Developments in Climate Modeling and Prediction

Can we make useful climate predictions for 2030?

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The Climate Prediction Problem/Paradox

We can predict the weather one week into the future…

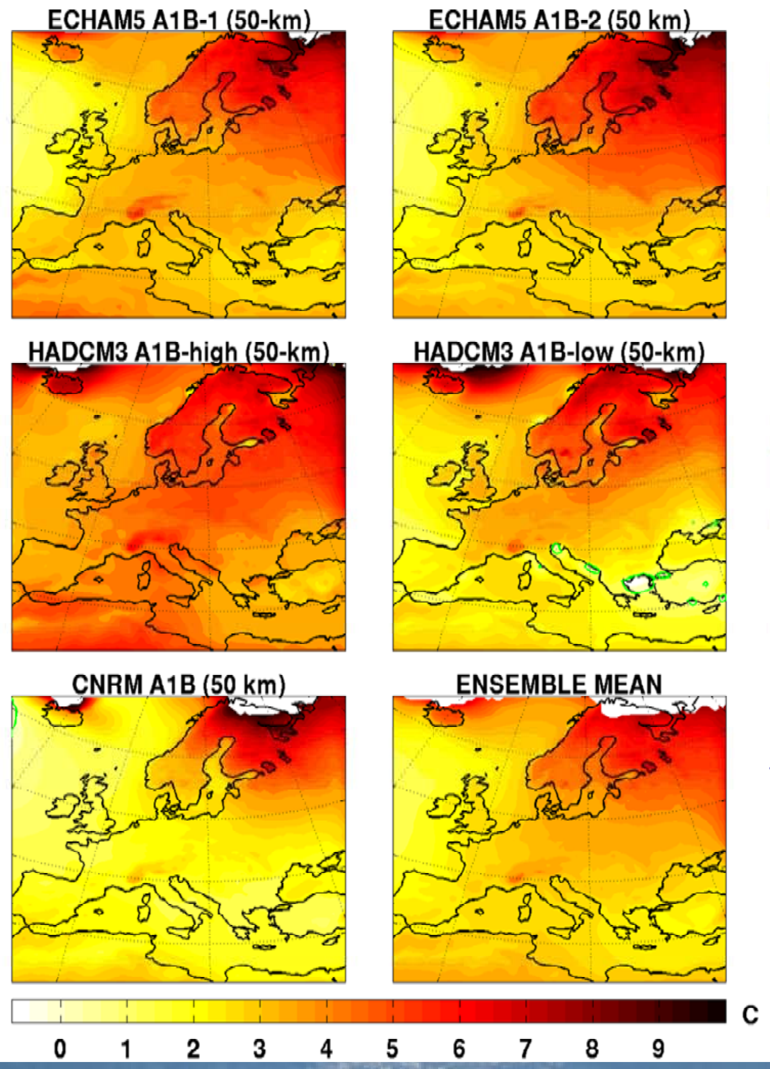
We confidently state that by 2100, anthropogenic global warming will be easily recognisable against natural climate variability…(cf., IPCC simulations)

Yet we make no statements about the climate of the year 2015 or 2022 or even the period 2030-2035

Why is this ? When might we be able to say something useful on these timescales?

Jochem Marotzke, MPI, Hamburg

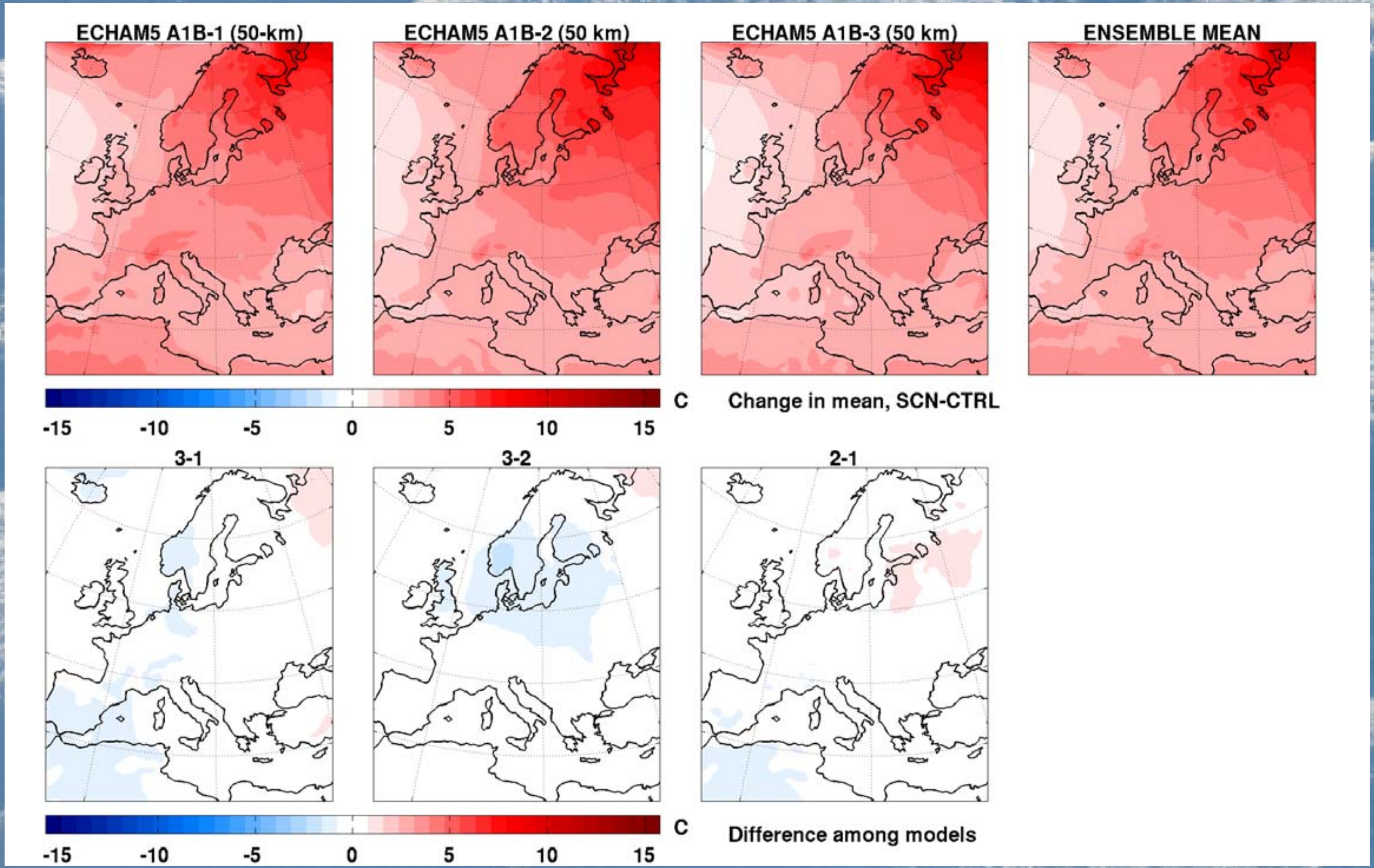
Change in winter surface temperature (2061-2090)-(1961-1990) for A1B scenario, as downscaled by a single RCM for a range of GCMs and an ensemble of common GCMs each started from different initial dates



The Climate Change signal is large and robust for all GCMs by the end of the Century.

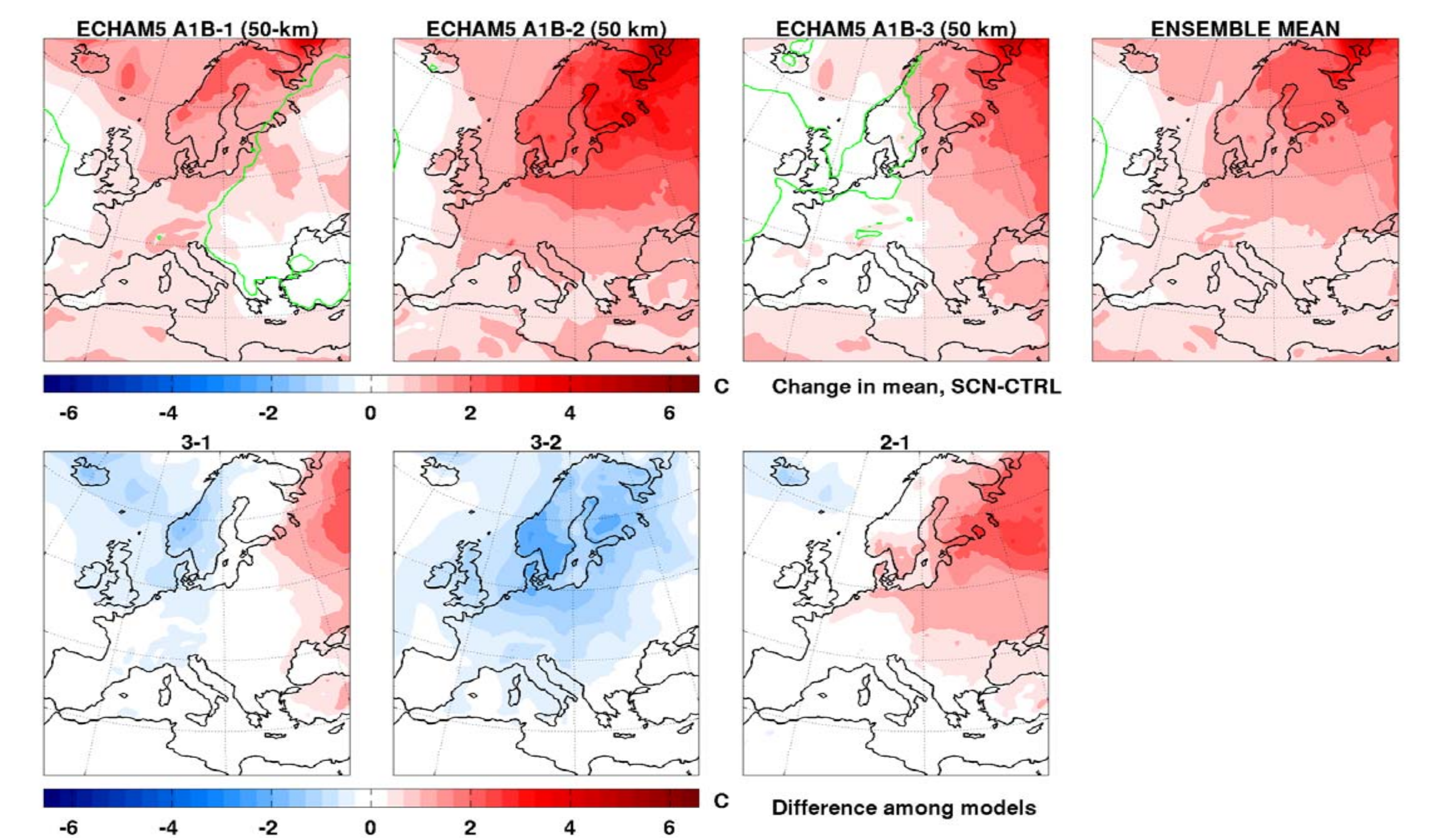
Figure courtesy G.Nikulin SMHI

Comparing 3 RCM runs all using the ECHAM5 A1B GCM as boundary forcing but with each ECHAM5 run started from a different date in 1860, allows for an estimate of the variability of the simulated climates in 2061-2090.



The model estimate of natural variability (as defined by different initial dates) is a lot smaller than the forced climate change signal by 2075

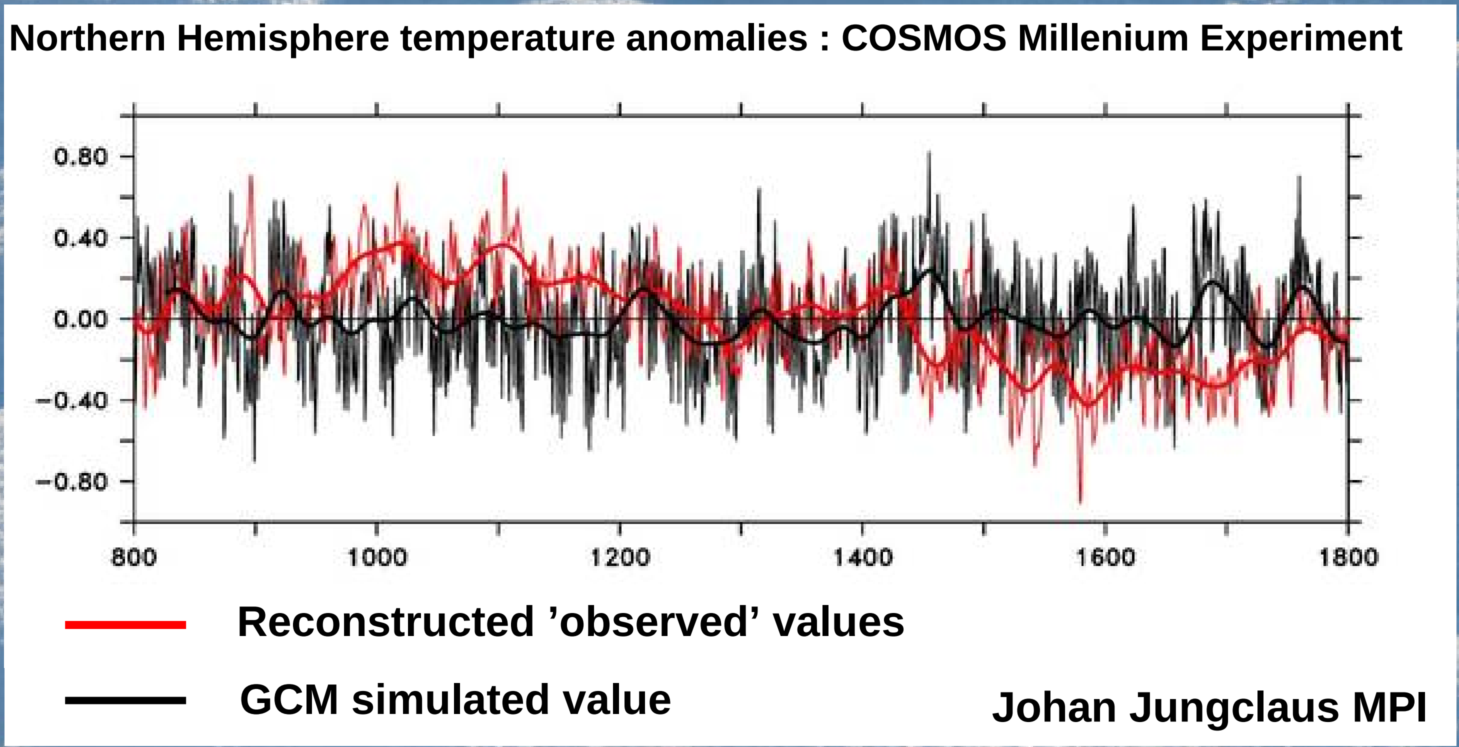
On shorter timescales ~2030 the model representation of natural variability (spread across the 3 members) in some areas is of similar magnitude to the total climate change signal (2016-2045) – (1961-1990)



This makes it difficult to give a clear statement about climate change in 2030: This is an important timescale for many adaptation problems

Why is this so?

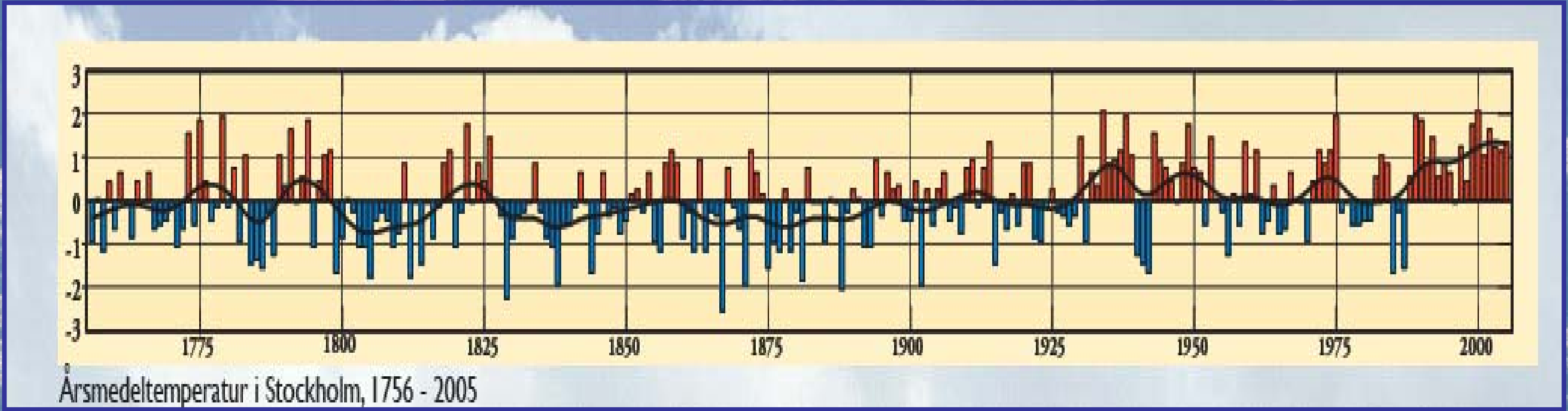
When we make climate simulations we 'spin-up' the ocean over thousands of simulated years forced only by: The Sun, Earth's rotation and pre-industrial concentrations of greenhouse gases.



Climate models can simulate a realistic amount of natural variability. But there is no reason to expect this variability is occuring at the same time as it is in reality. **i.e The model calendar is largely imaginary**

In terms of **natural variability cycles** we have absolutely no way of knowing where we are in relation to any observed variability when we start a future climate integration, say in the year 2005

Observed Annual Mean Temperature Stockholm 1750-2005



Any greenhouse gas induced trend is likely/hopefully included

A more accurate prediction of the climate evolution over the short term might arise if we could initialize the slowly varying components (ocean, sea-ice, soil moisture etc) with observations

Decadal predictability and climate prediction

The predictability we are familiar with arises from an estimate of future changes in radiative forcing agents, and the climate system response to those changes.

Predictability might also arise from information contained in the initial state of the system

- "committed warming"
- natural variability of the system

Tom Delworth GFDL

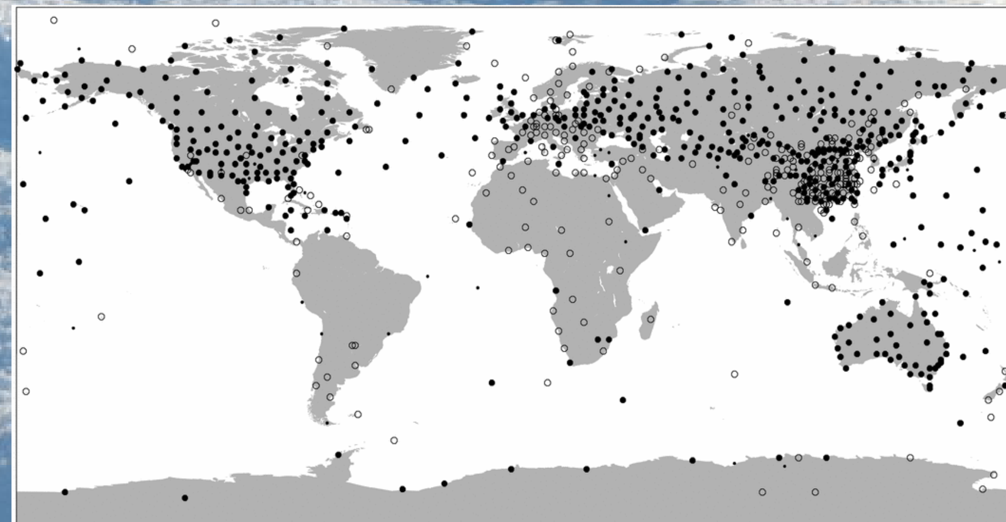
Assuming we can (i) observe this (ii) assimilate the information into our models, (iii) the variability has a predictable component and (iv) our models are good enough to simulate the subsequent evolution of the climate system

We may be able to make some useful statements regarding the Evolution of the climate system on a 1-30 year timescale.

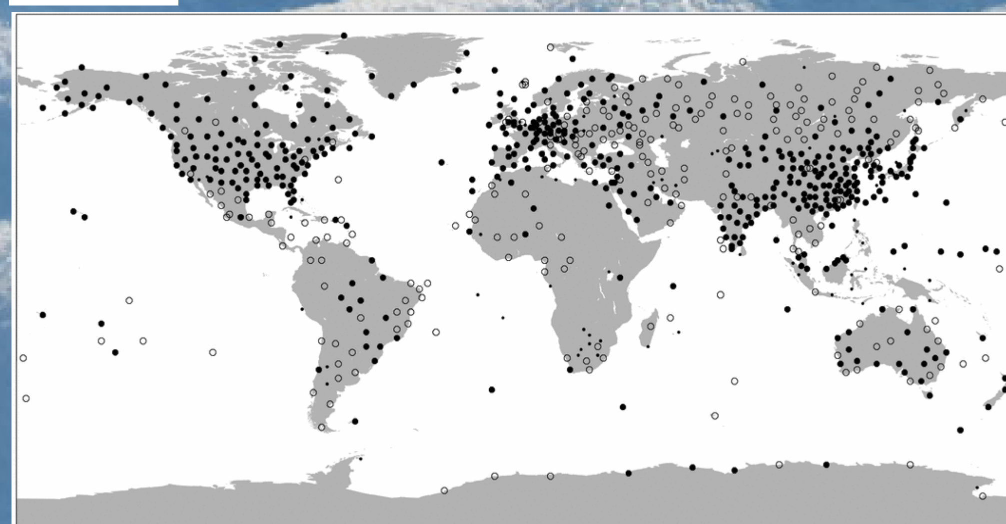
Climate Prediction as a mixed initial/boundary value problem

Radiosonde coverage

1958



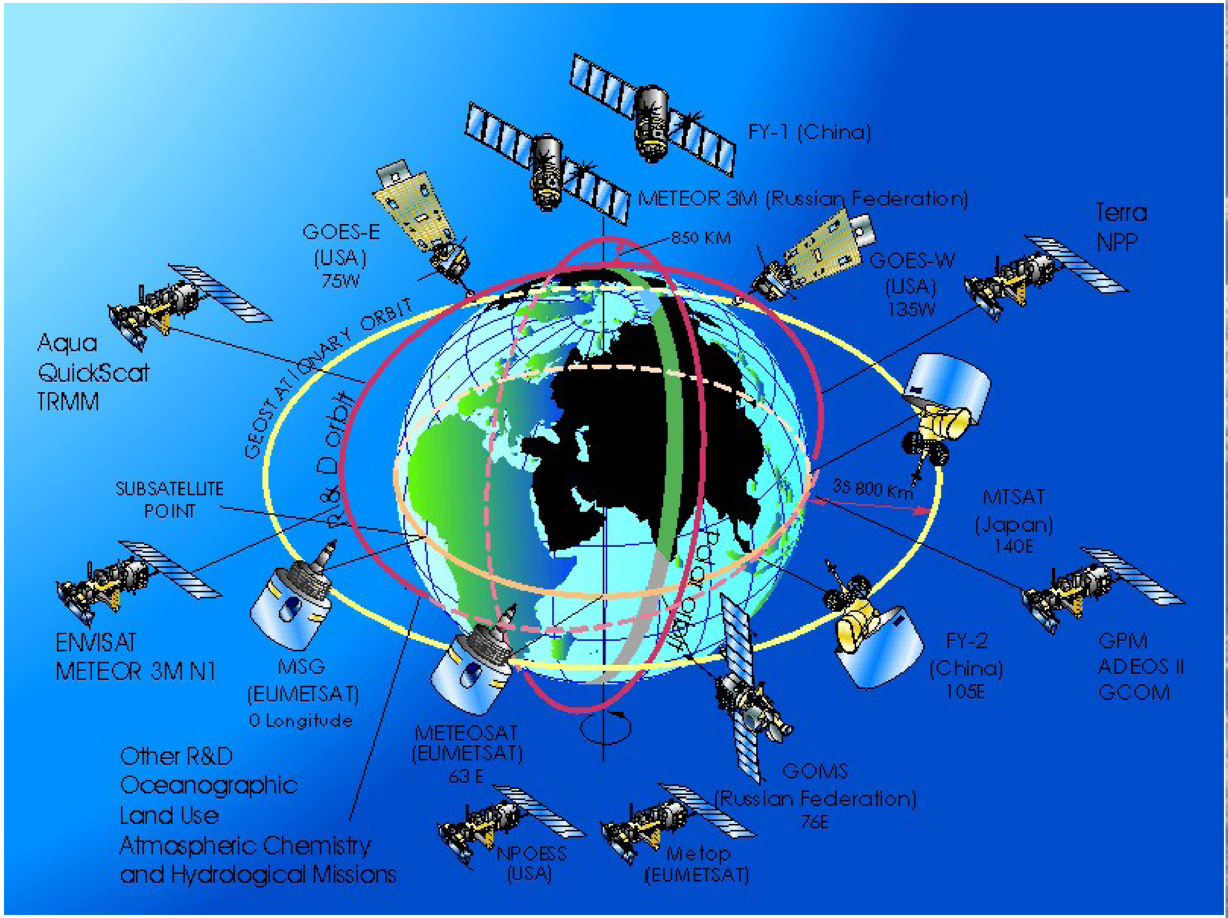
2004



Lessons from the Past

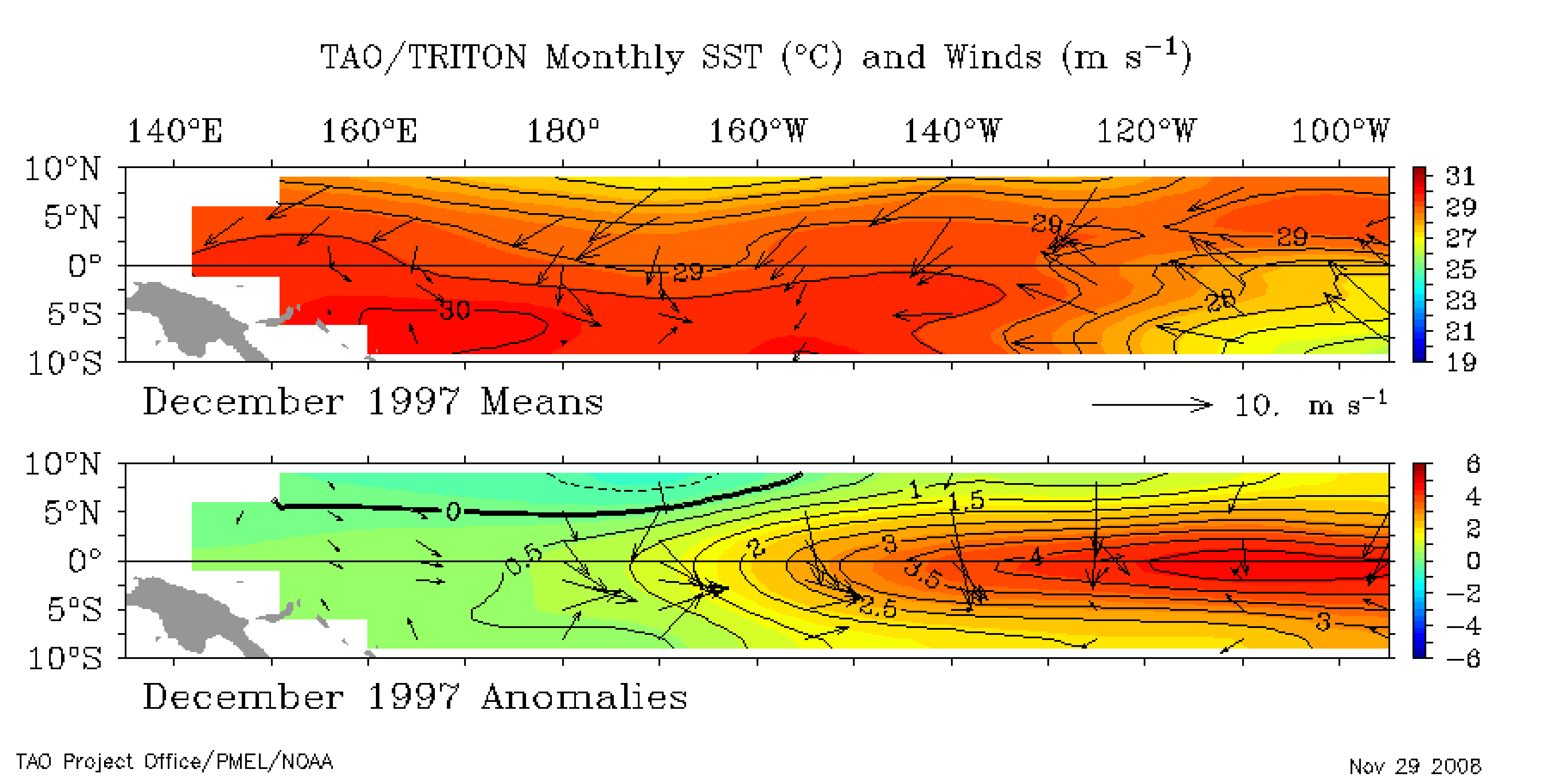
Numerical Weather Prediction really became successful once adequate observations and suitable assimilation/initialization techniques were developed to start models from

Satellites have greatly increased both the amount and spatial/temporal coverage of observations available to NWP

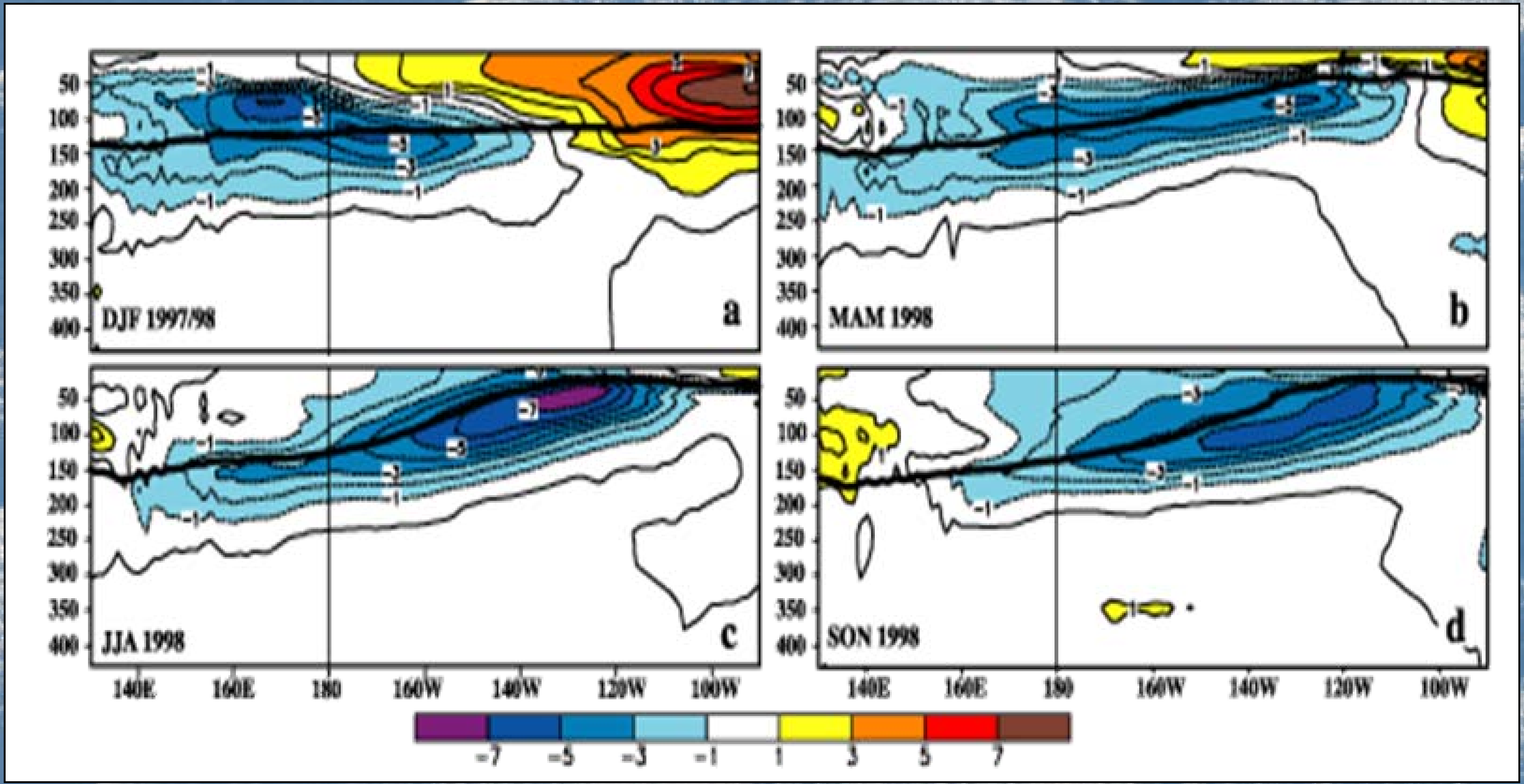


With improved assimilation techniques this has led to an increase in the accuracy of weather prediction over the past 20 years

Improvements in coupled (ocean-atmosphere) models, along with observational developments (e.g. TAO array in the tropical Pacific) that allowed the subsurface ocean to be initialized, led to the development of seasonal prediction: Mainly tied to ENSO forecasting



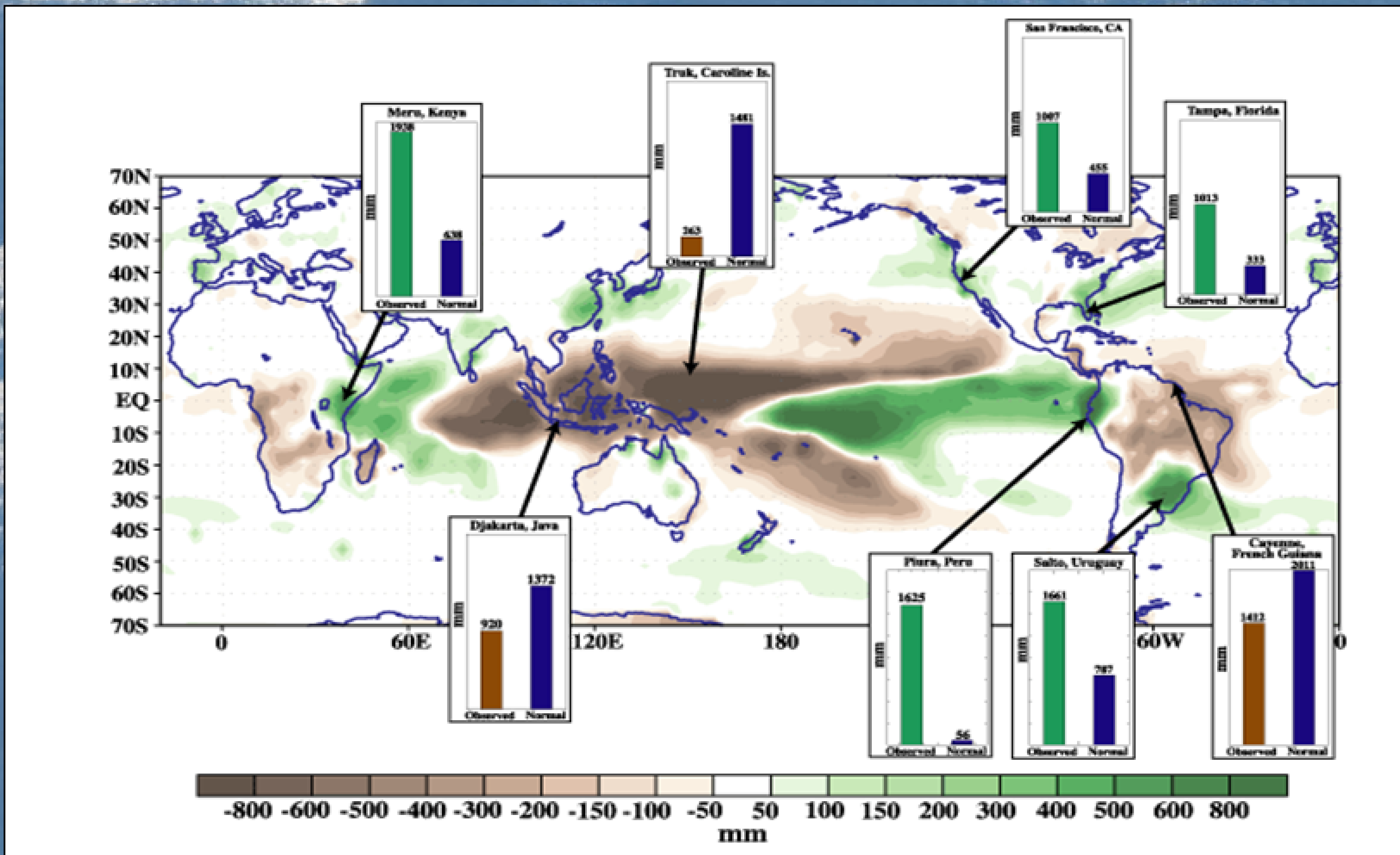
Seasonal Mean Ocean thermal anomalies as a function of depth along the Equatorial Pacific : ENSO event of 1997-1998



An accurate initialization of ocean temperatures and surface winds along with a good coupled model can allow skillful forecasts of the evolution of ENSO events with a 3-12 month lead time

Atmospheric teleconnections act to communicate the impact of equatorial Pacific SST anomalies around the globe

Accumulated Rainfall anomalies Nov1997-Apr1998 expressed as departures from the seasonal mean rainfall for 1979-1995



Questions of relevance to decadal climate prediction

Are there slowly varying modes of the climate system that have a predictable evolution (most likely in the ocean, sea-ice, soil ?)

Do these modes have tangible impacts on climate variables of relevance for adaptation either locally or remotely?

Do we have sufficient observations to define an initial state?

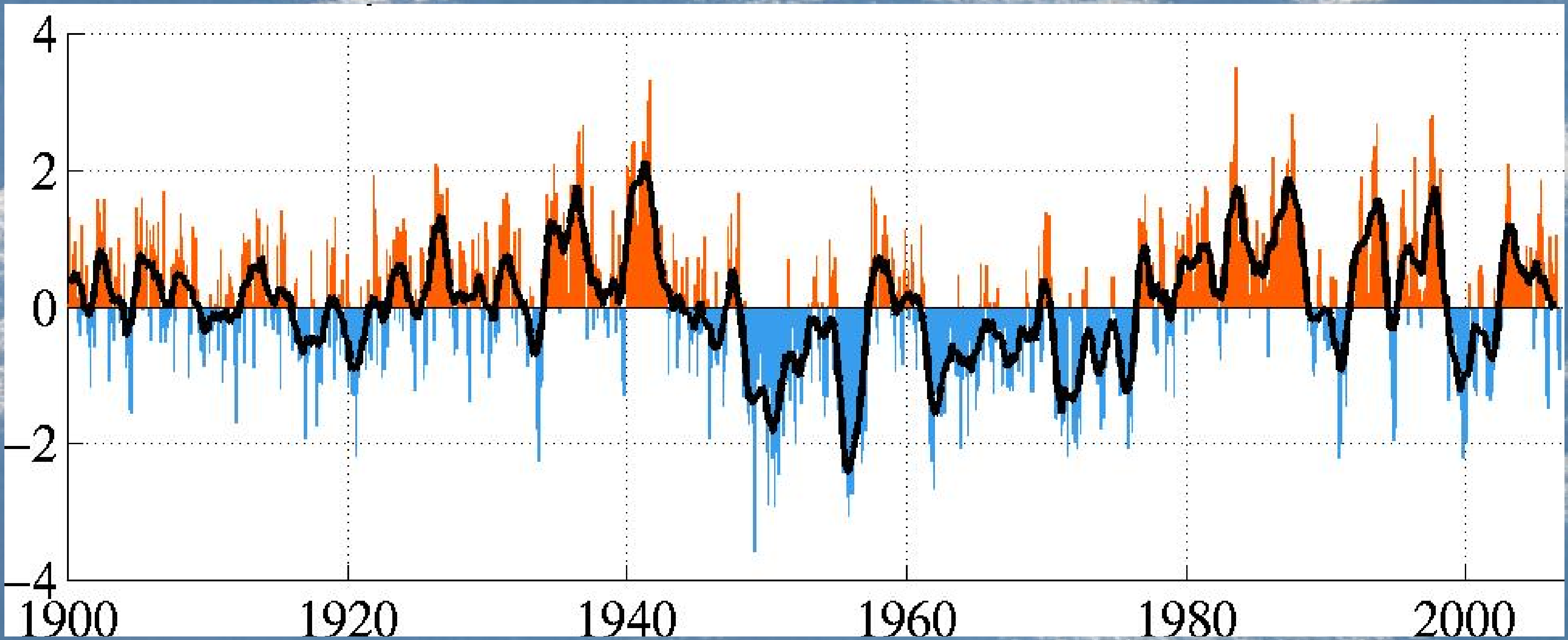
Can we assimilate this information into our climate models?

Are models good enough to do something with this information ?

Decadal timescale variability in the North Pacific Ocean

Monthly values of the Pacific Decadal Oscillation index: 1900-2006

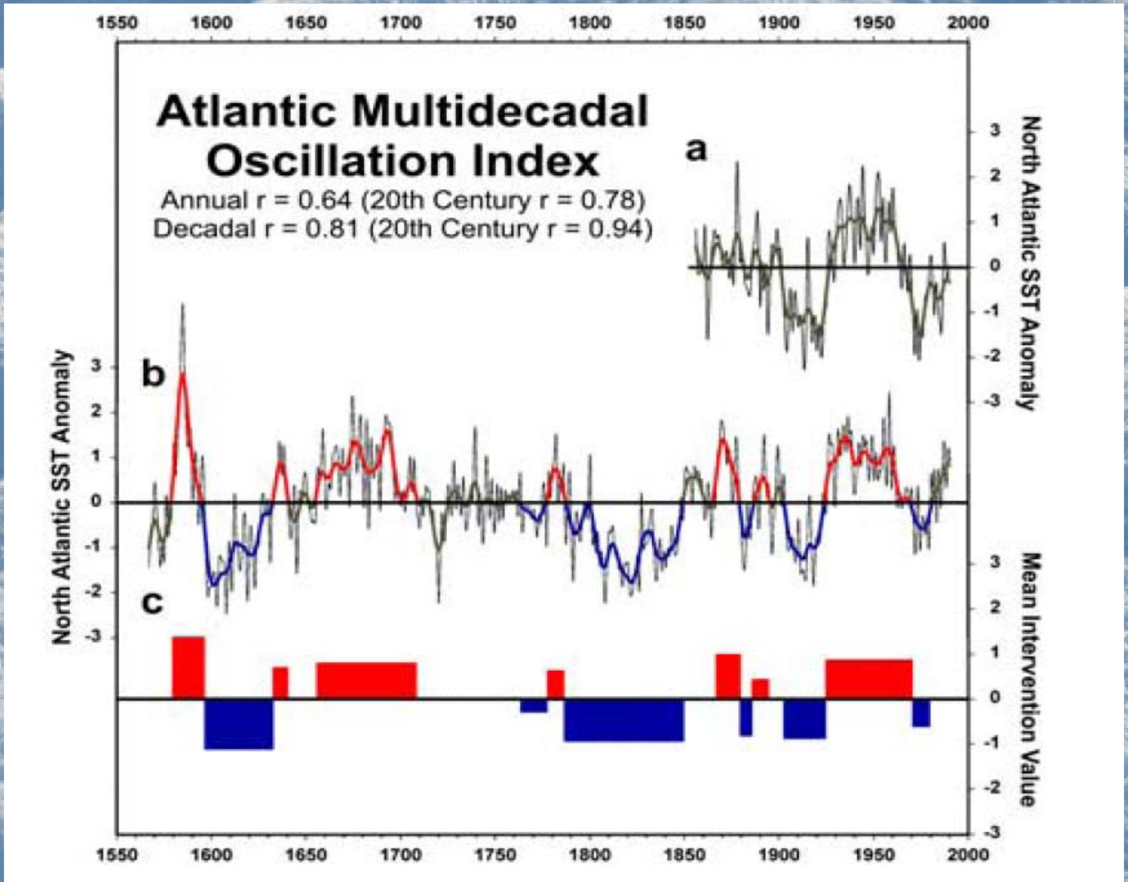
The leading principal component of North Pacific monthly SST variability



S.Hare, N.Mantua et al.

The Atlantic Meridional Oscillation index

A 10-yr moving average of annual North Atlantic SST anomalies

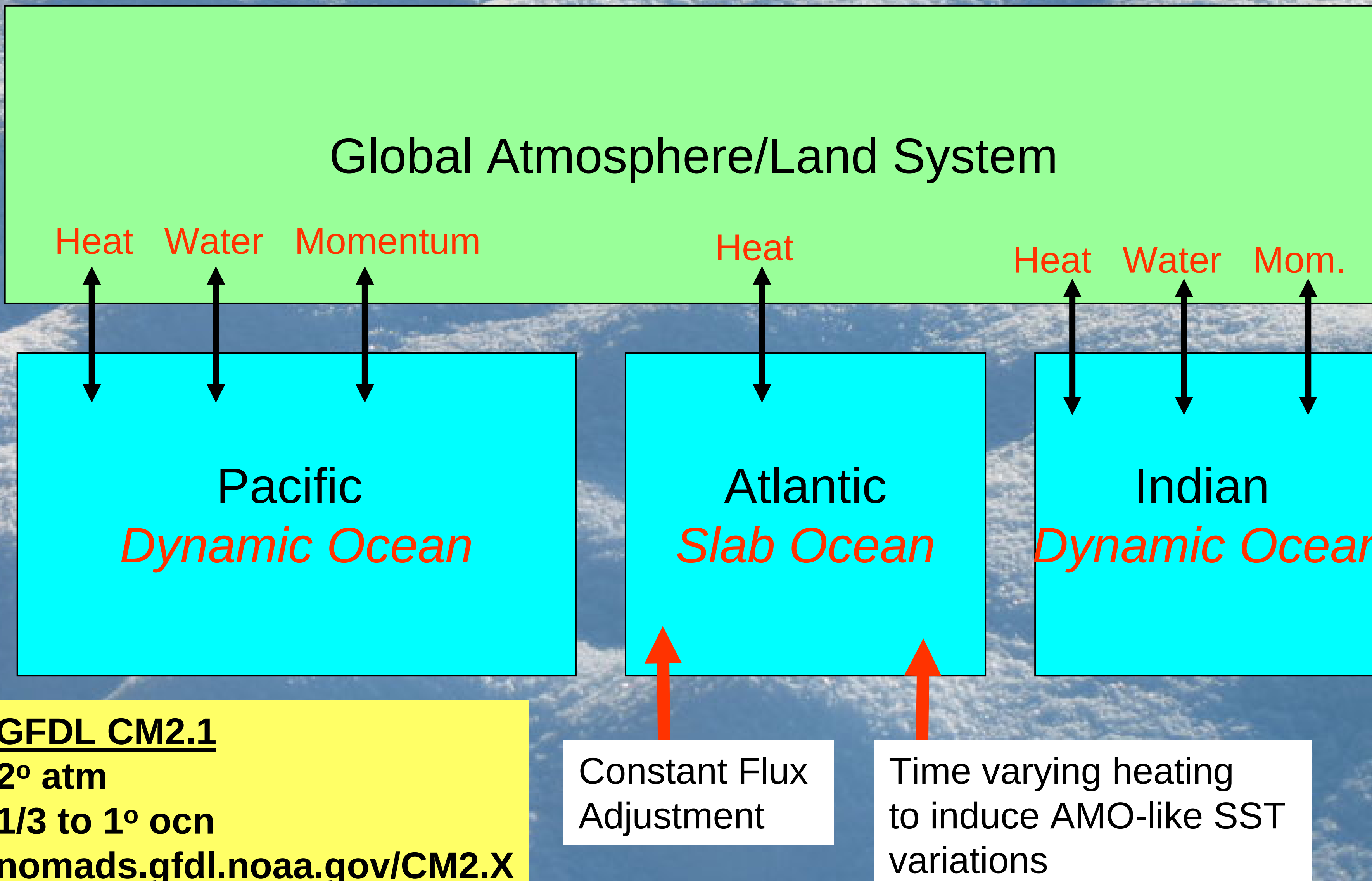


Linked to variability in the Atlantic vertically overturning circulation

S.Gray et al. 2004

A Modeling Example from GFDL (T. Delworth et al. GFDL)

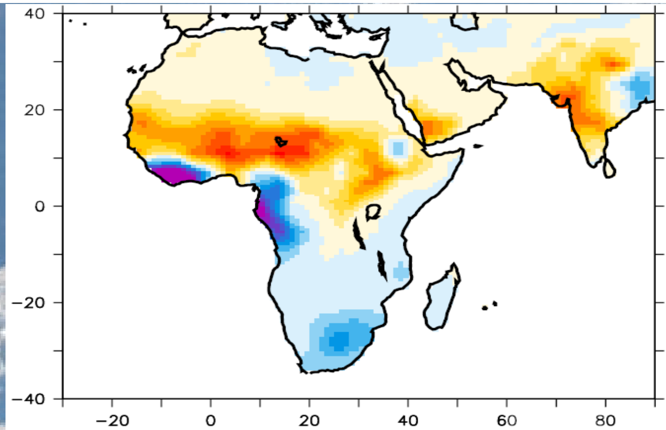
Hybrid coupled model - based on GFDL CM2.1

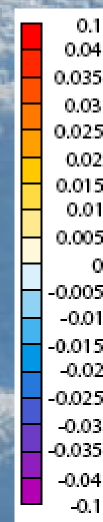


GFDL CM2.1
2º atm
1/3 to 1º ocn
nomads.gfdl.noaa.gov/CM2.X

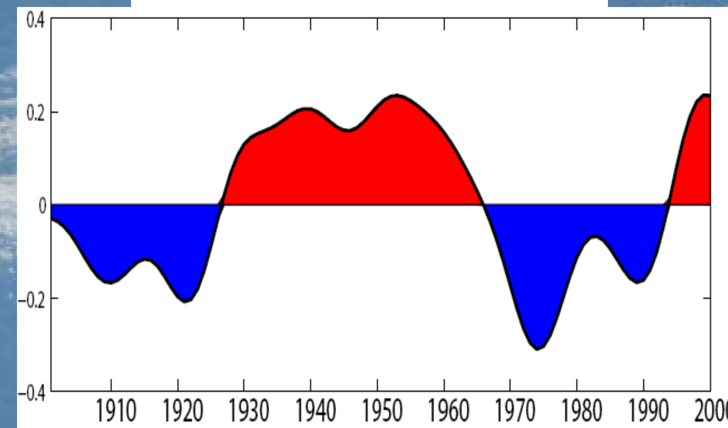
AMO decadal variability does appear to project onto Sahel and India summer decadal rainfall statistics. Given a reasonable AMO the GFDL model appears capable of simulating this teleconnective variability

Regression of modeled LF JJAS rainfall anomaly on modeled AMO Index

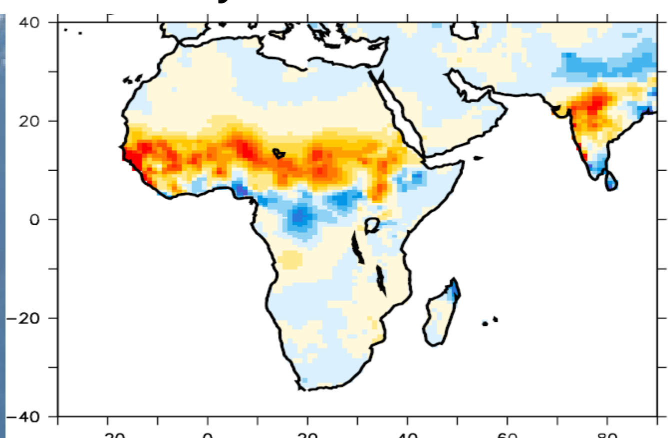




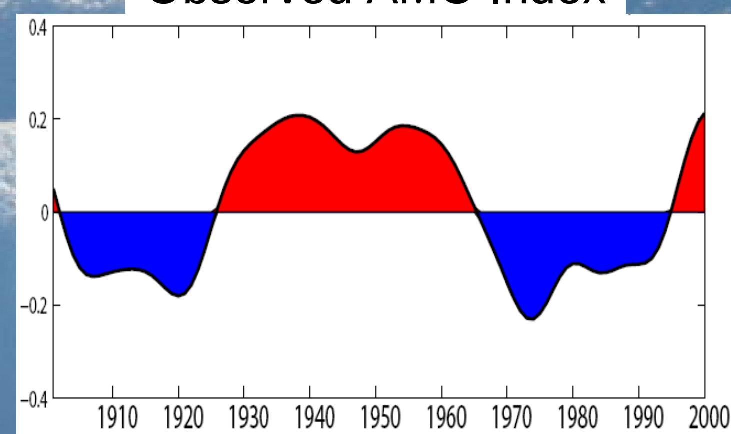
Modeled AMO Index



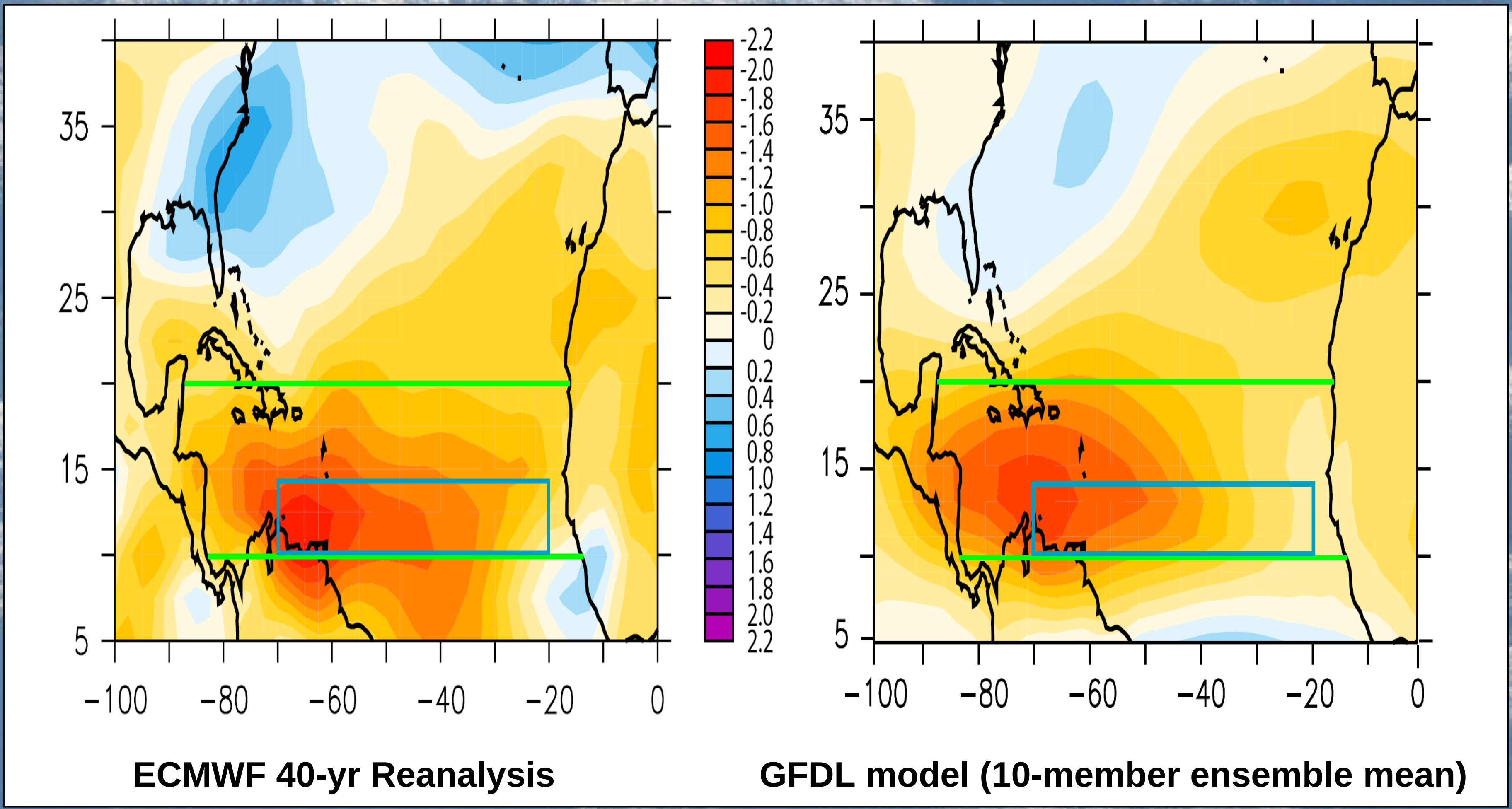
Regression of observed (CRU) LF JJAS rainfall anomaly on observed AMO Index



Observed AMO Index



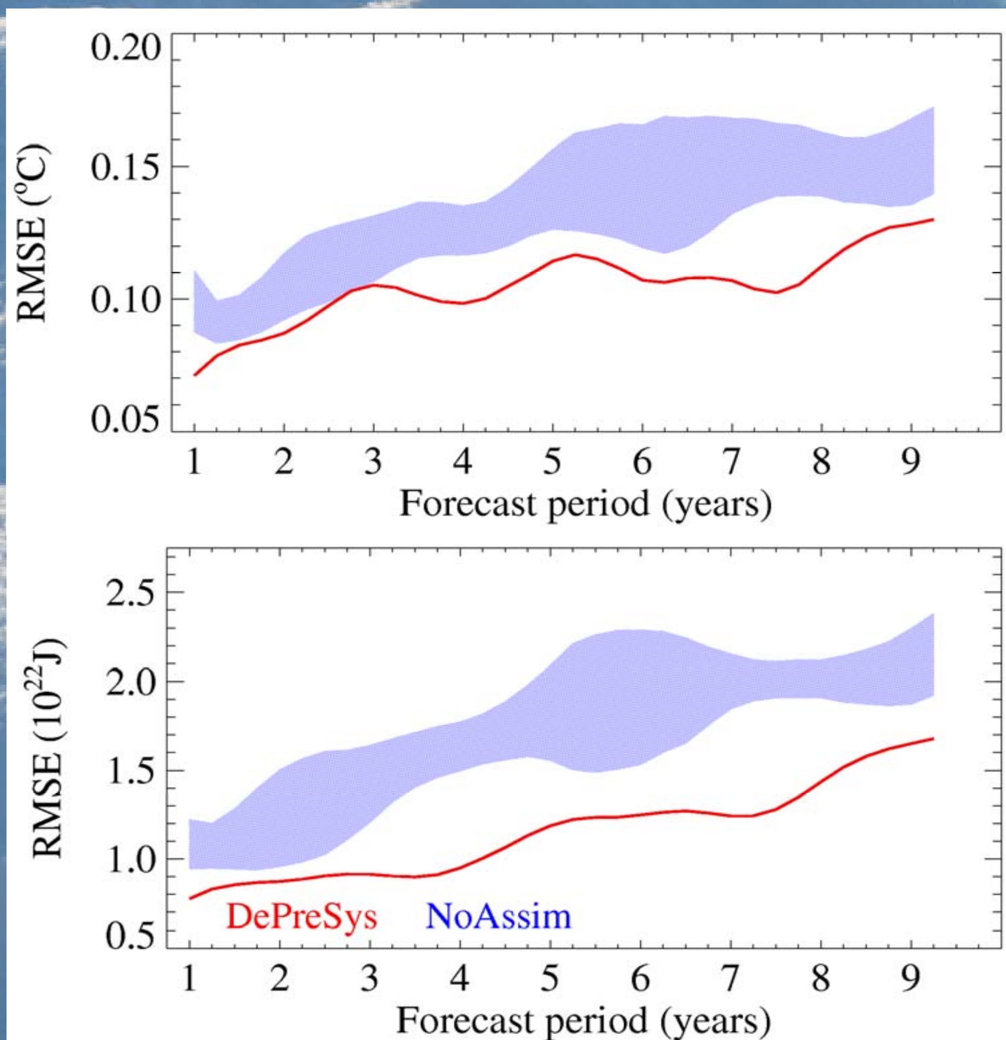
Regression of LF ASO vertical shear of zonal wind (m/s) on the AMO index (1958-2000)



Vertical Shear of the zonal wind is an important control on interannual variability of Atlantic tropical cyclone activity

There appears to be some increased skill (in a quantitative sense) when observations are included in coupled climate model Predictions

Results from the UK Met. Office DePreSys integrations



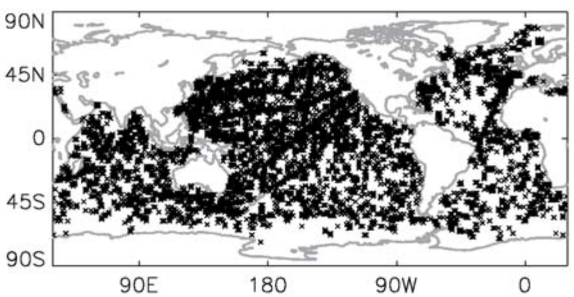
Global annual mean surface temp (T_S)

Global annual mean ocean heat content in upper 113m (H)

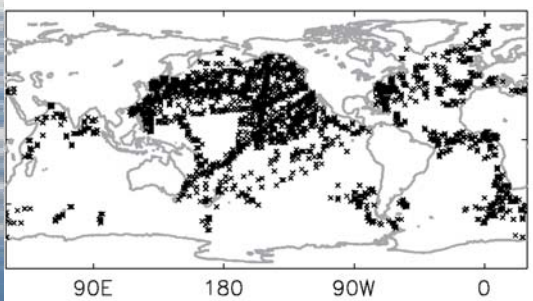
D. Smith etal. UKMO

Surface and subsurface ocean observations are a crucial component of any attempt at decadal climate prediction

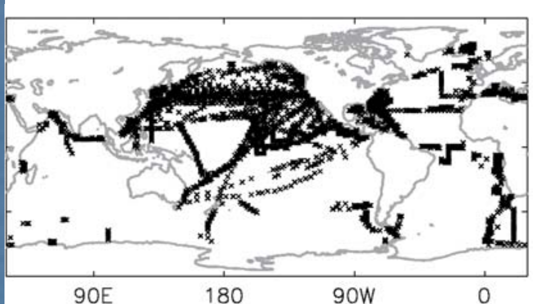
T obs: 301m: Feb 2007



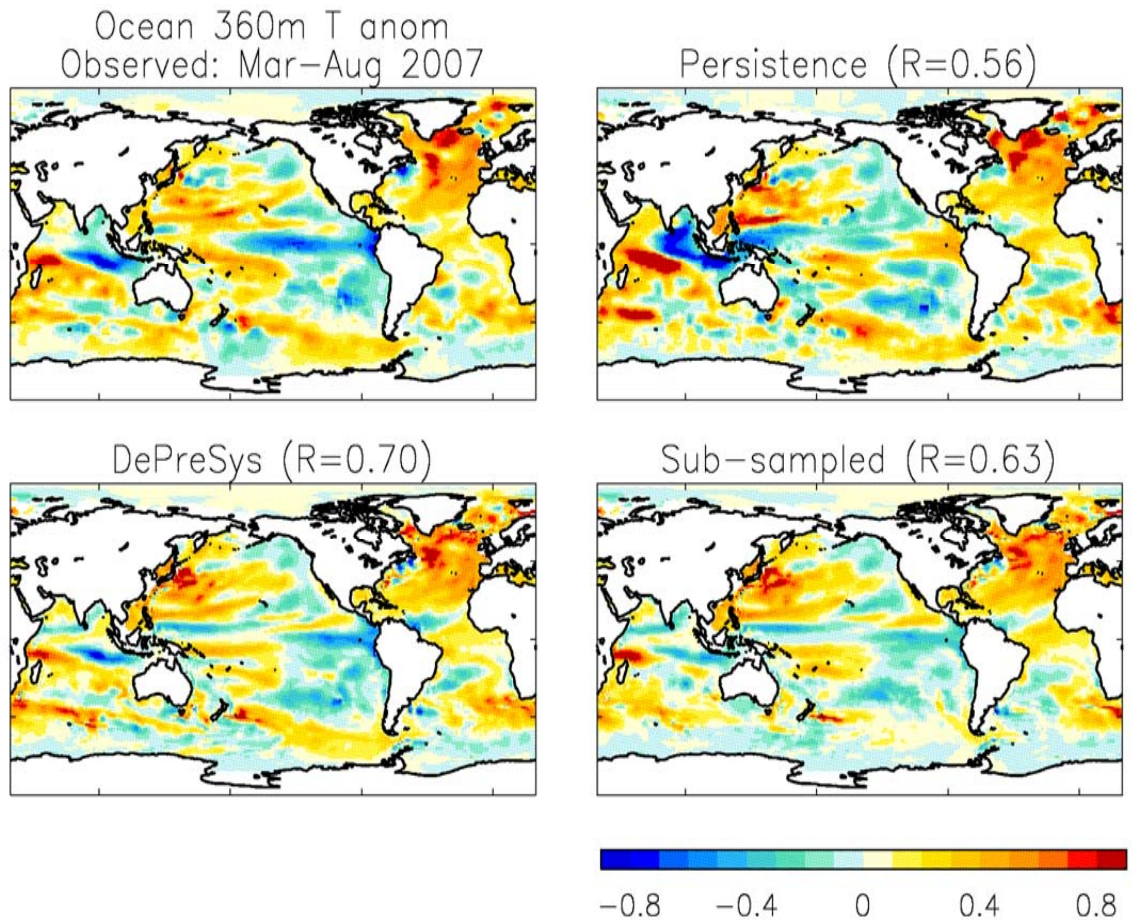
Sub-sampled obs



obs: 301m: Feb 1980



DePreSys Forecasts initialized March 2007



D. Smith et al. UKMO

WCRP

WORLD CLIMATE RESEARCH PROGRAMME

The World Climate Research Programme Strategic Framework 2005-2015

"It is now possible for WCRP to address the seamless prediction of the climate system from weekly weather to seasonal, **interannual**, **decadal** and centennial climate variations and anthropogenic climate change"

Climate Prediction builds on past improvements in both the Global Observing System and Climate Models but requires further developments in both areas to best support short timescale impact and adaptation needs.

SMHI

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CLIMATE, IMPACTS & ADAPTATION