Climate Predictions and Projections Over the Coming Decades

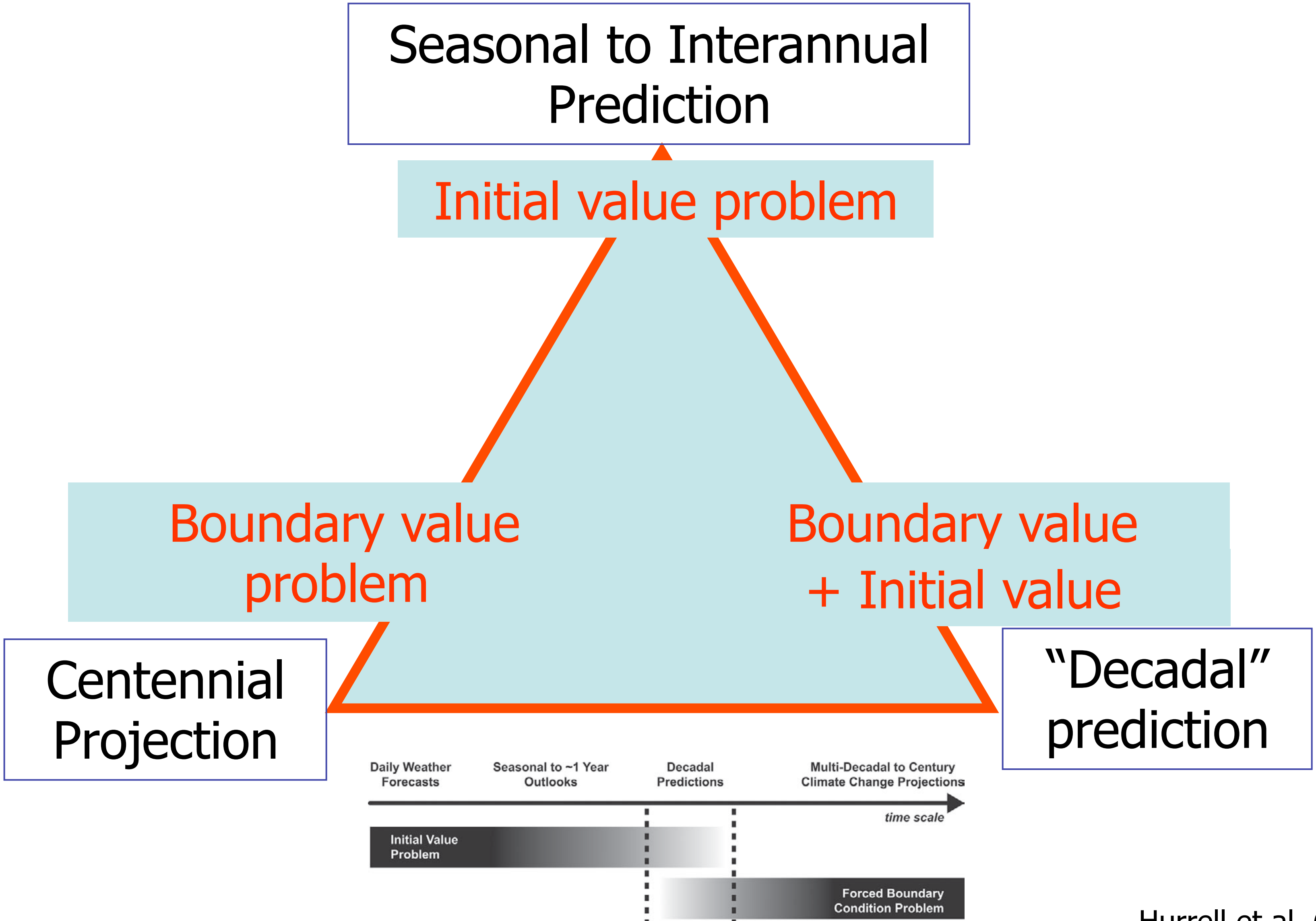
Uncertainty due to Natural Variability

Jim Hurrell

Clara Deser, Adam Phillips

National Center for Atmospheric Research

Climate Prediction



Hurrell et al. (2009)

Climate Prediction: Sources of Uncertainty

Forcing (or Scenario Uncertainty)

- GHG emission scenarios (e.g., B1, A1B, A2, RCPs) ozone, sulfate aerosols, land use, black carbon …

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Climate Prediction: Sources of Uncertainty

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Response (or Model Uncertainty)

- Model sensitivity (different physics, parameterizations, resolution …)
- 20+ different climate models in both IPCC AR4 and AR5

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Climate Prediction: Sources of Uncertainty

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Response (or Model Uncertainty)

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- 20+ different climate models in both IPCC AR4 and AR5

Internal (Natural) Variability

- Atmosphere and Ocean
- Coupled atmosphere-ocean interactions
- Ensembles (multiple simulations)

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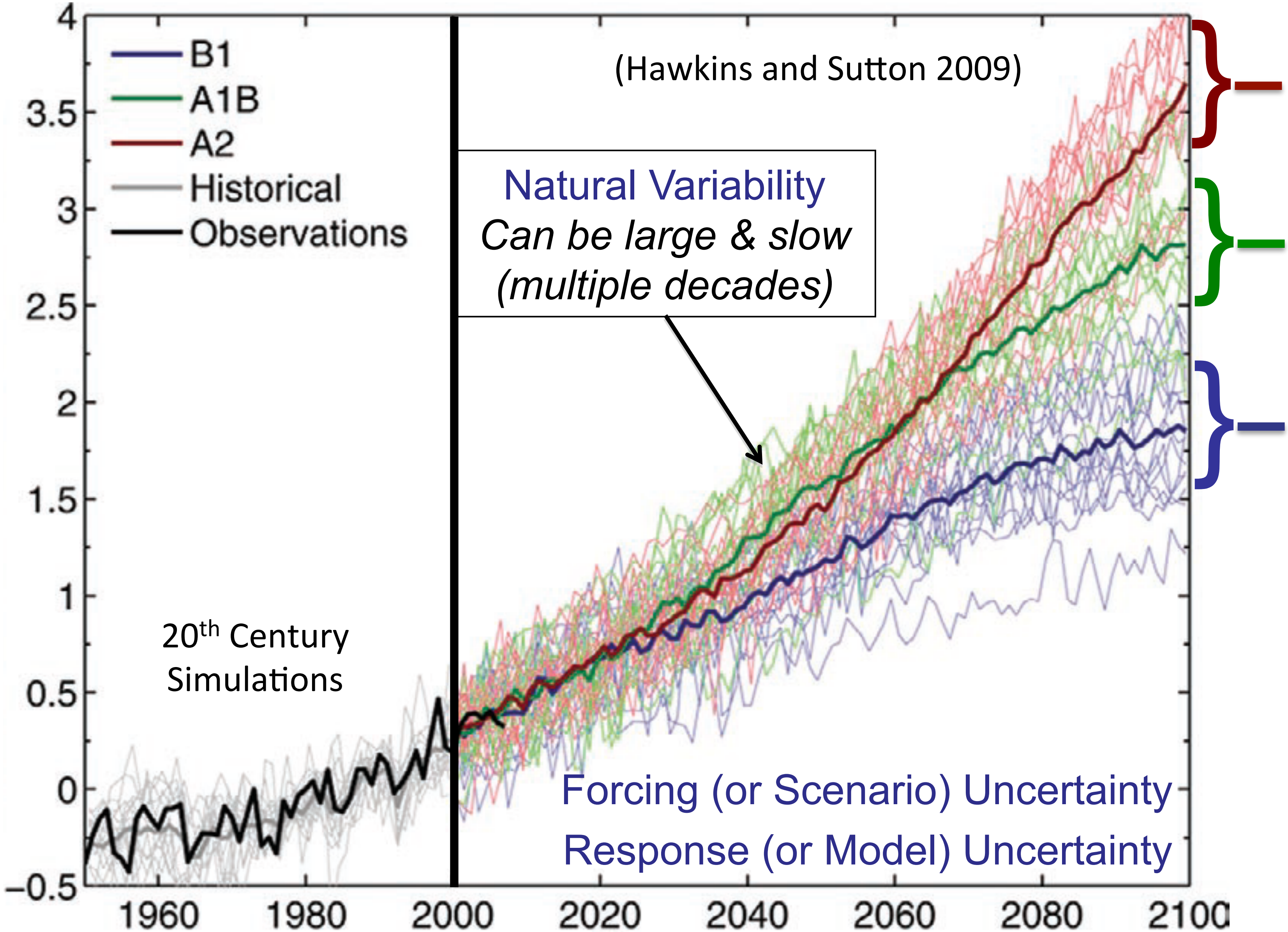
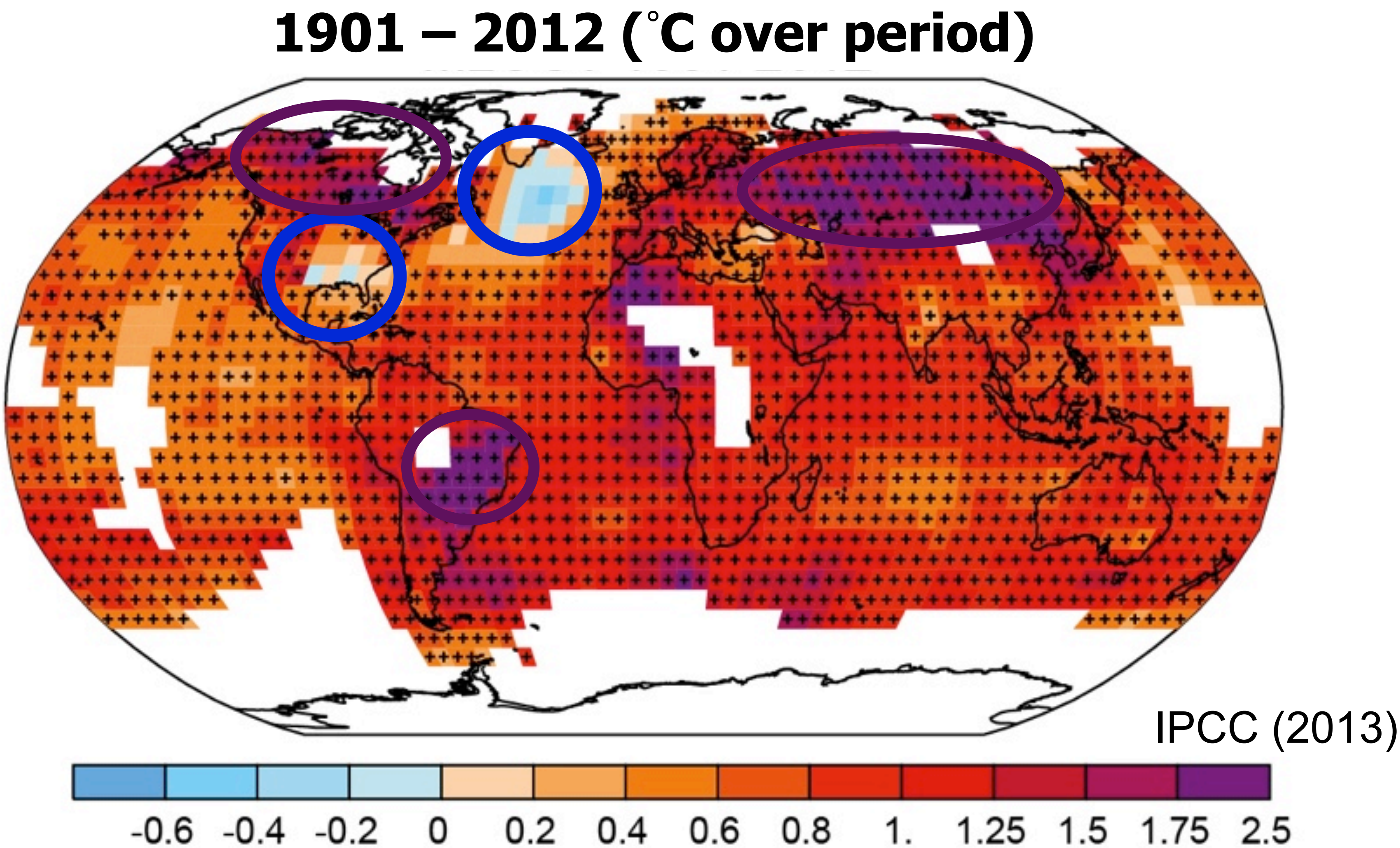
Projected Global SAT (IPCC AR4)



Linear Trend of Surface Temperature



Mixture of internal variability and forced climate change

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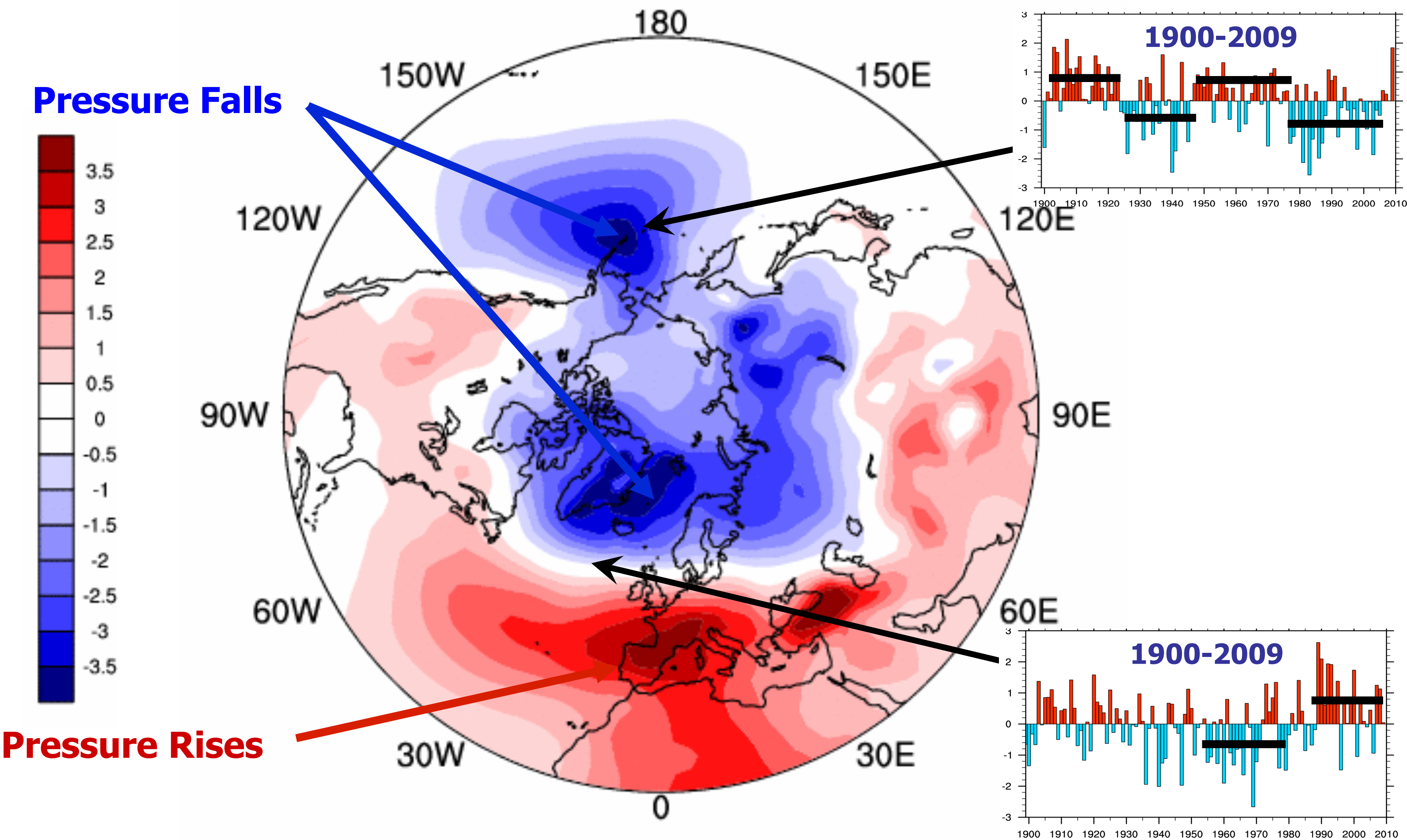
Decadal Climate Variability

Change in Winter Sea Level Pressure (1980-2009)



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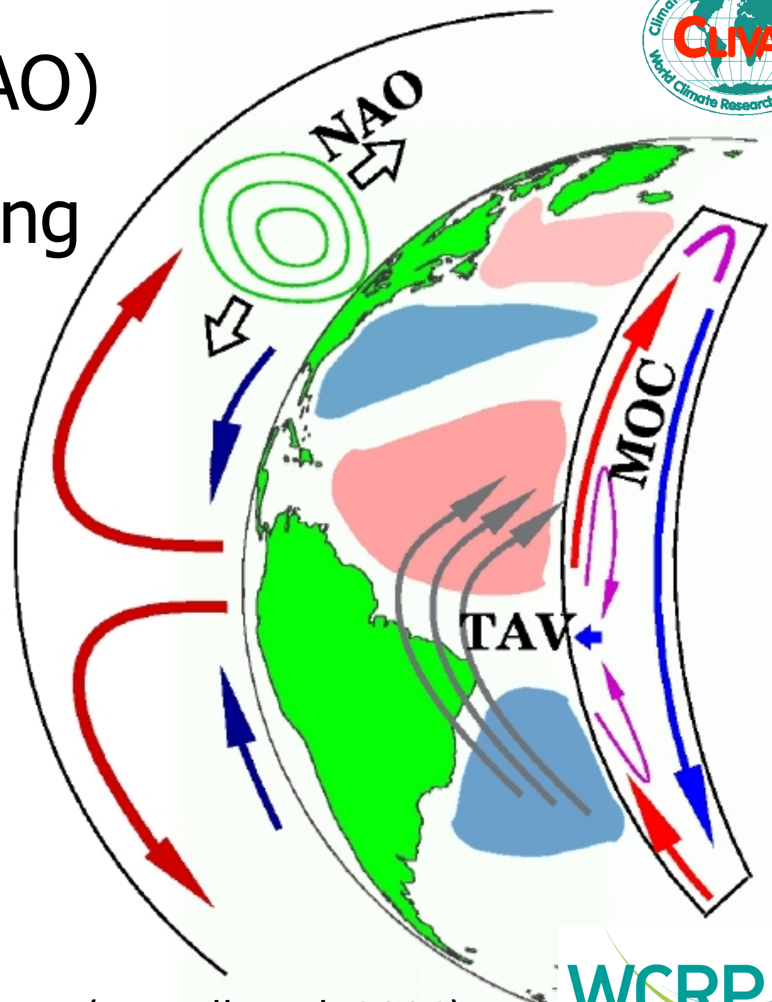
Natural Variability over the Atlantic

Major Phenomena

- North Atlantic Oscillation (NAO)
- Atlantic Meridional Overturning Circulation (AMOC)
- Tropical Atlantic Variability

➢ All significant modes of natural variability

➢ Variations and significant impacts from seasonal to multi-decadal time scales



(Hurrell et al. 2006)

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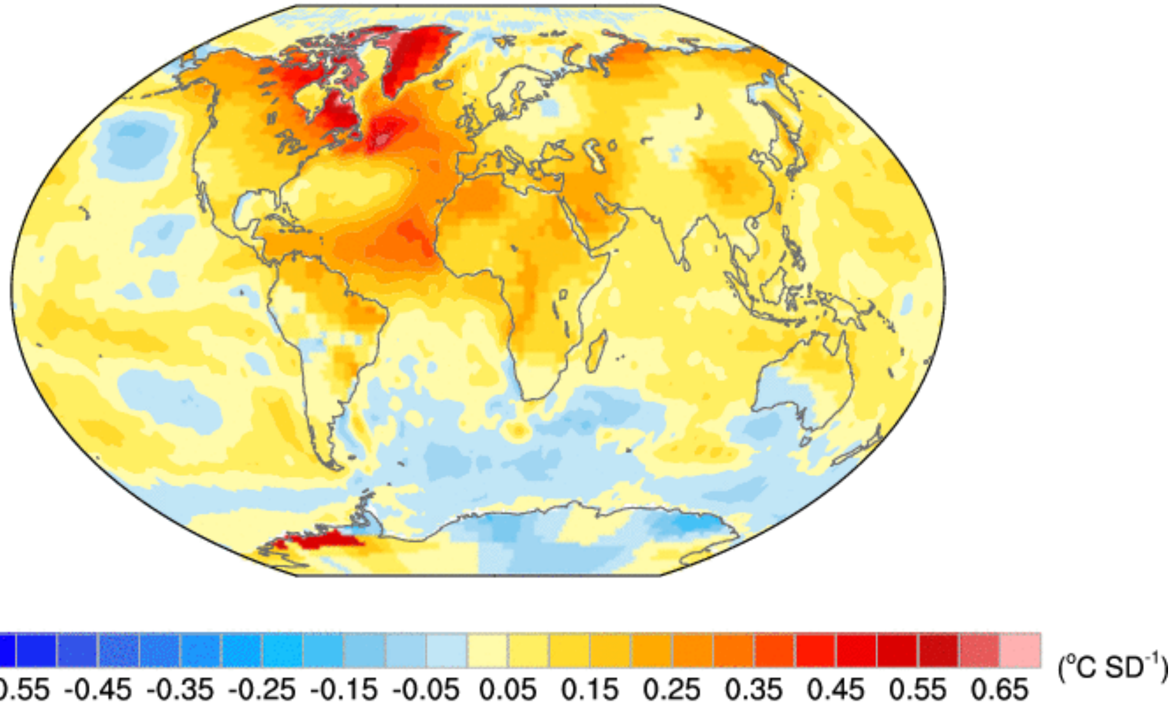
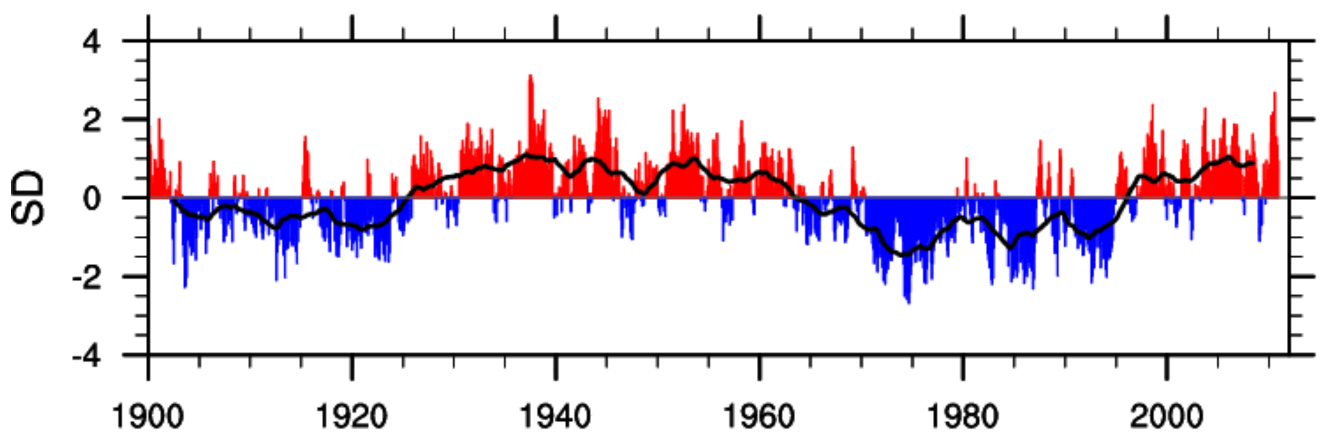
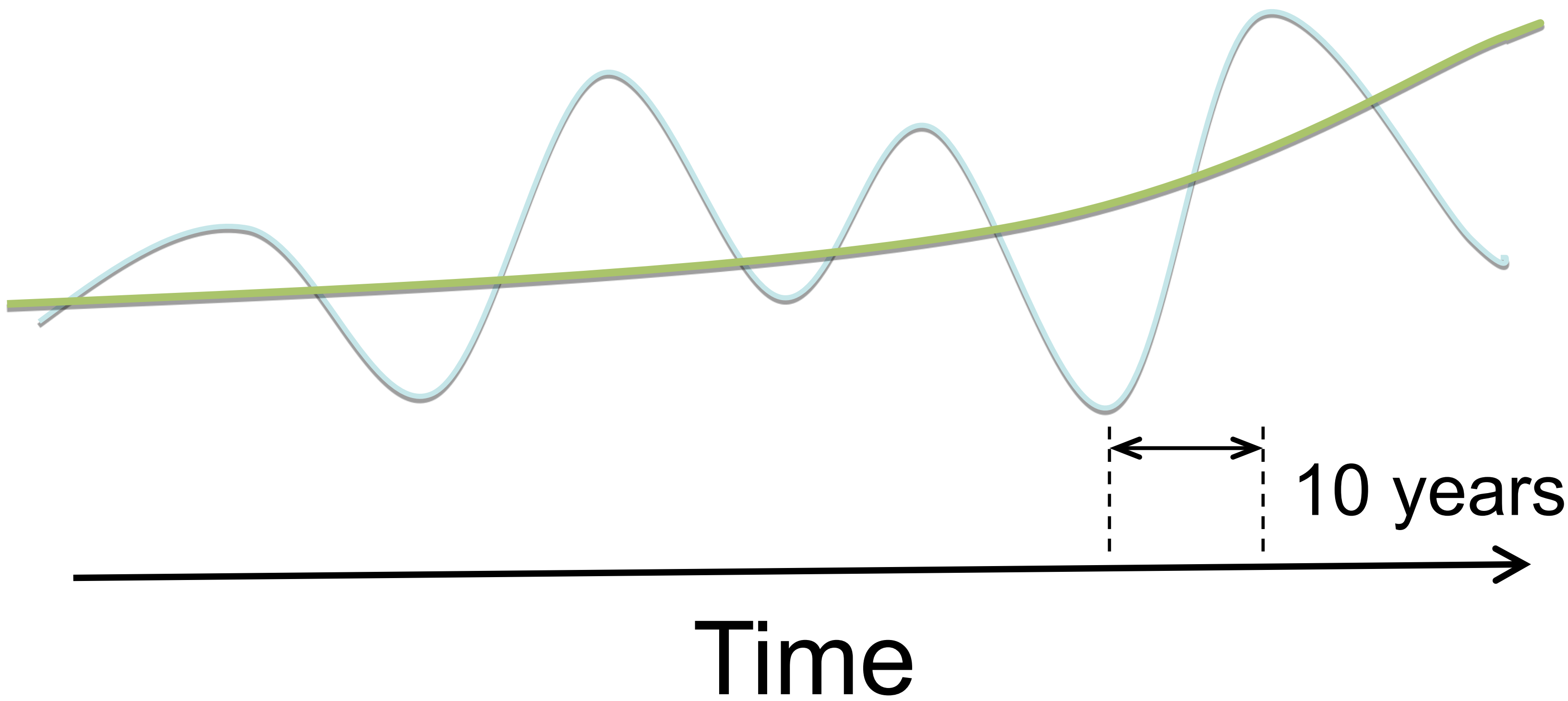
Unforced Multi-Decadal Variability

North Atlantic SST





The Challenge:
Assessing Climate Change in the Presence of Unforced Multi-decadal Variability



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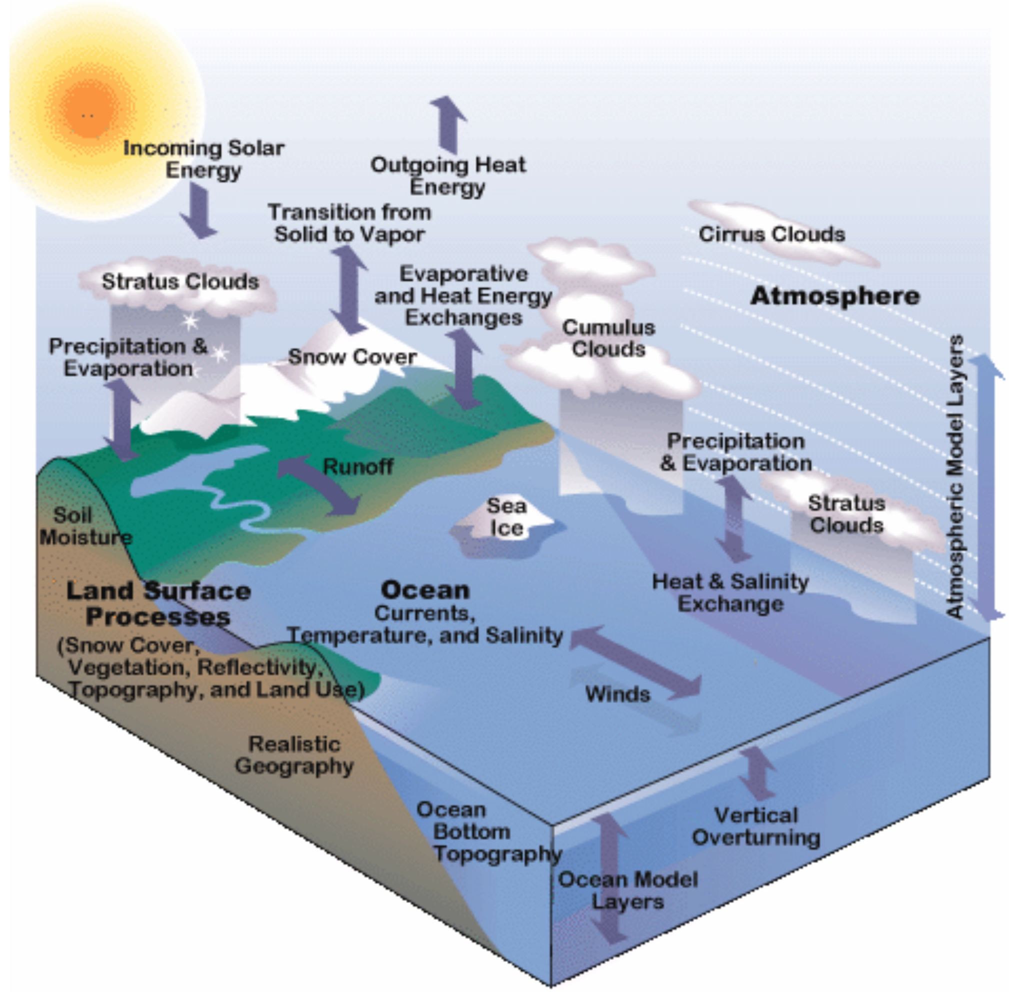
The Community Earth System Model

www.cesm.ucar.edu

- **CESM: a set of different geophysical component models that exchange boundary data via a coupler**
- **Code base developed over 20+ yrs: runs on multiple platforms, resolutions and model configurations**
- **CESM is used to:**
  - **Explore Earth's climate history and processes responsible for variability and change**
  - **Estimate future of environment for policy formulation**
- **Developed by NCAR NSF, DOE, Universities, National Laboratories**
- **Fully documented, frequently and freely distributed, fully supported releases**
- **Capacity Building (e.g., tutorials and workshops)**

Modeling the Earth System



The Community Earth System Model

www.cesm.ucar.edu

(Hurrell et al. 2013)

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Many New Results and Capabilities

Special Collection J. Climate Papers:

http://www.cesm.ucar.edu/publications/pub.info.html

or at AMS:

http://journals.ametsoc.org/page/CCSM4/CESM1

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CESM Experiments and Diagnostics

CESM 1.0 Experiments, Data and Diagnostics

www.cesm.ucar.edu/experiments/cesm1.0/

NCAR UCAR | CESM COMMUNITY EARTH SYSTEM MODEL

earth • modeling • climate

CESM Models

Home » CESM Models » CESM Experiments » CESM 1.0 Experiments, Data and Diagnostics

CESM 1.0 EXPERIMENTS, DATA AND DIAGNOSTICS

Stand-Alone Diagnostics

- CAM4.0
- CAM5.0
- CLM4.0
- CICE4.0
- POP2

J. Climate Special Issue Collection

- CCSM4
- CESM1 (restricted)

Note that although CESM1.0 supersedes CCSM4.0, users can run equivalent CCSM4.0 experiments from the CESM1.0 code base. Also note that the CCSM4.0 experiments below are equivalent to running CESM1.0 (CAM4). All current CESM release codebases (e.g. cesm1_0, cesm1_0_1, etc.) can also reproduce the climates shown below.

If you still have questions after reviewing the details of the model runs below, it is recommended that you contact the relevant CESM Working Group Liaison.

Note about CCR diagnostics: Sudden large spikes in CCR diagnostic fields most likely indicate a CCR software diagnostics failure, and have absolutely nothing to do with the fidelity of the simulation. Use CCR diagnostics with caution.

Jump To: Control Simulations | 20th Century Single-Forcings Simulations | 20th Century All-Forcings Simulations | RCP Simulations | AMIP Simulations | CO_2 Simulations | Paleoclimate Simulations

CONTROL SIMULATIONS

Brief Description	Case Details	Diagnostics	Length of Run Diagnostics	
CCSM4 1° Pre-Industrial Control **Case Name**: b40.1850.track1.1deg.006 **Data Availability**: CESM | CMIP5	Details	...ean ...ean	CCR	Ocean Timeseries
CCSM4 1° Pre-Industrial Control (MOAR) **Case Name**: b40.1850.track1.1deg.006a **Data Availability**: CESM | CESM (6hr) | CMIP5	Details	...ean	---	Ocean Timeseries
CCSM4 2° Pre-Industrial Control		...ean		

Case Name: b40.1850.track1.1deg.006
Machine: NCAR:bluefire
CMIP5 ID: 3.1-X
Compset: B_1850_TRACK1_CN
Resolution: 0.9x1.25_gx1v6
Years: 1-1300
Time Frequencies Saved: Monthly
Initialization: year 863
HPSS Location: /CCSM/csm/b40.1850.track1.1deg.006
Start/End Dates: 9/3/09, 1/3/10
Data Release Date (Full): 5/1/11

www.cesm.ucar.edu/experiments/cesm1.0/

NCAR UCAR | CGD's Climate Analysis Section

Climate Variability Diagnostics Package

Methodology | Metrics Table
Climatological Period Used: Full
Input Namelists: OBS | Models
Derived Namelists: PR | PSL | SND | TAS | TS
Created: Tue Feb 25 16:33:08 MST 2014
CVDP Version 3.0.7

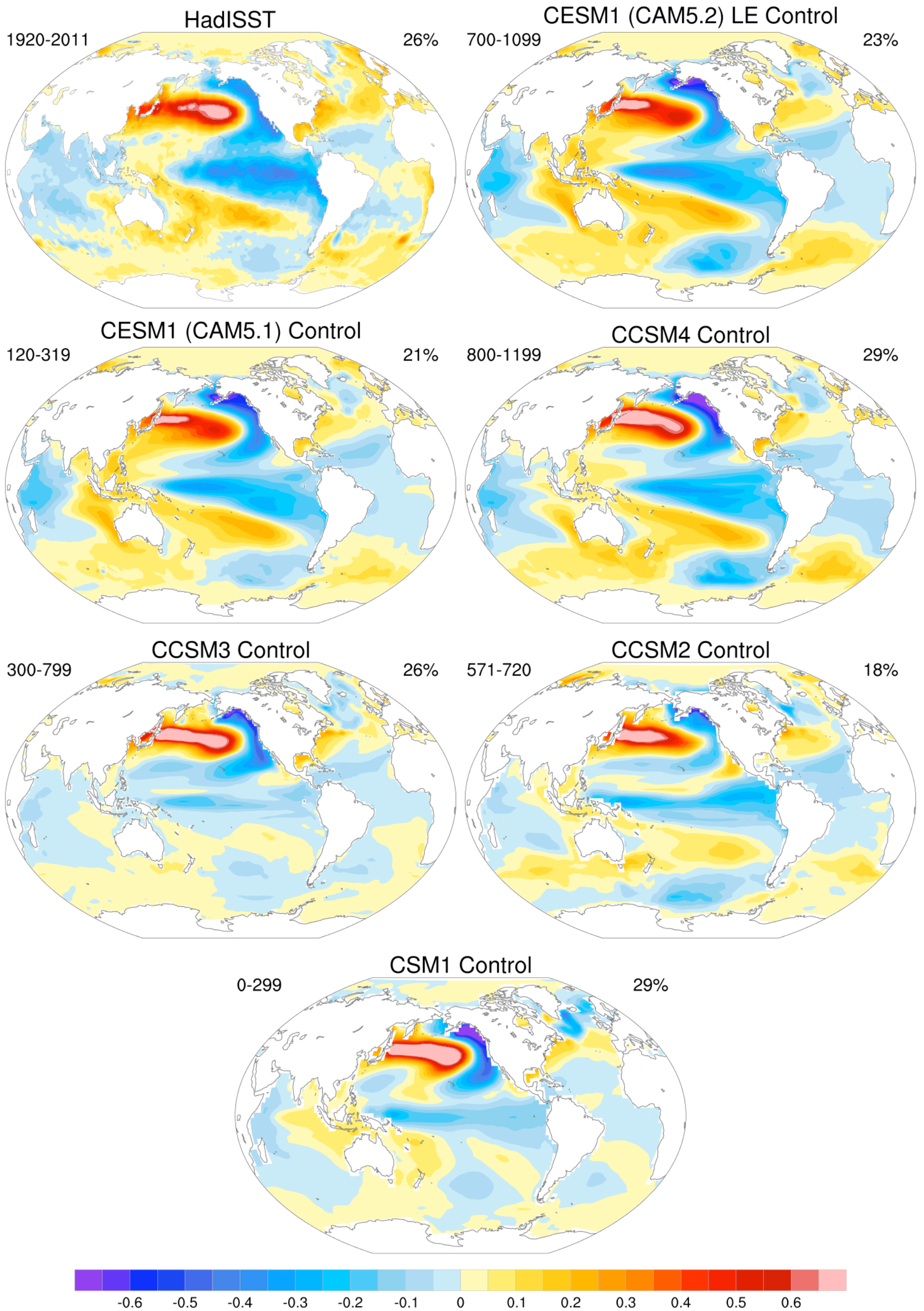
CESM Comparison

Means and Standard Deviation Maps

SST	DJF	MAM	JJA	SON	Annual
TAS	DJF	MAM	JJA	SON	Annual
PSL	DJF	MAM	JJA	SON	Annual
PR	DJF	MAM	JJA	SON	Annual

Coupled Modes of Variability

AMO	Pattern	Timeseries	Power Spectra
PDO	Pattern	Timeseries	Power Spectra
ENSO	Spatial Composites	JJA^{0}	SON^{0}
		DJF^{+1}	MAM^{+1}
		El Niño Hovmöller	La Niña Hovmöller
	Niño3.4	Timeseries	Power Spectra
		Monthly Std. Dev.	Running Std. Dev.



Climate Variability and Diagnostics Package

Pacific Decadal Oscillation

1st EOF of North Pacific SST

(20°:90°N, 110:160°E)

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Climate Variability Diagnostics Package

Atmospheric Modes of Variability

NAM	Patterns	DJF	MAM	JJA	SON	Annual	Monthly
	Timeseries	DJF	MAM	JJA	SON	Annual	Monthly
	SST Regressions	DJF	MAM	JJA	SON	Annual	Monthly
SAM	Patterns	DJF	MAM	JJA	SON	Annual	Monthly
	Timeseries	DJF	MAM	JJA	SON	Annual	Monthly
	SST Regressions	DJF	MAM	JJA	SON	Annual	Monthly
NAO	Patterns	DJF	MAM	JJA	SON	Annual	Monthly
	Timeseries	DJF	MAM	JJA	SON	Annual	Monthly
	SST Regressions	DJF	MAM	JJA	SON	Annual	Monthly
PNA	Patterns	DJF	MAM	JJA	SON	Annual	Monthly
	Timeseries	DJF	MAM	JJA	SON	Annual	Monthly
	SST Regressions	DJF	MAM	JJA	SON	Annual	Monthly
NPO	Patterns	DJF	MAM	JJA	SON	Annual	Monthly
	Timeseries	DJF	MAM	JJA	SON	Annual	Monthly
	SST Regressions	DJF	MAM	JJA	SON	Annual	Monthly
PSA1	Patterns	DJF	MAM	JJA	SON	Annual	Monthly
	Timeseries	DJF	MAM	JJA	SON	Annual	Monthly
	SST Regressions	DJF	MAM	JJA	SON	Annual	Monthly
PSA2	Patterns	DJF	MAM	JJA	SON	Annual	Monthly
	Timeseries	DJF	MAM	JJA	SON	Annual	Monthly
	SST Regressions	DJF	MAM	JJA	SON	Annual	Monthly

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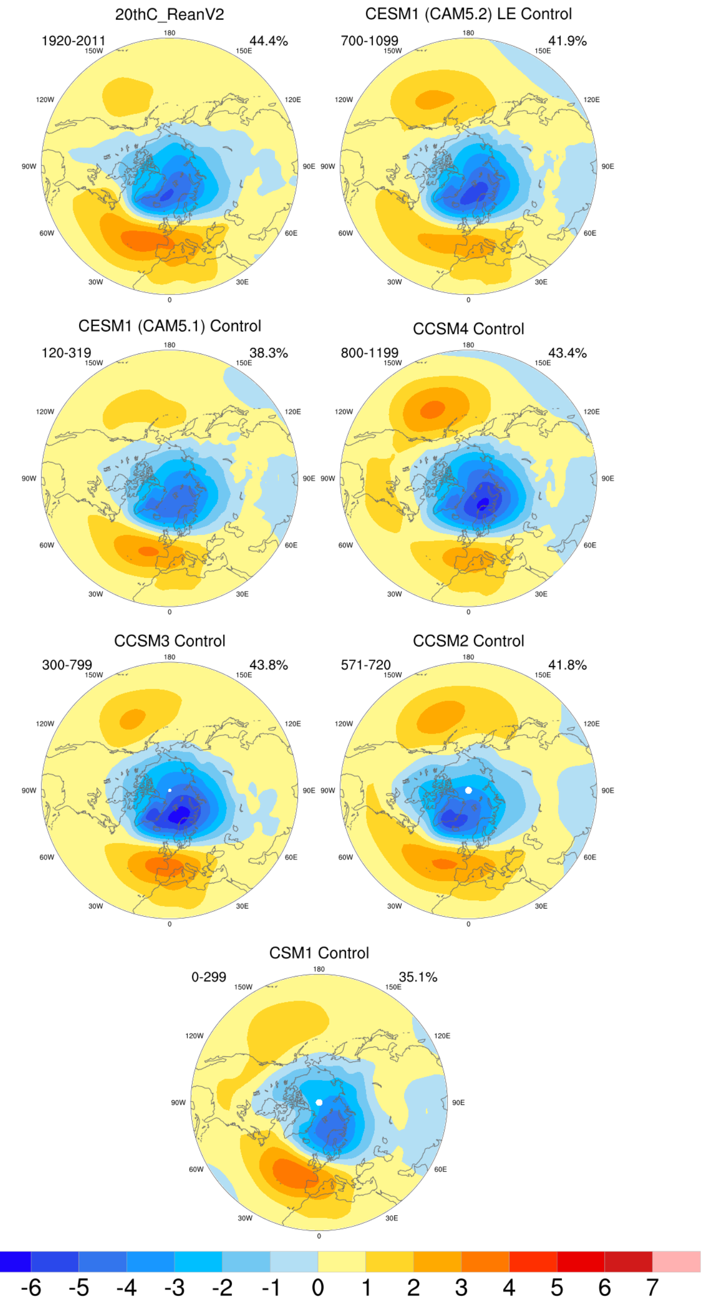
Climate Variability and Diagnostics Package

North Atlantic Oscillation

1st EOF of North Atlantic SLP

(20°:80°N, 90°W:40°E)



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CGD's Climate Analysis Section

Climate Variability Diagnostics Package

Global Trend Maps

SST	DJF	MAM	JJA	SON	Annual	Monthly
TAS	DJF	MAM	JJA	SON	Annual	Monthly
PSL	DJF	MAM	JJA	SON	Annual	Monthly
PR	DJF	MAM	JJA	SON	Annual	Monthly
SND	DJF	MAM	JJA	SON	Annual	Monthly

Global Timeseries

SST	DJF	MAM	JJA	SON	Annual	Monthly
TAS	DJF	MAM	JJA	SON	Annual	Monthly
PR	DJF	MAM	JJA	SON	Annual	Monthly

Global Timeseries Running Trends (Monthly)

SST	8yr	10yr	12yr	14yr	16yr
TAS	8yr	10yr	12yr	14yr	16yr

Zonal Averages

PR	DJF	MAM	JJA	SON	Annual

Additional Indices

North Pacific Index	Tropical North Atlantic SST	Tropical South Atlantic SST	Tropical Indian Ocean SST
niño1+2 Timeseries	niño3 Timeseries	niño4 Timeseries	Indian Ocean Dipole

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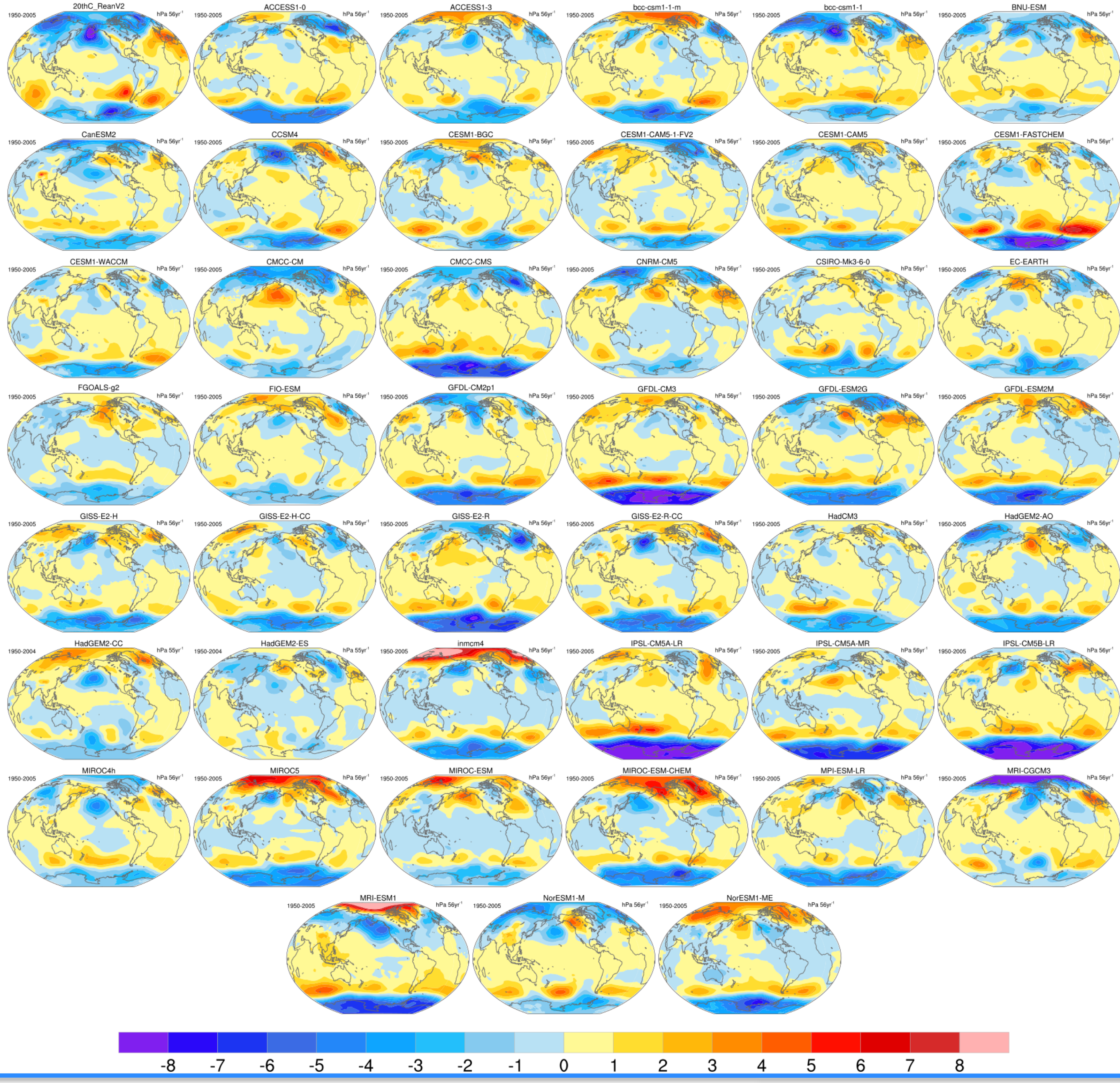

CMIP5 Historical 1950-2005

PSL Trends 1950-2005 (DJF)

The NCAR Large Ensemble Project:

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

Uncertainty Arising from Natural Variability

40 member ensemble from 2000-2061

http://www.cesm.ucar.edu/working_groups/Climate/experiments/ccsm3.0/

Deser, Phillips, Bourdette, Teng (2012): *Climate Dynamics*

(also articles by Branstator, Teng, Meehl and others)

30(+) member ensemble from 1920-2100

http://www.cesm.ucar.edu/experiments/cesm1.1/LE/

Kay et al. (2014): *Bulletin of the American Meteorological Society*

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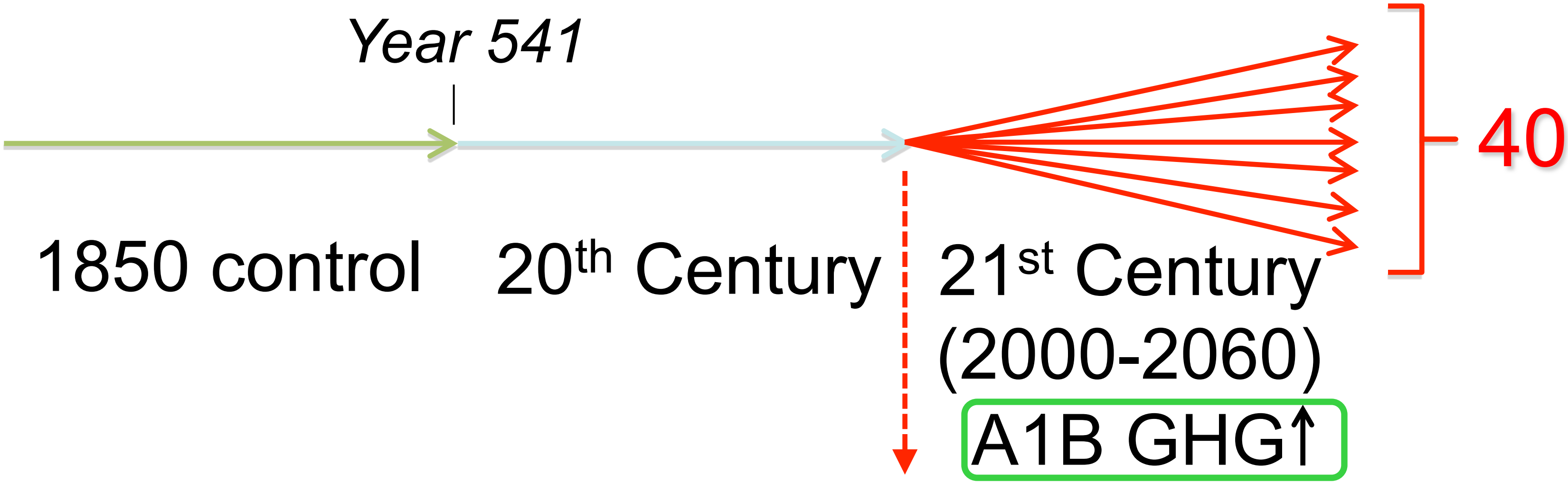
Uncertainty Arising from Natural Variability

40 CESM Integrations



different atmospheric initial states
same ocean, sea ice, land initial states

i.e., spread is not predictable

Uncertainty due to Natural Variability

Projected European Climate

Winter Surface Air Temperature Trends
2010-2060

Hurrell, Deser and Phillips (2014), *Geophysical Research Letters*

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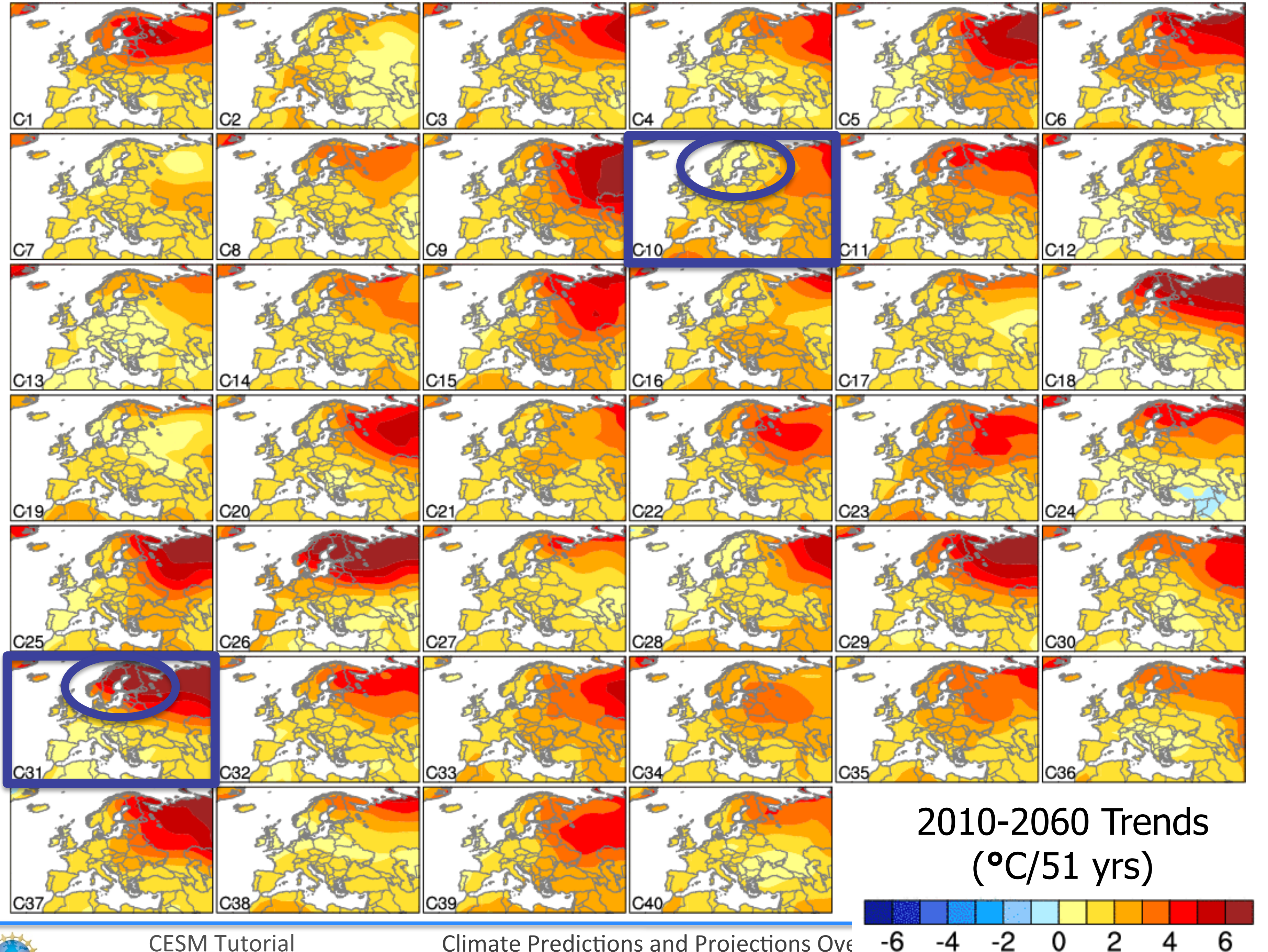
C1
C2
C3
C4
C5
C6
C7
C8
C9
C10
C11
C12
C13
C14
C15
C16
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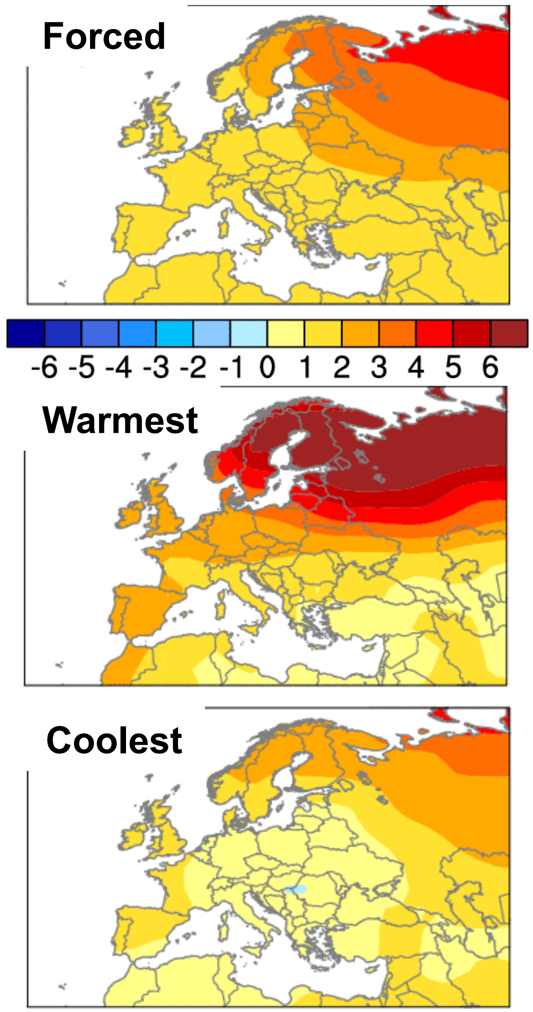
C26
C27
C28
C29
C30
C31
C32
C33
C34
C35
C36
C37
C38
C39
C40
2010-2060 Trends
(°C/51 yrs)
-6 -4 -2 0 2 4 6

Uncertainty due to Natural Variability

Projected European SAT

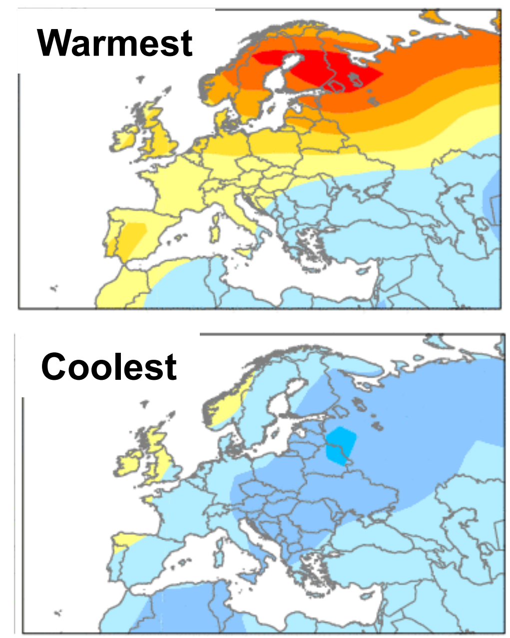
DJF
2010-2060



Run 26

Run 13

Natural (Total – Forced)



- Forced and unforced amplitudes similar over Europe
- Unforced component has large spatial scales

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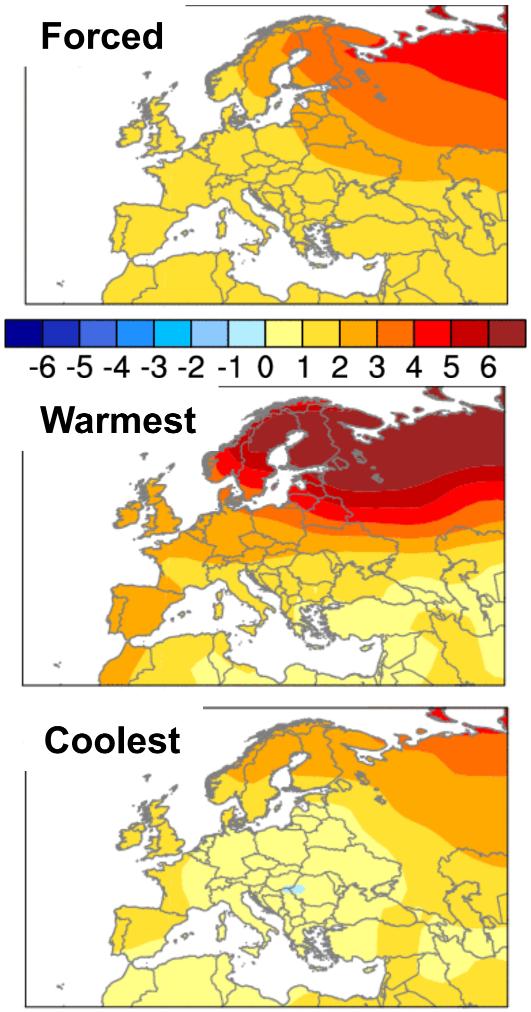
Uncertainty due to Natural Variability

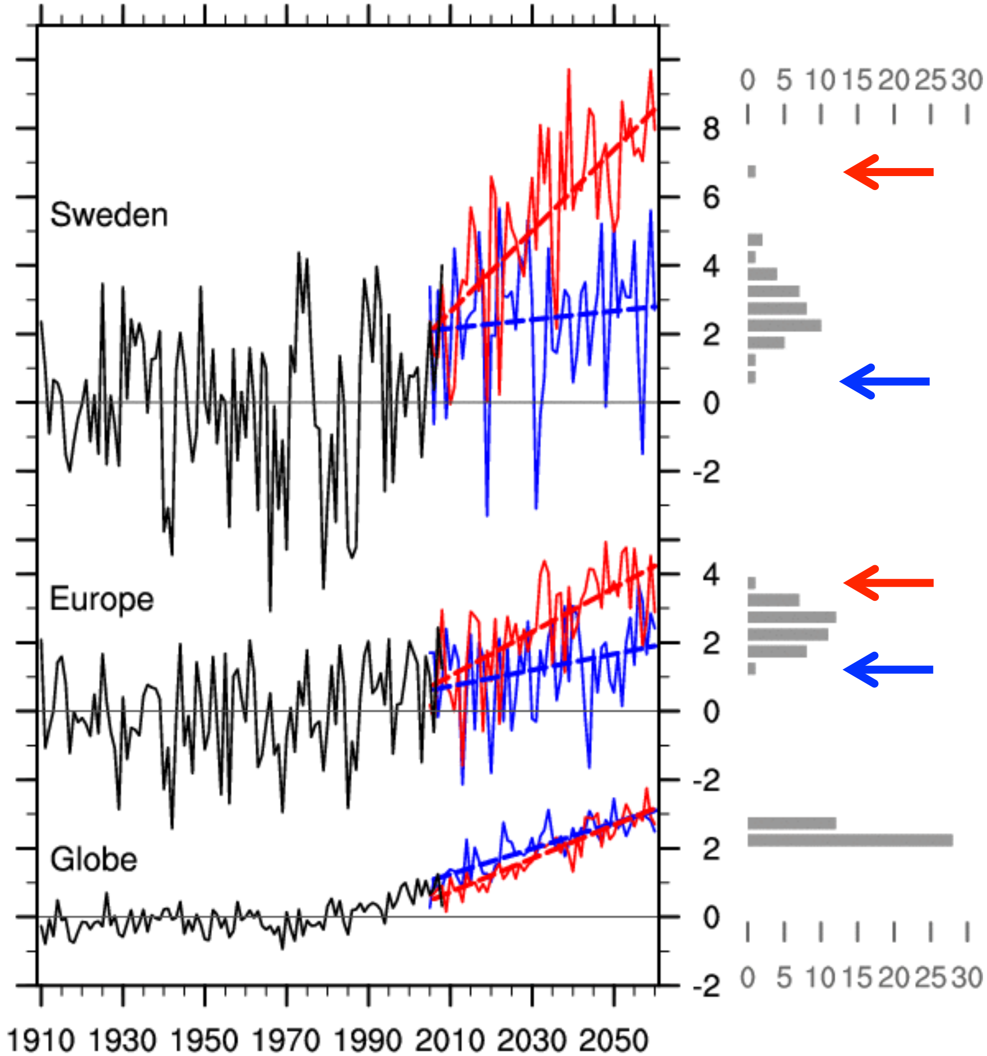
Projected European SAT

DJF
2010-2060

Run 26

Run 13





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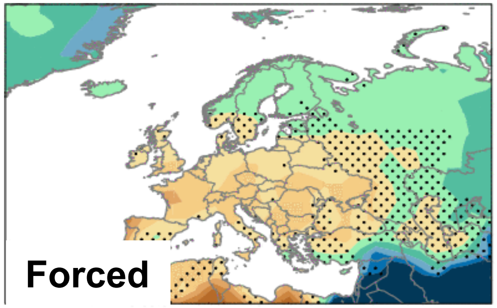
Uncertainty due to Natural Variability

Projected European Precipitation

DJF
2010-2060



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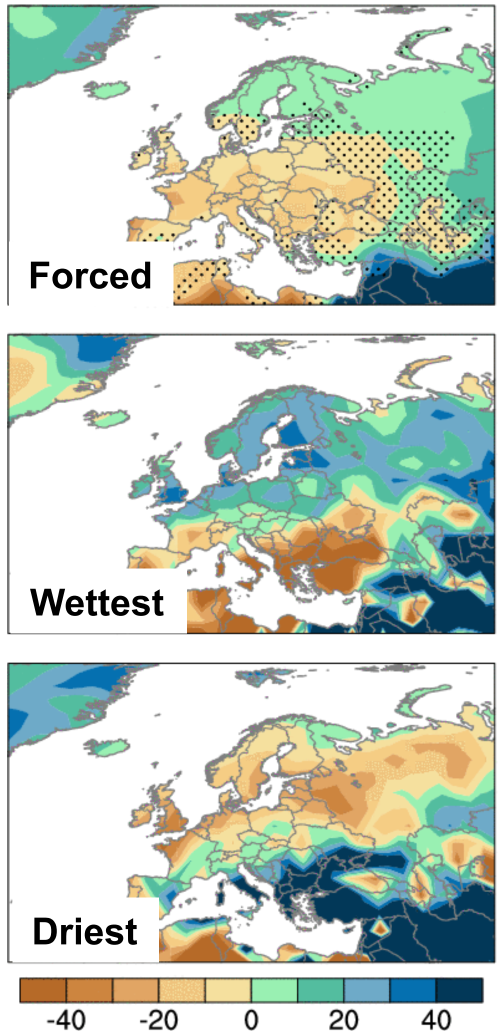
Uncertainty due to Natural Variability

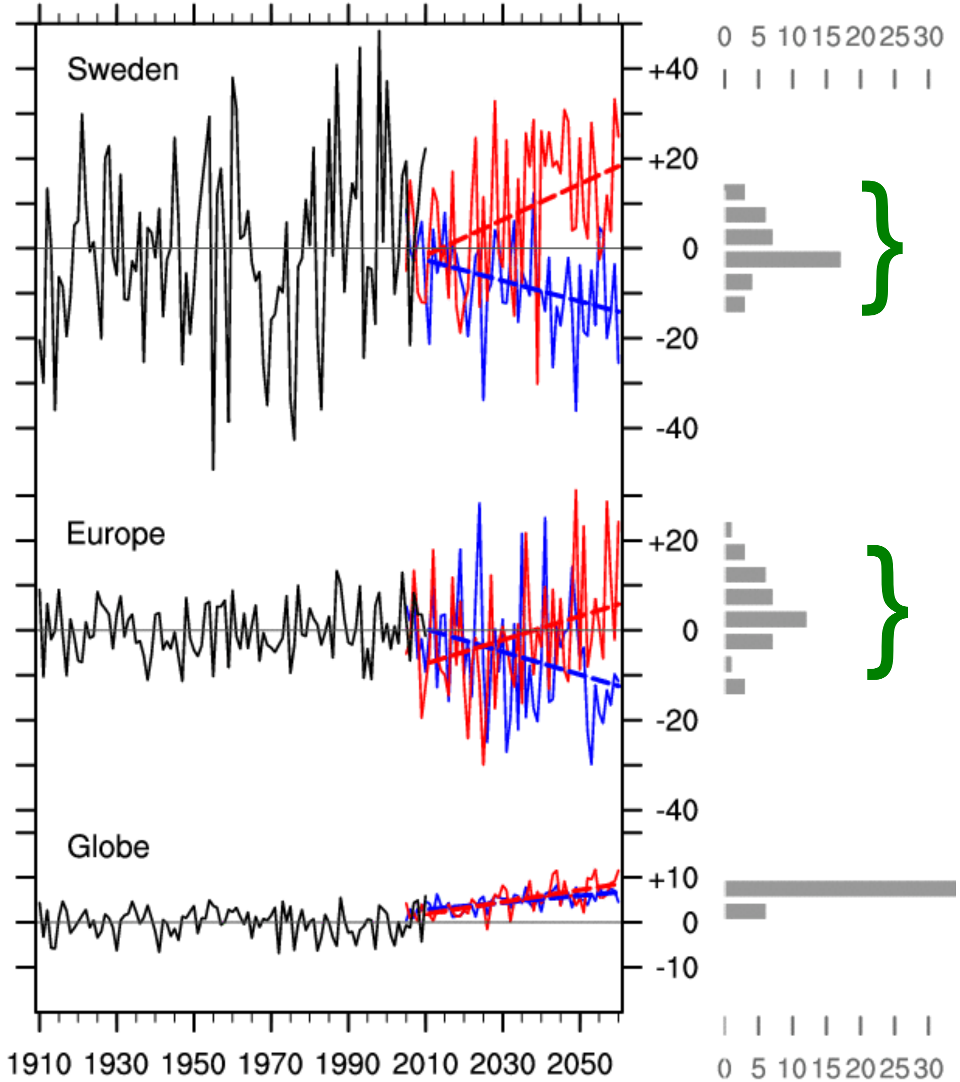
Projected European Precipitation

DJF
2010-2060

Run 3

Run 9





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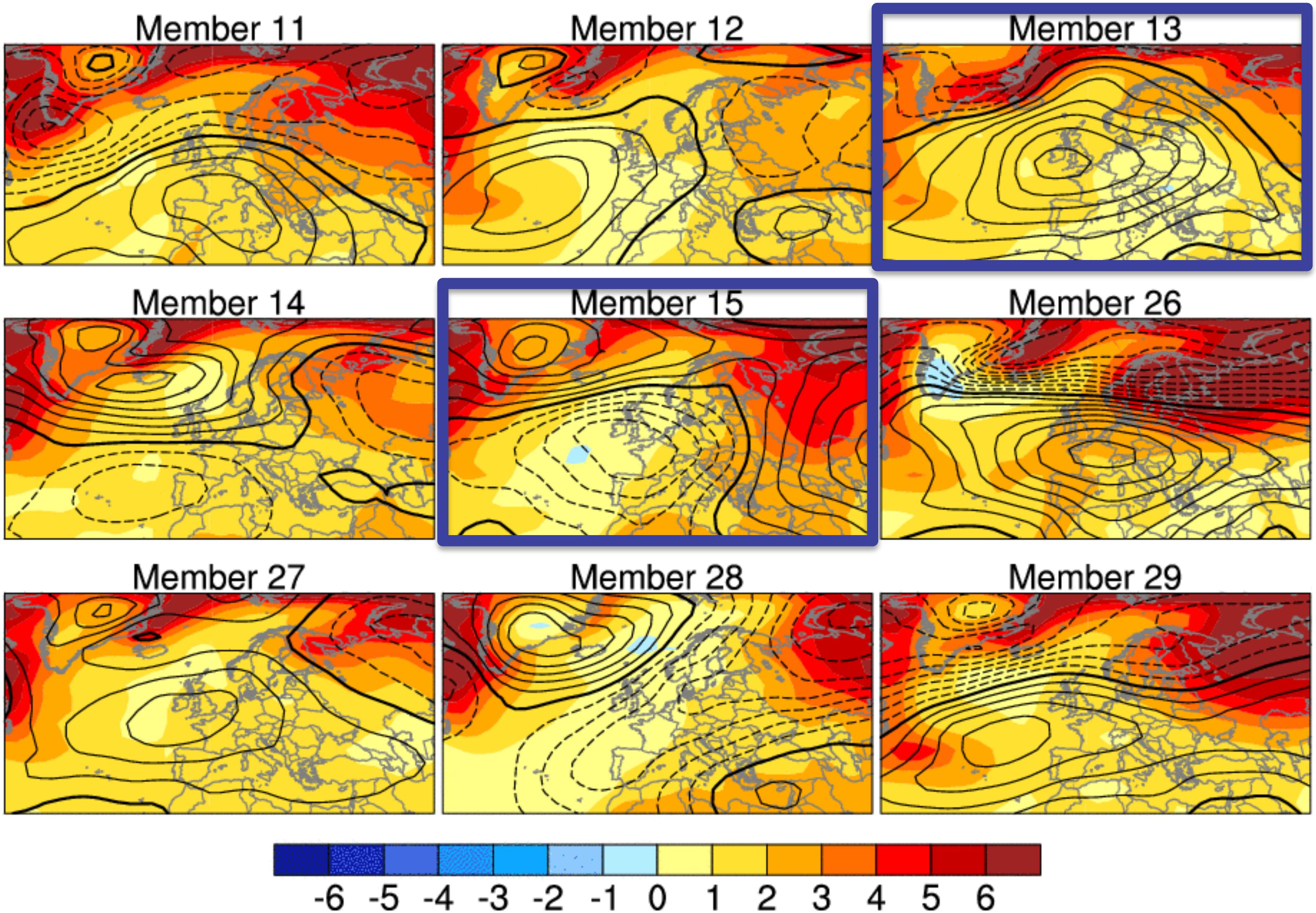
Dominant Source of Noise: Dynamics

SLP and Air Temperature Trends 2010-60



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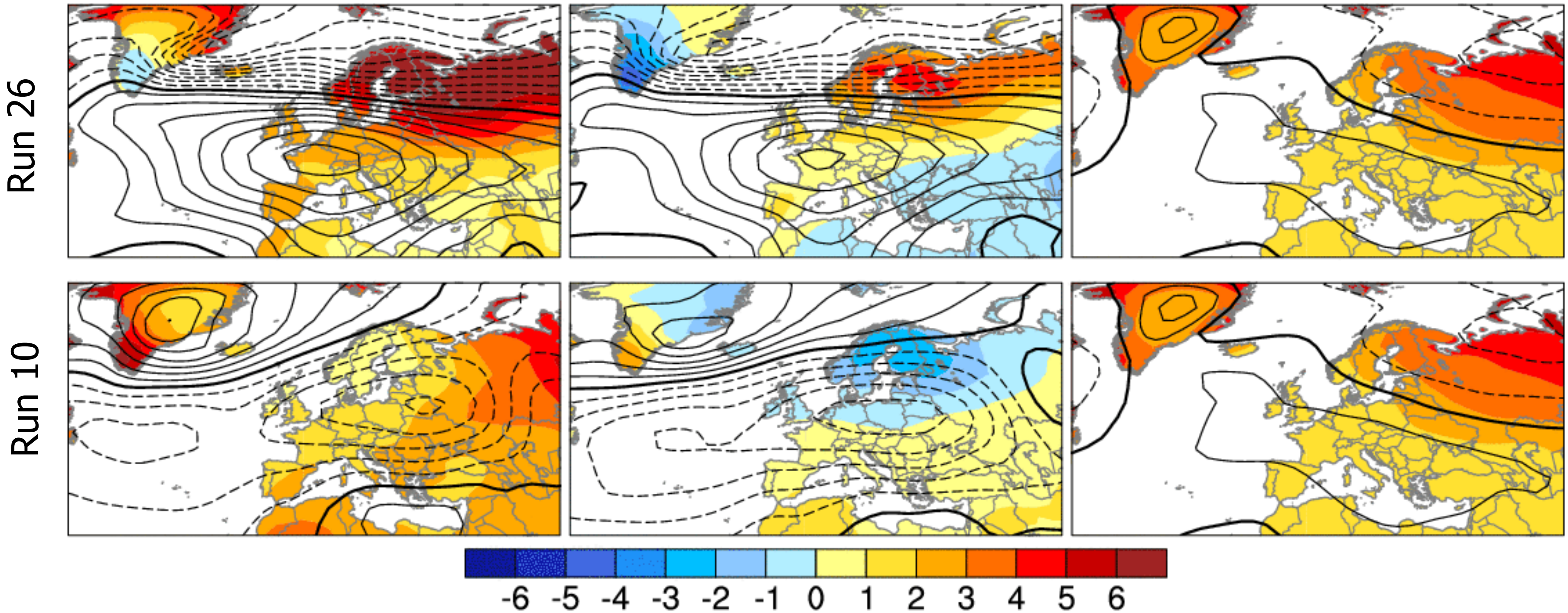
Dominant Source of Noise: Dynamics

Projected European SLP and SAT (DJF)

Two of 40 realizations

Total = Natural + Forced



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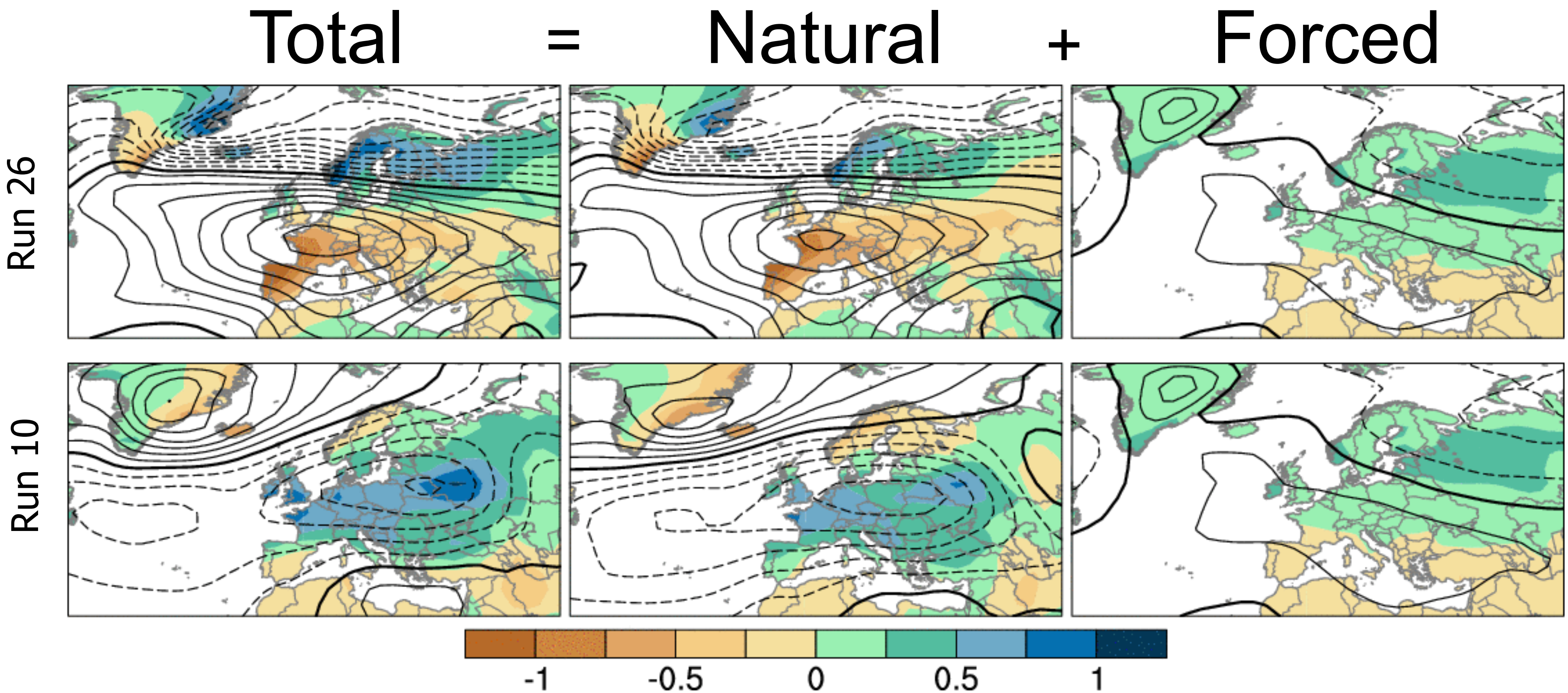
Uncertainty due to Natural Variability

Projected European SLP and Precipitation (DJF)

Two of 40 realizations



- Natural component can be larger than forced
- Natural component has large spatial scales

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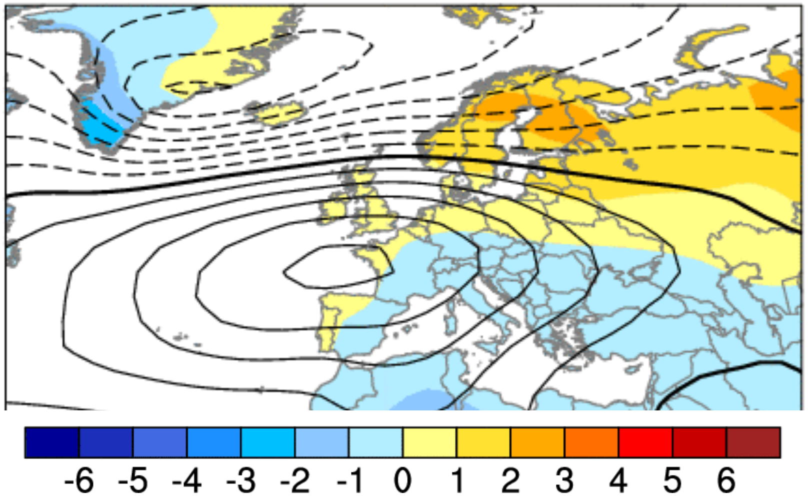
Leading EOF (67%) of 40 SLP Trend Maps

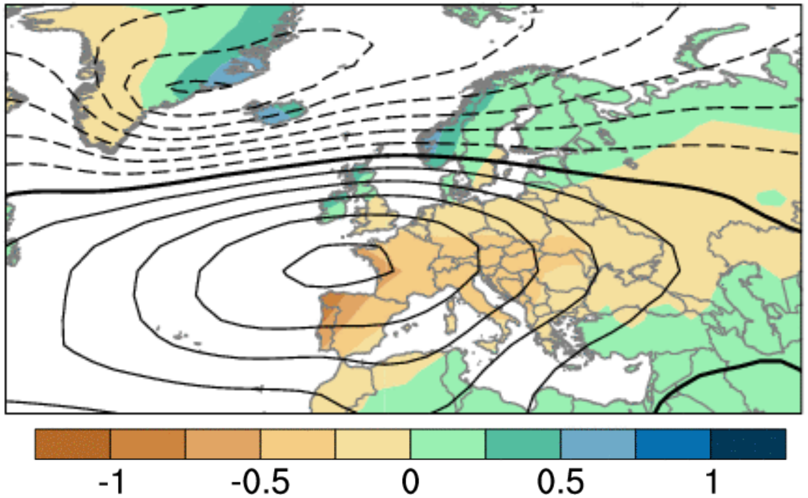
(Dominant pattern of SLP trend uncertainty)

Regressions on SLP PC1



SLP and Surface Air T (DJF)

→ North Atlantic Oscillation



SLP and Precipitation (DJF)

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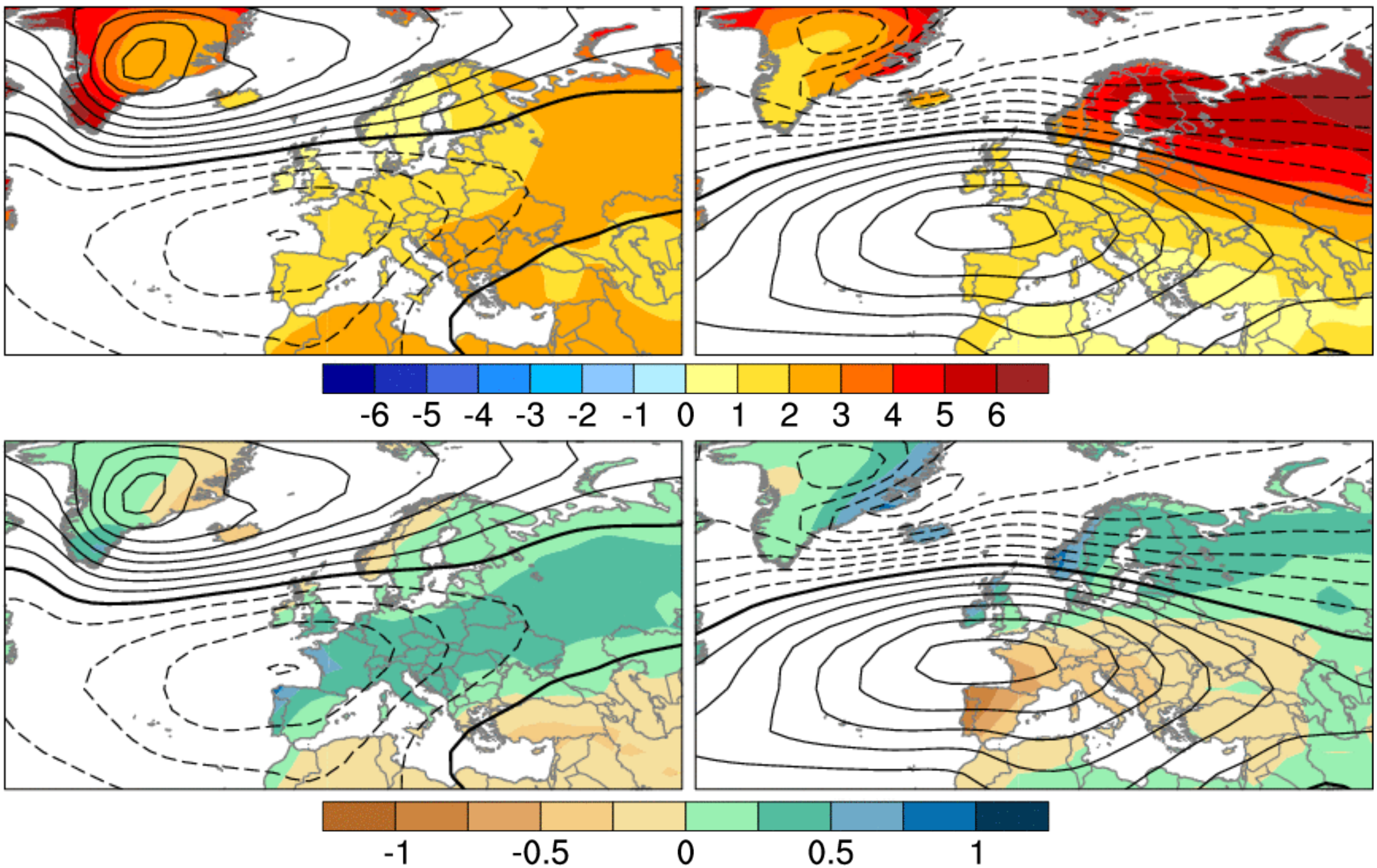
Range of Outcomes

(Due to uncertainty introduced by NAO)

Forced – NAO

Forced + NAO



Summary and Outlook

Toward Reducing Uncertainty

1) Expect a range of climate change outcomes on regional scales due to natural variability of the atmospheric circulation, e.g. the NAO over Europe and the PNA over North American (see Deser talk)

2) Understanding of processes and mechanisms of natural variability, and encapsulating this knowledge in models, is thus of critical importance

3) Much larger ensembles of model projections are needed to properly compare climate change signals between models and the real world

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