A Perspective on Decadal Variability and Predictability

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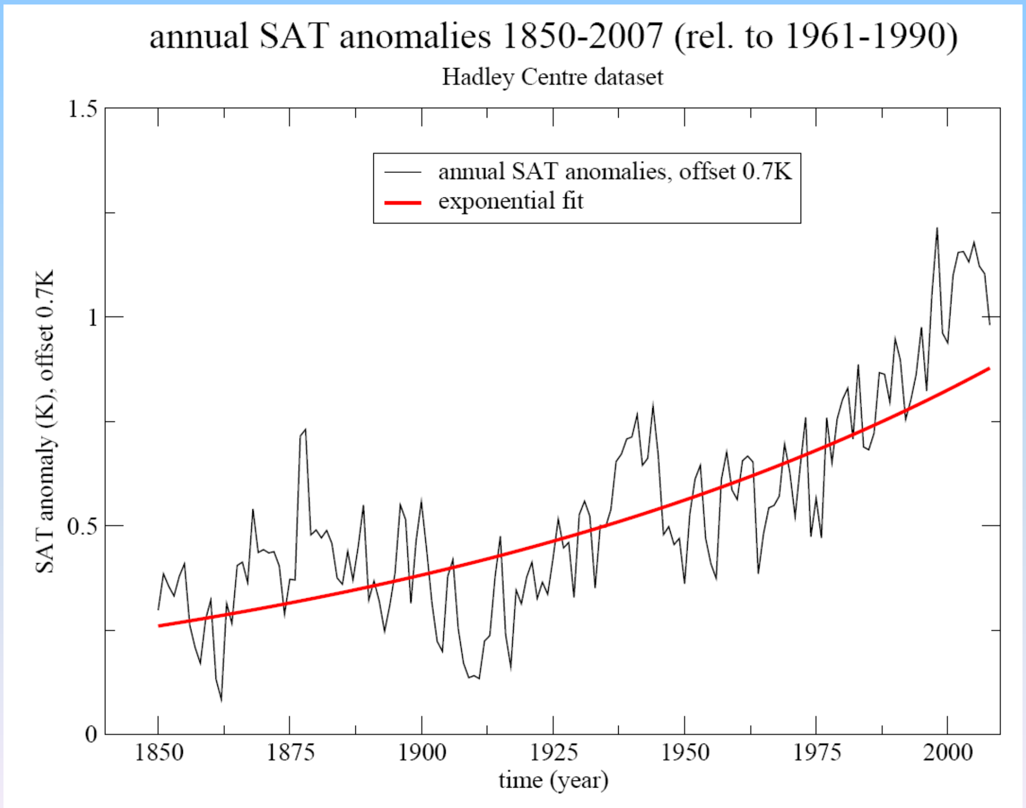


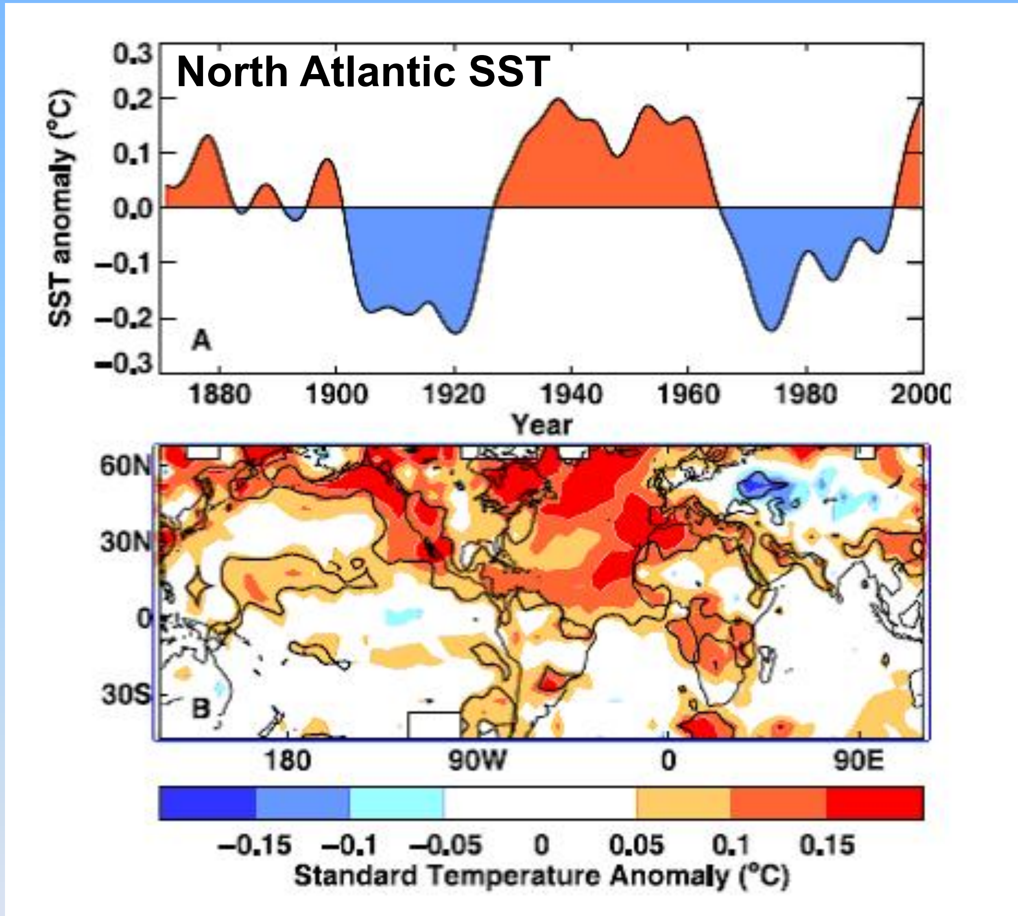
The New York Times

…Mojib Latif…wrote a paper last year positing that cyclical shifts in the oceans were aligning in a way that could keep temperatures over the next decade or so relatively stable, even as the heat-trapping gases linked to global warming continued to increase.

By ANDREW C. REVKIN

Published: September 21, 2009

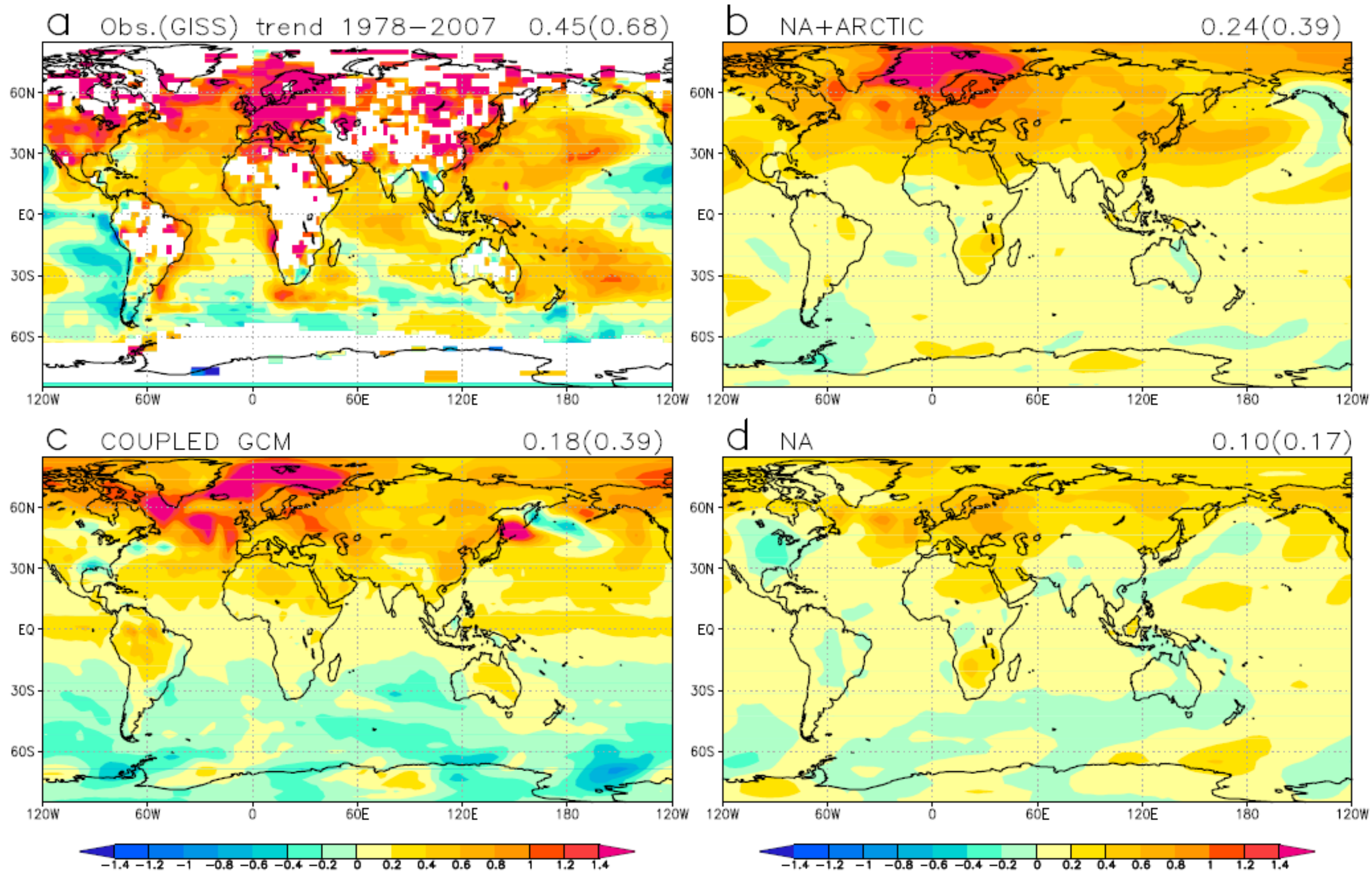
AMO impact



Knight et al. 2005

The AMO has a projection on Northern Hemisphere and even global SAT

AMO impact, SAT 1978-2007?



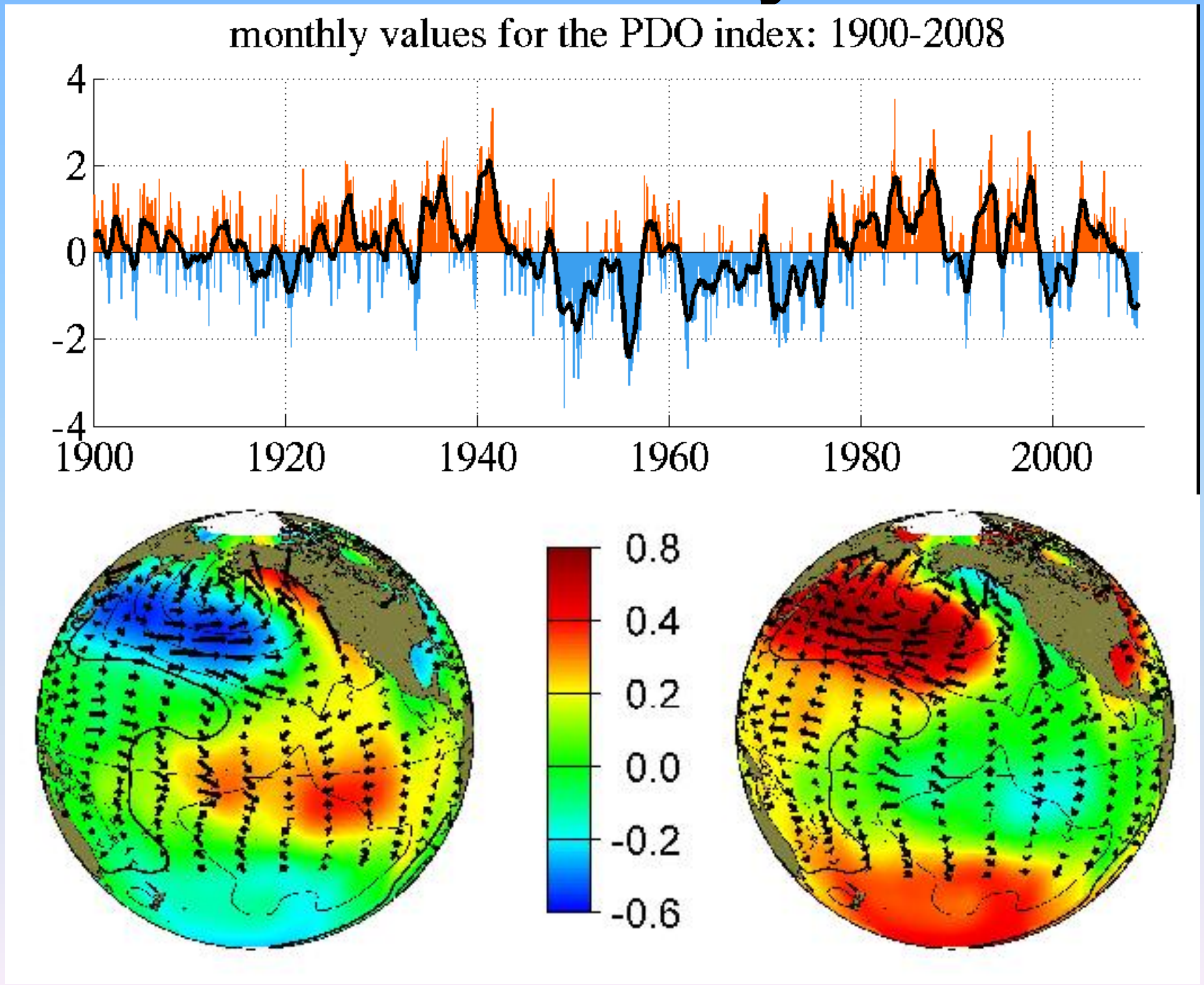
Semenov et al., 2009

The last decades may contain a strong contribution from internal variability

Outline

- Mechanisms of decadal variability
- History of decadal prediction
- What are the limiting factors?
- Challenges

The Pacific Decadal Oscillation/ Variability



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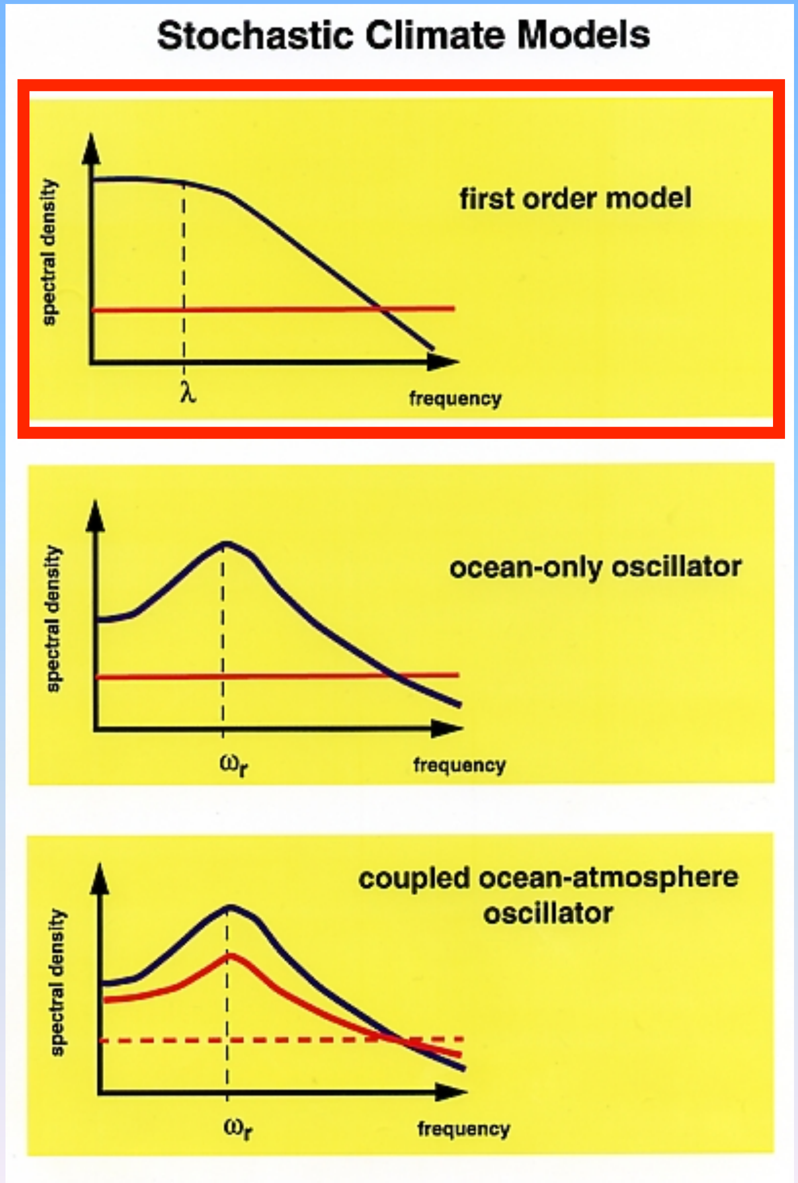
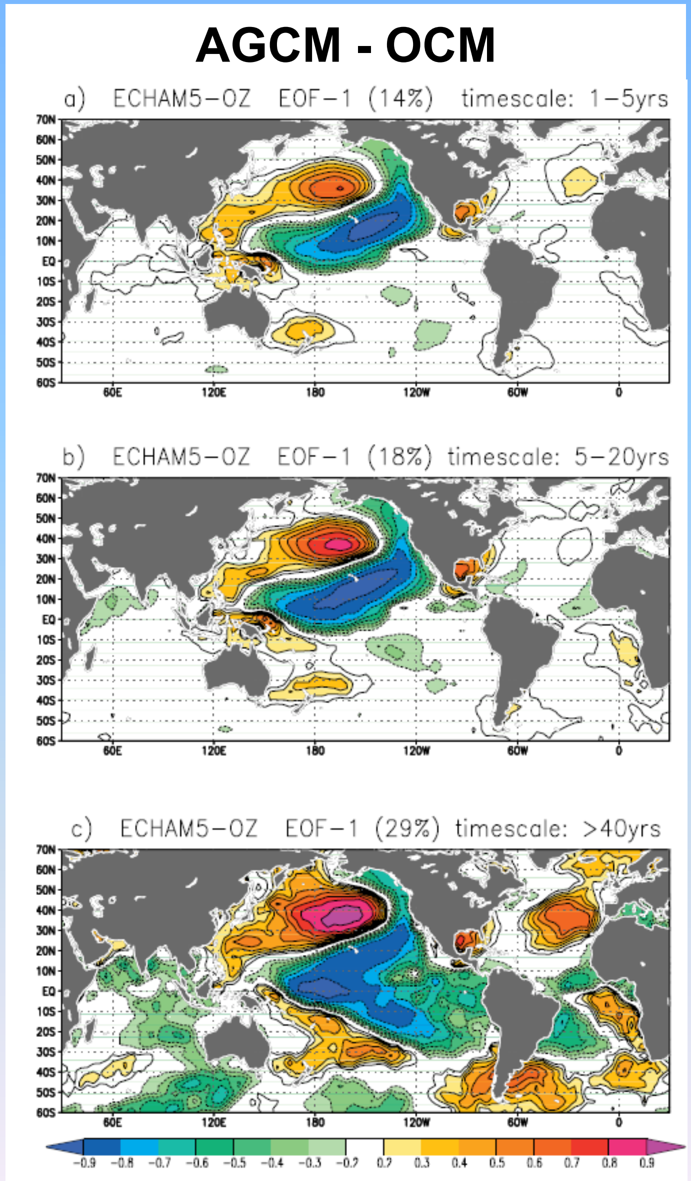
A stochastic view for the Pacific





Hyper mode, Dommenget and Latif 2008

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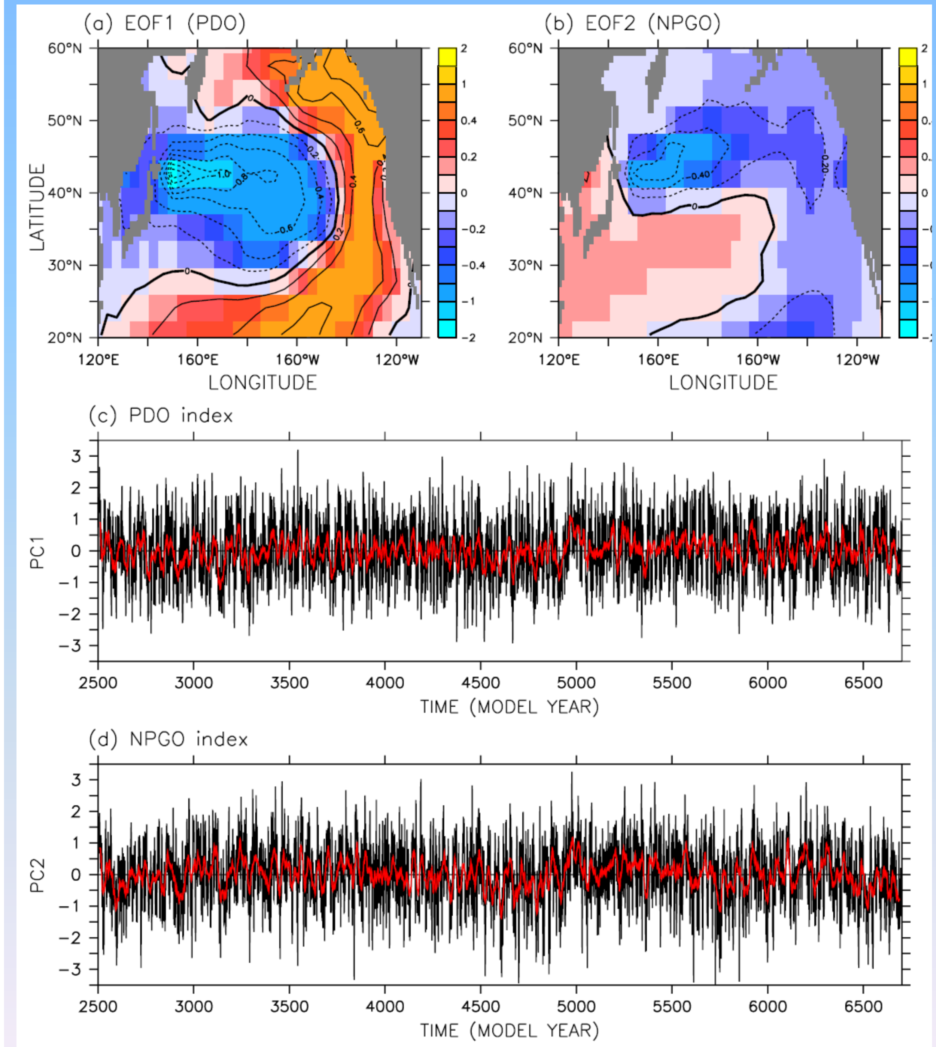
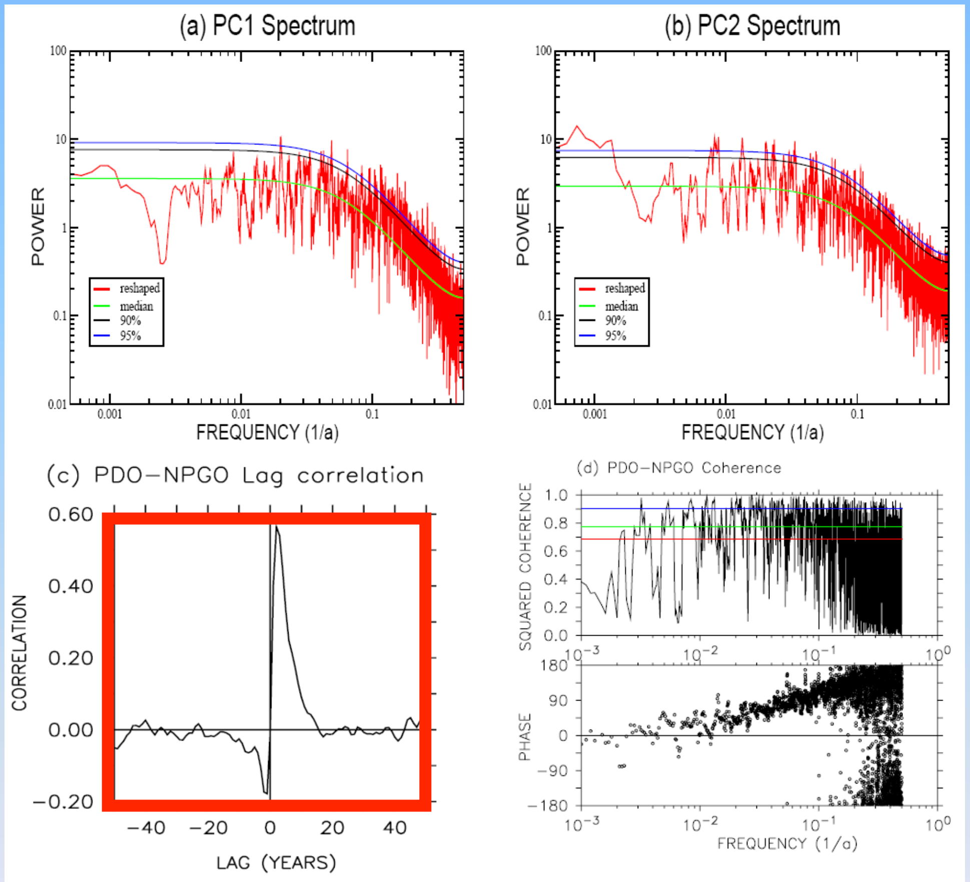
Interannual to decadal predictability originates from gyre adjustment





Multi-millennial control run of KCM, lag ~2-10 years

Courtesy W. Park

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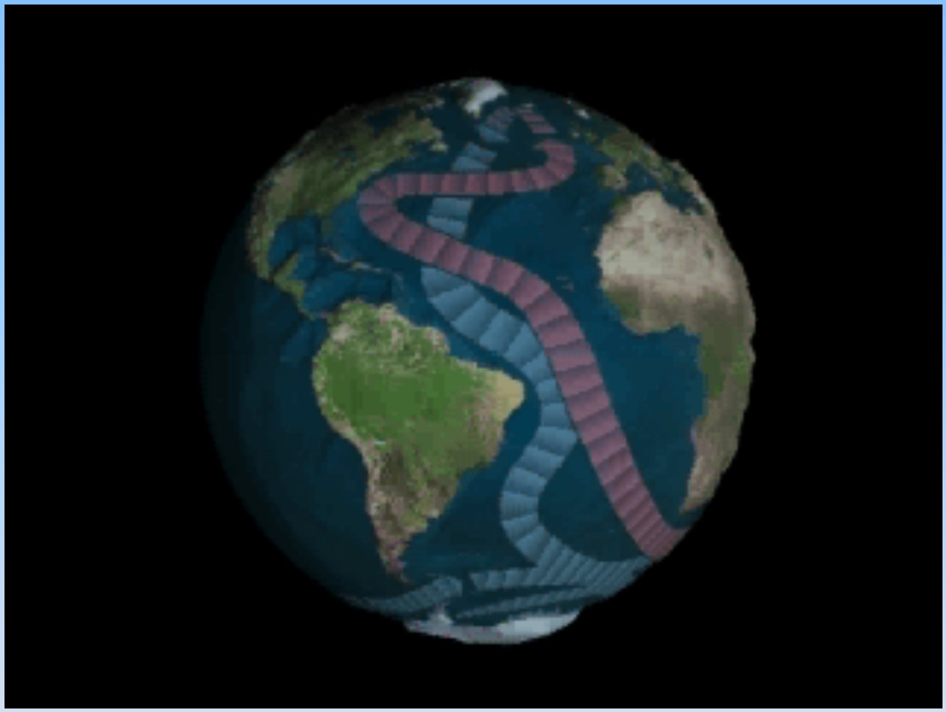
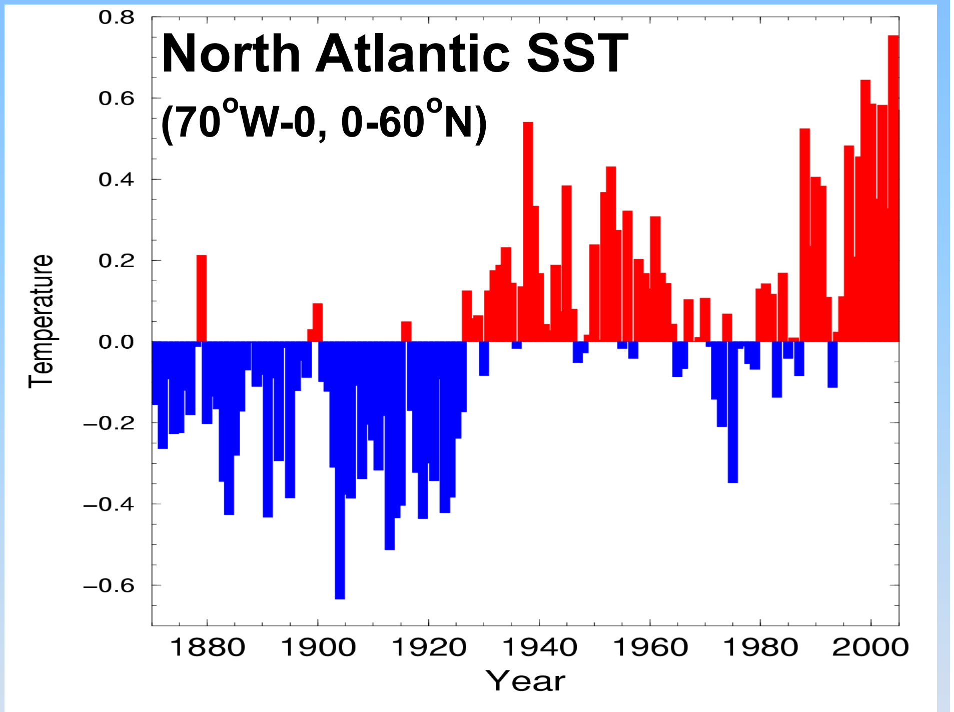
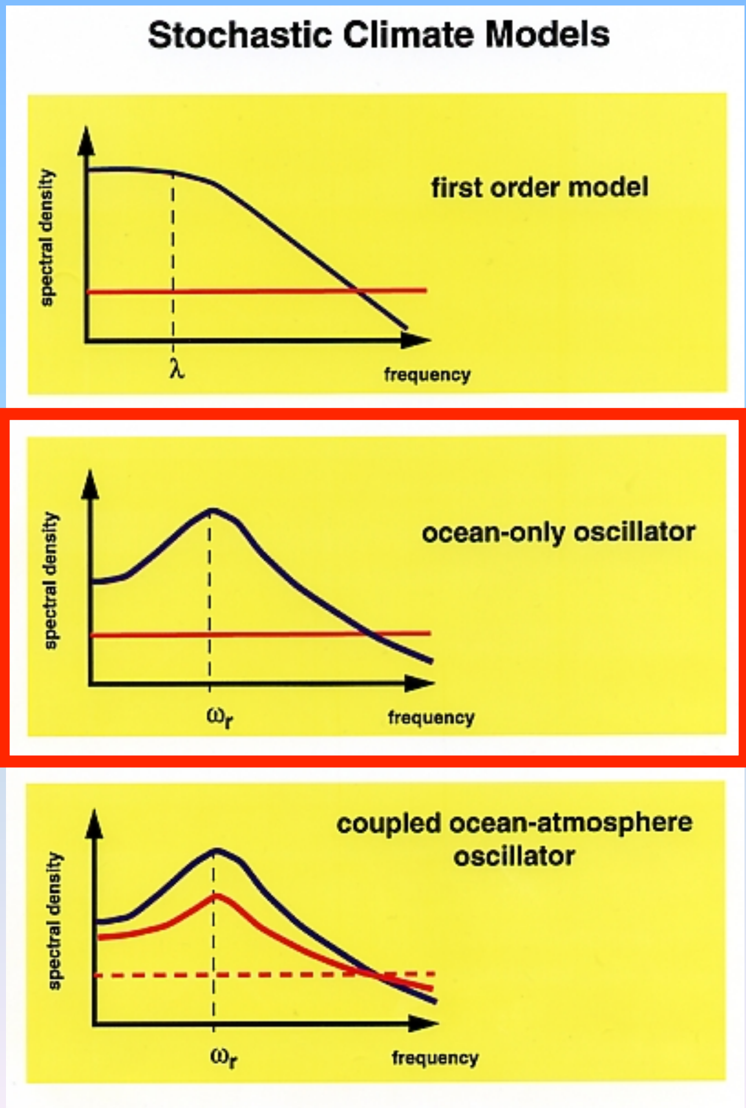
Atlantic Multidecadal Oscillation/ Variability

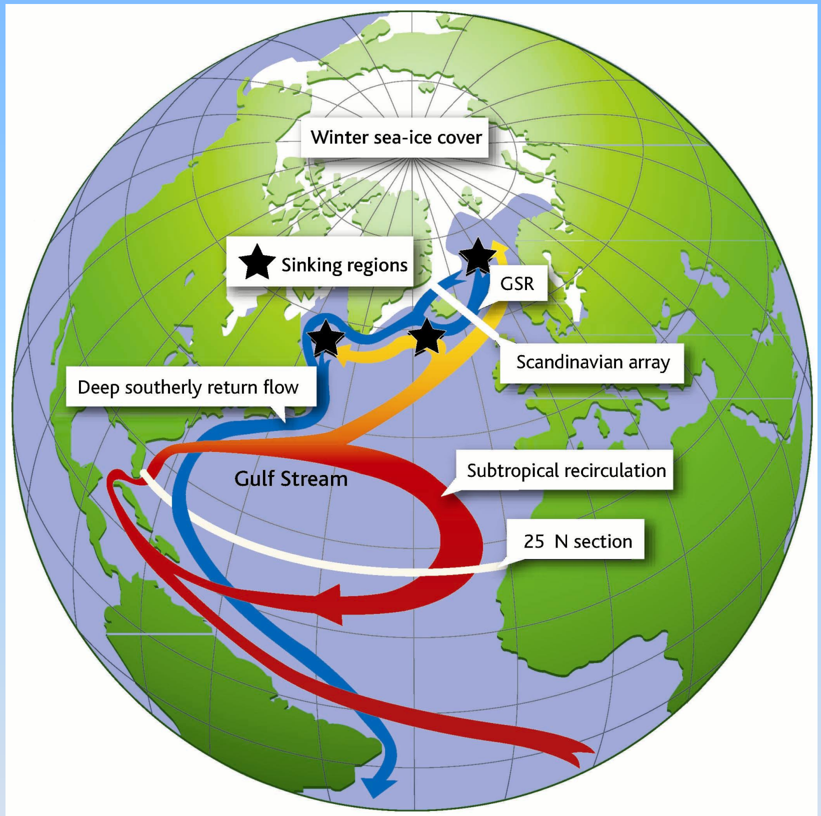




Changes in hurricane activity and Sahel rain, for instance, can be traced back to variations in Atlantic sea surface temperature (SST)

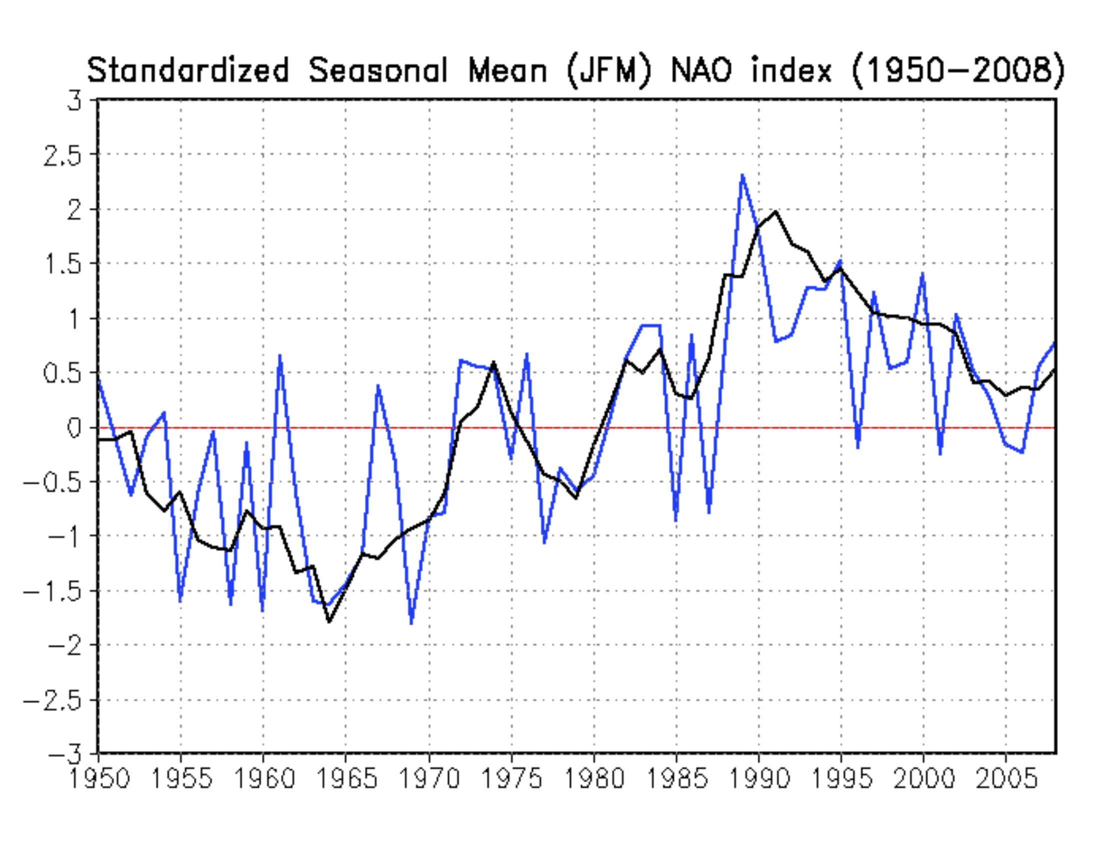
Decadal predictability stems from MOC adjustment

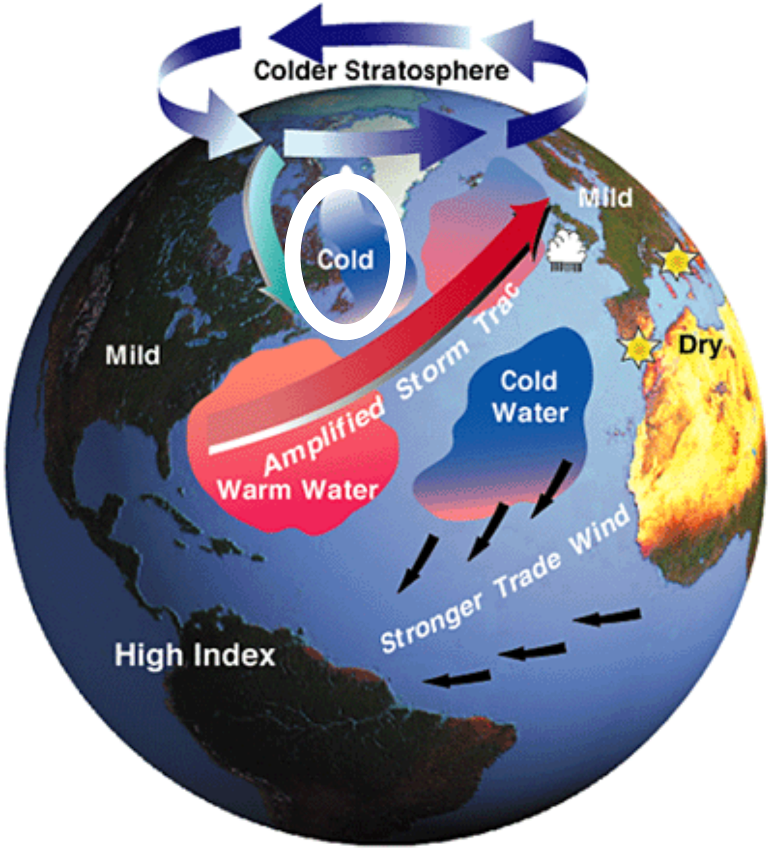




Most evidence points towards the "ocean-only" oscillator in the Atlantic

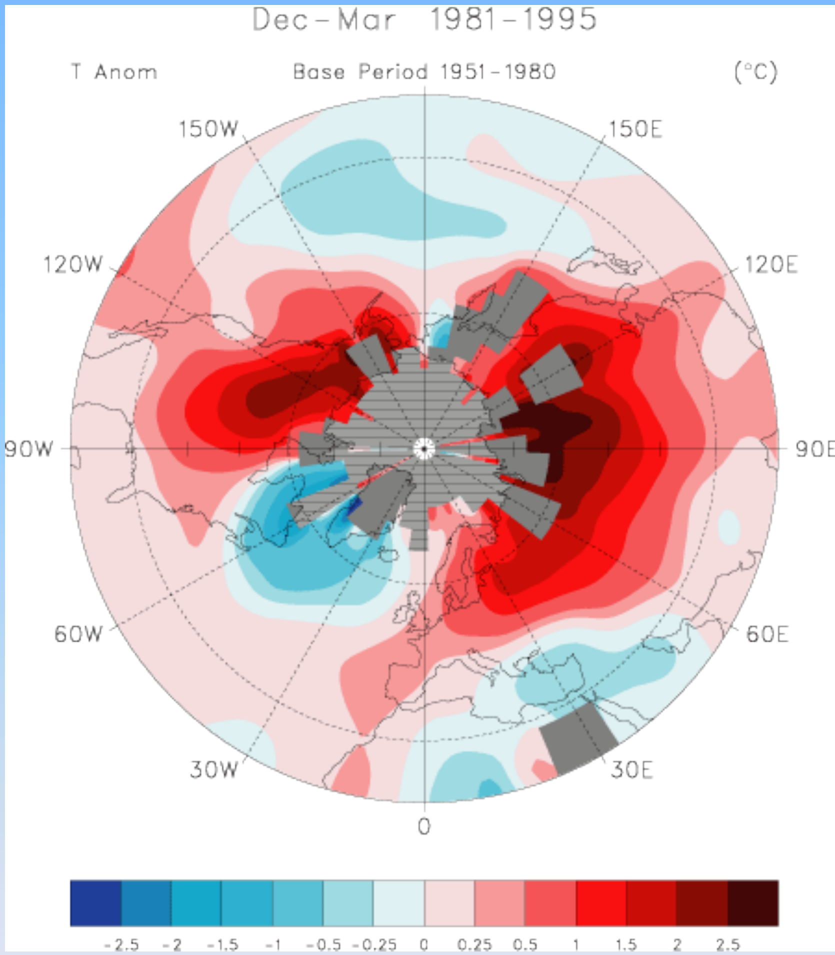
Decadal variations in the North Atlantic Oscillation

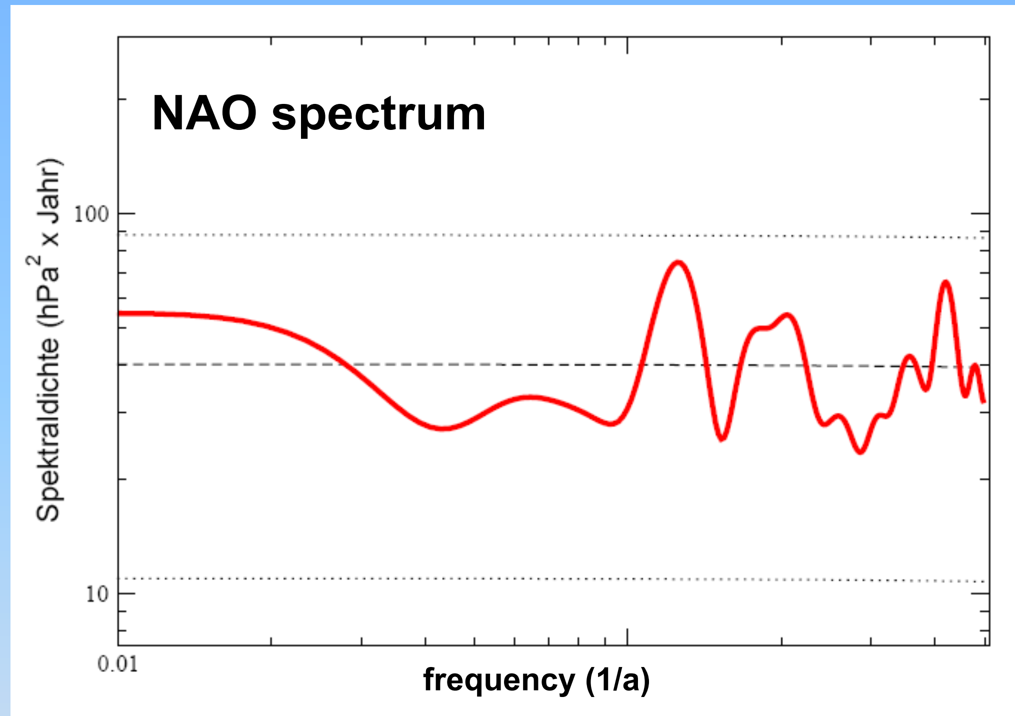




NAO drives Labrador Sea convection

NAO spectrum





The NAO spectrum is almost white, so that a simple stochastic scenario may apply

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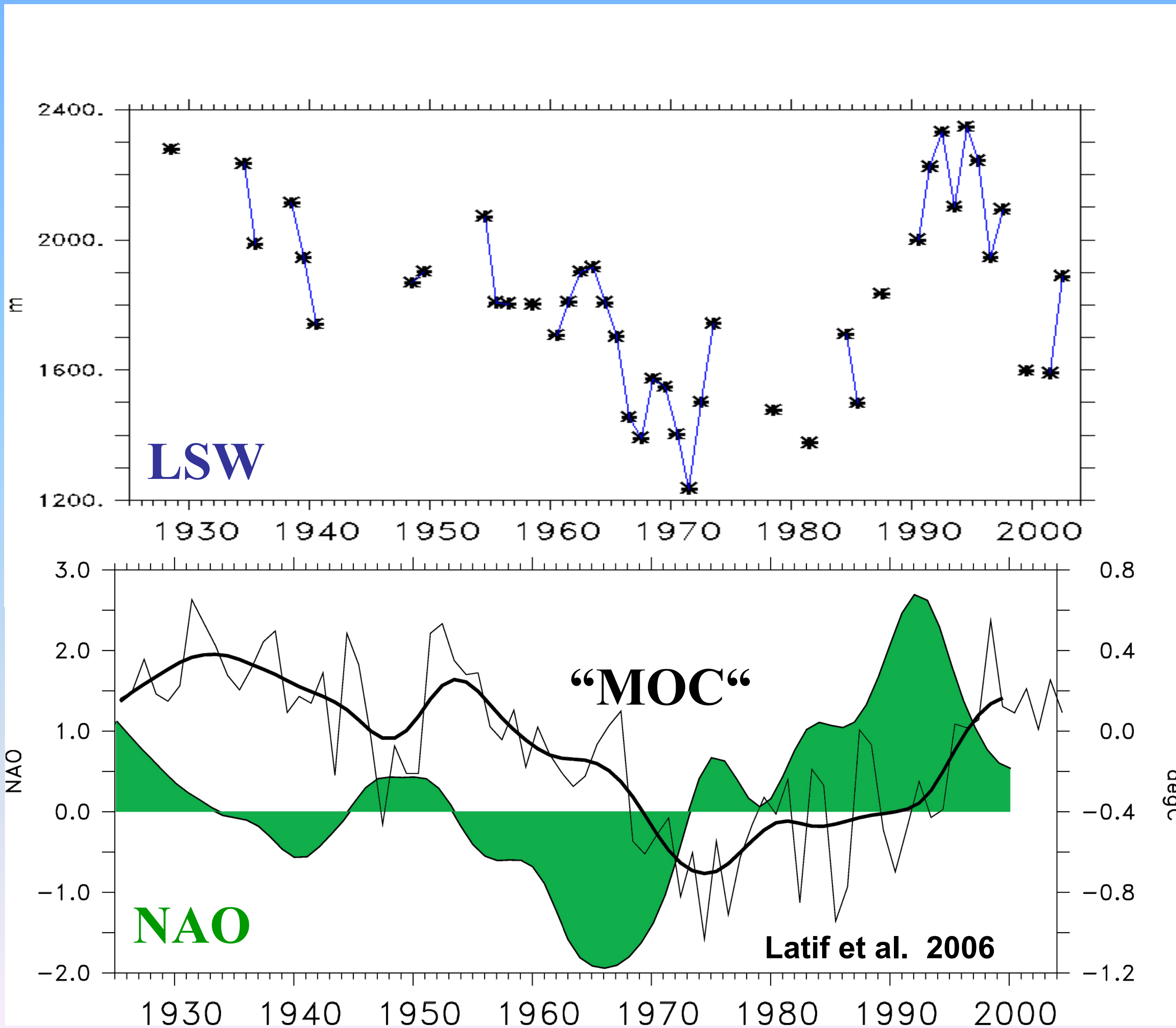
NAO → LS convection → "MOC"



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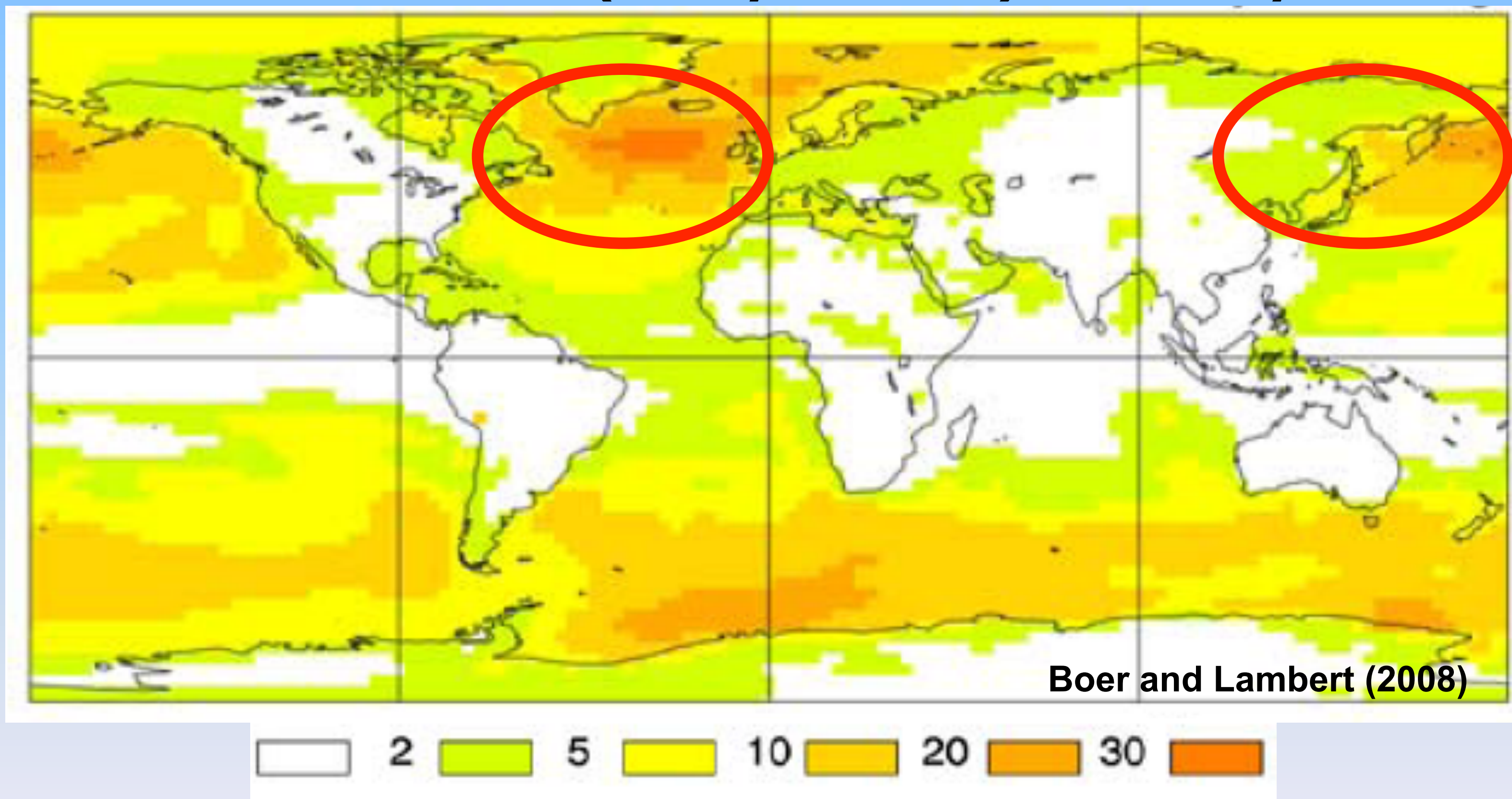
Outline

- Mechanisms of decadal variability
- **History of decadal prediction**
- What are the limiting factors?
- Challenges

Potential Predictability in Surface Air Temperature

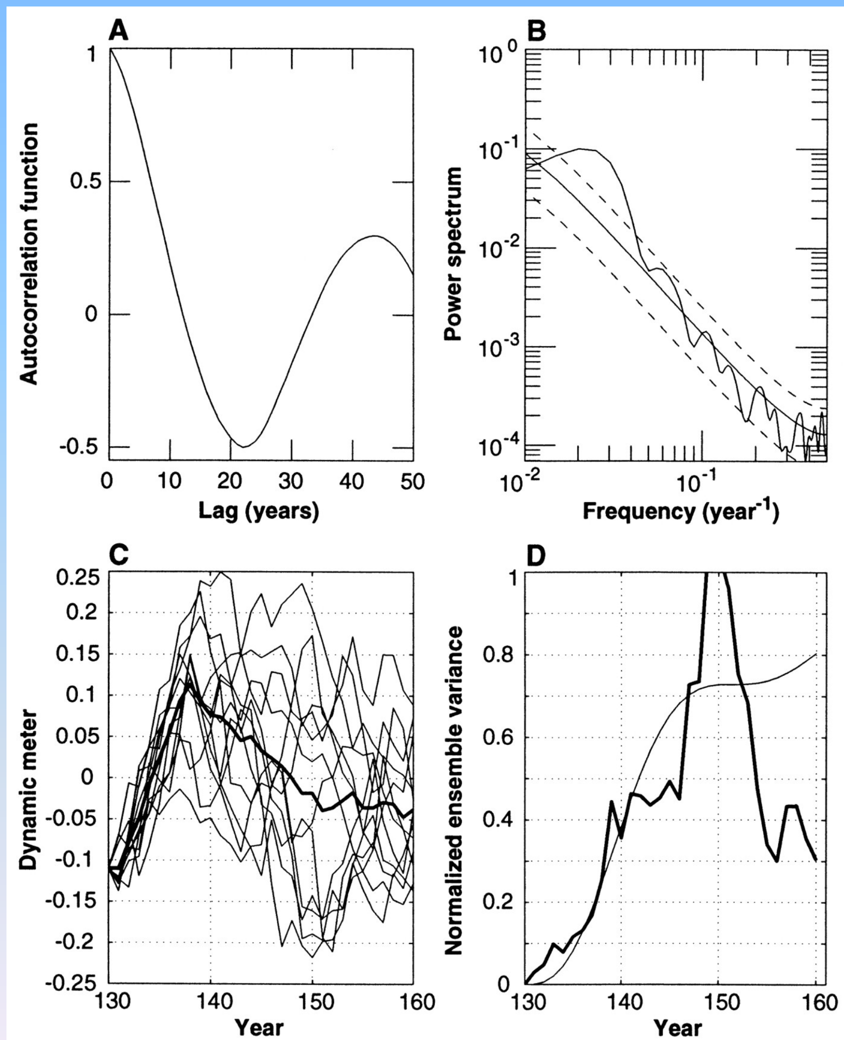
IPCC AR4 Models (8900 yrs Control) 10 yr means

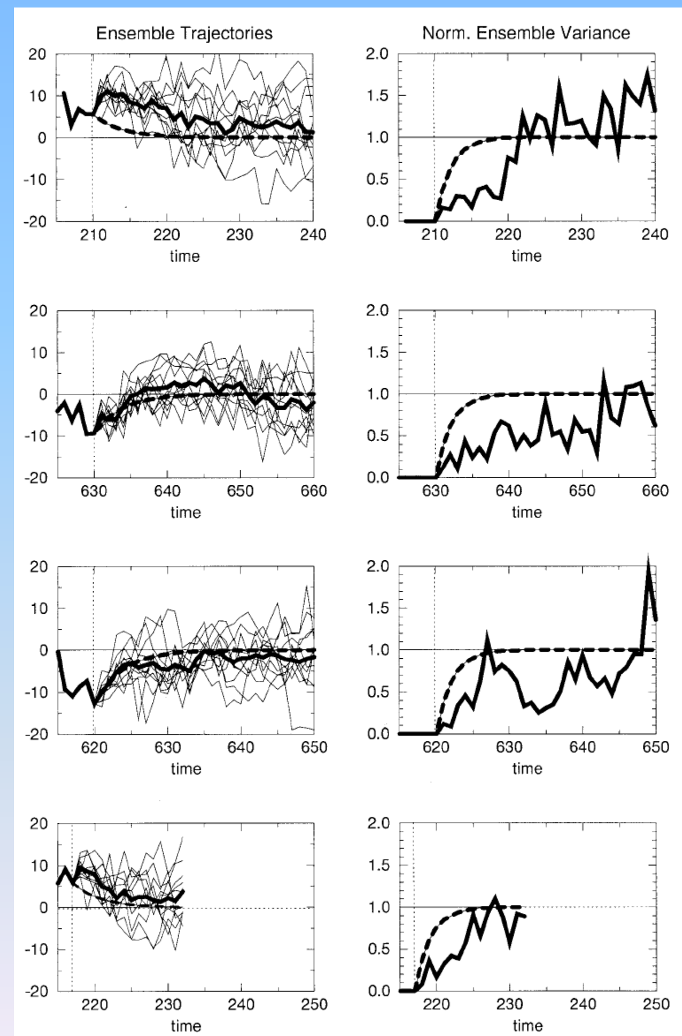


potential predictability variance fraction (σ_v^2/σ^2)

Higher extra-tropical SST Predictability

The history of decadal prediction: perfect predictability studies





Griffies and Bryan 1997

Grötzner et al. 1999

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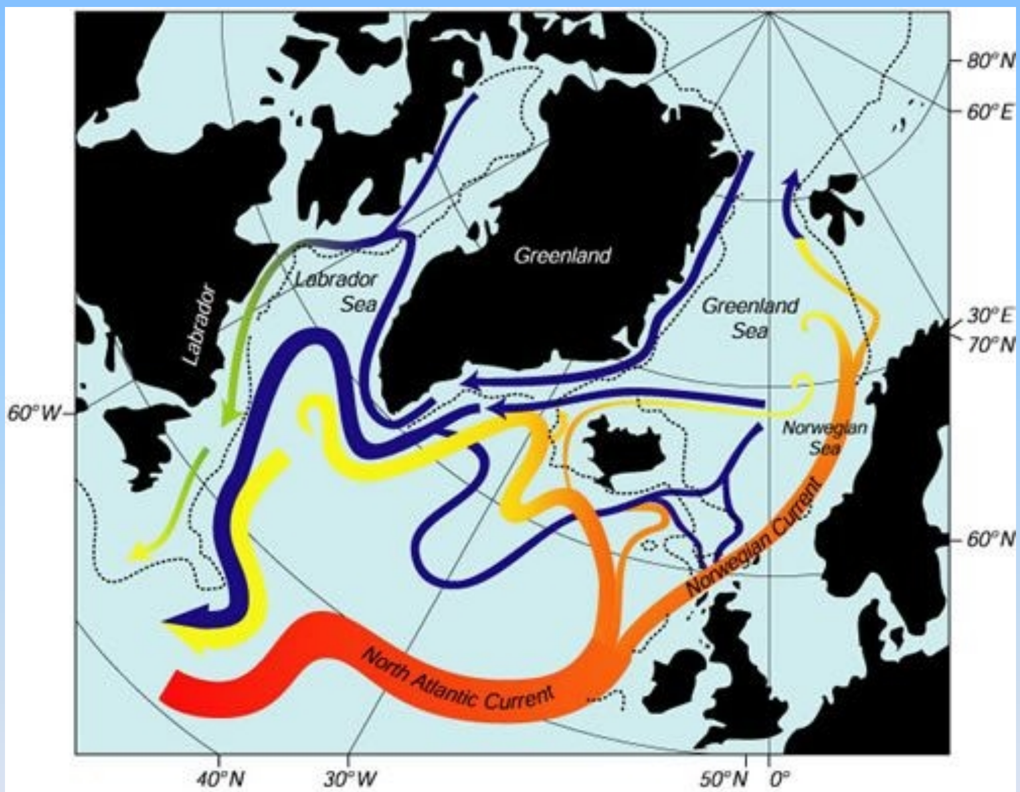
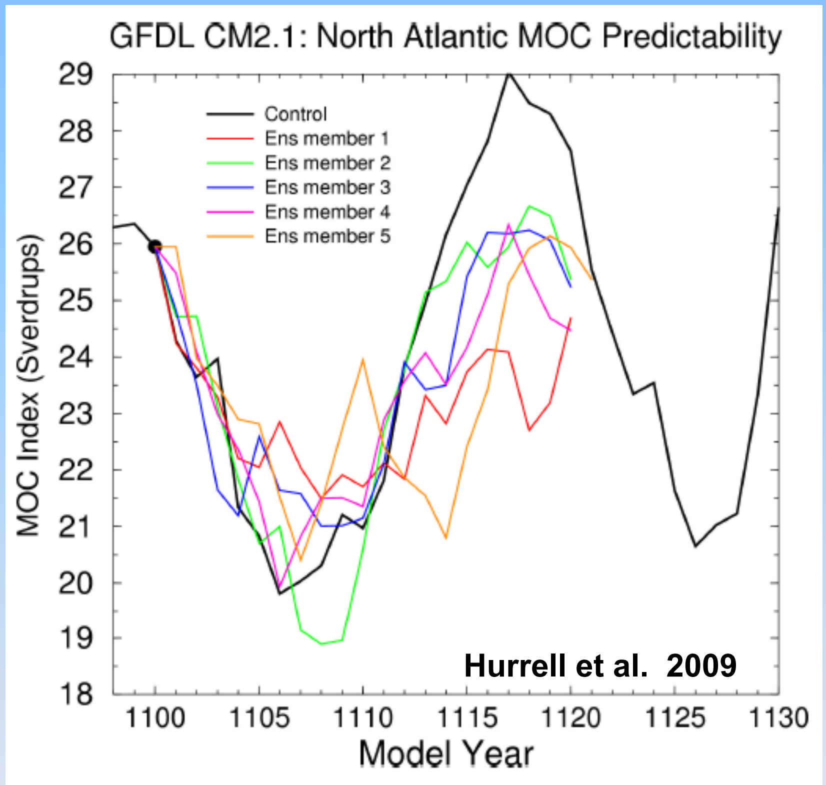
Current state-of-the-art models yield similar results





The MOC is predicable at a lead of one to two decades in perfect model studies

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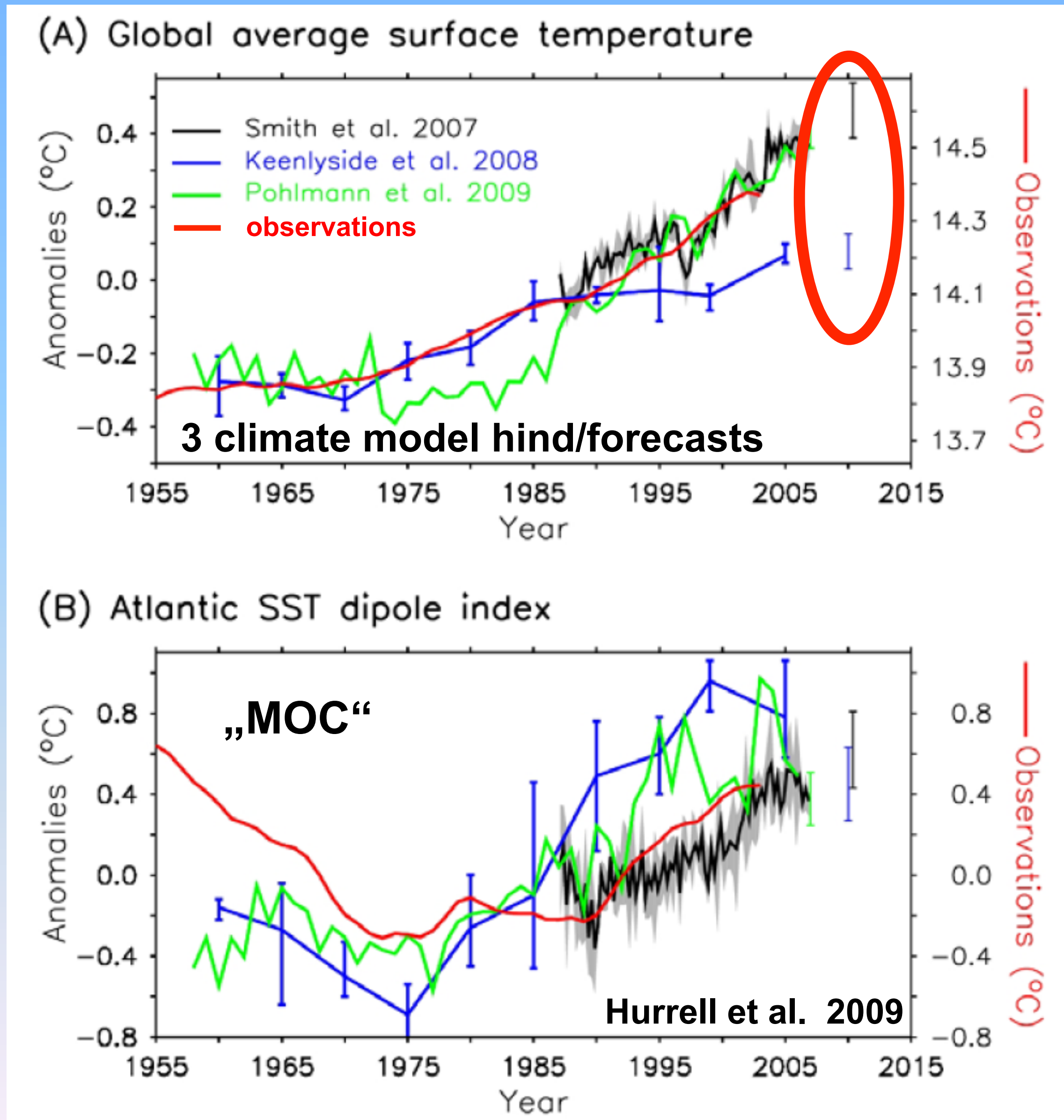
Forecasts for the next decade



Outline

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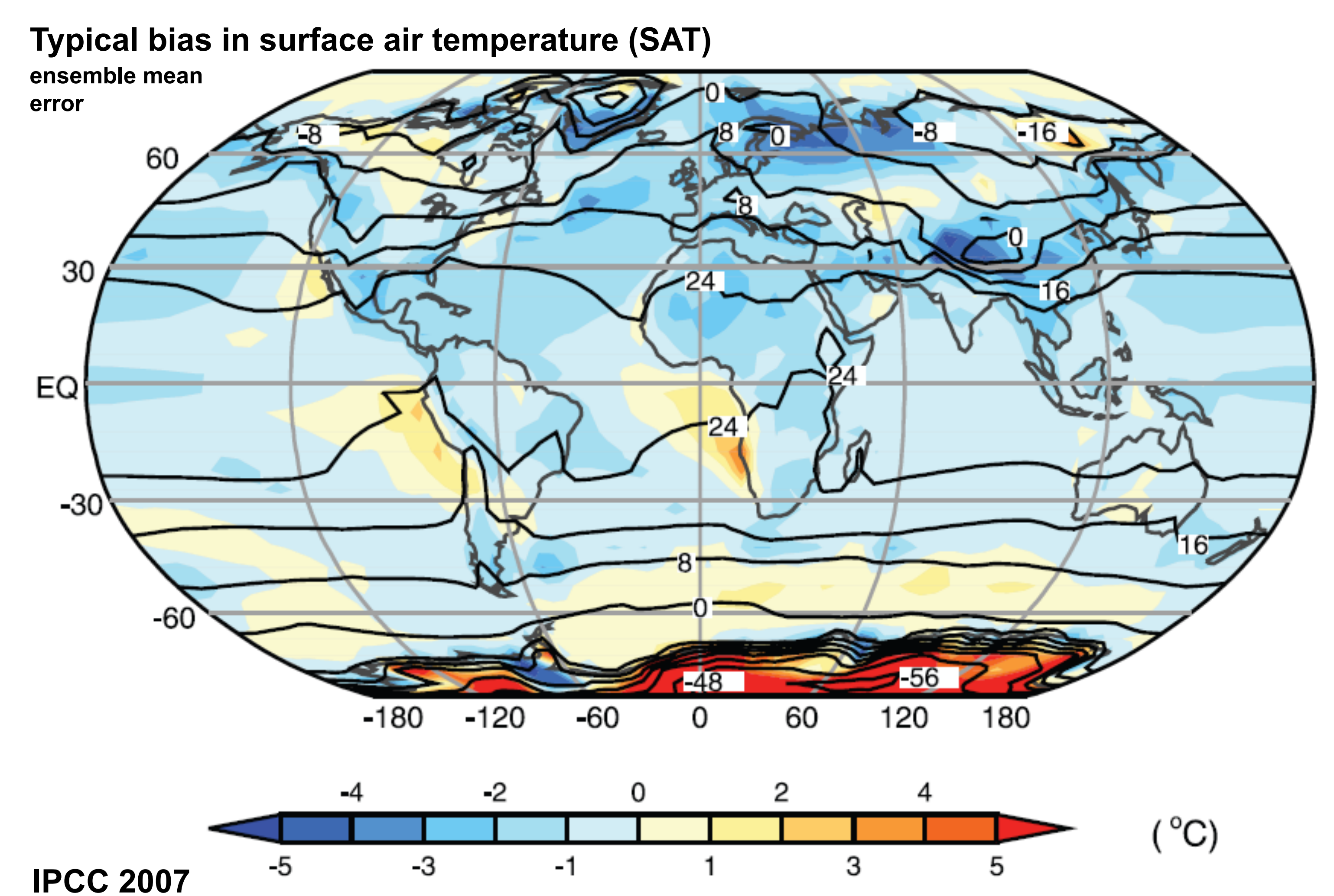
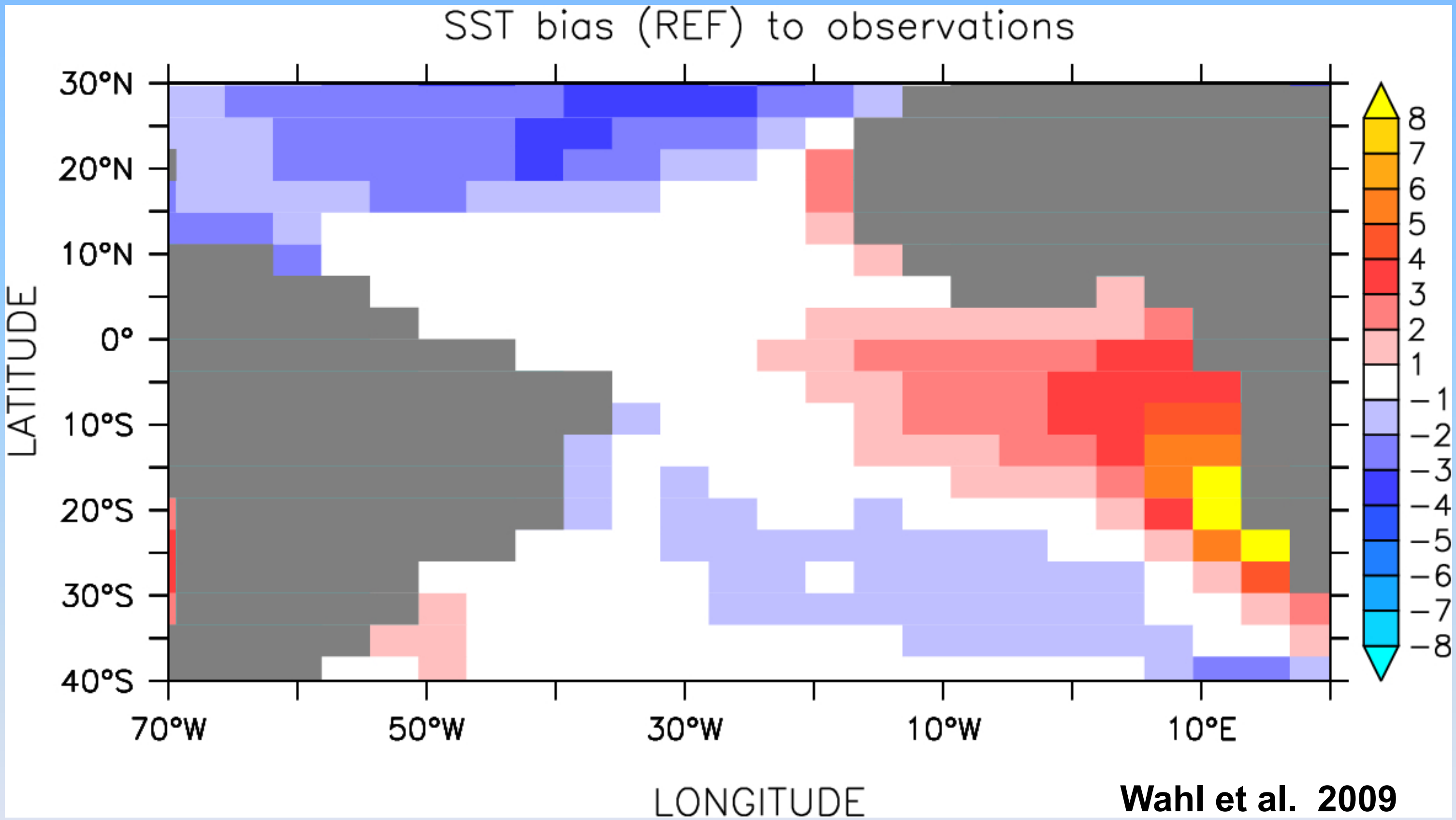
- History of decadal prediction
- **What are the limiting factors?**
- Challenges

Model biases are large



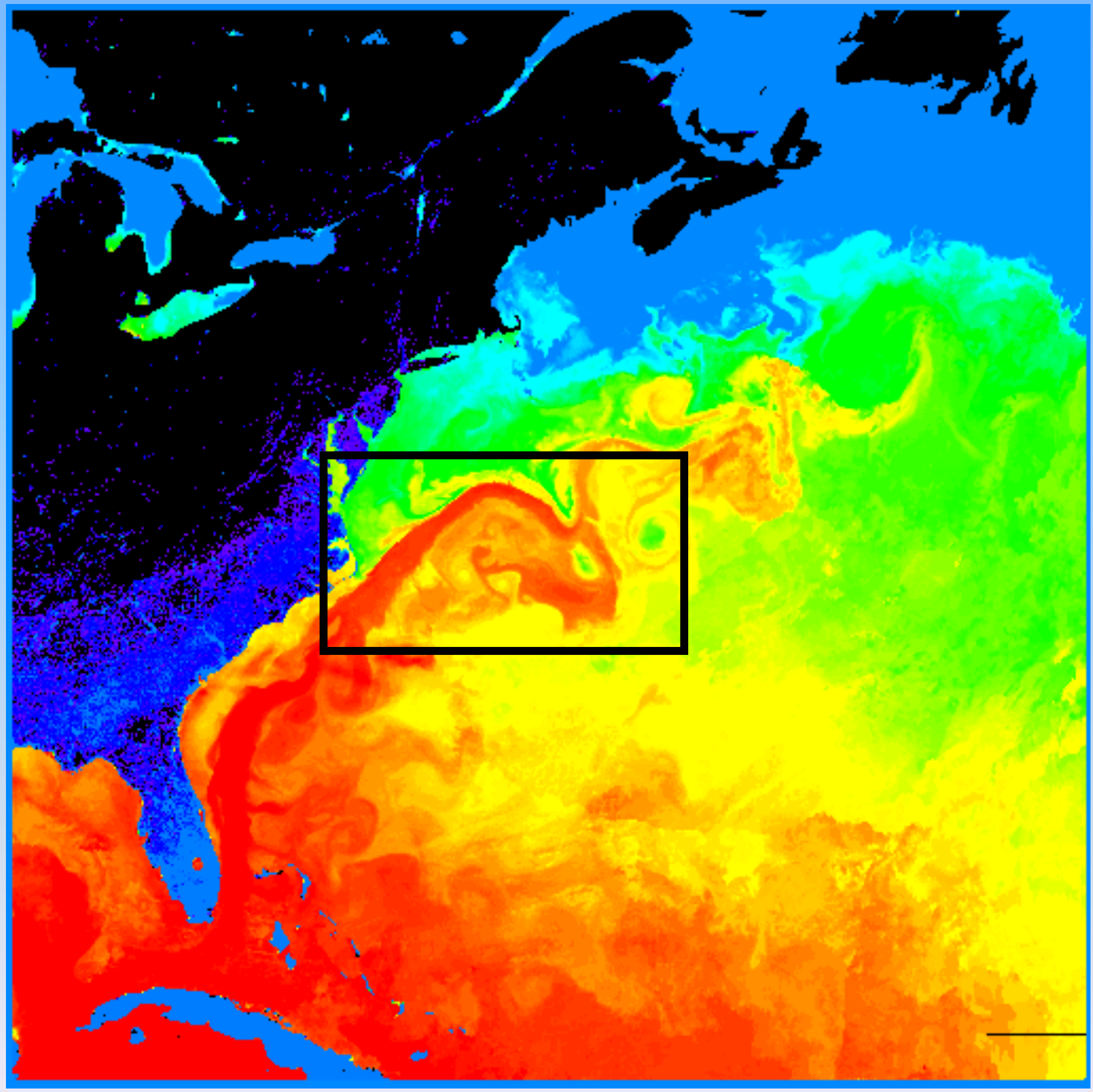
Errors of several degrees (°C) in some regions

The Tropical Atlantic SST bias in the Kiel Climate Model (KCM)



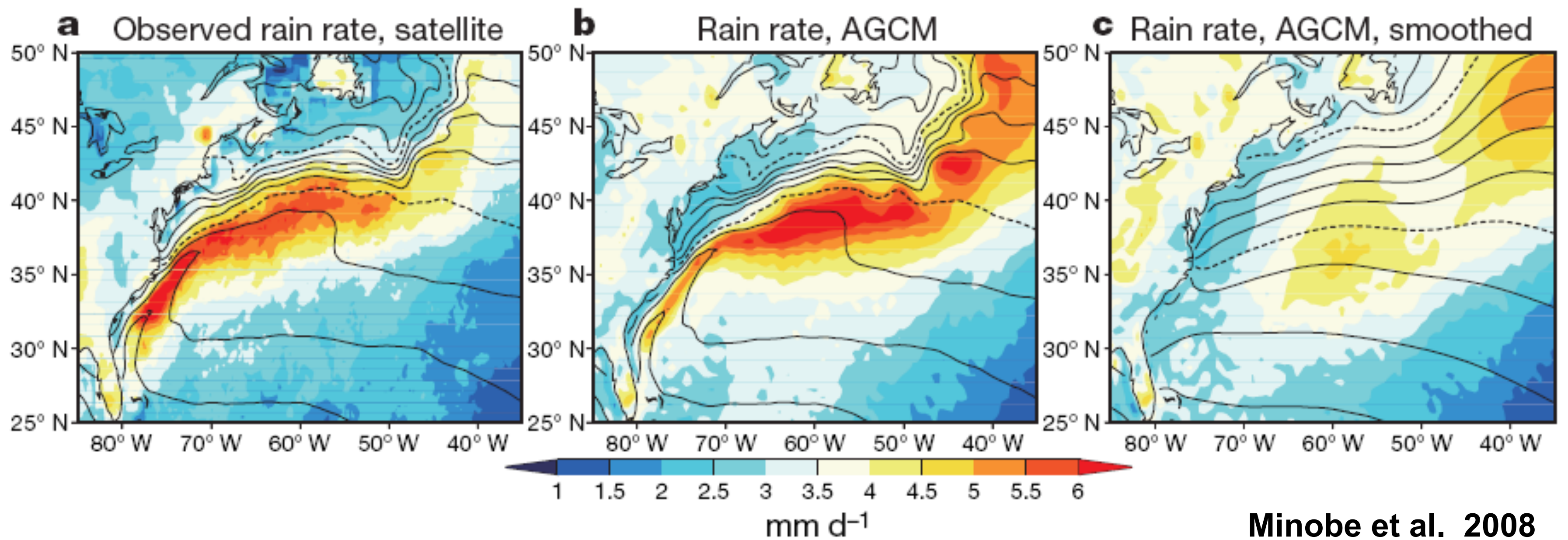
The zonal SST gradient along the equator is reversed in many models. Bad news for prediction in the Tropics.

Gulfstream SST front



Represention of small-scale processes

Atmospheric response: resolution matters



Minobe et al. 2008

The AGCM has T239 horizontal resolution (~50 km) and 48 levels

Compared to the smoothed SST run, rain-bearing low pressure systems tend to develop along the Gulf Stream front in the control simulation

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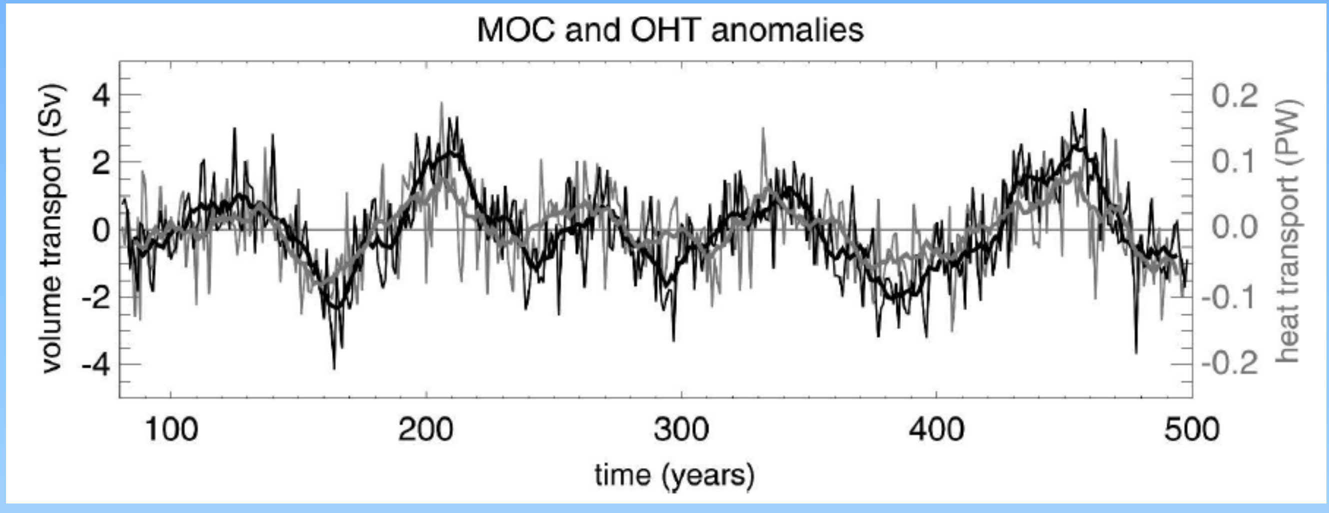
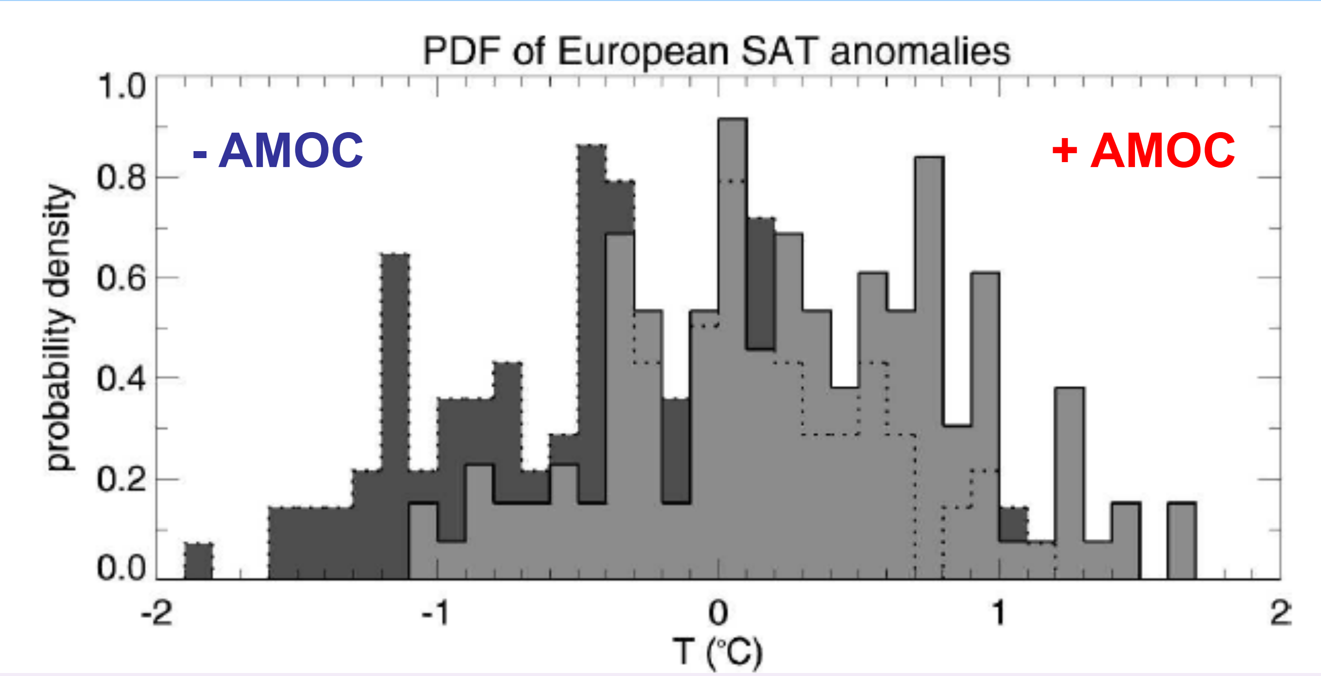
The signal-to-noise problem





Pohlmann et al. 2006

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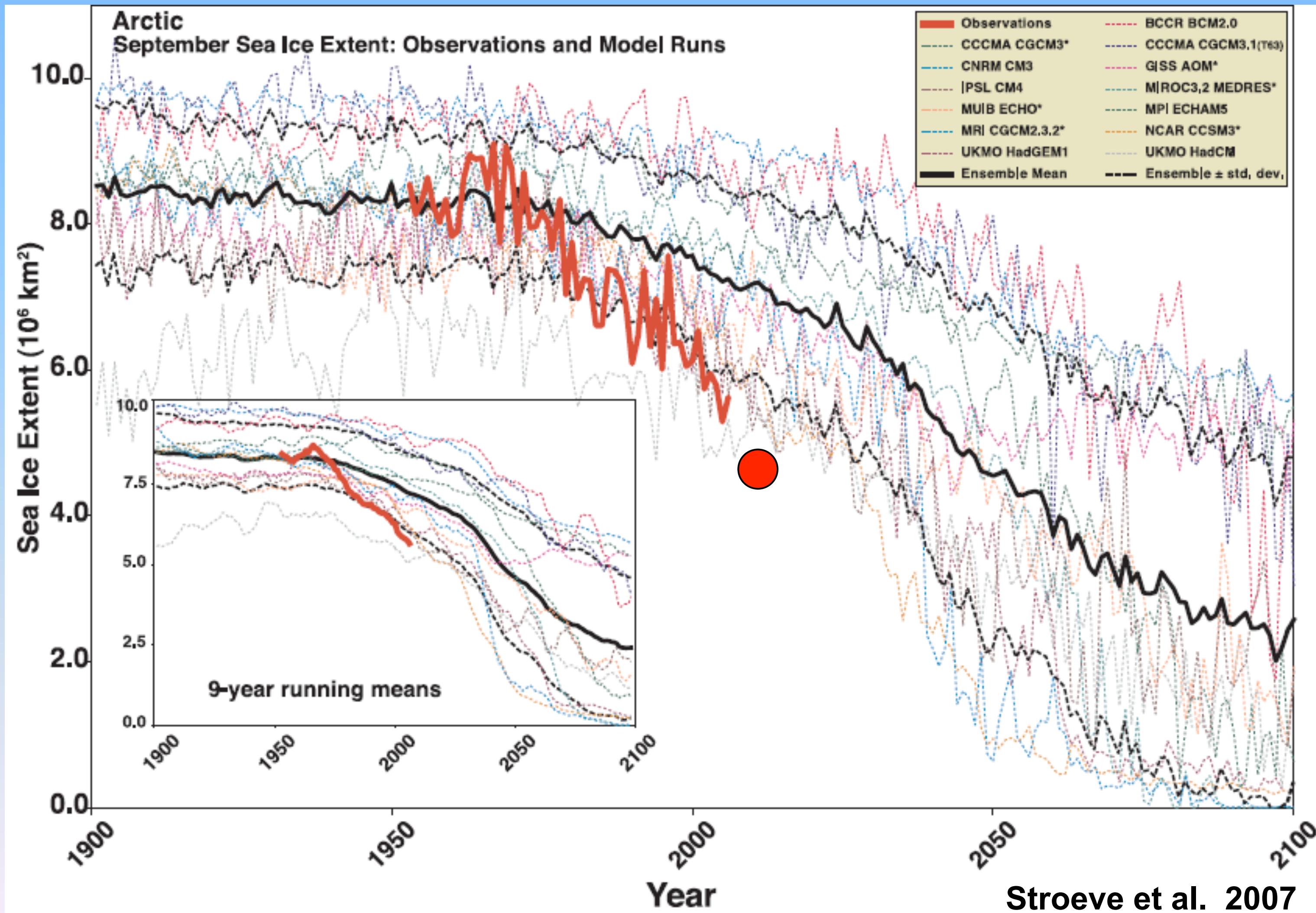
Arctic sea ice melts faster than projected by the models: why?



Stroeve et al. 2007

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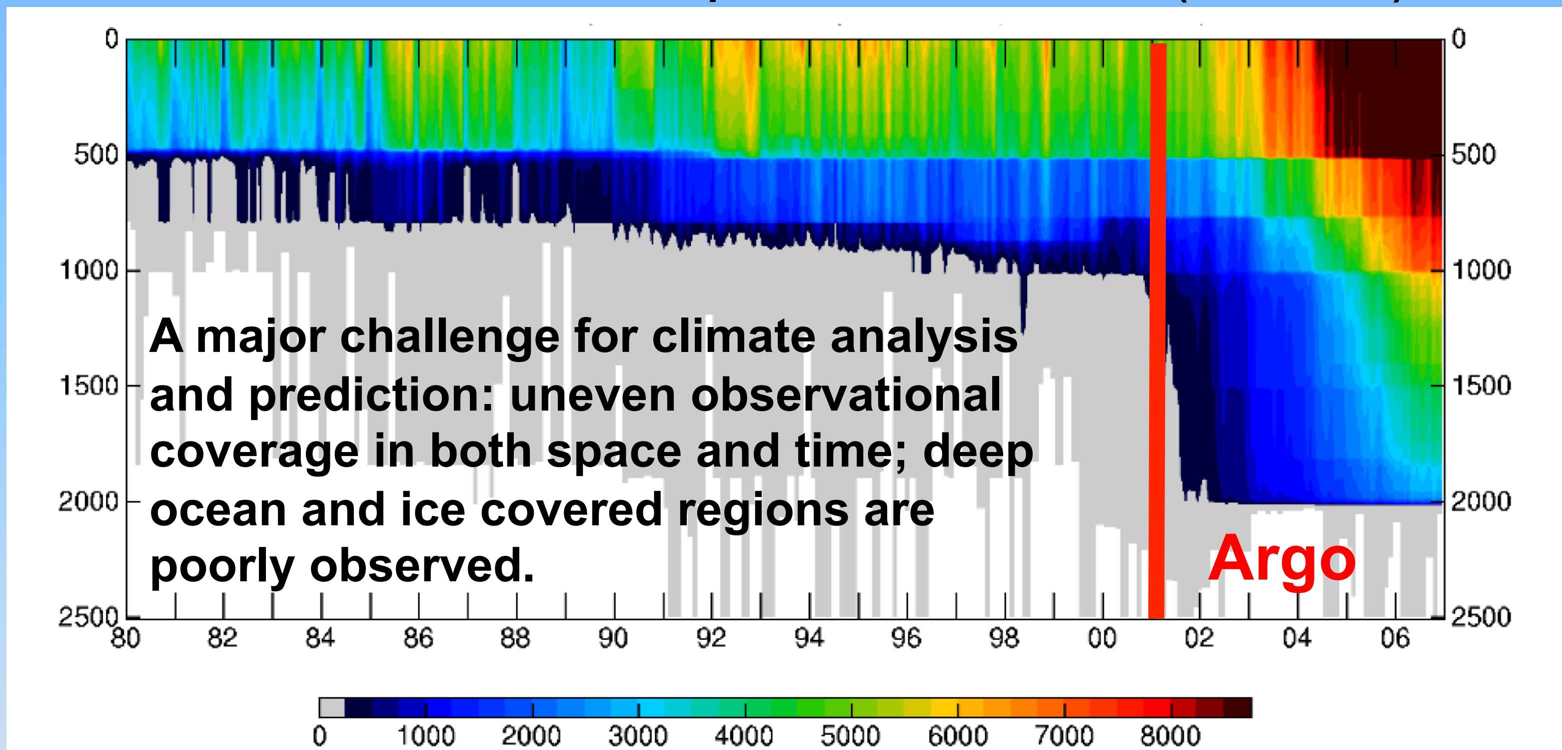
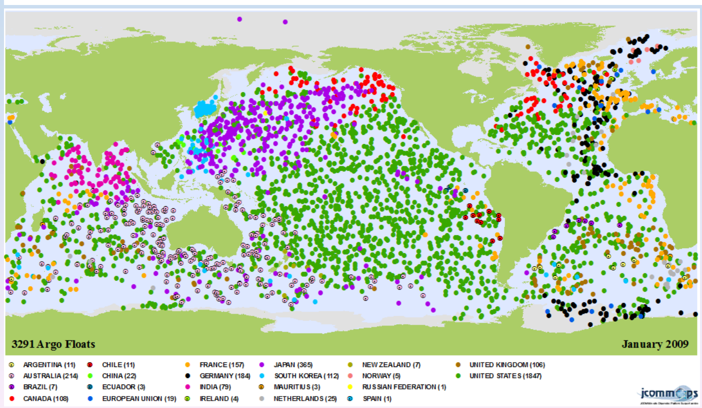
Do we have enough data?

Global Number of Temperature Observations (1980-2006)



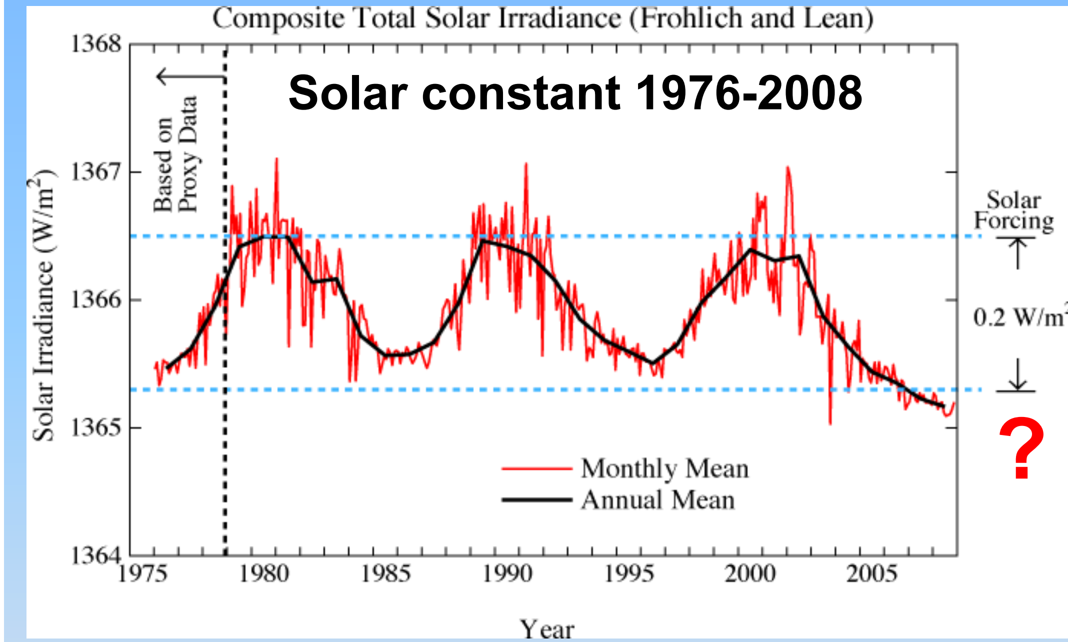
A major challenge for climate analysis and prediction: uneven observational coverage in both space and time; deep ocean and ice covered regions are poorly observed.

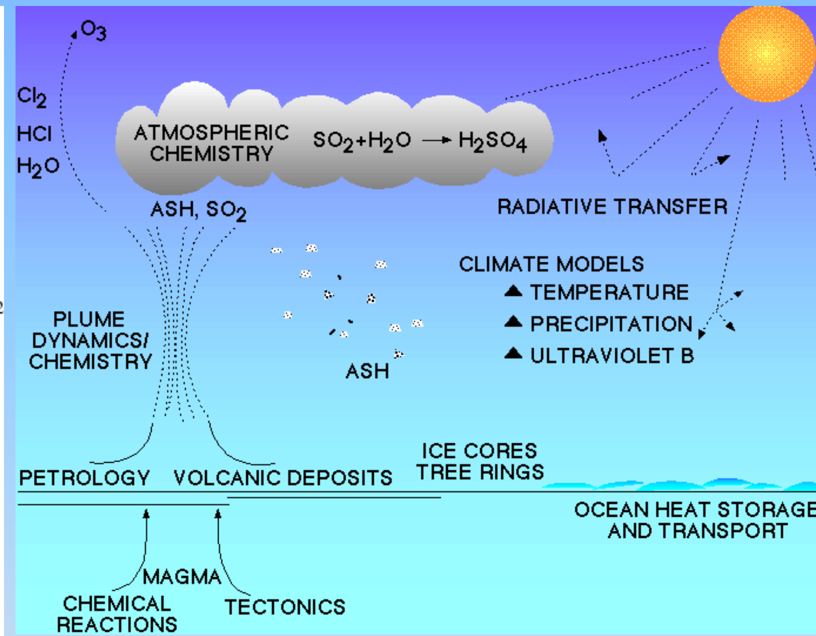


Courtesy Tony Rosati, Hurrell et al. (2009)

ARGO made a big difference. Is it sufficient?

Unpredictable external influences





Strong volcanic eruptions, for instance, can cause global cooling of about 0,2°C for a few years and persist even longer in the ocean heat content. If they happen, we can exploit their long-lasting climatic effects.

Outline

- Why decadal prediction
- Mechanisms of decadal variability
- What is the decadal predictability potential
- **Challenges**

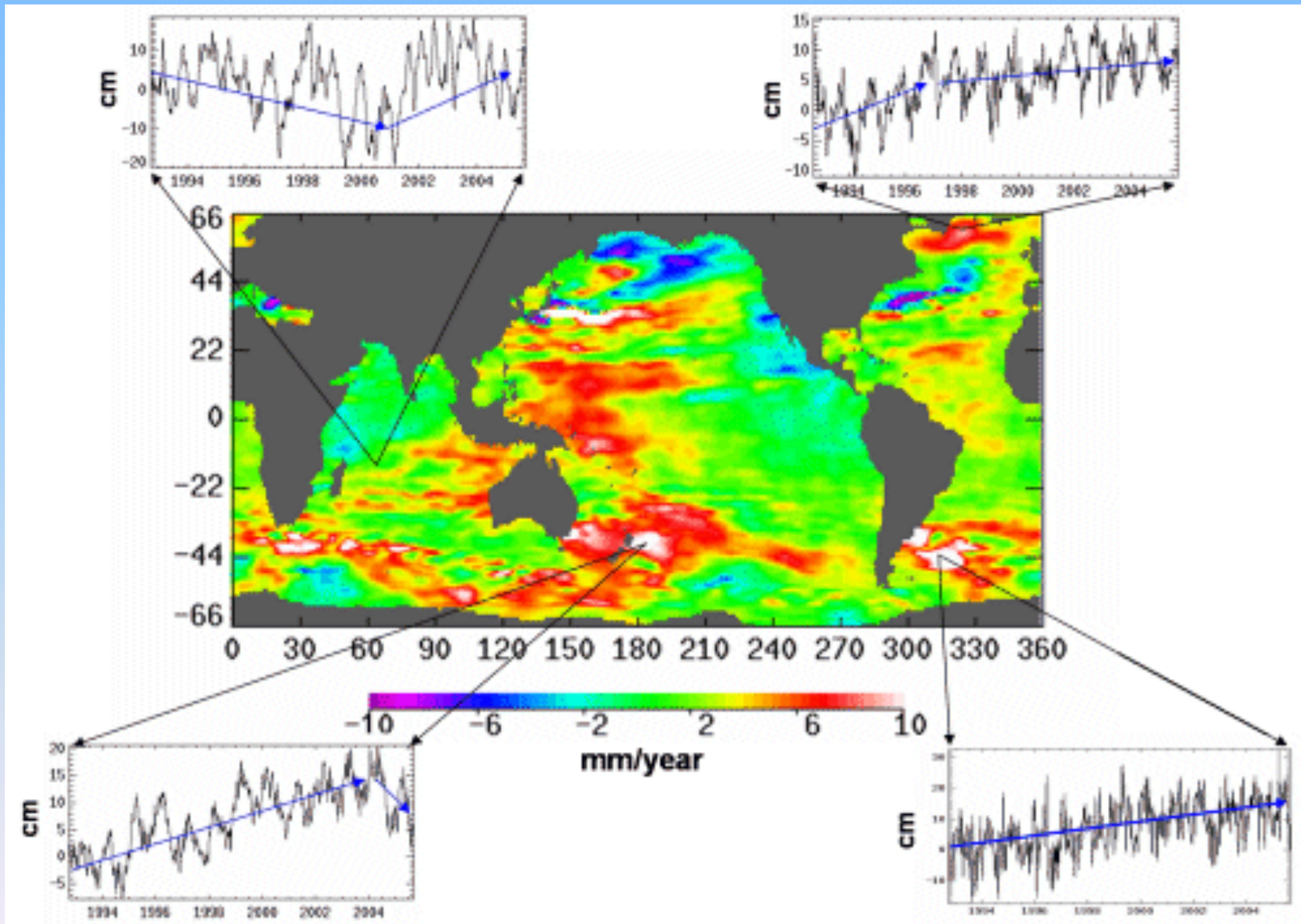
Challenges

- A decadal predictability potential for a number of societal relevant quantities is well established.
- The signal-to-noise ratio is a problem. How can we best use decadal forecasts?
- We need a better understanding of the mechanisms of decadal variability (atmospheric response to extra-tropical SST).
- We need a suitable climate observing system (ocean, land surface, sea ice...). Is the current one sufficient?
- We need „good“ models! We know from NWP that reduction of systematic bias helps. Biases in climate models are still large.
- Higher resolution helps. Yet we still need improved parameterizations.
- The models are not complete. More physics must be incorporated (e. g., ice, stratosphere, chemistry,...).
- Much increase in computing power is necessary.

To realize the full decadal predictability potential we need a coordinated scientific programme under the auspices of the World Climate Research Programme (WCRP)

Decadal variability in sea level

Topex/Poseidon 1993-2005



St. Michaels 12 Oct 2009

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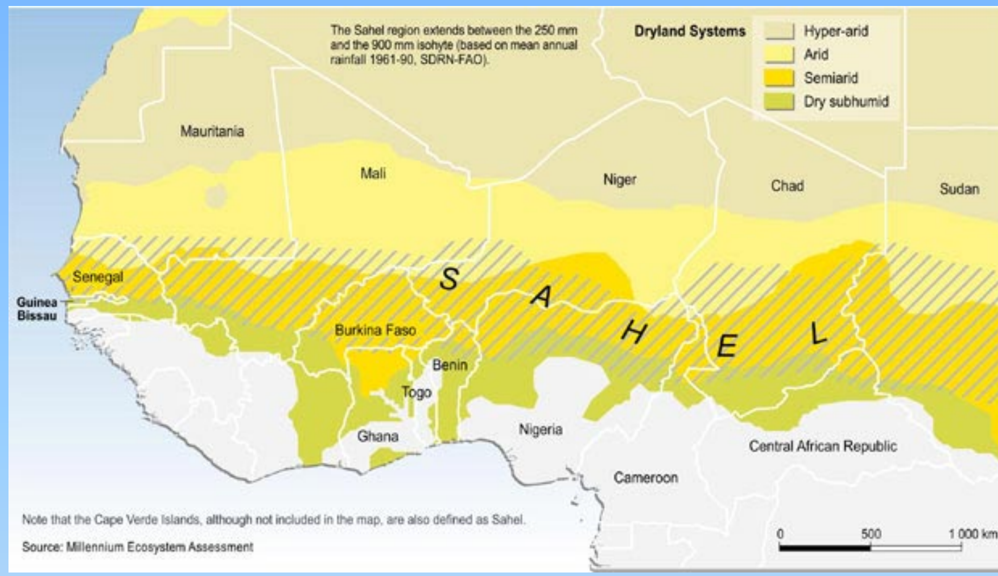
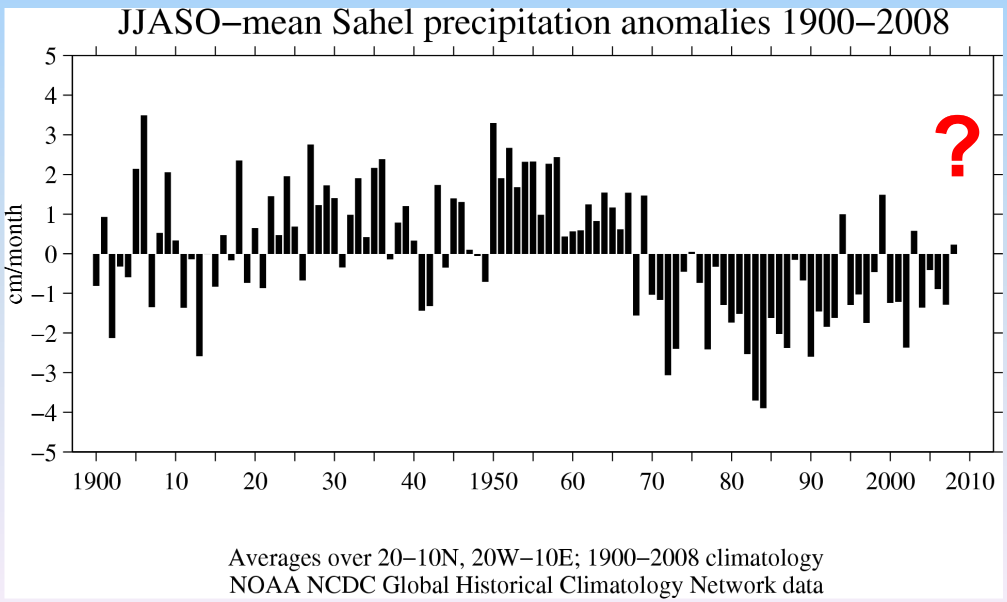
Decadal variations in Sahel rainfall





St. Michaels 12 Oct 2009

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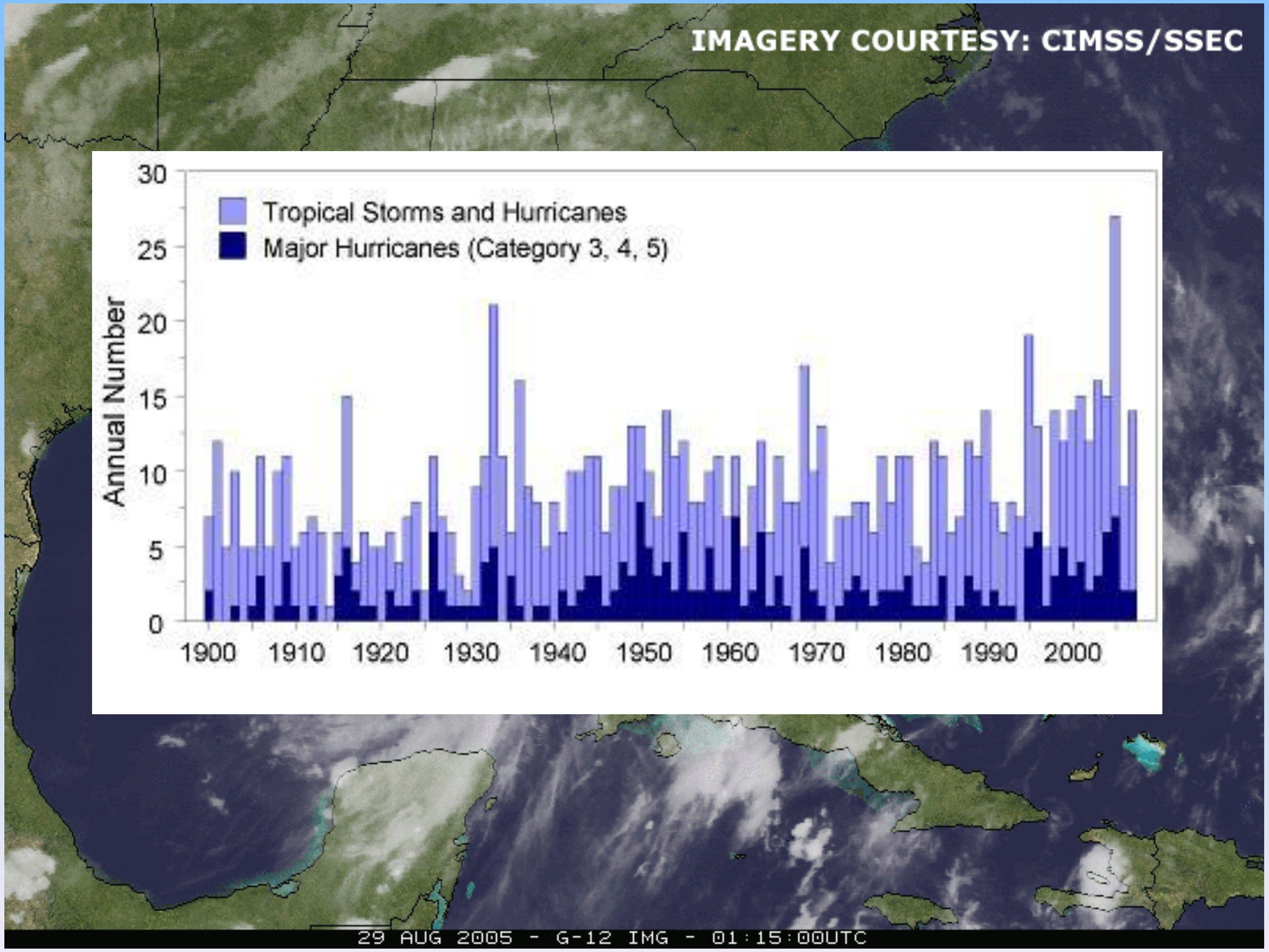
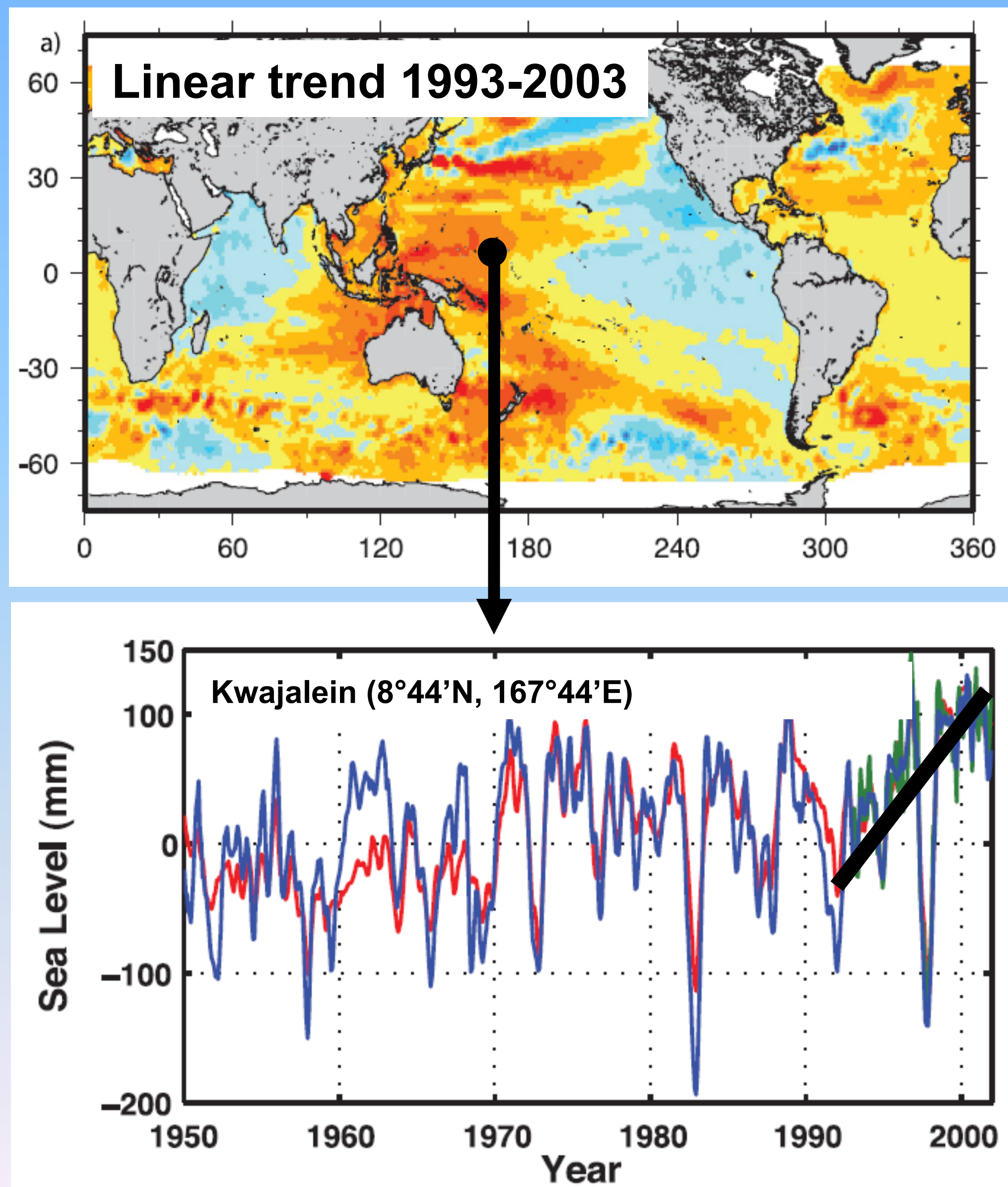
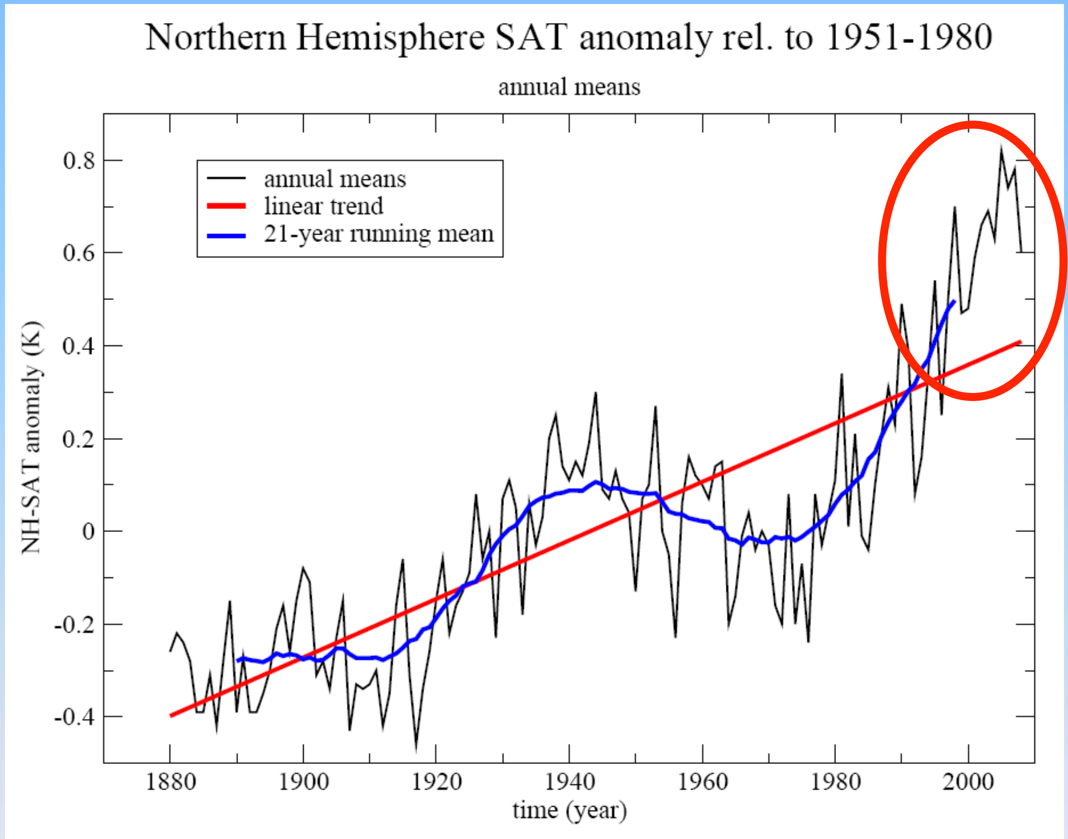
Decadal variations in Atlantic hurricane activity



Decadal variability in sea level

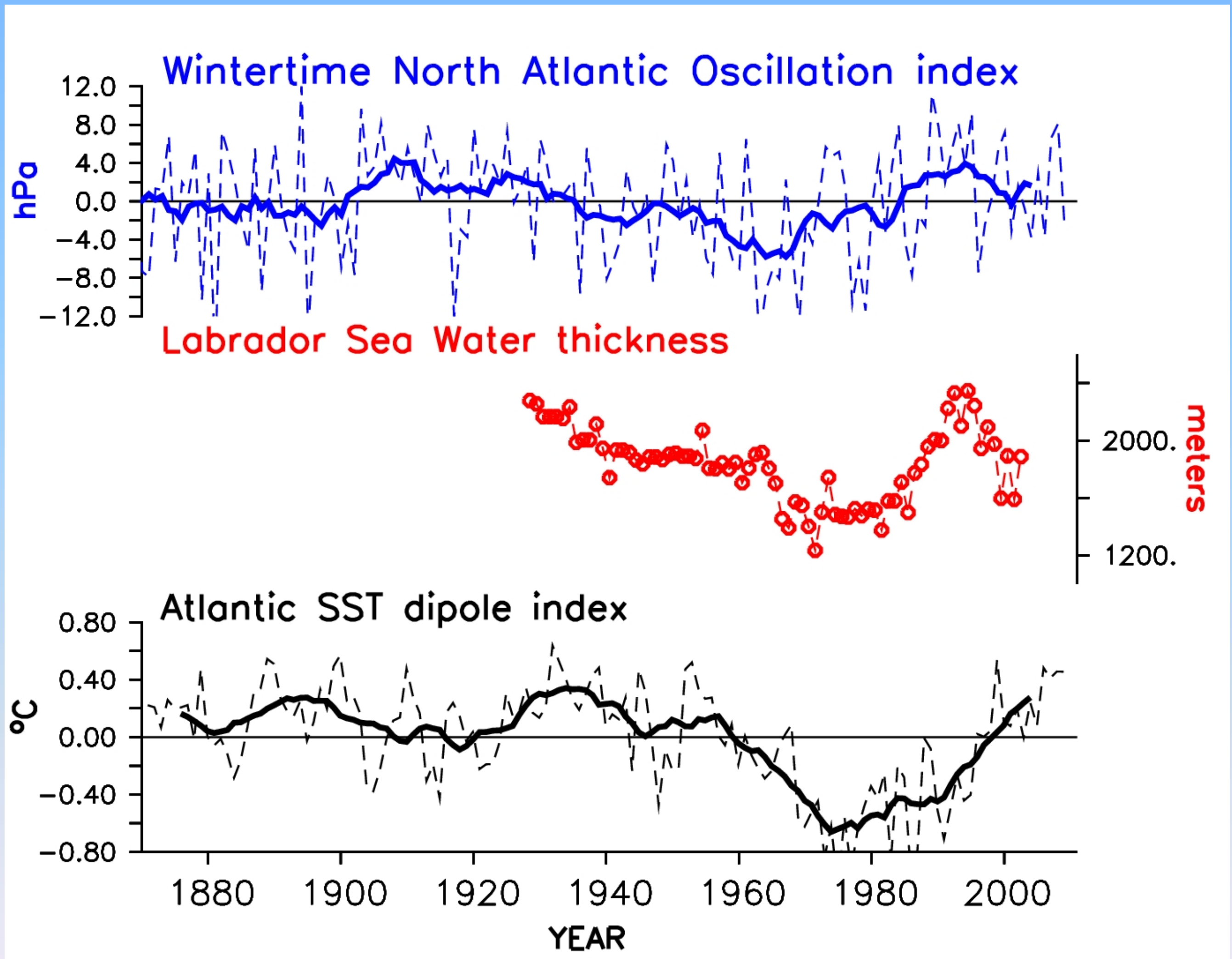


Changes in the AMO are felt on a hemispheric and even global scale

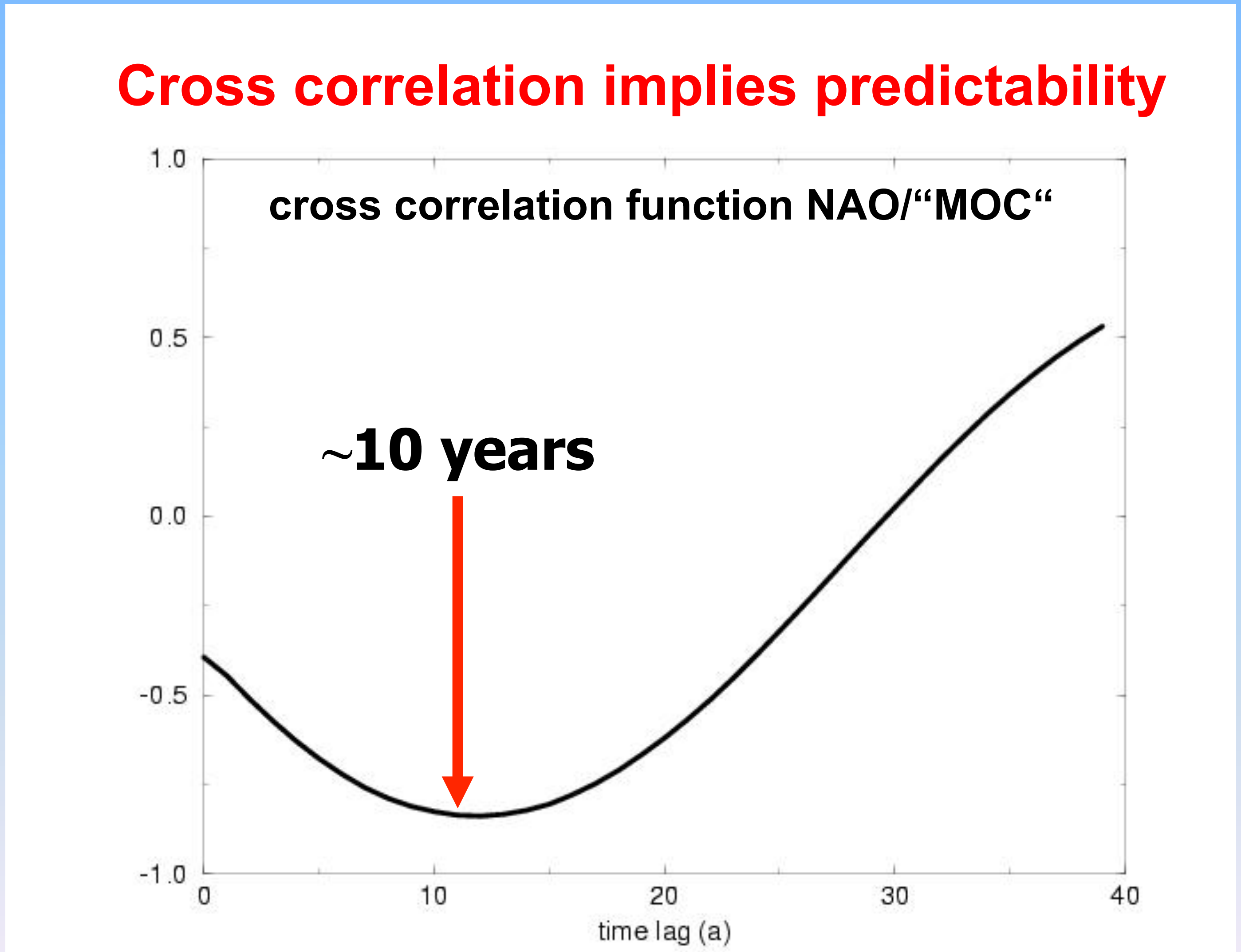


How much did internal decadal variability contribute to the warming during the recent decades?

The NAO as a driver of the MOC



NAO leads “MOC“ (SST dipole)



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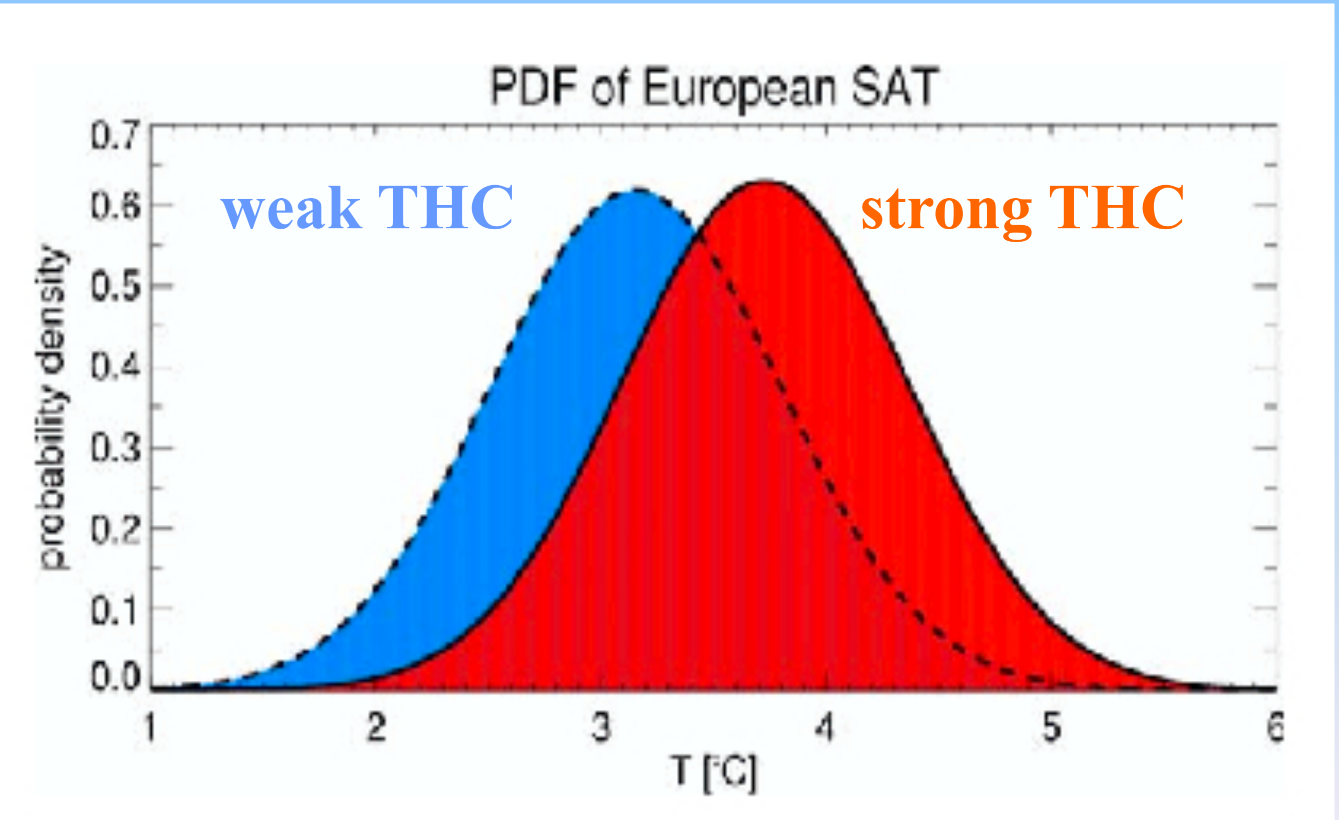
Shifts in PDFs of European SAT in response to MOC changes

coupled model simulation



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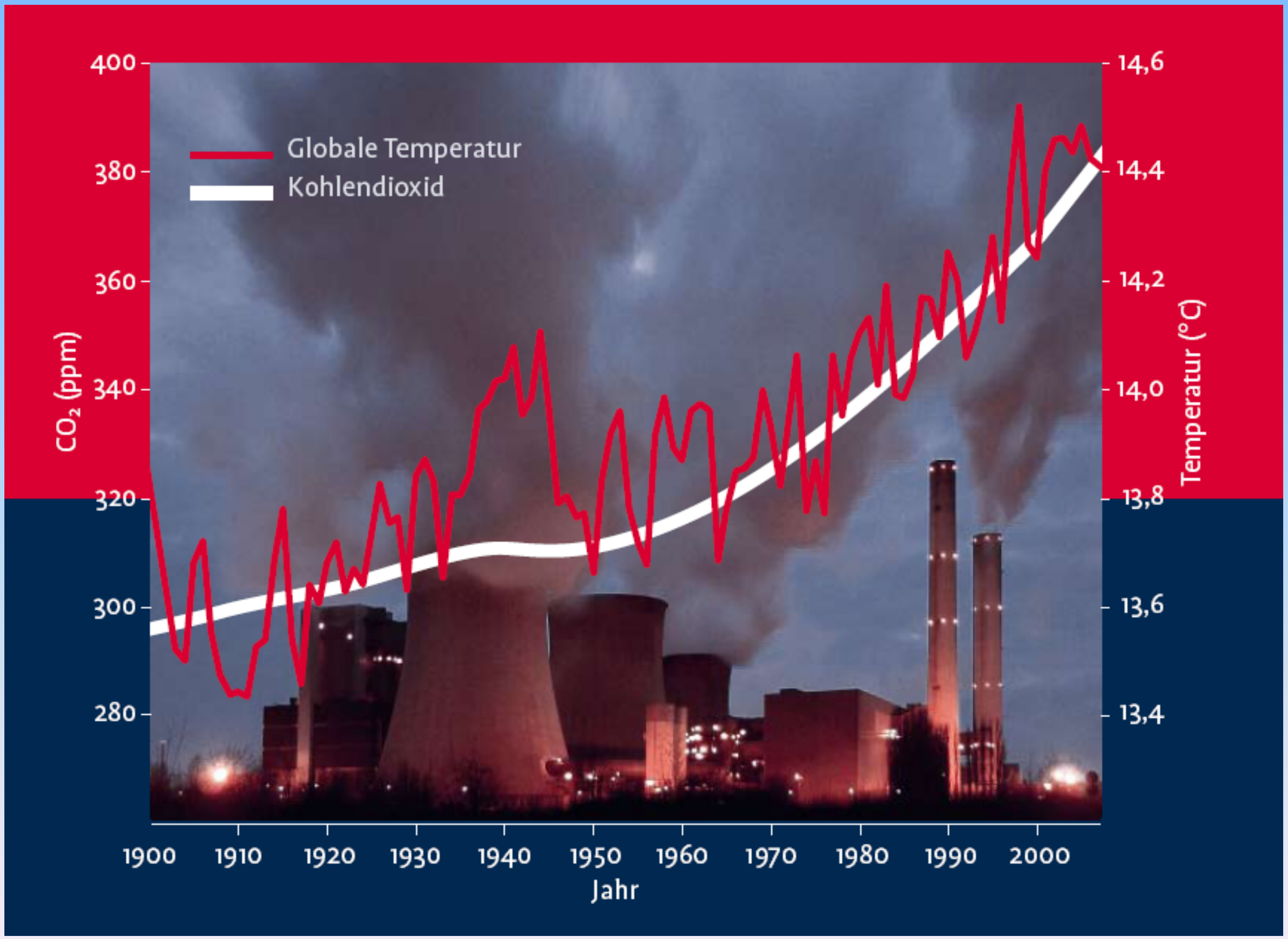
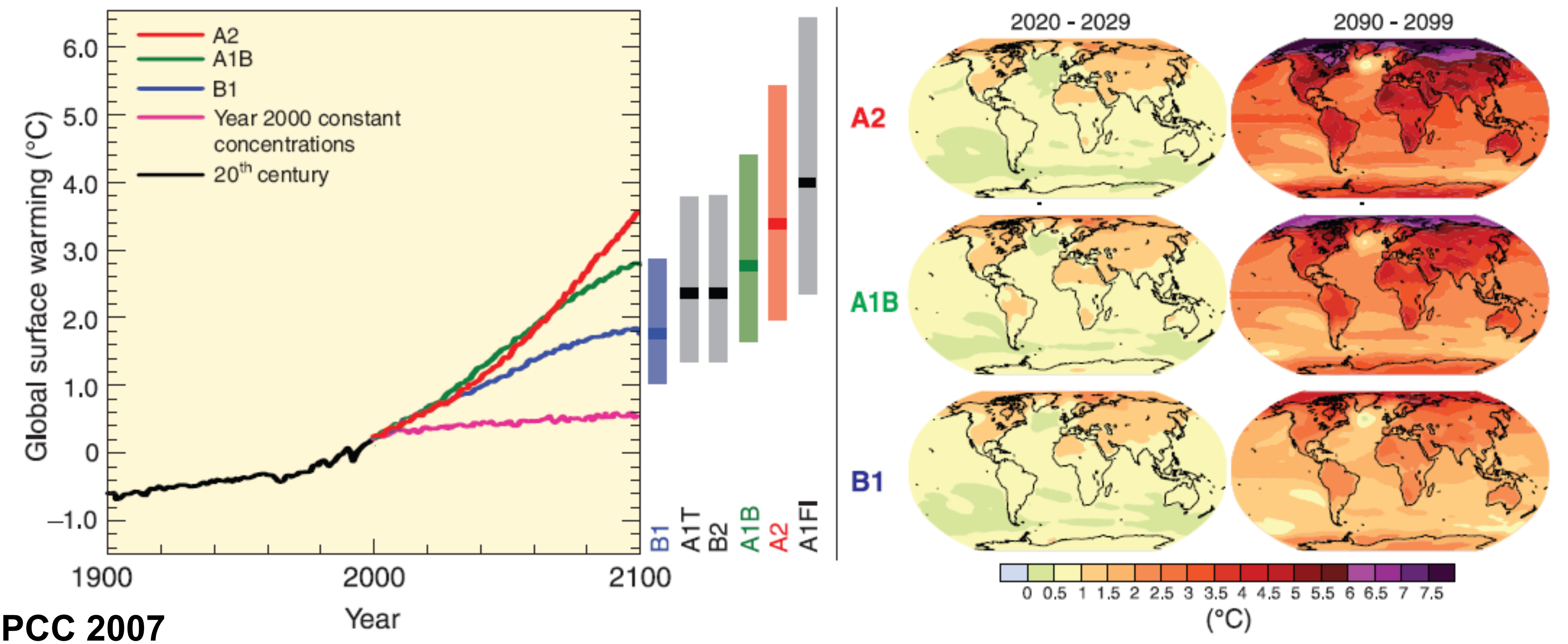
The natural variability can fool us



Global change prediction is a joint initial/boundary value problem



IPCC 2007

Projections were not initialized in IPCC-AR4

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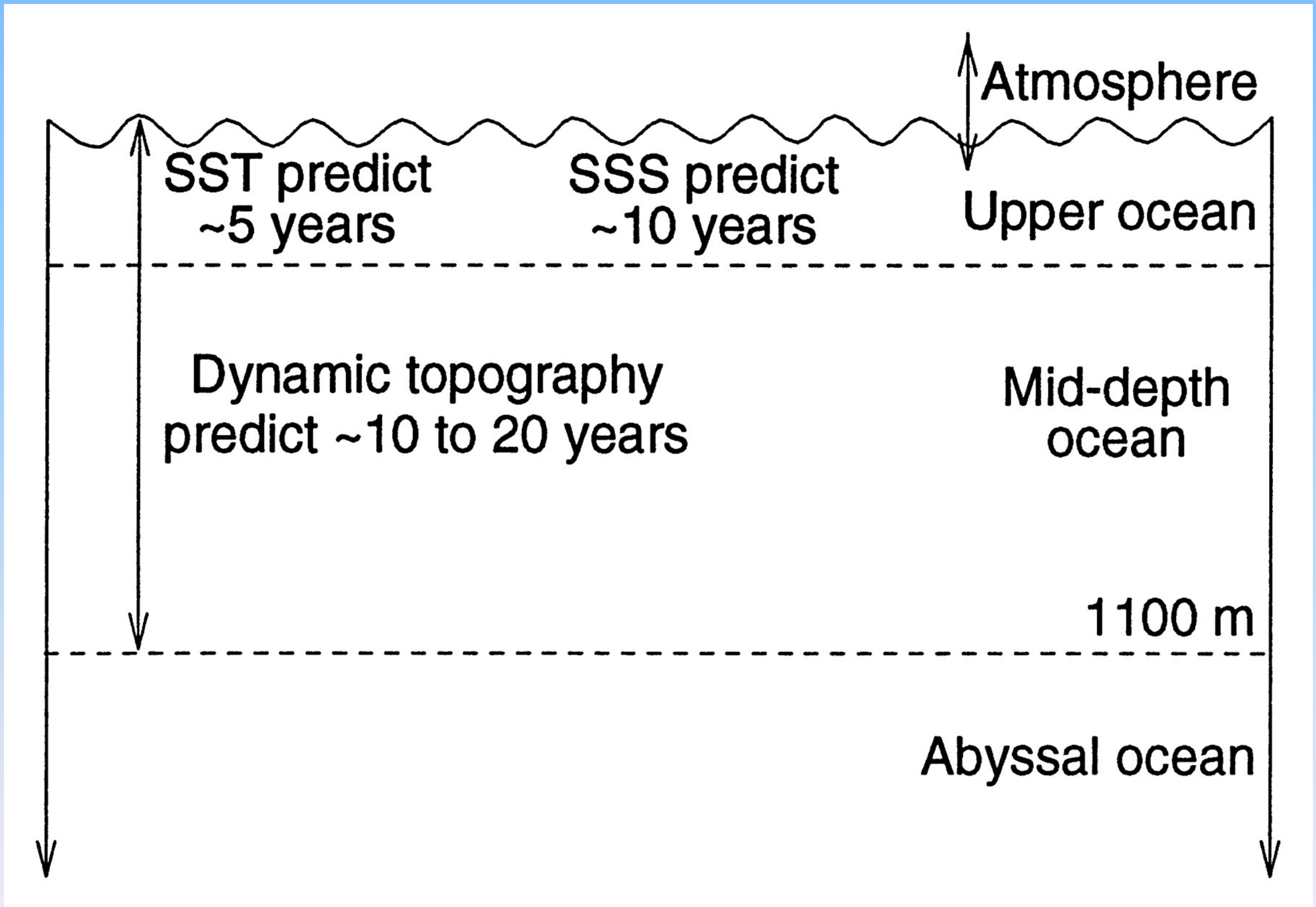
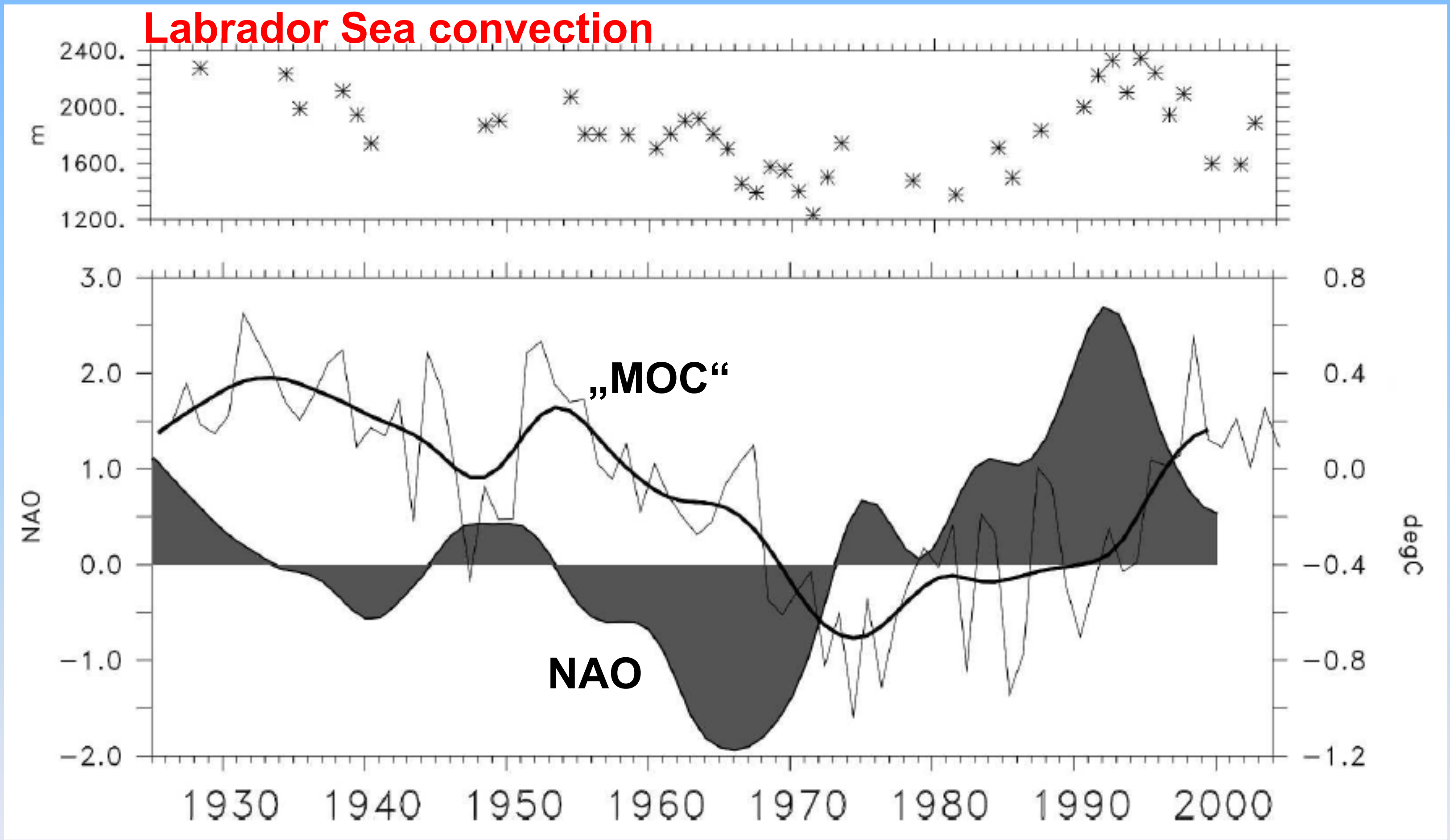
The basis for climate prediction



Griffies and Bryan 1997

NAO leads SST Dipole ("MOC")



Latif et al. 2006

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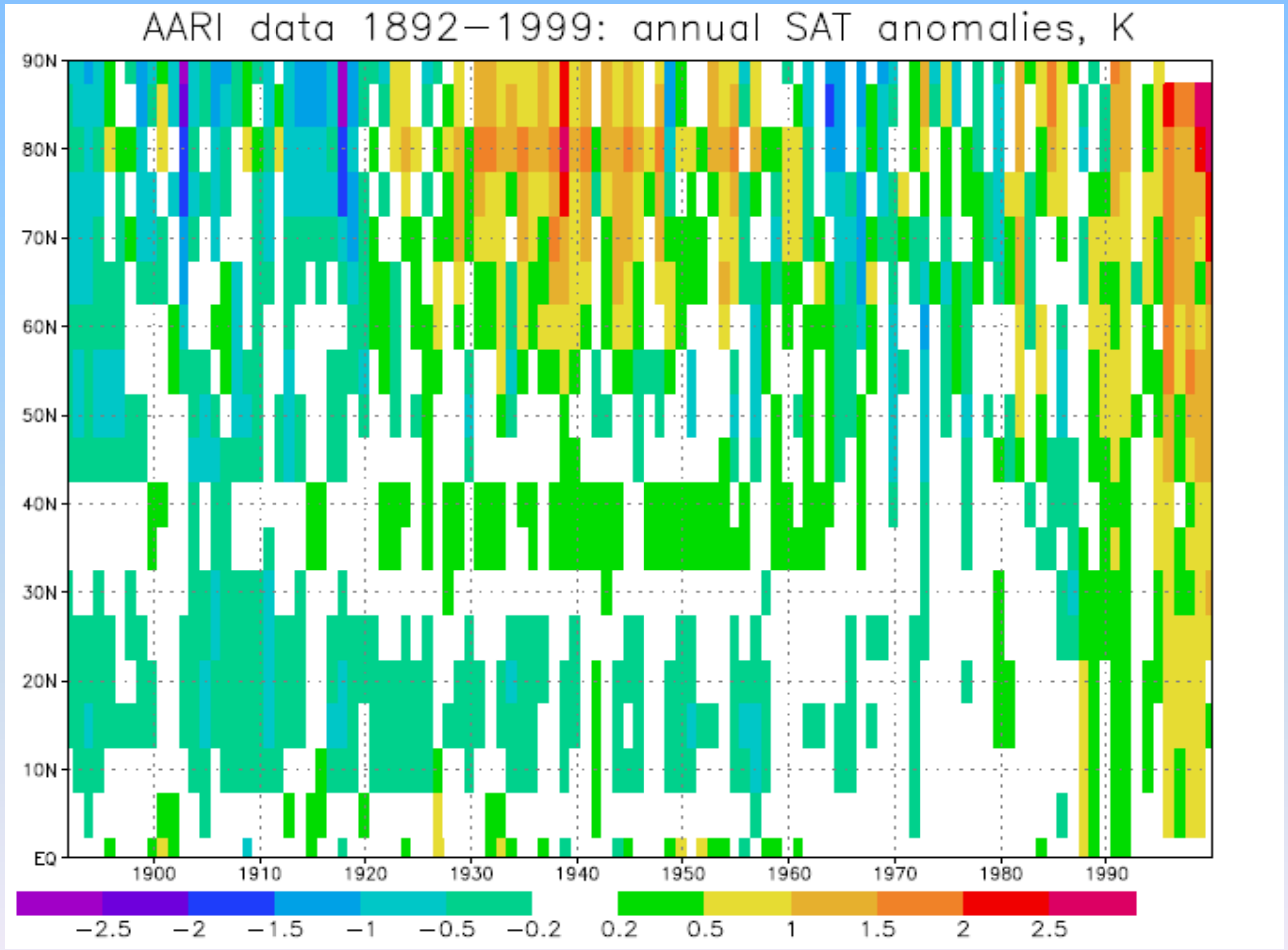
Northern Hemisphere SAT zonal means



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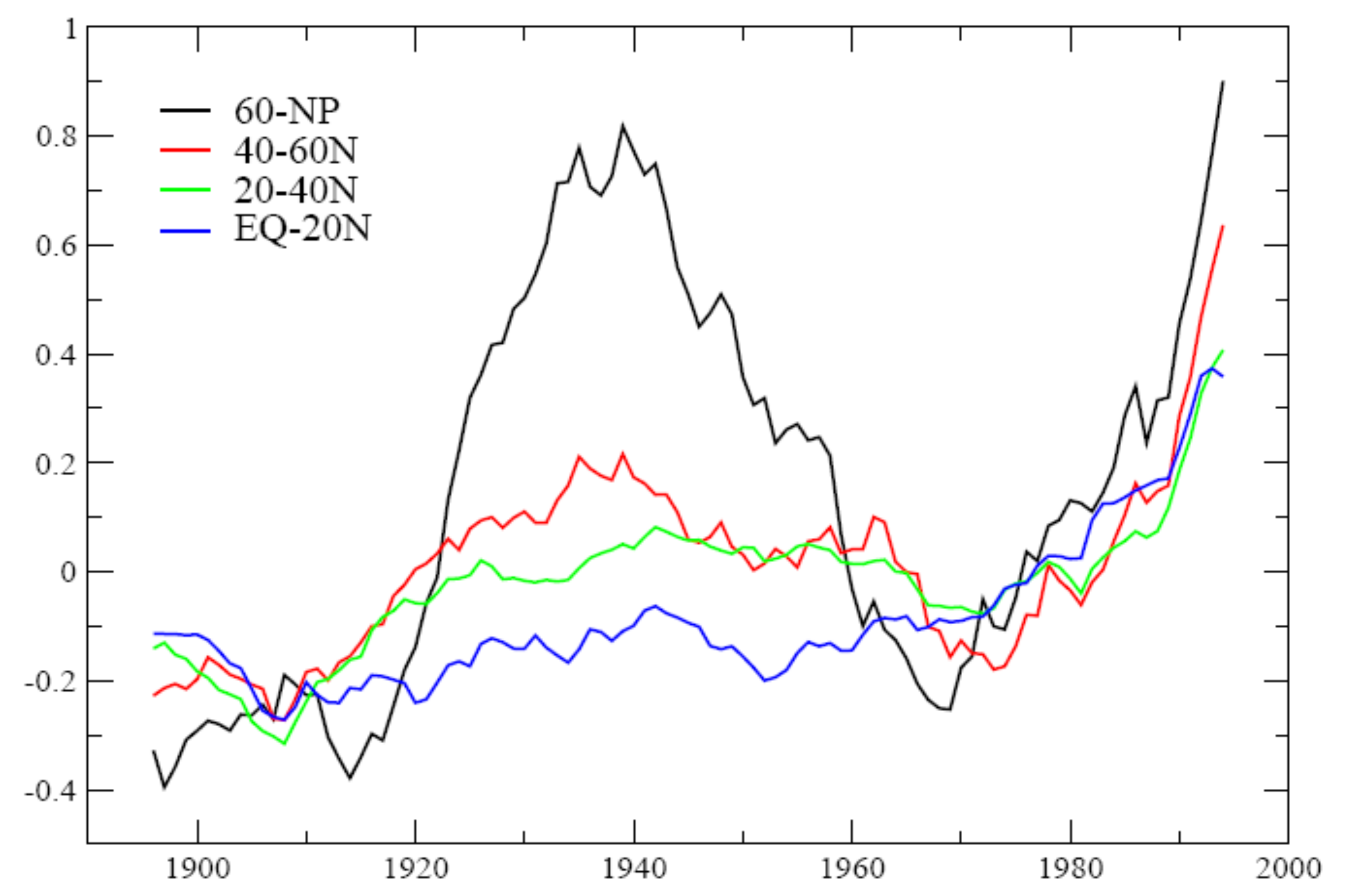
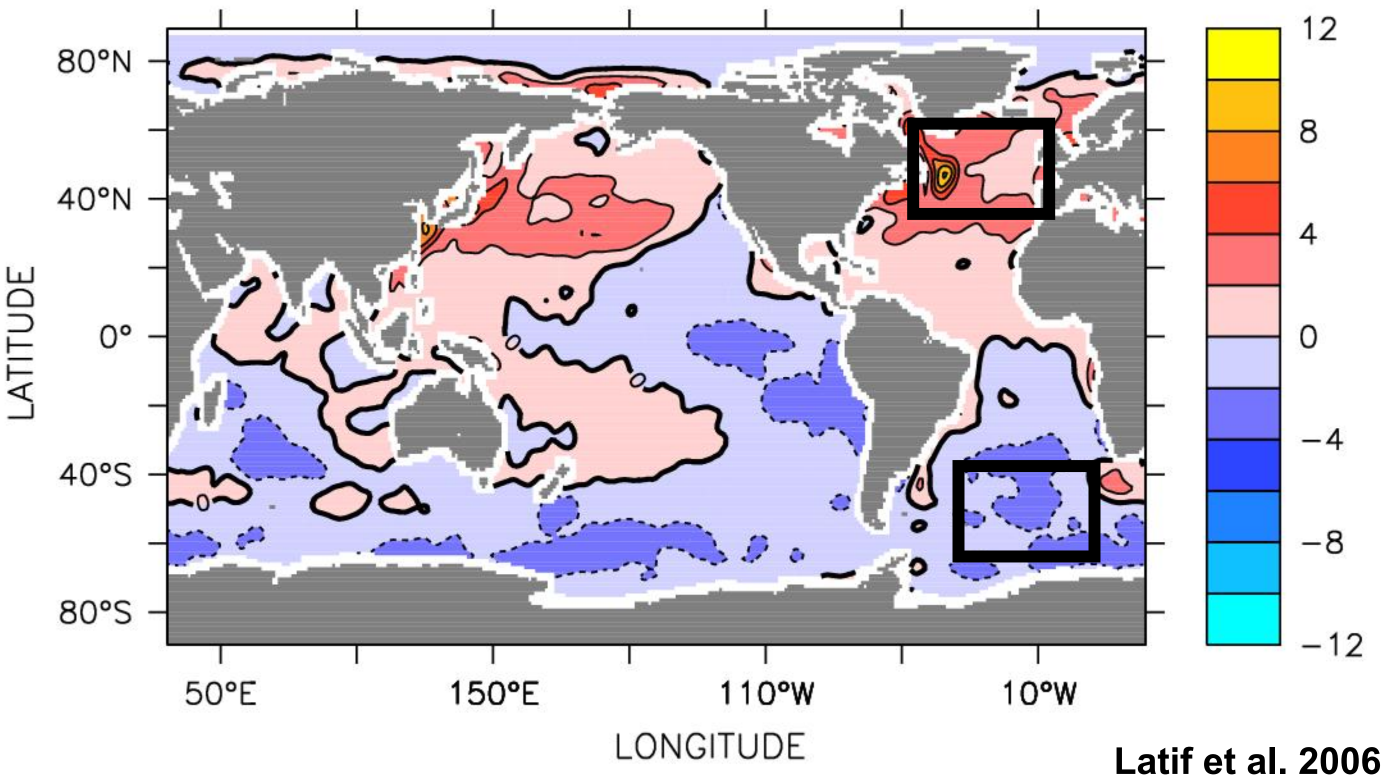
SAT in different zonal bands



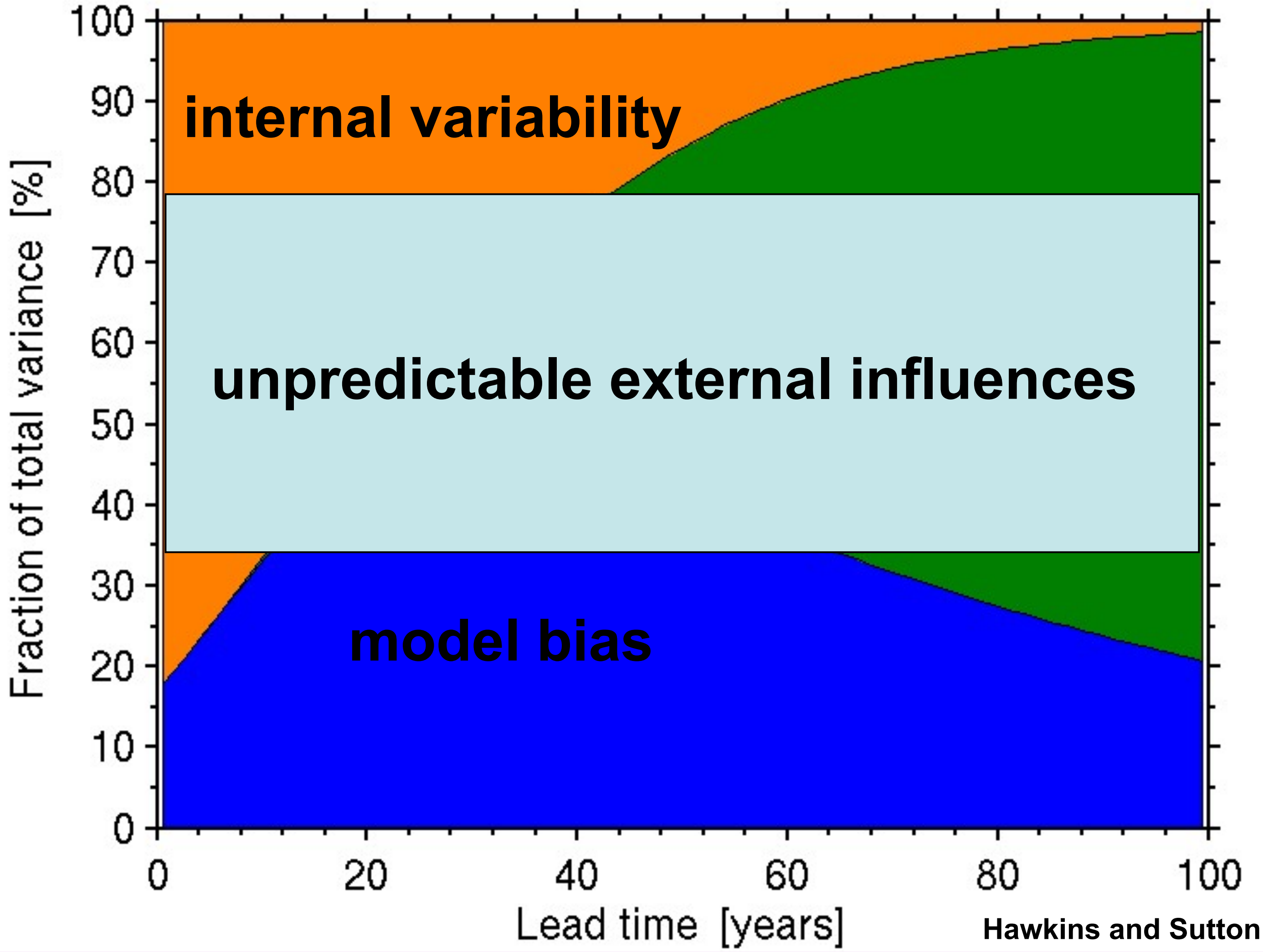
Definition of the „MOC“ - index, SST (NA) – SST(SA)

SST trend 1980-2004, global mean removed



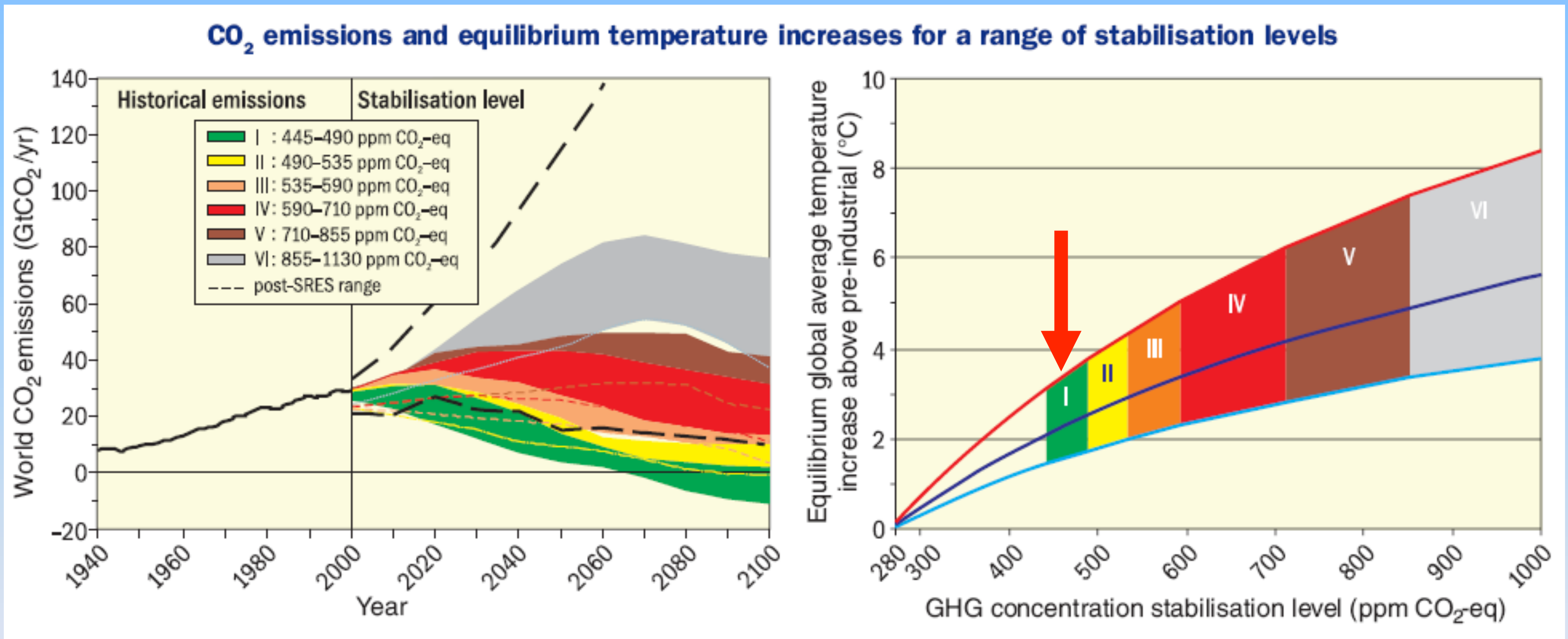
Latif et al. 2006

The uncertainty in climate projections for the 21st century



Hawkins and Sutton 2009

The scenario uncertainty becomes important in the long run



IPCC 2007

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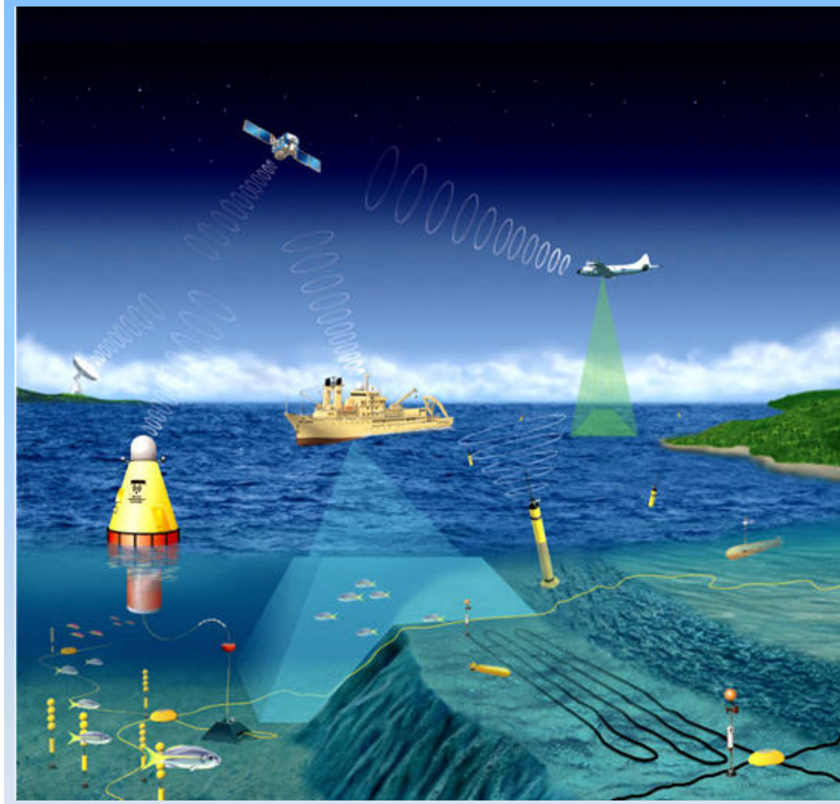
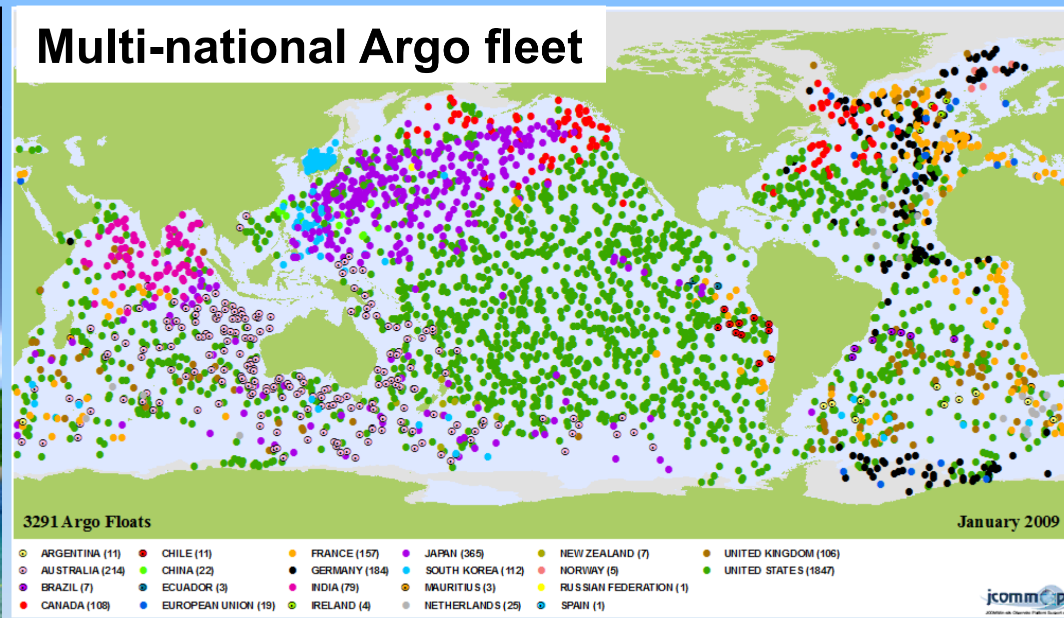
Climate observing system

Example: ocean observing system





We need climate observations to initialize the models to forecast variations up to decadal time scales