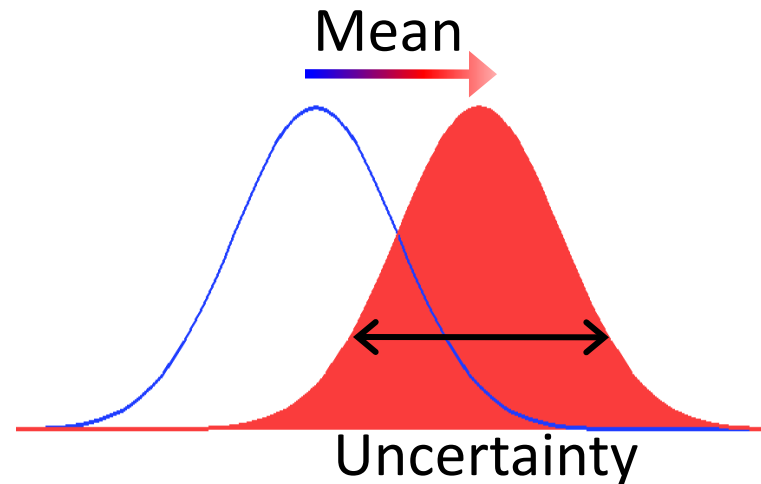


# Uncertainty in Climate Change Projections over North America: The Role of Internal Variability

Clara Deser

Adam Phillips, Haiyan Teng



CESM Climate Variability and Change Working Group Meeting  
March 15, 2012

# 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 Variability**

- atmosphere
- ocean
- coupled atmosphere-ocean system

# IPCC Fourth Assessment Report

## *Climate Change 2007: The Physical Science Basis*

- Forcing

3 Scenarios for 21<sup>st</sup> Century (B1, A1B, A2)

- Model Sensitivity

22 Coupled General Circulation Models A1B

- Internal Variability

Poorly Sampled

# Simulations	1	2	3	4	5	6	7
# Models	11	1	3	3	3	0	1

*CMIP3; CMIP5 expected to be similar*

# The CCSM3 (T42) Large Ensemble Project: Uncertainty due to Natural Variability

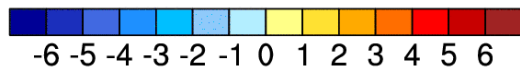
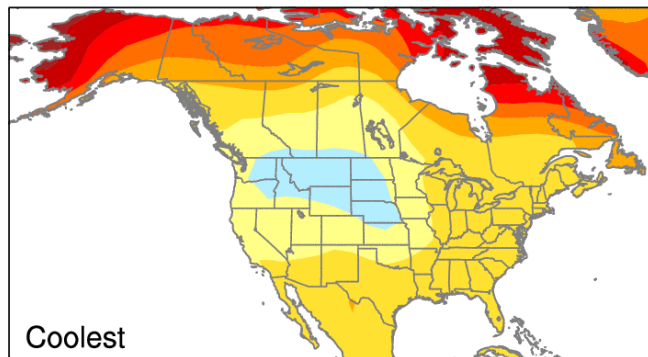
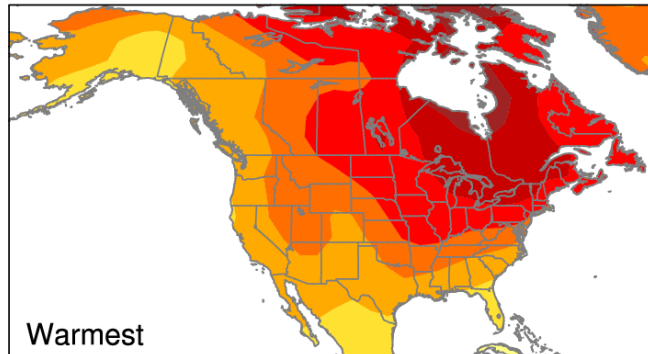
One Forcing, One Model, 40 Simulations (2000-2060)

SRES A1B GHG Scenario (380 → 570 ppm)  
& *ozone hole recovery, sulfate aerosols, black carbon, solar*

Initial conditions from year 1999 of a 20<sup>th</sup> century integration  
(*perturbations to the atmospheric initial conditions only*)

# DJF TRENDS 2005-2060

Temperature ( $^{\circ}\text{C}$ )

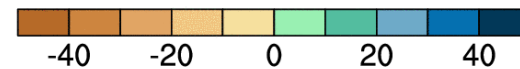
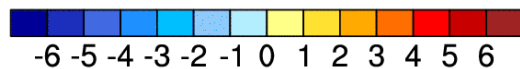
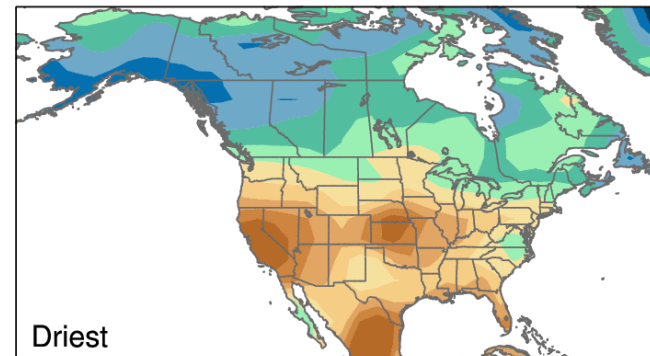
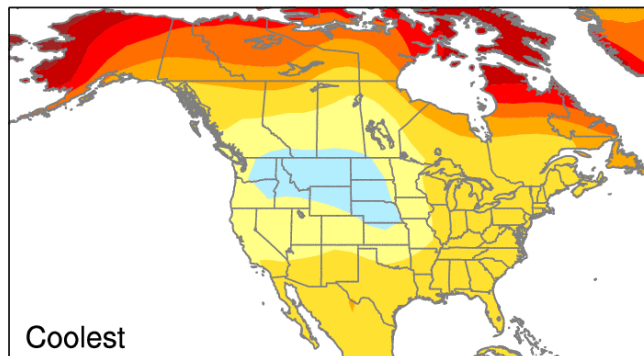
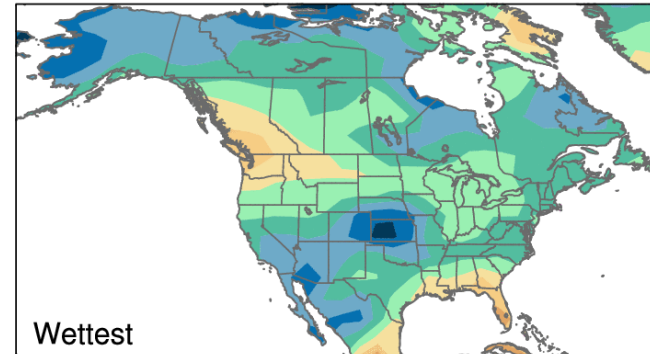
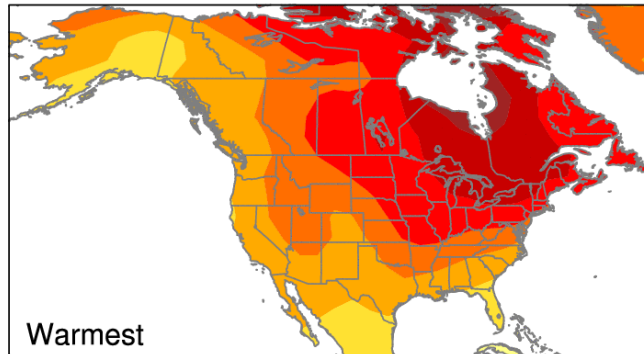


*Deser et al., submitted*

# DJF TRENDS 2005-2060

Temperature (°C)

Precipitation (% mean)

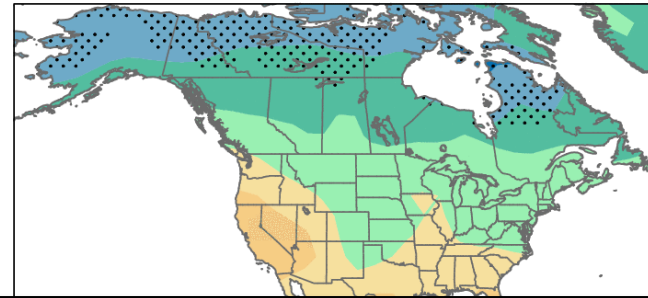
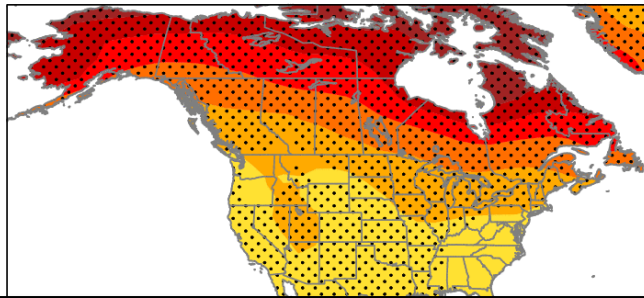


*Deser et al., submitted*

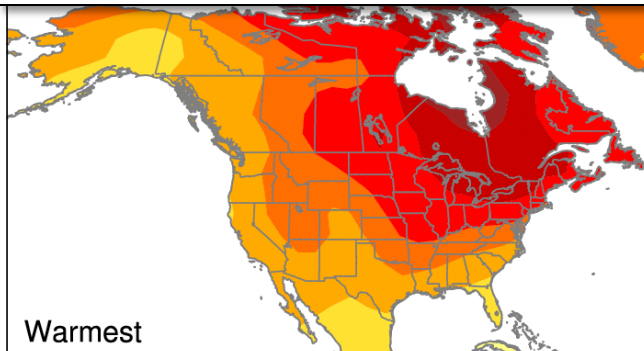
# DJF TRENDS 2005-2060

Temperature (°C)

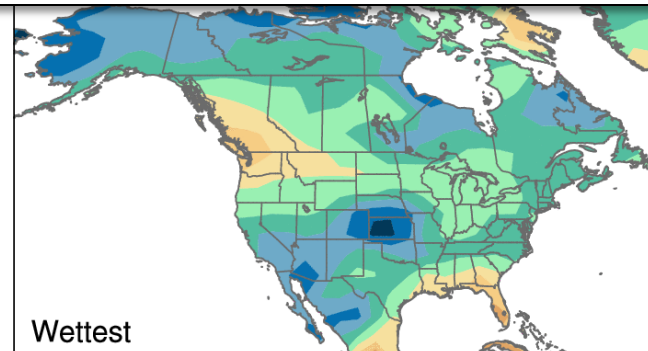
Precipitation (% mean)



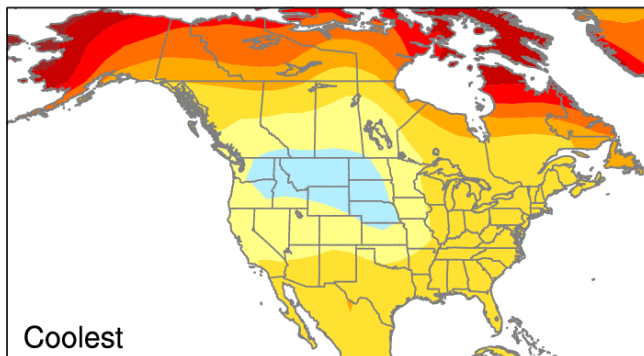
*Stippling: Ensemble Mean Trend > 2σ of the 40 trends*



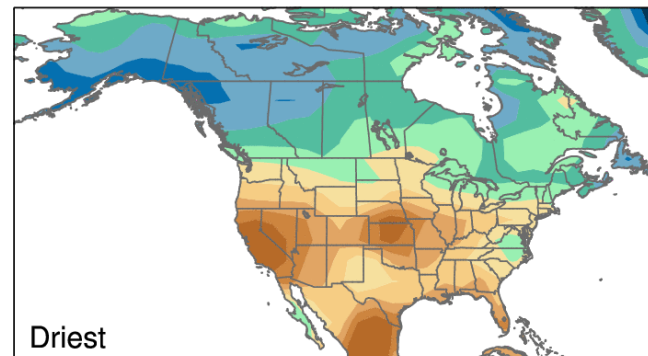
Warmest



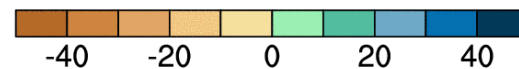
Wettest



Coolest



Driest

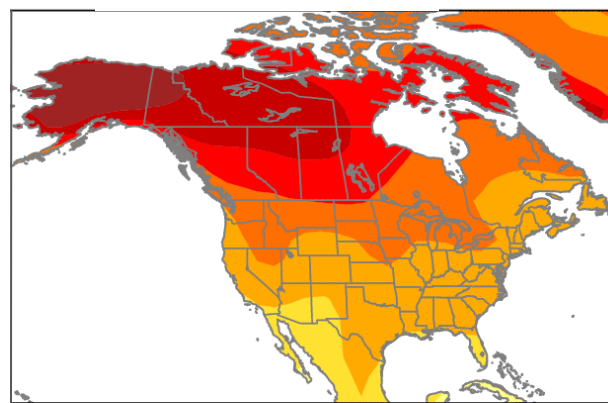
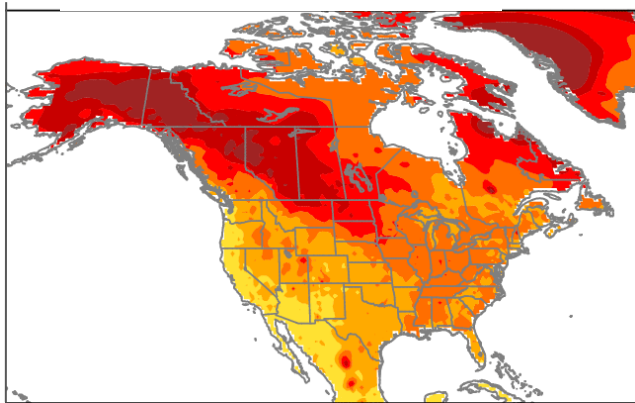


# 8-year low-pass filtered standard deviation

Observations  
(1910-2010)

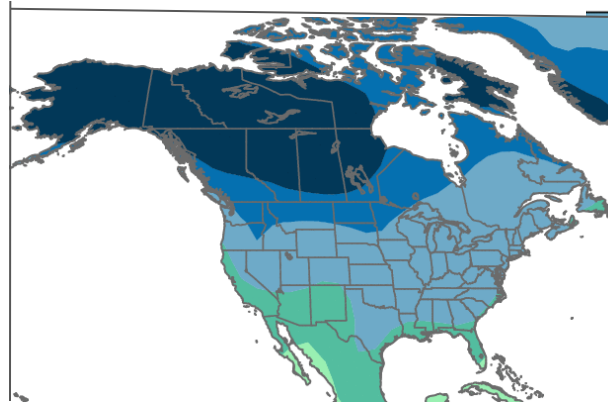
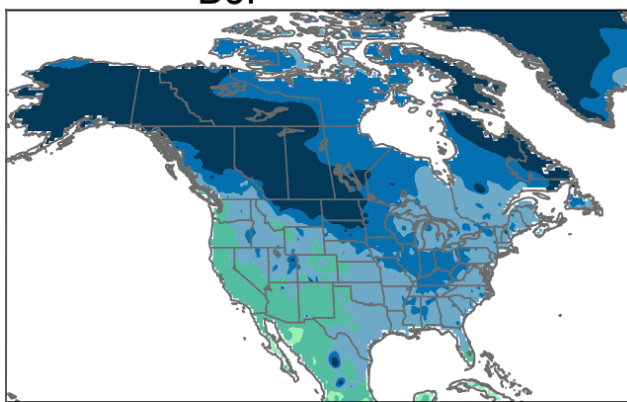
CCSM3  
(2400 yrs)

Temperature



DJF

Precipitation



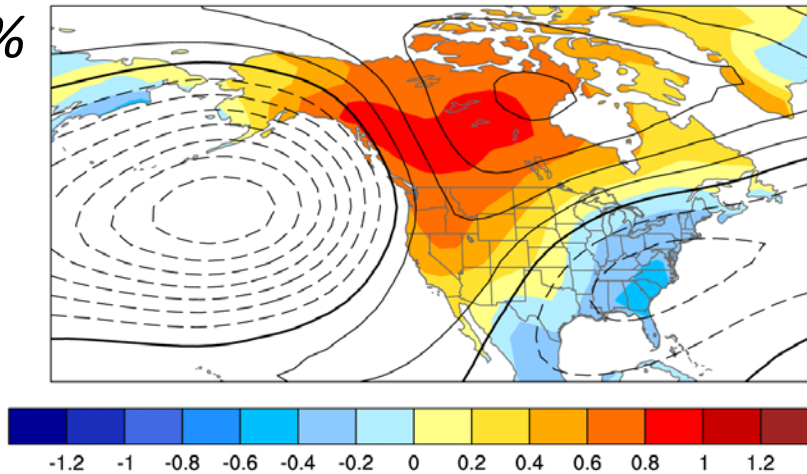


What is causing the variability  
in climate trends?

Look at atmospheric circulation variability

# Z500 EOF1 & Associated Air T Anomalies

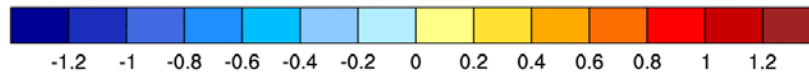
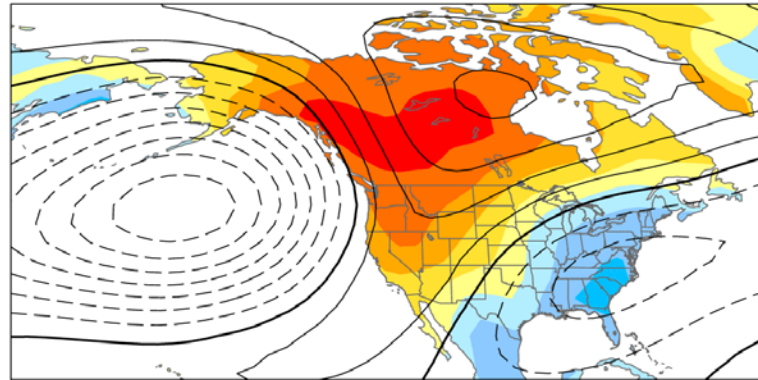
56%  
Trends  
(2005-2060)



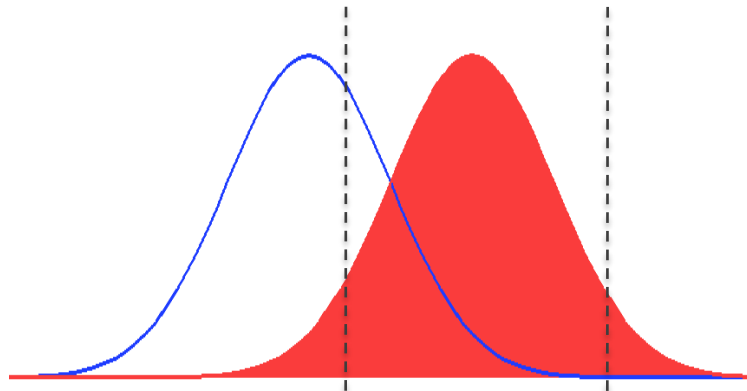
*Very similar to EOF1  
of interannual  
variability in  
control run and  
observations;  
“white noise”*

# Z500 EOF1 & Associated Air T Anomalies

56%  
Trends  
(2005-2060)



$-2\sigma$        $+2\sigma$



PC1 Z500 (PNA)

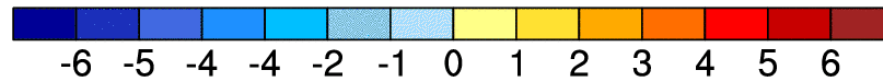
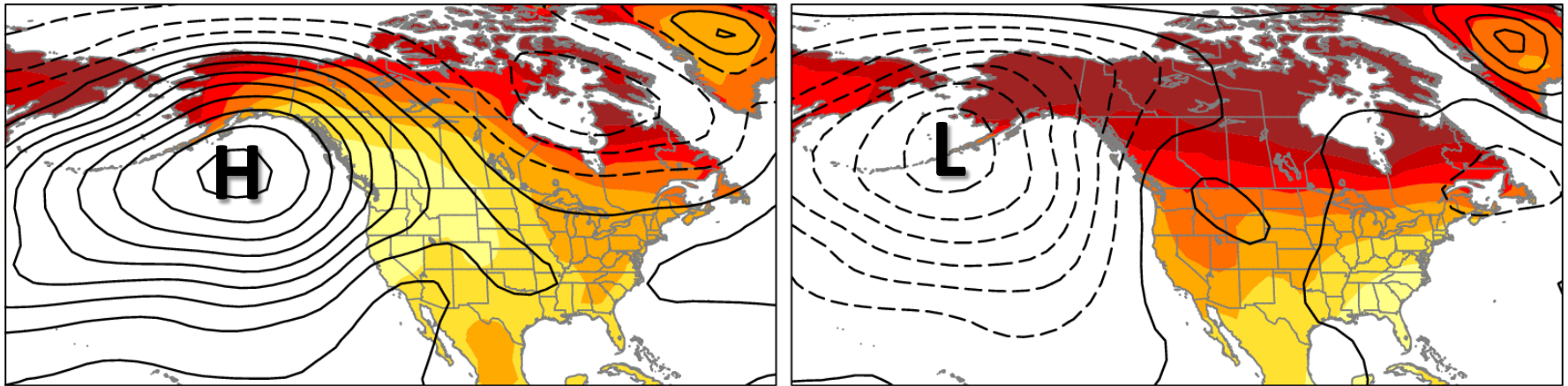
*Very similar to EOF1  
of interannual  
variability in  
control run and  
observations;  
“white noise”*

*Add and subtract  
this natural mode  
of circulation trend  
variability to the  
mean response*

# Natural Atmospheric Circulation Variability: A Range of Climate Change Outcomes

$-2\sigma$  PNA

$+2\sigma$  PNA



$^{\circ}\text{C}/56\text{yrs}$

Sea Level Pressure and Air Temperature  
Trends 2005-2060

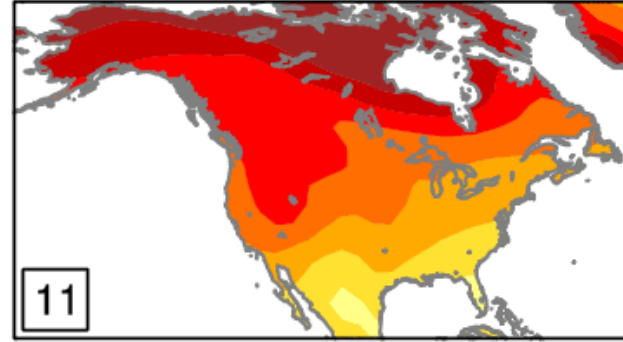
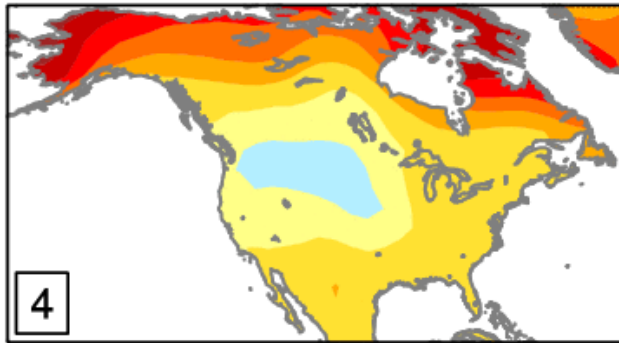
# Accounting for Natural Atmospheric Circulation Variability in Climate Change: A Way Forward



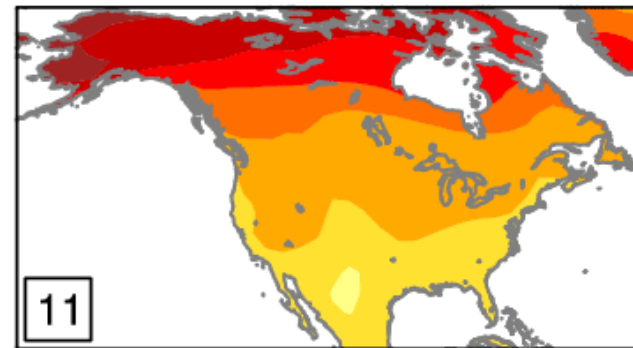
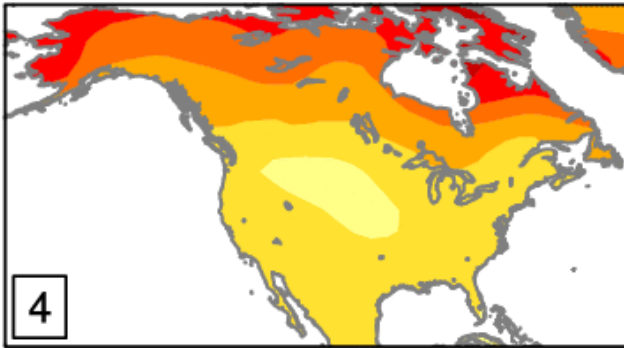
*Comparison among individual  
ensemble members*

# Air Temperature Trends (2005-2060): CCSM3

Raw

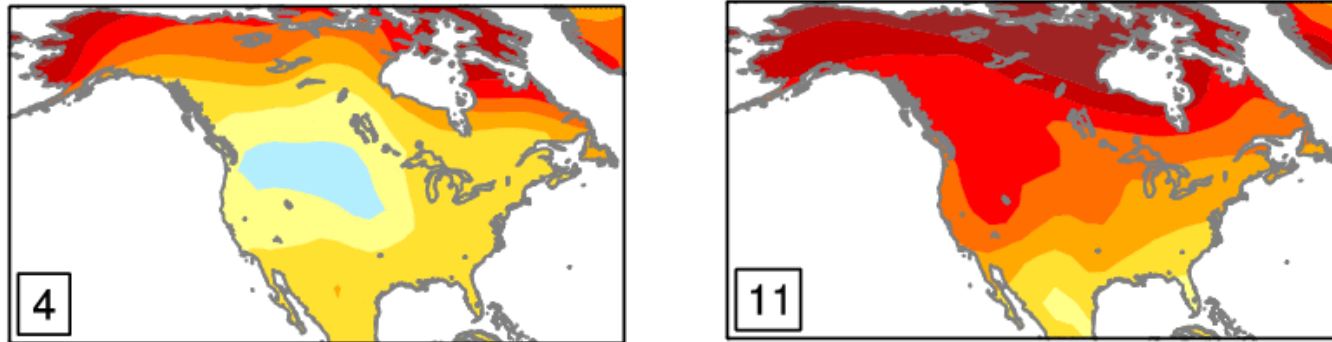


Circulation-Residual (5 EOFs)

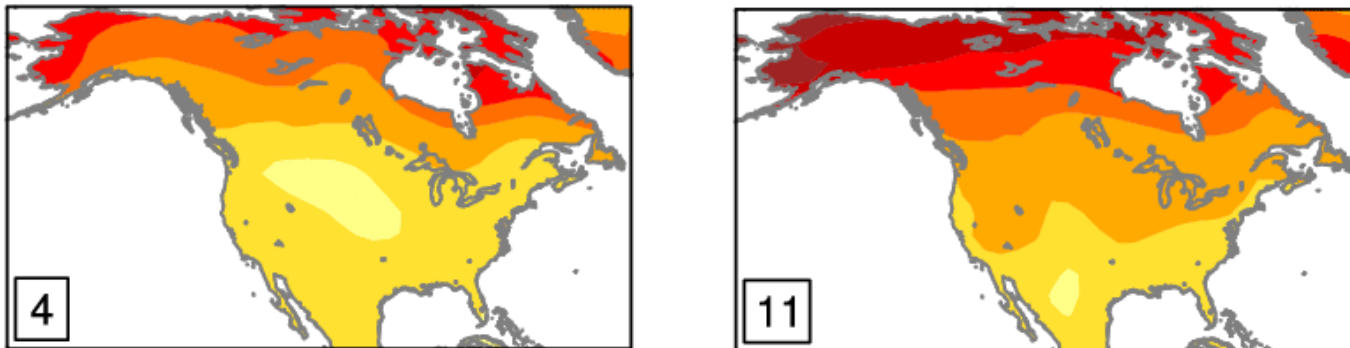


# Air Temperature Trends (2005-2060): CCSM3

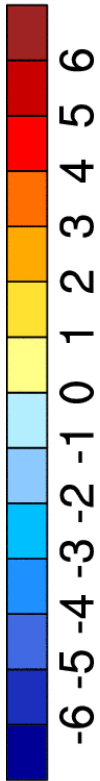
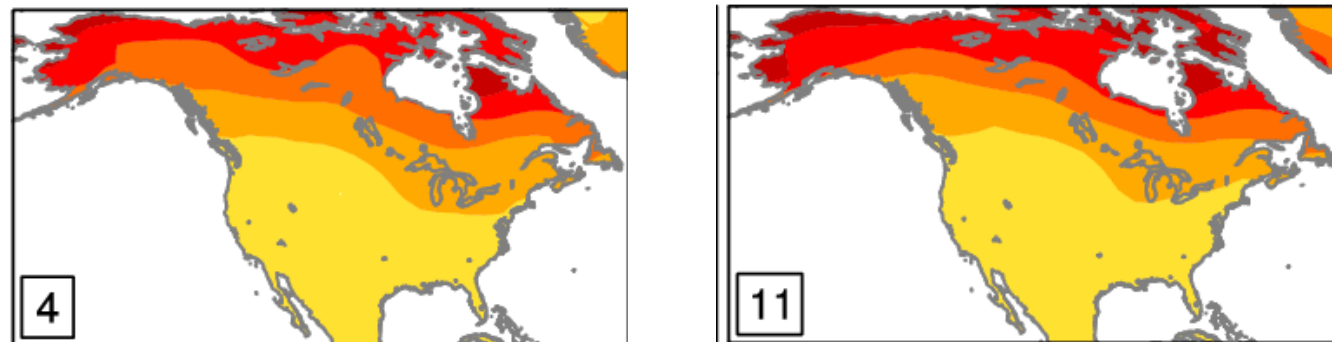
Raw



Circulation-Residual (5 EOFs)



Circulation-Residual (25 EOFs)



# Accounting for Natural Atmospheric Circulation Variability in Climate Change: A Way Forward



*Comparison among models*

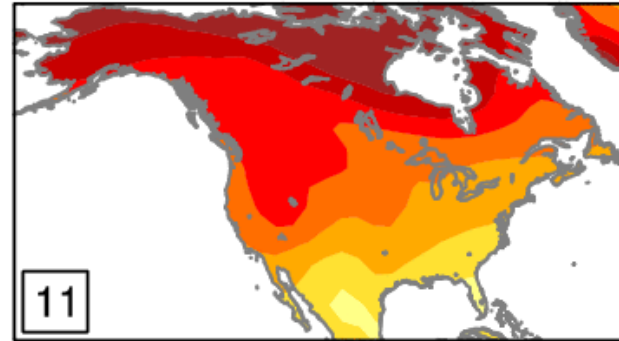
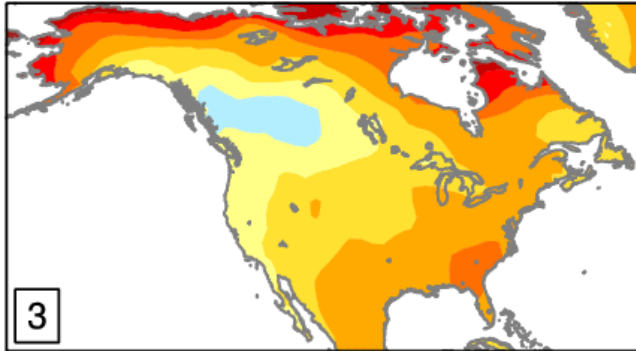


# Air Temperature Trends (2005-2060)

ECHAM (17)

Raw

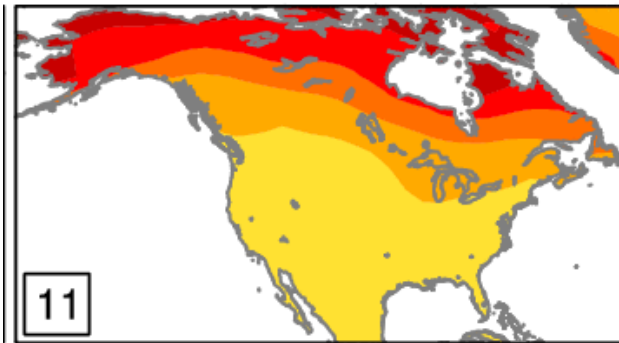
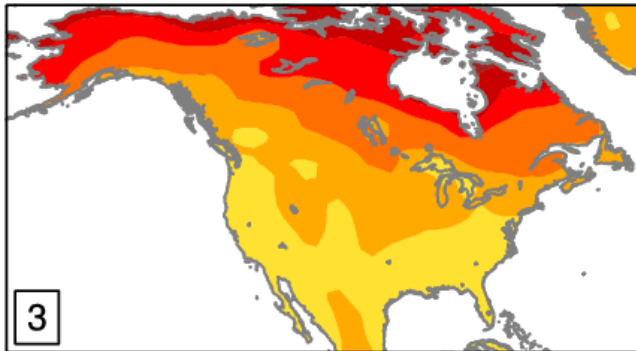
CCSM3 (40)



Circulation-Residual

ECHAM (17)

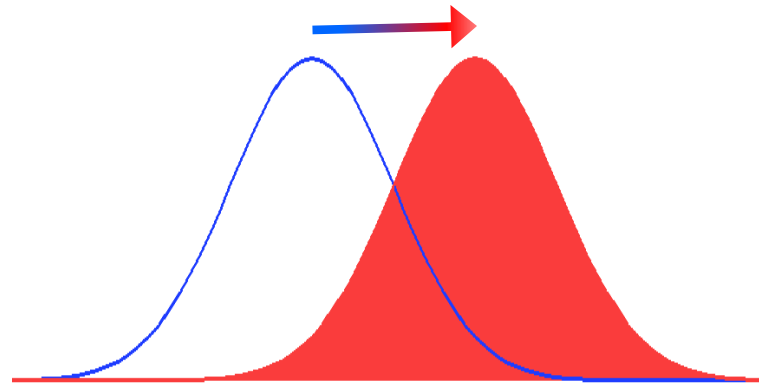
CCSM3 (40)



Future Work: Use long control simulations to estimate circulation-residuals

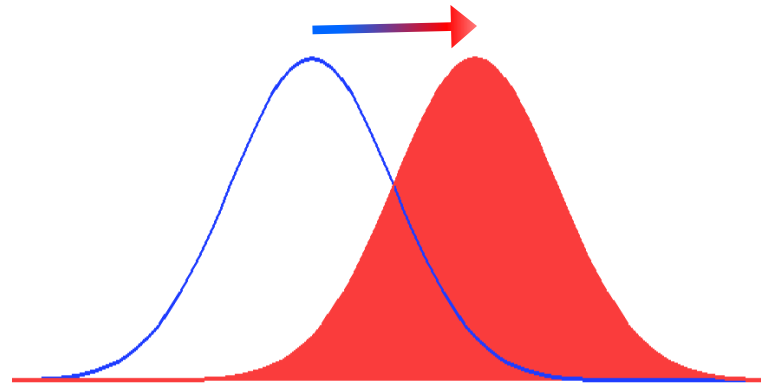
# Summary and Outlook

- 1) We should expect a range of climate change outcomes due to natural variability of the atmospheric circulation, even over the next 50 years



# Summary and Outlook

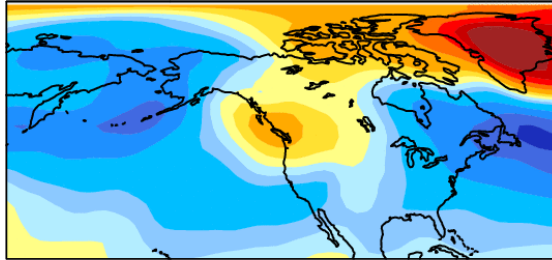
2) Models may differ due to natural atmospheric circulation variability: need large ensembles to discriminate between model sensitivity and natural variability



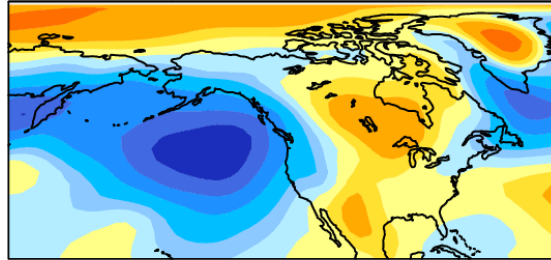
# CCSM3 Large Ensemble

## DJF SLP Trends 2005-2060

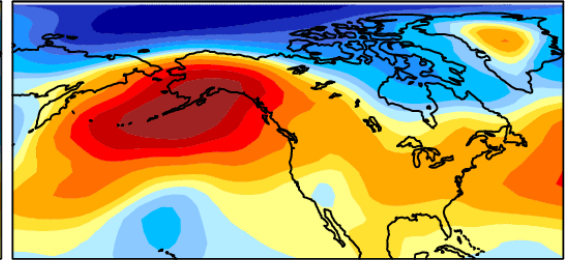
Member 10



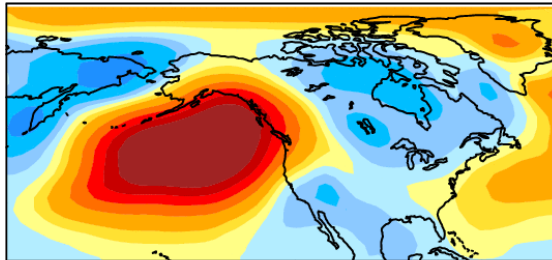
Member 11



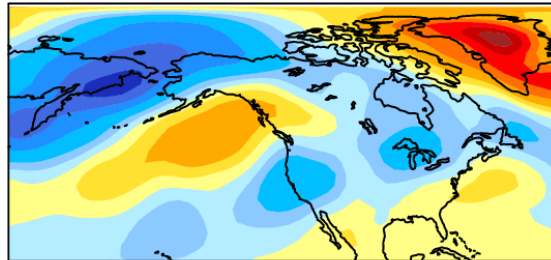
Member 12



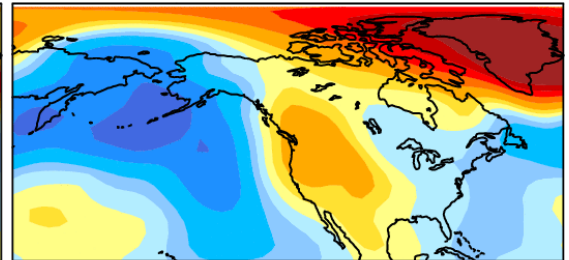
Member 13



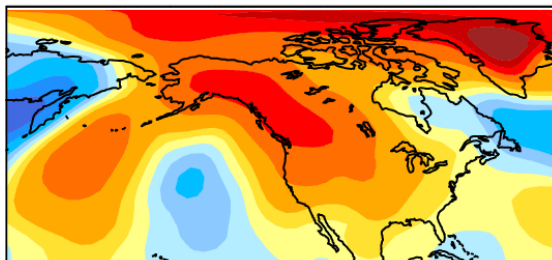
Member 14



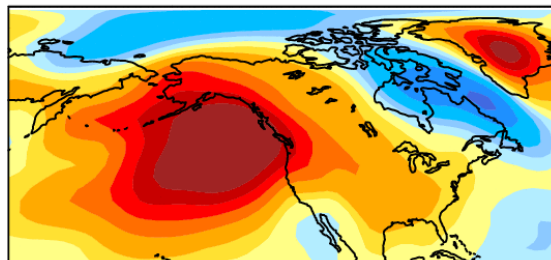
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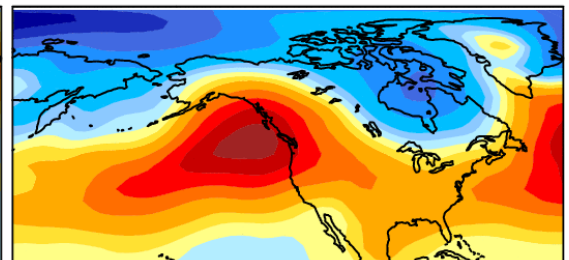
Member 16



Member 17



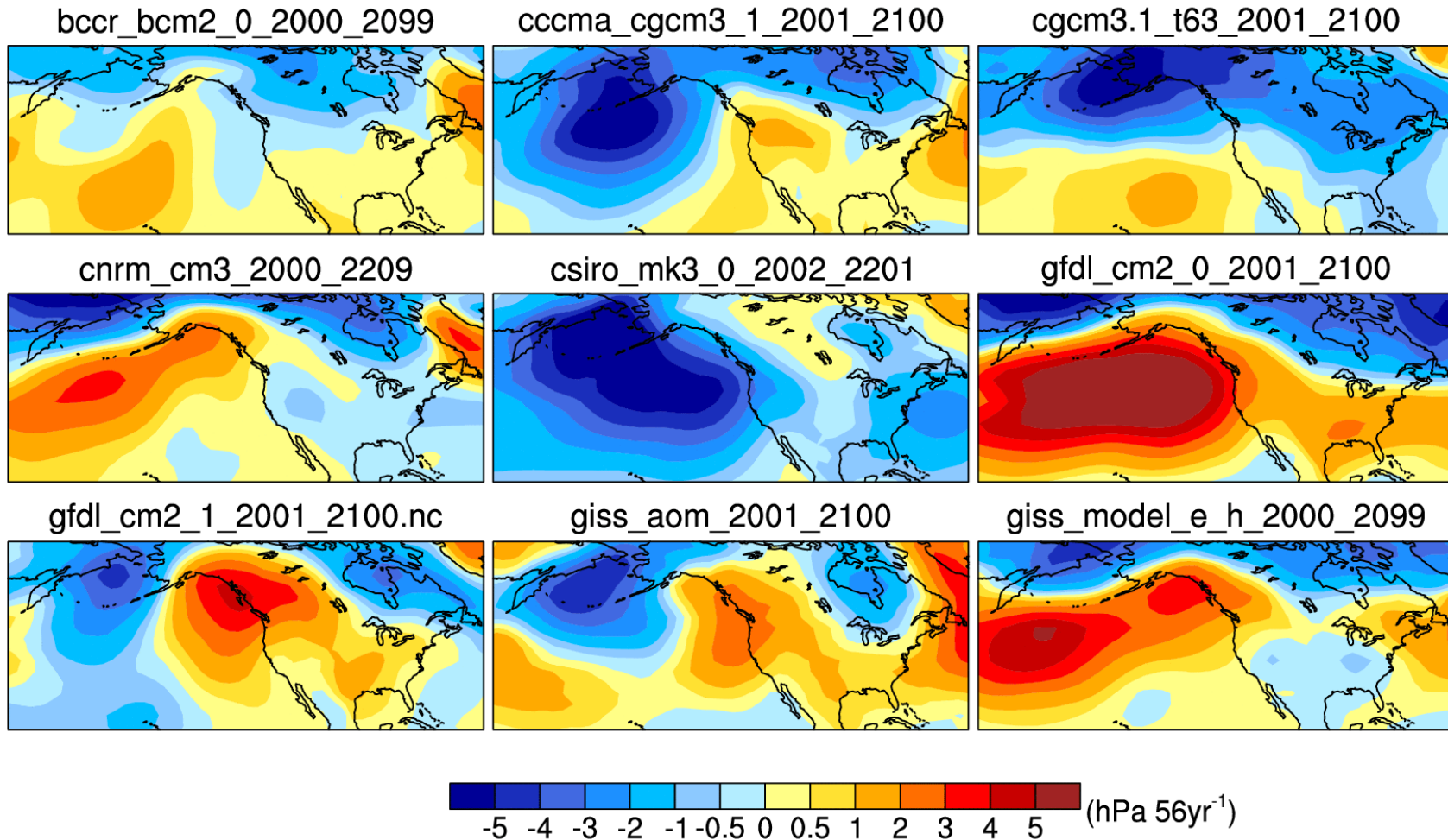
Member 18



Natural Variability (in one model)

# IPCC AR4 (CMIP3) Model Archive

## DJF SLP Trends 2005-2060



Model Sensitivity or Natural Variability?

# Thank You

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

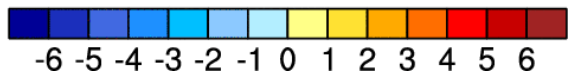
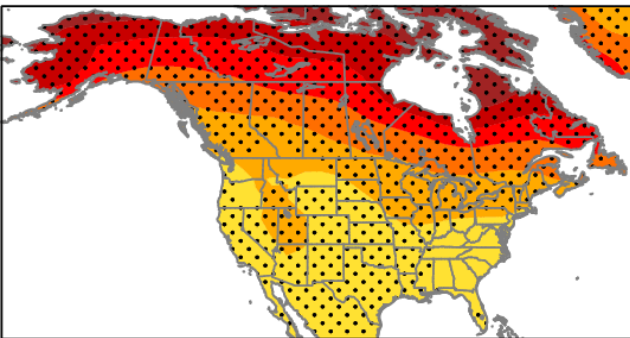
[http://www.cesm.ucar.edu/working\\_groups/  
Climate/index.html](http://www.cesm.ucar.edu/working_groups/Climate/index.html)

**EXTRA**



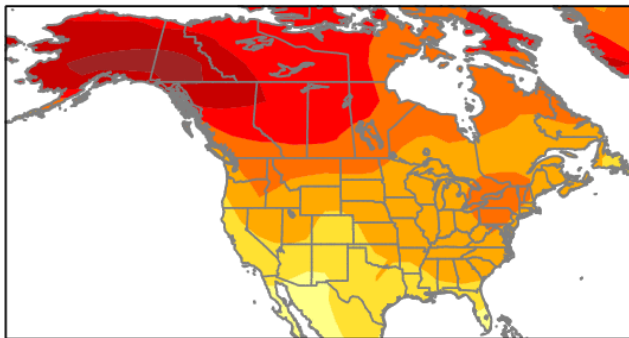
Ensemble Mean Trend

DJF



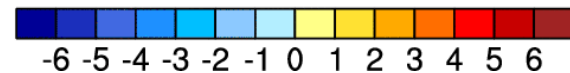
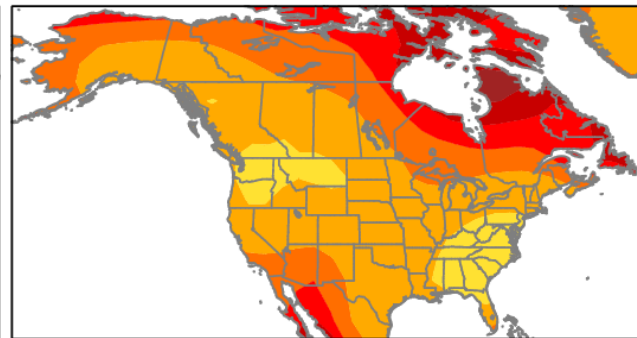
Trend Std. Dev.

DJF



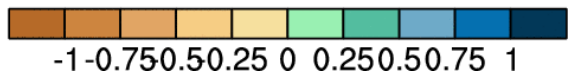
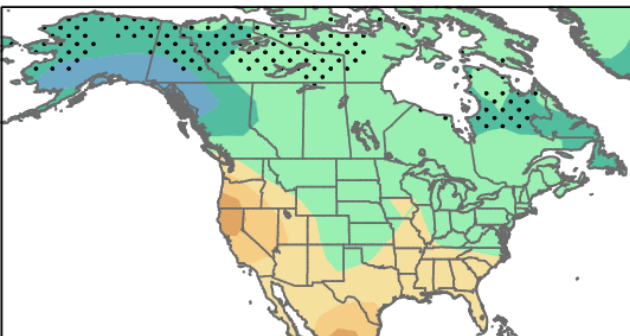
Ens Mn Trend / Trend Std Dev

DJF



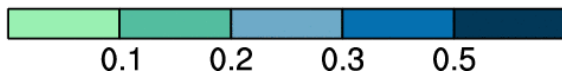
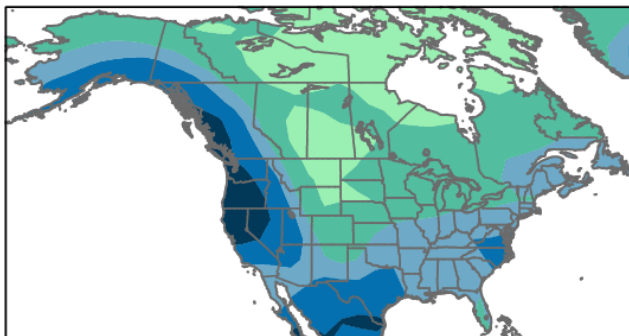
Ensemble Mean Trend

DJF



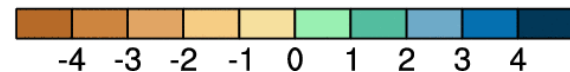
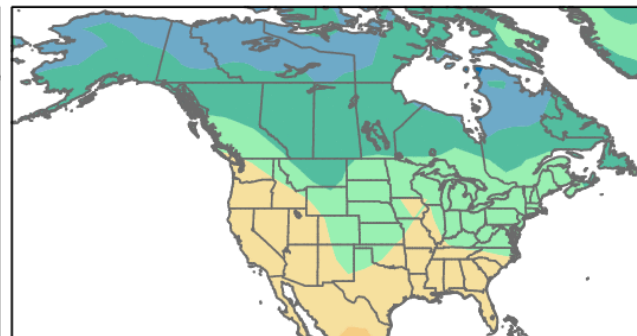
Trend Std. Dev.

DJF



Ens Mn Trend / Trend Std Dev

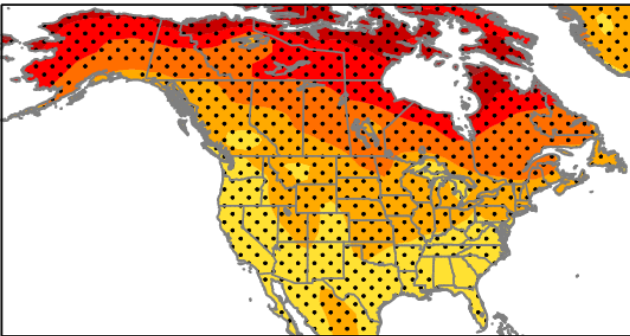
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Ensemble Mean Trend

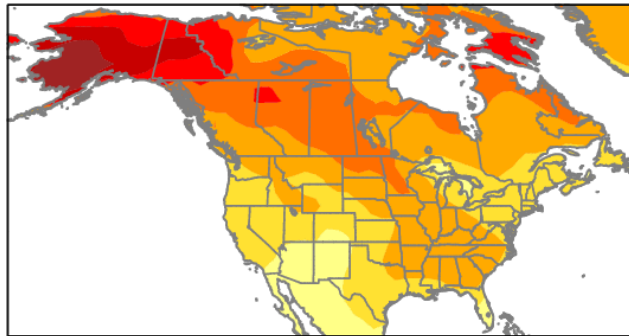
DJF



17-mem ESSENCE

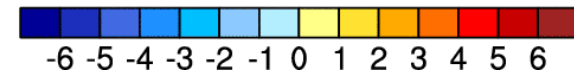
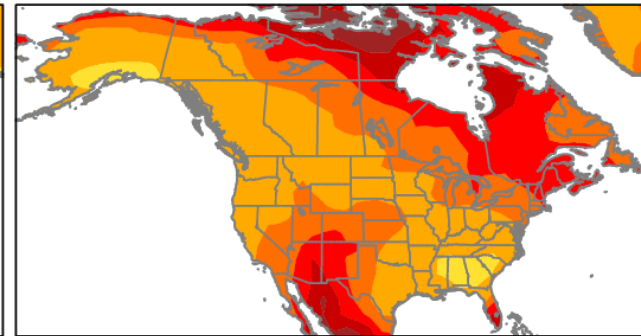
Trend Std. Dev.

DJF



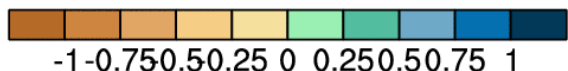
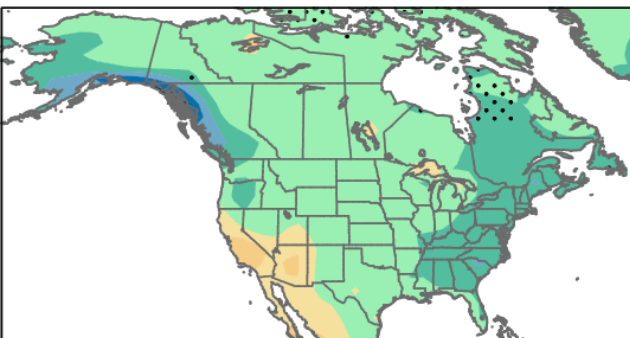
Ens Mn Trend / Trend Std Dev

DJF



Ensemble Mean Trend

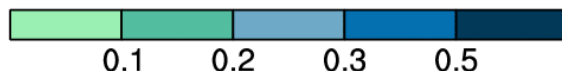
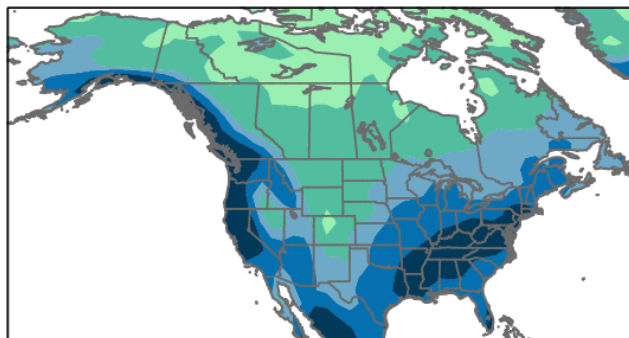
DJF



17-mem ESSENCE

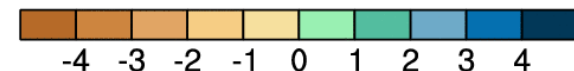
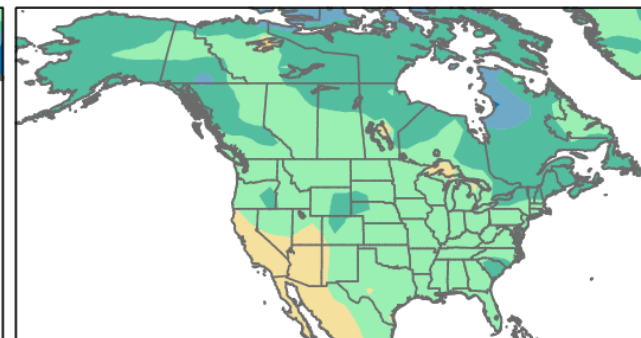
Trend Std. Dev.

DJF



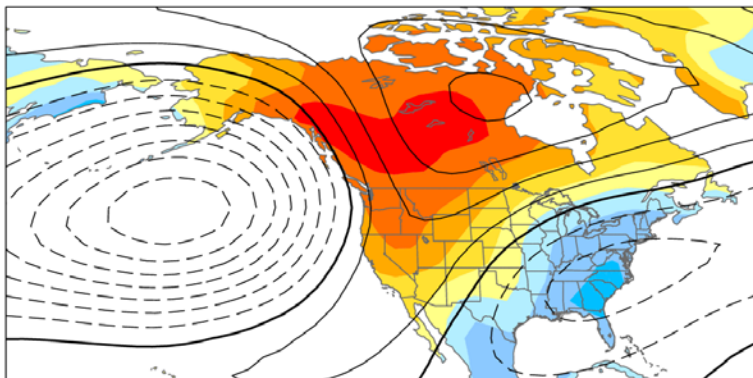
Ens Mn Trend / Trend Std Dev

DJF



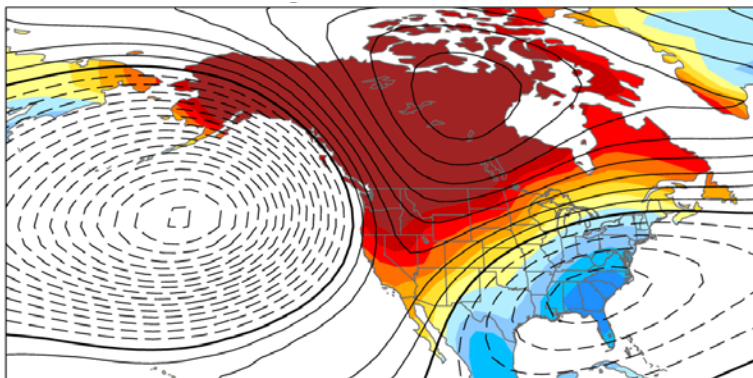
# Z500 EOF1 & Associated Air T Anomalies

Trends (2005-2060)



56%

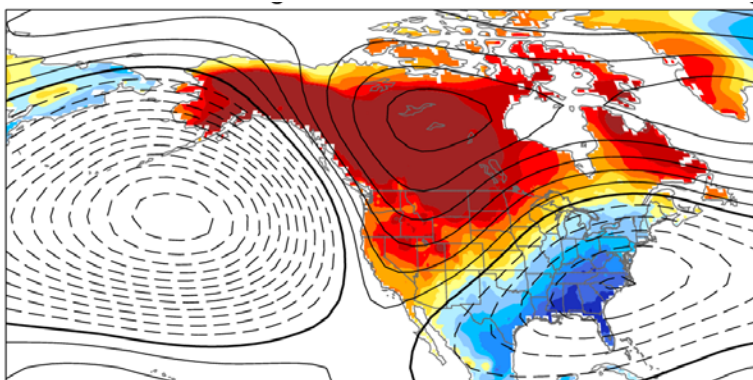
Inter-annual  
Variability  
(CCSM3 Control Run)  
*500 years*



*No preferred  
timescale*

44%

Inter-annual  
Variability  
(Observations)  
*60 years*



37%

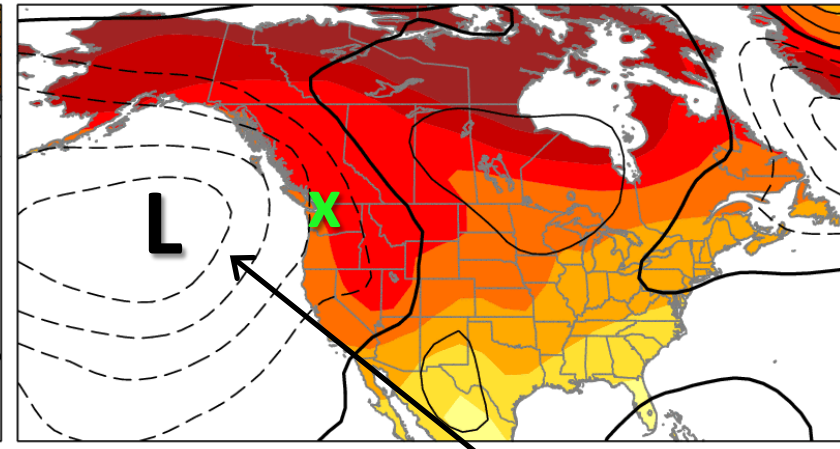
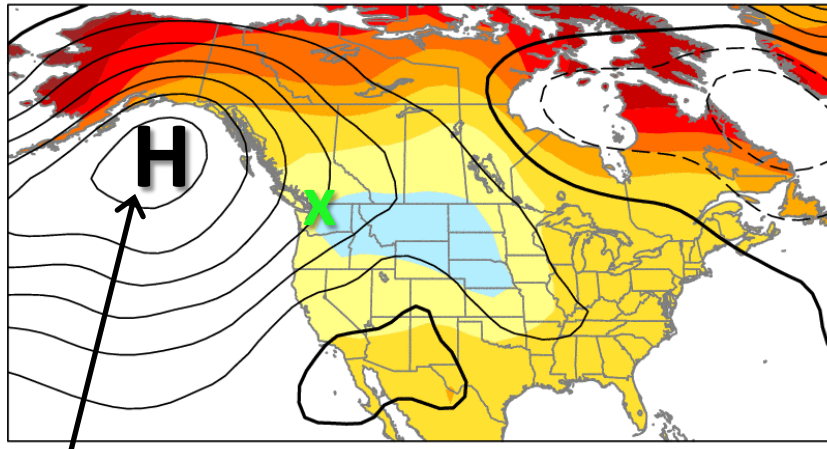


2005-2060

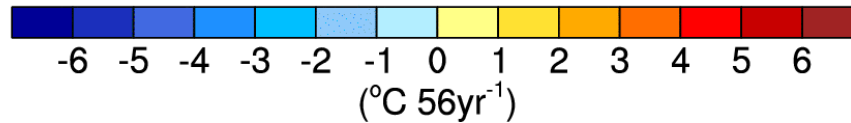
# Air Temperature and Sea Level Pressure Trends

Ensemble Member 4  
(0°C warming at Seattle)

Ensemble Member 11  
(4°C warming at Seattle)

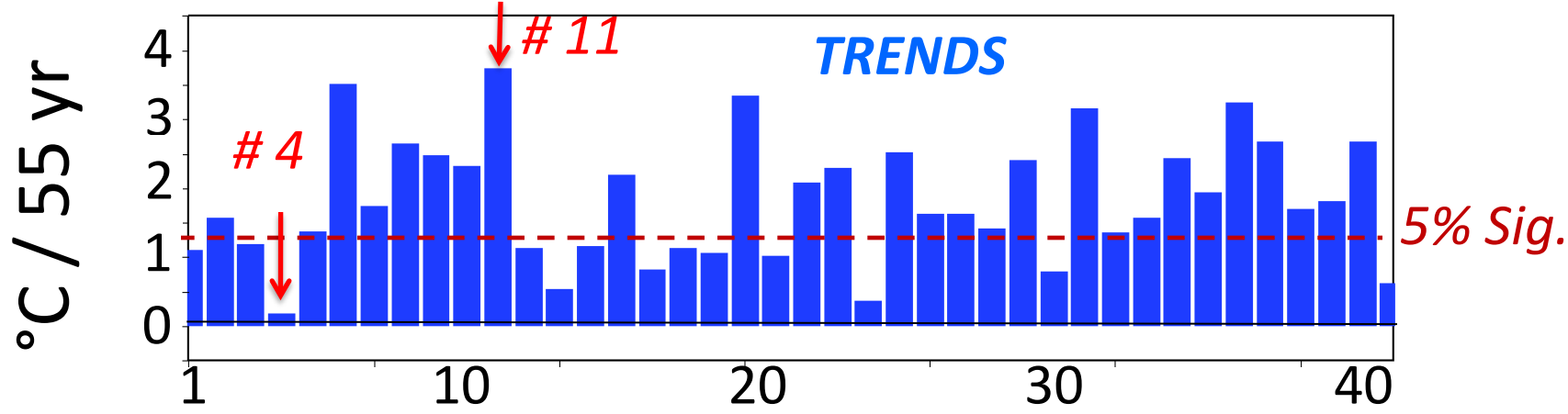
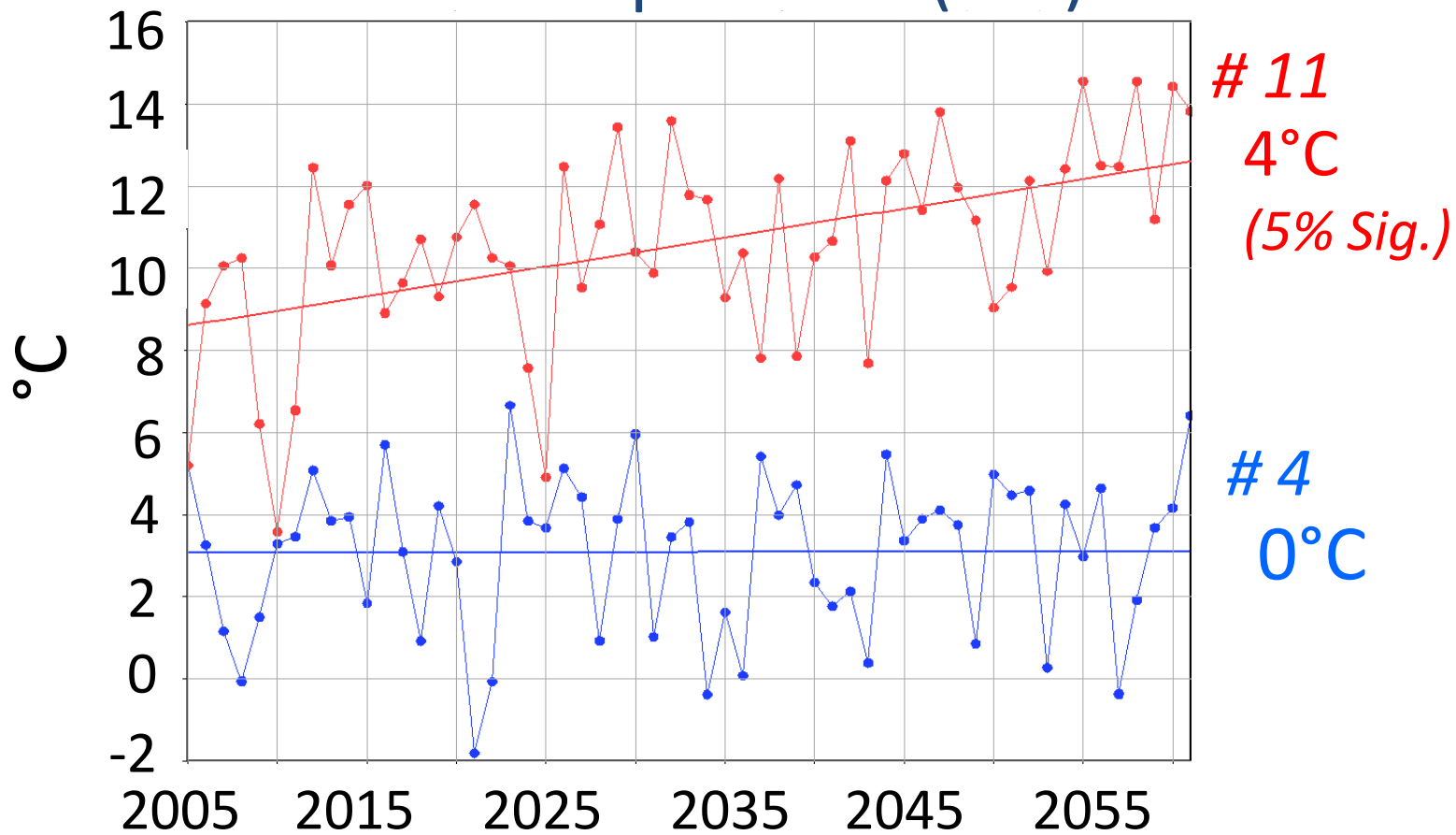


+ 6 hPa



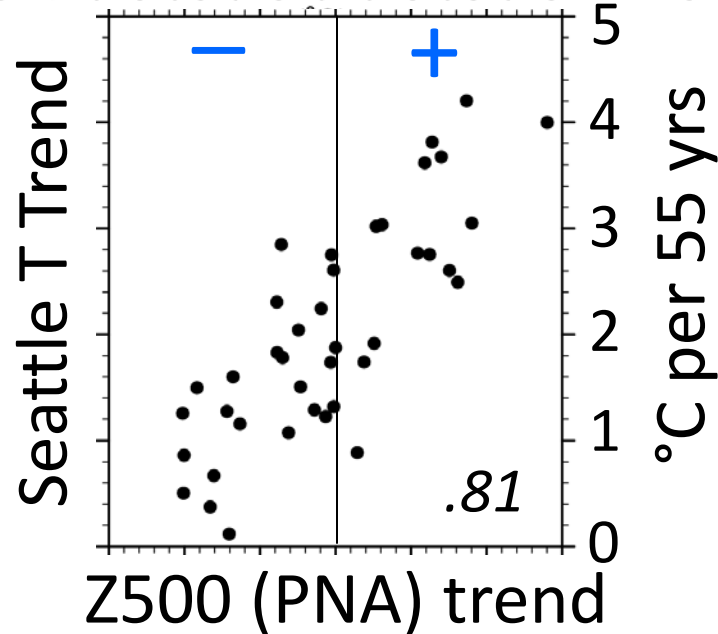
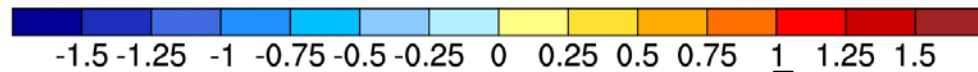
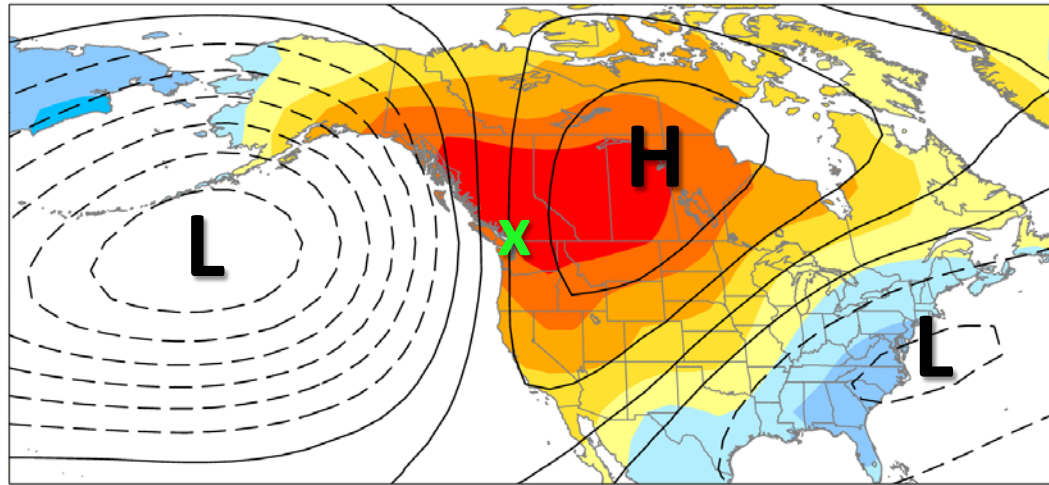
- 4 hPa

# Seattle Temperature (DJF)



# Regressions on Seattle Temperature Trends

## Z500 & Temperature Trends



# Seattle Temperature Trends 2005-2060

Raw trends

PNA circulation-residual trends

