Oceans and Climate: Extending the Range of Predictions

Tony Rosati

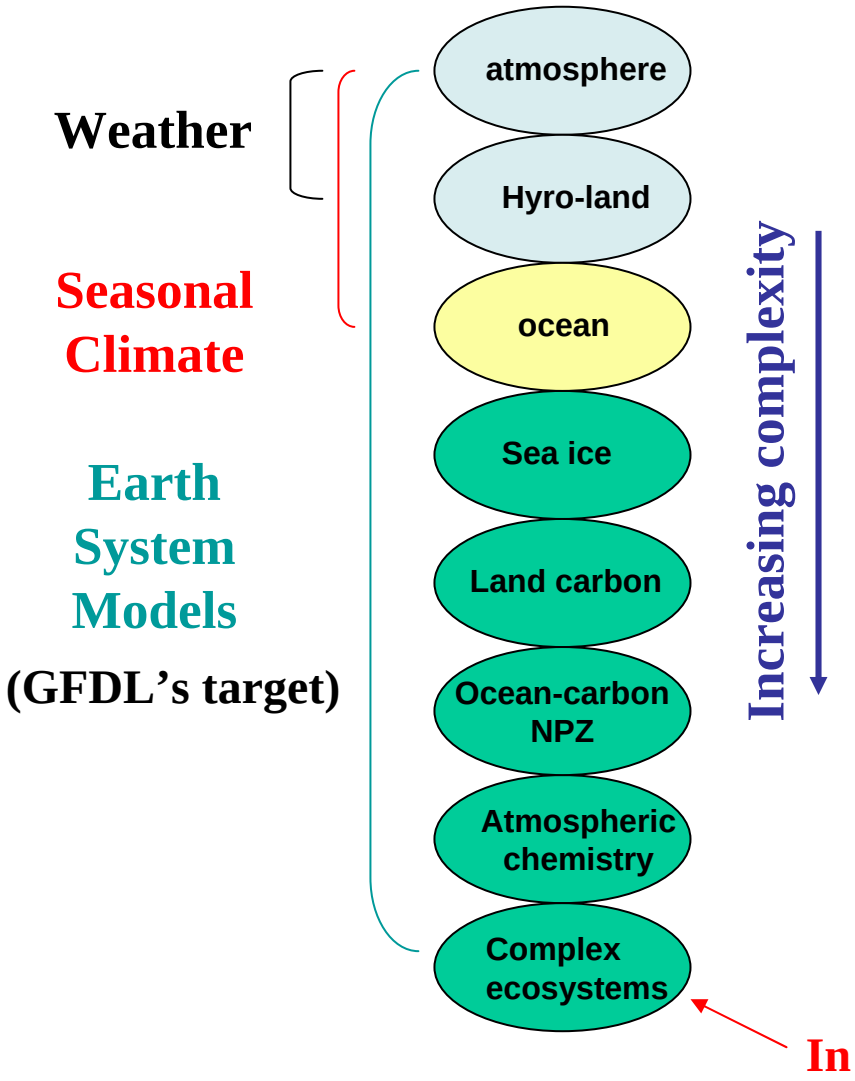
Geophysical Fluid Dynamics Laboratory

Princeton, NJ 08540

Climate's Role in Policy and Management Decisions
(Reincarnation of 1420's Status?)

Unraveling the "black magic" behind climate predictions

Models Enable Understanding, Prediction, and Planning for the Future



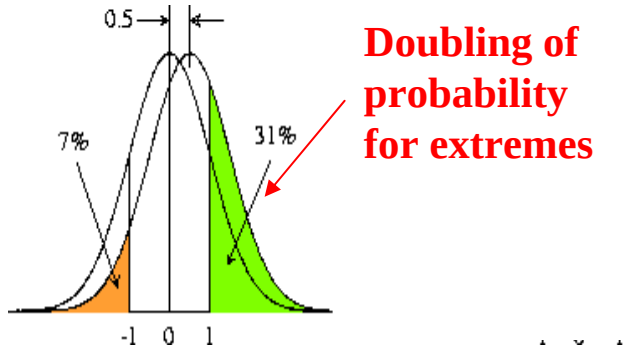
Societal Issues Impacted

Protection of life and property

Resource management (water, agriculture, economy, energy)

Policy issues related to global change and adaptation: changing extremes, environmental and human health, environmental economics, biodiversity, land use

Sources of Predictability



Shifts in distributions change probabilities for extremes

Weather

- Current state of atmosphere
- Deterministic, out to days in advance

Seasonal Climate

- Tropical ocean and land state
- Probabilistic, next seasons of deviations from climatological* seasonal means

Decadal to Centennial Projections

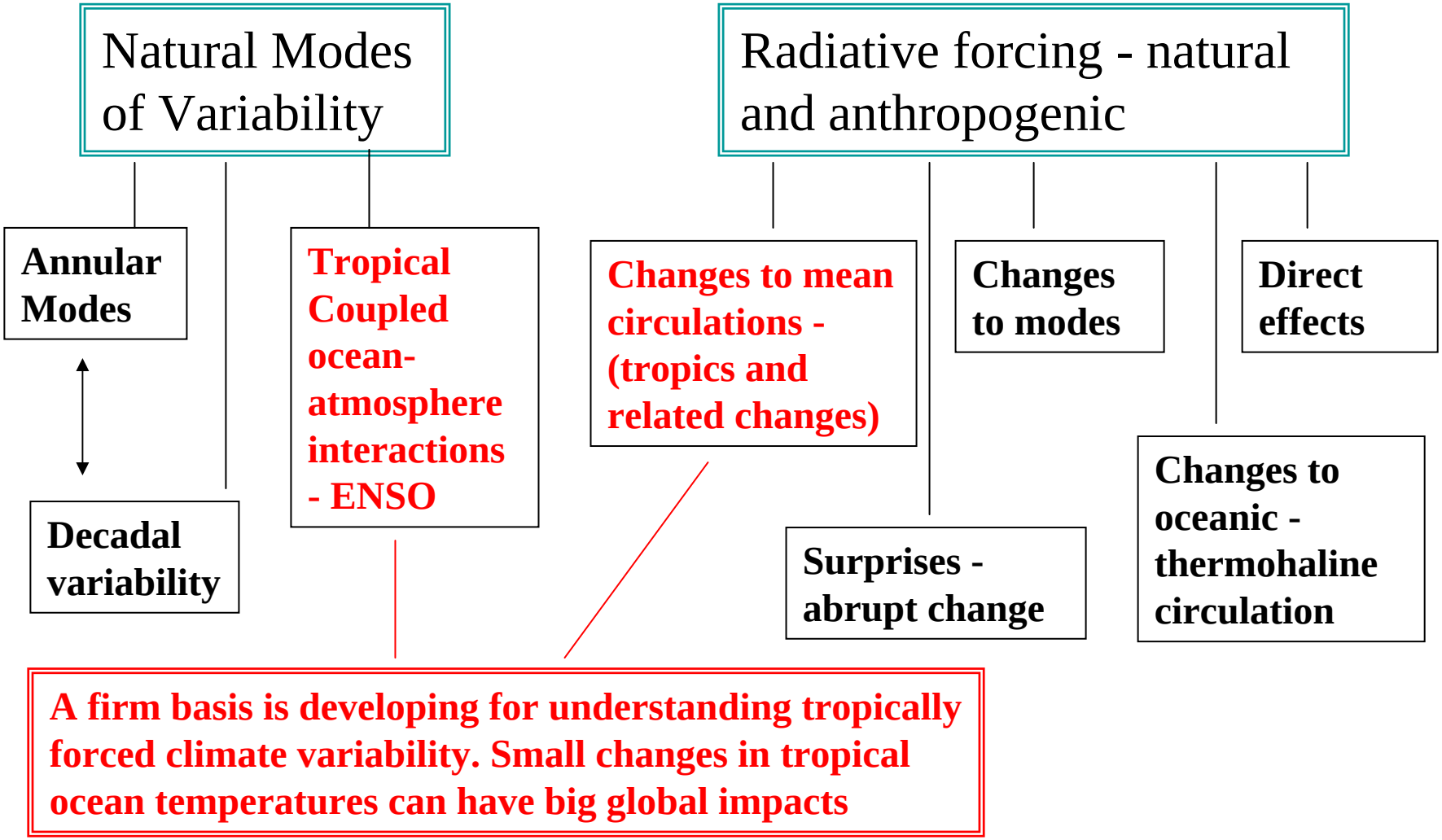
- Changes in solar forcing, volcanoes, natural oscillations
- Anthropogenic greenhouse gas – radiative forcing scenarios
- Probabilistic, scenarios of future climatologies*

*Climatology – a statement of "normal"- typically averages over 30 years of means, extremes, etc.

Linkages exist between centennial –decadal - seasonal – weather regimes

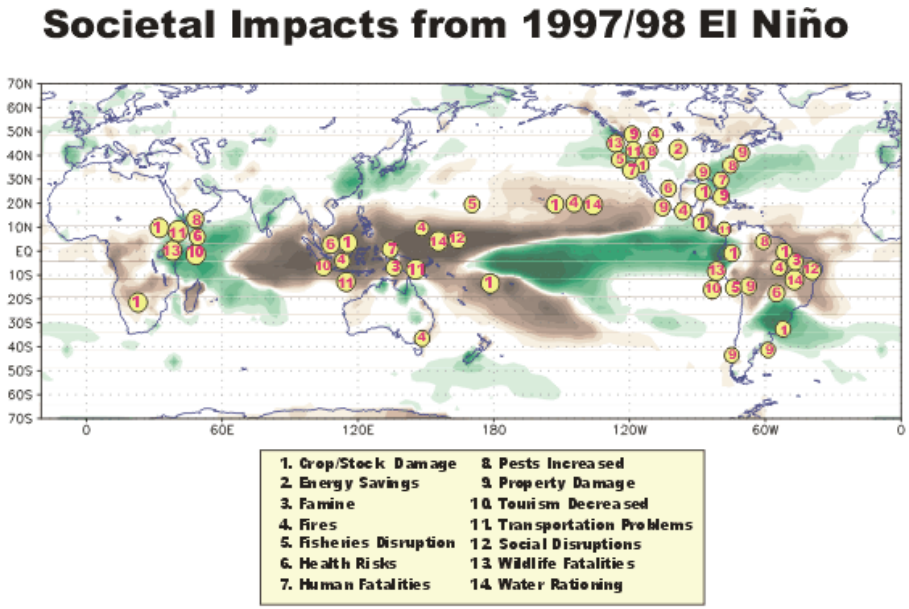
Global Impacts Result from Natural and Anthropogenic Effects

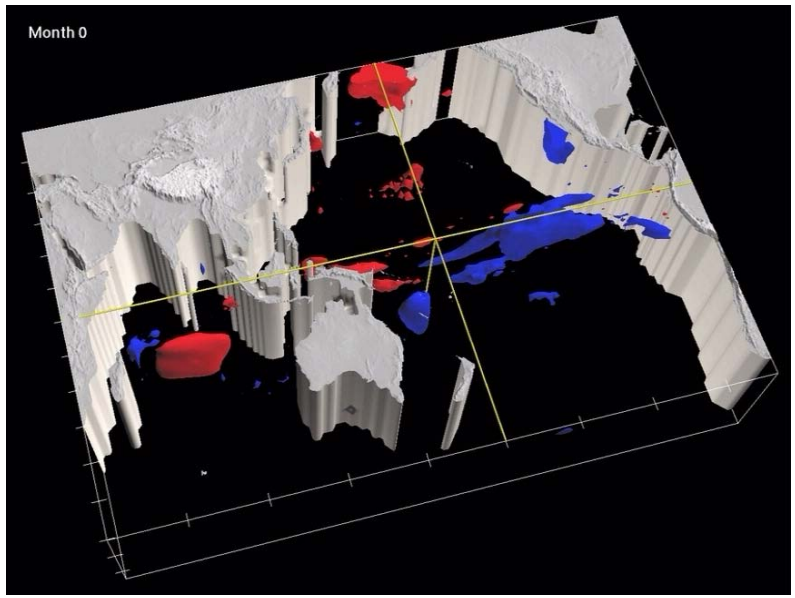
Credible assessments and predictions come from synergistic use of simulations, observations, and numerical diagnostic experiments.



Understanding Ocean-Atmosphere Interactions in the Tropical Pacific has Laid the Foundations for Physics – Based Seasonal Forecasts

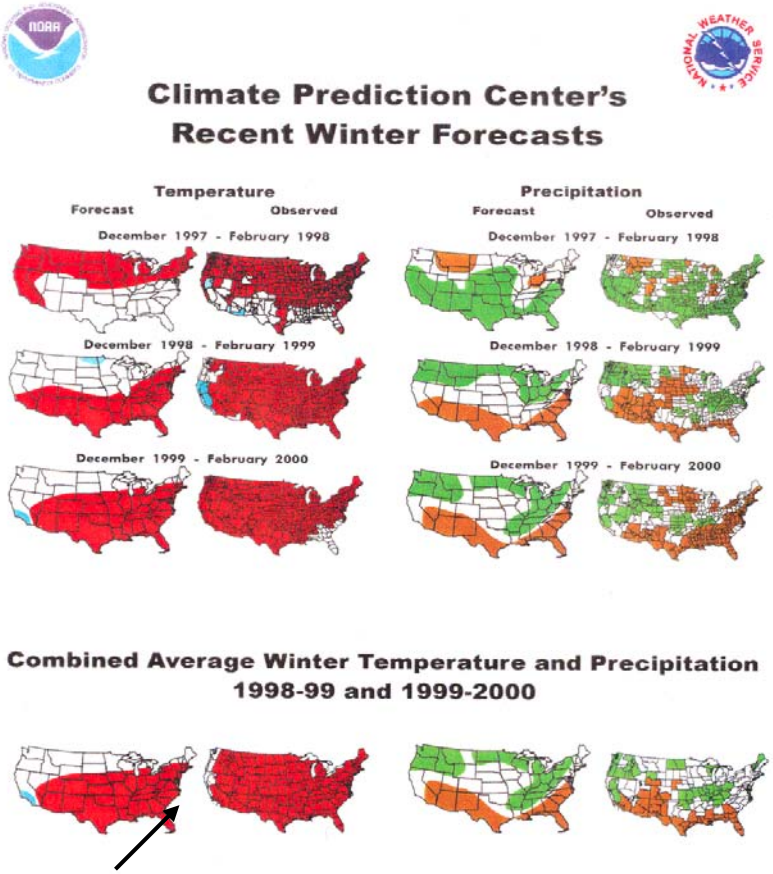
The close interplay between hypotheses, successes in confronting theories and observations, and observed (and attributable) impacts were factor in this success.





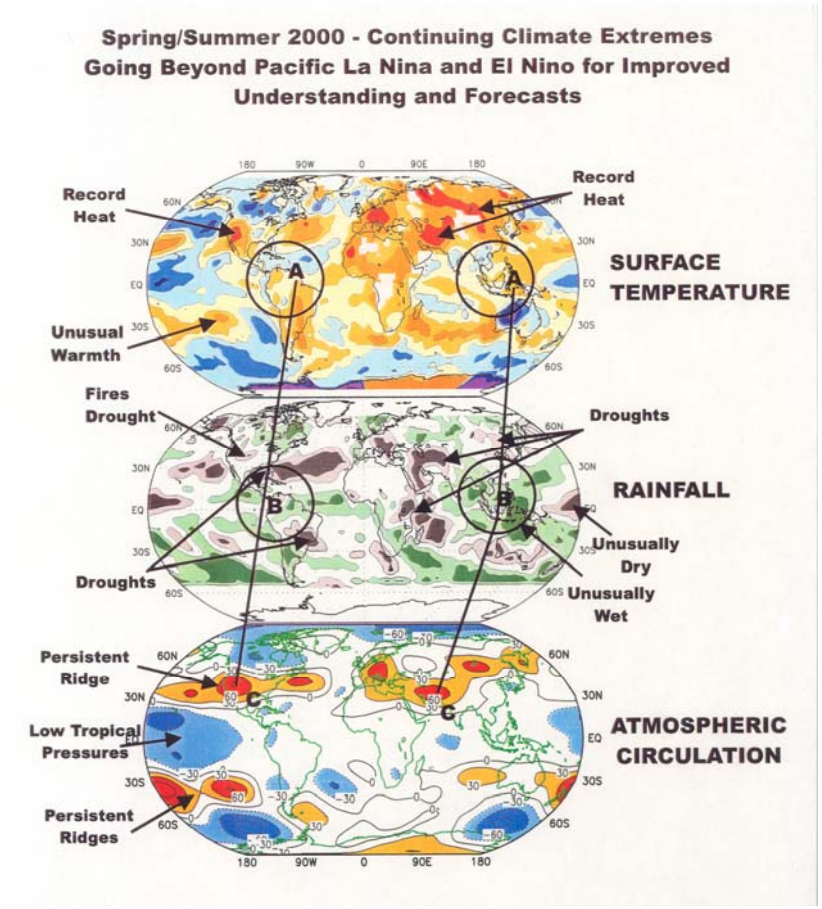
Evolution of El Nino and La Nina

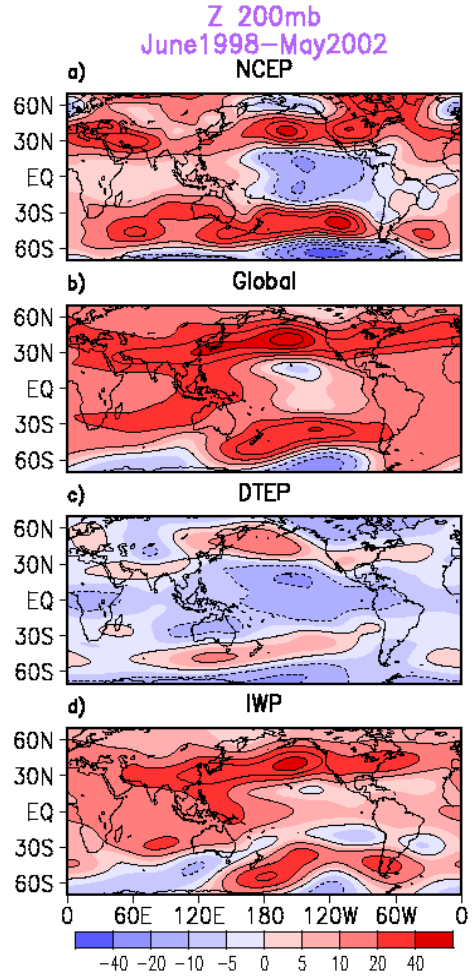
Atmospheric Circulation Pattern Changes Driven by ENSO-related Topical Convections Shifts Enable Predictions of Regional Climate Anomalies



There is more going on than just El Nino/La Nina

Is the character of ENSO changing as a result of global warming- or is there something else going on?





Observations

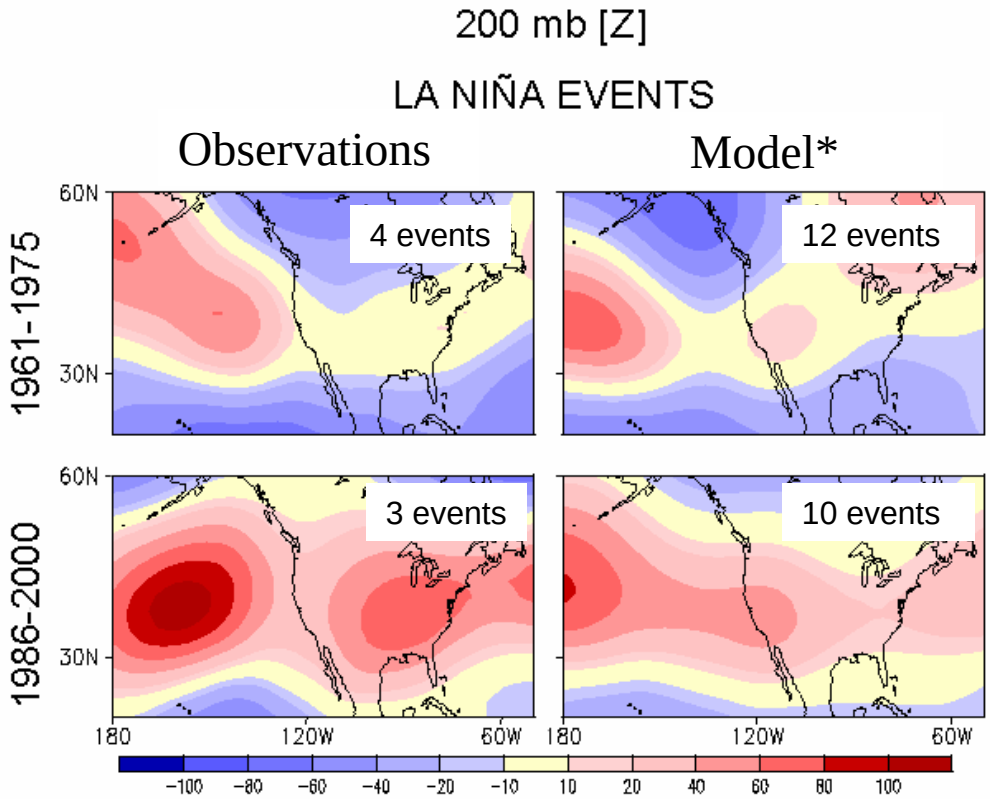
Model forced with observed global SSTA's

Forcing with Pacific SSTA

Forced with Western Pacific – Indian Ocean SSTA

The anomalous ocean warming trend in Indo-Pacific region is the major contributor to recent global droughts and heat waves

Are the Impacts of Seasonal Climate Variability Changing Over North America?

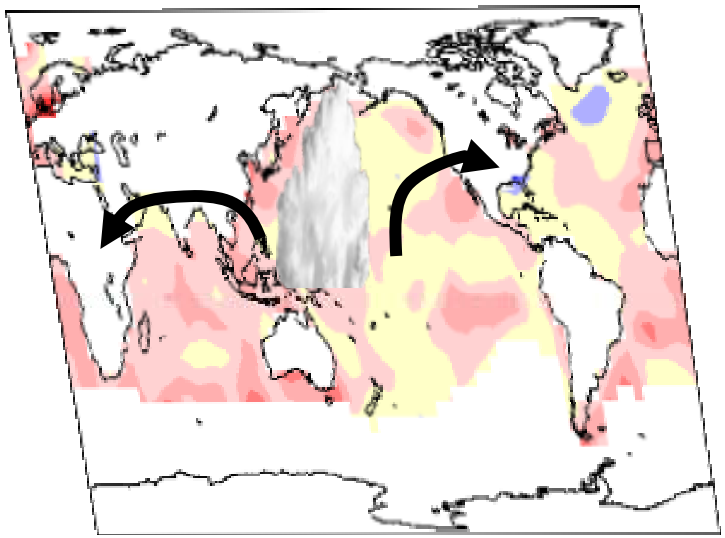


Warmer and drier

Model – runs started in 1860 and forced with natural and anthropogenic changes to radiative forcings. Wintertime pattern. Same tendency occurs for El Nino events

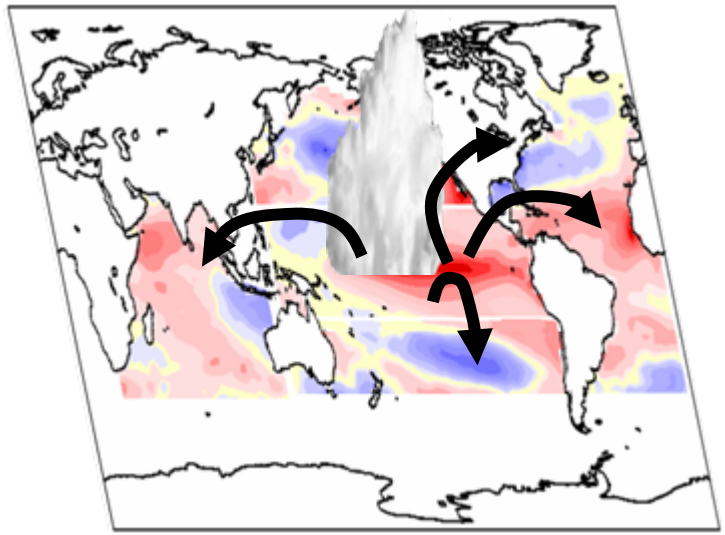
A Growing Awareness That Changes in Tropical Convection on Variety of Timescales Alter Global Circulation Patterns

Multi-year to decadal time scales implicated in global droughts, heat waves, other environmental impacts



"small" but persistent trend in ocean warming and eastward shift of convection

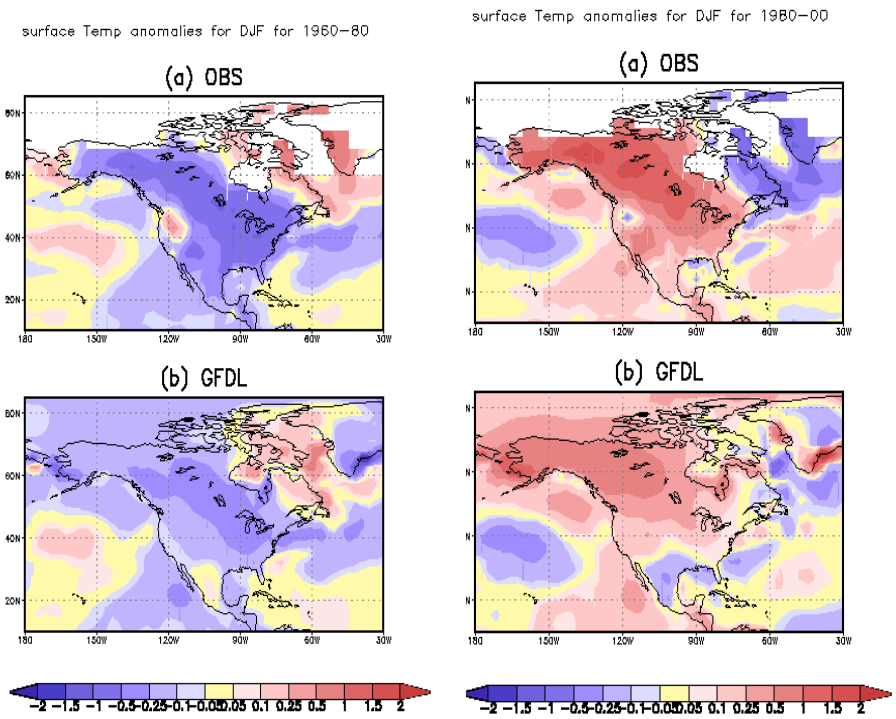
Seasonal to Interannual Time Scales – ENSO related impacts



Large interannual east-west shifts in convection

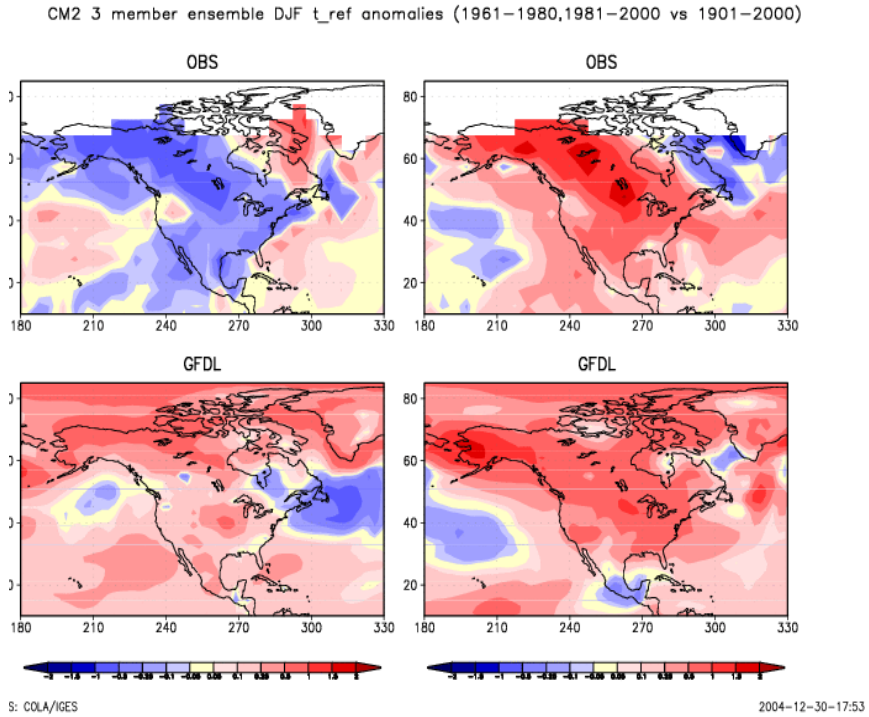
Some Regional Decadal Predictability is Associated with Global Warming

Model forced with observed SSTs



Ocean specified - land predicted

Specified radiative forcing from 1860

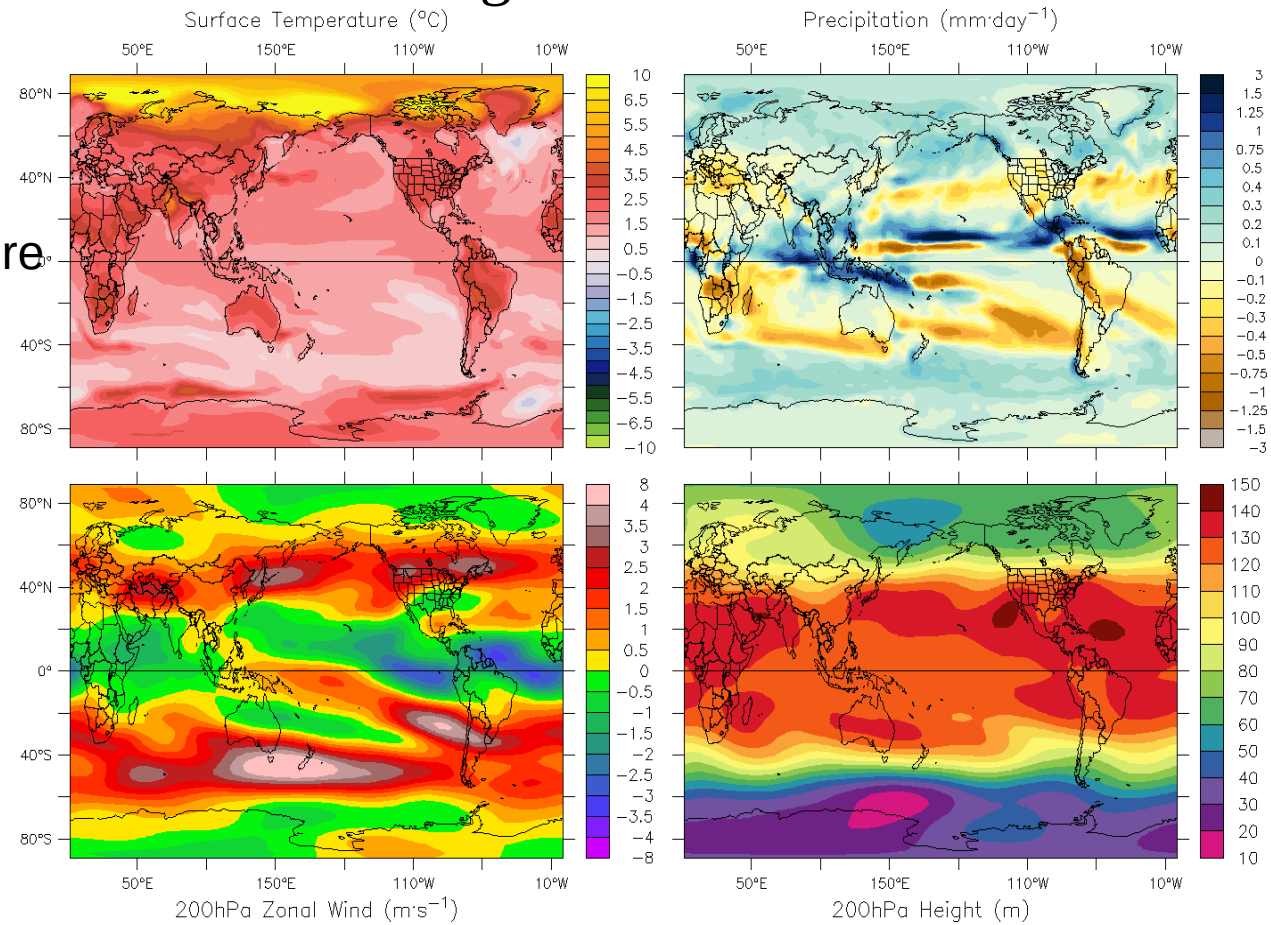


Ocean and Land predicted, but missing impacts of natural decadal variability

What Future Changes Might be Anticipated?
Changes in Fall at 2X

Surface temperature

rainfall



U200

Z200

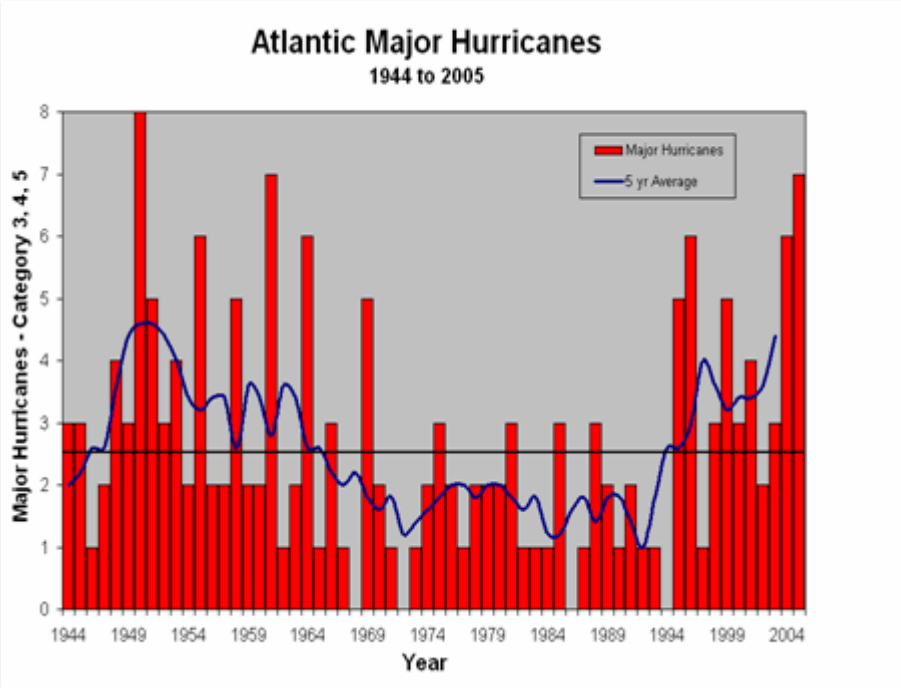
SON Differences of 2x from 1860–Run

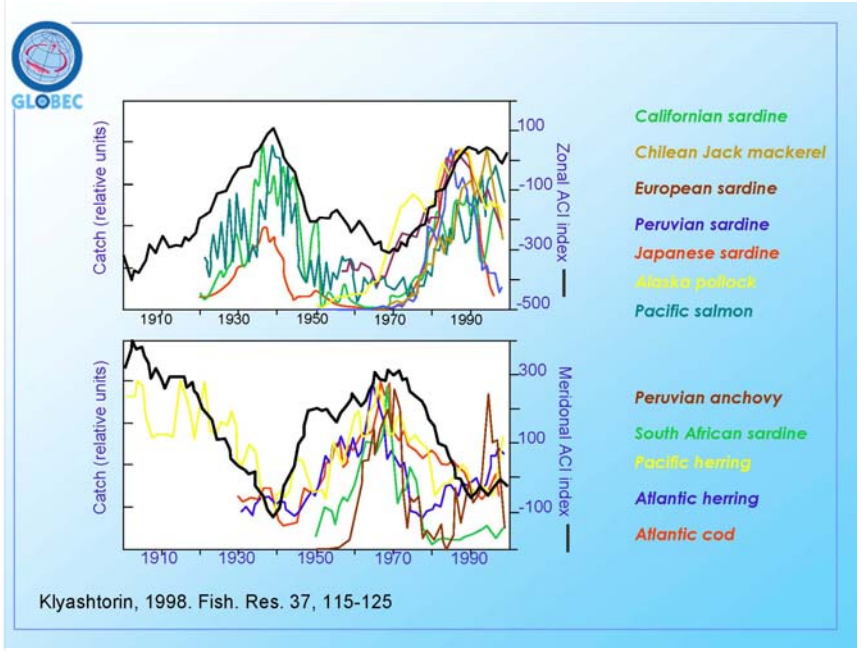
The poleward expansion of the subtropical highs is most pronounced in fall and summer. These results are robust across most climate models.

Understanding Both Natural Climate Variability and Global Warming is Critical for Attribution Studies

Global decadal climate variability underlies much of these variations

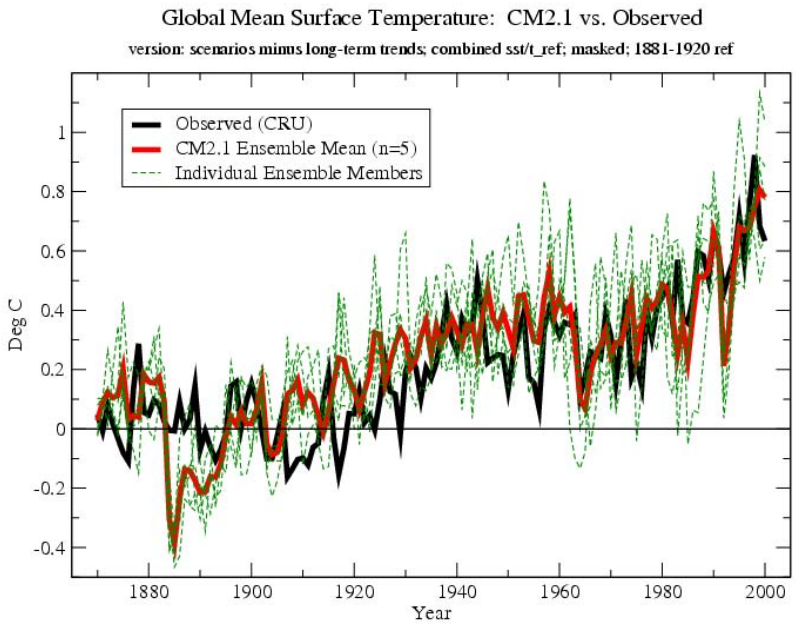
What are the common mechanisms linking droughts, hurricanes, fisheries?



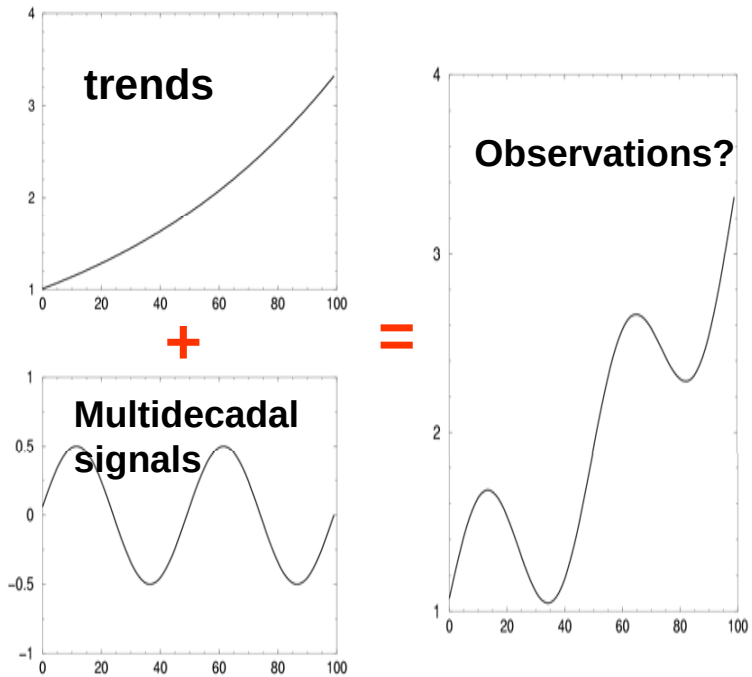


How Well Do We Understand the Climate of the 20th Century?

Successful Simulations?

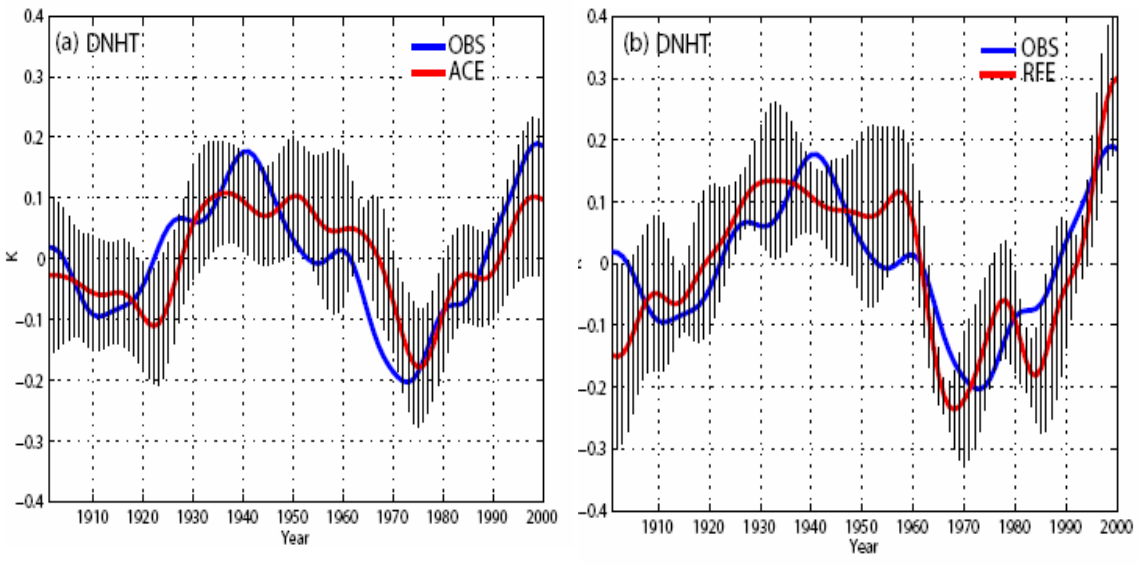


Or is the explanation more complicated?



What is the Origin of the Decadal Variability in Northern Hemisphere Temperatures?

(Blue: Observed temperatures with the linear 100 yr trend removed)



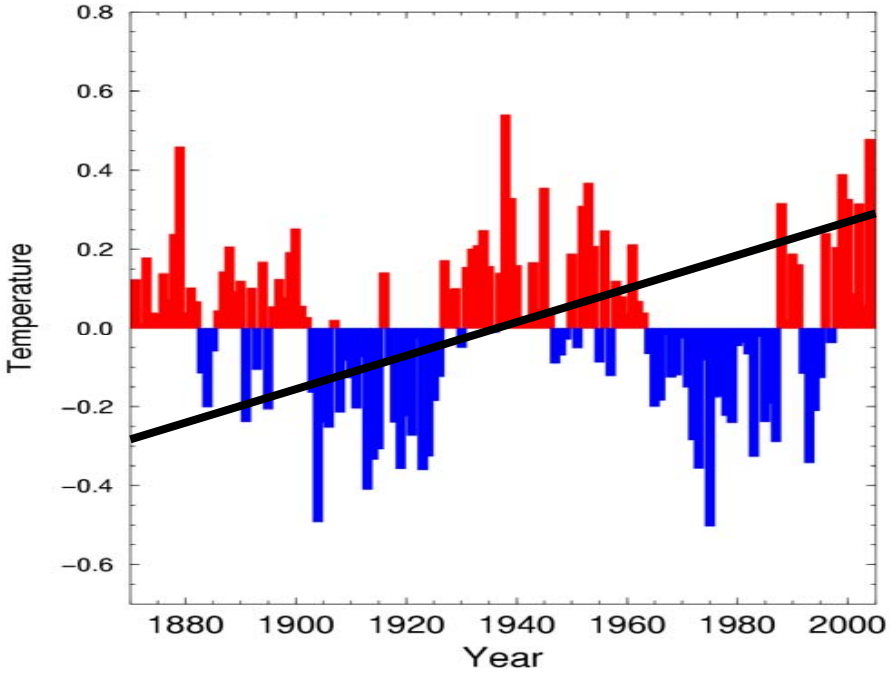
Red: ensemble mean temperature where Atlantic temperatures were specified

Red: ensemble mean when model forced with radiative forcing with linear trend removed

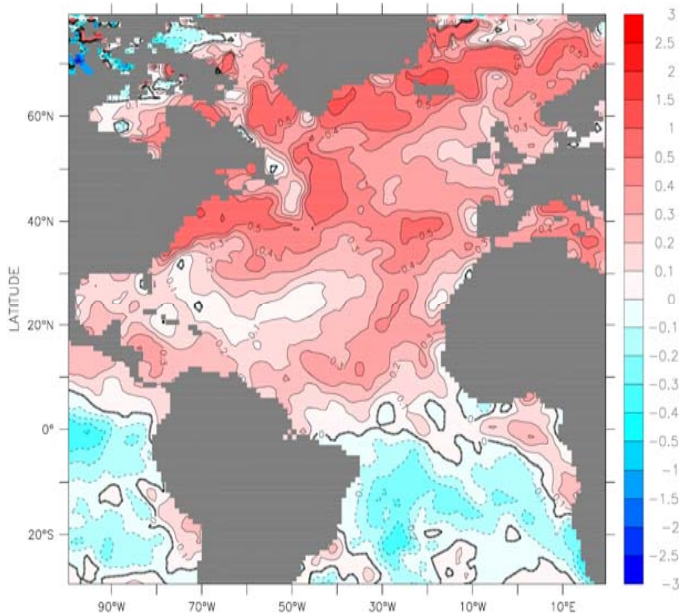
Is there a link between radiative forcings and Atlantic decadal variability??

Decadal Variability is a Major Factor in Atlantic During the 20th Century

Average North Atlantic Temperatures with trend removed



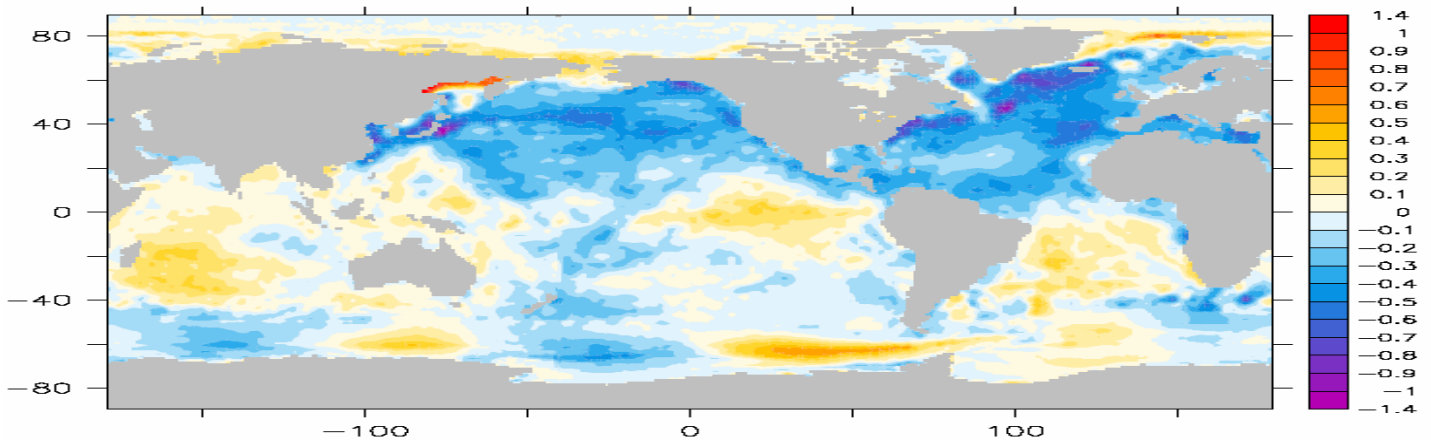
Sea Surface Temperature (SST) Differences 1941-1960 minus 1965-1984



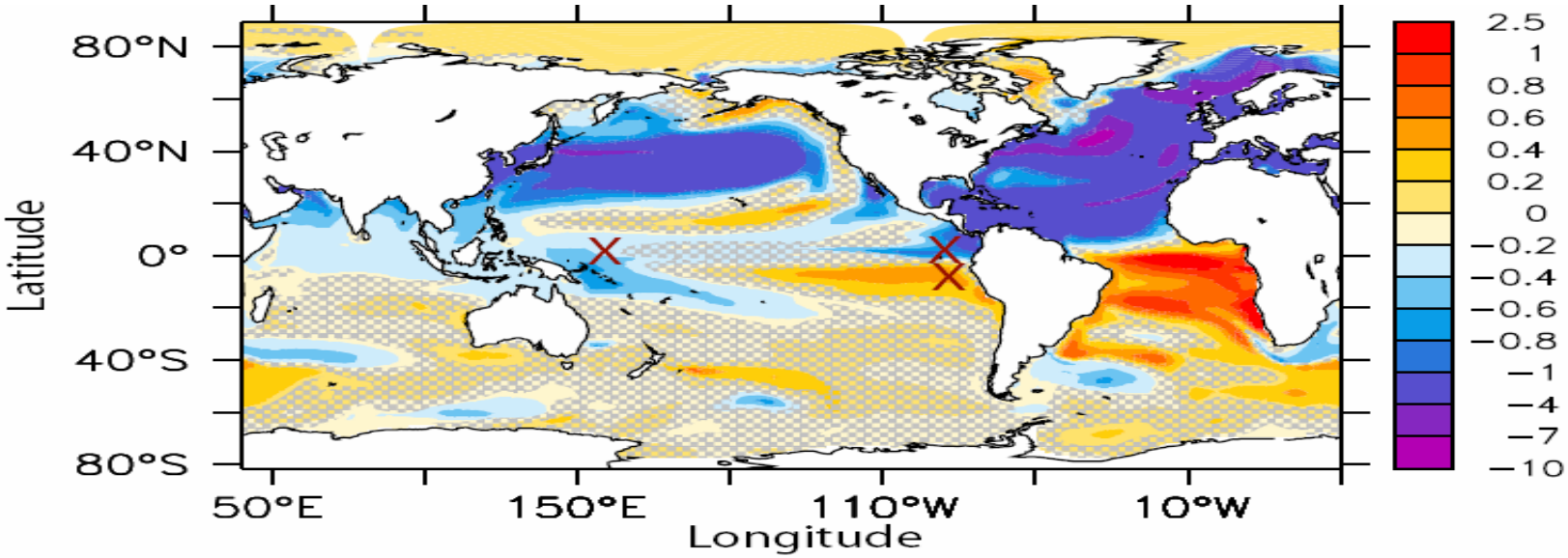
This variation is termed the Atlantic Multi-Decadal Oscillation (AMO)

Atlantic Changes (Decadal and Longer) Have Global Impacts

Observed SST Difference (1971-1990) – (1941-1960) (HadISST, detrended)

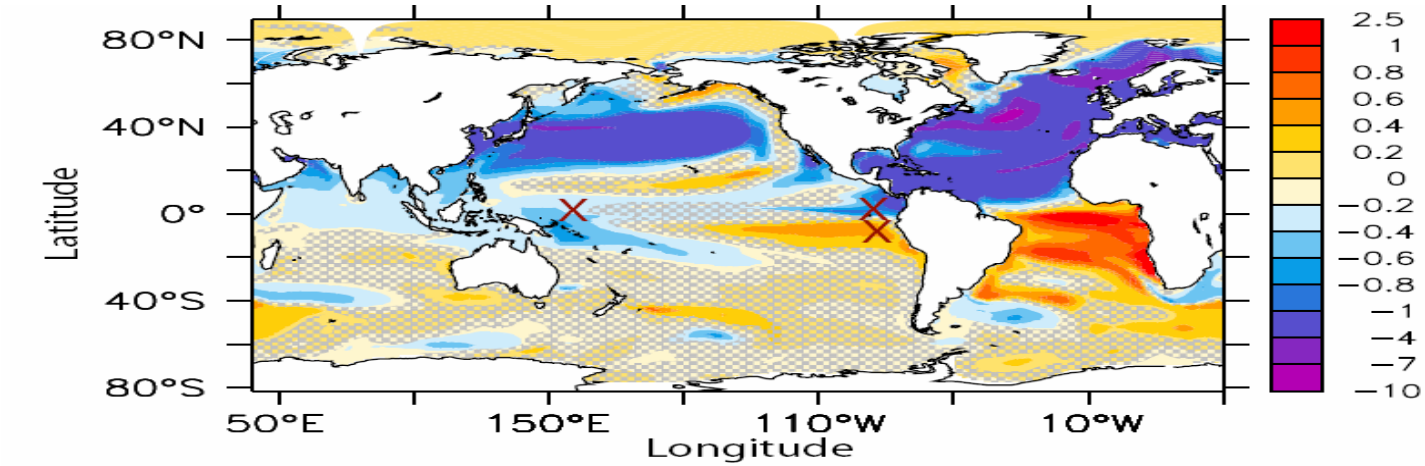


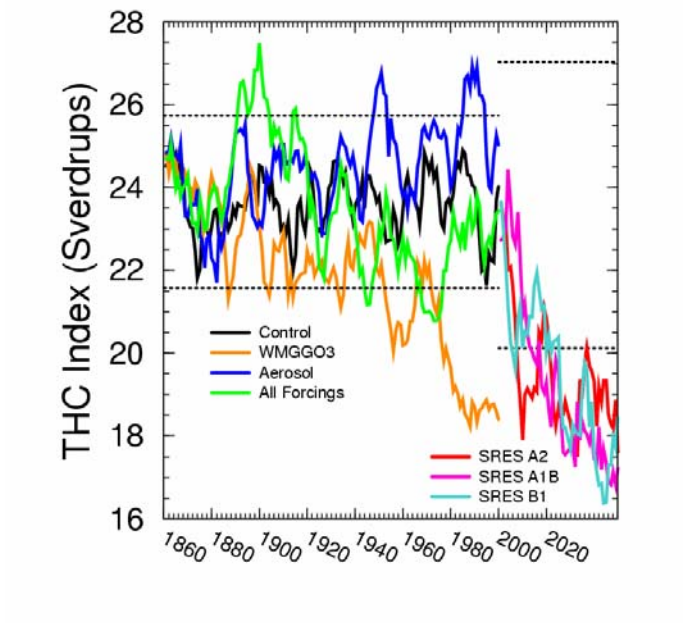
Simulated SST anomaly from the water-hosing experiment (Zhang and Delworth 2005)



What is the Potential for Abrupt Changes in the Near Future?

Global temperature changes resulting from an Atlantic THC shut down



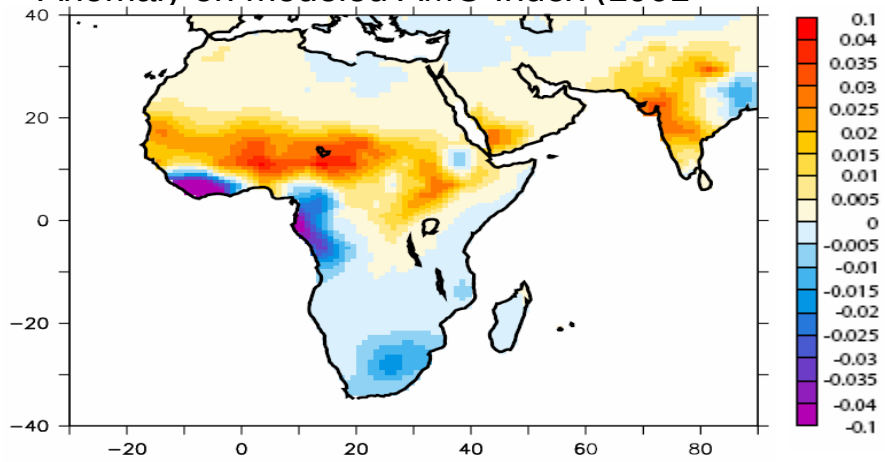


Models suggest a slow down of the Atlantic thermohaline circulation (THC) in the 21st C

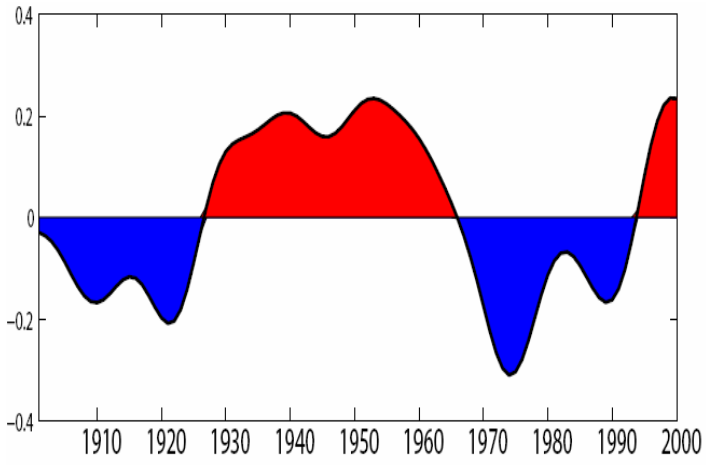
Note: the aerosol effects have delayed the onset of this

The AMO is Linked to Regional Rainfall Anomalies

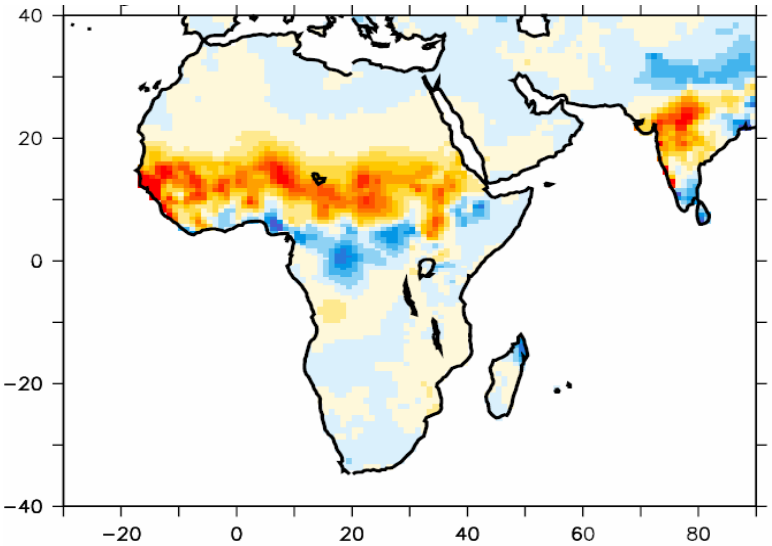
Regression of modeled LF JJAS Rainfall Anomaly on modeled AMO Index (1901-



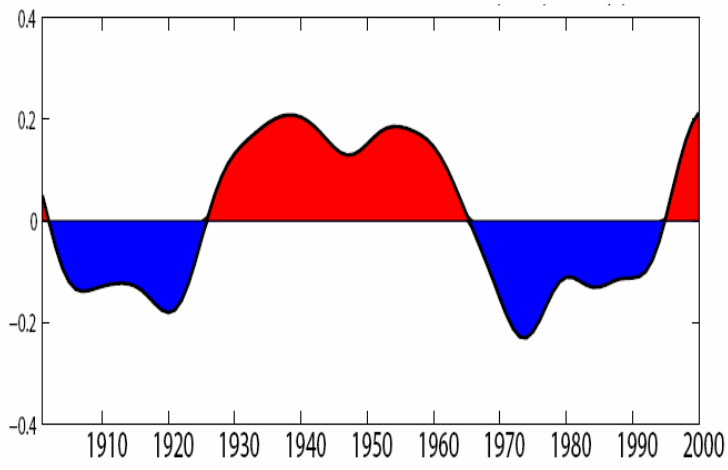
Modeled AMO Index



Regression of observed LF JJAS Rainfall Anomaly (CRU data) on observed AMO Index

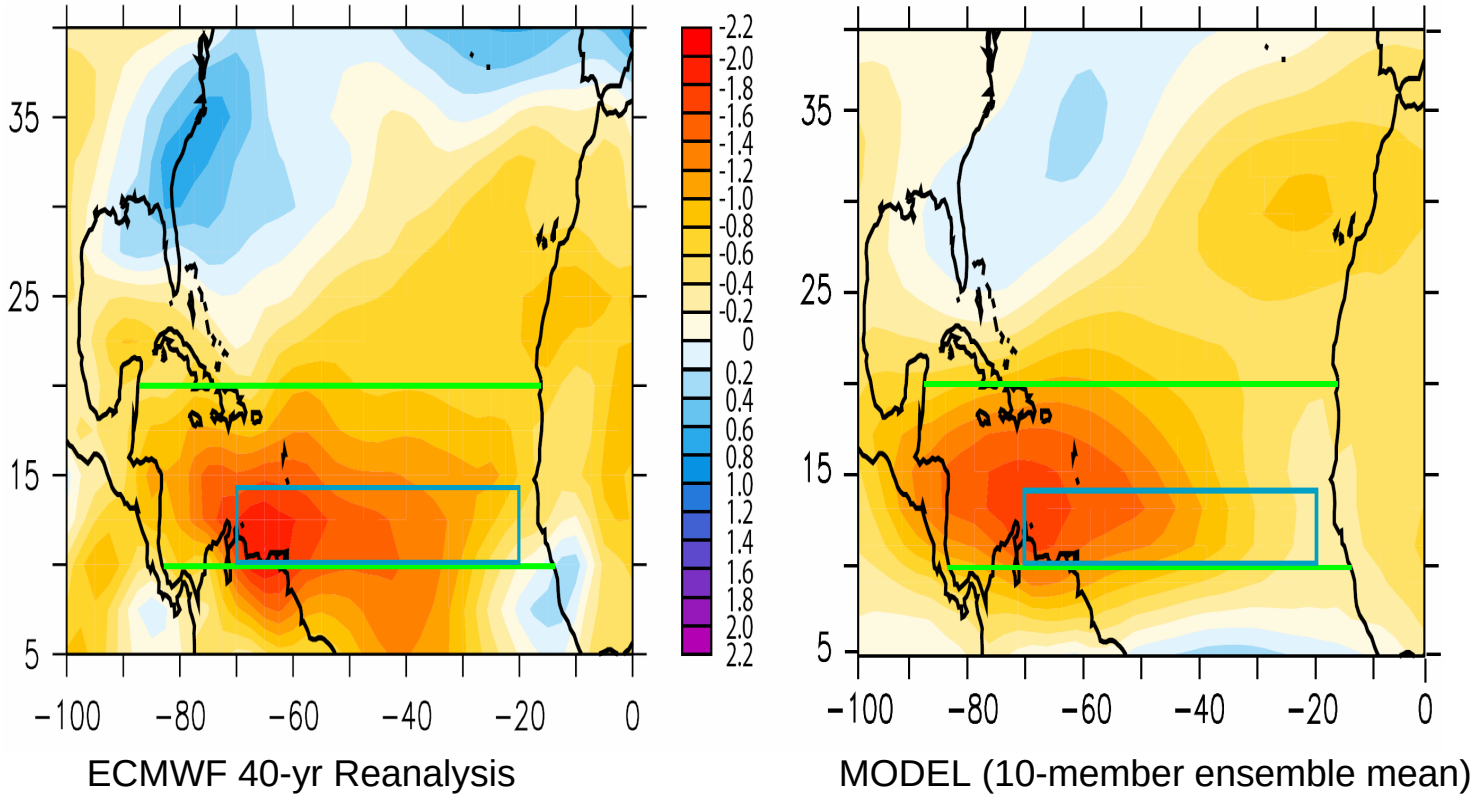


Observed AMO Index



The AMO Has Played an Important Role During the 20th Century in Decadal Modulation of Hurricane Activity

Regression of LF ASO vertical shear of zonal wind (m/s) on AMO index (1958-2000)



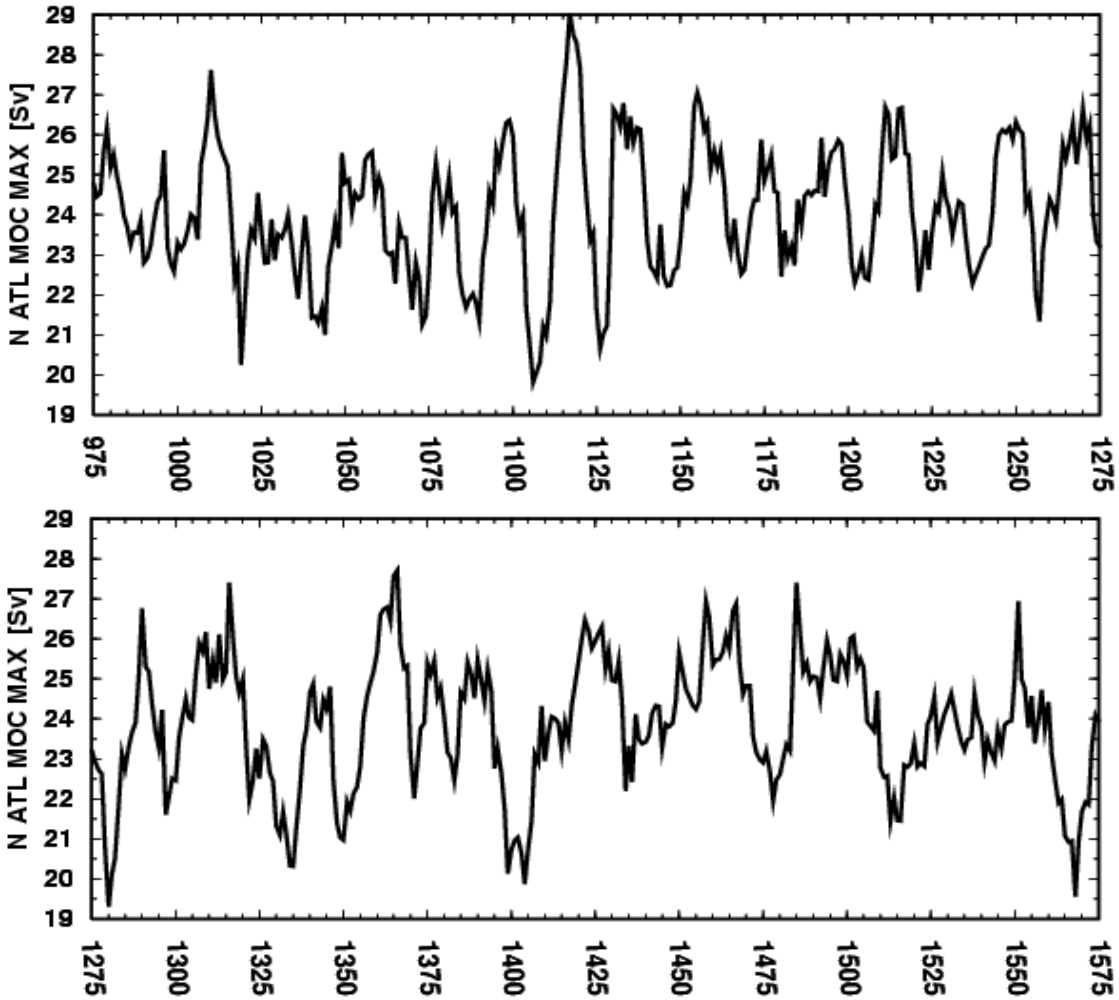
ECMWF 40-yr Reanalysis

MODEL (10-member ensemble mean)

Studies, which are currently under way to study the decadal predictability of the AMO, show some promise

Decadal Variability is Present in GFDL's Models – This Enables Decadal Predictability Studies

The N. Atl. MOC in the 1860 Control



Decadal Predictability Experimental Design

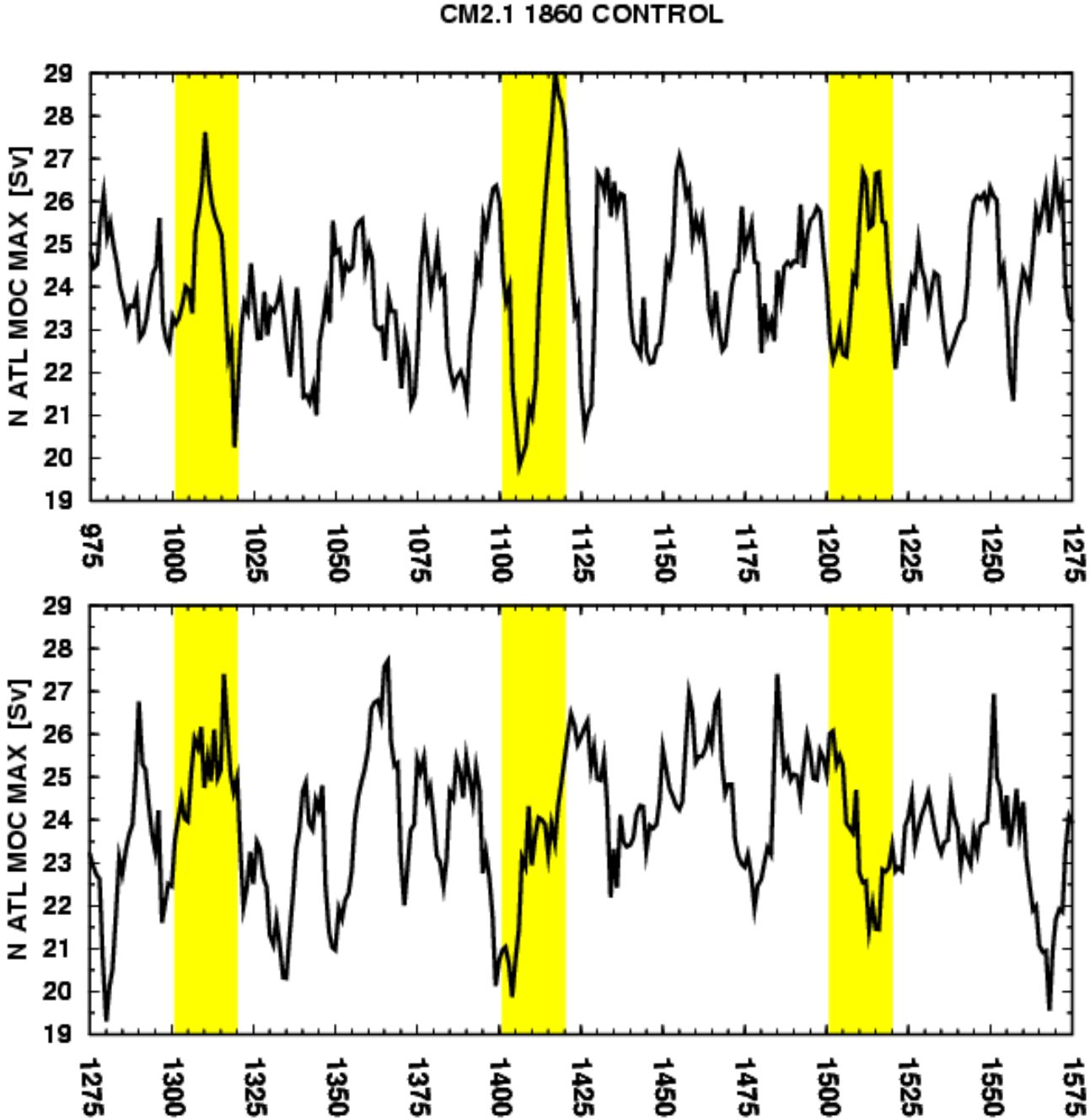
Our investigation begins by arbitrarily selecting 6 points in time from the long control experiment.

The 6 "initialization points" are separated by 100 years. (1 Jan 1001, 1101, 1201, 1301, 1401 & 1501)

We first focus on the annual mean N. Atlantic MOC strength for the 20 year periods beginning at each of the 6 initialization points. So, they are…

1001-1020	**1301-1320**
1101-1120	**1401-1420**
1201-1220	**1501-1520**

The N. Atl. MOC in the 1860 Control

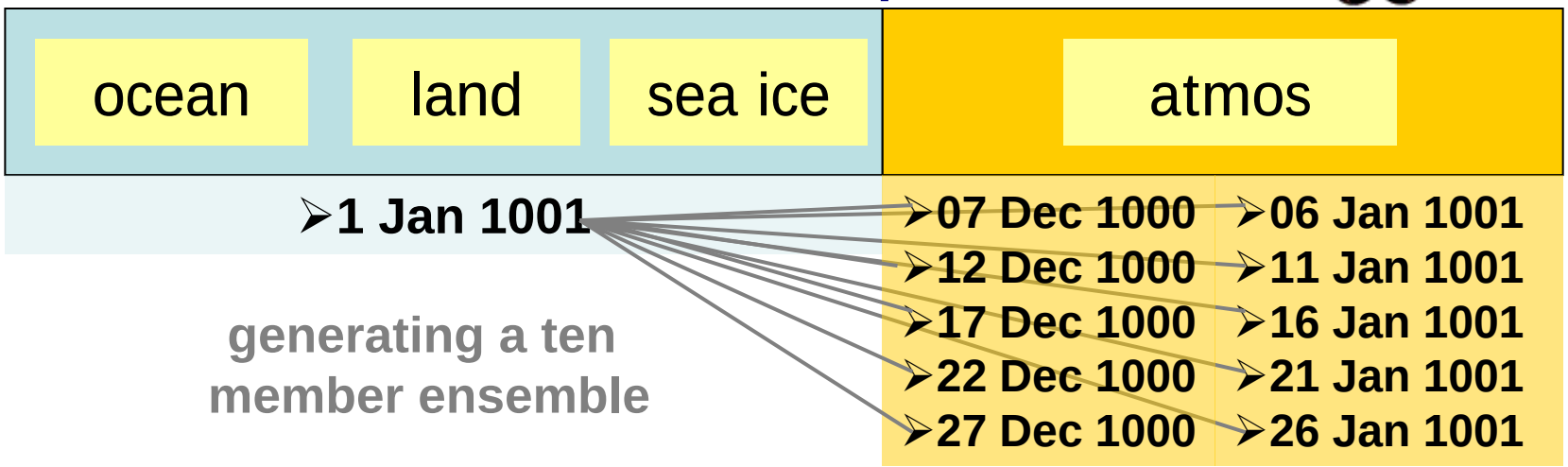


Preliminary Experimental Design

Building some small ensembles:

The CM2.1 model produces a separate restart file for each of its 4 main subcomponents.

In our first line of inquiry, we generated ensembles of 20 year long runs by mixing atmospheric restarts drawn from days >5 days and < 1 month from the 1 Jan initialization used for the ocean, land & sea ice restarts. For example…

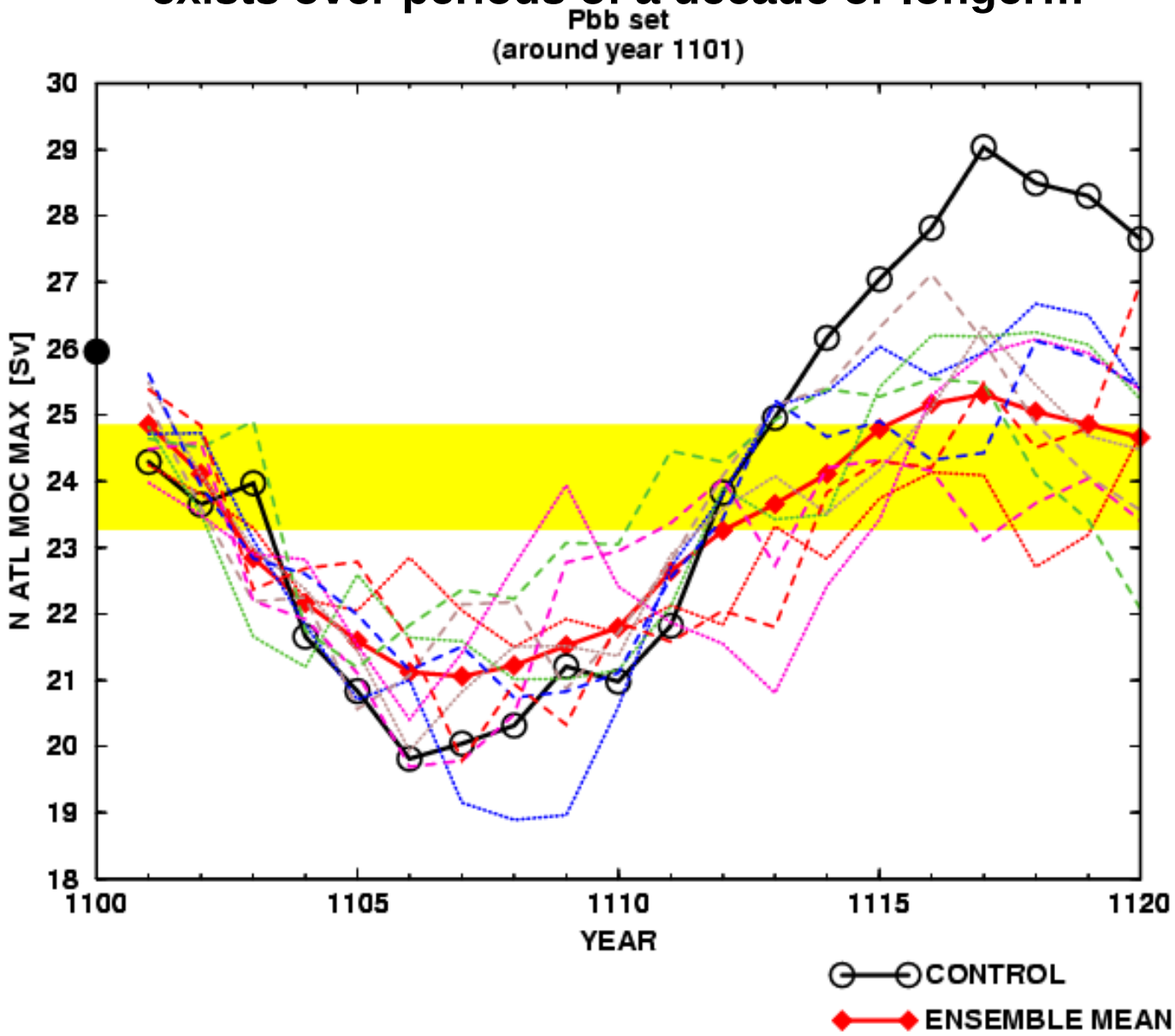


2 ways (of many) of looking at the ensemble results…

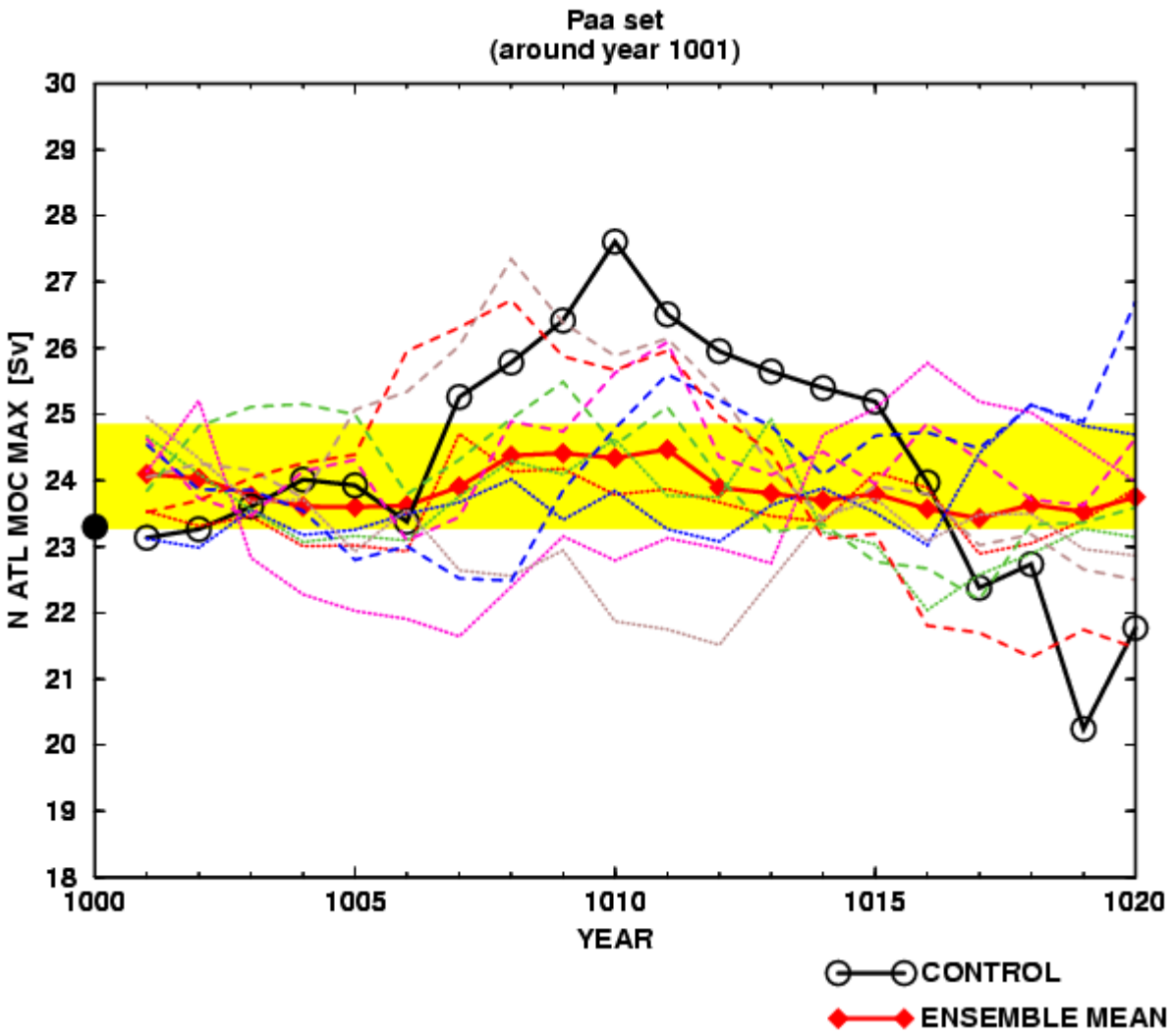
1) Treat the original control model results as the "truth" and compare the ensemble to the truth, year by year, to get a skill score measure (e.g., RMSE). Determine if the skill of the ensemble is significantly better than the model climatology or persistence.
2) Consider potential predictability to exist as long as the ensemble forecast distribution can be distinguished from the climatological distribution (e.g., via Kuiper statistic).

   Quantitative evaluations will be made when the ensemble size is expanded.

?? Will the ensemble members suggest Atl. MOC exists over periods of a decade or longer…



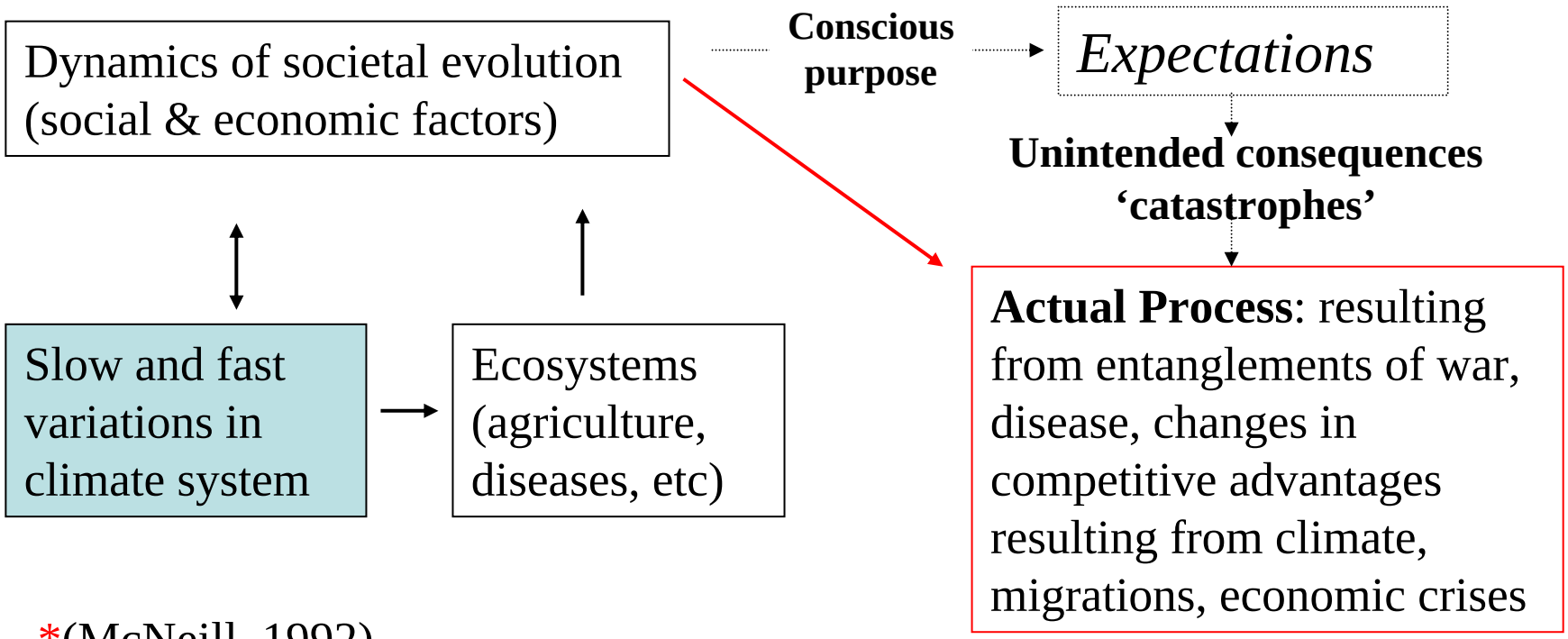
…or not? And why?



•Climate impacts result from complex interactions between natural and anthropogenically induced climate phenomena

•Research is unraveling these interactions to enable a 'predictive understanding' of our future

•Climate and Societal Impacts, a much more complex problem: 'Conservation of Catastrophes*'



*(McNeill, 1992)