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SCHOOL of MARINE &
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UNIVERSITY OF MIAMI

Seasonal to Decadal Prediction

Ben Kirtman

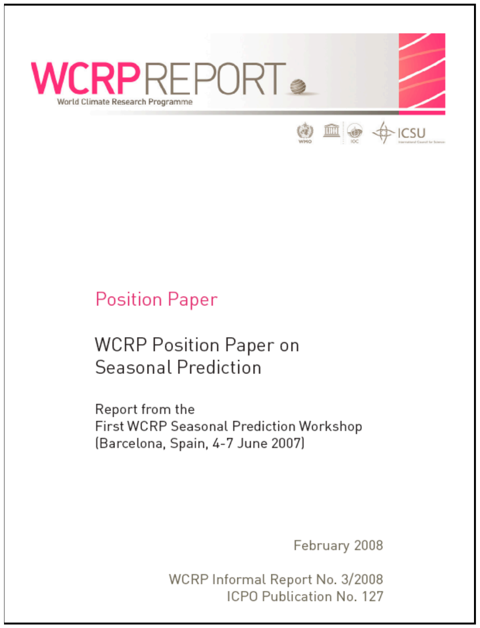
Rosenstiel School of Marine and Atmospheric Science

University of Miami

Seasonal to Decadal Prediction

- **Recent Seasonal Predictability and Prediction Assessments**
  - Current Forecast Capability (ENSO, Global T_{2m}, P)
  - Maximum Predictability Not Achieved
- **Improving Prediction Quality**
  - Untapped Sources of Predictability
  - Improving the building blocks of forecast systems
- **Decadal: Prediction and Predictability**
- **Lessons Learned Outstanding Issues**

1st WCRP Seasonal Prediction Workshop


WCRP REPORT
World Climate Research Programme
ICSU

Position Paper

WCRP Position Paper on Seasonal Prediction

Report from the
First WCRP Seasonal Prediction Workshop
(Barcelona, Spain, 4-7 June 2007)

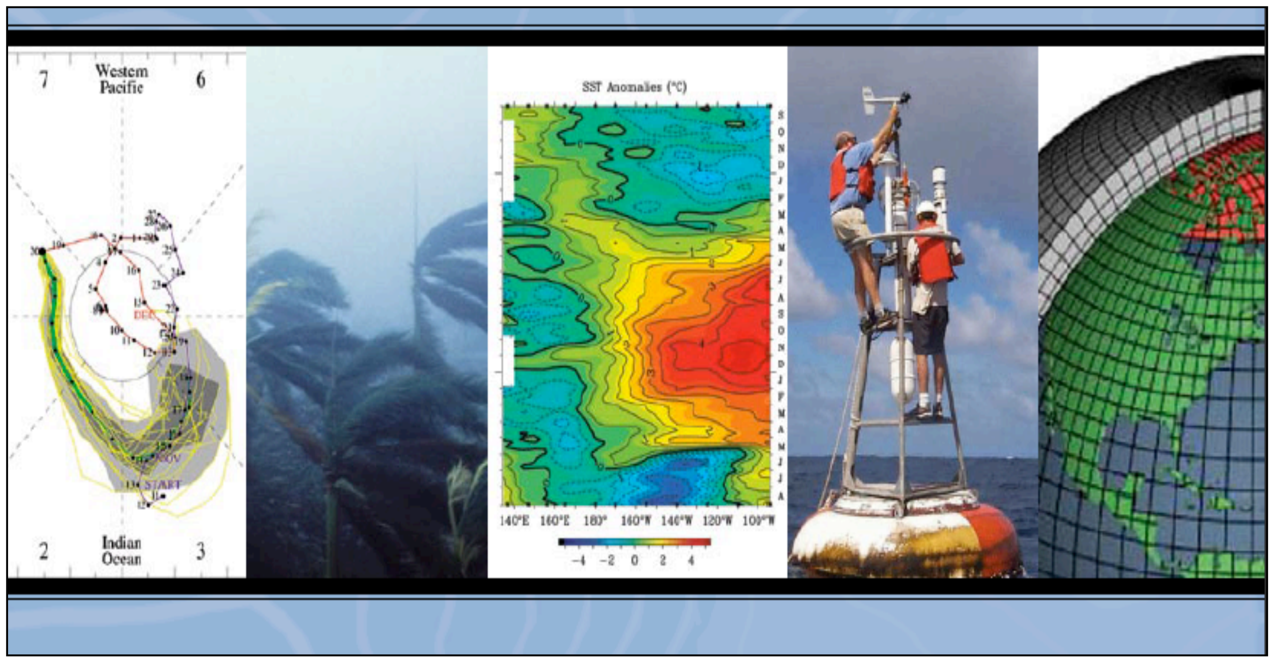
February 2008

WCRP Informal Report No. 3/2008
ICPO Publication No. 127

Kirtman and Pirani (2009)

Assessment of Intraseasonal to Interannual Climate Prediction and Predictability

US National Academies



http://www.nap.edu/catalog.php?record_id=12878

Maximum Predictability has Not been Achieved

Predictability - "The extent to which a process contributes to prediction quality"

Many sources of predictability remain to be fully exploited by ISI forecast systems

- Land Interactions (e.g., Soil Moisture, Snow Cover; Vegetation changes)
- Sea-Ice Interactions (i.e., atmosphere-ice; ocean-ice)
- Troposphere-Stratosphere Interactions
- Sub-Seasonal Variability (e.g., MJO)

Improving Forecast System Building Blocks

- **Sustaining and Enhancing Observing Systems**

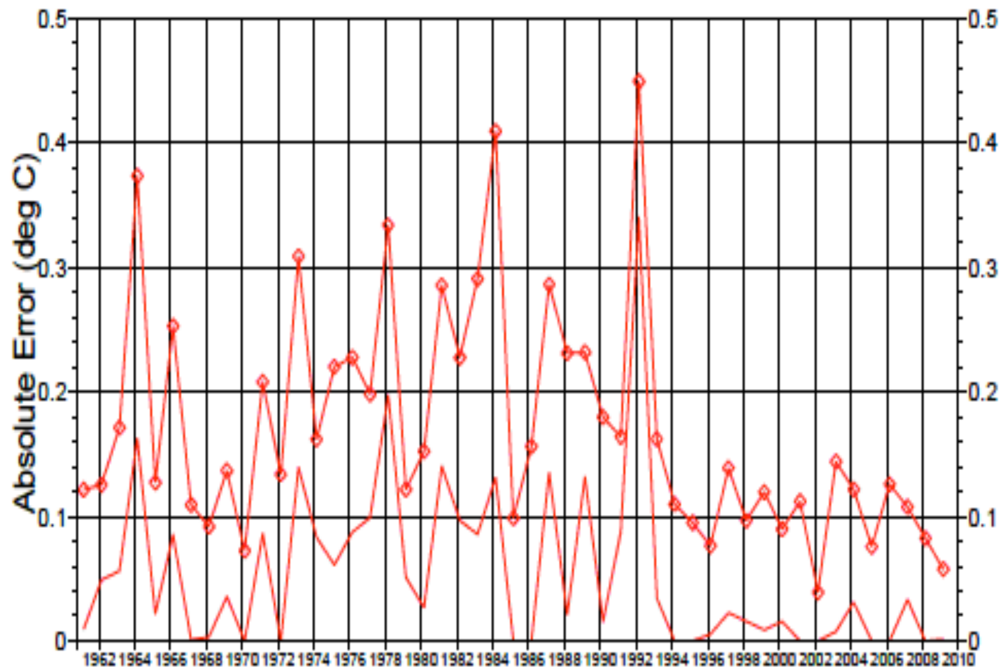
- **Improving Data Assimilation Systems (component wise and the coupled system)**

- **Quantifying Sources of Uncertainty**

- **Reducing Model Errors**

ENSO Prediction: Current Status

- Observations by TAO/TRITON have been critical to progress in understanding and simulation.
- Dynamical models are competitive with statistical models.
- MME mean outperforms individual models



TAO Fully Operational

ENSO Prediction: Current Status

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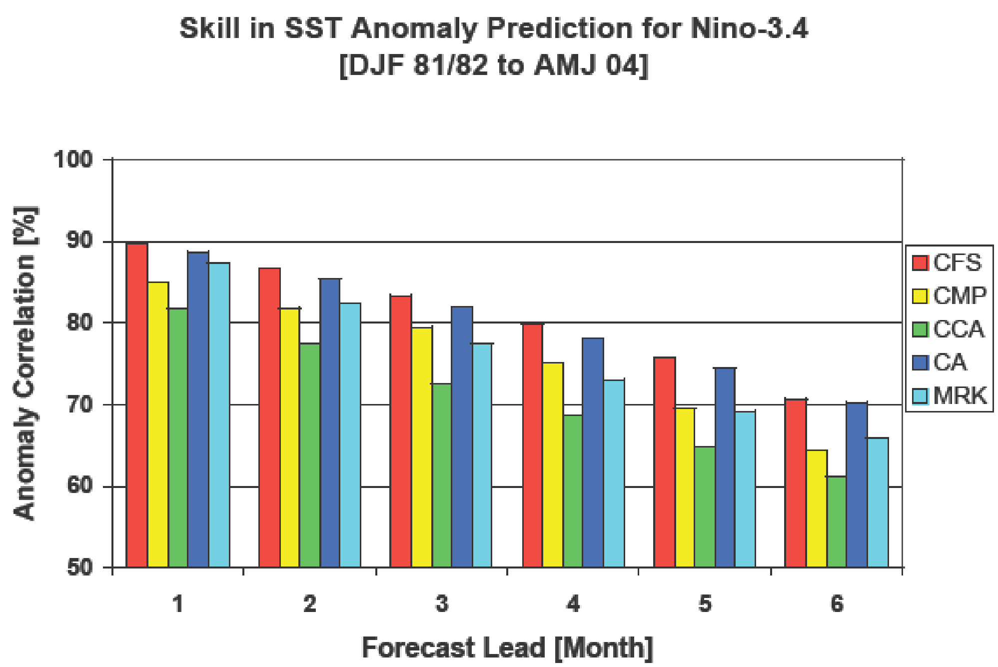

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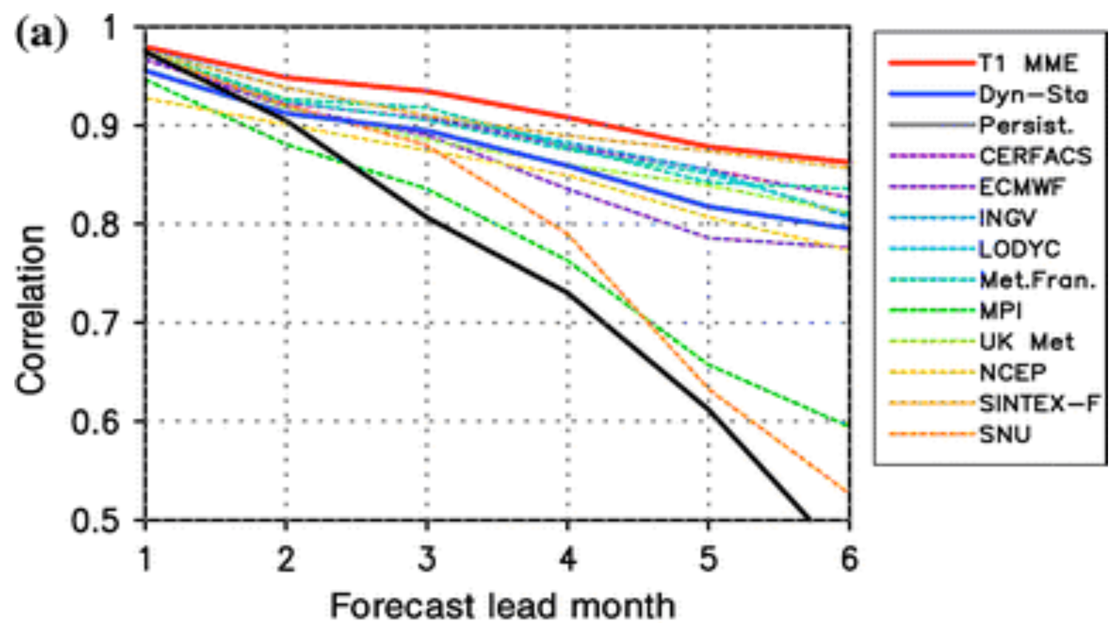
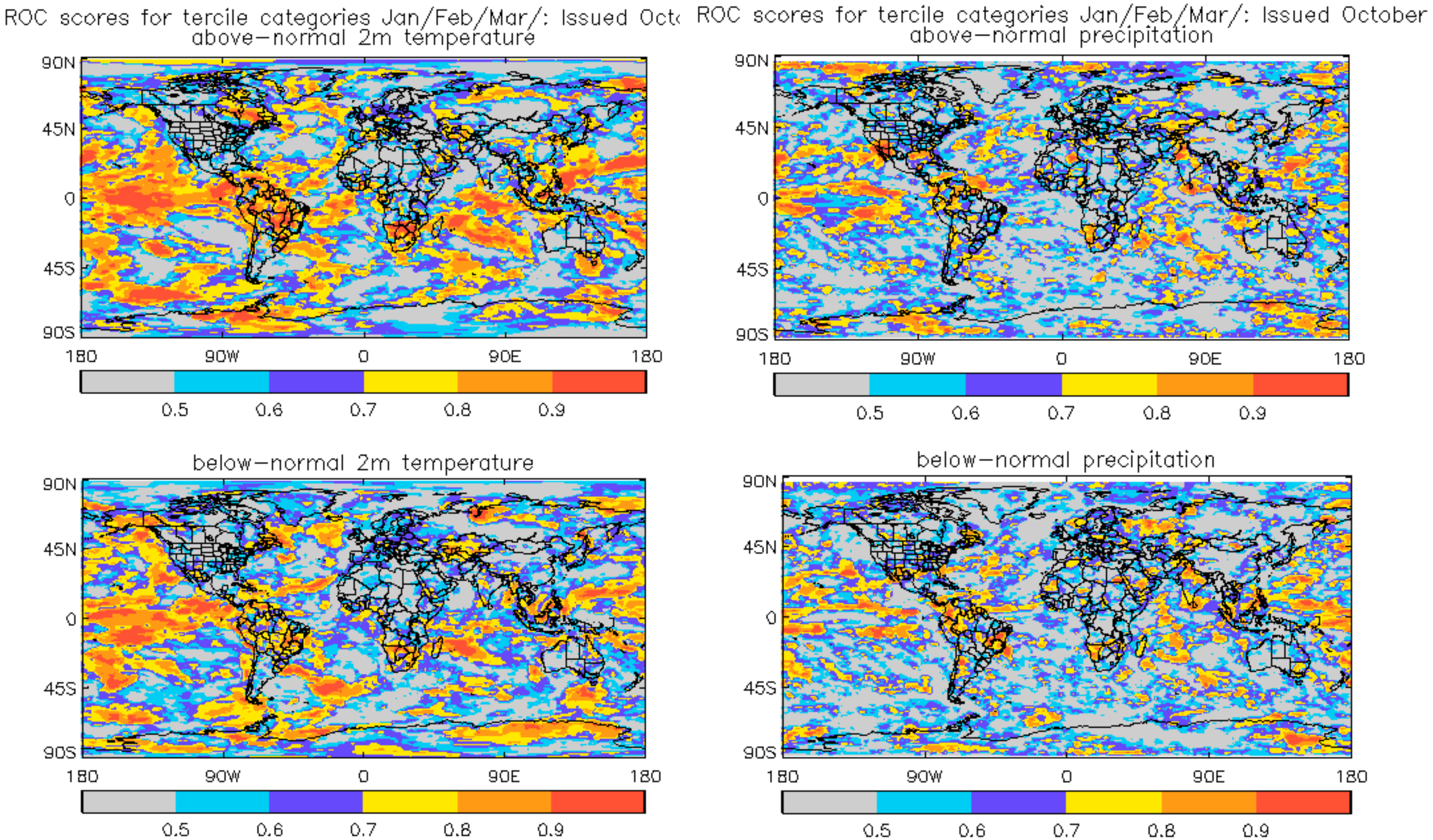
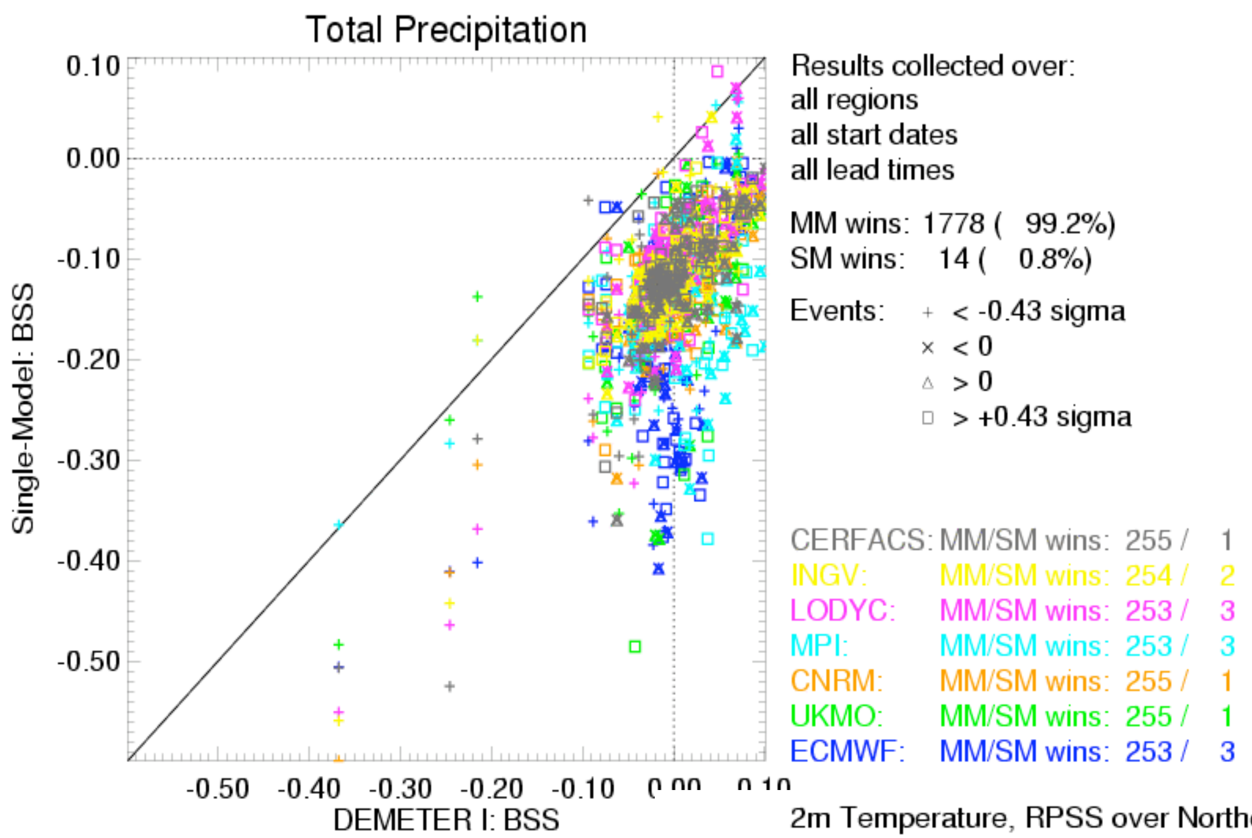
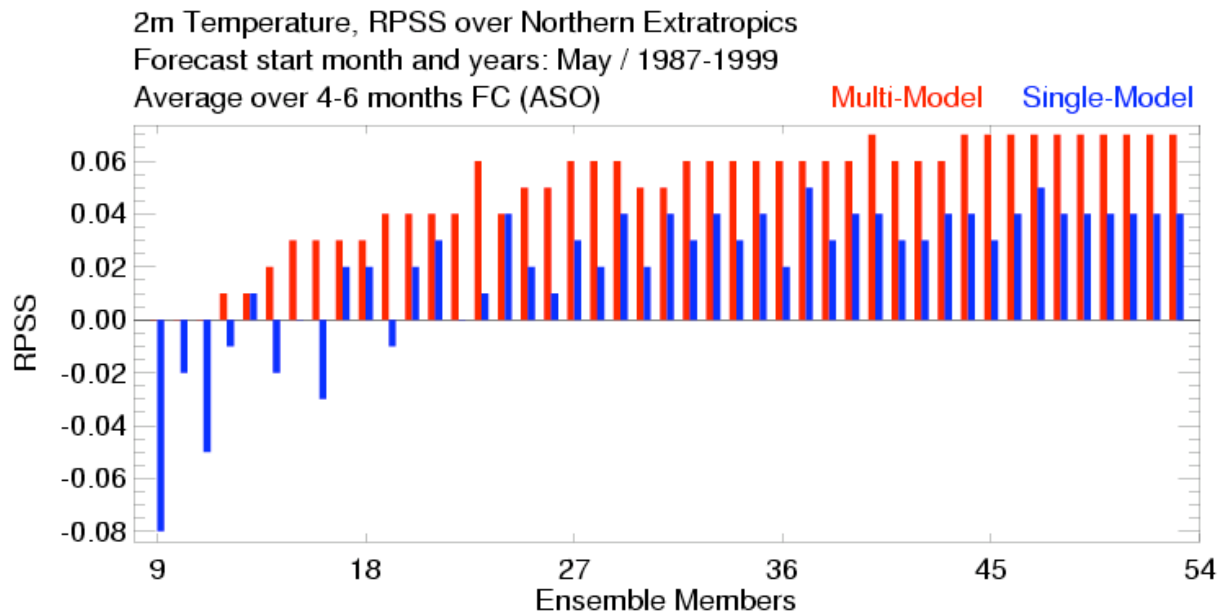


Seasonal Forecast ROC Scores for T_{2m} and Precipitation





Multi-Model vs. Single Model



Large Ensemble vs. Multi-Model

Brier Skill Score for Lower/Upper tercile (1980-2001)

Temperature and Precipitation

Region	2m Temperature				Precipitation			
	JJA		DJF		JJA		DJF	
	$E_T^-(x)$	$E_T^+(x)$	$E_T^-(x)$	$E_T^+(x)$	$E_p^-(x)$	$E_p^+(x)$	$E_p^-(x)$	$E_p^+(x)$
Australia	**10.7**	**10.1**	1.3	-0.4	-1.3	-2.5	-3.1	-3.6
Amazon Basin	**14.4**	9.1	**23.4**	**25.7**	2.2	2.1	**9.5**	**8.9**
Southern South America	**8.5**	**8.2**	-1.2	1.8	**7.8**	5.0	-0.7	-2.8
Central America	**12.1**	**9.9**	**14.8**	6.3	2.6	-0.7	8.7	8.5
Western North America	**6.5**	**7.7**	3.9	2.3	3.2	**5.5**	-0.6	0.0
Central North America	-4.1	-3.6	**-7.5**	0.3	-1.8	**-7.0**	3.7	5.3
Eastern North America	0.6	5.7	4.1	9.5	**-4.5**	**-8.3**	**9.2**	6.0
Alaska	3.0	2.1	0.0	-0.7	-0.1	0.3	2.4	4.9
Greenland	3.6	4.2	**8.0**	5.8	**-1.4**	-0.5	-2.1	-2.0
Mediterranean Basin	**7.6**	**10.7**	3.2	3.2	-0.5	0.1	1.6	-0.9
Northern Europe	-4.4	-4.2	4.8	2.9	-1.0	1.9	-1.1	-0.9
Western Africa	**10.4**	**11.8**	**18.1**	**17.2**	-1.6	-2.0	**-4.9**	**-3.5**
Eastern Africa	**12.6**	5.8	**13.3**	**10.3**	0.1	-0.3	1.2	0.6
Southern Africa	5.6	-1.1	**15.9**	**15.7**	0.7	-1.2	5.4	3.6
Sahara	**7.6**	**7.4**	6.9	3.9	**-2.6**	**-4.8**	**-2.7**	**-2.7**
Southeast Asia	10.7	5.9	8.7	**18.1**	**14.7**	**10.3**	3.4	2.5
East Asia	**4.7**	**7.9**	**10.8**	**10.0**	0.6	-1.0	-1.6	-0.9
South Asia	4.9	**13.1**	**7.6**	**8.6**	-1.6	**-3.0**	2.0	0.5
Central Asia	0.8	3.8	1.3	-0.4	0.5	0.1	-3.1	-3.6
Tibet	**10.7**	**10.1**	**23.4**	**25.7**	-1.1	0.0	**9.5**	**8.9**
North Asia	**14.4**	9.1	-1.2	1.8	-1.3	-2.5	-0.7	-2.8

Predictability - "The extent to which a process contributes to prediction quality"

Many sources of predictability remain to be fully exploited by ISI forecast systems

- Land Interactions (e.g., Soil Moisture, Snow Cover; Vegetation changes)
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Climate Historical Forecast Project (CHFP)

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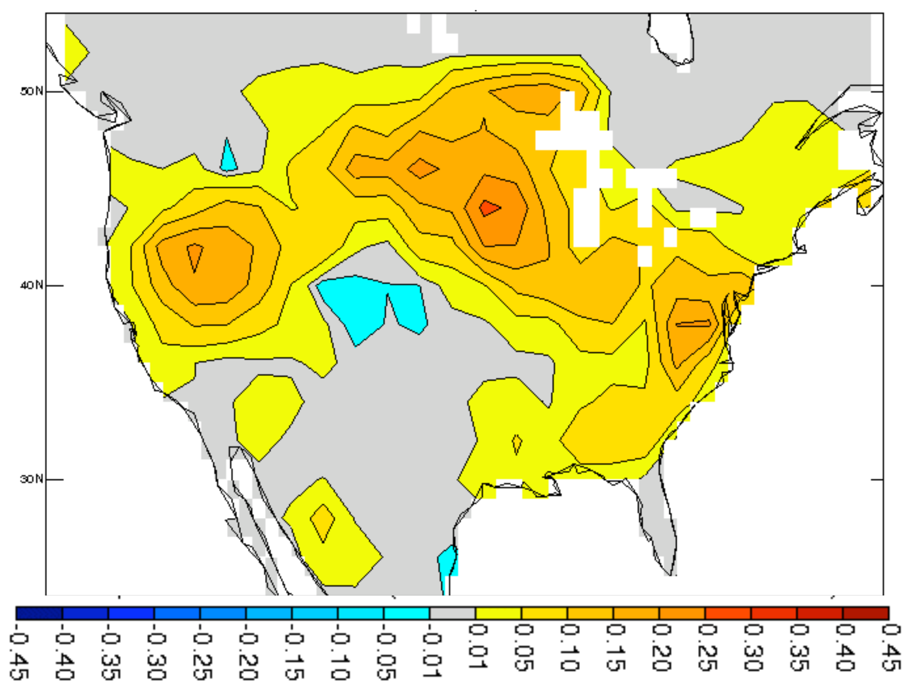
GLACE-2

- Initialization is a challenge due to spatial and temporal heterogeneity in soil moisture

GEWEX WCRP

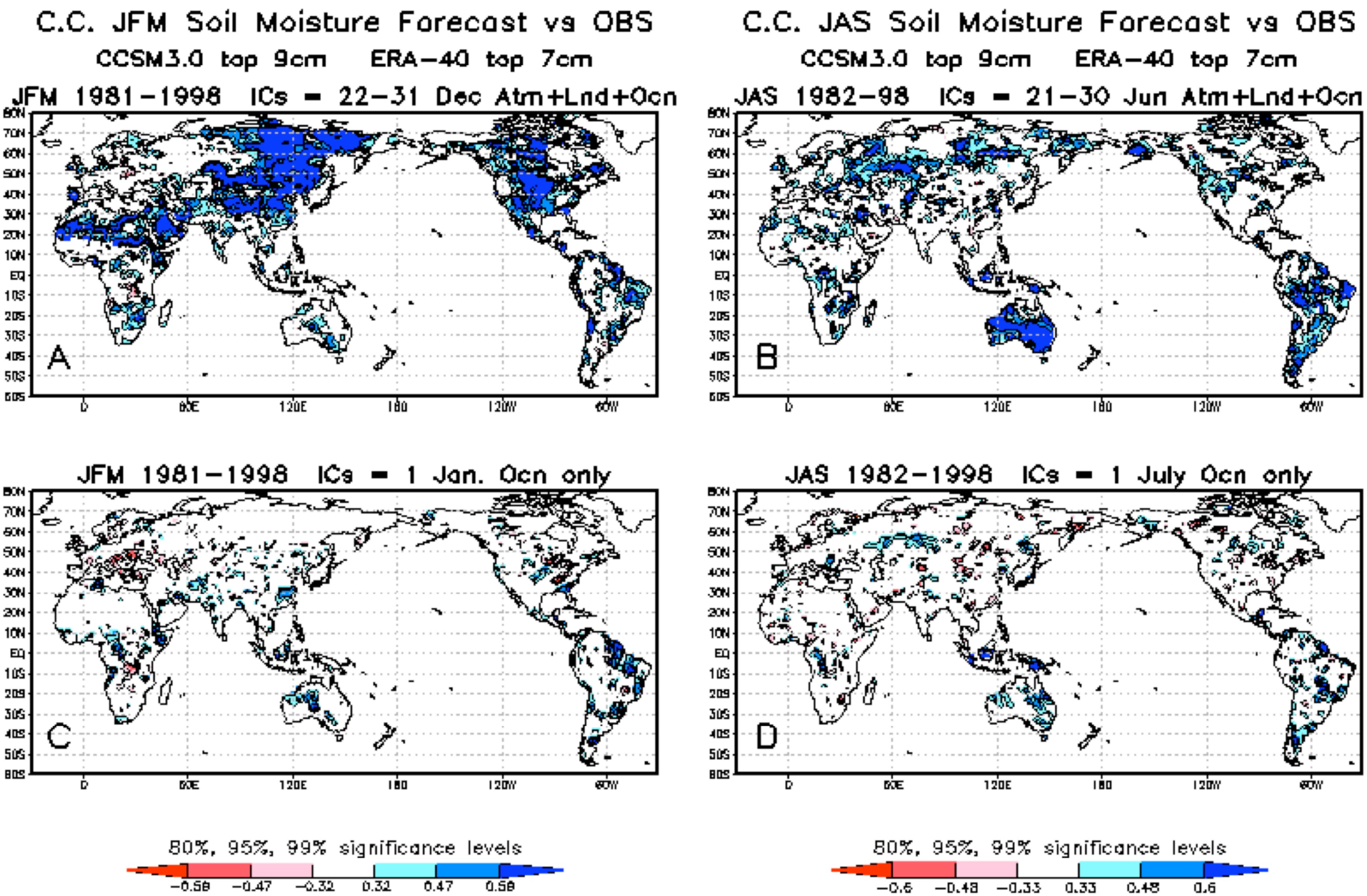
- Procedures for measuring of land-atmosphere coupling strength are still being developed

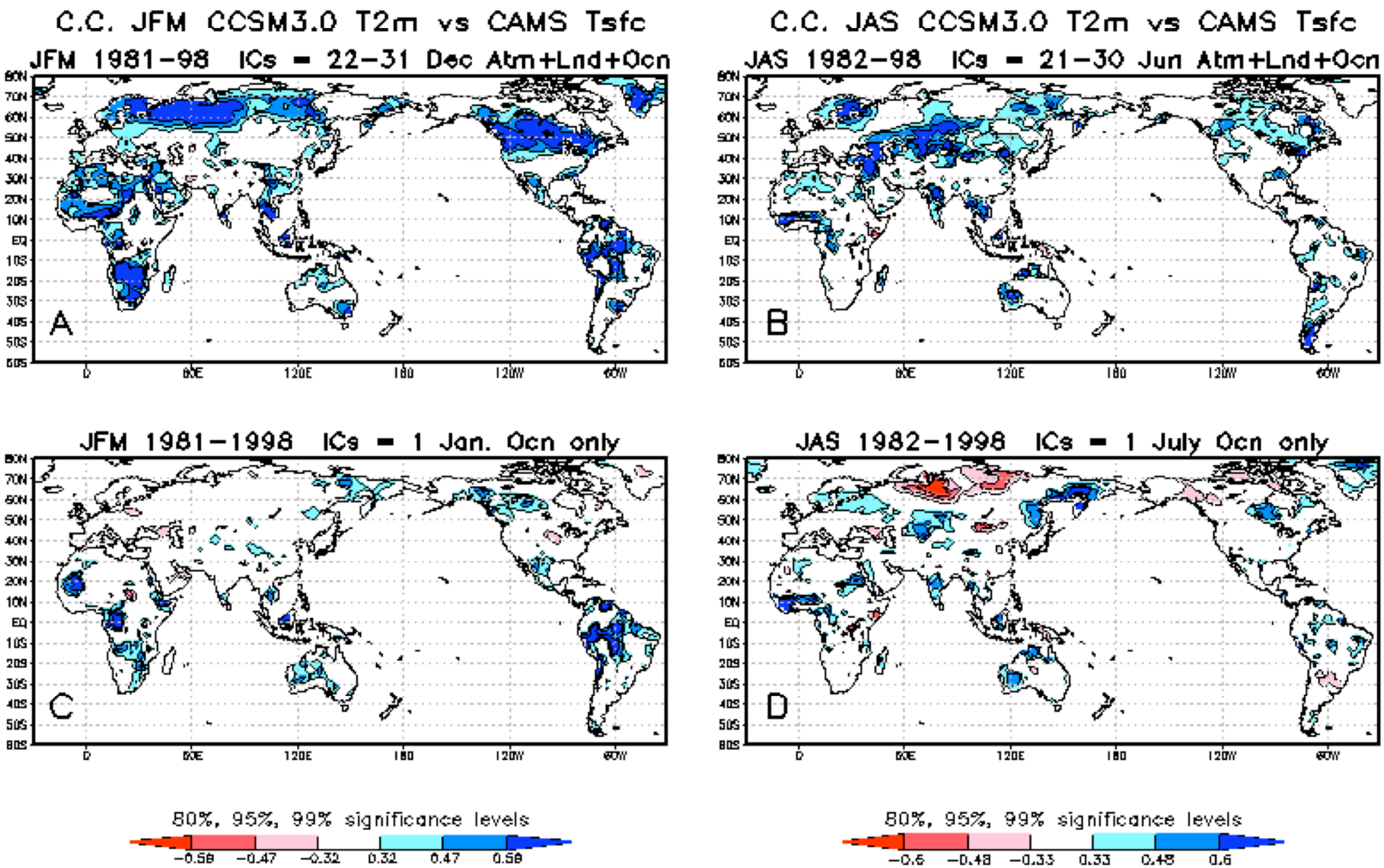
Forecast skill: r^2 with land ICs minus that obtained w/o land ICs



- **Land Data Assimilation Systems (LDAS) coupled with satellite observations could contribute to initialization**

- **Further evaluation and intercomparison of models are necessary**


C.C. JFM Soil Moisture Forecast vs OBS
CCSM3.0 top 9cm ERA-40 top 7cm
JFM 1981-1998 ICs = 22-31 Dec Atm+Lnd+Ocn
A
C.C. JAS Soil Moisture Forecast vs OBS
CCSM3.0 top 9cm ERA-40 top 7cm
JAS 1982-98 ICs = 21-30 Jun Atm+Lnd+Ocn
B
JFM 1981-1998 ICs = 1 Jan. Ocn only
C
JAS 1982-1998 ICs = 1 July Ocn only
D
80%, 95%, 99% significance levels
-0.58 -0.47 -0.32 0.32 0.47 0.58
80%, 95%, 99% significance levels
-0.6 -0.48 -0.33 0.33 0.48 0.6


C.C. JFM CCSM3.0 T2m vs CAMS Tsfc
JFM 1981-98 ICs = 22-31 Dec Atm+Lnd+Ocn
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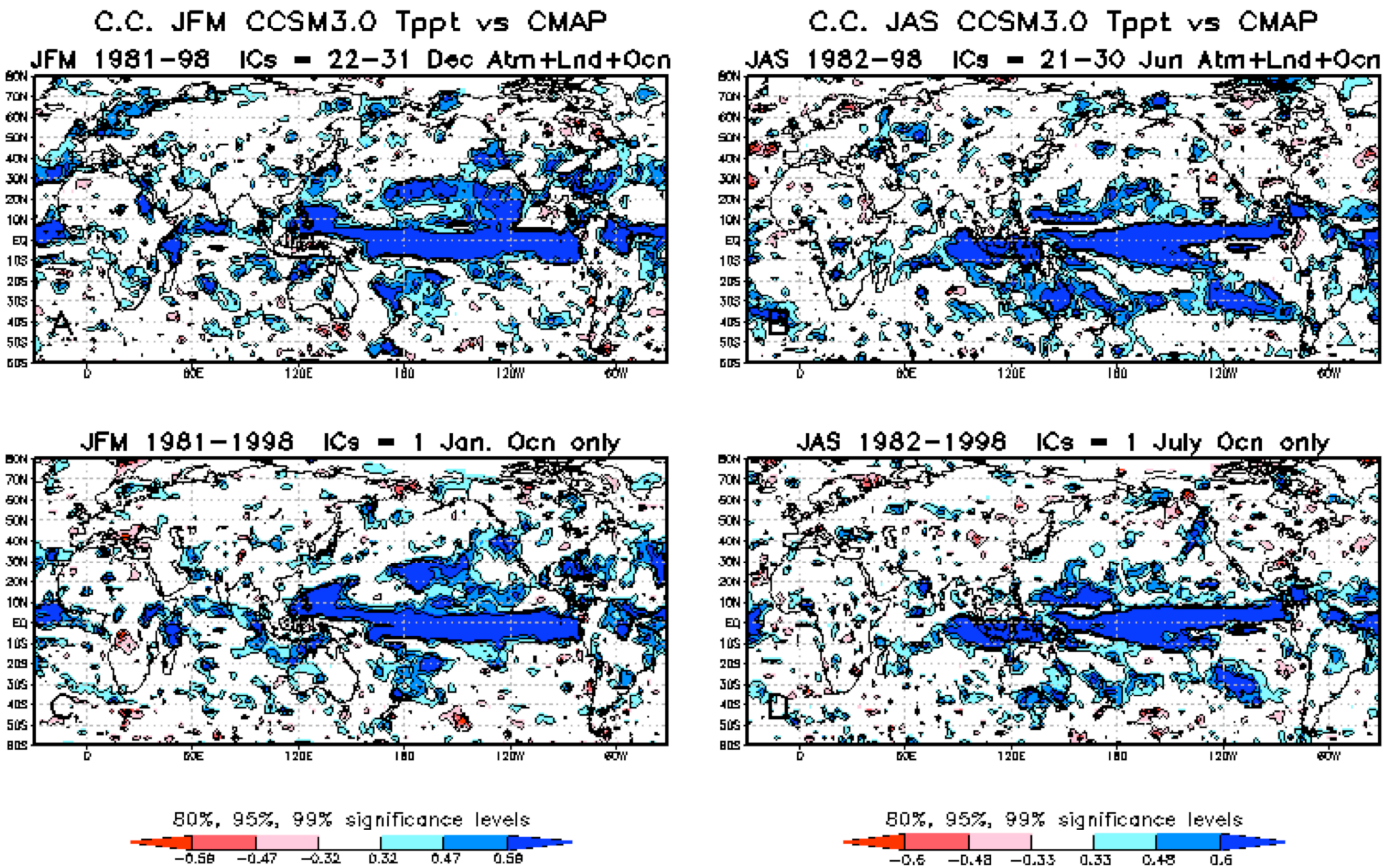
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Conclusions of First GLACE-2 Analysis

1. Almost all of the expected GLACE-2 submissions are in.

2. The individual models vary in their ability to extract forecast skill from land initialization (not shown). In general,
   -- Low skill for precipitation
   -- Moderate skill (in places) for temperature, even out to two months.

3. Land initialization impacts on skill increase dramatically when conditioned on the size of the initial local soil moisture anomaly.

   → If you know the local soil moisture anomaly at time 0 is large, you can expect (in places) that initializing the land correctly will improve your temperature forecast significantly, and your precipitation forecast slightly, even out to 2 months.

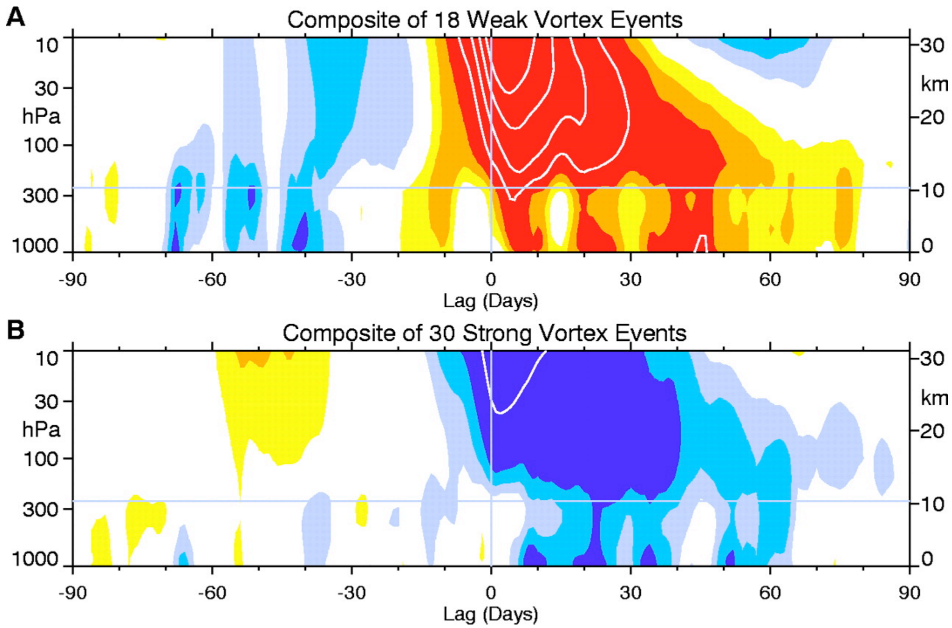
4. The results highlight the potential usefulness of improved observational networks for prediction.

Additional Predictability Likely Associated with Stratospheric Dynamics

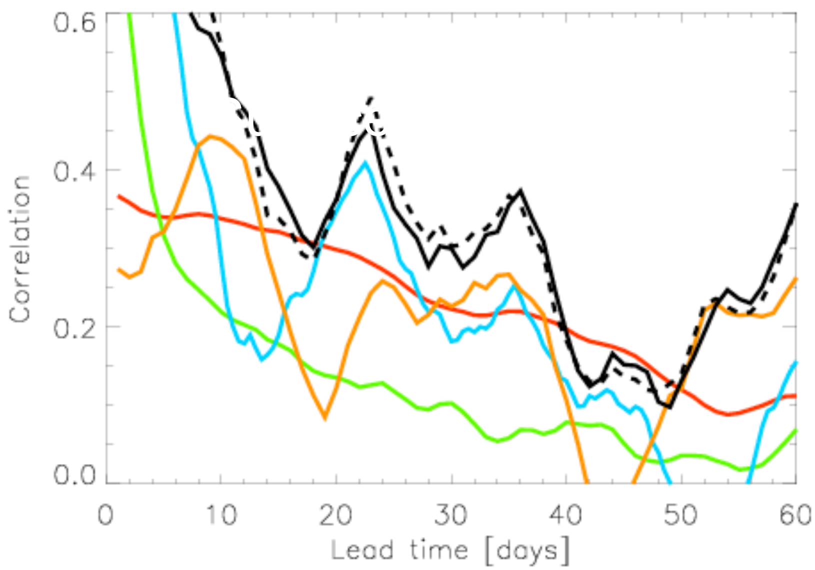
Stratosphere resolving HFP

Goal: Quantifying Skill Gained Initializing and Resolving Stratosphere in Seasonal Forecast Systems

- Parallel hindcasts from stratosphere resolving and non-resolving models
- Action from WGSIP-12: Endorse as subproject of CHFP
- SPARC to recommend diagnostics



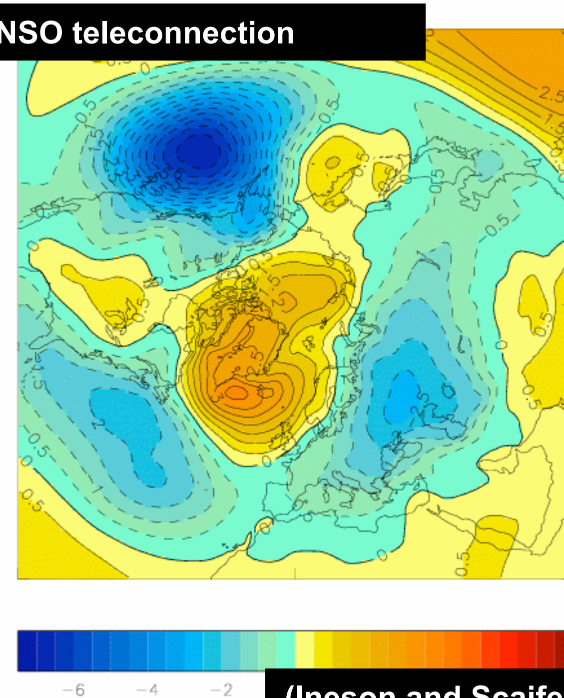
(Baldwin and Dunkerton 2001)



Dynamical forecast

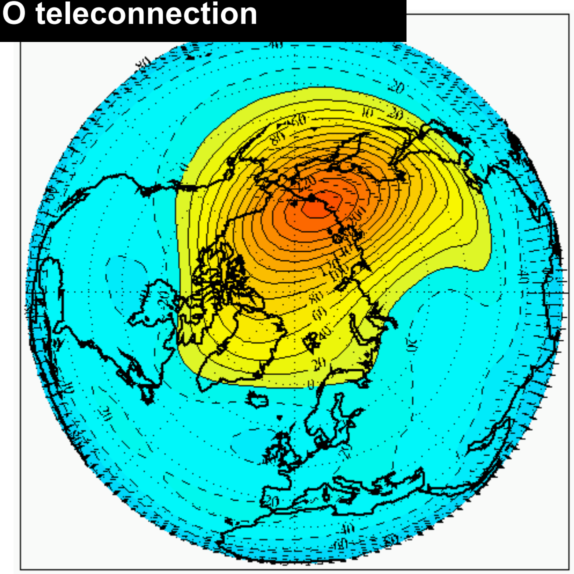
(Christiansen 2005)

ENSO teleconnection



(Ineson and Scaife, 2009)

QBO teleconnection



(Marshall and Scaife 2009)

Links across WCRP

Explore Seasonal Predictability Associated with Sea-Ice

- **Sea-Ice Initialization Experiment:**
  - **Follow CHFP Protocols for Other Components, Data**
  - **Initializing with observed Sea-Ice vs. Climatology**
    - **1 May, 1 November 1996 and 2007**
    - **8 Member Ensembles**
- Spring snow melt into soil moisture and influence on spring temperature anomalies

WCRP World Climate Research Programme

Links across WMO

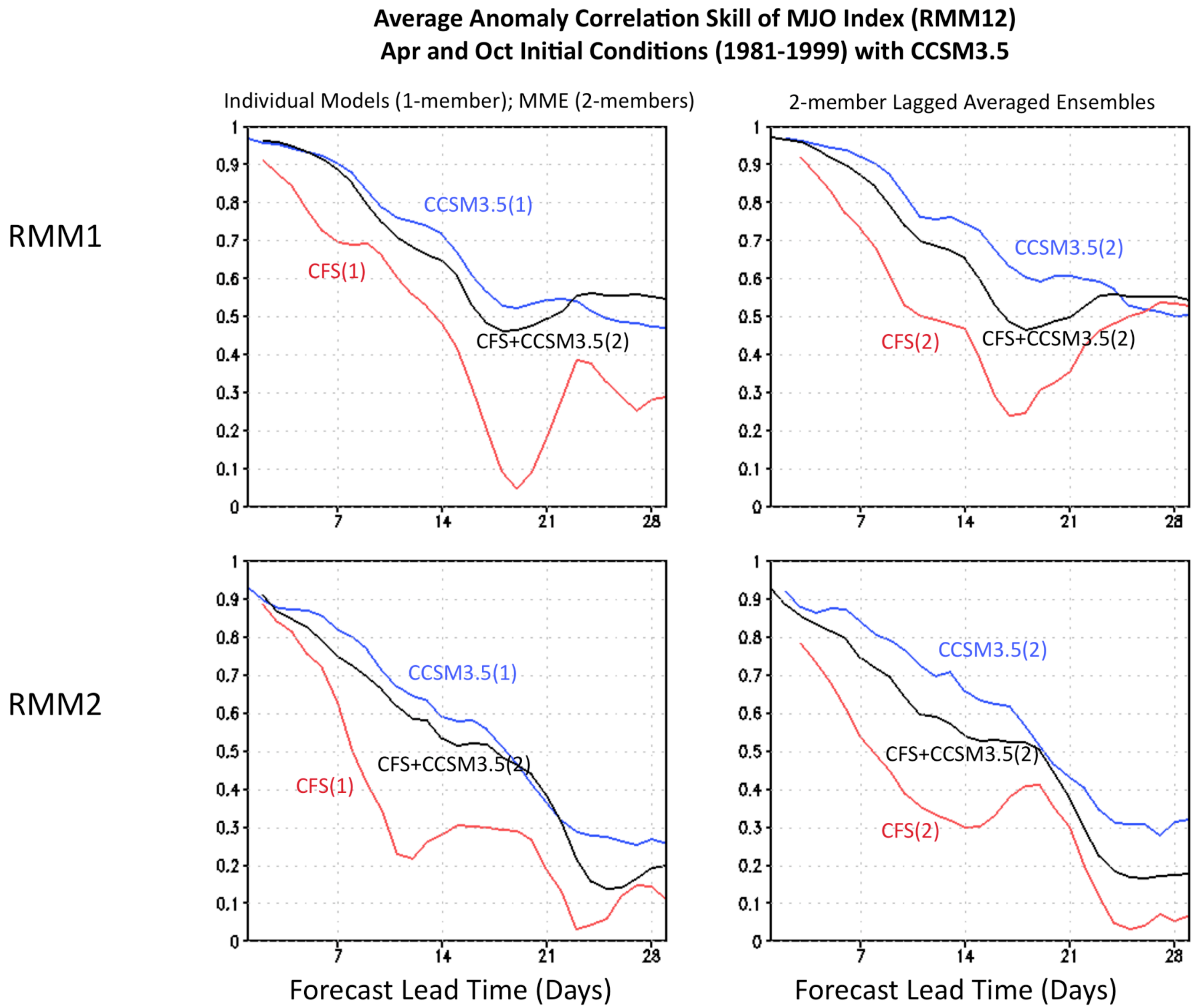
THORPEX
A World Weather Research Programme

Several areas of potential collaboration on intraseaonal time-scales:

- **Investigate how much ocean-atmosphere coupling impacts skill**
- **Role of resolution on skill**
- **Multi-Scale interactions**
- **Ensemble techniques**
- **Intraseasonal Variability (e.g., MJO)**

WCRP
World Climate Research Programme

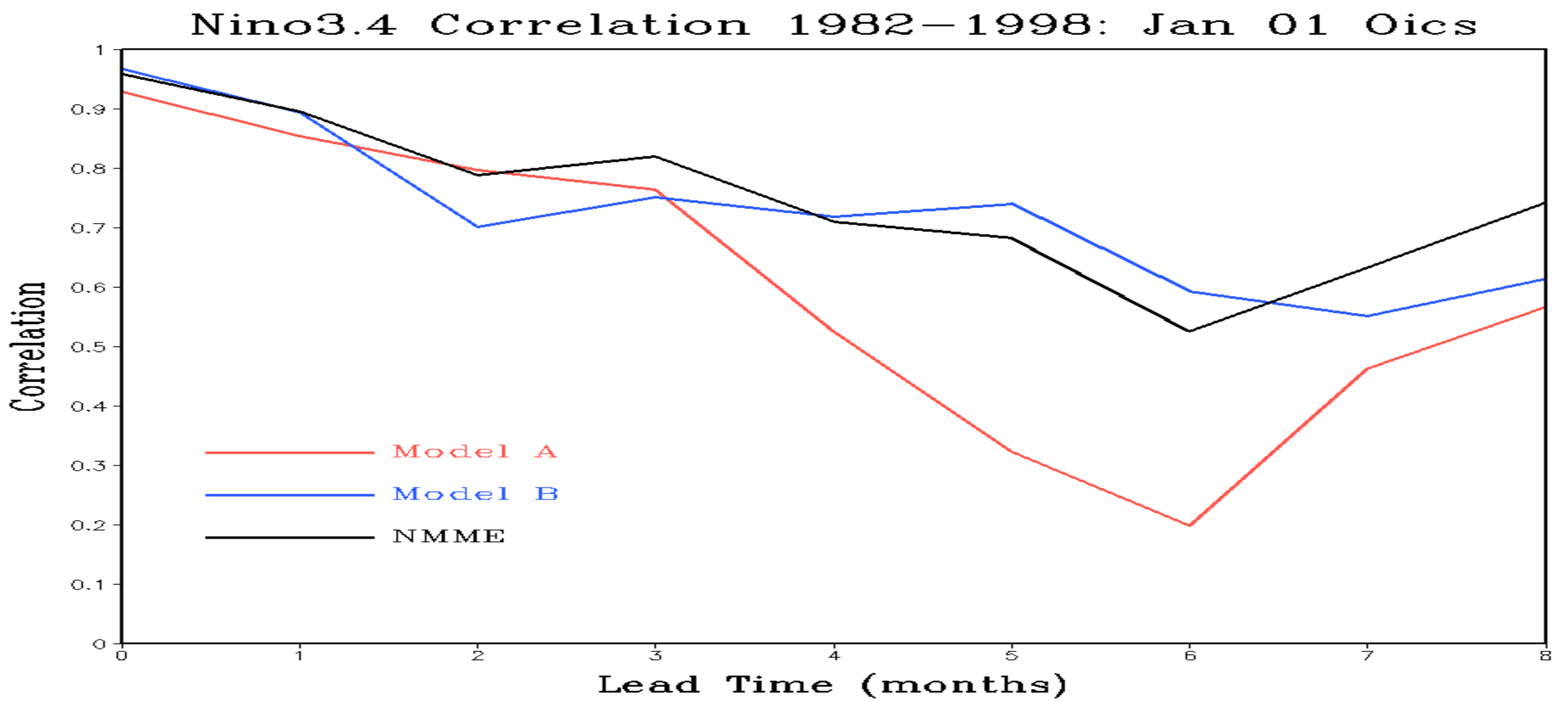
Forecasting of MJO is relatively new; many dynamical models still represent MJO poorly



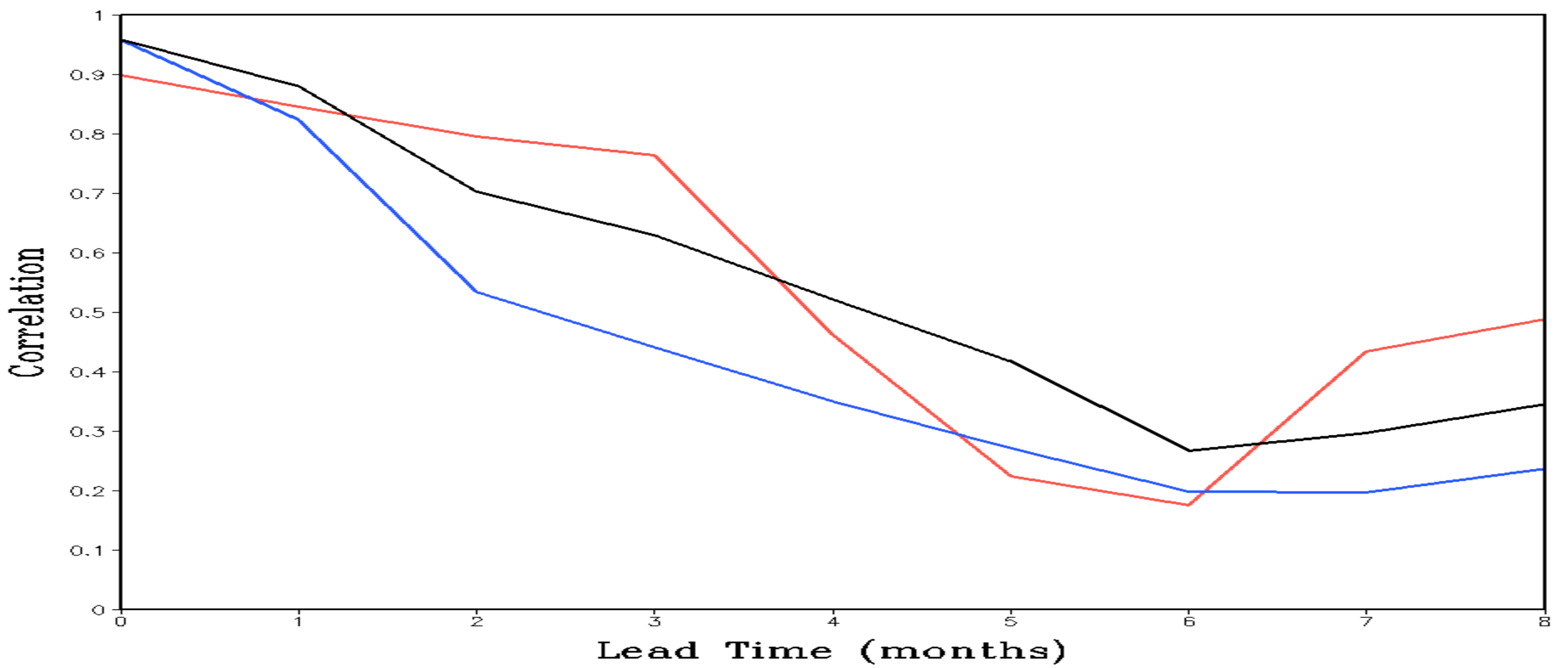
Improving Forecast System Building Blocks

- **Sustaining and Enhancing Observing Systems**
- **Improving Data Assimilation Systems (component wise and the coupled system)**
- **Quantifying Sources of Uncertainty**
- **Reducing Model Errors**

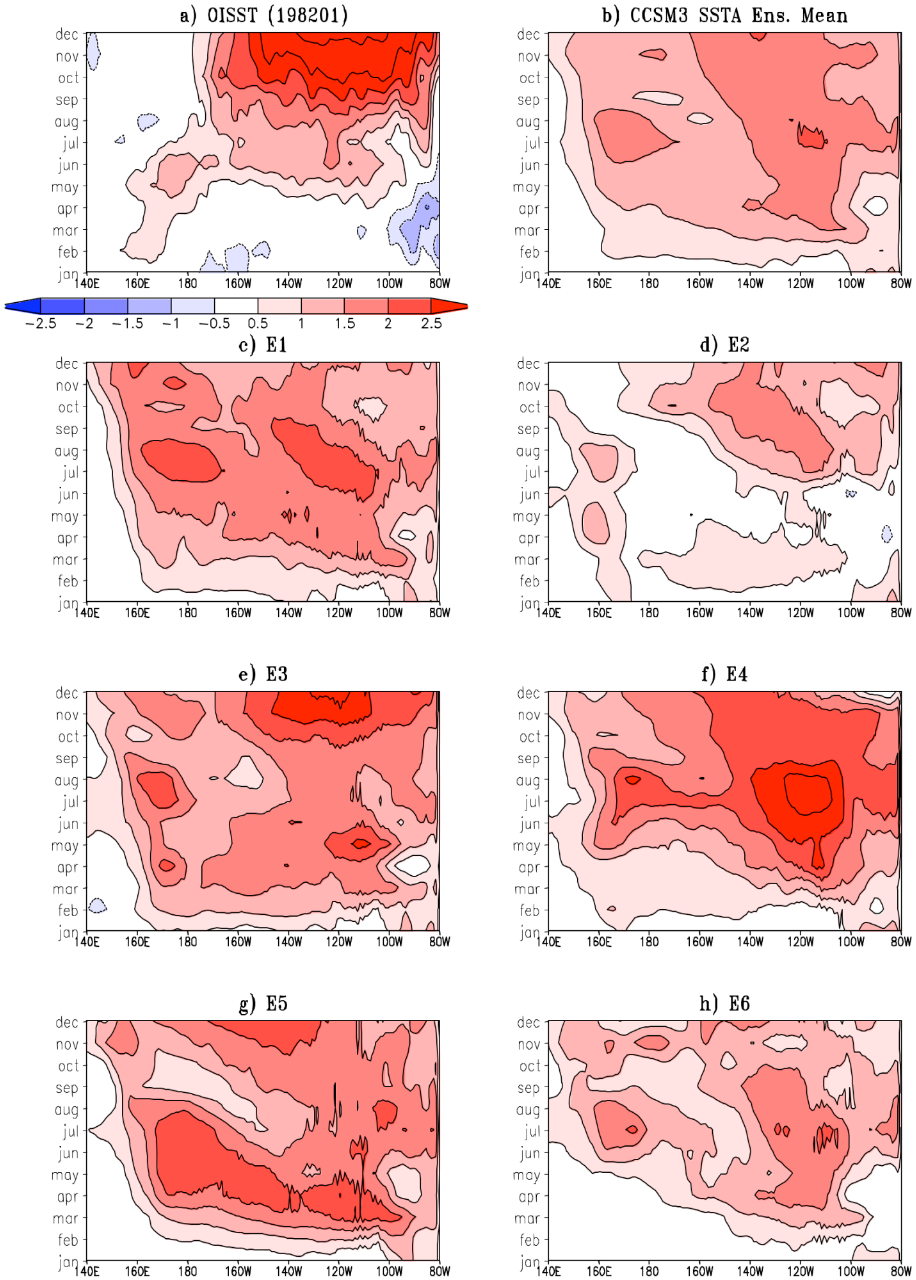
Bias Removed



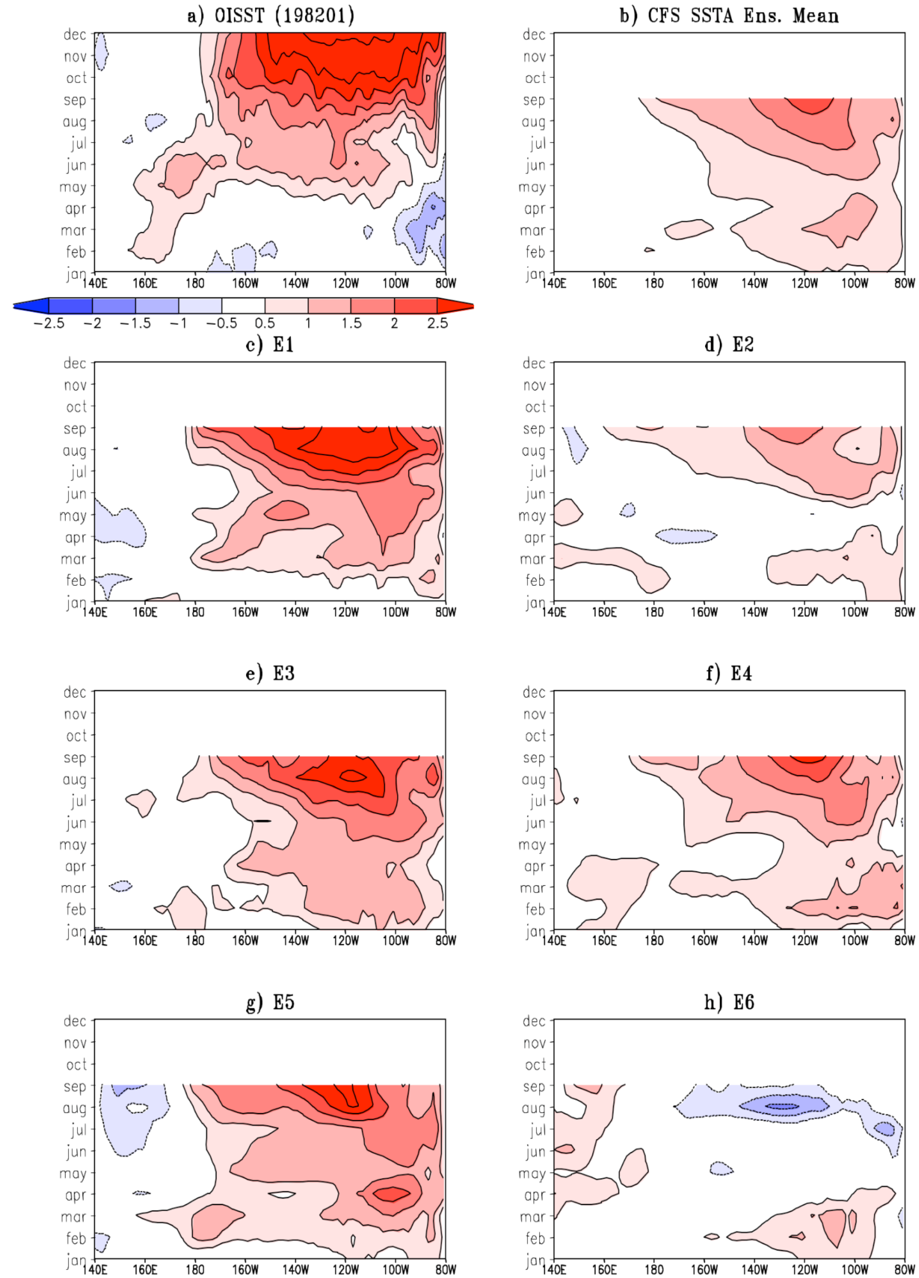
Bias Included



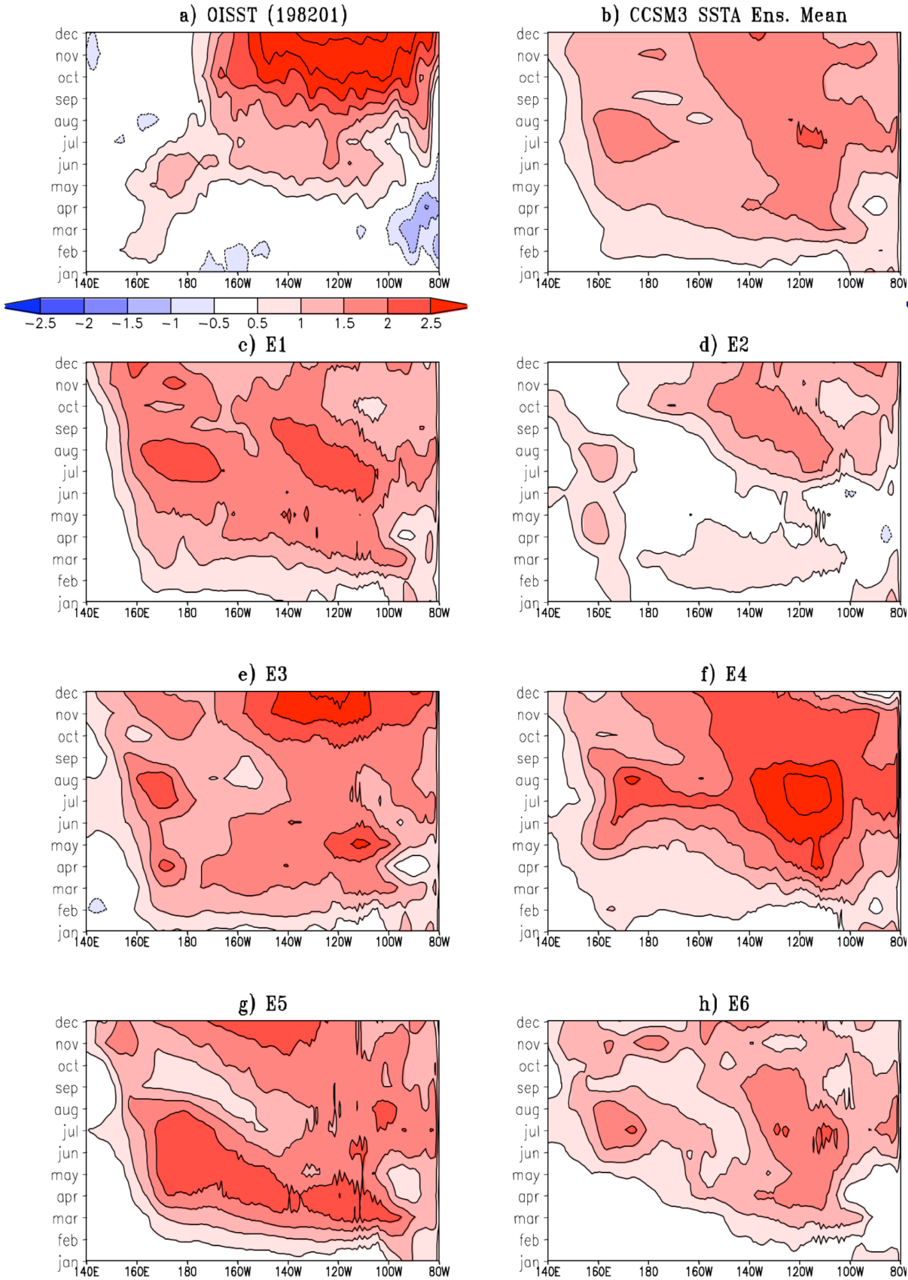
CCSM3.0 Jan 1982 IC



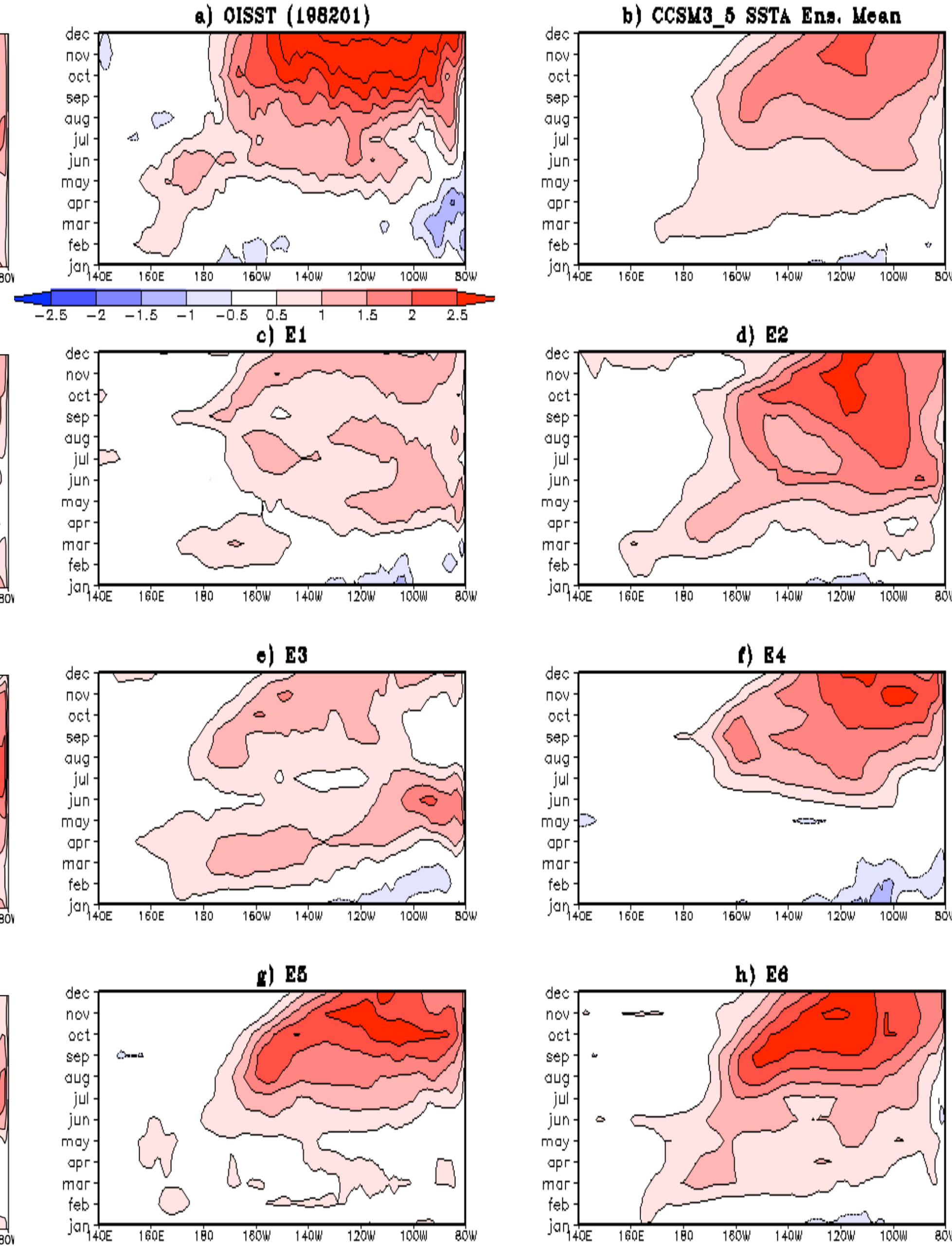
CFS Jan 1982 IC

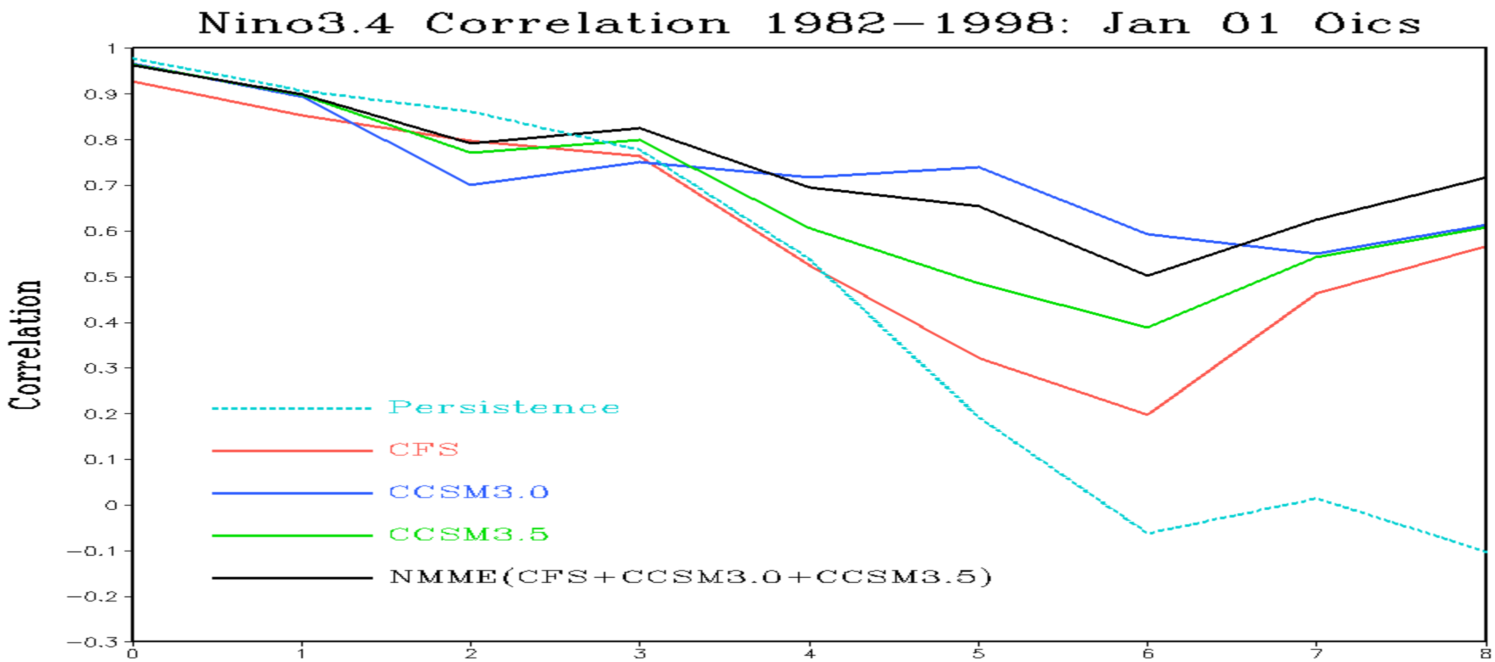


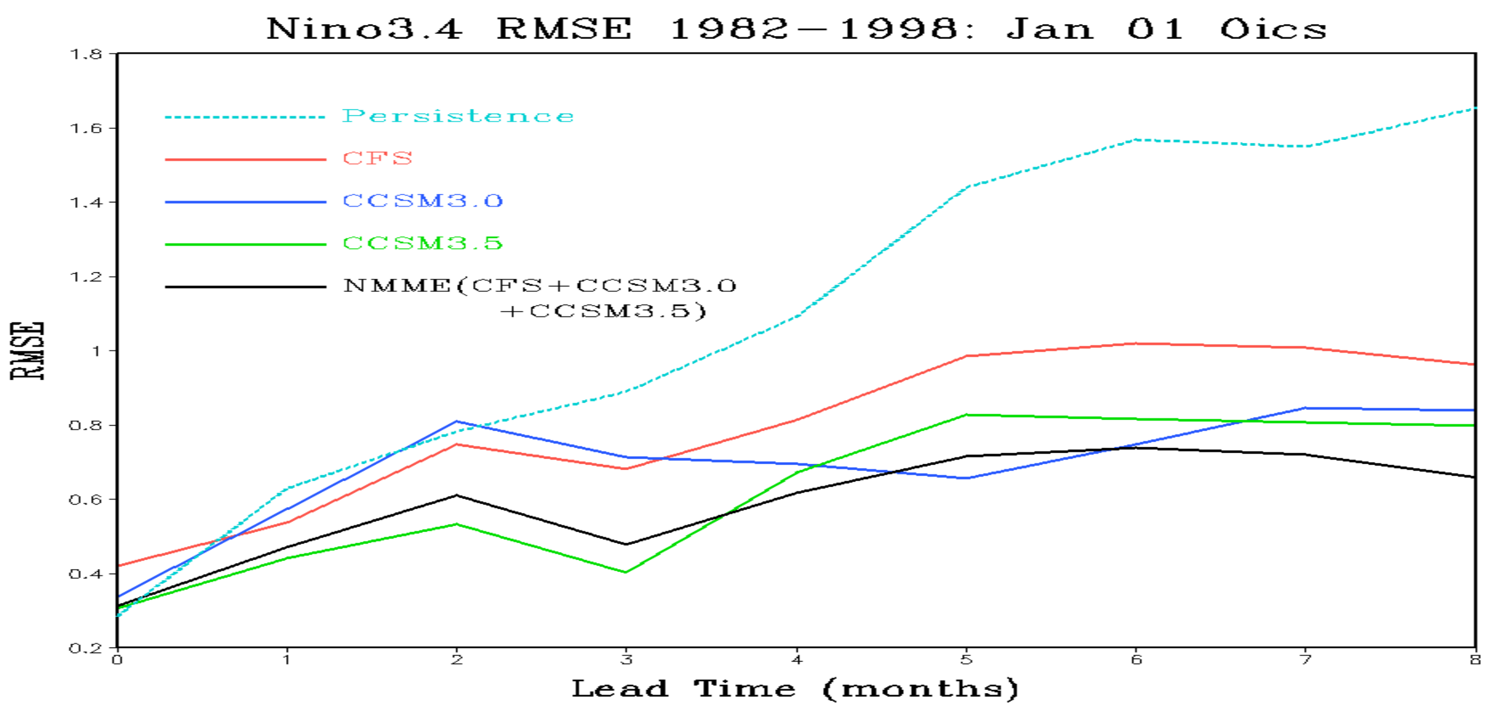
CCSM3.0 Jan 1982 IC



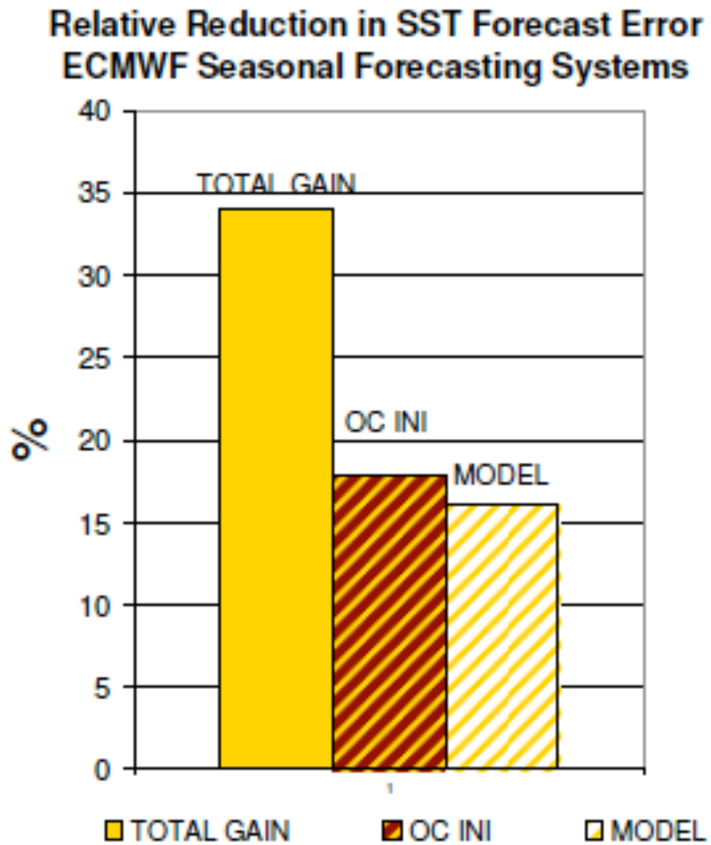
CCSM3.5 Jan 1982 IC

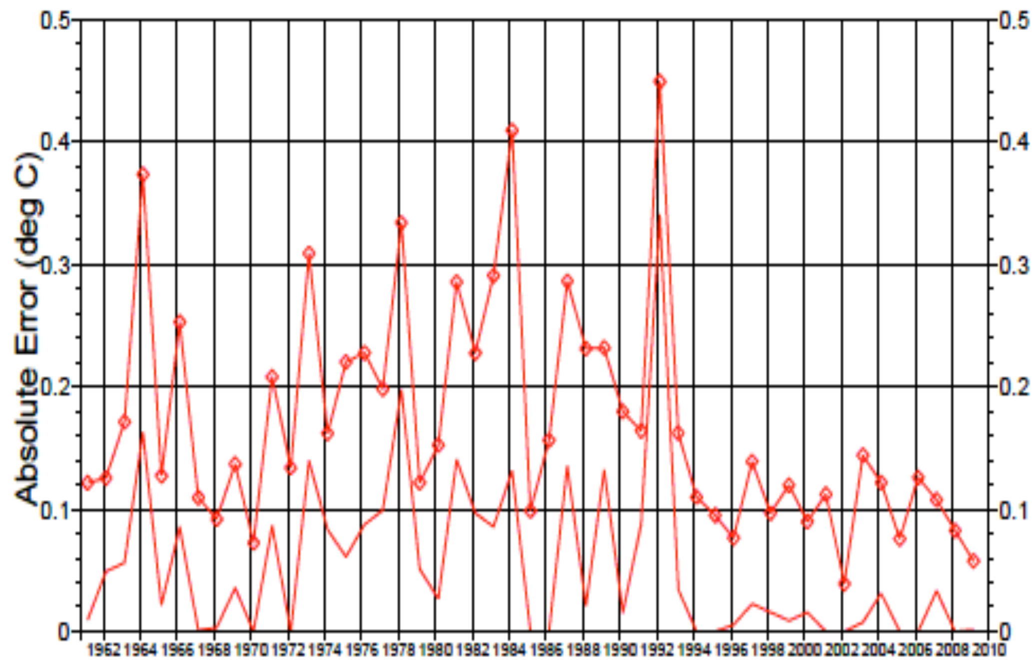



Nino3.4 Correlation 1982−1998: Jan 01 Oics
Correlation
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
−0.1
−0.2
−0.3
0
1
2
3
4
5
6
7
8
Persistence
CFS
CCSM3.0
CCSM3.5
NMME(CFS+CCSM3.0+CCSM3.5)

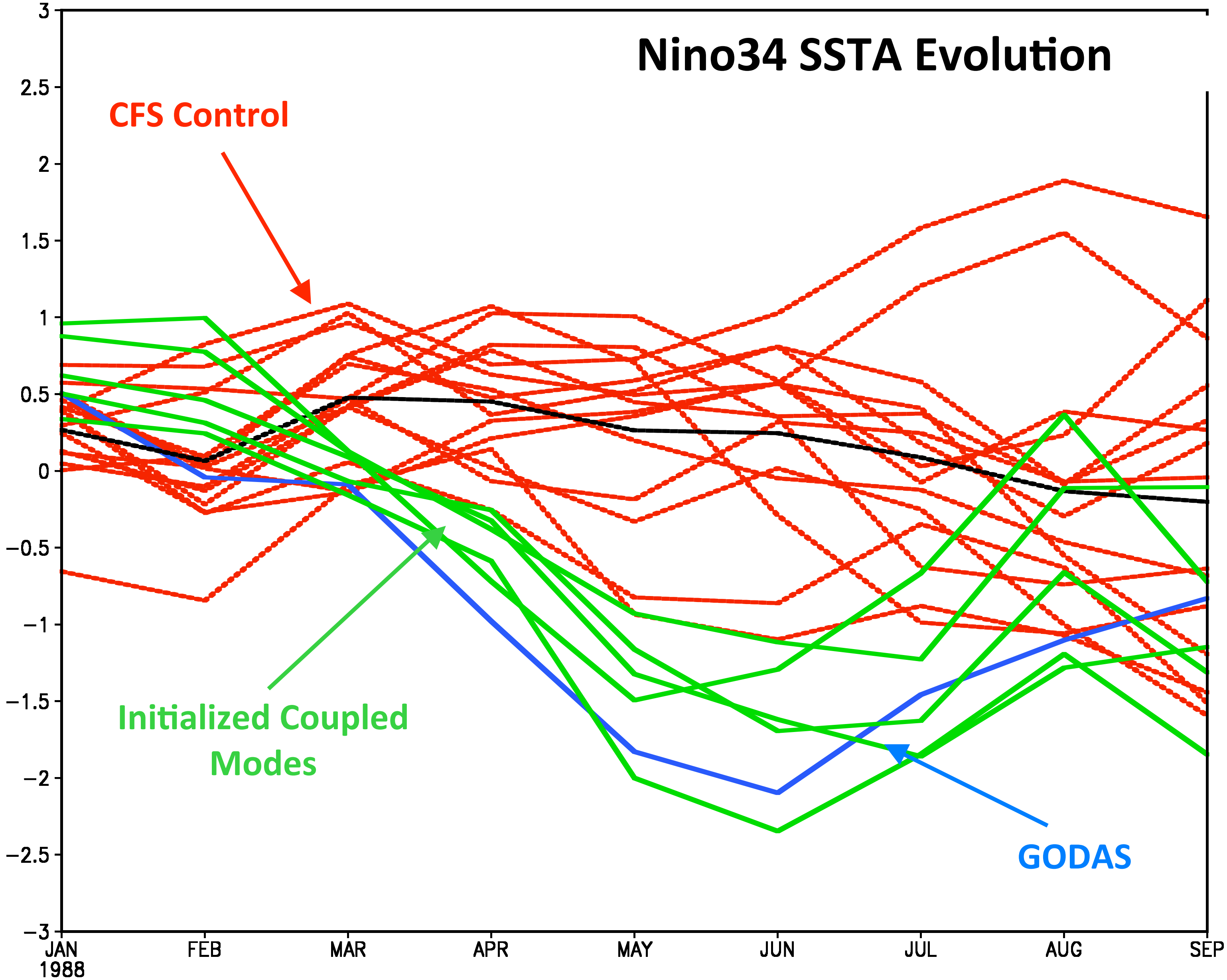

Nino3.4 RMSE 1982−1998: Jan 01 Oics
RMSE
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1
2
3
4
5
6
7
8
Lead Time (months)
Persistence
CFS
CCSM3.0
CCSM3.5
NMME(CFS+CCSM3.0
+CCSM3.5)

Improvements to Building Blocks





Initializing the Coupled Modes of the Coupled Model
Coupled Data Assimilation

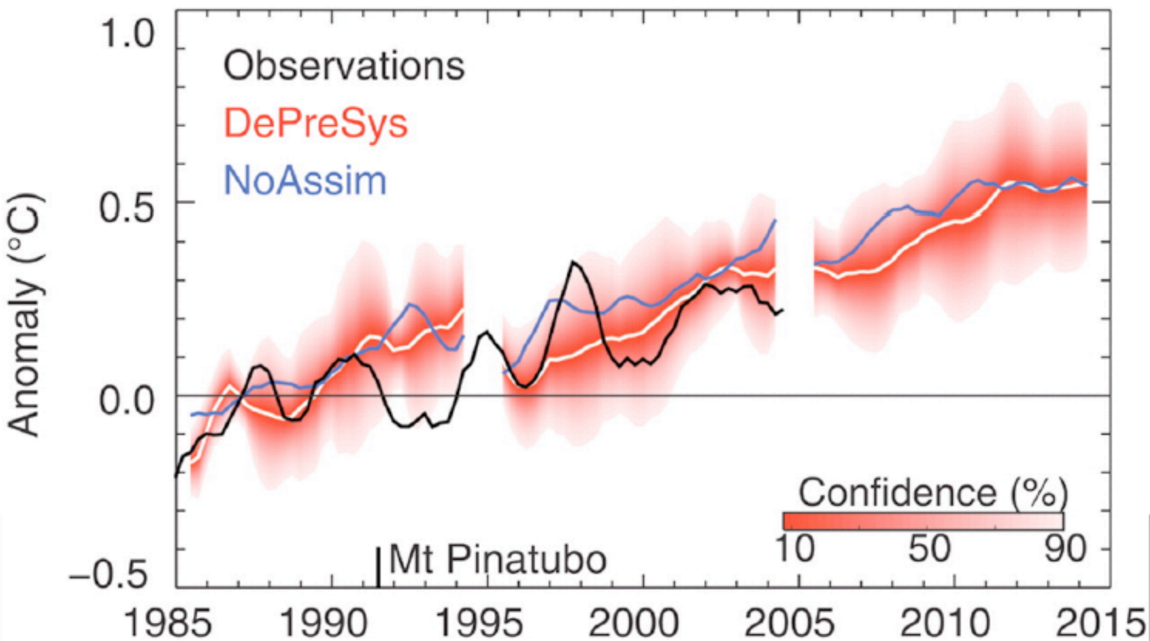


WCRP World Climate Research Programme

What do we need to do?

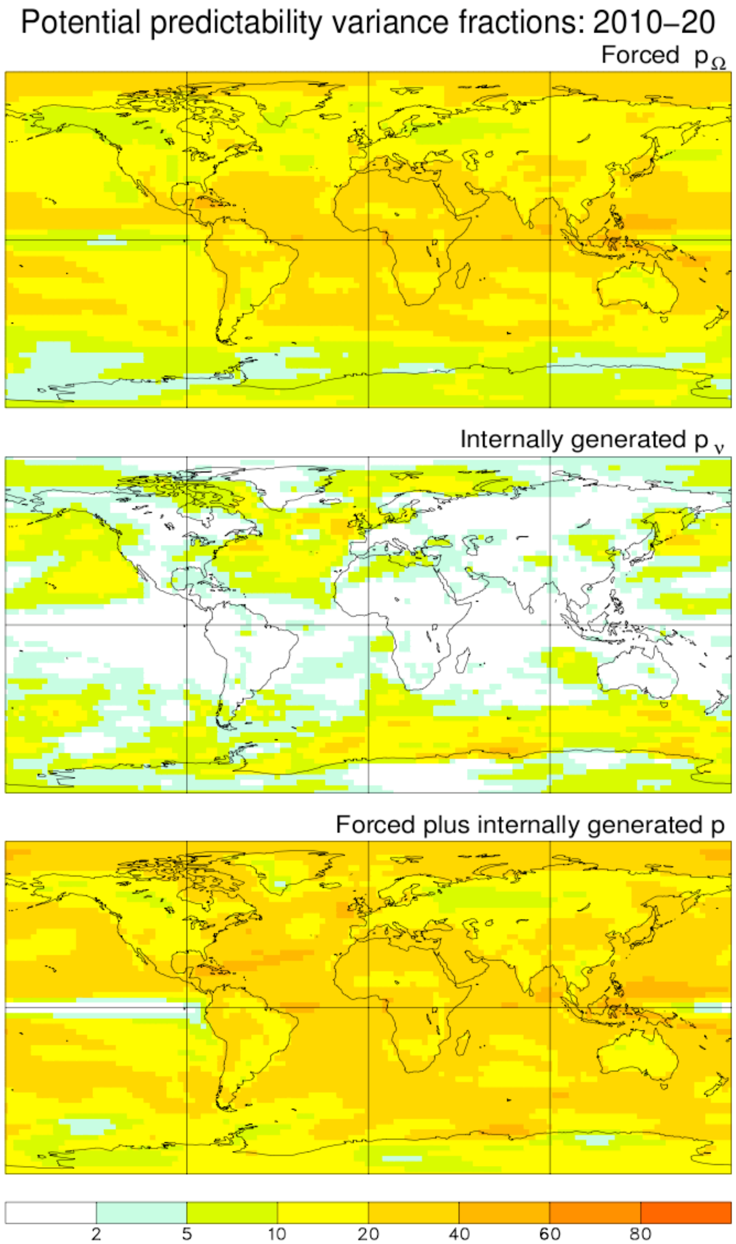
WCRP Priority Tasks (7)

- Develop and test next generation climate models: First decadal climate prediction



Fundamentals: coupled climate model run including the oceans.

Smith et al., Science 10.08.2007



p_Ω

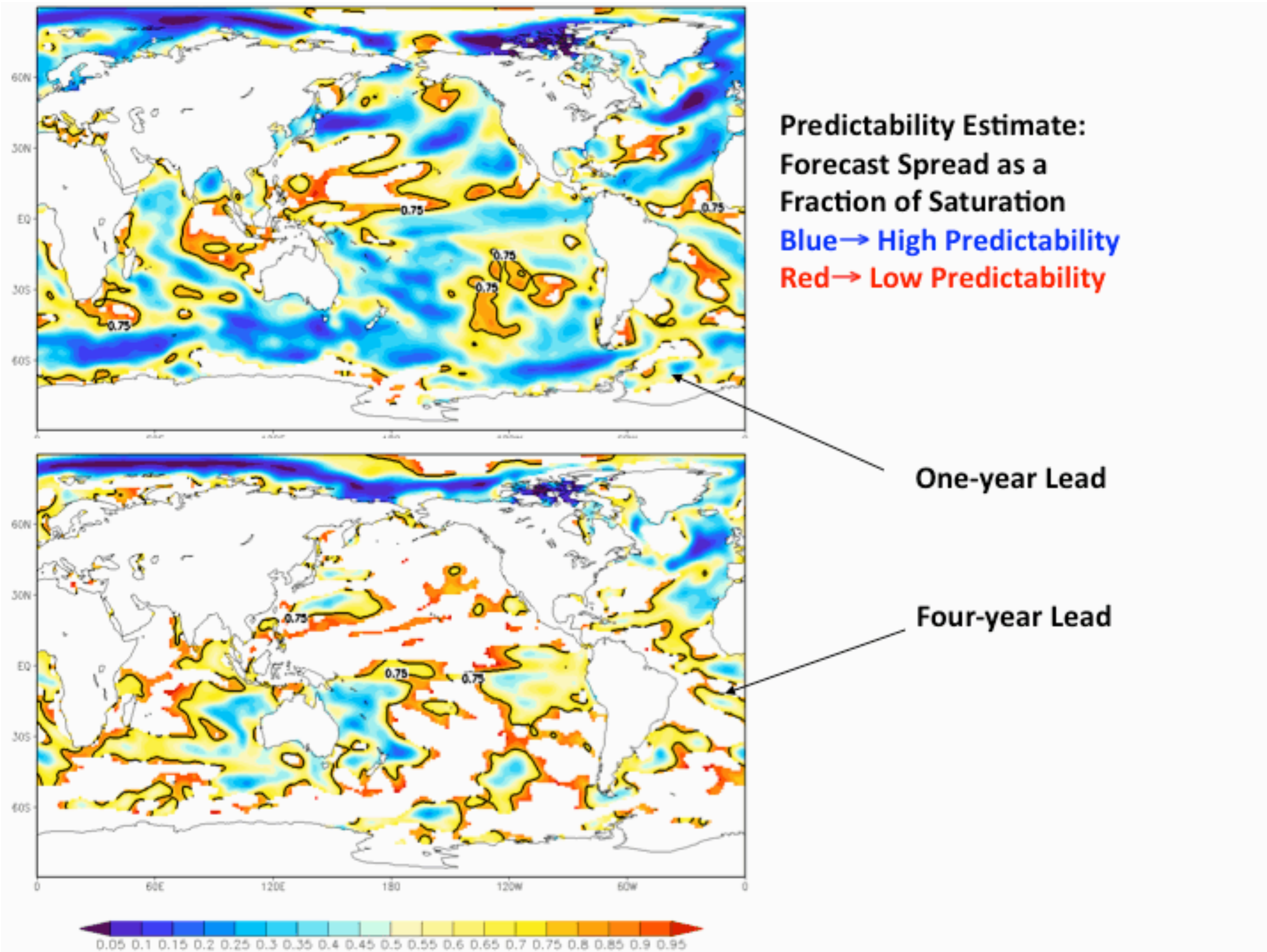
p_ν

p

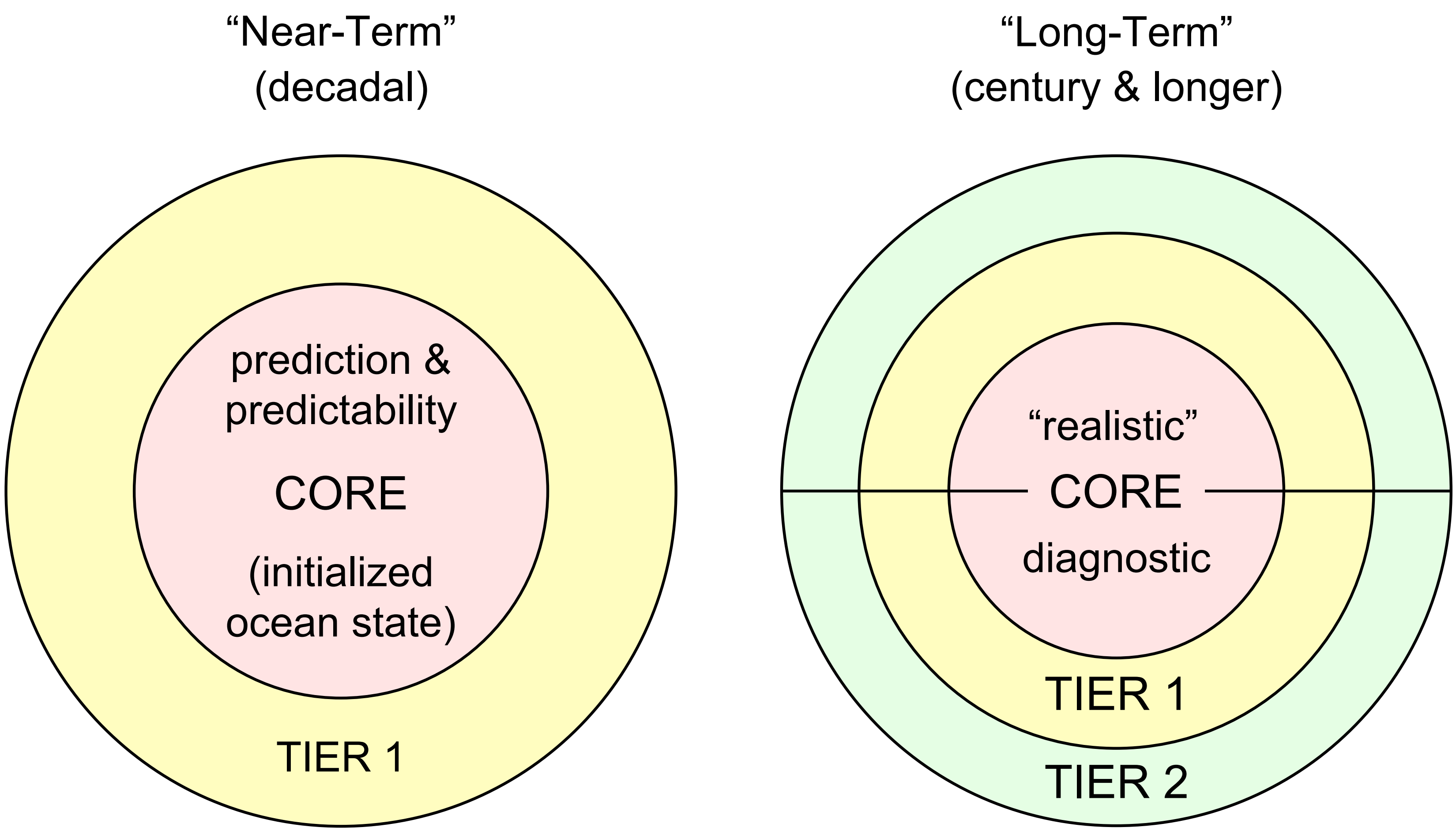
Potential predictability of temperature for *2010-20* *("next decade")*

- percentage of total variance over decade
  - associated with forced component
  - associated with internal variability
- p_Ω and p_ν tend to be inverses of one another so $p = p_\Omega + p_\nu$ is more uniform than either

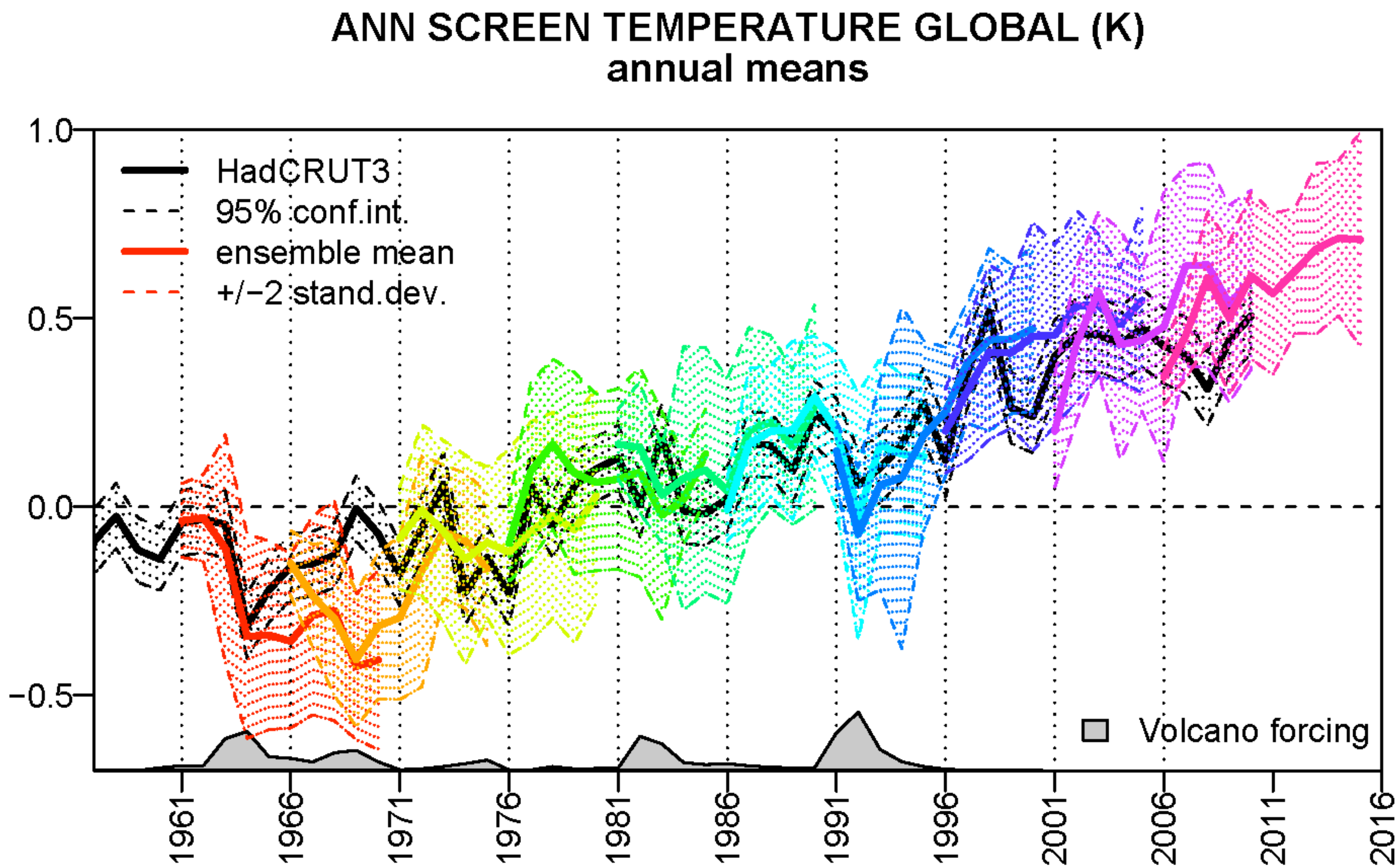
Boer 2008


Predictability Estimate:
Forecast Spread as a
Fraction of Saturation
Blue→ High Predictability
Red→ Low Predictability
One-year Lead
Four-year Lead
60N
30N
EQ
30S
60S
0
60E
120E
180
120W
60W
0.75
0.05 0.1 0.15 0.2 0.25 0.3 0.35 0.4 0.45 0.5 0.55 0.6 0.65 0.7 0.75 0.8 0.85 0.9 0.95

CMIP5 Experiment Design

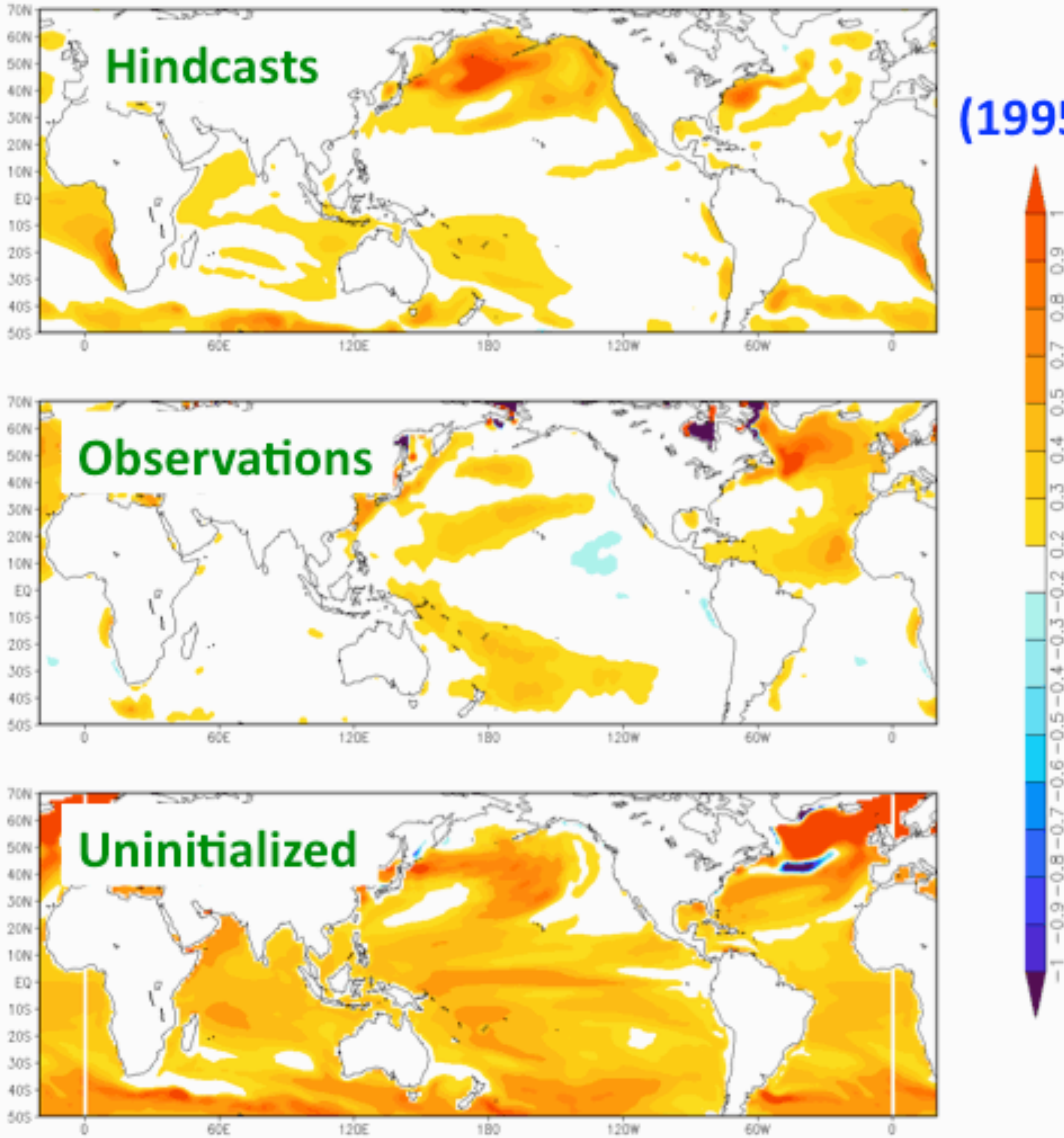


Decadal forecast results to 2015



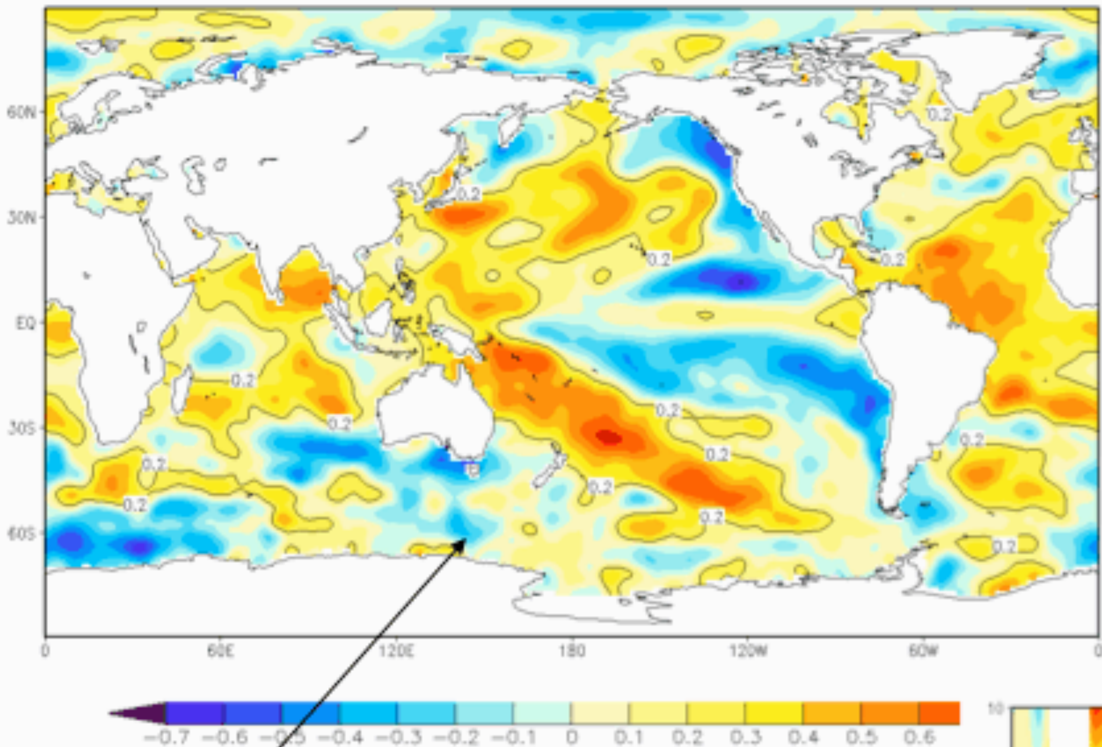
CCCma

Global Trends:
(1995-2009) – (1980-1994)

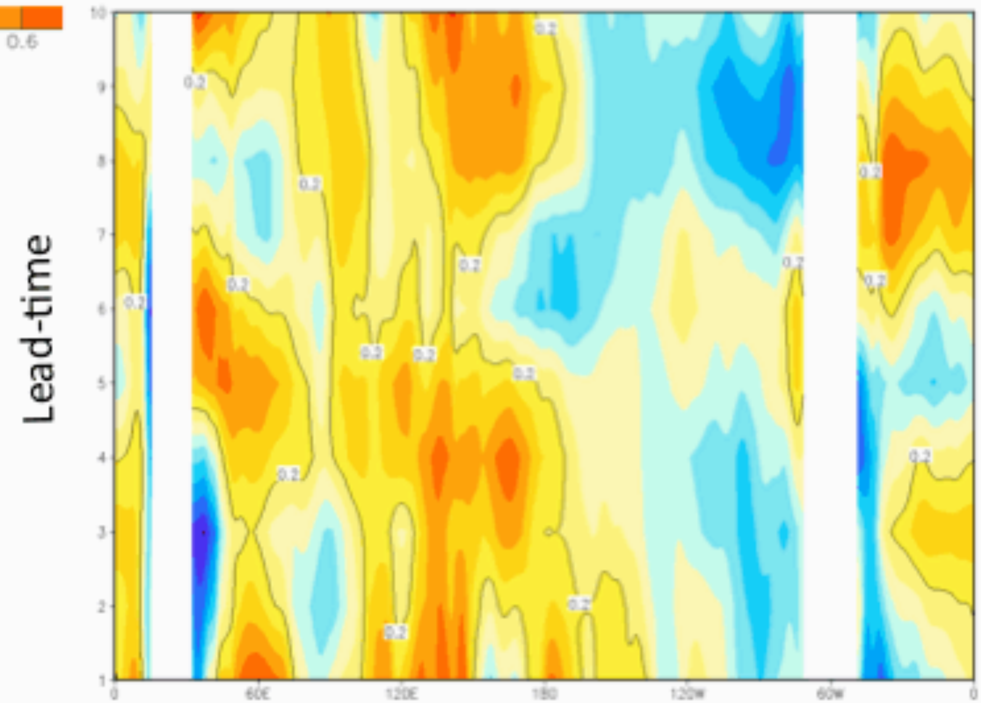


U. Miami

Hindcast Annual Mean SSTA Correlation Coefficient



Lead-Time 8-years



Southern Tropics (30S-2S)
Lead-Times 1-10 years

Exchange of Decadal Prediction Information

GFDL – *Tony Rosati* **MRI-JMA** – *Kimoto Masahide*
SMHI – *Klaus Wyser,Colin Jones* **KNMI** – *Wilco Hazeleger*
IC3 – *Francisco Doblas-Reyes* **MPI** – *Daniela Matei*
RSMAS – *Ben Kirtman* **CCCMA-EC** – *George Boer*
IfM-GEOMAR - *Mojib Latif* **CERFACS** – *Laurent Terray*

Adam Scaife and Doug Smith

WGSIP July 2010

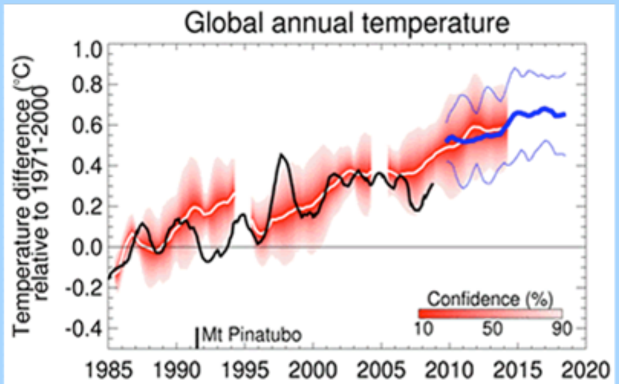
We plan to keep initial exchange very simple:

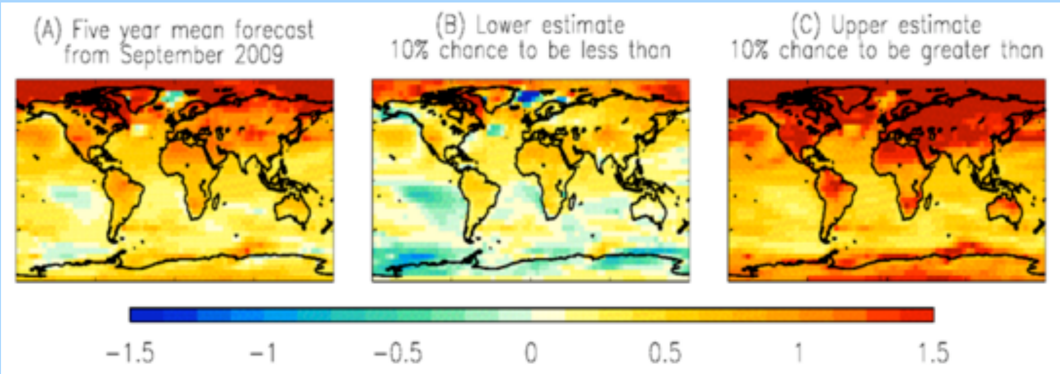
Global Annual Mean Temperature

One file for each year, each member

<u>Exchanged</u> once per year around October

Example diagnostics:



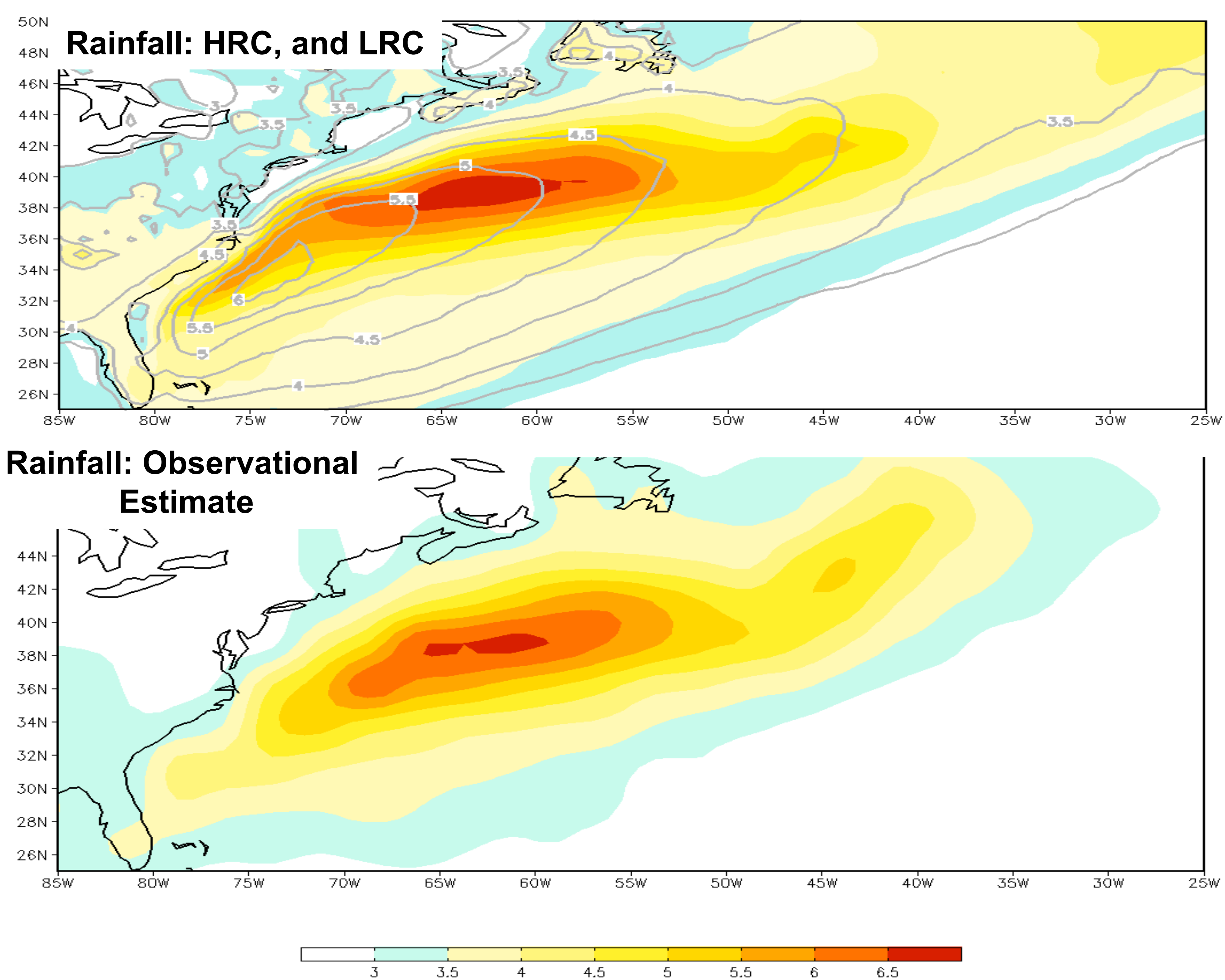


Lessons Learned

- One-Tier Systems have more Skill then 2-tier systems
- Probabilistic Problem
- Multi-Model Useful
- No-Cheating Testing of Prediction Systems
- Sample Size Issues
- Statistical and Dynamical Techniques are Complementary

Outstanding Issues

- **Quantifying Forecast Uncertainty Due to Uncertainty in Model Formulation**
  - Multi-Model Helps, but Ad-Hoc; Need Models of Model Error (e.g., Stochastic physics)
- **Quantifying Forecast Uncertainty Due to Uncertainty in Observational Estimates**
  - Initial Condition Problem
- **Model Error**
  - Need for International Coordinated Effort at Improving Models
    - Multi-Model is Not an Excuse for Neglecting Model Improvement; Resolution
- **Data Assimilation (Coupled Assimilation) and Forecast Initialization**
- **Sustained and Enhanced Observing Systems**
- **Climate System Component Interactions**
  - Coupled Ocean-Land-Ice-Atmosphere; External Forcing vs. Natural Variability
- **Quantifying the Limit of Predictability**
  - Identifying Sources and Mechanisms for Predictability


Rainfall: HRC, and LRC
50N
48N
46N
44N
42N
40N
38N
36N
34N
32N
30N
28N
26N
85W 80W 75W 70W 65W 60W 55W 50W 45W 40W 35W 30W 25W
Rainfall: Observational Estimate
44N
42N
40N
38N
36N
34N
32N
30N
28N
26N
85W 80W 75W 70W 65W 60W 55W 50W 45W 40W 35W 30W 25W
3 3.5 4 4.5 5 5.5 6 6.5