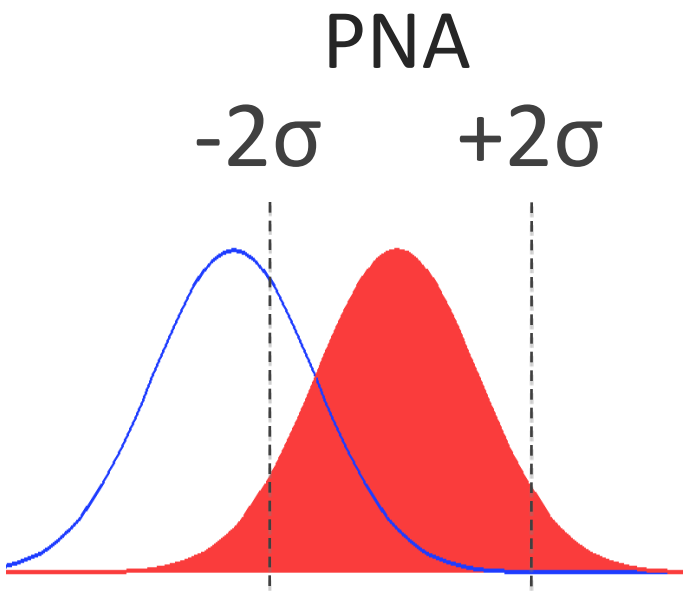
"white noise" (unpredictable)

e.g., can get 55-year trends by chance

Accounting for the Effects of Natural Atmospheric Circulation Variability on Future Climate Change

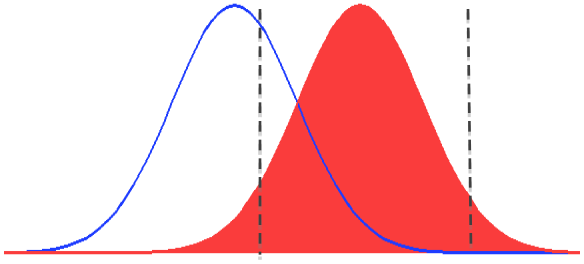
"Pacific-North American Pattern"





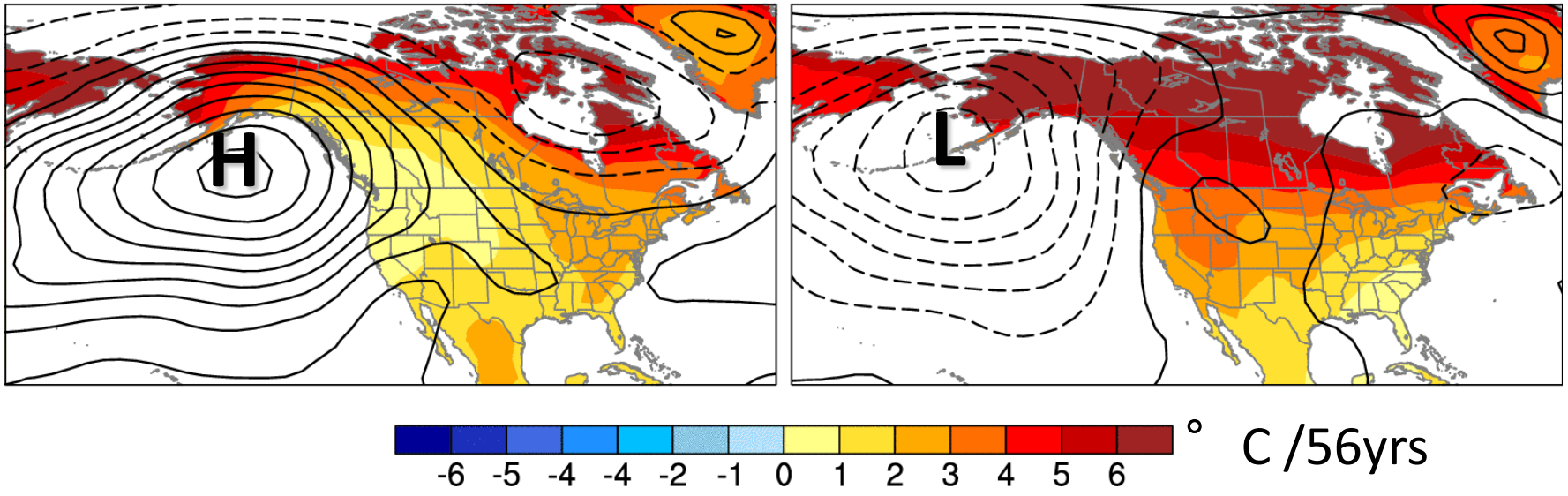
Add/Subtract naturally-occurring "PNA" Variation To/From Forced Climate Signal

Future T and SLP Trends 2005-2060



-2σ PNA

+2σ PNA

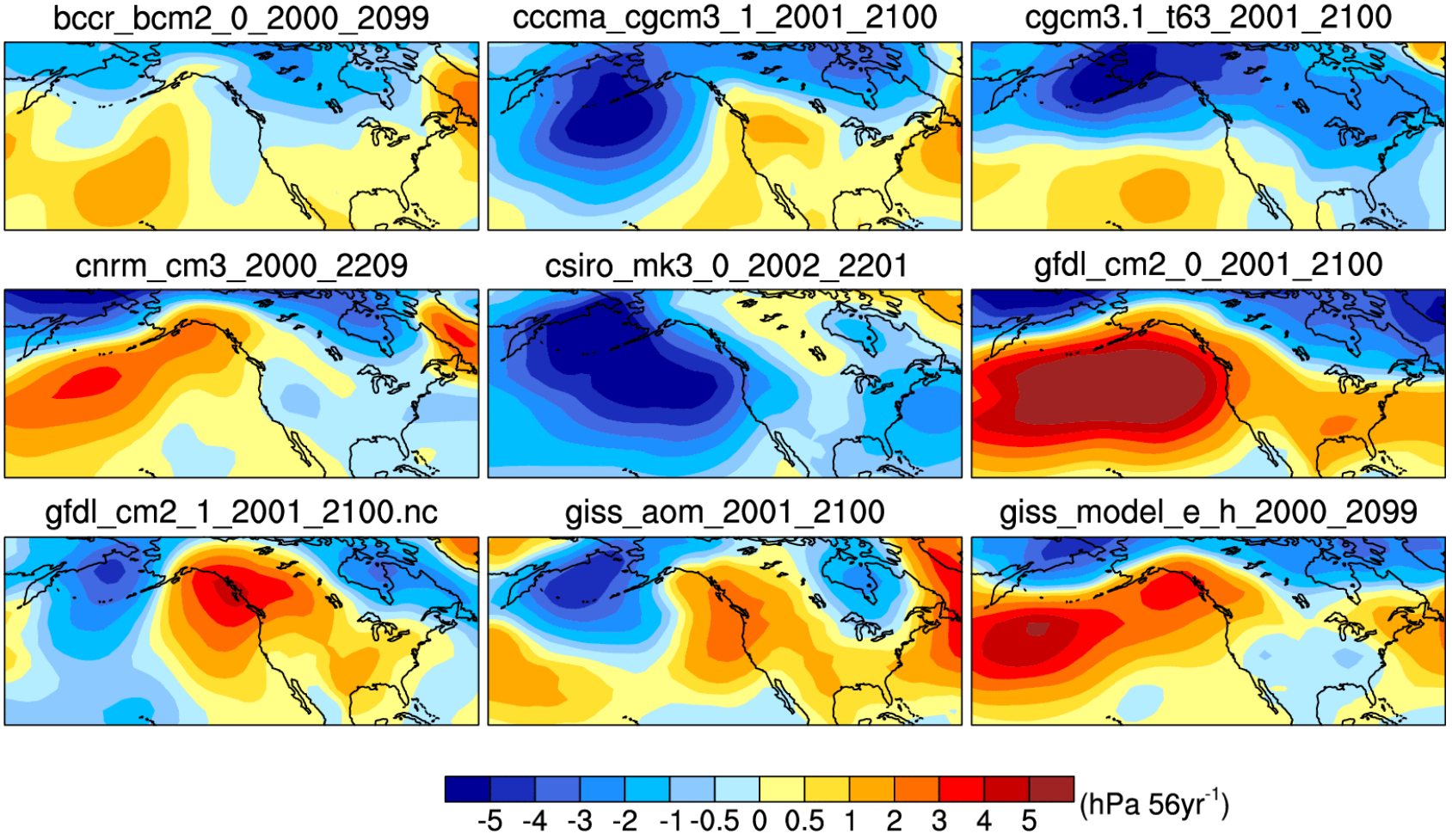


A Range of Outcomes Due to Natural Atmospheric Circulation Variability

How should we compare single realizations from different models?

IPCC AR4 (CMIP3) Model Archive

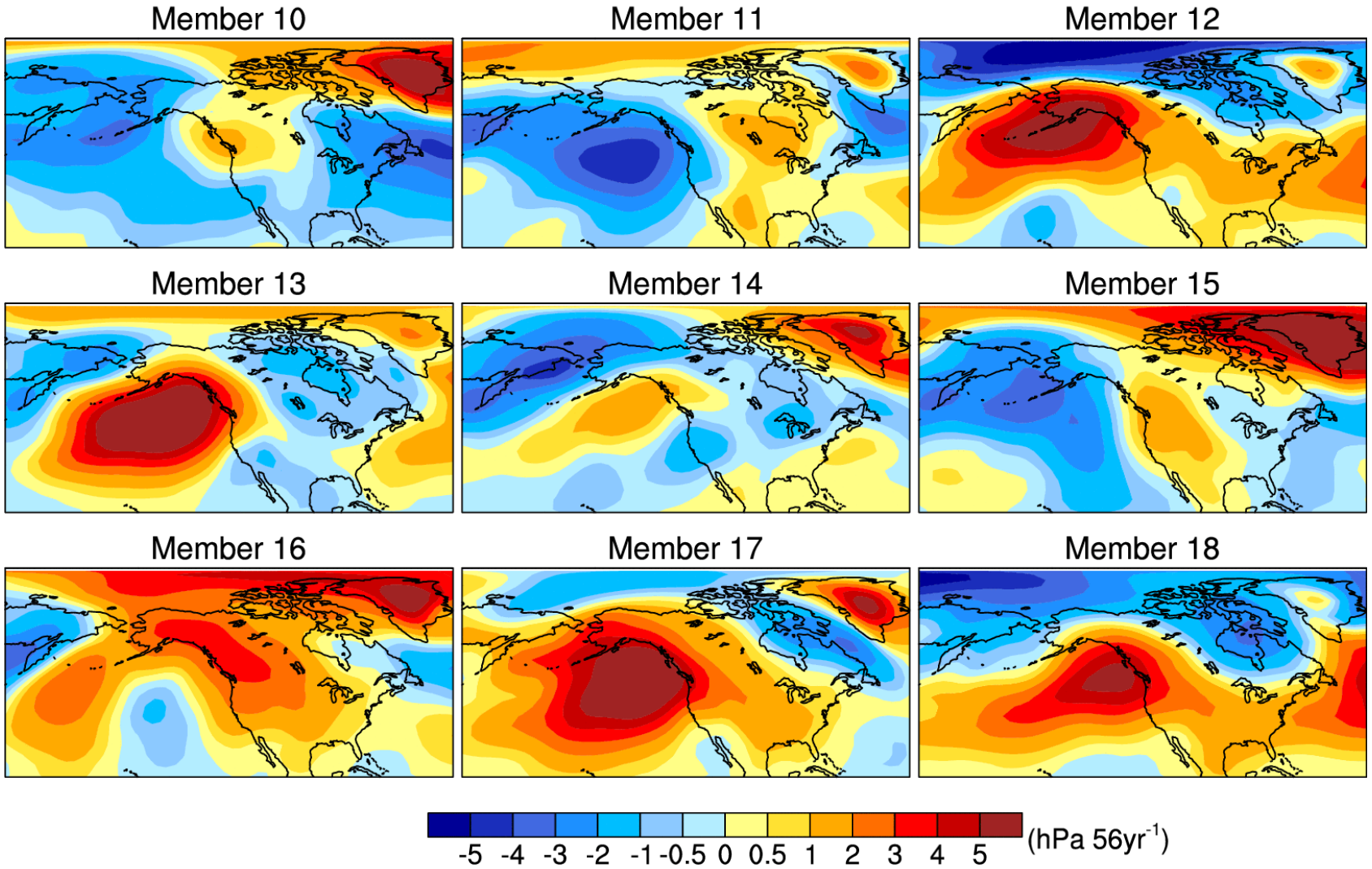
DJF SLP Trends 2005-2060



Model Sensitivity or Natural Variability?

CCSM3 Large Ensemble

DJF SLP Trends 2005-2060



Natural Variability (in one model)

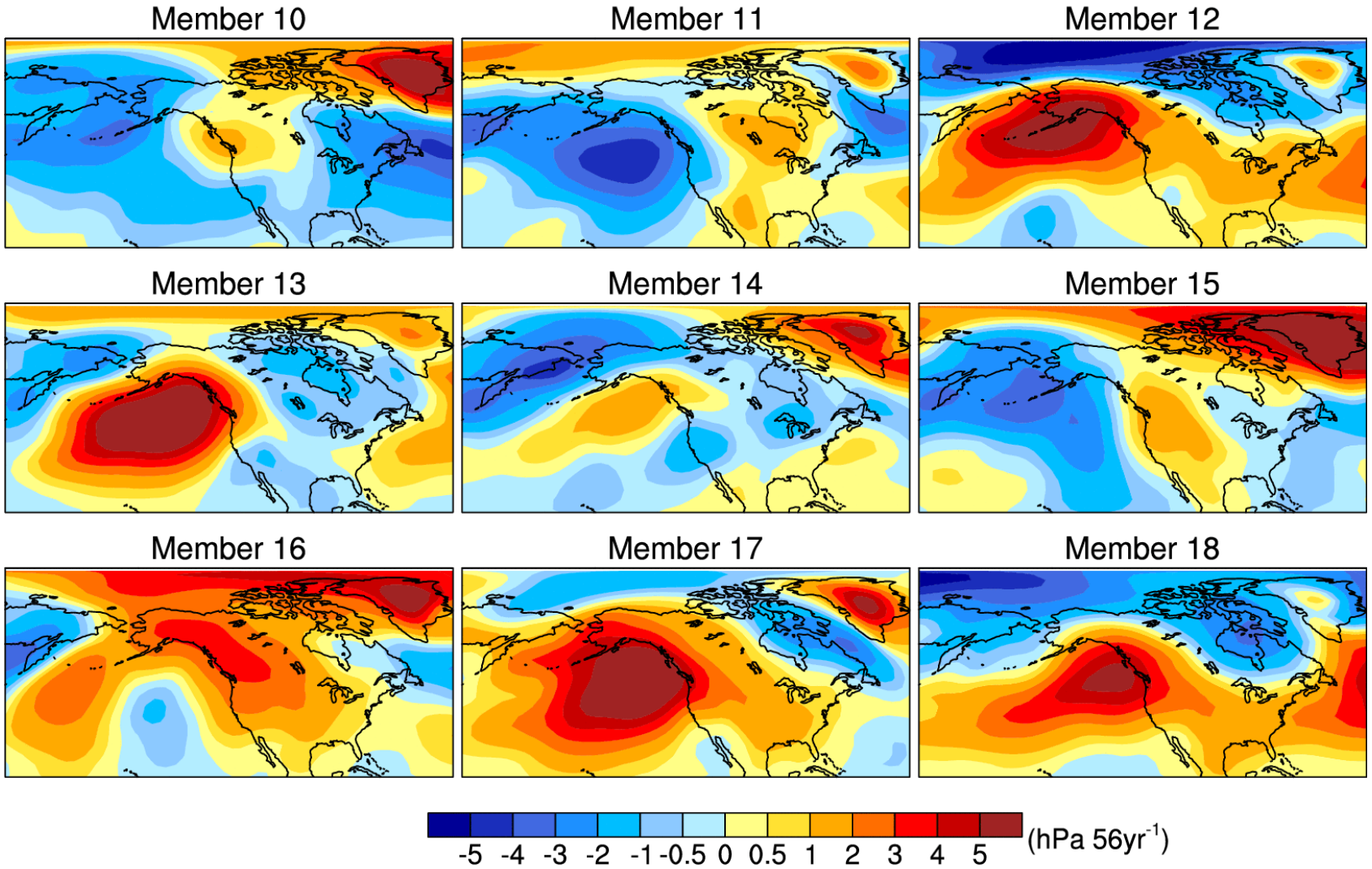
How should we compare single realizations from different models?

Remove contribution from natural atmospheric circulation variability (“*dynamical adjustment*”)

1) Subtract projection of SLP trend *(- ensemble mean)* onto EOFs of the 500-yr CCSM3 control run

CCSM3 Large Ensemble

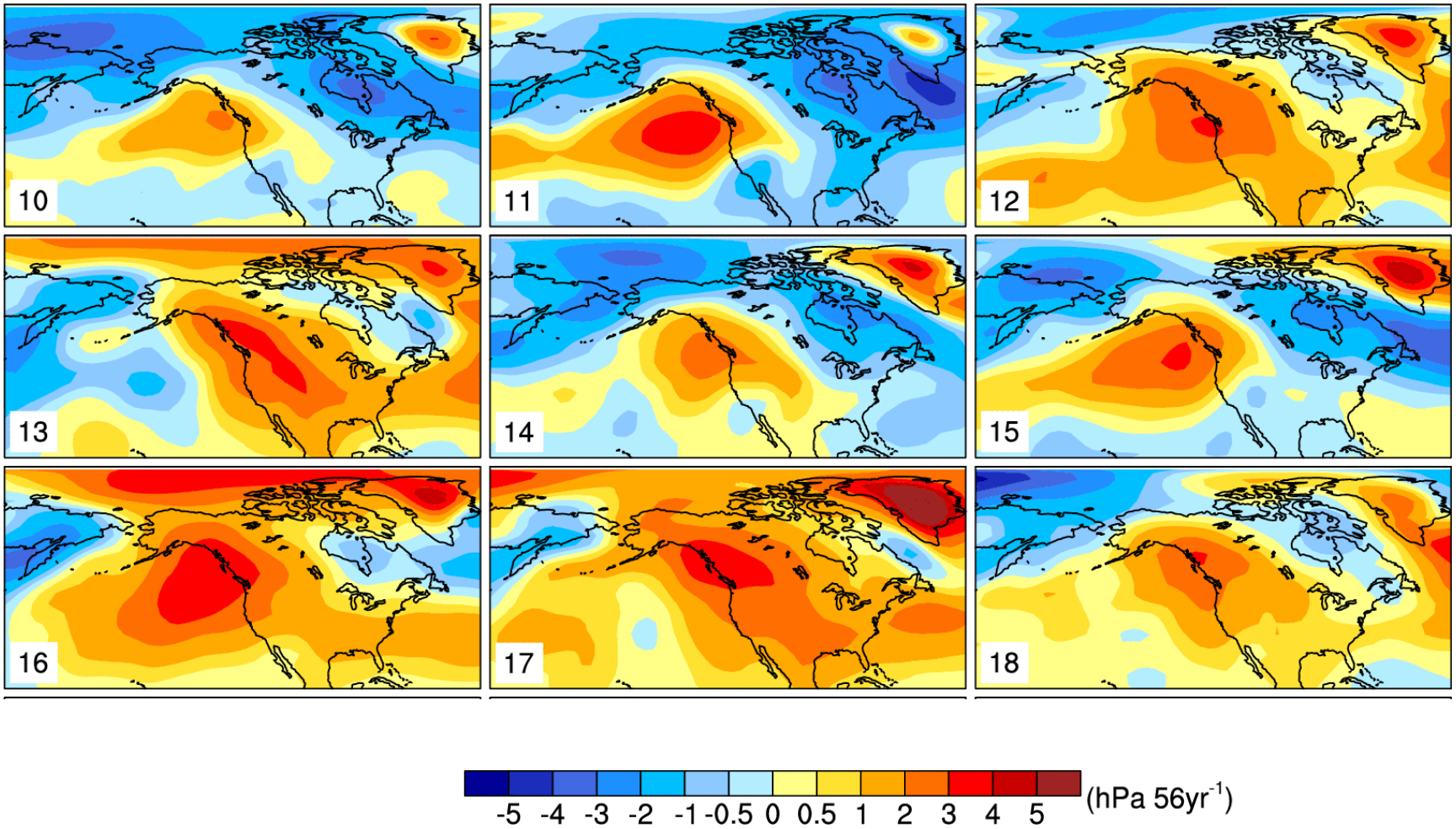
DJF SLP Trends 2005-2060



Natural Variability (in one model)

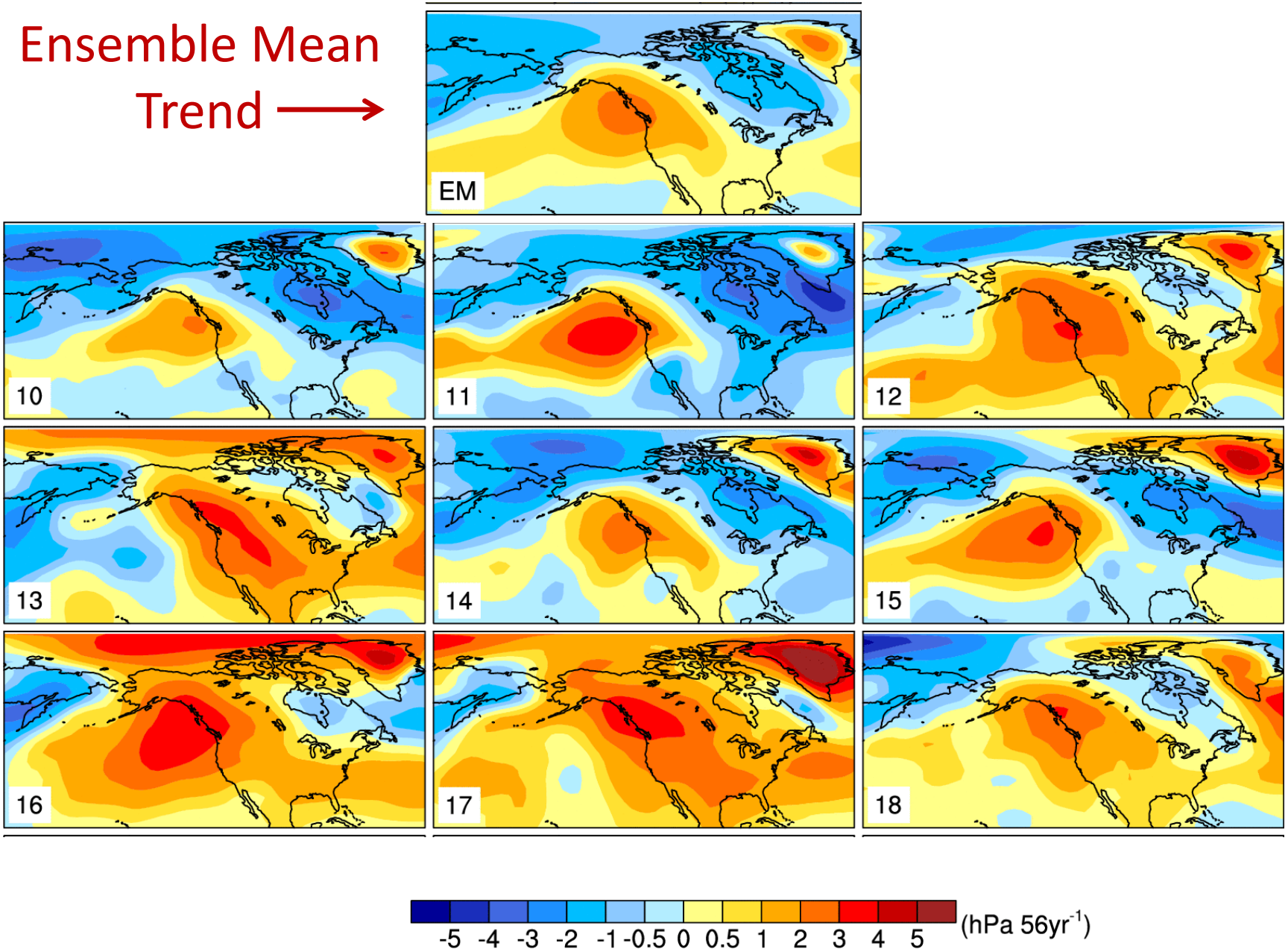
CCSM3 Large Ensemble

DJF SLP Trends 2005-2060



Dynamically-Adjusted

Ensemble Mean Trend ⟶



Dynamically-Adjusted

How should we compare single realizations from different models?

Remove contribution from natural atmospheric circulation variability ("*dynamical adjustment*")

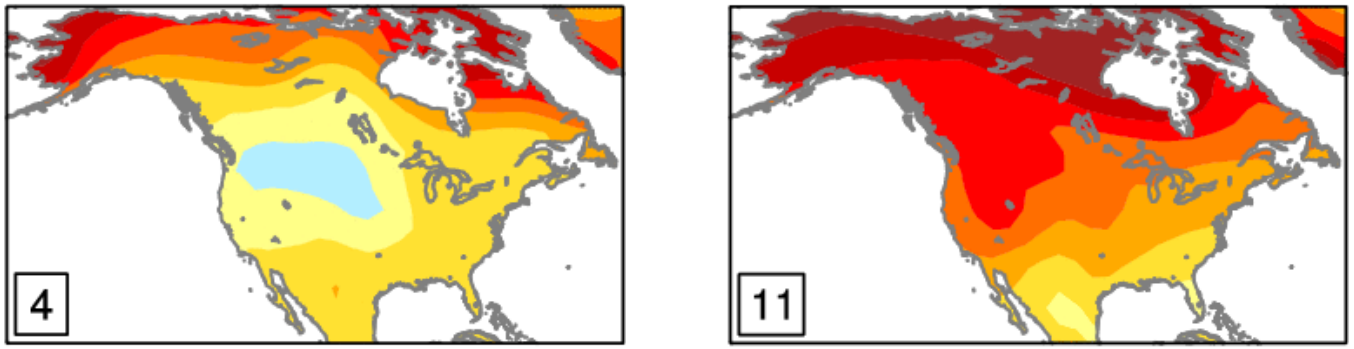
1) Subtract projection of SLP trend *(- ensemble mean)* onto EOFs of the 500-yr CCSM3 control run

2) Subtract associated temperature trend projections

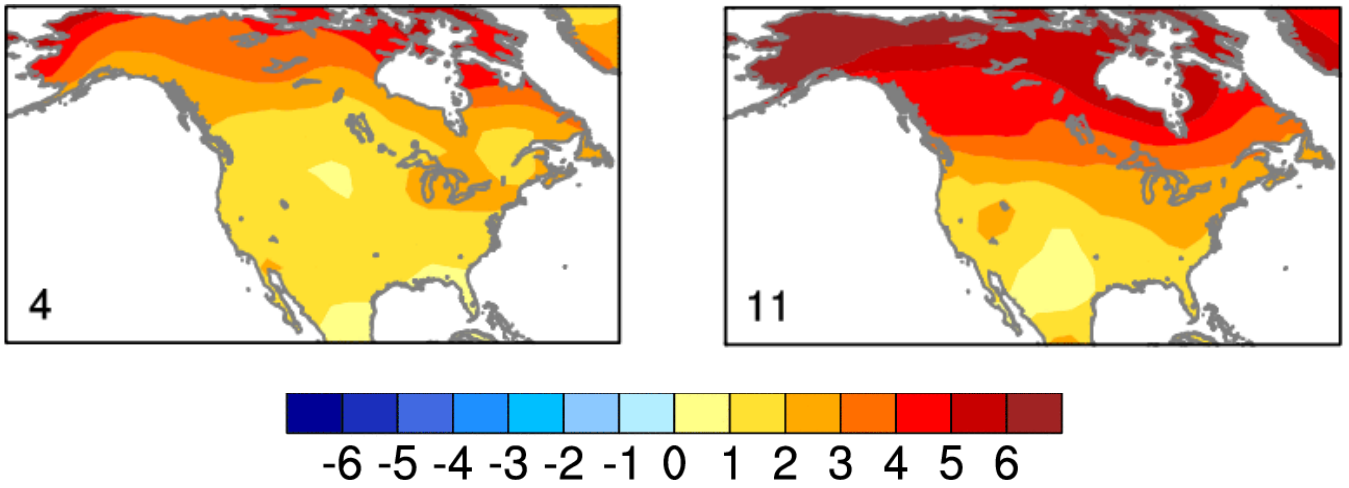
Air Temperature Trends (2005-2060)

CCSM3

Raw

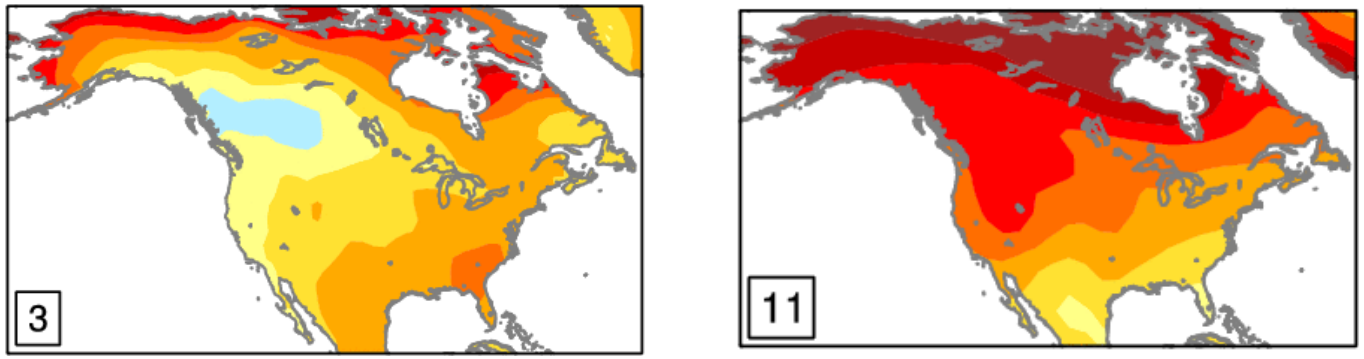


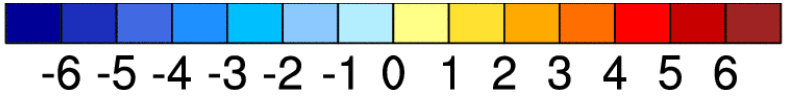
Dynamically-adjusted



Air Temperature Trends (2005-2060)

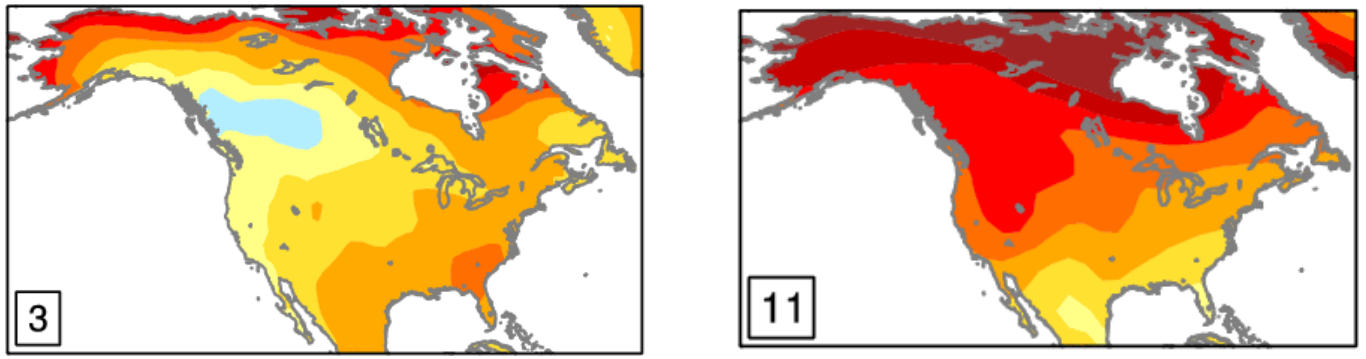
ECHAM5 Raw CCSM3





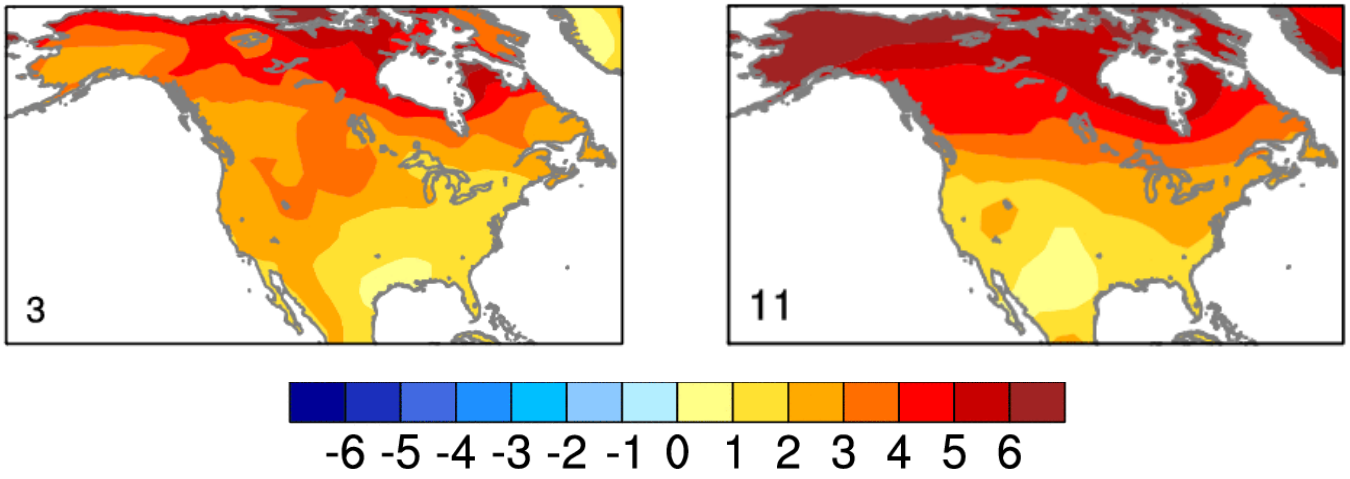
Air Temperature Trends (2005-2060)

ECHAM5 Raw CCSM3



Dynamically-adjusted

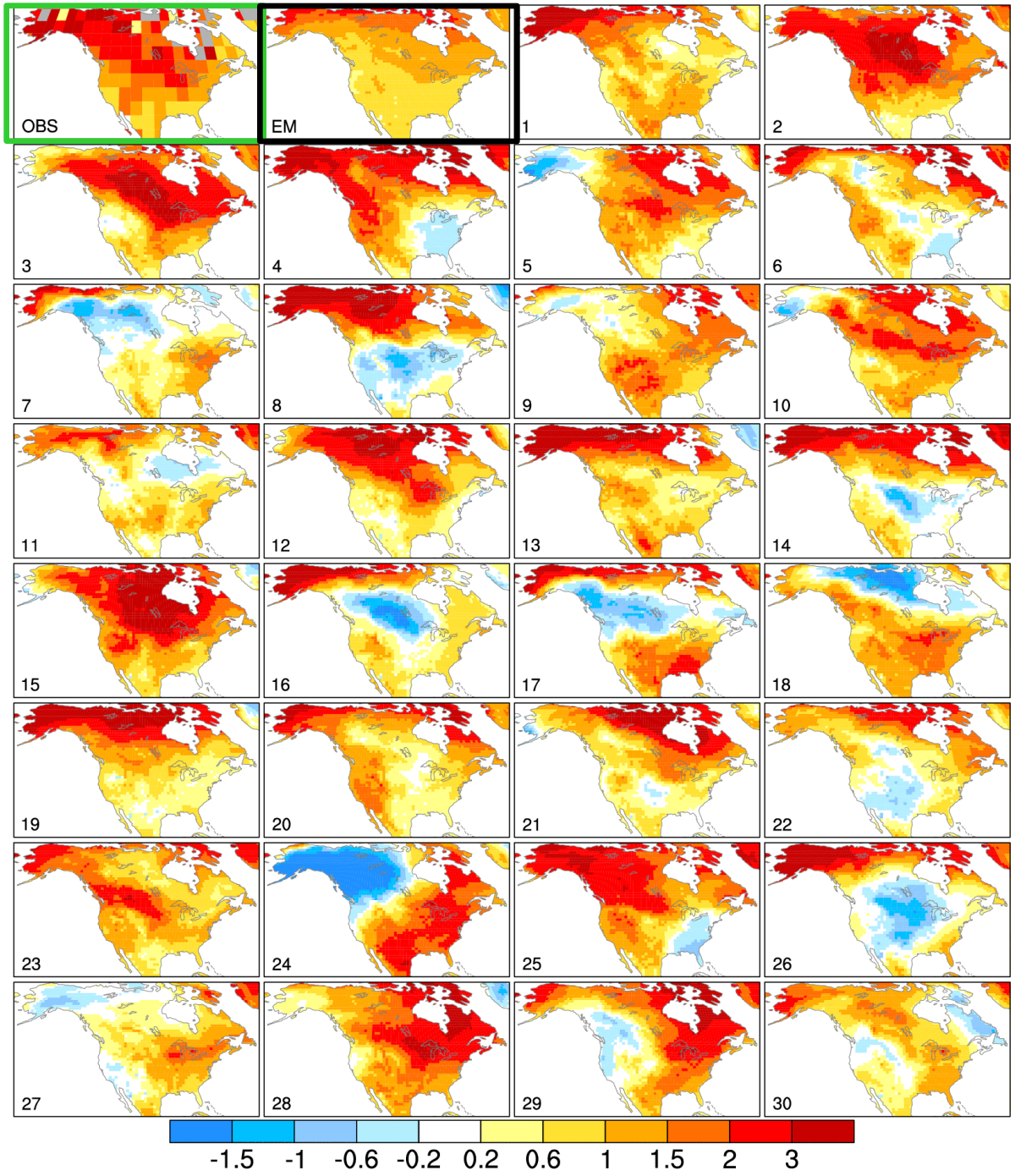
ECHAM5 CCSM3



How should we compare the single realization in nature with the single realizations in different models?

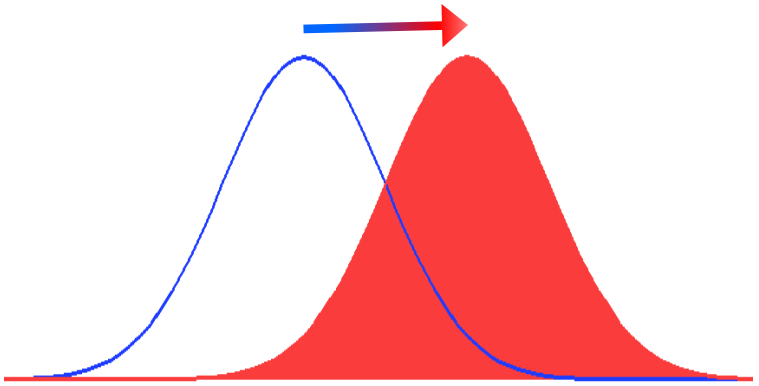
Perform a similar “dynamical adjustment” but need to think about how to define “natural variability” in observations

Air Temperature Trends (1970-2005)
CCSM4



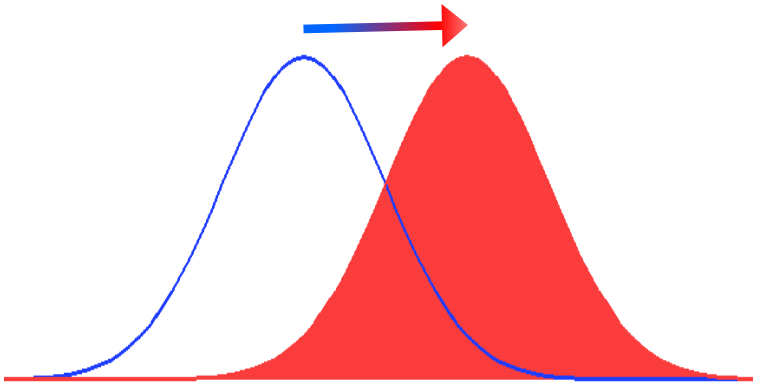
Summary and Outlook

1) Expect a range of climate change outcomes due to natural variability of the atmospheric circulation, even over the next 50 years.



Summary and Outlook

2) Run large (~ 30-40 member) ensembles to properly compare climate change signals between different models, and between models and nature.



Thank You

CCSM3 Large Ensemble output available from the CESM Climate Change and Variability Working Group

http://www.cesm.ucar.edu/working_groups/Climate/

Deser et al., *Climate Dynamics*, 2012
Deser et al., *Nature Climate Change*, in press