Jun. 23, 2014, ICTP TTA-2, Trieste, Italy

Seamless Prediction of Weather and Climate from Days to Decades

Part I: Weather-Intraseasonal-Seasonal

Part II: Seasonal-Decadal and Climate Change

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Seamless Prediction of Weather and Climate from Days to Decades

Part II: Seasonal – Decadal - Climate Change

1. *Introduction: Examples of Climate Variability*
2. *Seasonal Predictability and Prediction*
3. *Decadal Predictability and Prediction*
4. *Predictability of Climate Change*
5. *Summary*

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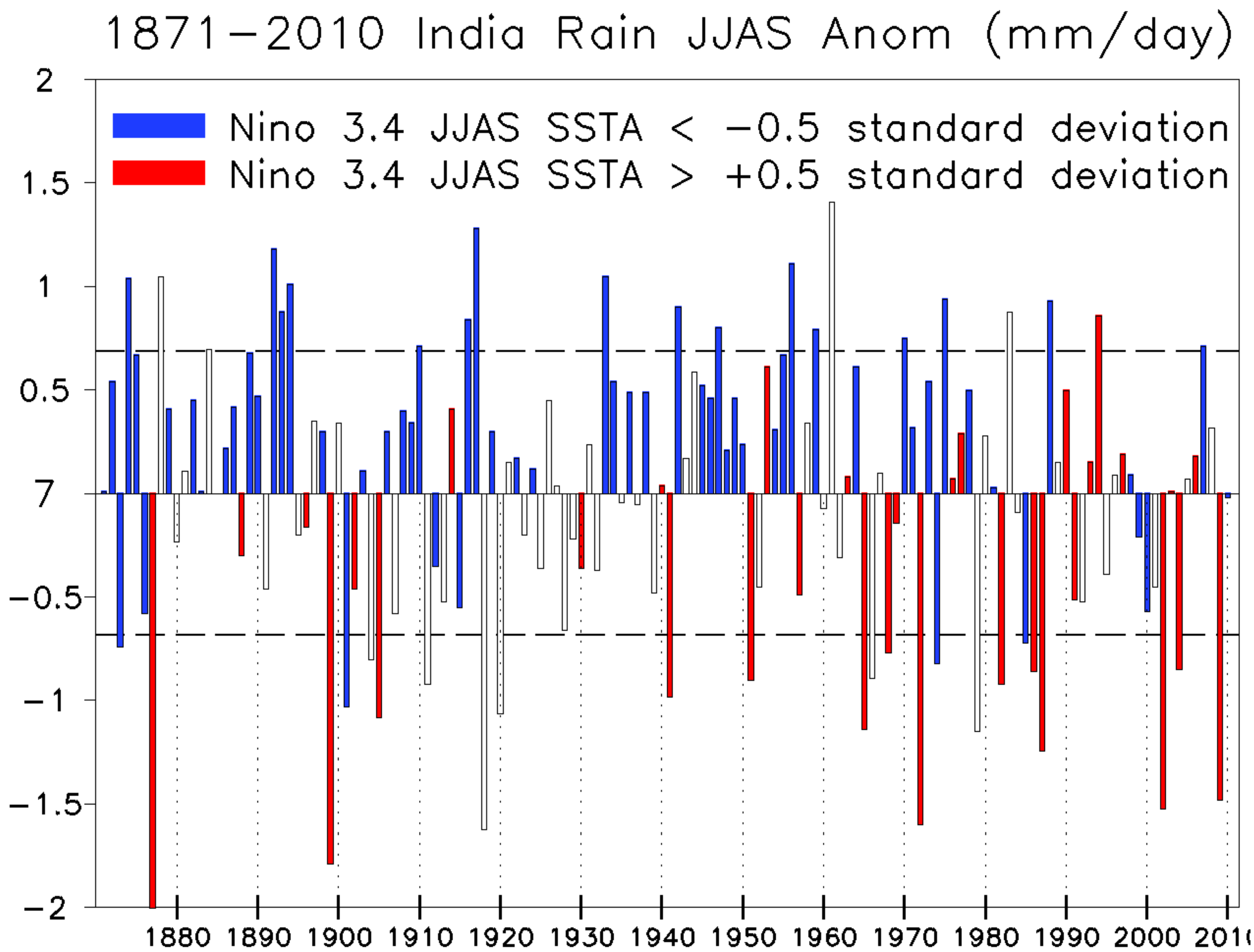
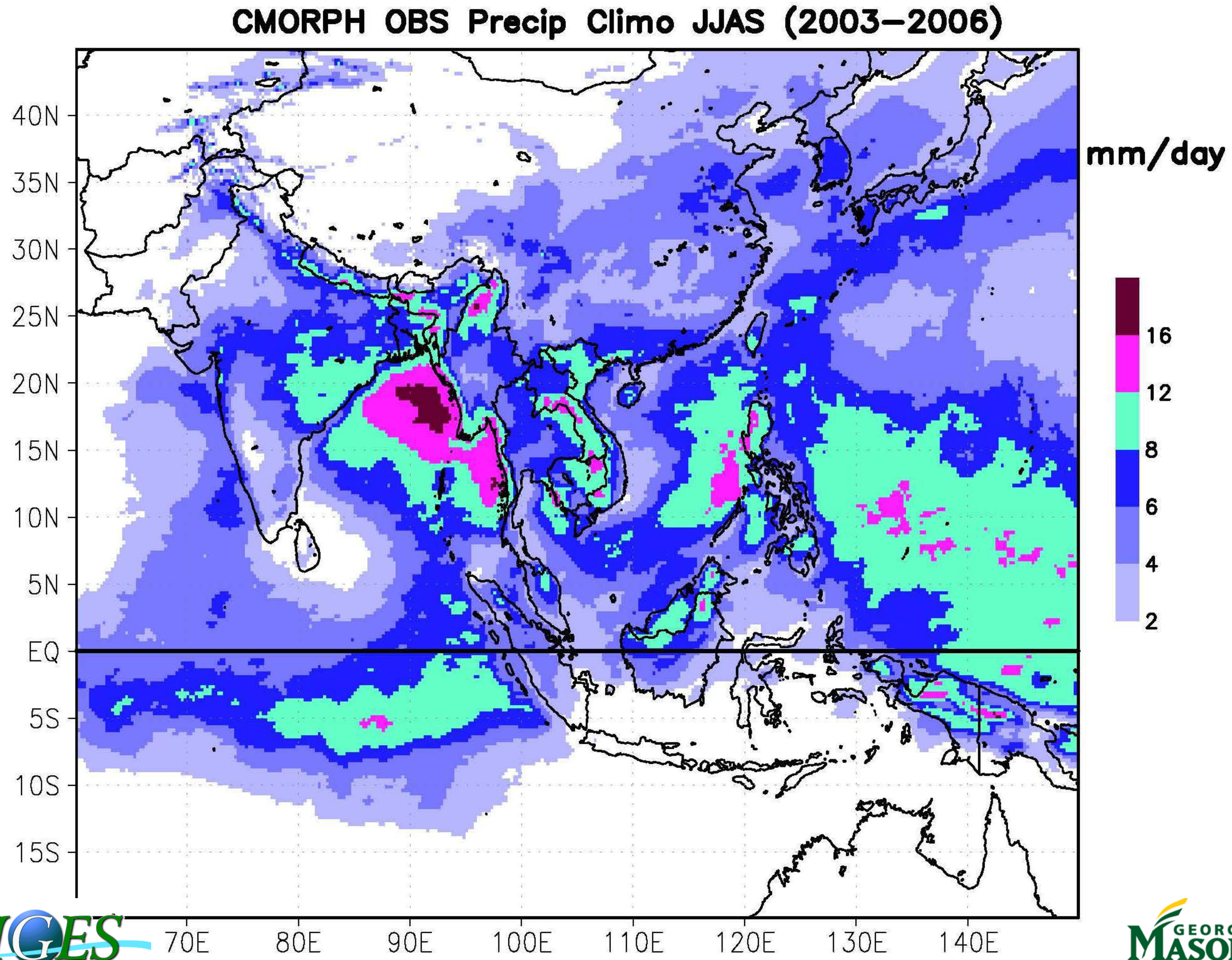


1871–2010 India Rain JJAS Anom (mm/day)
Nino 3.4 JJAS SSTA < −0.5 standard deviation
Nino 3.4 JJAS SSTA > +0.5 standard deviation
2
1.5
1
0.5
0
−0.5
−1
−1.5
−2
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010



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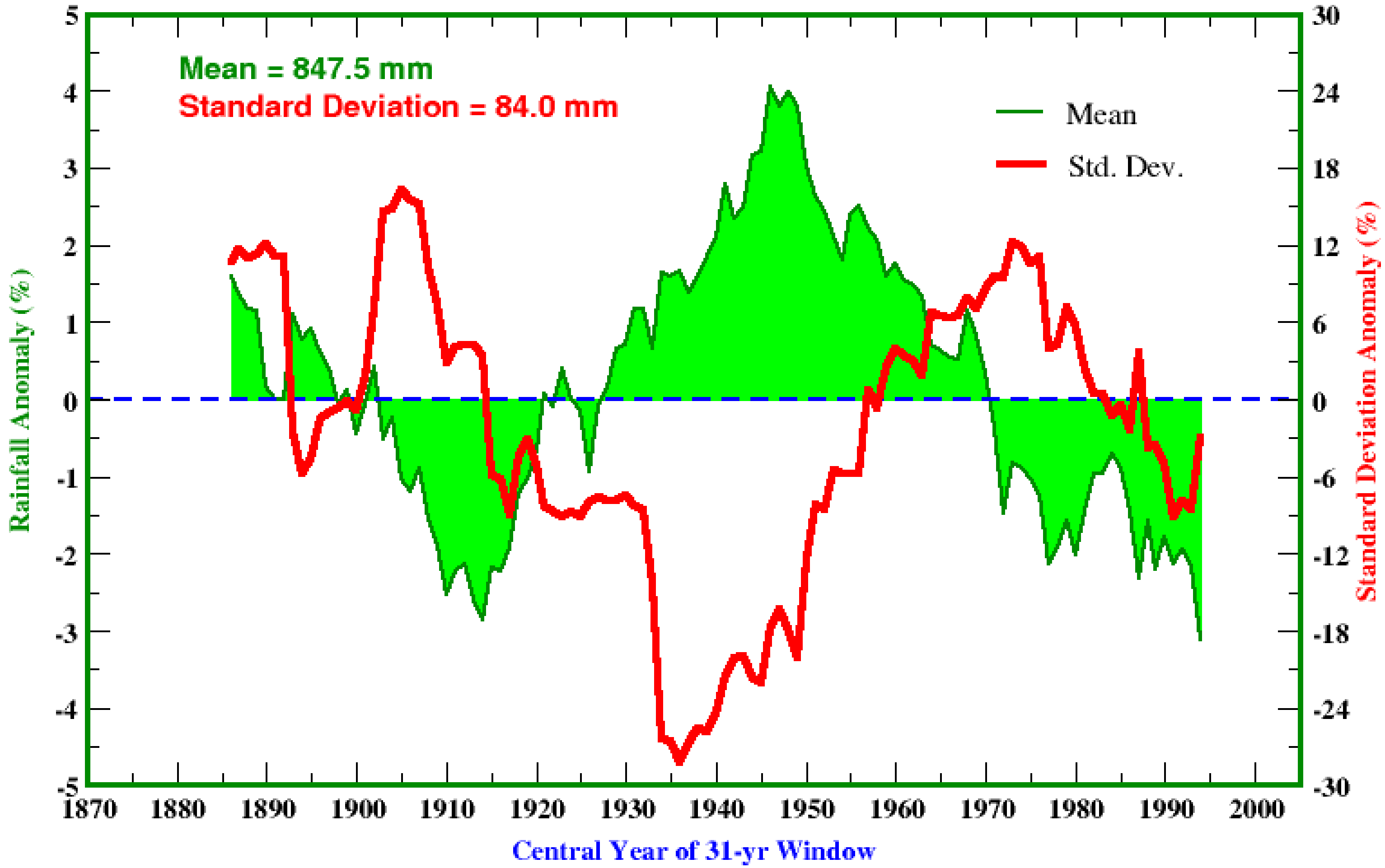
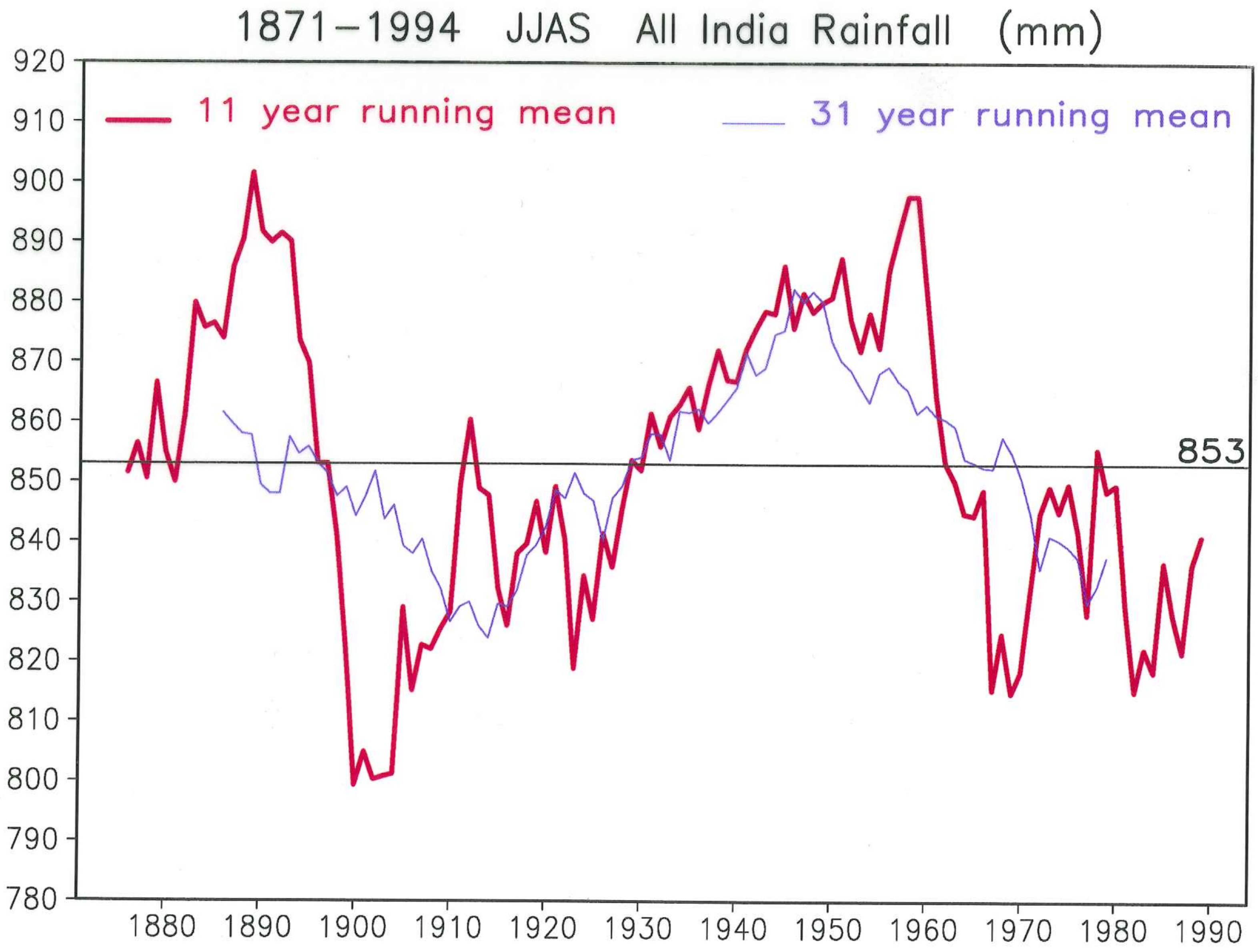
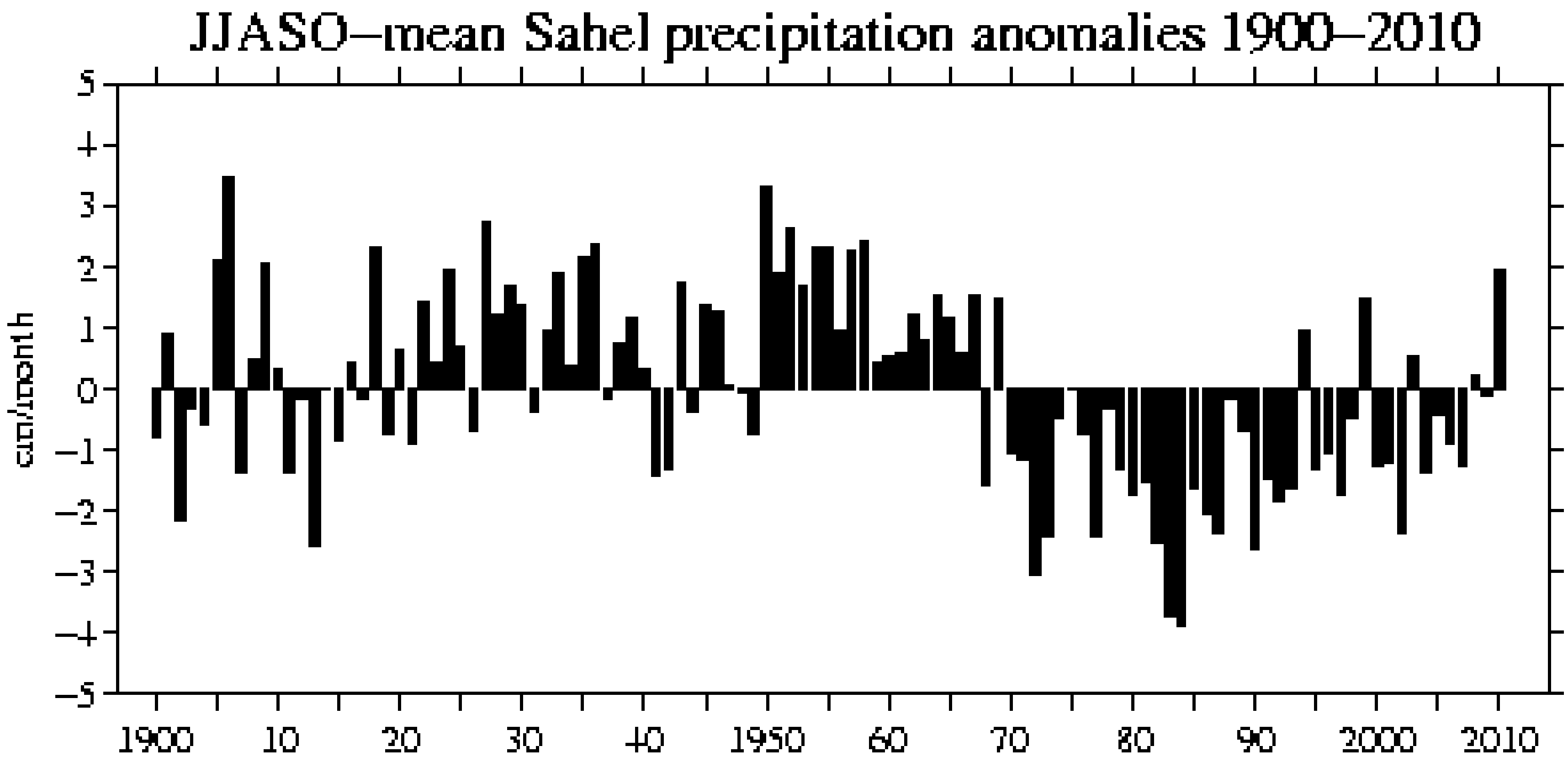
Epochal Patterns of All-India Summer Monsoon Rainfall



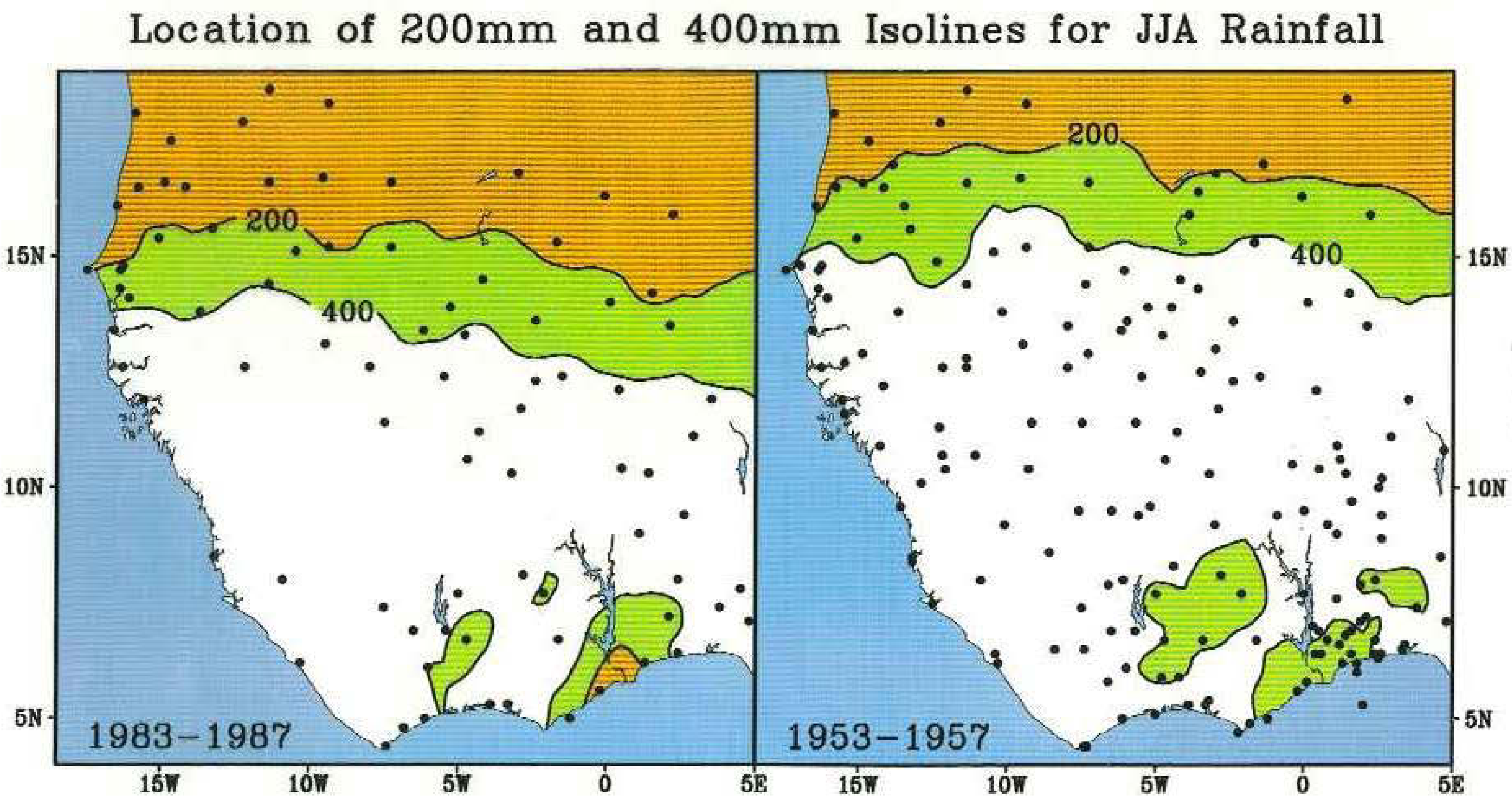


1871–1994 JJAS All India Rainfall (mm)
11 year running mean
31 year running mean
853
920
910
900
890
880
870
860
850
840
830
820
810
800
790
780
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990

Sahel Rainfall

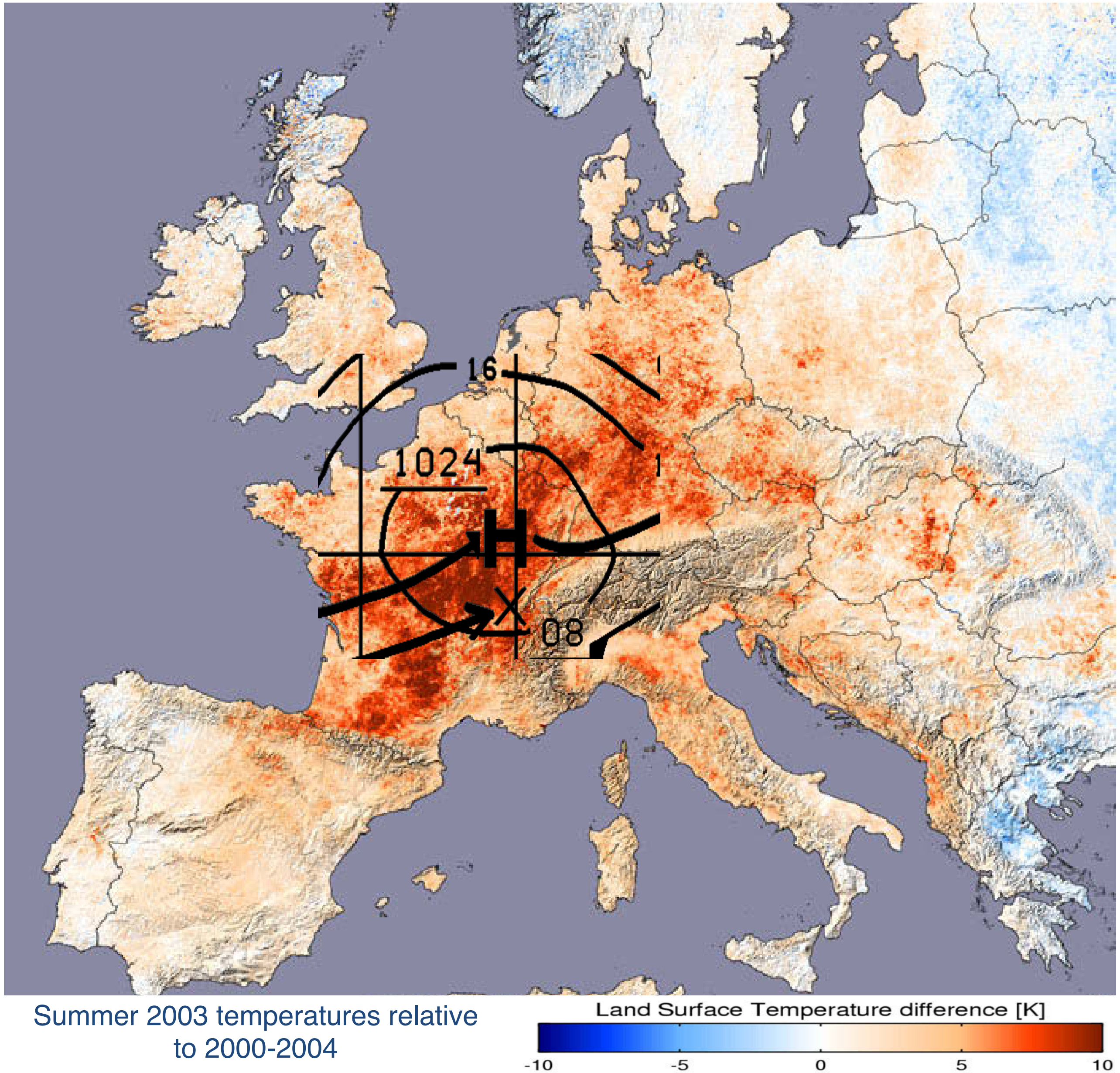


Sahel rainfall index (JJASO mean anomaly, 10-20ºN, 20ºW-10ºE)



Location of 200mm and 400mm Isolines for JJA Rainfall
200
400
15N
10N
5N
15W
10W
5W
0
5E
1983-1987
1953-1957

Summer 2003 European Heat Wave



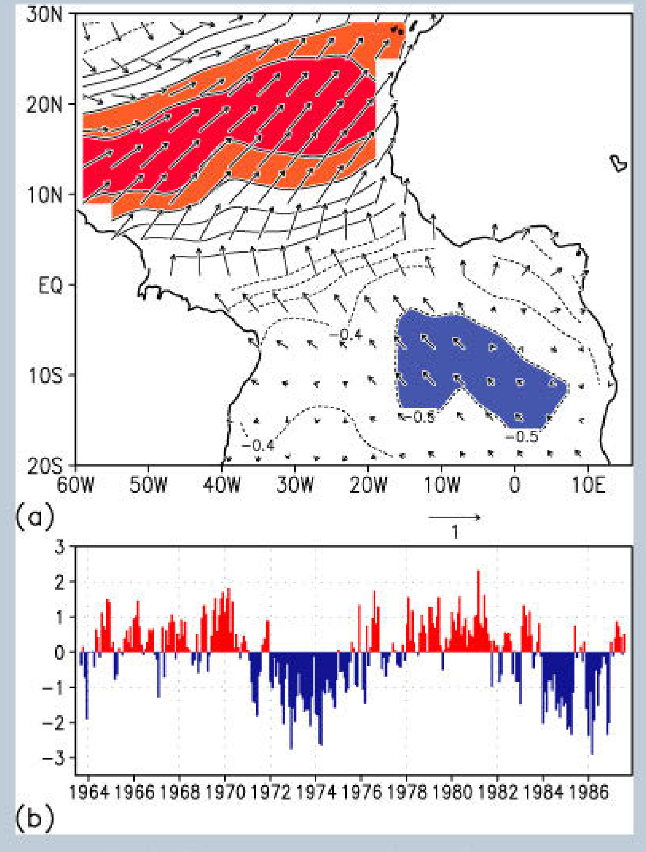
Summer 2003 temperatures relative to 2000-2004

- The immediate cause of the heat-wave was a persistent high pressure center over Northwest Europe.

… and the interannual variations need not be ENSO-like:

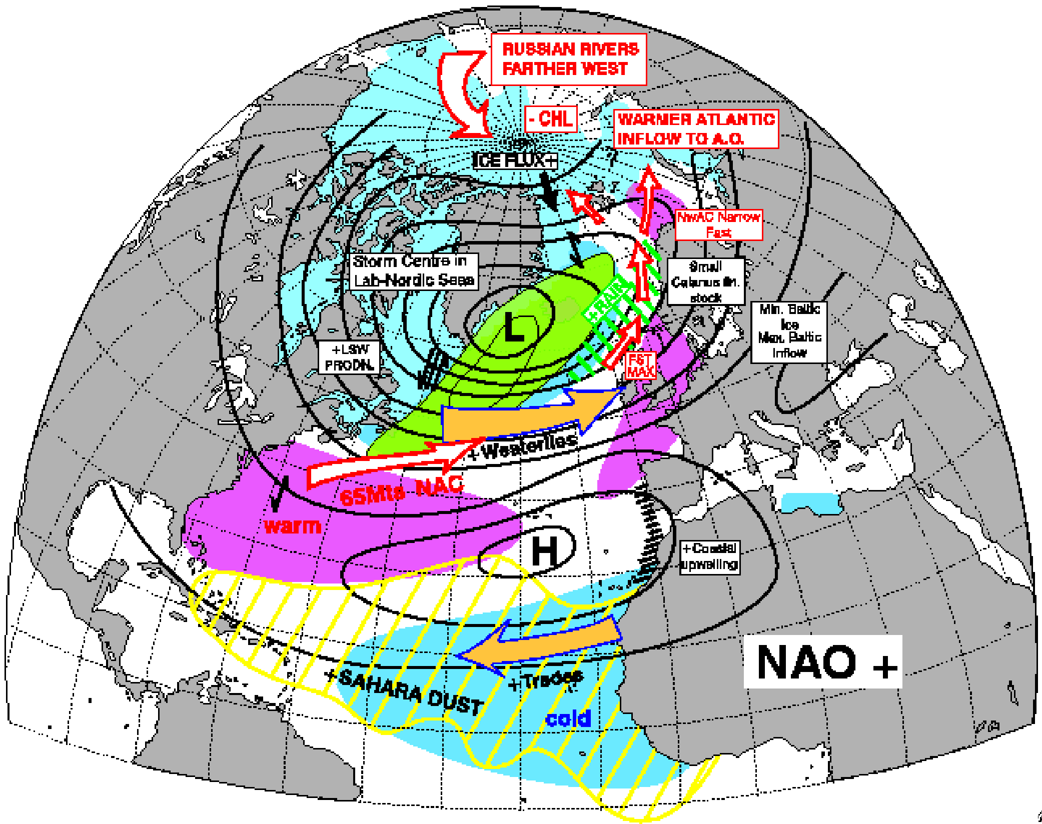
Tropical Atlantic Climate Variability

An Atlantic Dipole ?



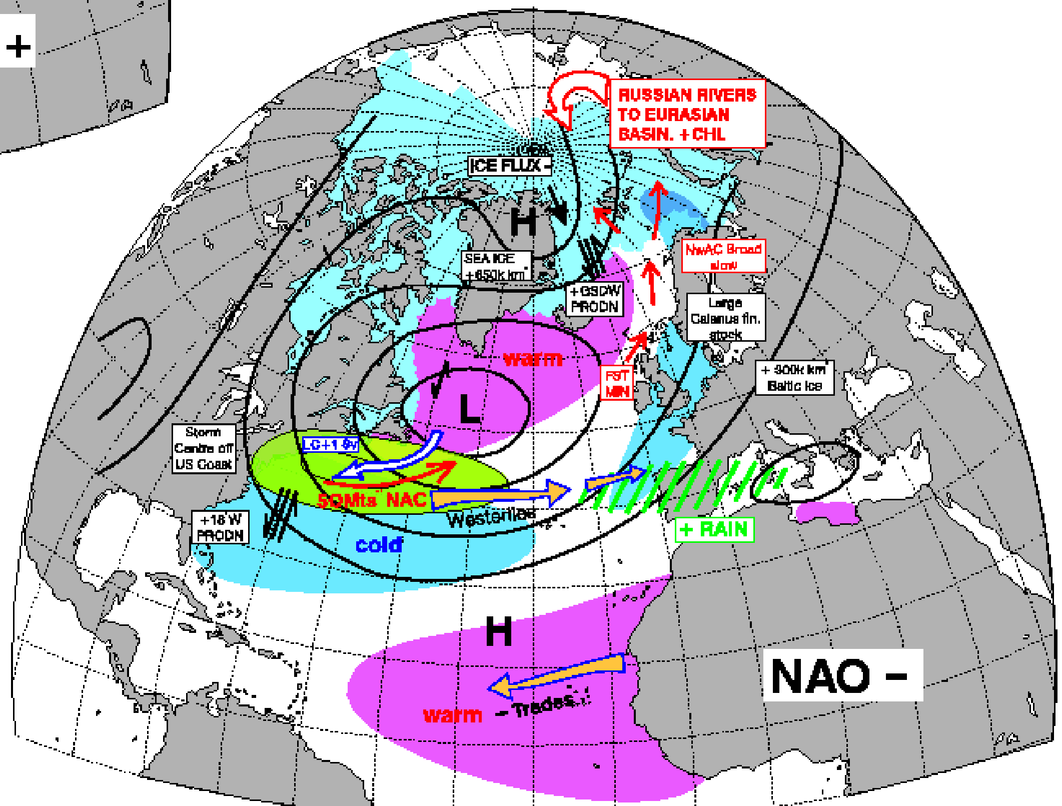
The dominant joint patterns of sea surface temperature and surface wind stress variability over the Atlantic for the period September 1963 to August 1987 and the associated time series. The time series show a dominant signal at lower frequencies but as well, there are seasonal and interannual fluctuations (Nobre and Shukla, 1996, J. Climate, 9, 2464-2479).

AV/D2/99-8



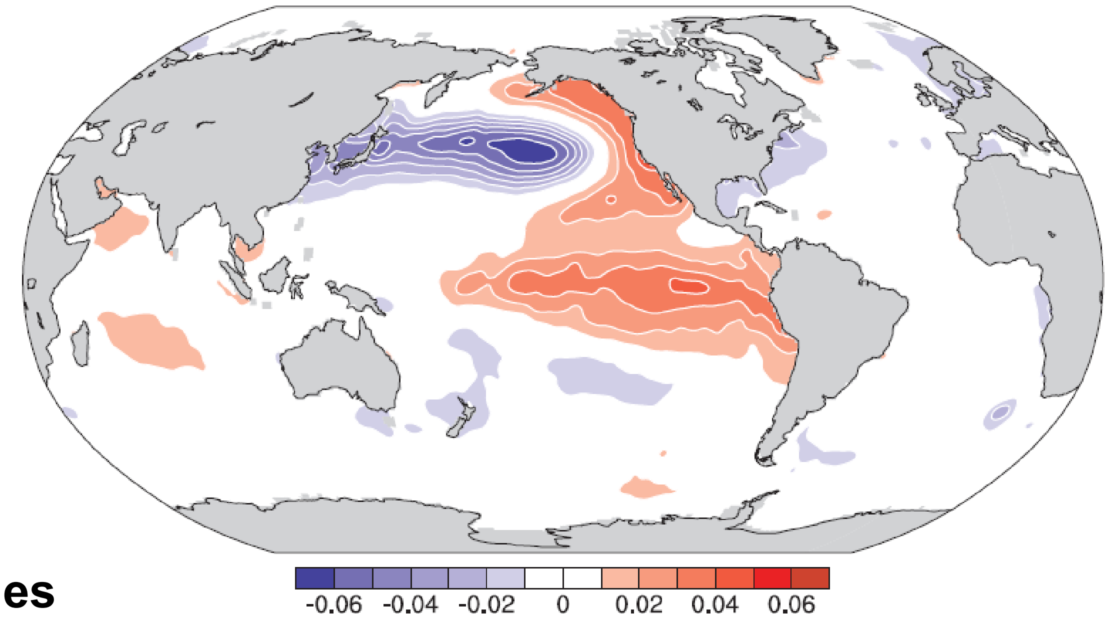
North Atlantic Oscillation:

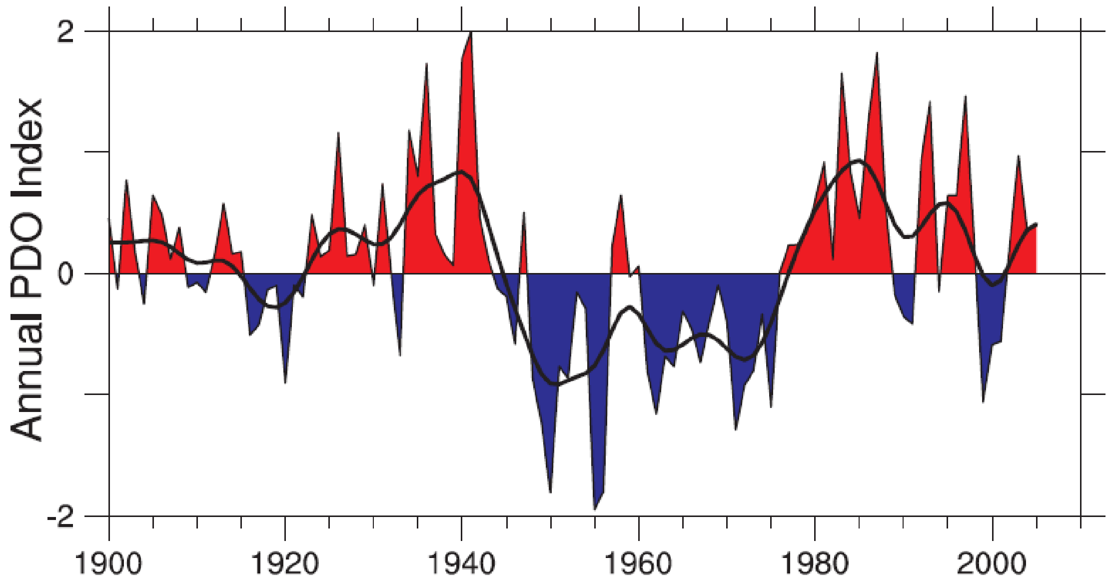
the major mode of variation in the extra-tropical winter climate (contracted in summer)



Pacific Decadal Oscillation (PDO)

Fig. 3.28
Leading EOF pattern for Pacific SST N of 20N
top: Spatial structure
bot: Annual time series

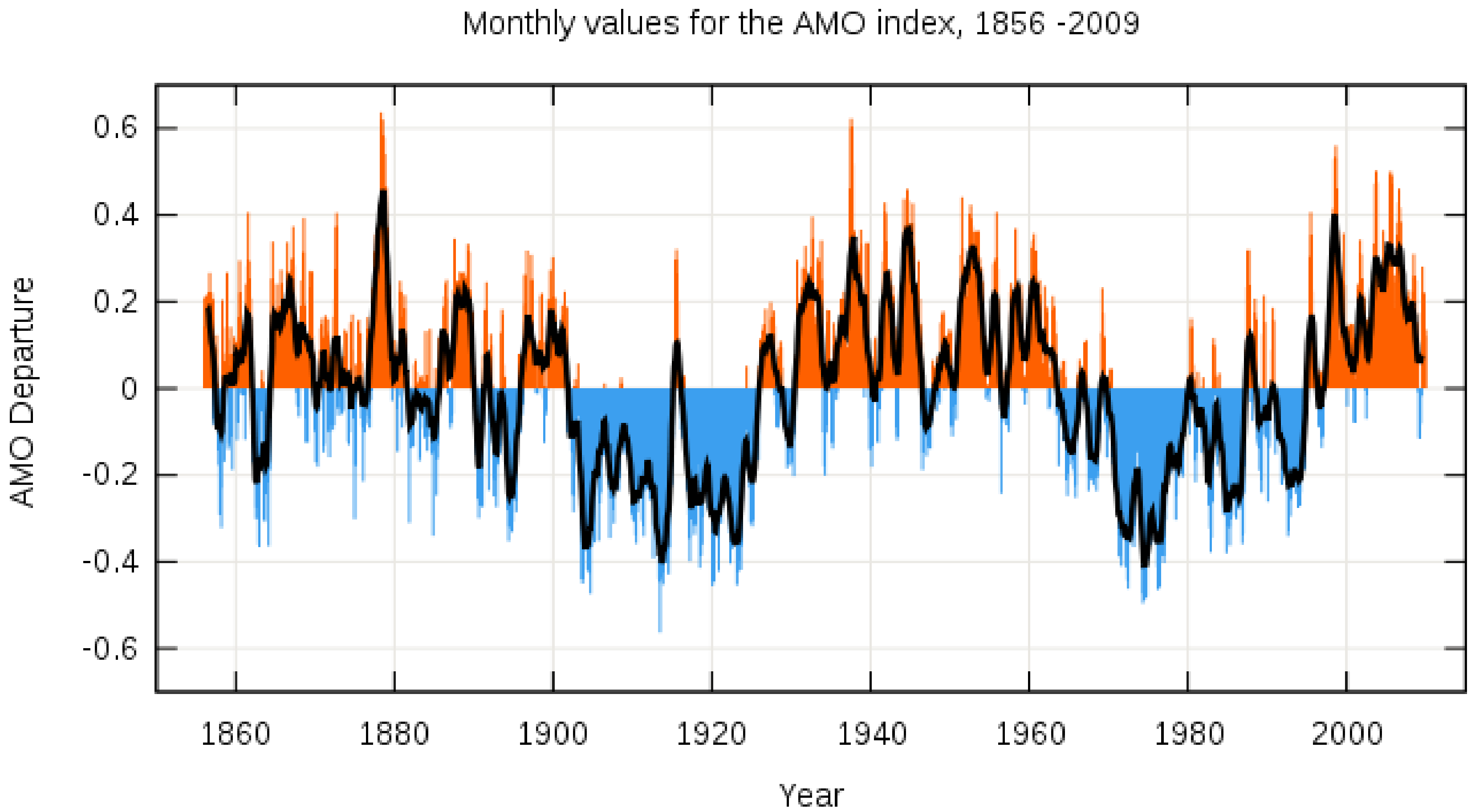




also associated with anomalies in Pac winds, fisheries, etc.

Some evidence in ’90s that PDO due to extra-tropical air-sea interaction.
Since then, “decadal ENSO” seen as more likely cause
PDO mechanisms not well understood.

Atlantic Multi-decadal Oscillation



The Atlantic Multi-decadal Oscillation Index is defined as area weighted average detrended SST anomaly over the North Atlantic, 0 to 70°N.

From Numerical Weather Prediction (NWP)
To Dynamical Seasonal Prediction (DSP) (1975-2004)

"Predictability in the midst of chaos"

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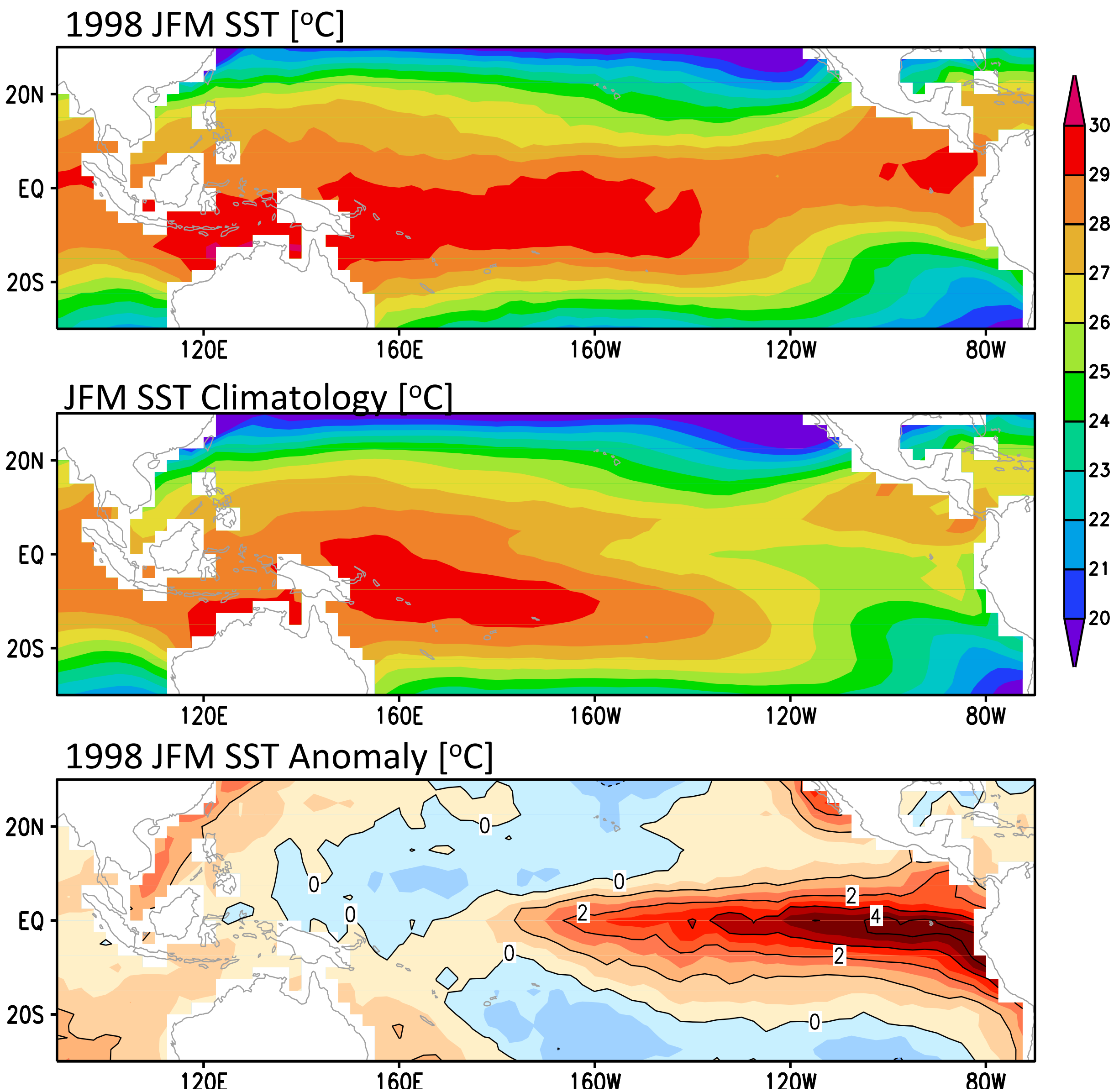
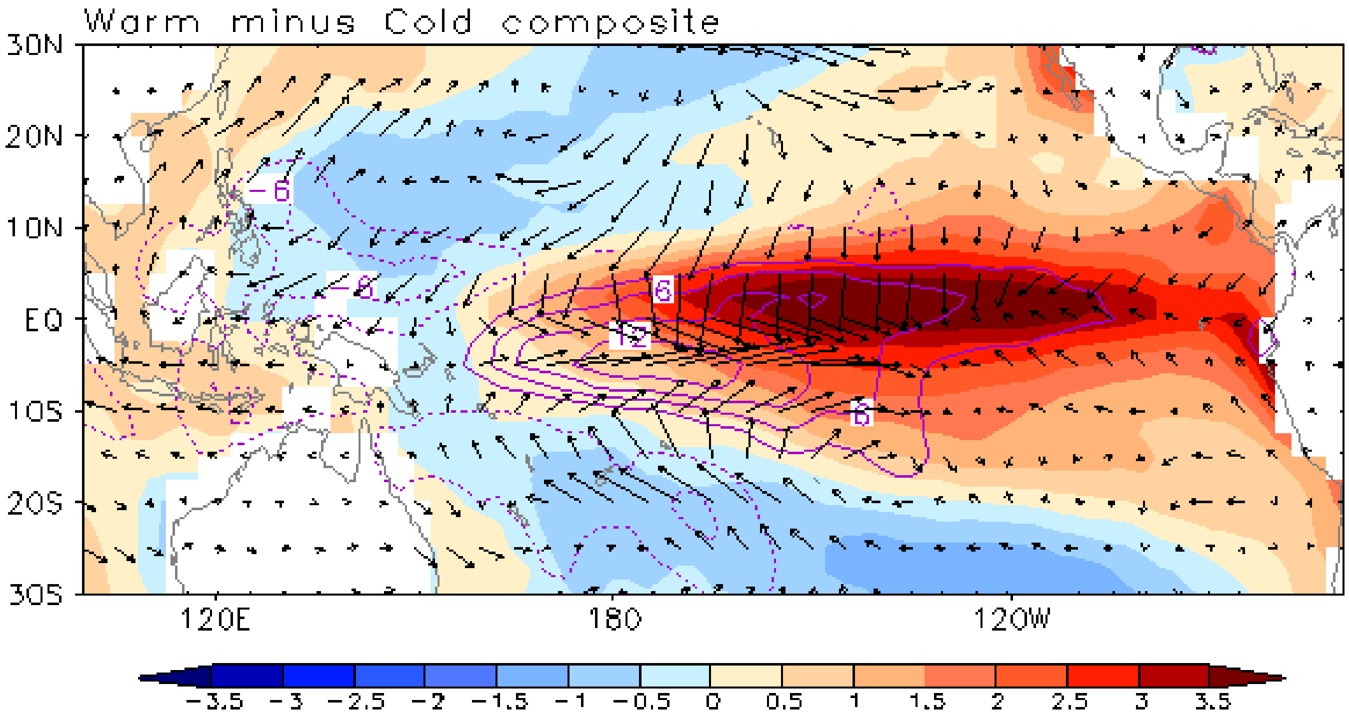
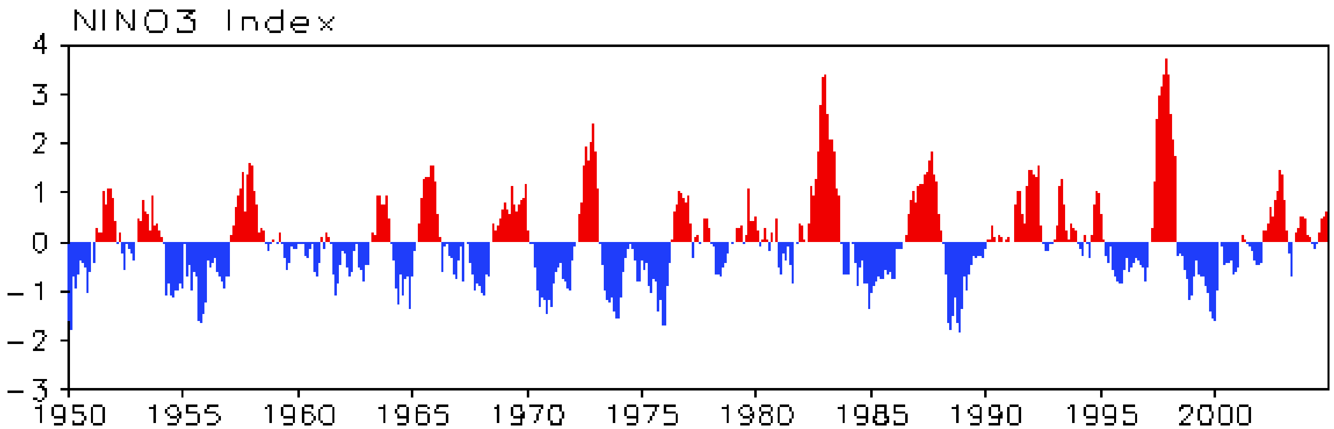
El Nino/Southern Oscillation



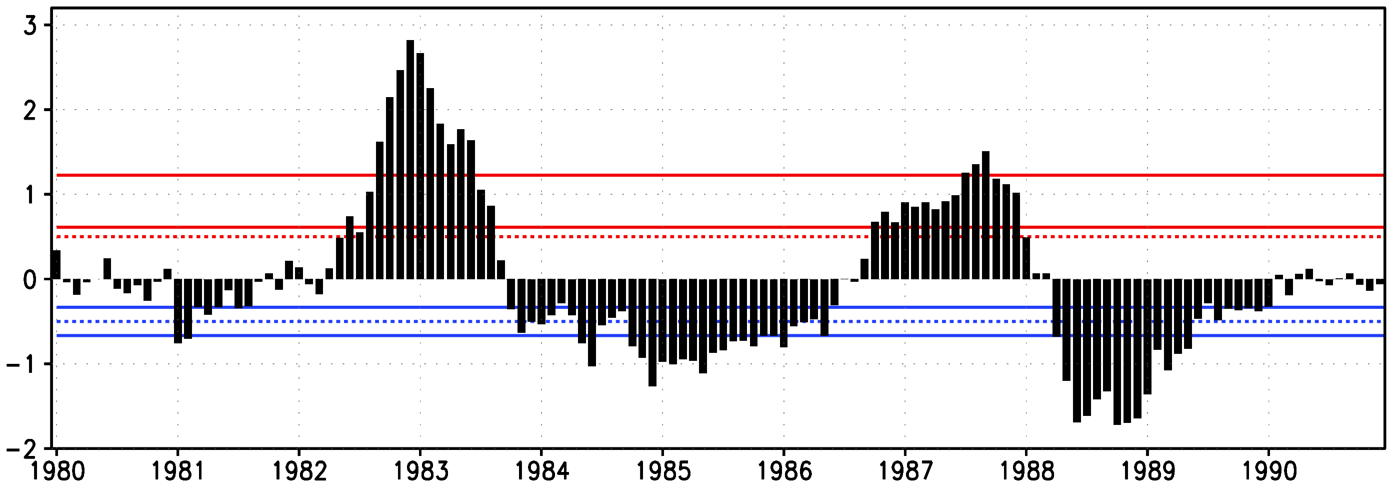
El Nino/Southern Oscillation

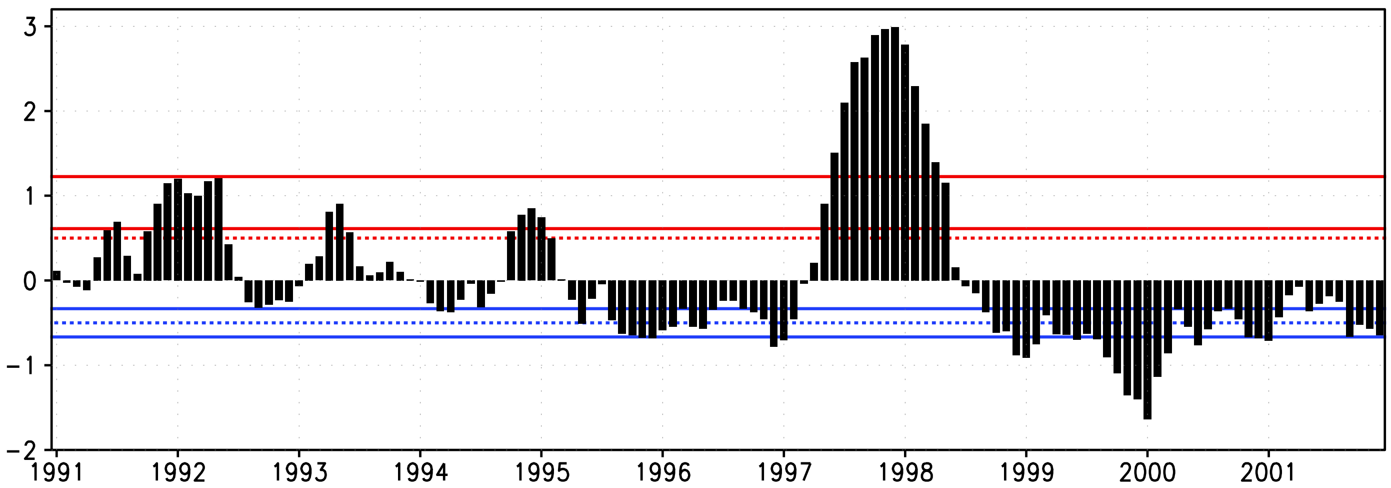




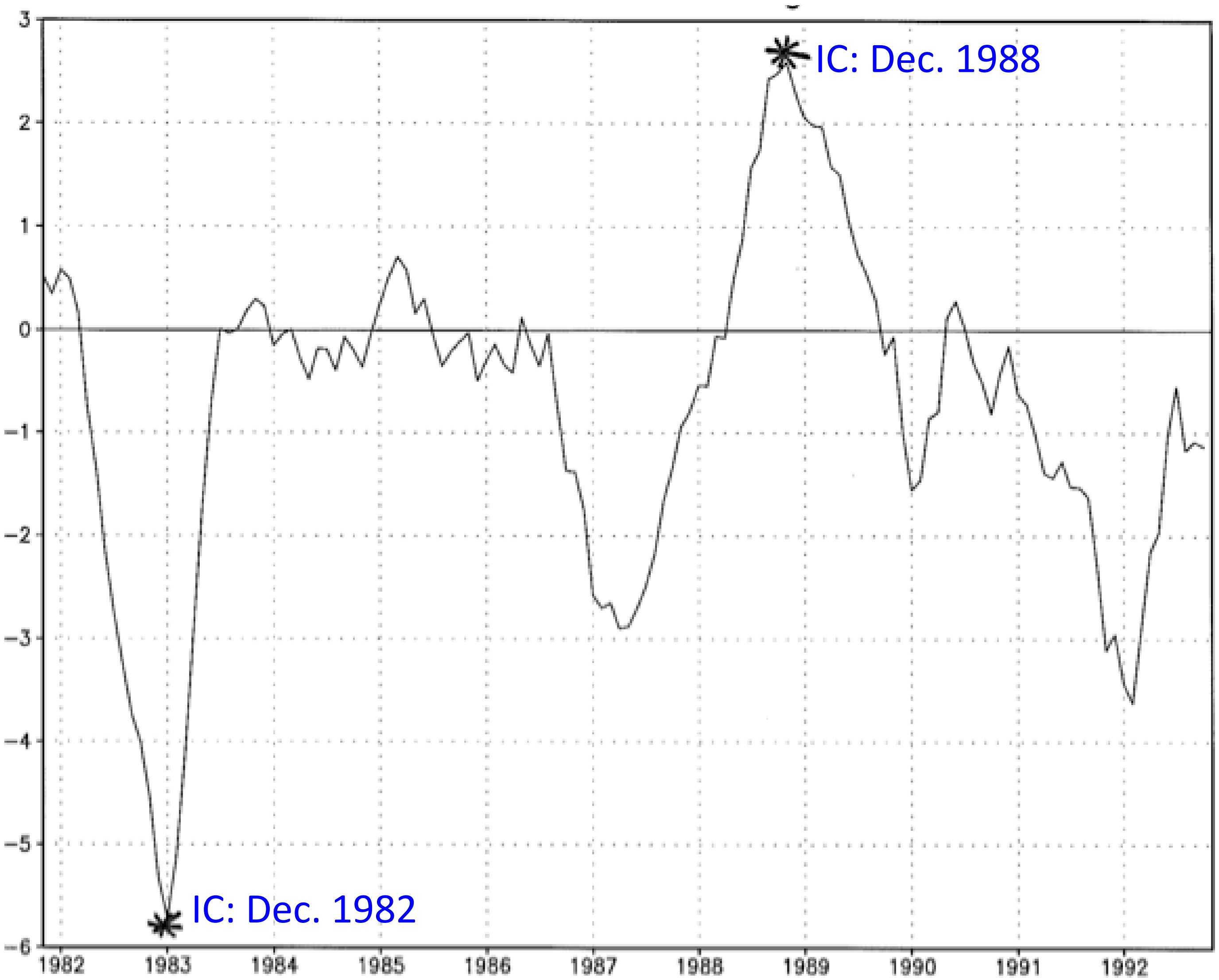
Interannual Variability of Tropical Pacific SSTA

(NINO3, 150°-90°W, 5°S-5°N)





Observed 5-month running mean SOI



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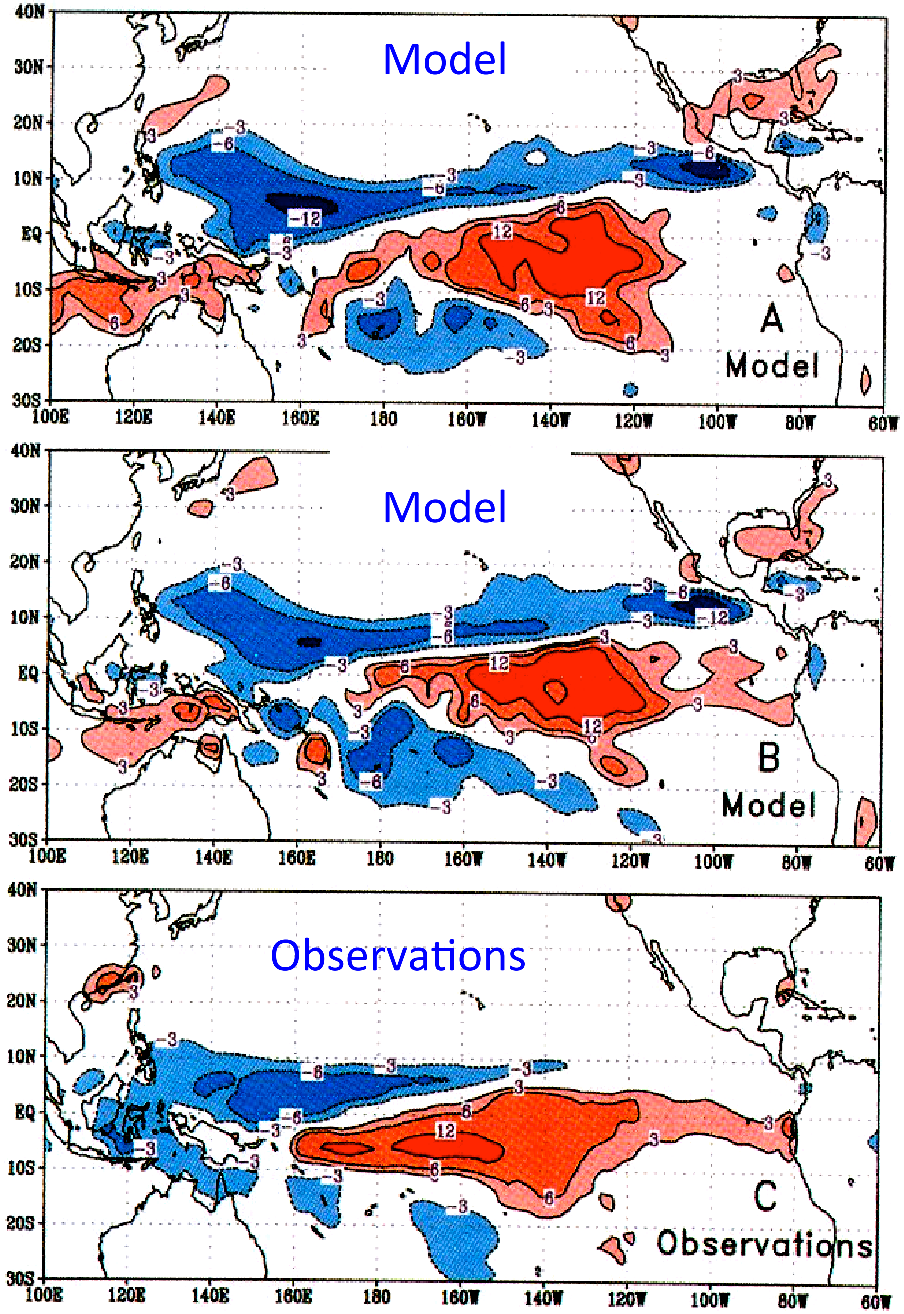
JFM Mean Rainfall Anomalies

“Predictability in the Midst Of Chaos”

IC: Dec. 1988

IC: Dec. 1982

B.C.(SST): 1982 -83



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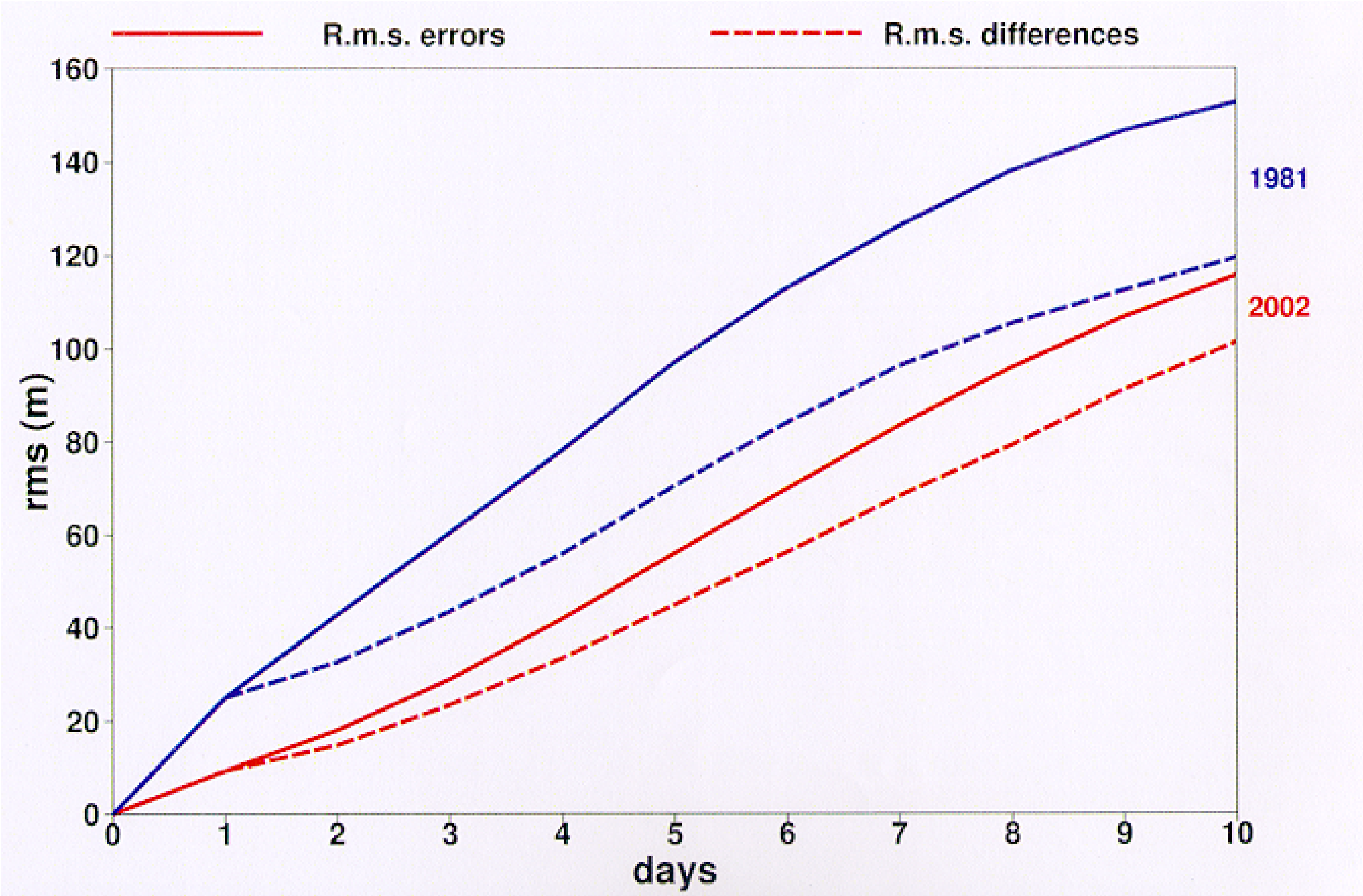
RMS Error and Differences between Successive Forecasts

Northern Hemisphere 500 hPa Height in Winter



Current Limits of Predictability, A. Hollingsworth, Savannah, Feb 2003

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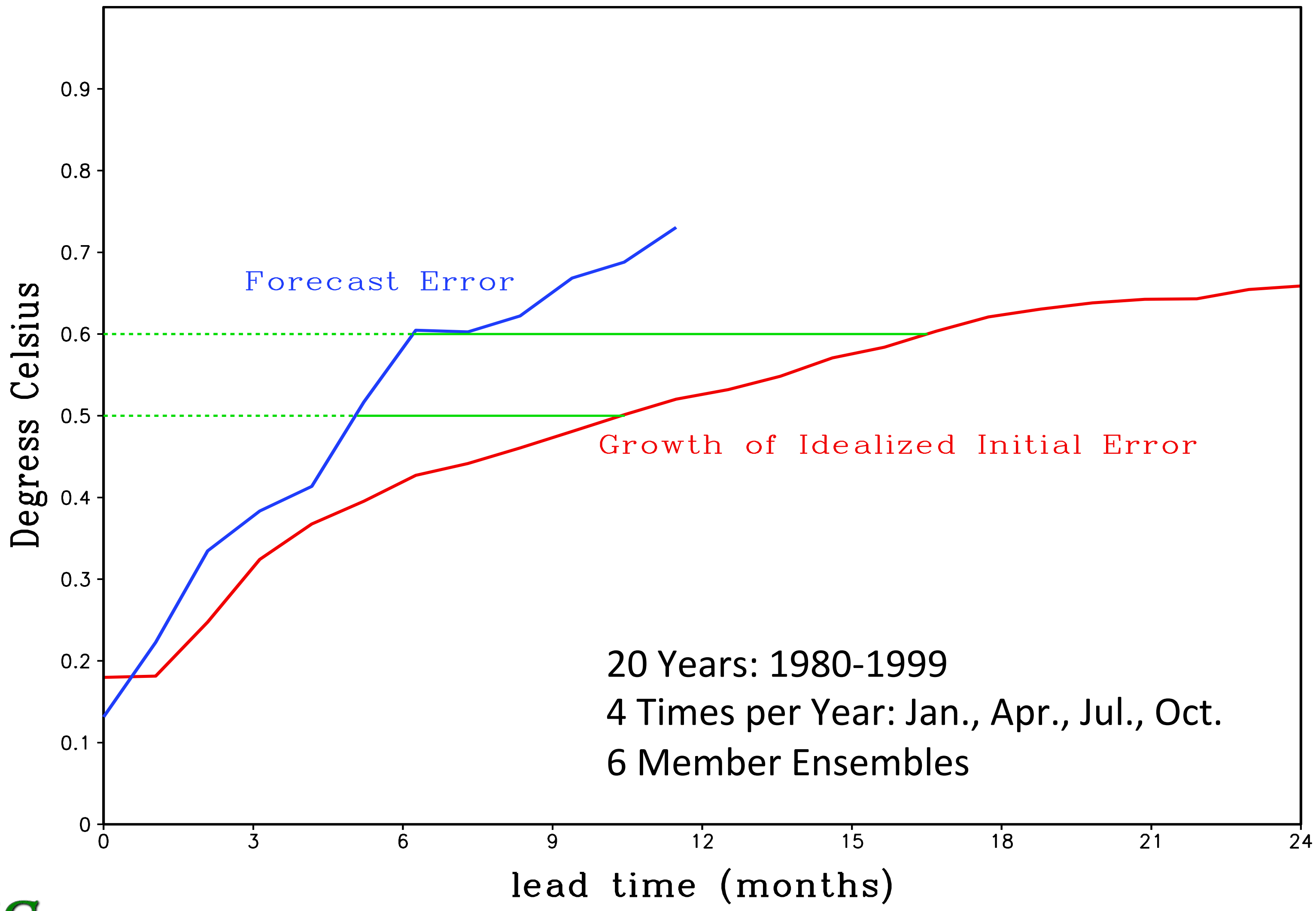
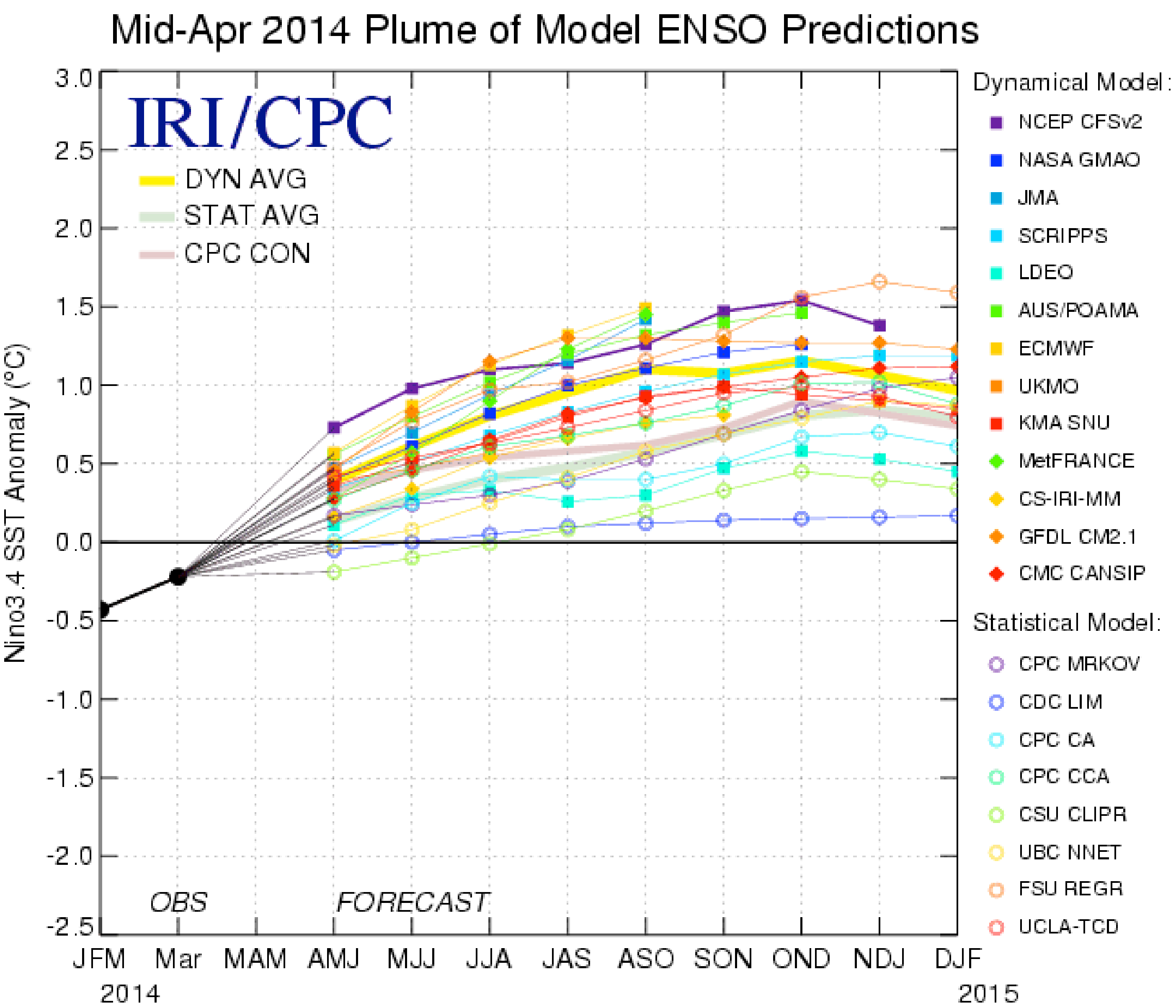
Current Limit of Predictability of ENSO (Nino3.4)

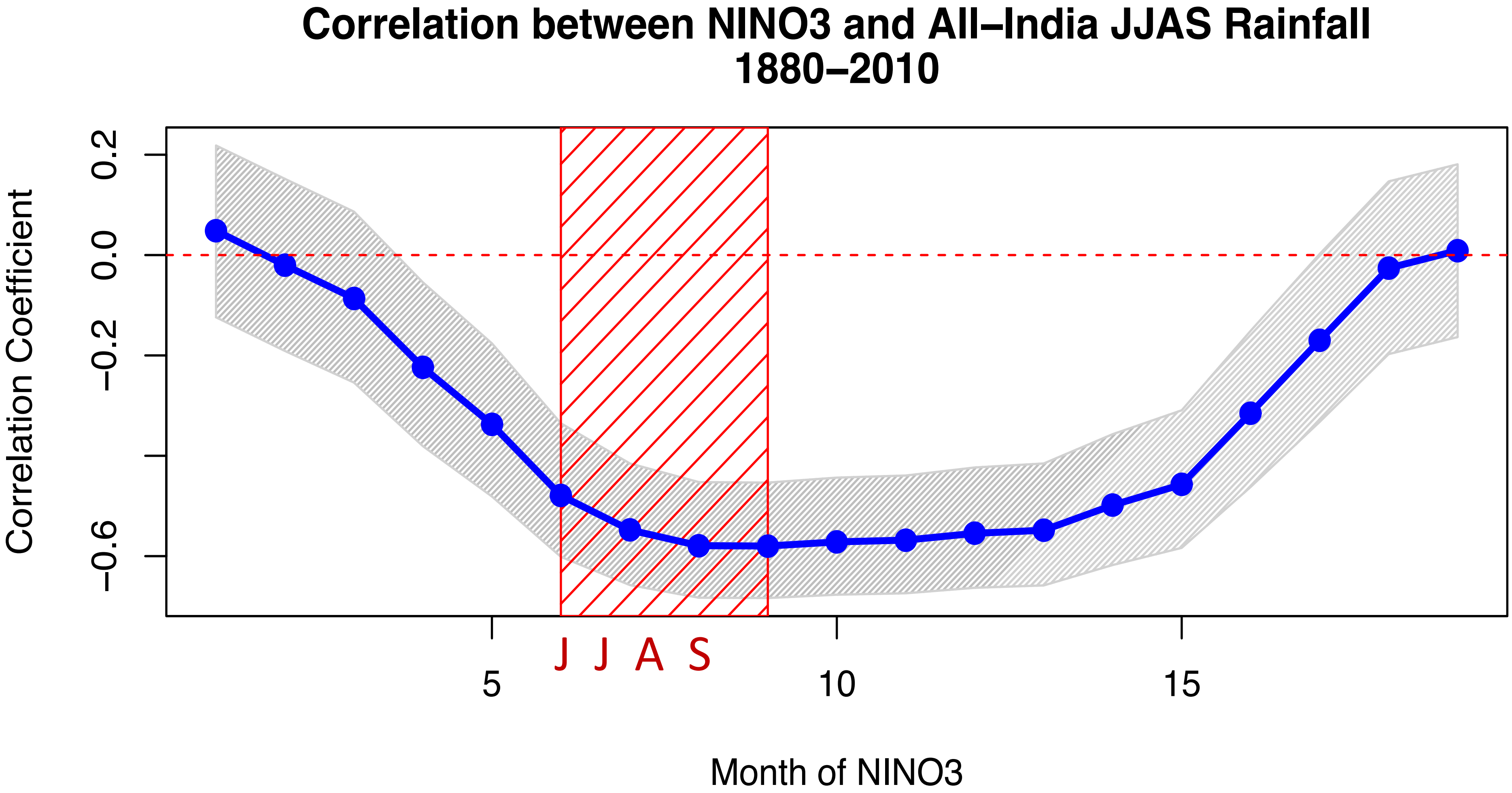
Potential Limit of Predictability of ENSO

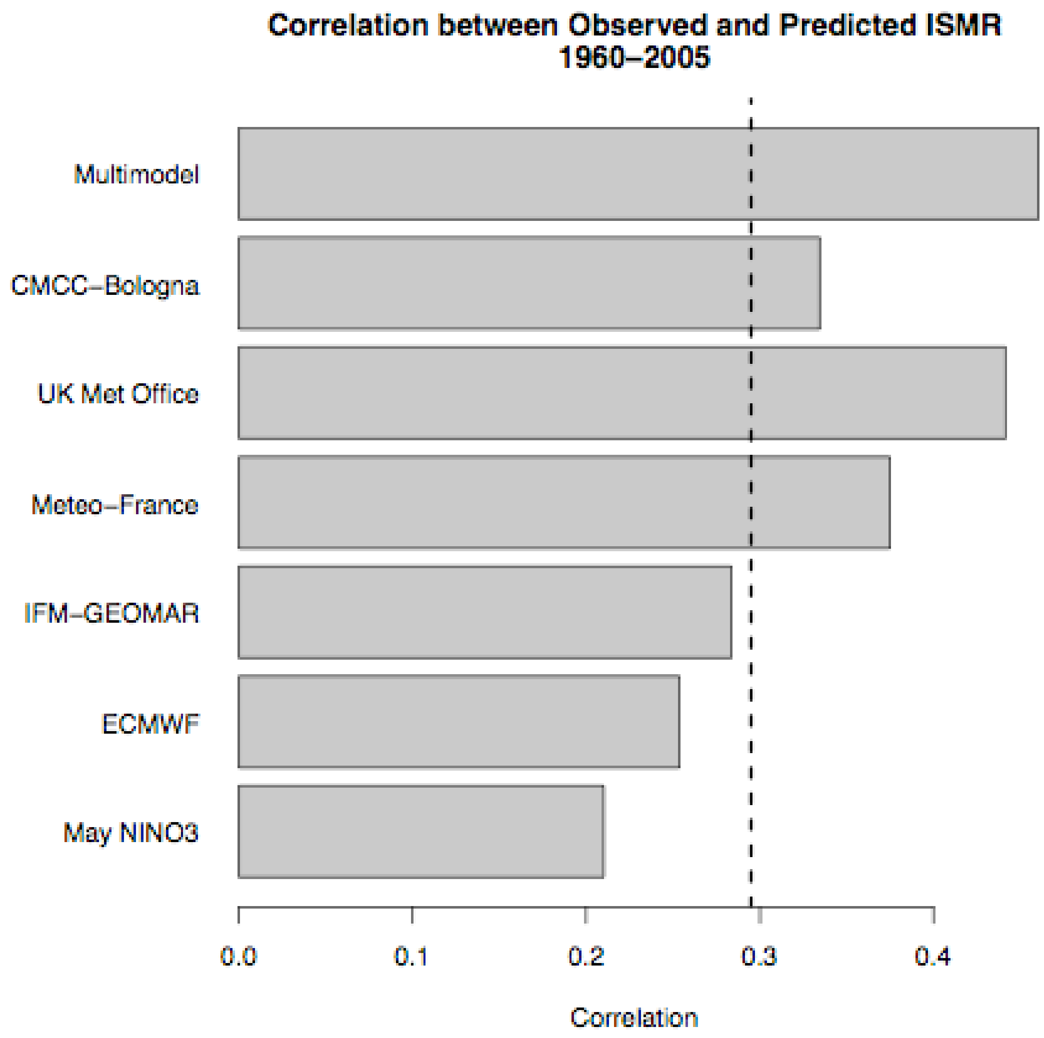


Kirtman, 2003

Nino3.4 SST anomaly predictions from March 2014




Correlation between NINO3 and All–India JJAS Rainfall
1880–2010
Correlation Coefficient
0.2
0.0
−0.2
−0.6
J J A S
5
10
15
Month of NINO3



(46 years (1960-2005); Ens.=9)

For 1960-2005 Obs,

CC (April Nino3, ISMR): −0.18

CC (May Nino3, ISMR): −0.21

Correlation between observed and predicted JJAS all-India rainfall for hindcasts in the ENSEMBLES data set for the period 1960-2005. All-India rainfall in dynamical models is defined as the total land precipitation within 70E – 90E and 10N – 25N .

Last row shows empirical prediction using observed May NINO3.

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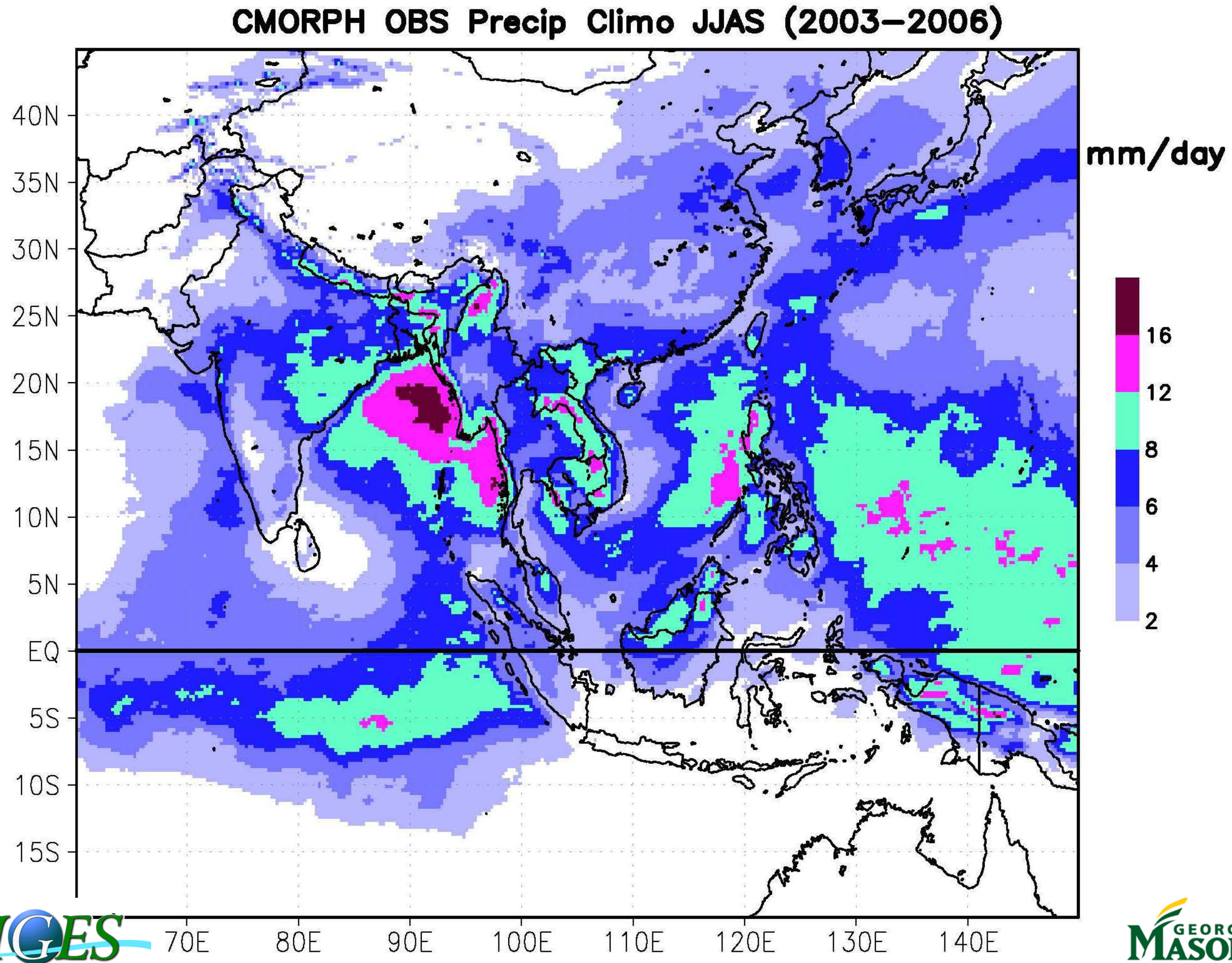
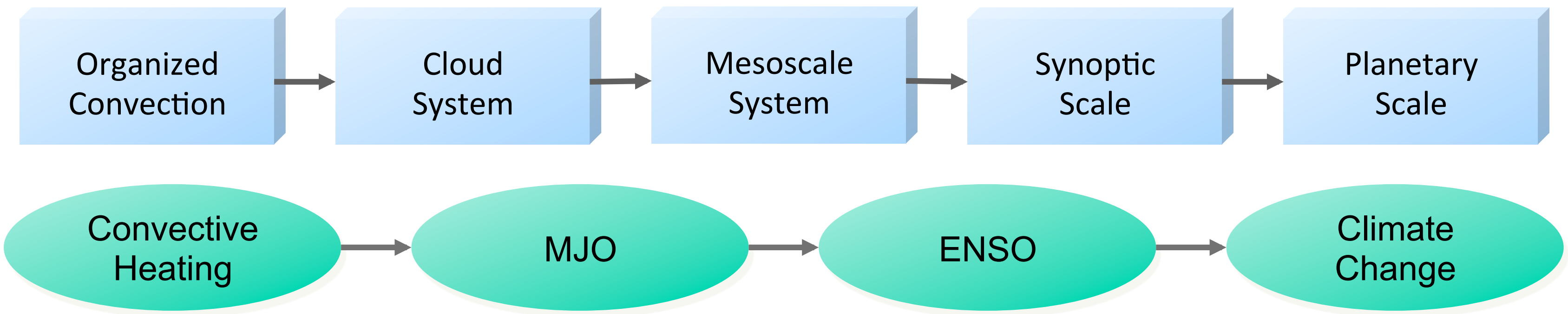

CMORPH OBS Precip Climo JJAS (2003–2006)
mm/day
16
12
8
6
4
2
40N
35N
30N
25N
20N
15N
10N
5N
EQ
5S
10S
15S
70E
80E
90E
100E
110E
120E
130E
140E

Seamless Prediction of Weather and Climate

From Cyclone Resolving Global Models to Cloud System Resolving Global Models

1. **Planetary Scale Resolving Models (1970~): *Δx*~500Km**
2. **Cyclone Resolving Models (1980~): *Δx*~100-300Km**
3. **Mesoscale Resolving Models (1990~): *Δx*~10-30Km**
4. **Cloud System Resolving Models (2000 ~): *Δx*~3-5Km♪**



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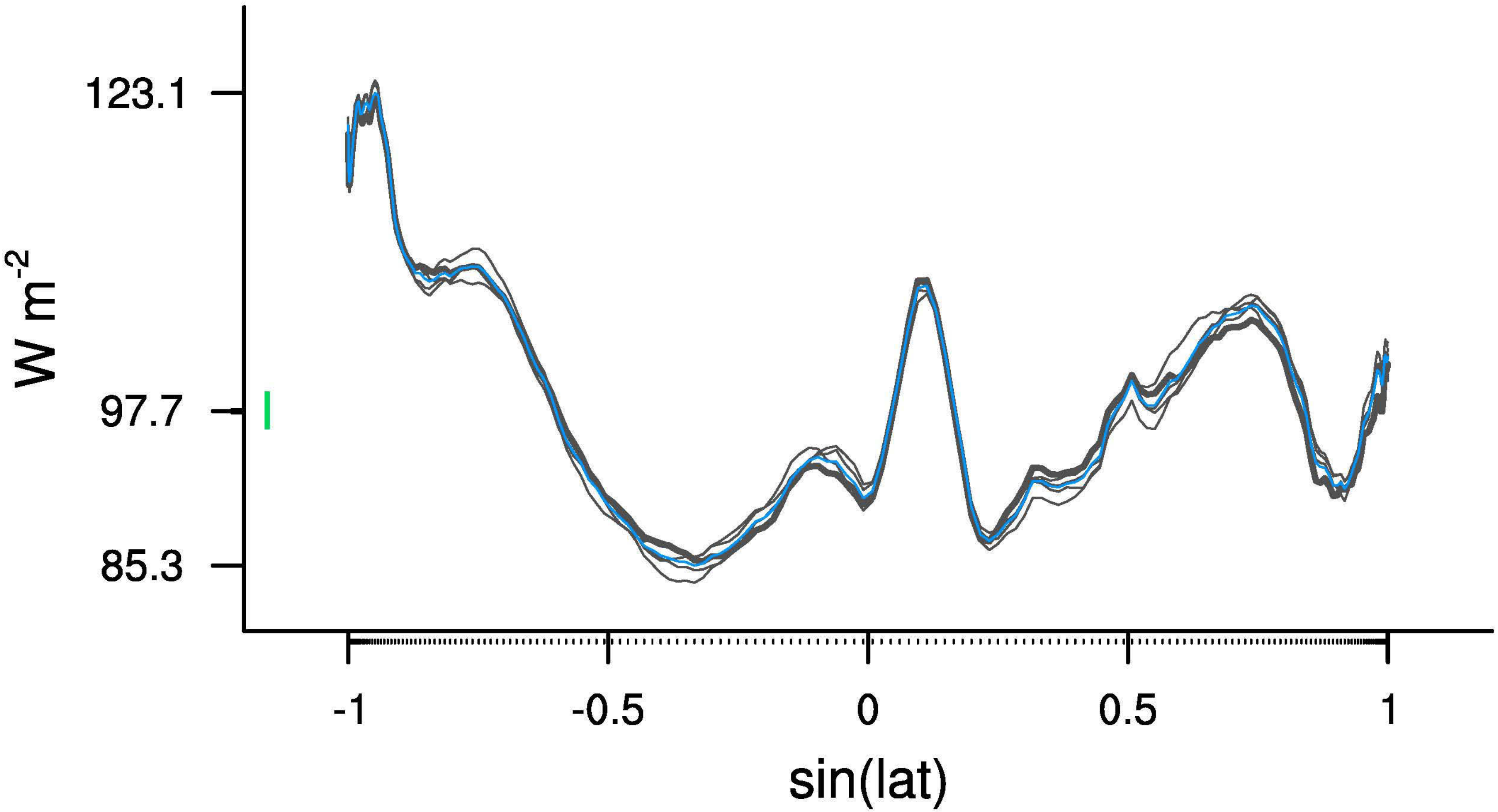
Examples of improved climate simulation by global climate models with higher numerical accuracy (high resolution) and improved physics

Annually & Zonally Averaged Reflected SW Radiation



Bjorn Stevens, UCLA
World Modelling Summit, ECMWF, May 2008

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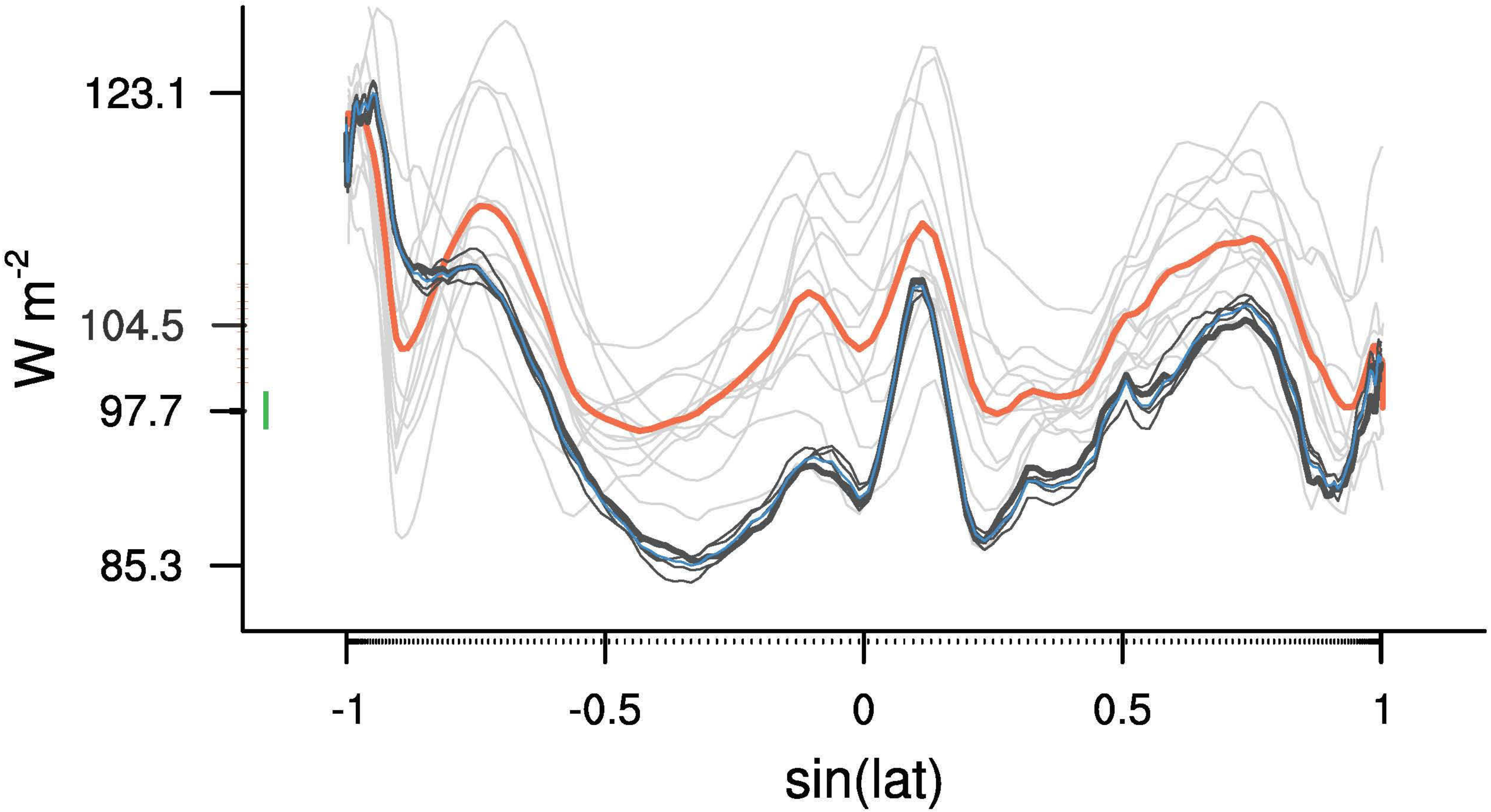
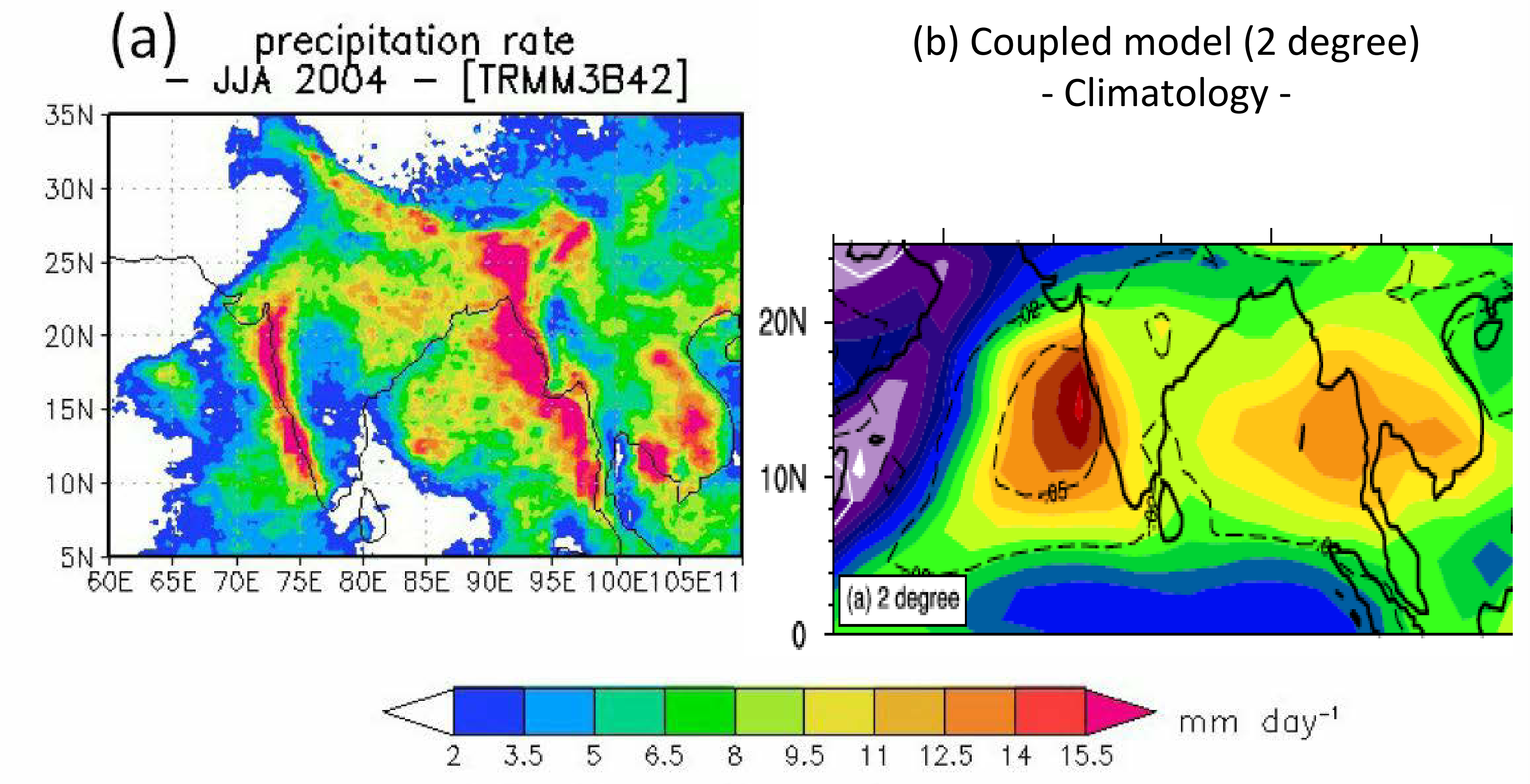
Annually & Zonally Averaged SW Radiation (AR4)



- 101-106 W/m2 (Wild et al., survey)
- 107 W/m2 (Trenberth and Kiehl (ERBE)
- 101 W/m2 (CERES)

Bjorn Stevens, UCLA
World Modelling Summit, ECMWF, May 2008

Monsoon Rainfall in Low Resolution Model



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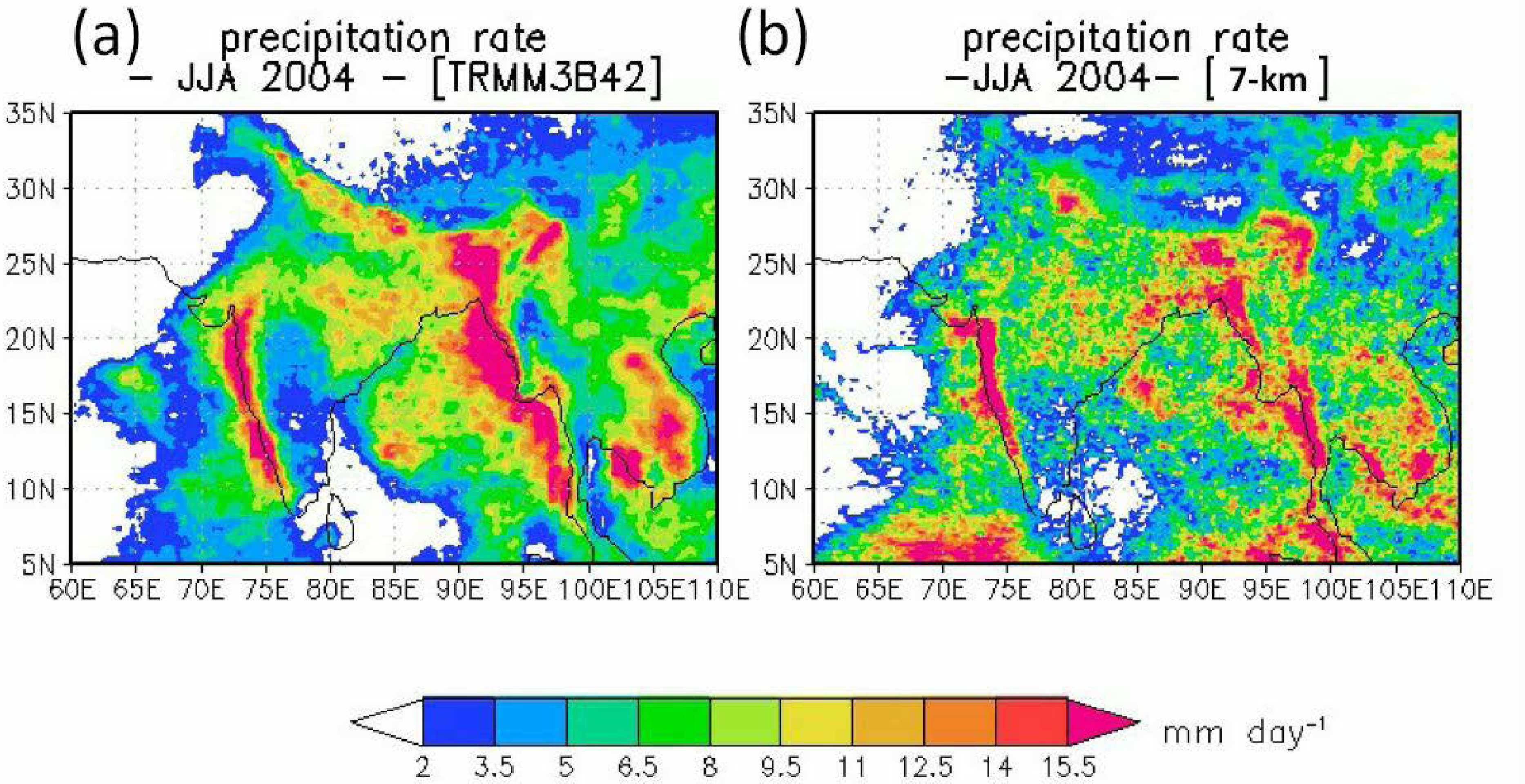
Monsoon Rainfall in High Resolution Model



Oouchi et al. 2009: (a) Observed and (b) simulated precipitation rate over the Indo-China monsoon region as June-July-August average (in units of mm day -1). The observed precipitation is from TRMM_3B42, and the simulation is for 7km-mesh run.

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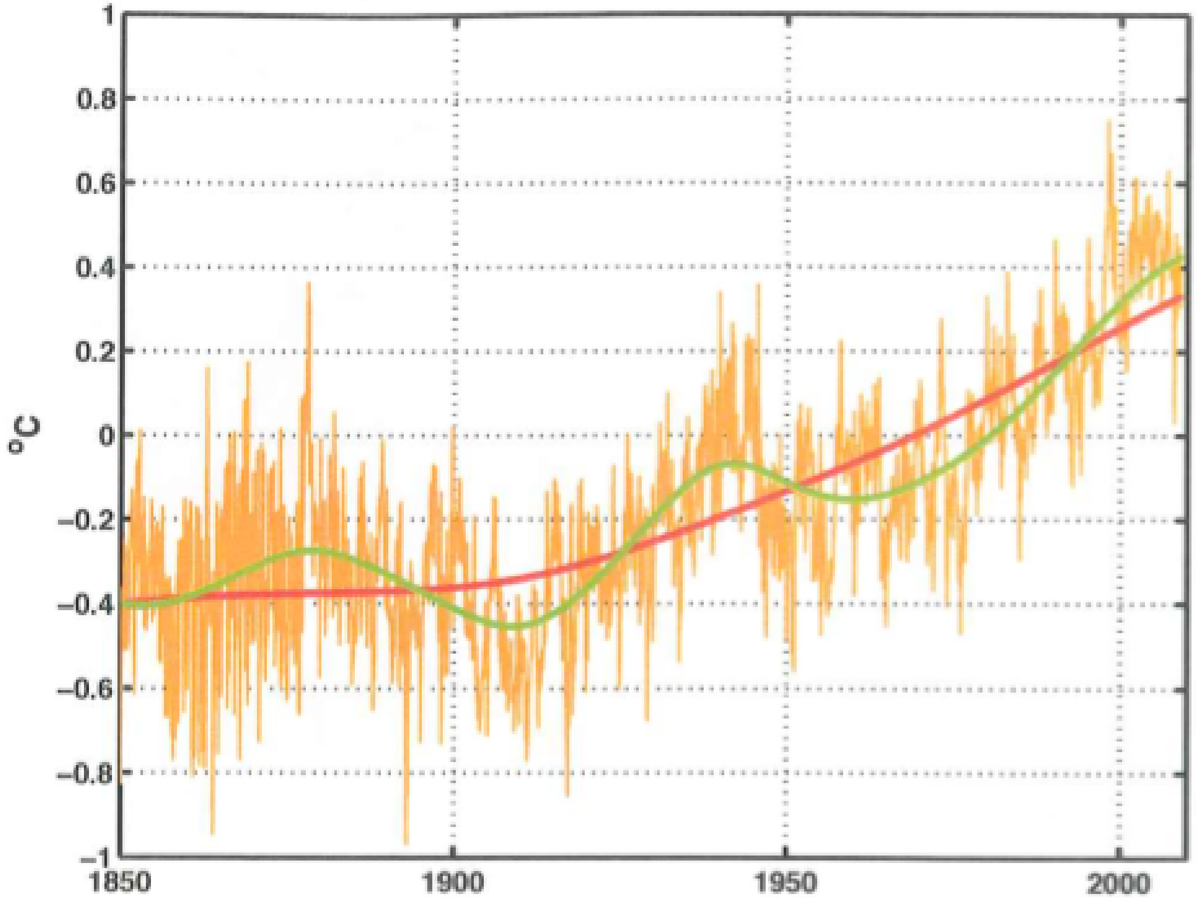
Global-mean Surface Temperature



On the Time-Varying Trend in Global-Mean Surface Temperature
by Huang, Wu, Wallace, Smoliak, Chen, Tucker
EEMD: Ensemble Empirical Mode Decomposition; MDV: Multi Decadal Variability

Figure 4: Reconstruction of the raw GST time series (brown lines) using ST only (red lines) and ST + MDV (green lines).

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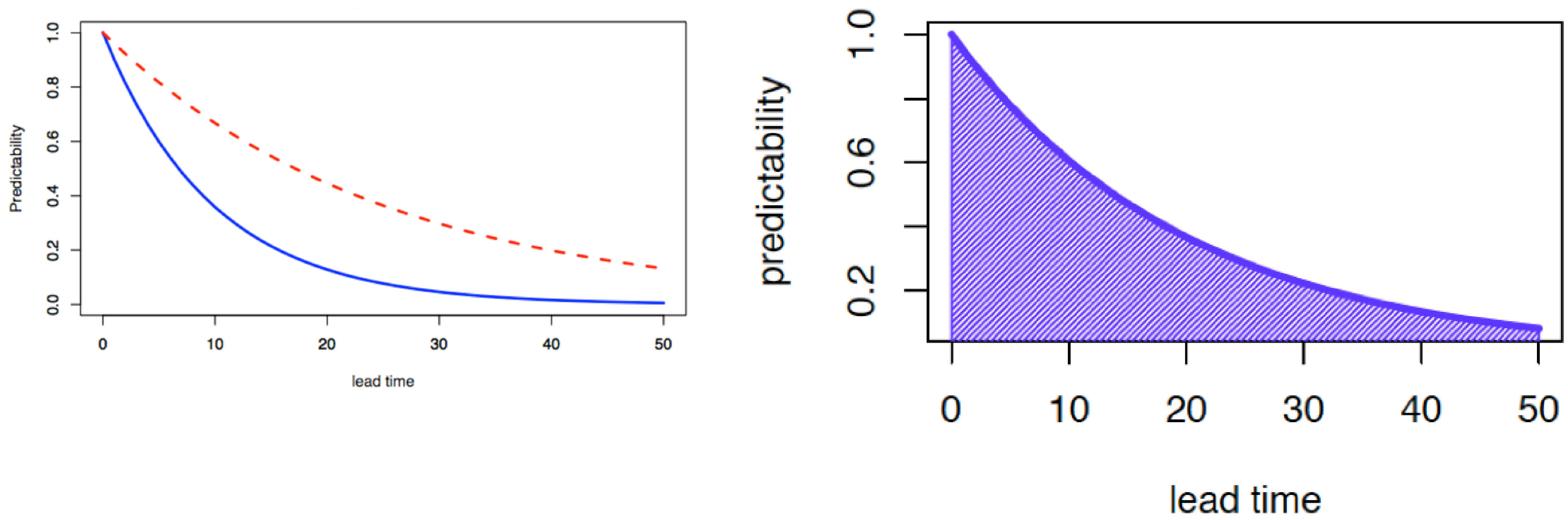
Average Predictability Time (APT)

APT = integral of 2P over all lead times



$$APT = 2\int_0^\infty \left(\frac{\sigma^2_{clim} - \sigma^2_{forecast}(\tau)}{\sigma^2_{clim}} \right) d\tau$$

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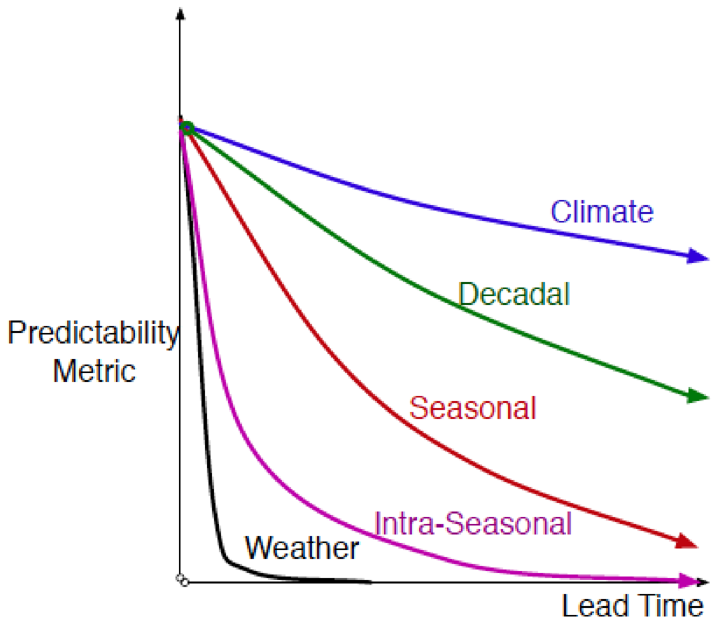
Decomposing Predictability

Find components that maximize APT (DelSole and Tippett 2009).

$$APT = 2\int_0^\infty \left(\frac{\sigma^2_{clim} - \sigma^2_{forecast}(\tau)}{\sigma^2_{clim}} \right) d\tau$$



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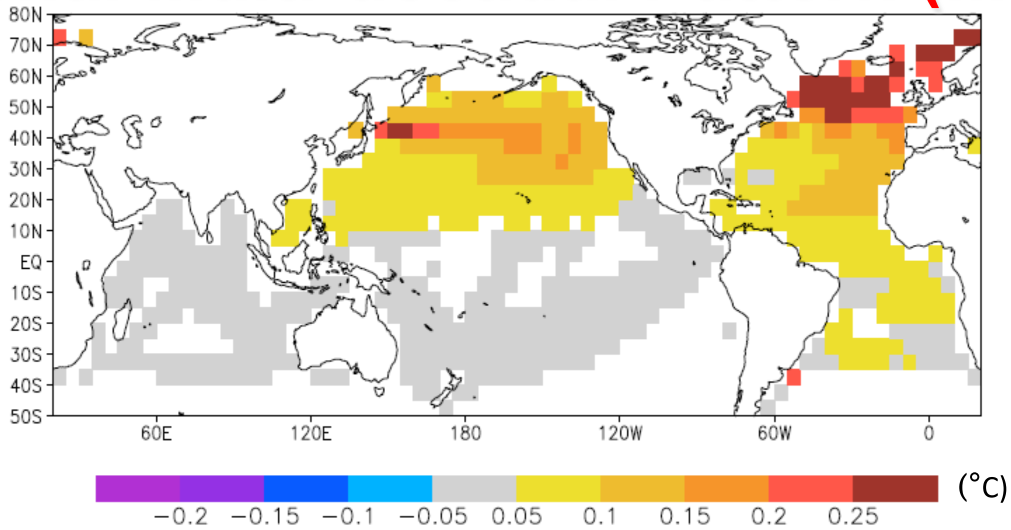
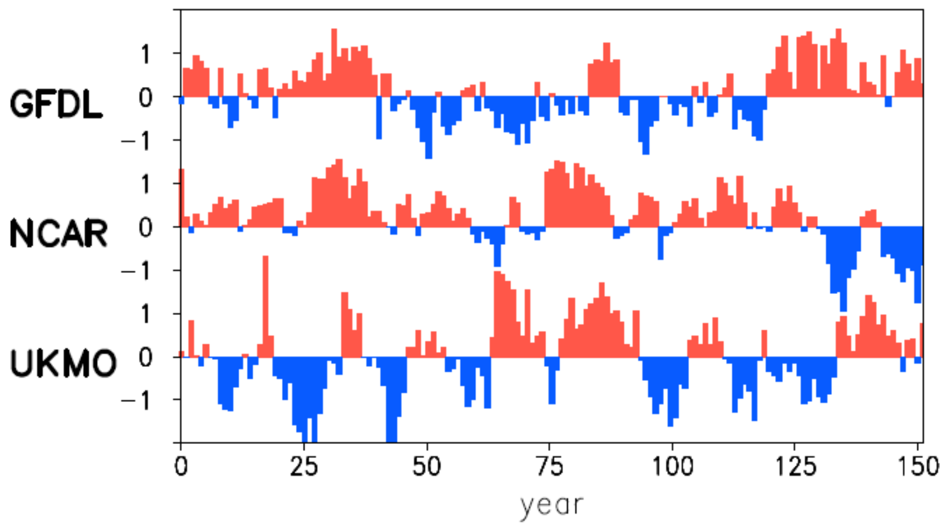
Leading Predictable Component (APT): Internal Multi-decadal Pattern (IMP)





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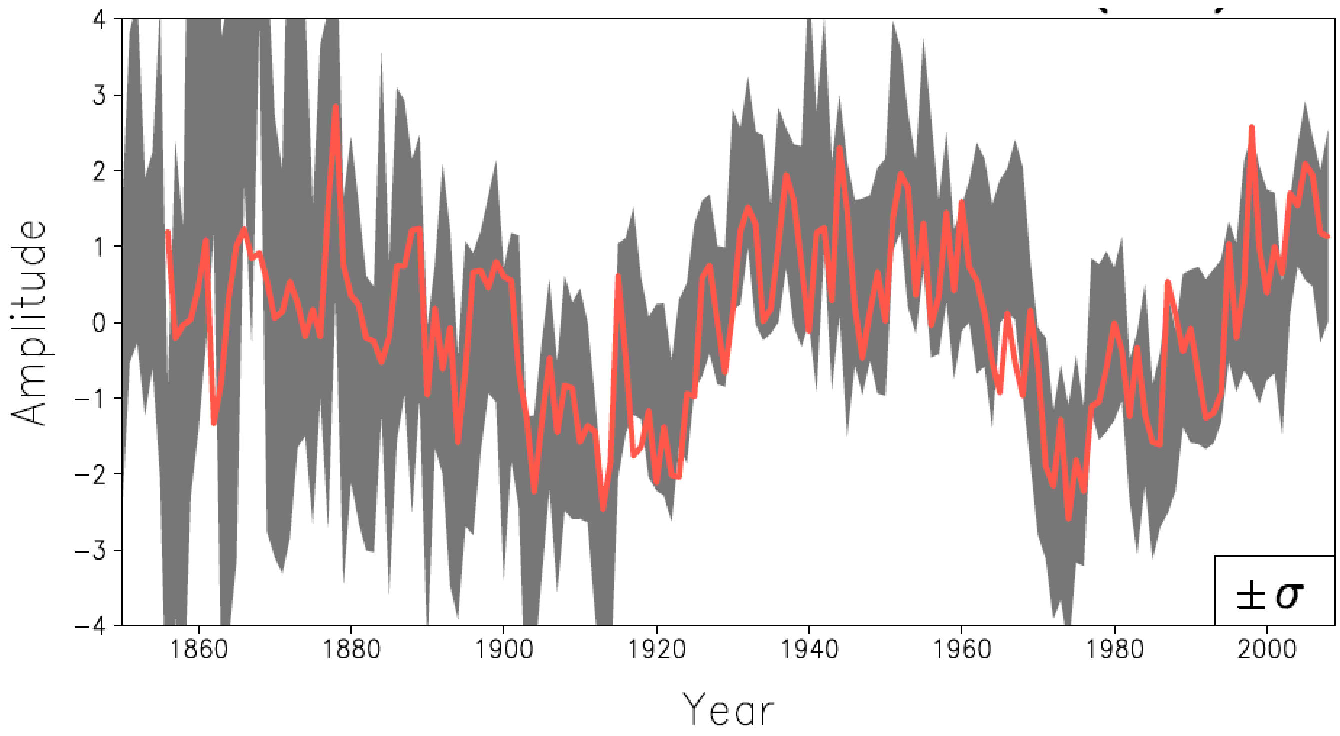
Internal Multi-decadal Pattern (IMP)



shaded area: 66% confidence interval of IMP in observations.

red line: Observed Atlantic Multidecadal Oscillation (AMO) index.

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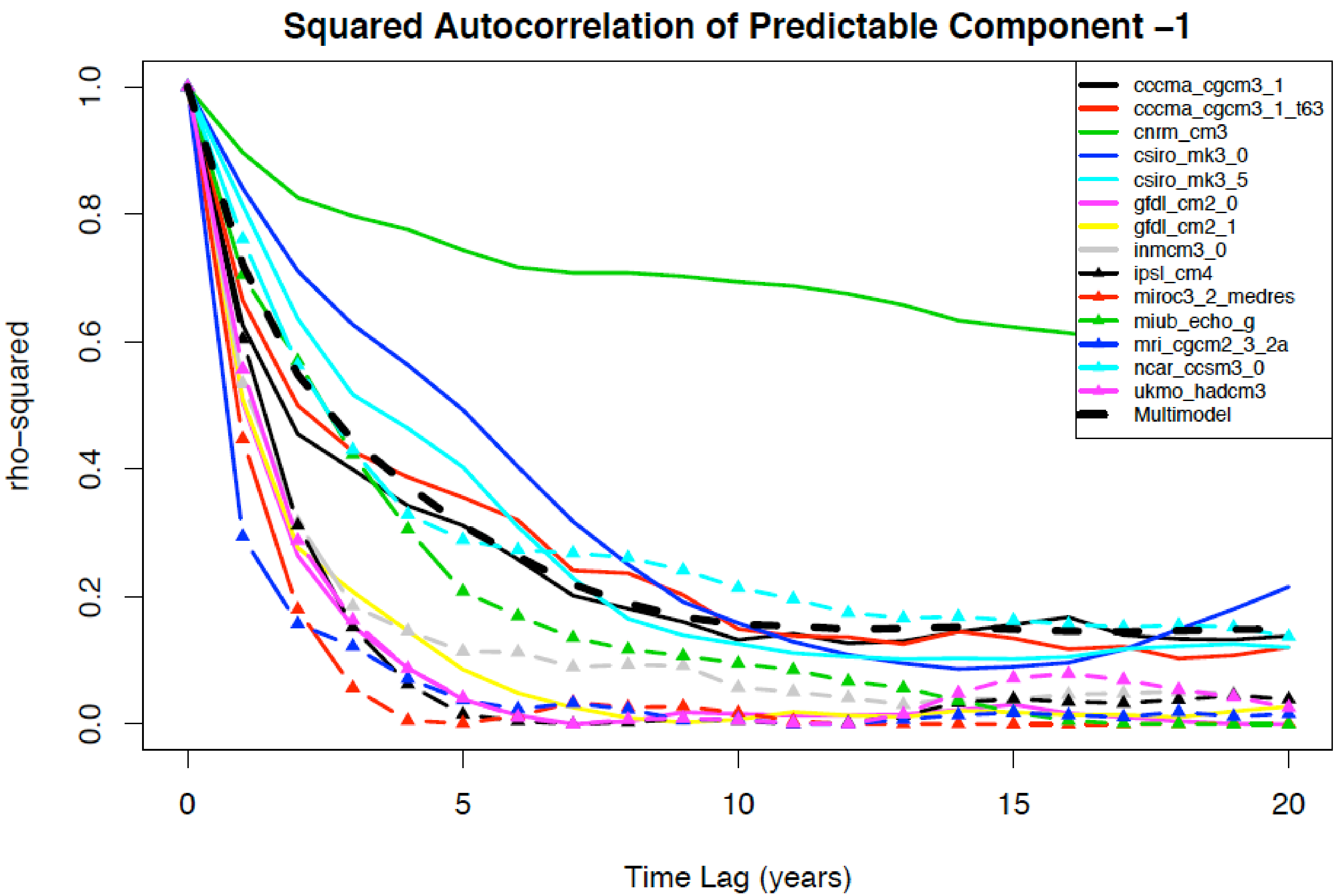
Scientific Basis for Decadal Predictability



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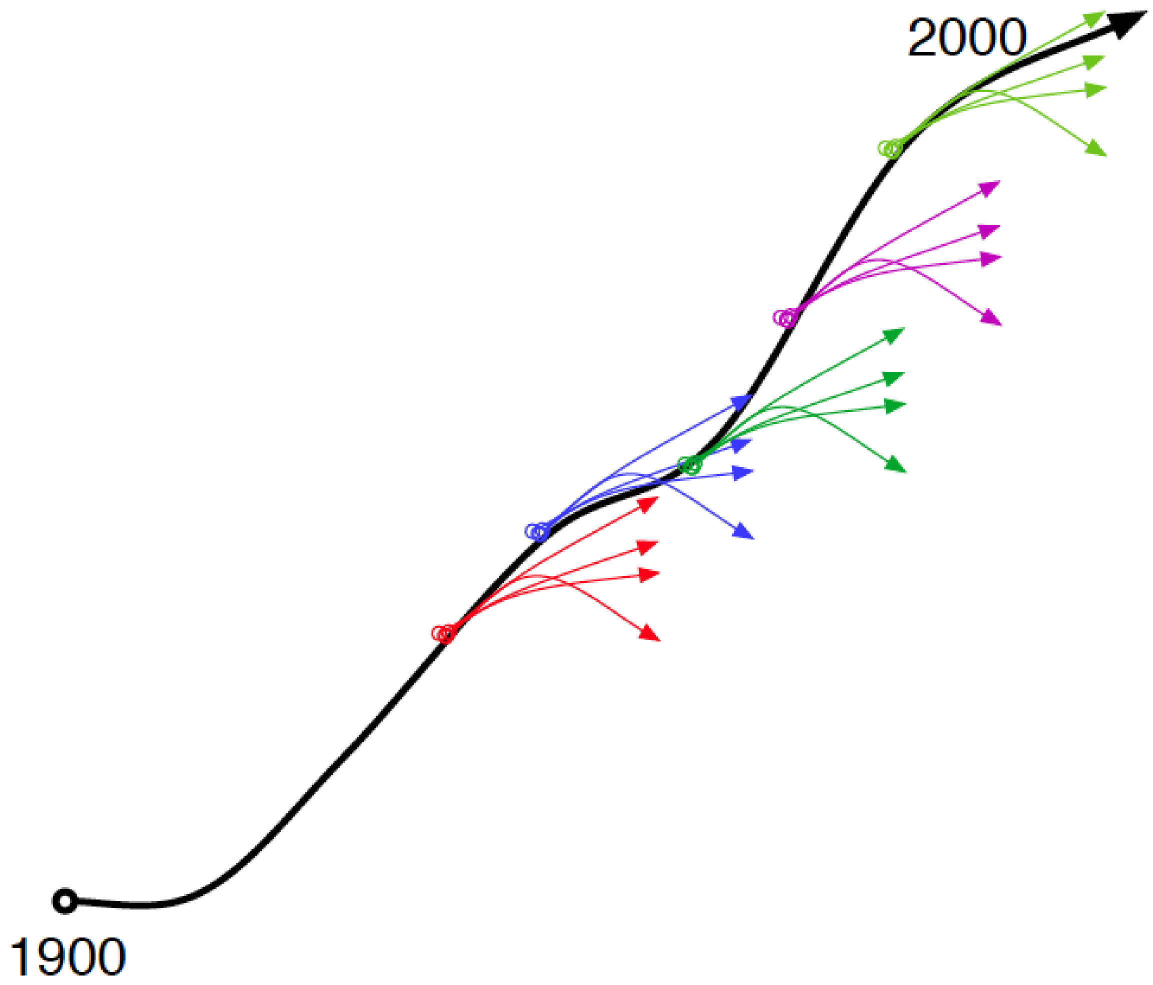
CMIP5 Decadal Hindcast Experiments



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Percent of Predictable Variance of Decadal Mean 2m-Temperature

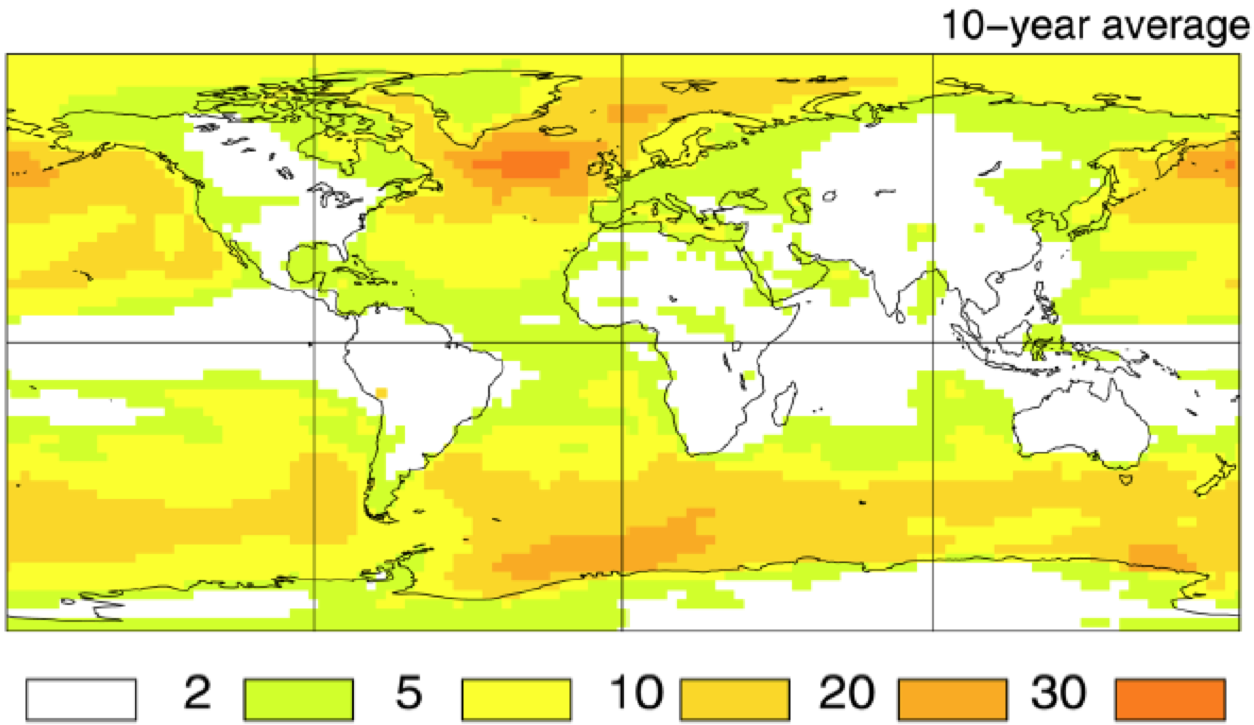

Figure: Boer and Lambert (2008)

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Predictions of Observed SST (DelSole, Jia, Tippett 2012)

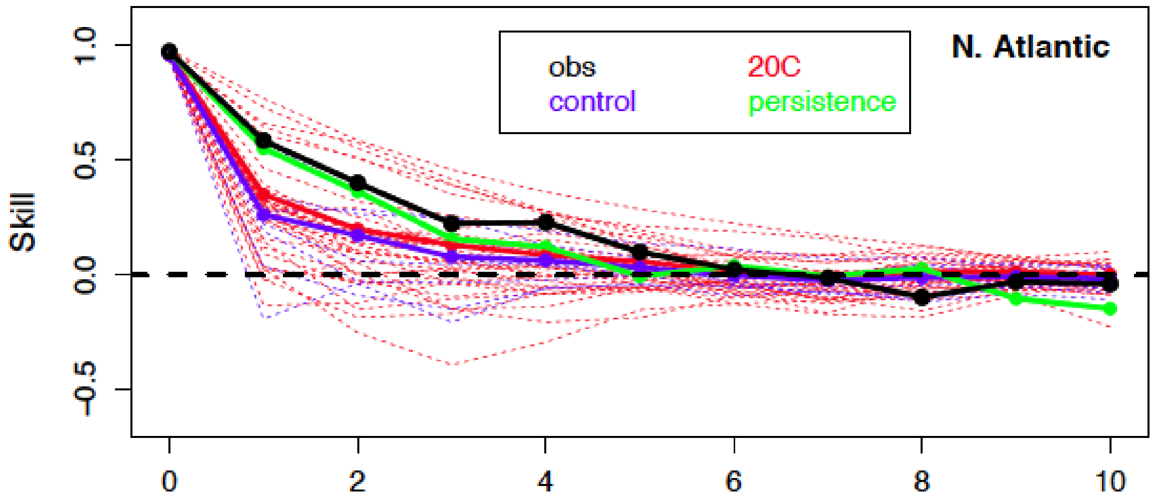
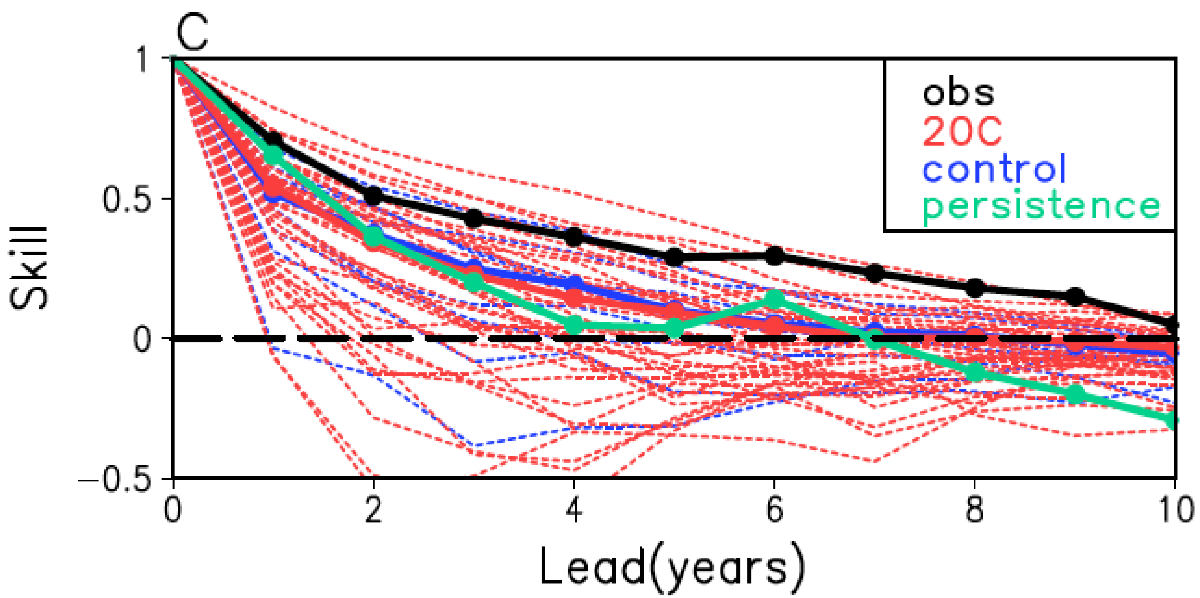


Figure: Skill for observed **unforced** N. Atlantic SST during 1910-2004.

Red: Predict independent twentieth century runs
Blue: Predict independent pre-industrial control runs
Green: Persistence
Black: Predict observed **unforced** anomalies

Skill in Predicting the Most Predictable Component in Observations (1910-2004).



The most predictable component is similar to AMO:
this result is for 8 CMIP5 control runs

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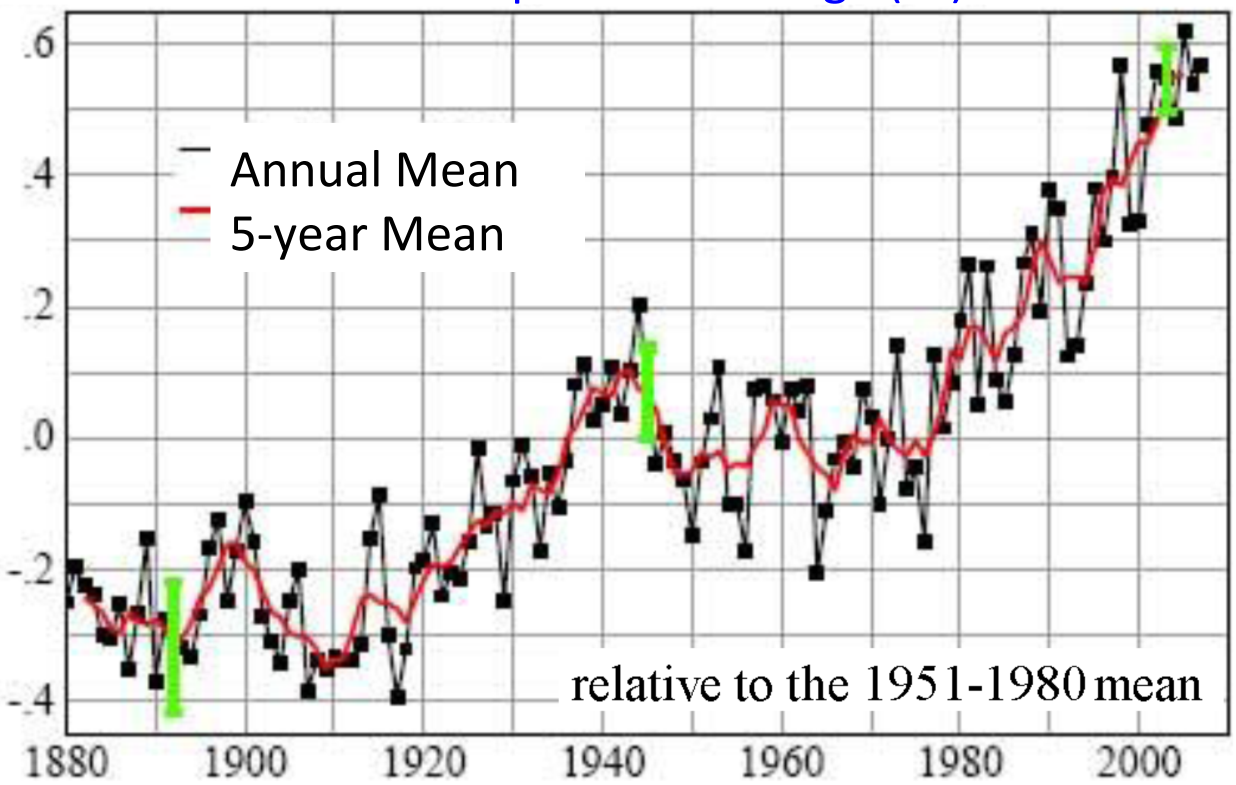
Global Warming

Global Warming is the increase in the average temperature of the Earth's near surface air and oceans since the mid-20th century and its projected continuation. (Wikipedia)

Global Temperature Change (°C)



Year A.D.

0.76°C (1.4°F) since 1900

0.55°C (1.0°F) since 1979

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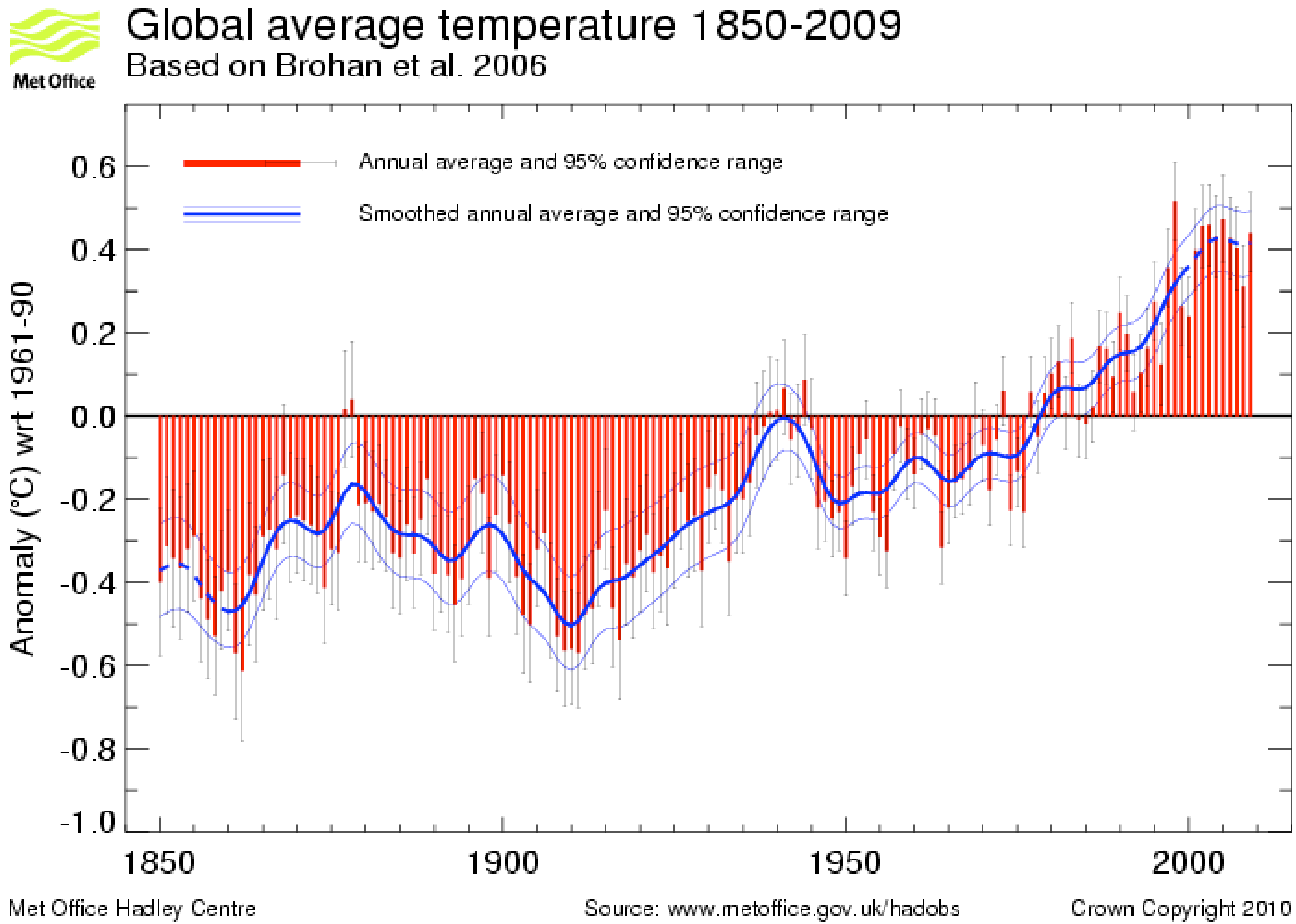
Combined land-surface air and sea-surface temperature anomaly



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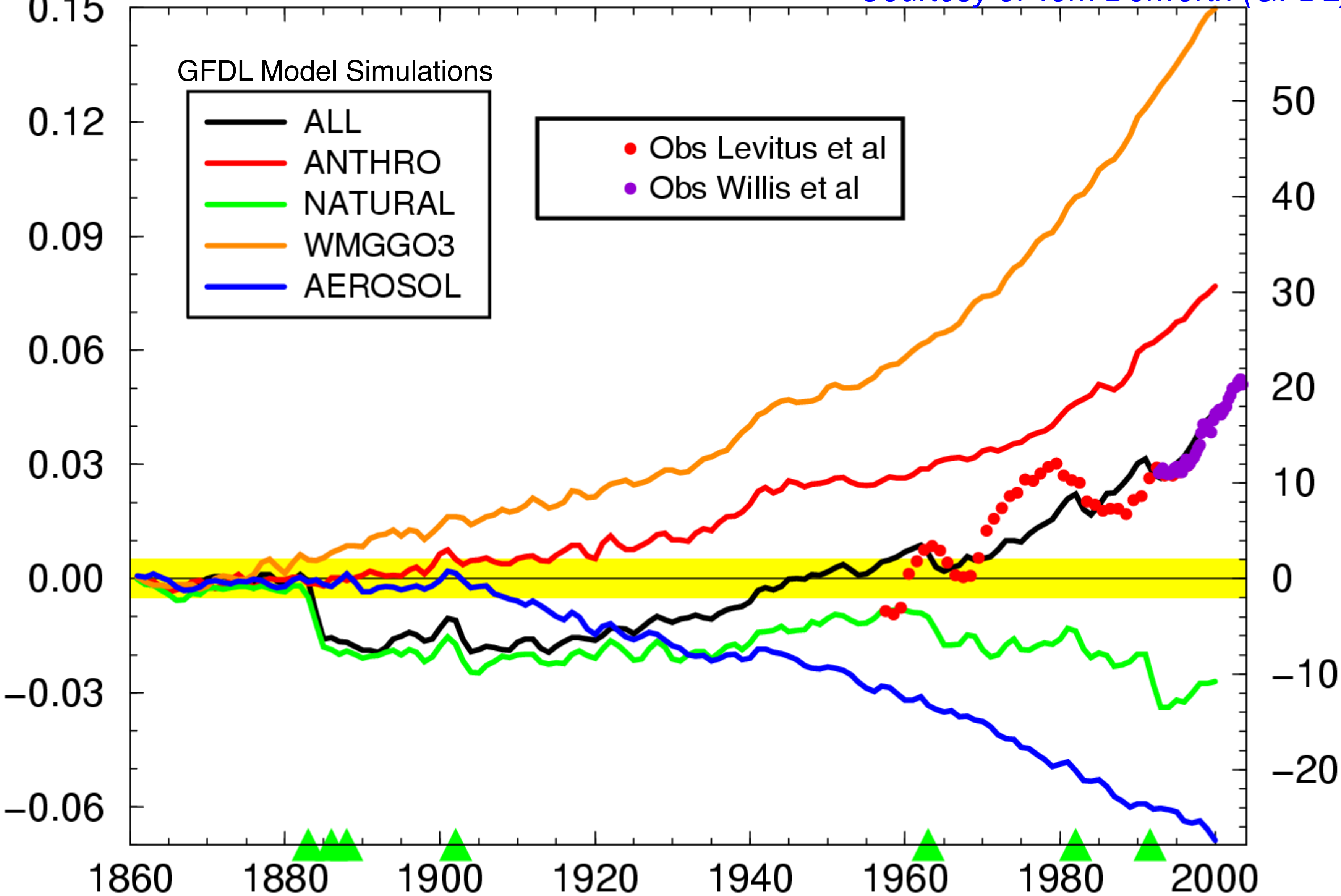
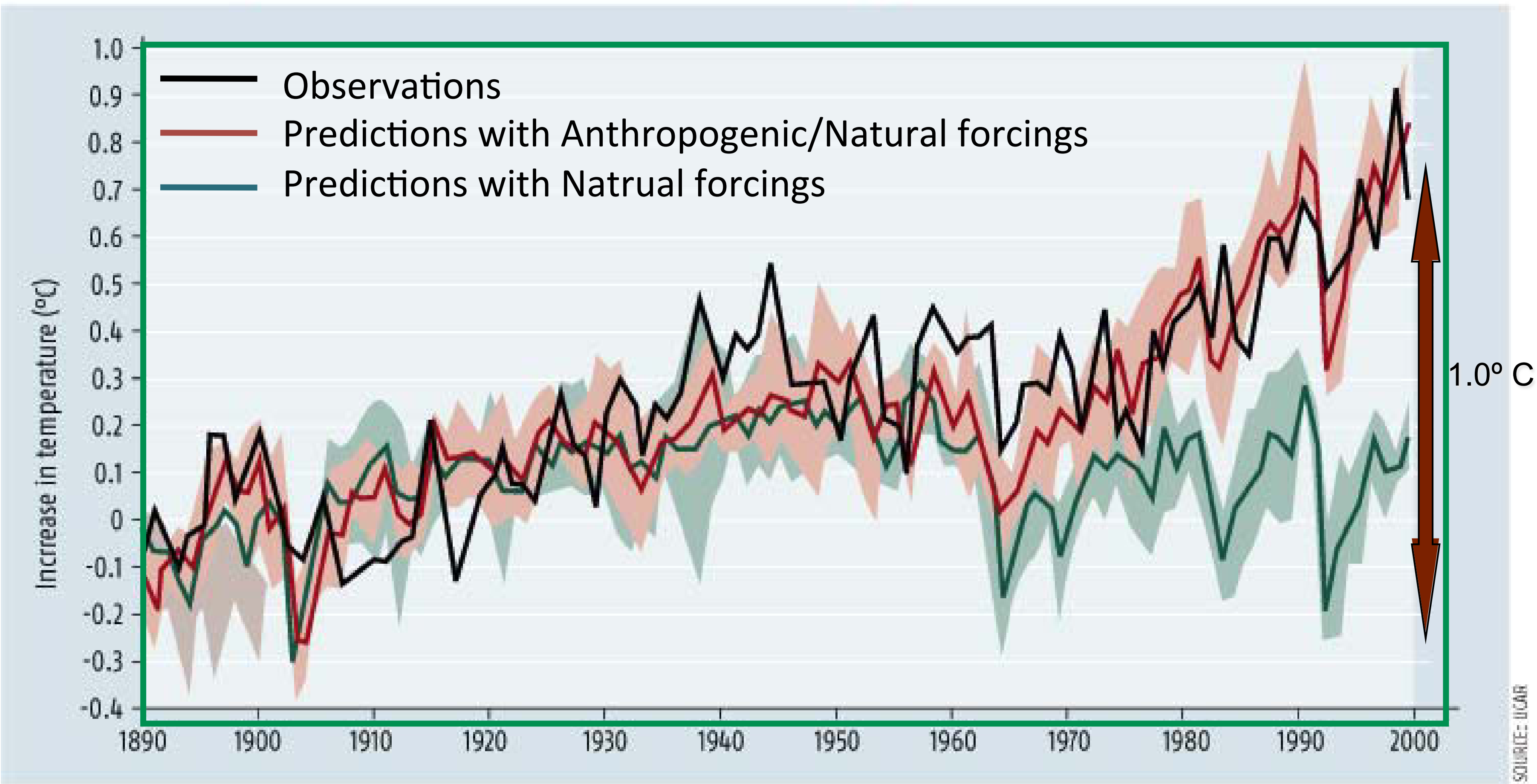
Global mean, volume mean ocean temperature

Courtesy of Tom Delworth (GFDL)



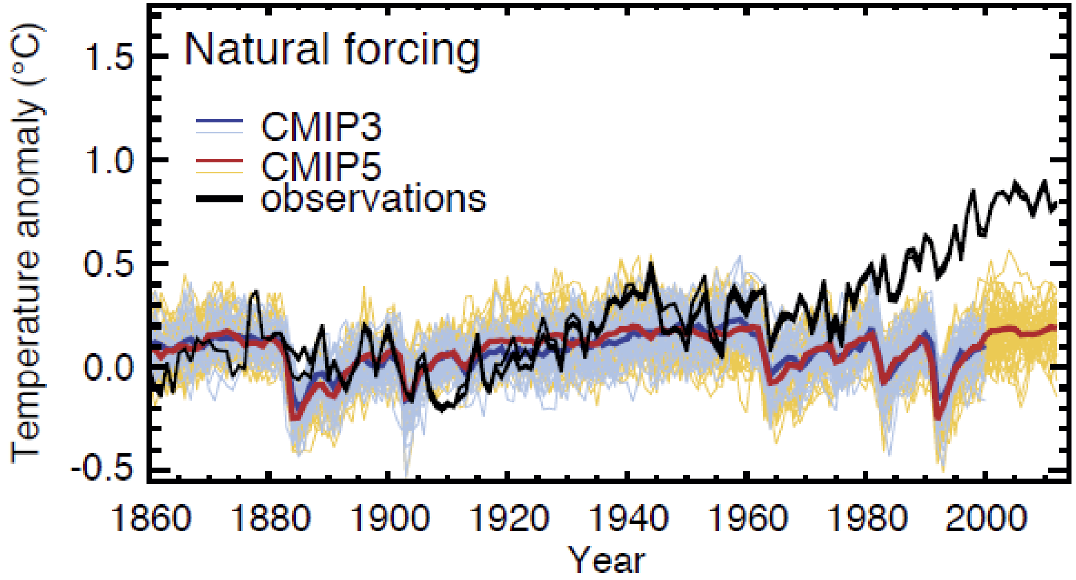
Natural Forcing cannot explain observations

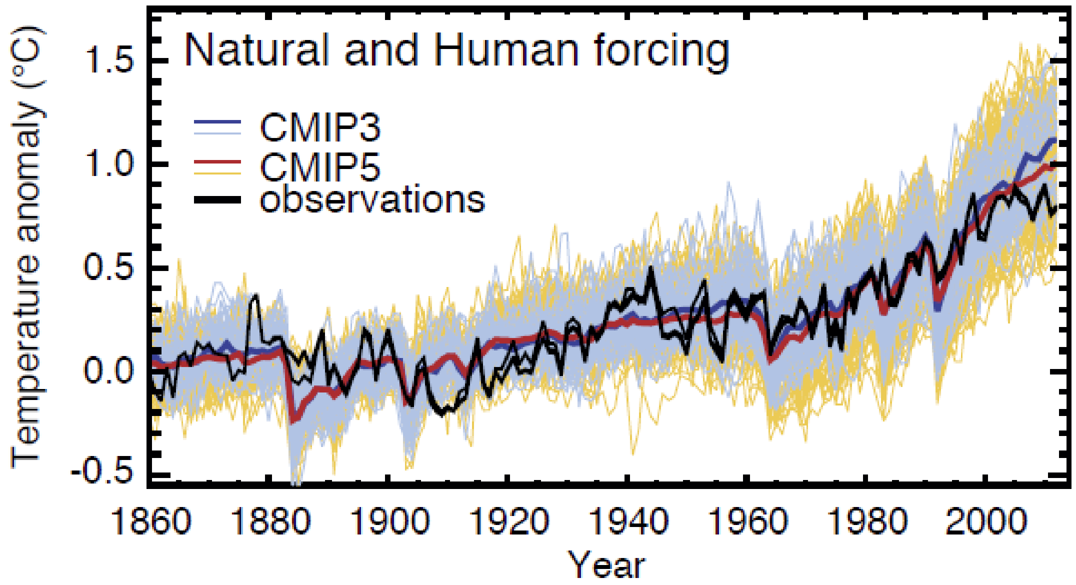


IPCC 2007

Center of Ocean-Land-Atmosphere studies

Natural Forcing cannot explain observations





IPCC 2013

Factors Limiting Predictability

Fundamental barriers to advancing weather and climate diagnosis and prediction on timescales from days to years are (partly) (almost entirely?) attributable to gaps in knowledge and the limited capability of contemporary operational and research numerical prediction systems to represent precipitating convection and its multi-scale organization, particularly in the tropics.

(Moncrieff, Shapiro, Slingo, Molteni, 2007)

Dynamical Prediction Experience
(~30 years)

- Weather ≈ 500,000 (30 years X 365 days X 50 centers)
- Seasonal ≈ 5,000 (30 years X 12 months X 15 centers)
- Decadal ≈ 5

Summary (1)

- **35 years ago, Dynamical Seasonal Prediction (DSP) was not conceivable; DSP has achieved a level of skill that is considered useful for some societal applications. However, such successes are limited to periods of large, persistent SST anomalies.**

- **The most dominant obstacle in realizing the potential predictability of seasonal variations is inaccurate models, and unbalanced initial conditions rather than an intrinsic limit of predictability.**

  (Models that simulate climatology "better" make better predictions.)

Summary (2)

1. An unforced, multidecadal SST pattern is identified in simulations using IPCC pre-industrial control runs and observations by a new statistical method.

2. Amplitude of this pattern helps explain major multi-decadal fluctuations in global mean temperature in the 20th century.

3. Both dynamical and empirical models can skillfully predict SSTs on multi-year time scales.

4. Empirical model derived from dynamical models show skill of predicting certain components of annual mean SST up to 9 years.

5. Recent decadal predictions show hindcast skill N. Atlantic

THANK YOU!

ANY QUESTIONS?

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