Living With Uncertainty: The Role of Weather Noise in Future Climate Change

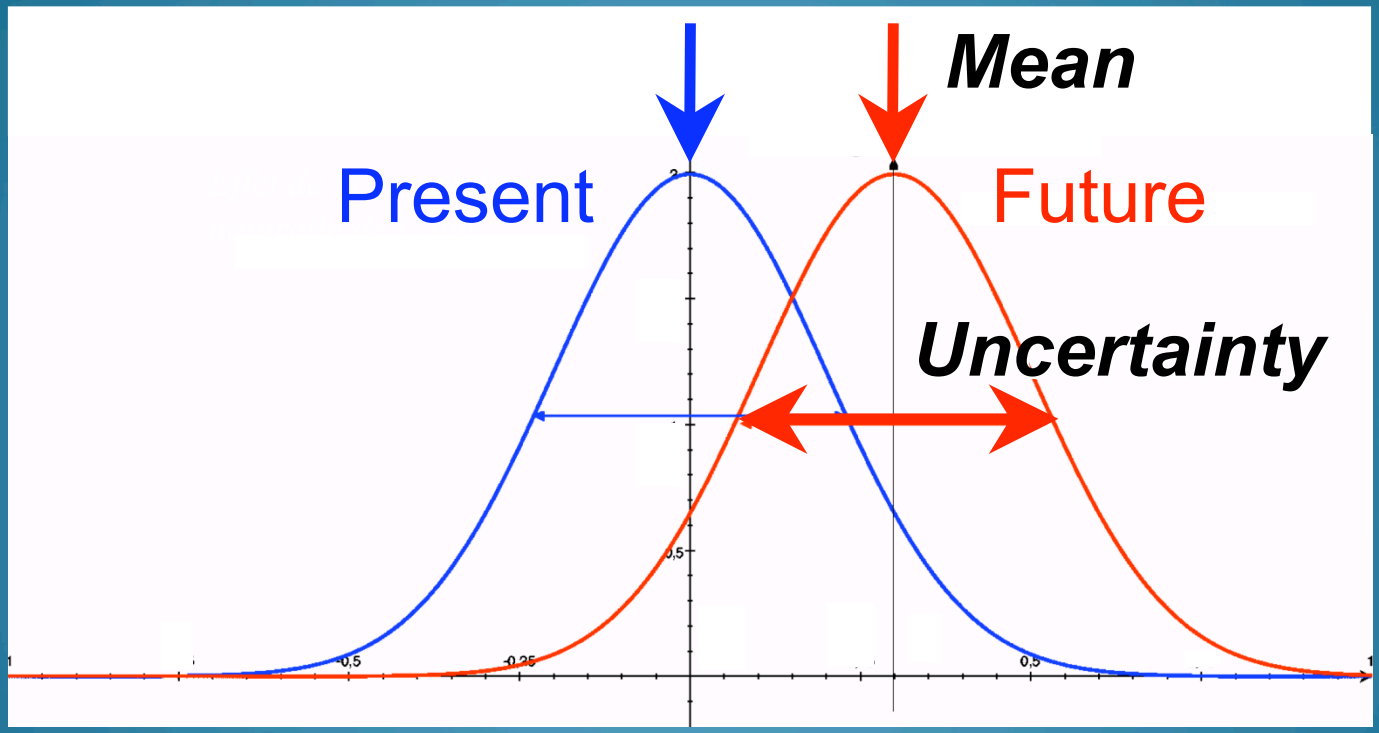
Clara Deser

Vincent Bourdette, Adam Phillips and Grant Branstator

National Center for Atmospheric Research

Workshop on Predicting the Climate of the Coming Decades

Climate Change



- Uncertainty in Future Climate Trend Projections

40 Climate Realizations, 2000 – 2060

Community Climate System Model version 3

IPCC AR4

A1B GHG scenario (380 → 570 ppm)

Stratospheric ozone recovery

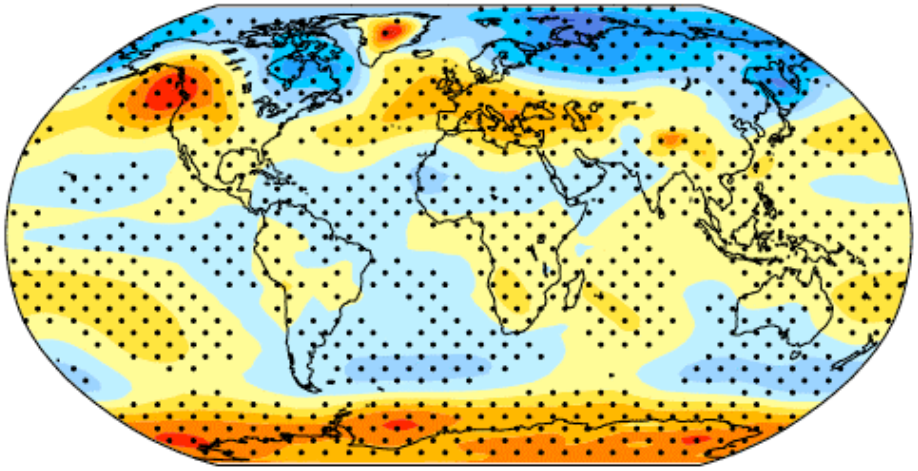
Each realization begins from a different atmospheric initial state

Projections of Future Climate Change

Sea Level Pressure (December-February)

Mean of the 40 realizations

Trend (2005 to 2060)



Stippling: 95% significance relative to spread of individual realizations

Projections of Future Climate Change

Sea Level Pressure (December-February)

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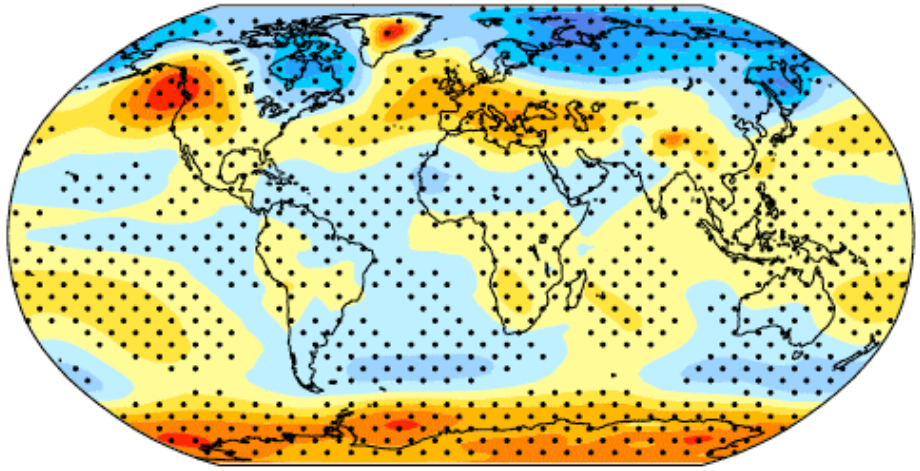

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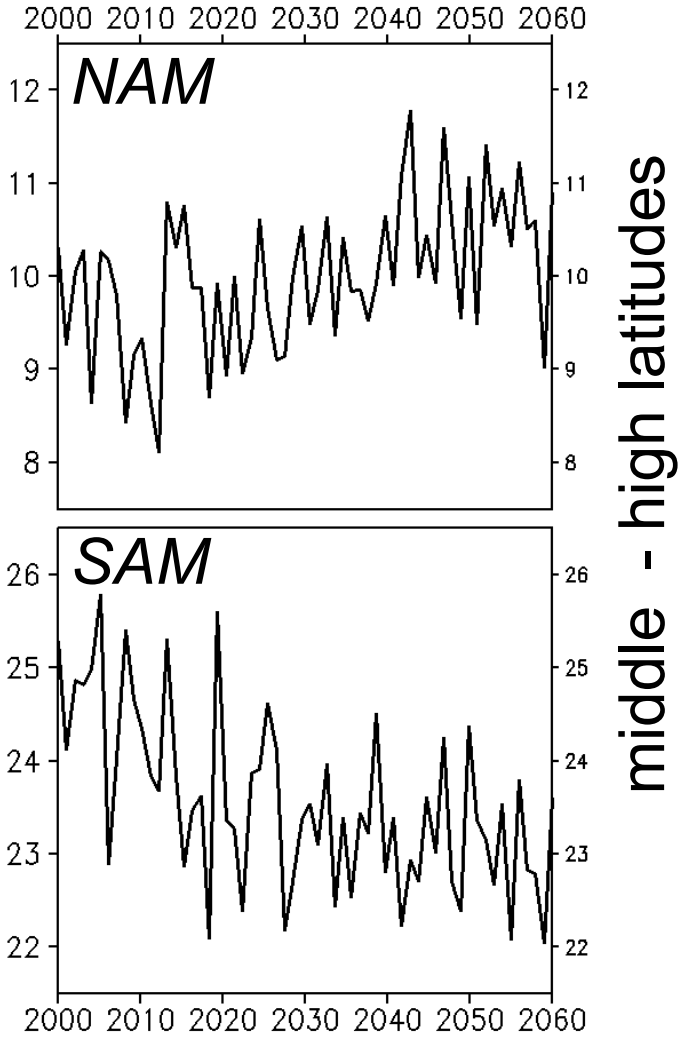

Projections of Future Climate Change

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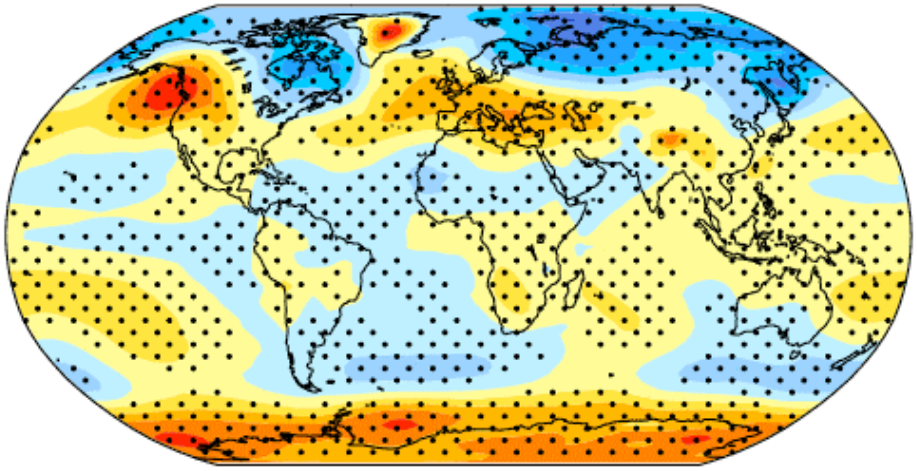

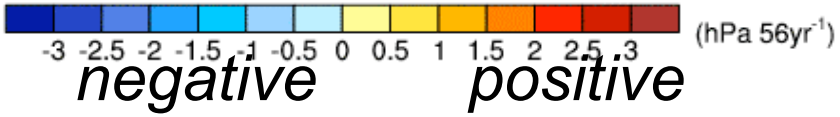

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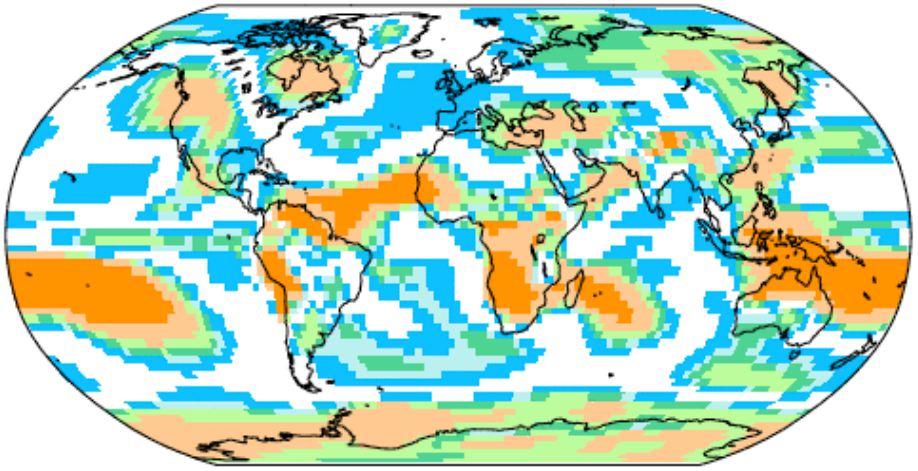
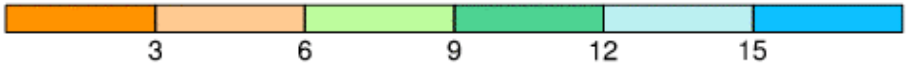
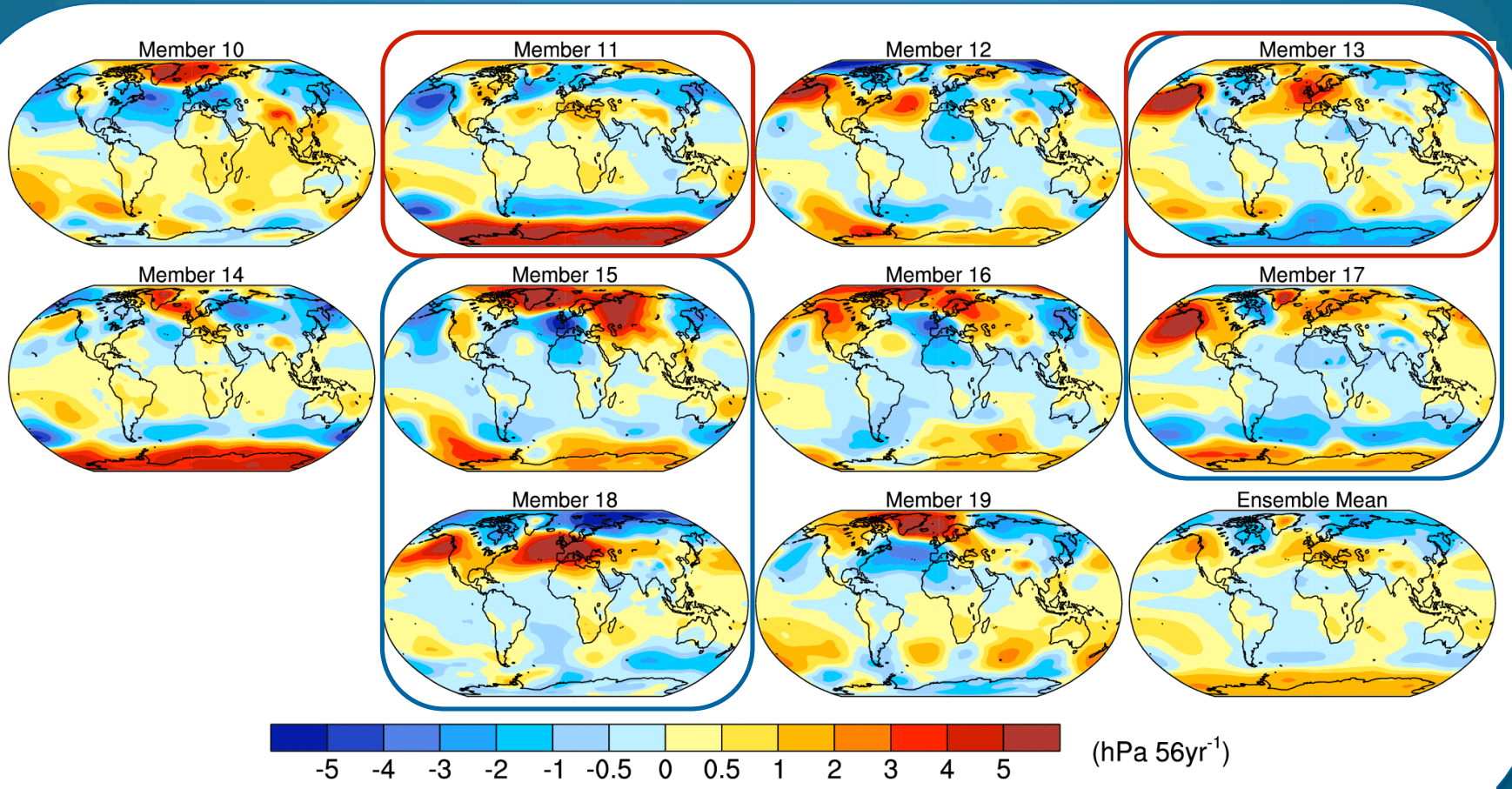


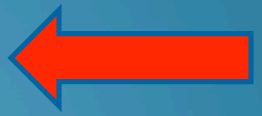


Minimum number of realizations needed to detect the trend where it is significant

Sea Level Pressure Trends in 10 Individual Realizations



Where Does the "Noise" Come From?

- Internal Atmospheric Variability 
  - e.g., low-frequency tail of "weather noise" *(Madden, 1979; Wunsch, 1999; Feldstein, 2000)*
- Coupled Ocean-Atmosphere Variability
  - e.g., low-frequency tail of ENSO "Pacific Decadal Oscillation"
- Internal Oceanic Variability
  - e.g., oscillations of the Atlantic thermohaline circulation ("Atlantic Multidecadal Oscillation")

Uncertainties: The Role of "Weather Noise"

Atmosphere (CAM3)

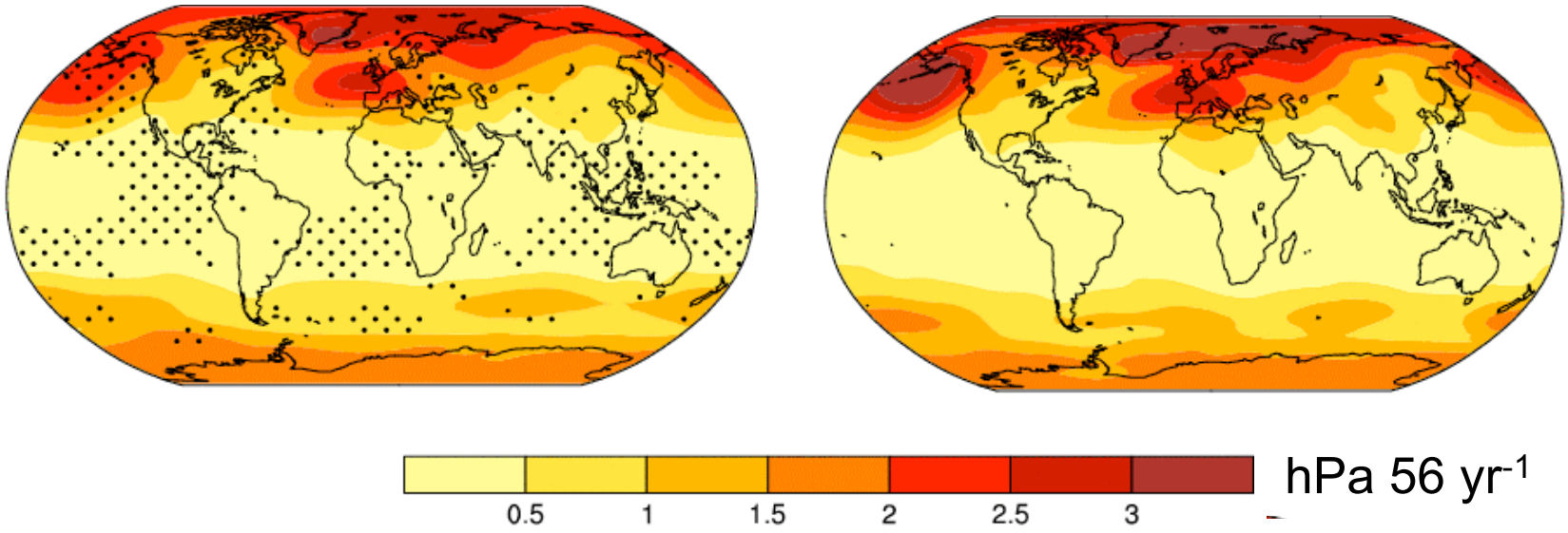
10,000 year control integration of the atmospheric model component of CCSM3

Forced with seasonally-varying SSTs and sea ice from late 20th century, but no year-to-year variability

Standard Deviation of SLP Trends

(56-year trends)
178 realizations of the atmospheric model control

(2005-2060 trends)
40 realizations of the coupled model



Stippling: standard deviations are significantly different (95%)

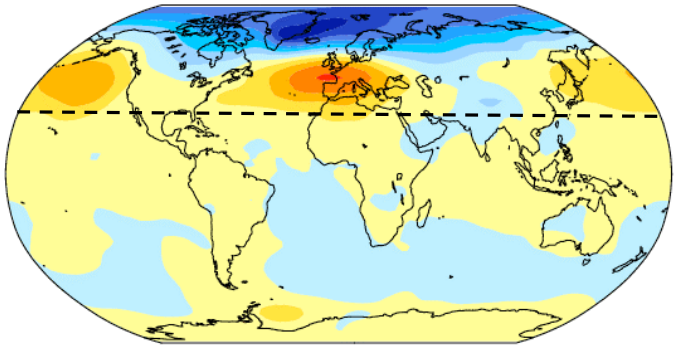
December-February

Dominant Patterns of the "Noise"
EOF1 of 56-year SLP Trends

NH

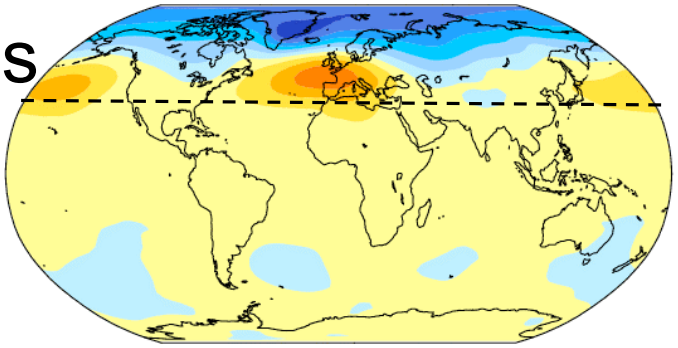
40 realizations coupled model (2005-2060)

36%

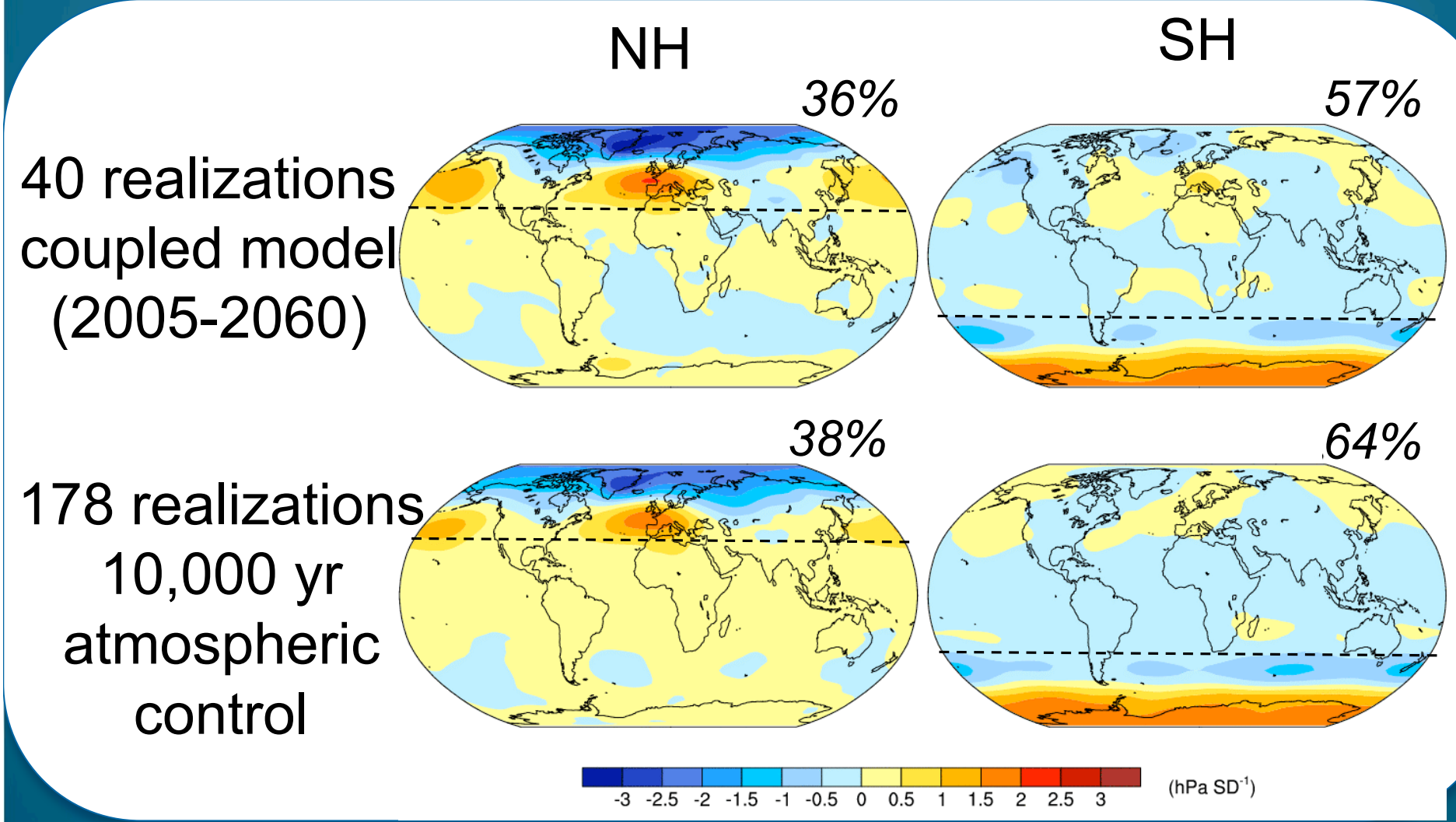


178 realizations 10,000 yr atmospheric control

38%



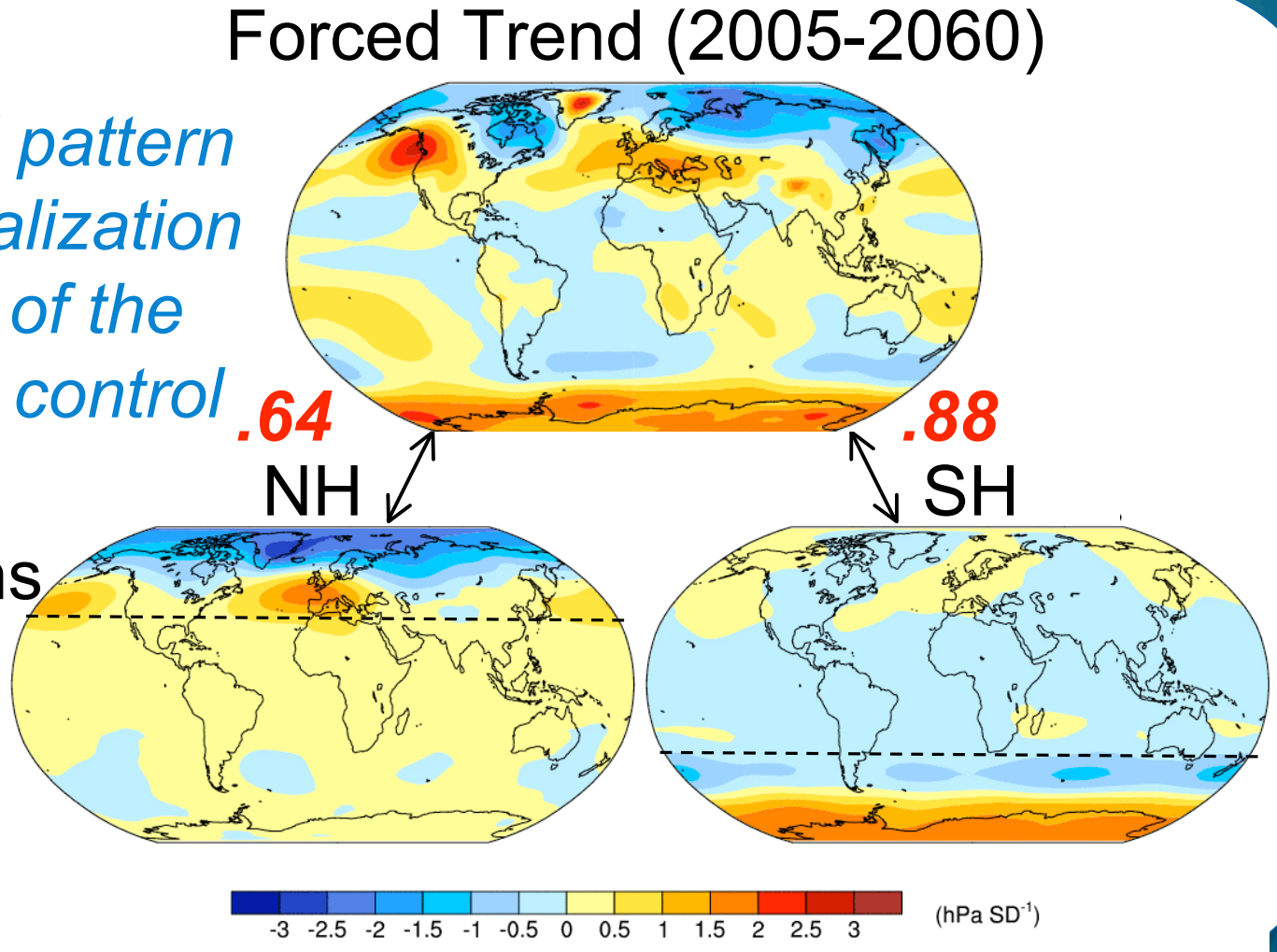
Dominant Patterns of the "Noise"
EOF1 of 56-year SLP Trends



Dominant Patterns of the "Noise"
EOF1 of 56-year SLP Trends

Project trend pattern from each realization onto EOF1 of the atmospheric control

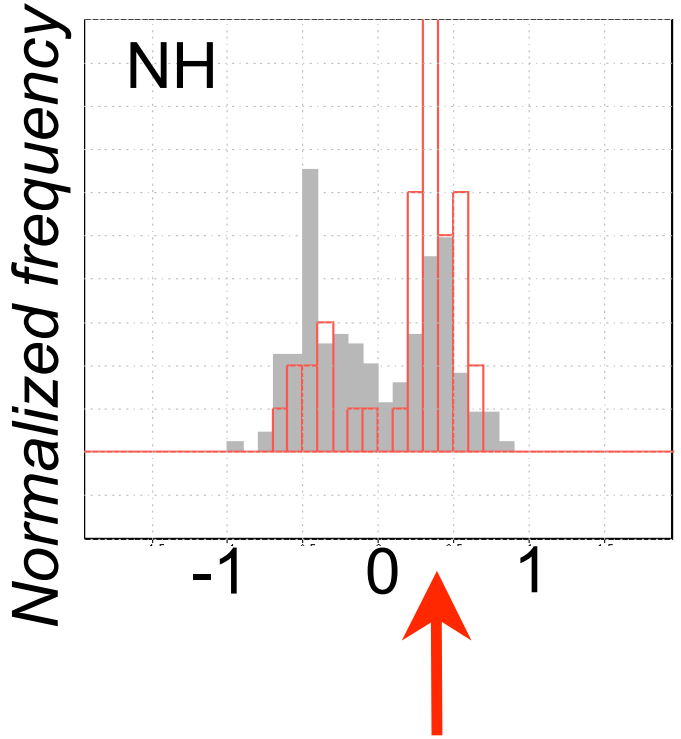
178 realizations
10,000 yr
atmospheric
control

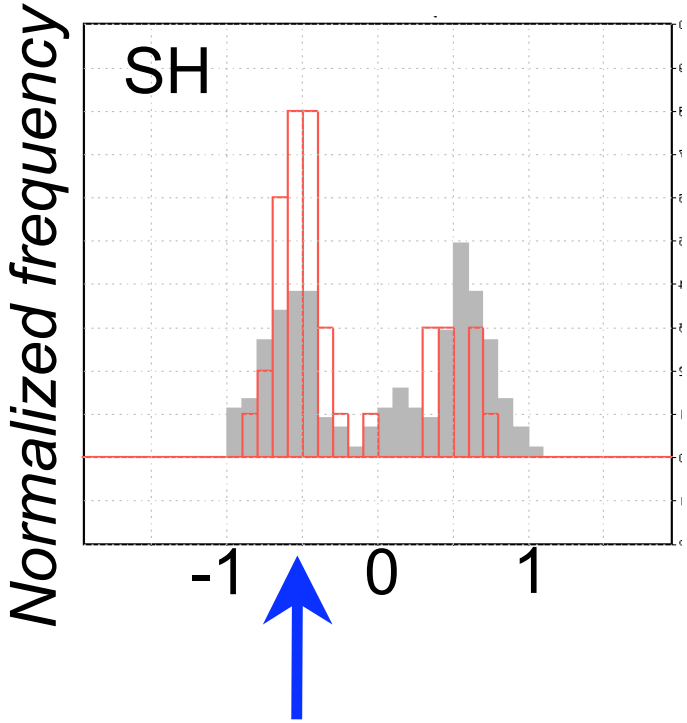


SLP Trends Projected onto EOF1 of the 10,000 yr Atmospheric Control

Coupled Model (2005 to 2060)

Atmospheric Model Control

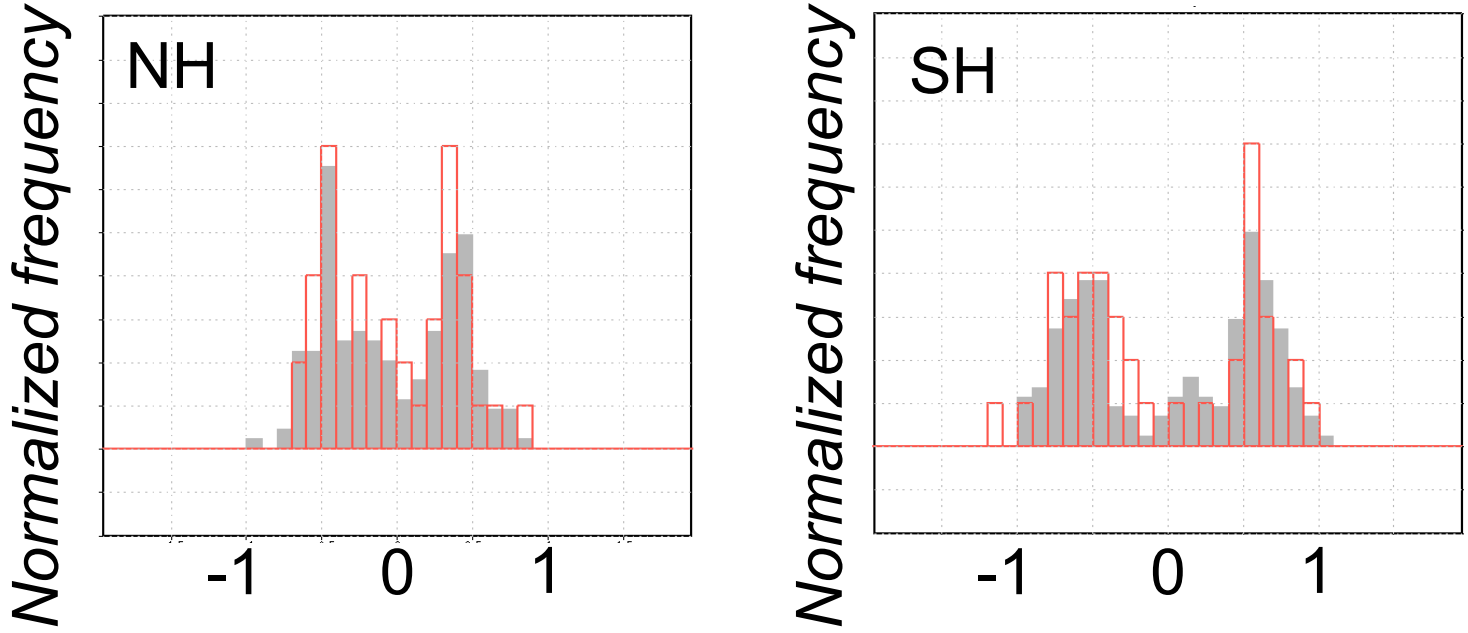




SLP Trends Projected onto EOF1 of the 10,000 yr Atmospheric Control

Coupled Model (2005 to 2060)

Atmospheric Model Control

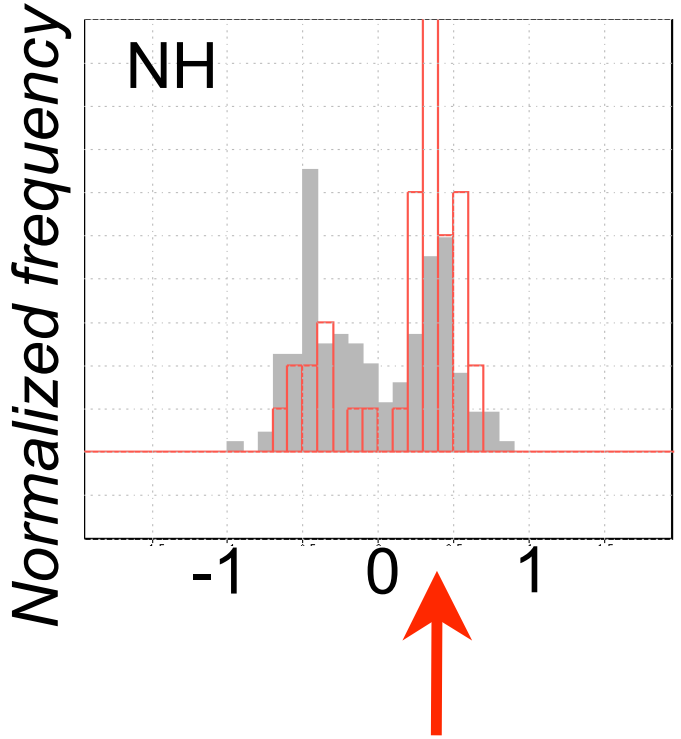


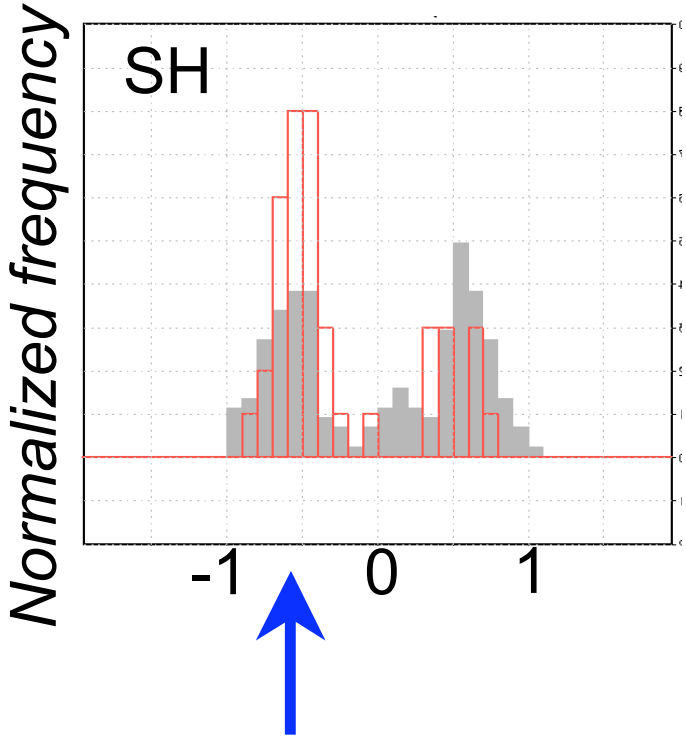
Ensemble Mean Trend Removed

SLP Trends Projected onto EOF1 of the 10,000 yr Atmospheric Control

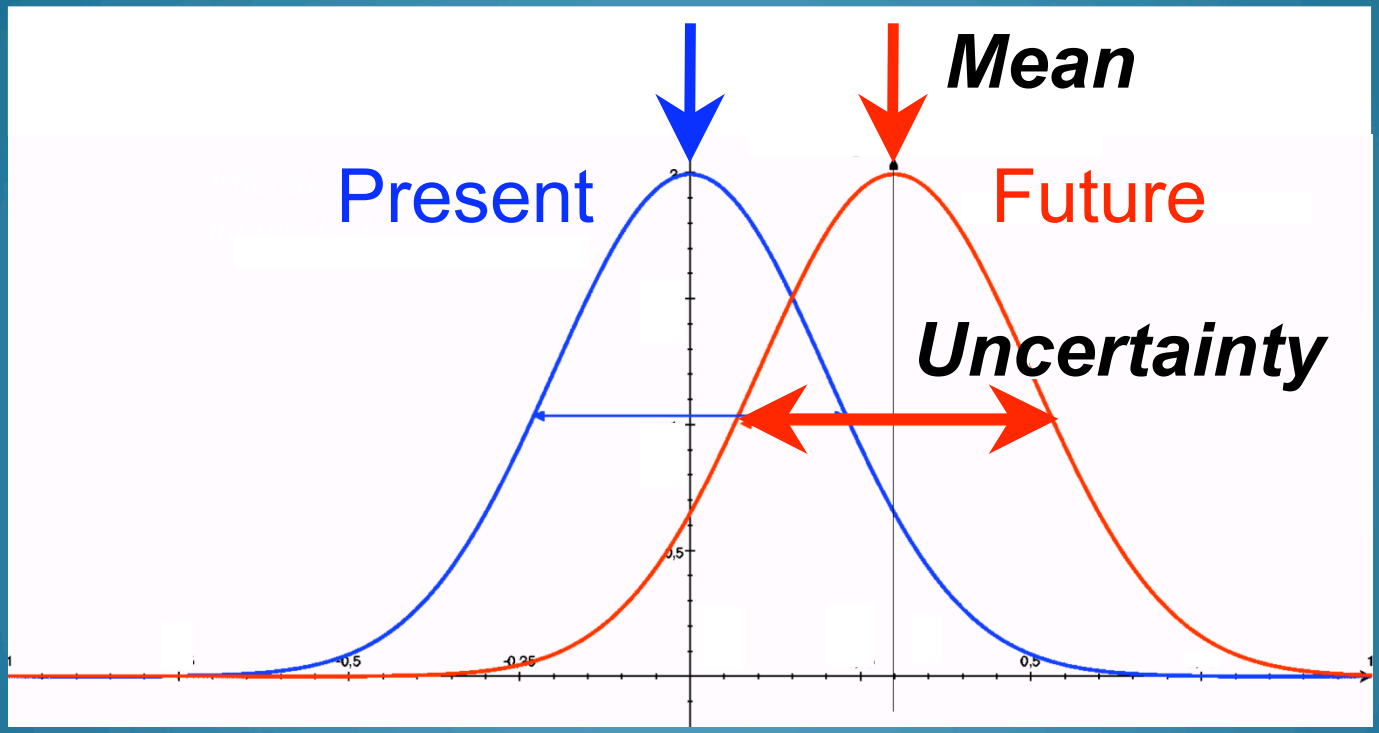
Coupled Model (2005 to 2060)

Atmospheric Model Control





Climate Change



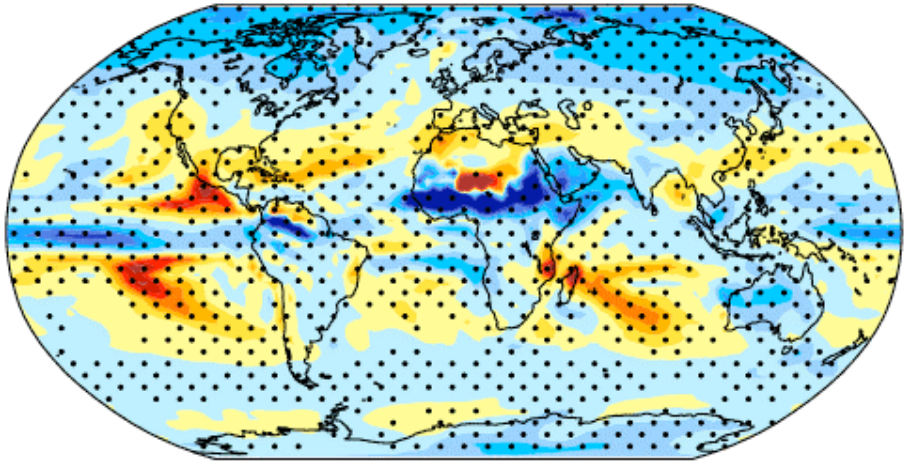
- Relatively large uncertainty in projected 21st century atmospheric circulation trends (NAM and SAM) due to intrinsic weather noise

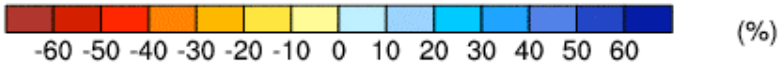
Projections of Future Climate Change

Precipitation (December-February)

Mean of the 40 realizations

Trend: 2005 to 2060

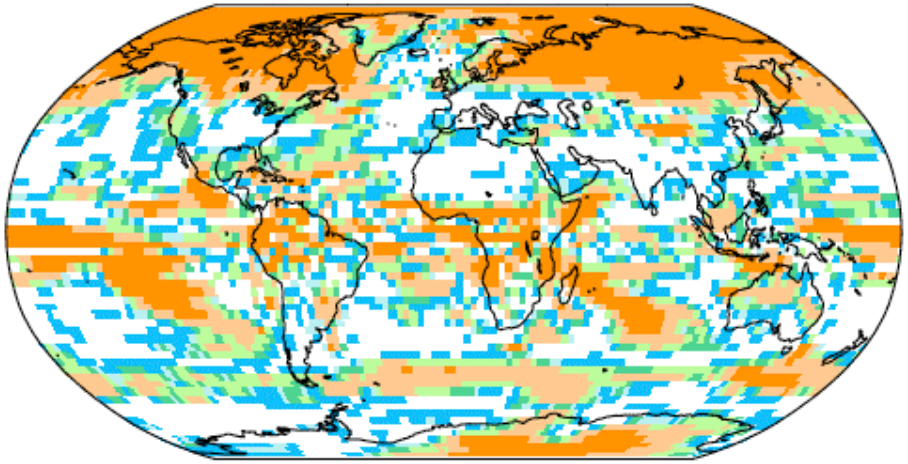


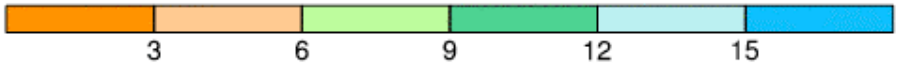


negative *positive*

Stippling: 95% significant relative to spread of individual realizations

realizations





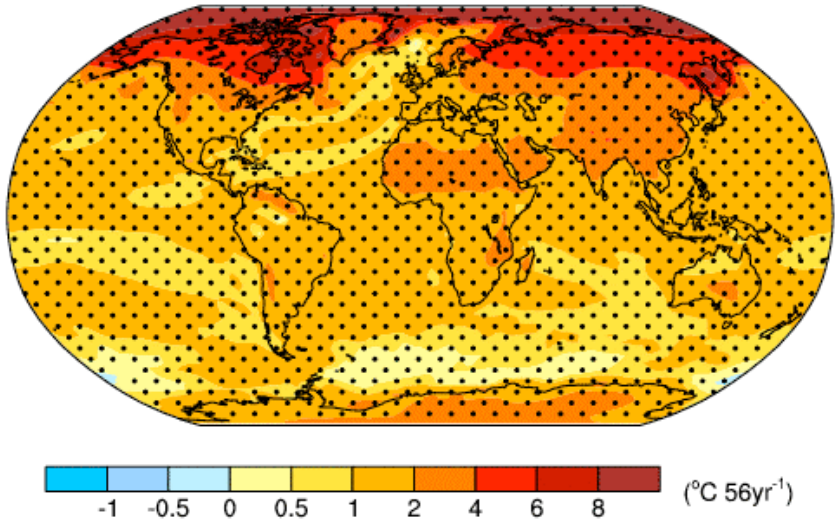
Minimum number of realizations needed to detect the trend where it is significant

Projections of Future Climate Change

Temperature (December-February)

Mean of the 40 realizations

Trend: 2005 to 2060



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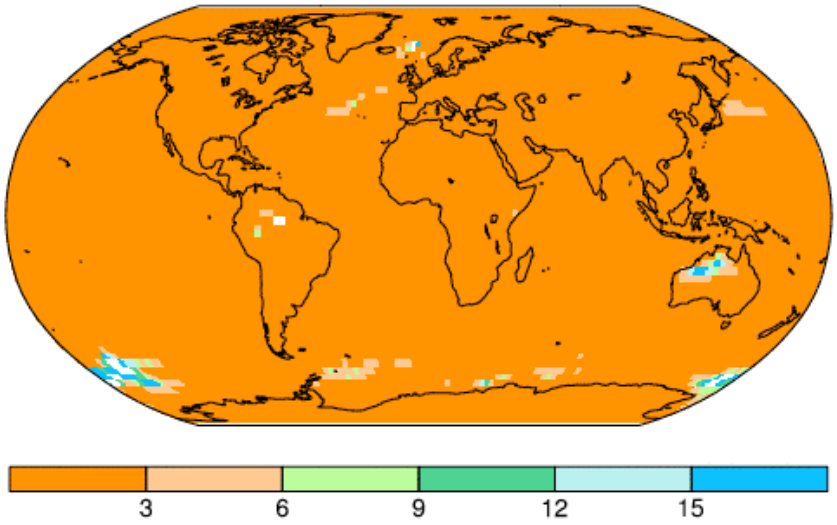


Minimum number of realizations needed to detect the trend where it is significant

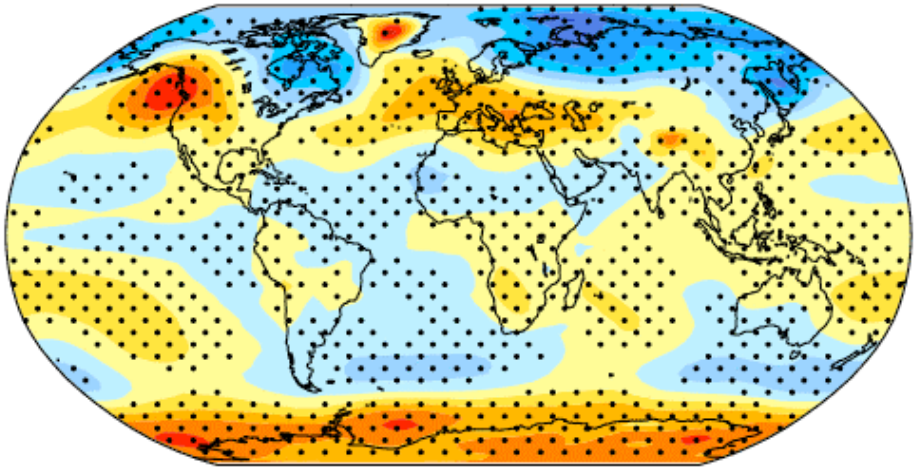
Thank You

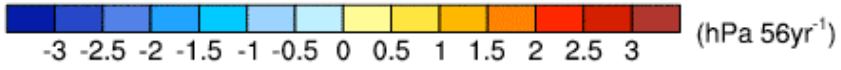
Projections of Future Climate Change

Sea Level Pressure (December-February)

Mean of the 40 realizations

Trend (2005 to 2060)





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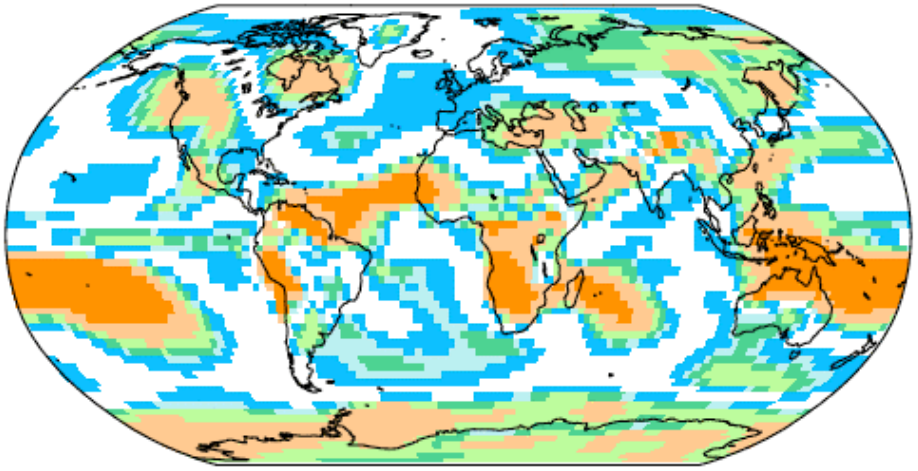
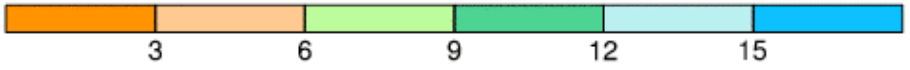




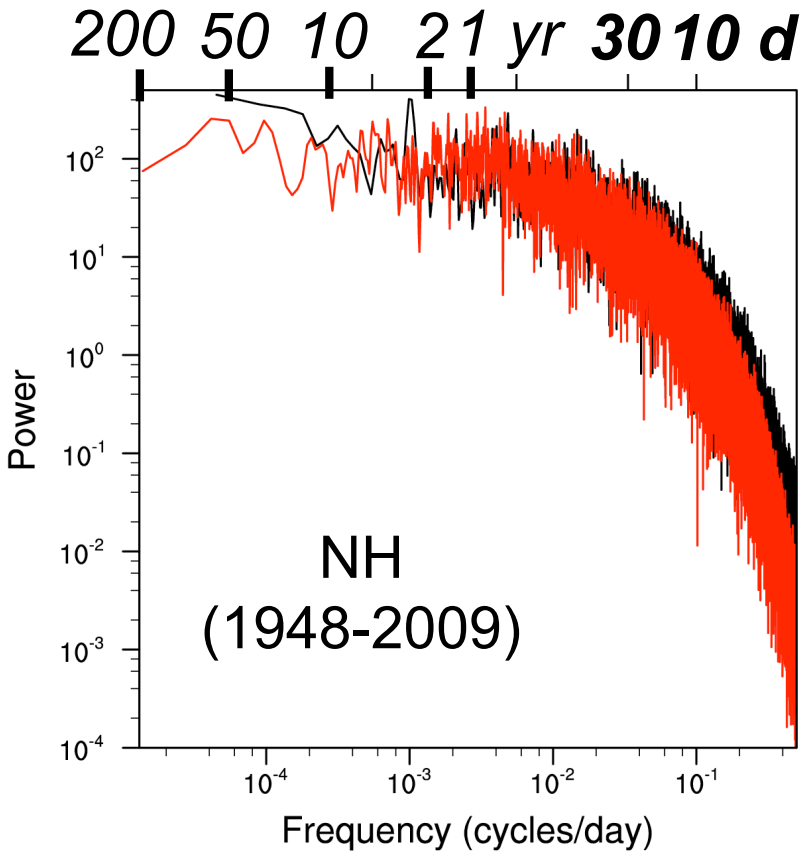
Minimum number of realizations needed to detect the trend where it is significant

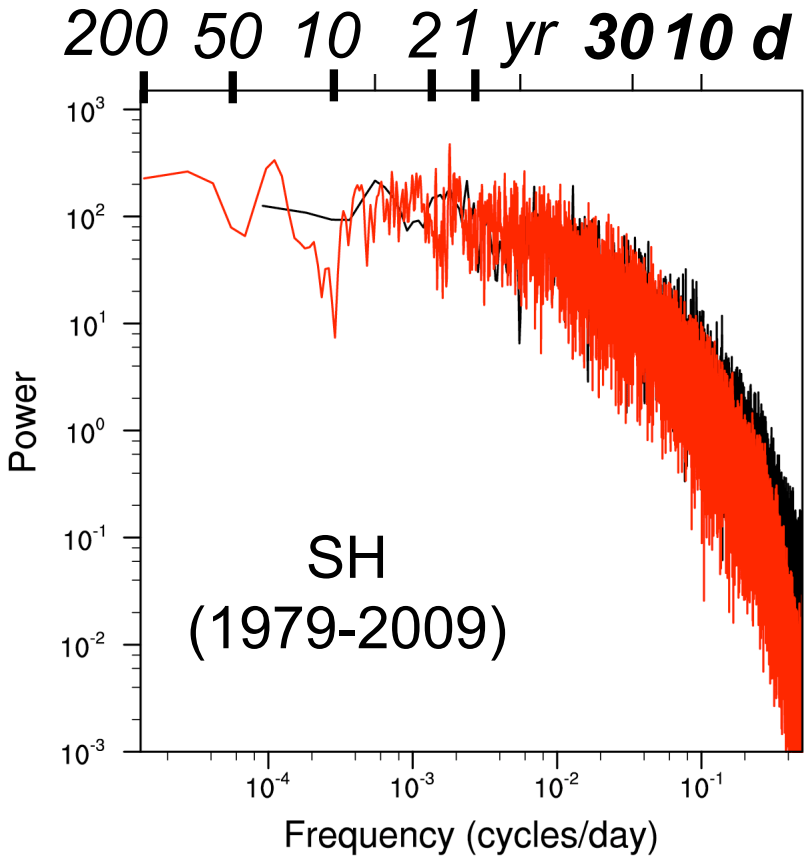
Power Spectra: Daily NAM and SAM Indices

PC1 NH and SH SLP Anomalies

Atmospheric model control (200 yr)

Observations (NCEP/NCAR Reanalyses)

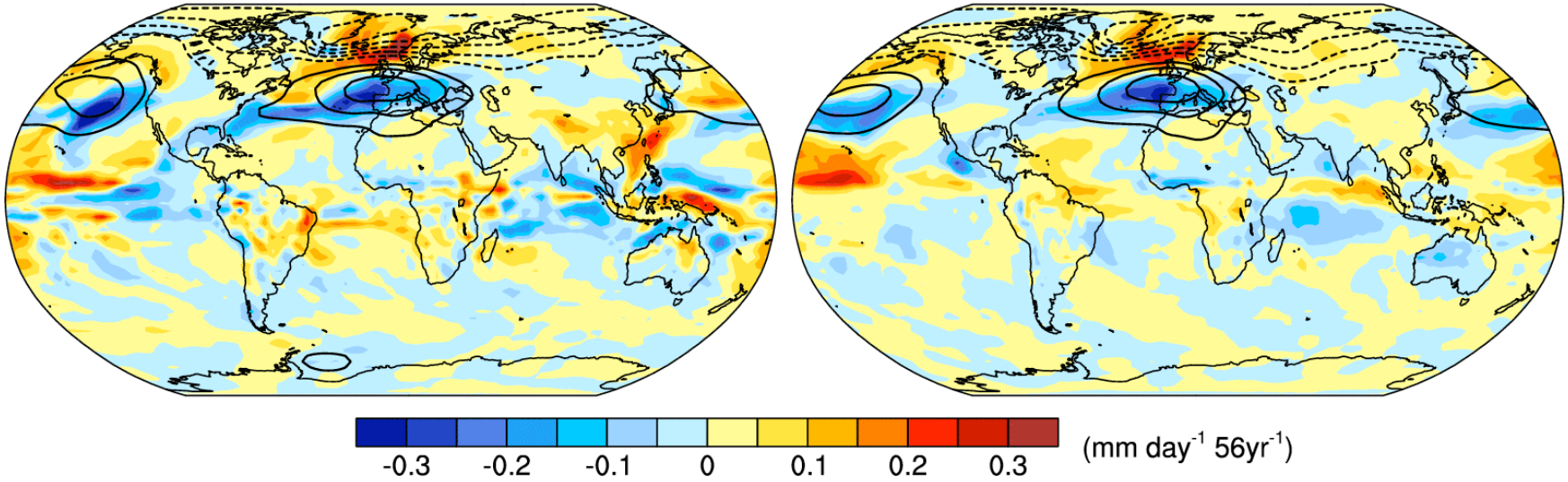




Dominant Patterns of the “Noise”
EOF1 of SLP Trends (2005-2060)

Coupled Model

10,000 yr Atm Control



SLP (contours) & Precipitation (color)

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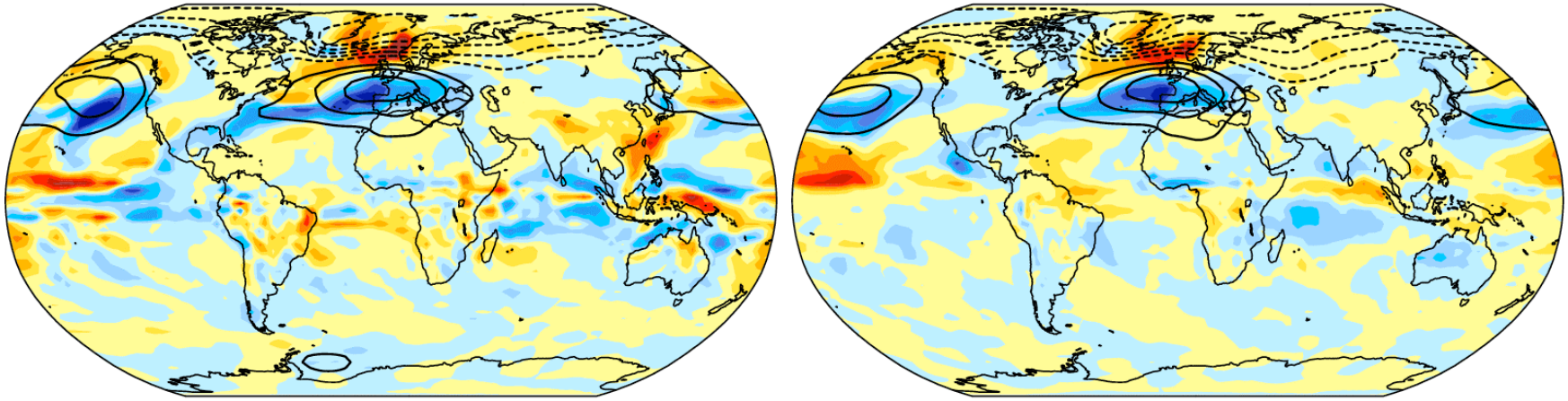
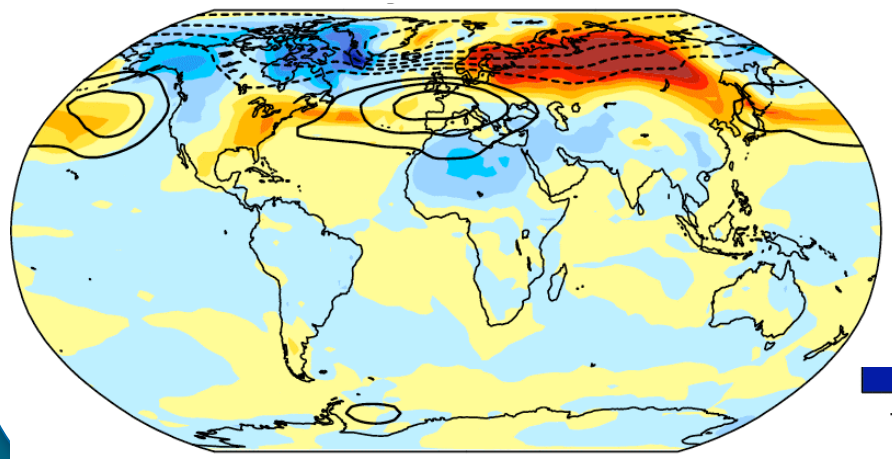
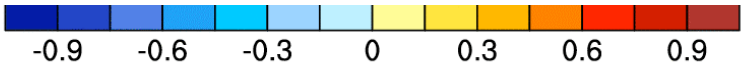
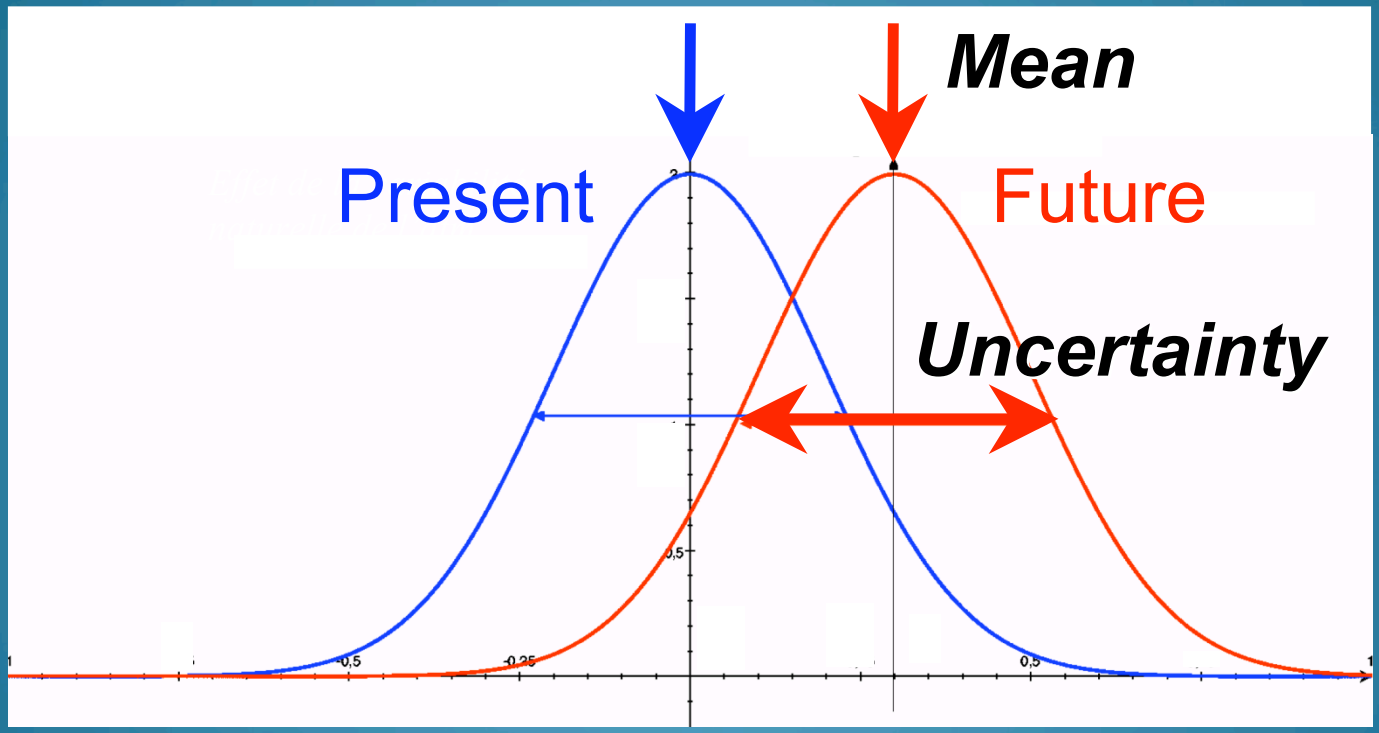




SLP (contours)
Air T (color)



Climate Change



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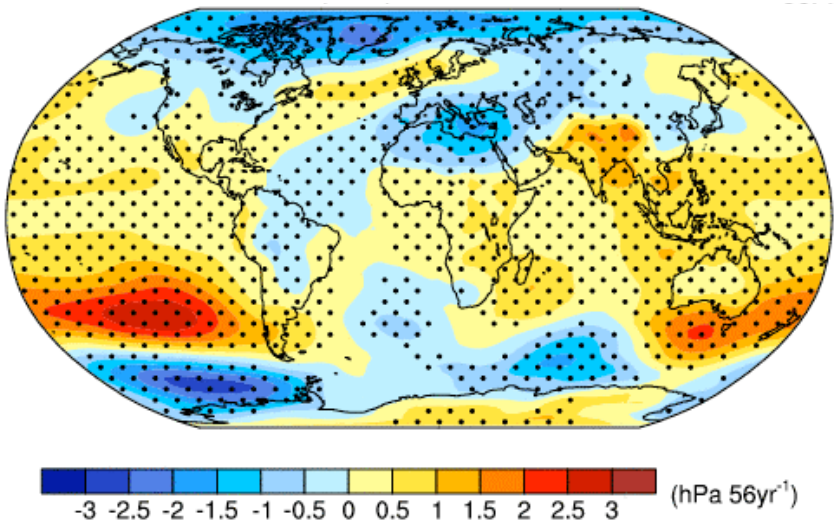
Projections of Future Climate Change

Sea Level Pressure Trend (June-August)

Mean of the 40 realizations

Trend: 2005 to 2060



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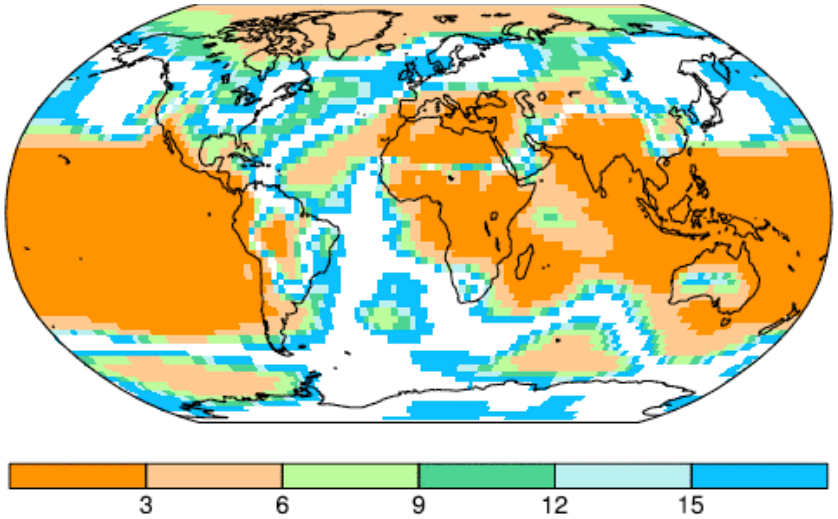


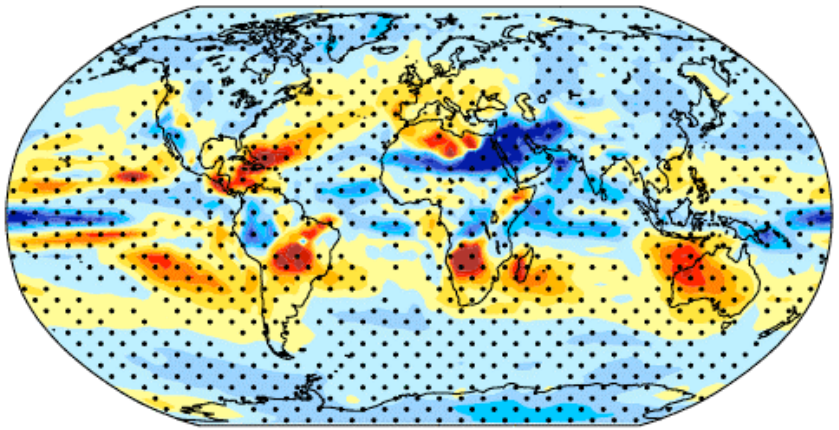
Minimum number of realizations needed to detect the trend where it is significant

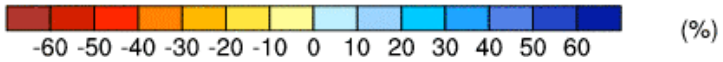
Projections of Future Climate Change

Precipitation Trend (June-August)

Mean of the 40 realizations

Trend: 2005 to 2060





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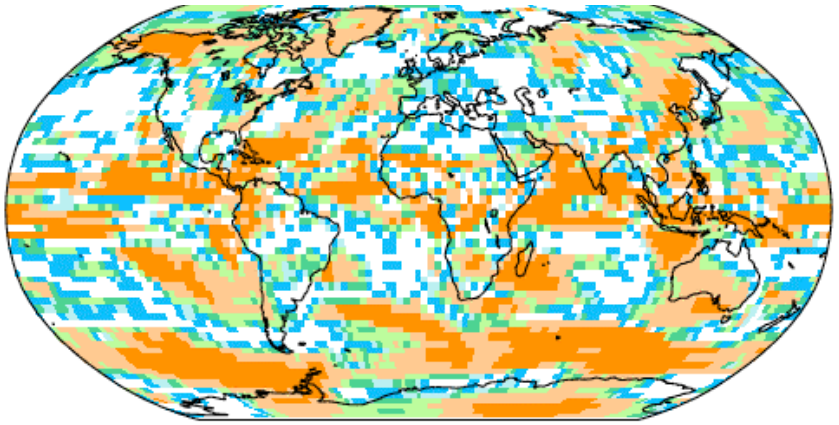

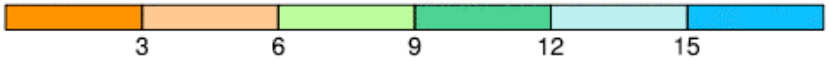

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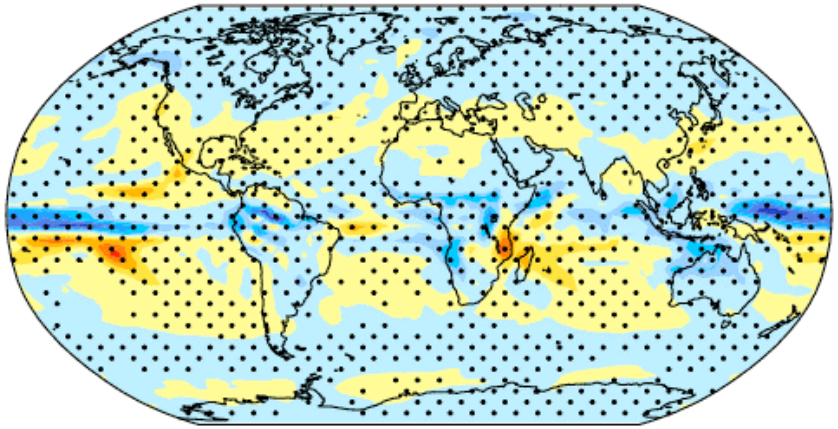
Projections of Future Climate Change

Precipitation Trend (December-February)

Mean of the 40 realizations

Trend: 2005 to 2060



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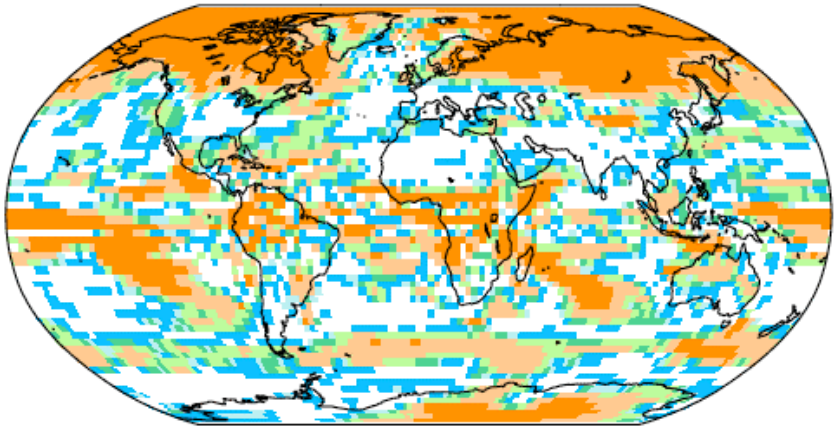
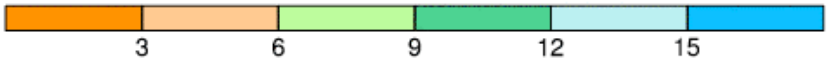




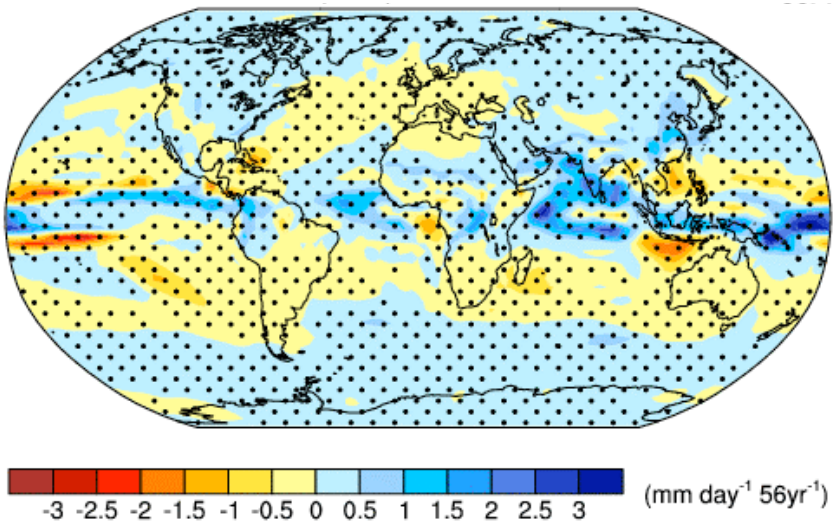
Minimum number of realizations needed to detect the trend where it is significant

Projections of Future Climate Change

Precipitation Trend (June-August)

Mean of the 40 realizations

Trend: 2005 to 2060



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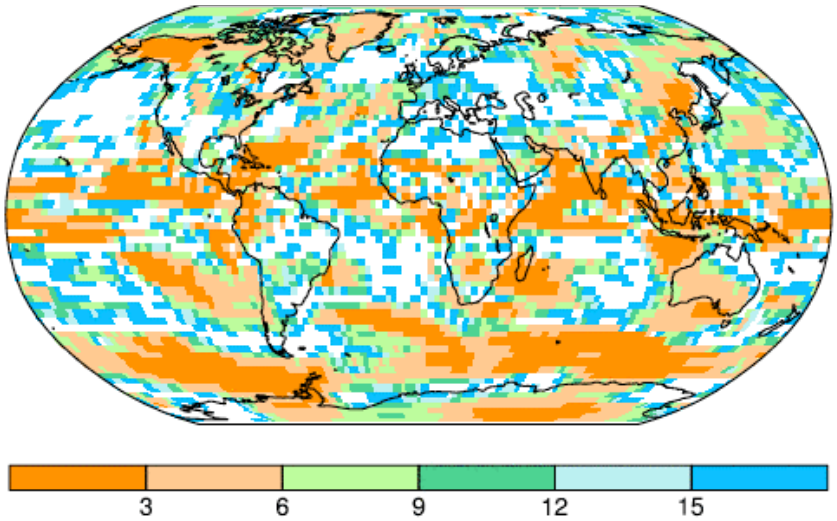


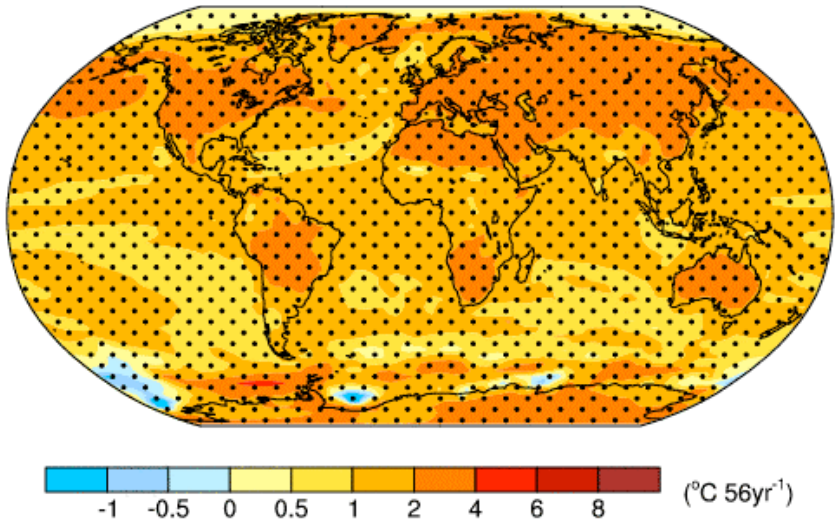
Minimum number of realizations needed to detect the trend where it is significant

Projections of Future Climate Change

Temperature Trend (June-August)

Mean of the 40 realizations

Trend: 2005 to 2060



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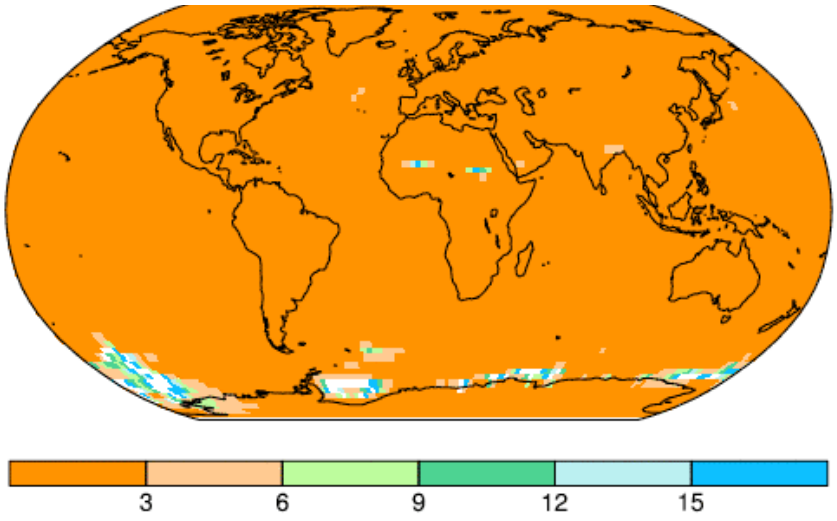
Stippling: 95% significant relative to spread of individual realizations

realizations

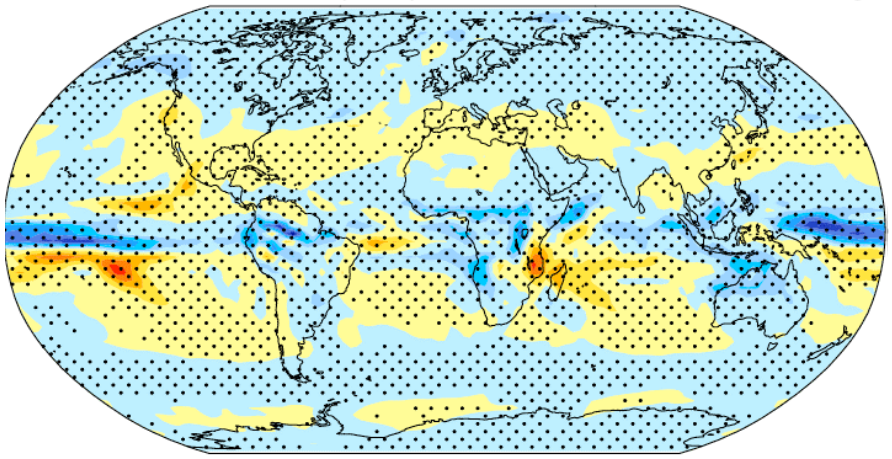


Minimum number of realizations needed to detect the trend where it is significant

Dominant Patterns of the "Noise"
EOF1 of SLP Trends (2005-2060)

Coupled Model

Ensemble Mean Trend (PPT)

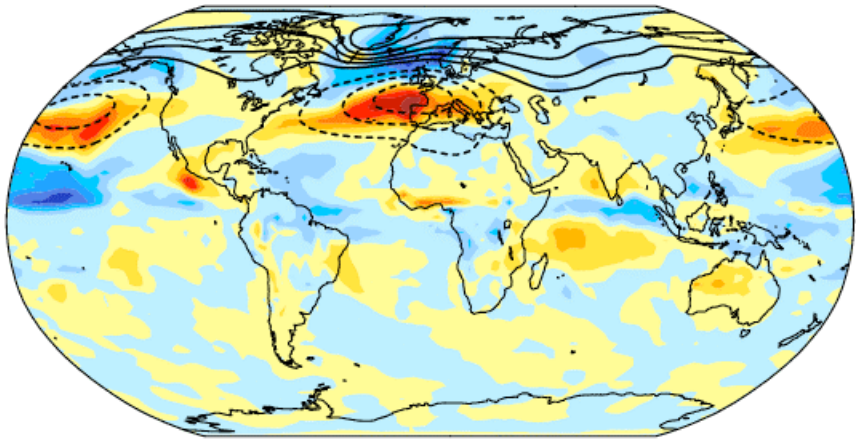


-3 -2.5 -2 -1.5 -1 -0.5 0 0.5 1 1.5 2 2.5 3

(mm day^{-1} 57yr^{-1})

DJF

10,000 yr Atm Control

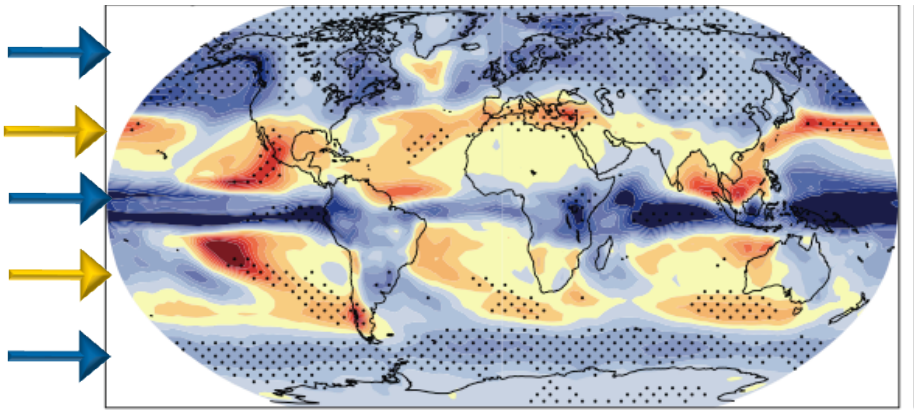


0.1 0.2 0.3

(mm day^{-1} 57yr^{-1})

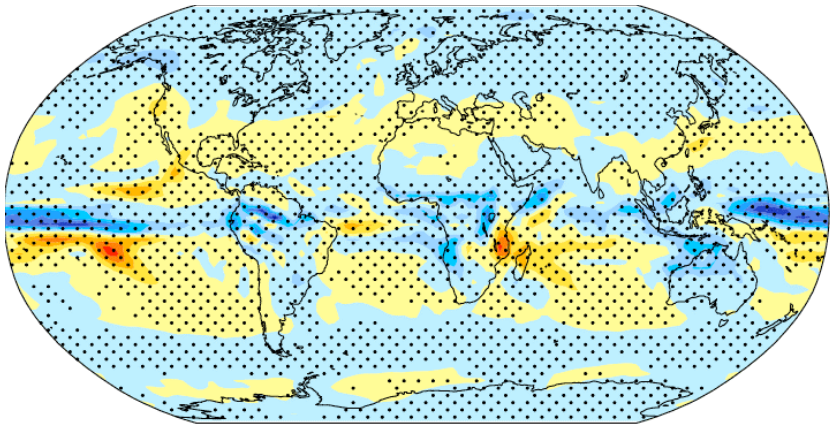
Projections of Future Climate Change
December-February Precipitation

23 IPCC models
~ 70 realizations
(2080-2099) – (1980-1999)



Dry Wet

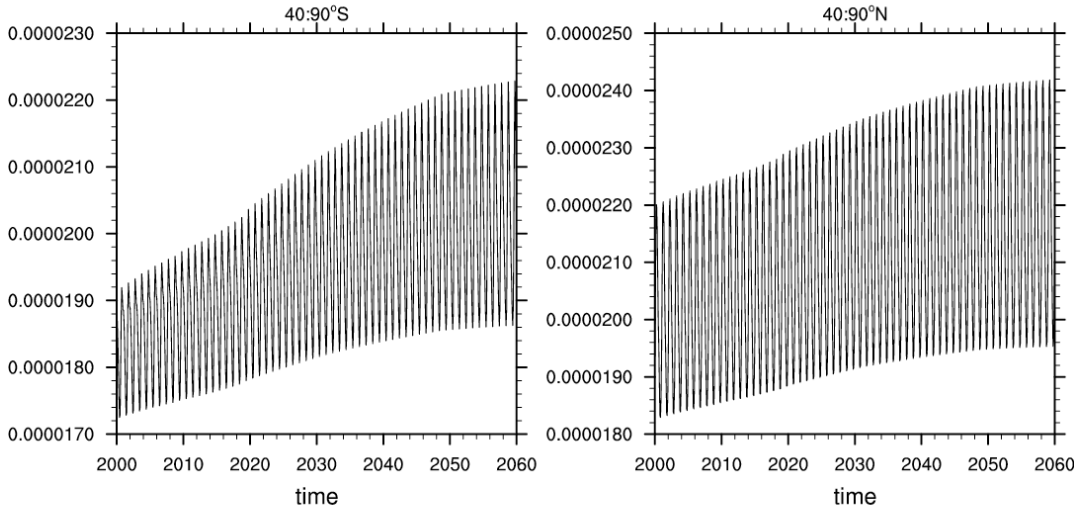
CCSM3
40 realizations
Trend 2005-2060

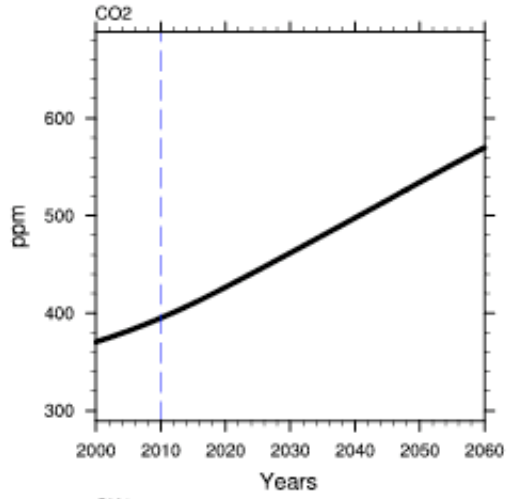


Dry Wet

Stippling: ensemble mean significant at 5% level relative to spread of individual ensemble members

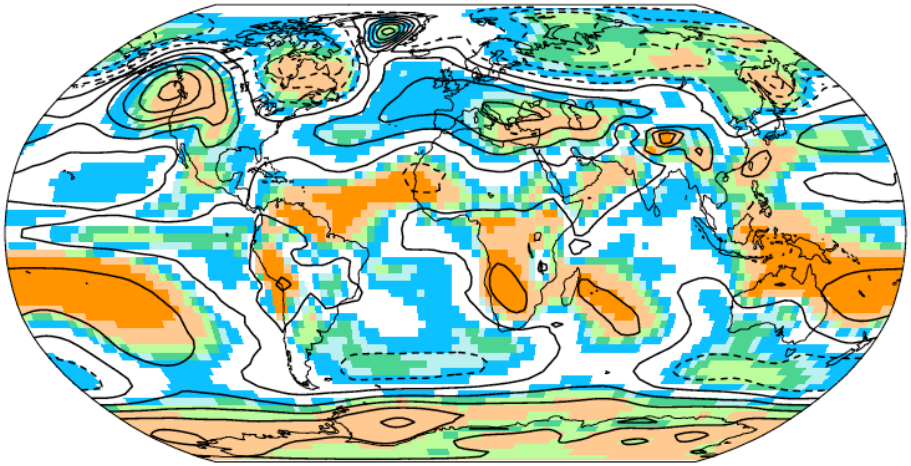
Vertically Integrated Ozone



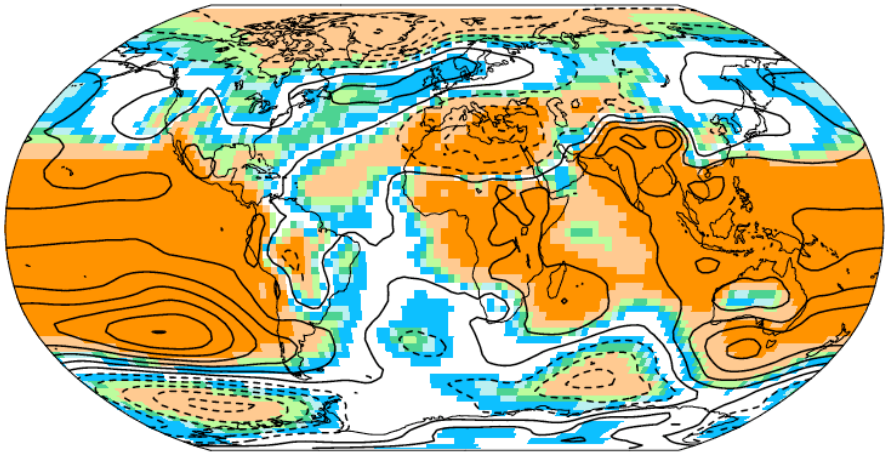


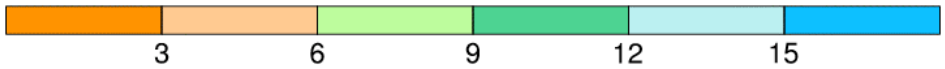
How many ensemble members are needed to detect the forced SLP response?

DJF



JJA





# of ensemble members