



Seasonal Predictability and Prediction Studies in COLA

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Thanks to **James Kinter, Jagadish Shukla, Ben Kirtman,
Dughong Min, Ben Cash**

APCC Working Group Meeting, 19 Sep 2007



COLA Research Objectives

COLA as a major interagency National center of excellence:

**Explore, Establish and Quantify the Predictability
and Prediction of Seasonal to Decadal Variability
in a Changing Climate**

- **Use Multiple State-of-the-Art Models**
- **Conduct Innovative Sensitivity and Predictability Experiments**
- **Dual Purpose: Enhance Understanding
 Improve Forecasts**

COLA Research Strategies

- **Nation's (NSF-NOAA-NASA) coupled O-A-L models**
 - Focus on **coupled** models; use forced component models for diagnosis
- Ensembles of **multiple model** realizations
 - **Hypothesis:** Ensembles of multiple models of comparable fidelity but different systematic errors are better for estimating climate PDF than single-model ensembles with multiple initial states
 - **Novel approaches:** anomaly coupling, regional coupling, interactive ensembles, anomaly initialization, empirical correction
- Apply knowledge of **S-I prediction** and **predictability** of current climate to a changing climate
 - Tropical land use changes
 - Global warming



Seasonal Forecast in COLA

- **Tier-2 Seasonal Forecast System**

 - COLA AGCM v1: four times per year

 - COLA AGCM v2: every month

- **Tier-1 Seasonal Forecast System**

 - COLA Anomaly Coupled Model: every month

- **Experimental Tire-1 Seasonal Forecast System**

 - CCSM 3: retrospective forecast

 - Advanced **multi-model ensemble** for both predictability and prediction, e.g., adaptation of CCSM3 for ENSO prediction

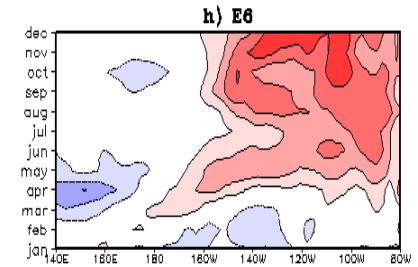
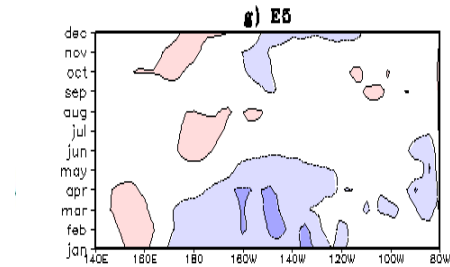
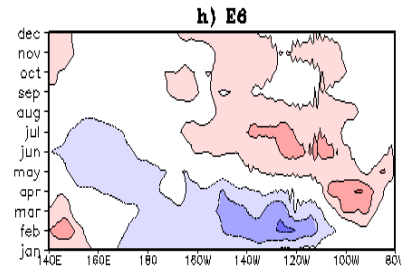
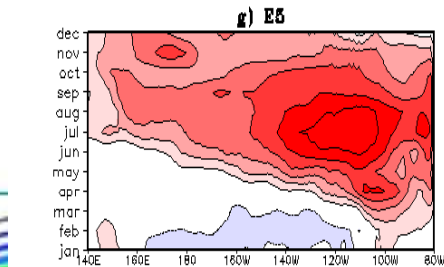
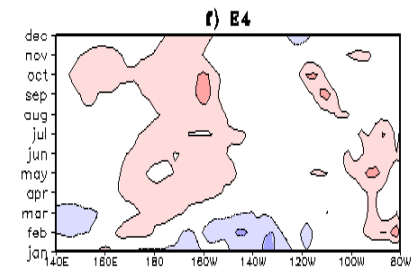
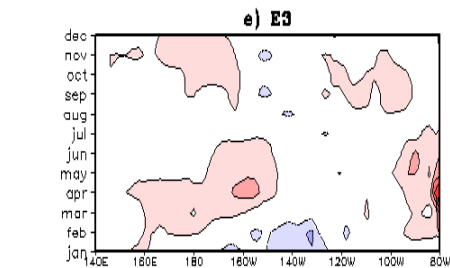
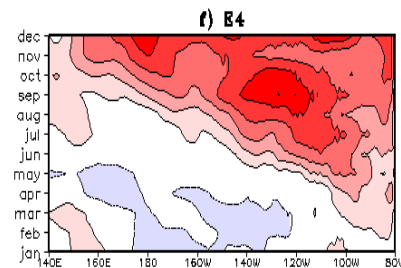
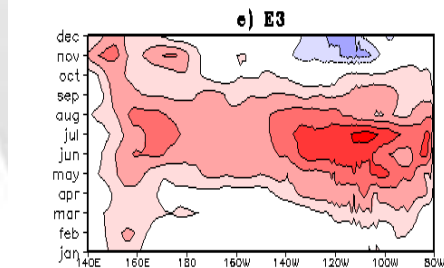
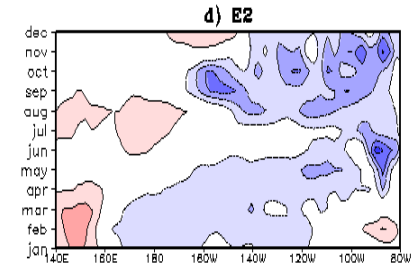
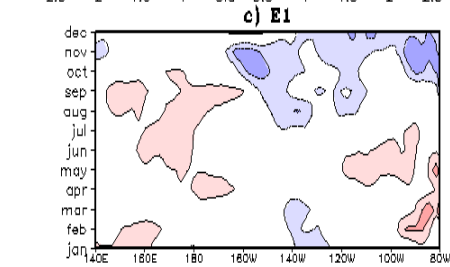
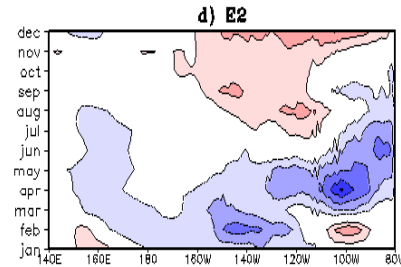
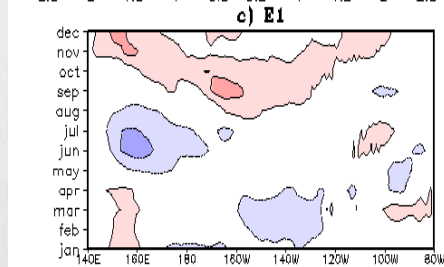
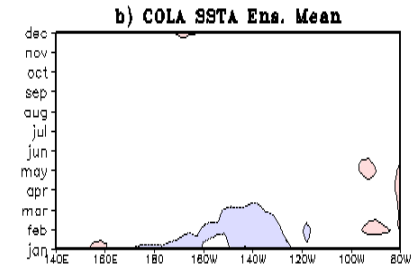
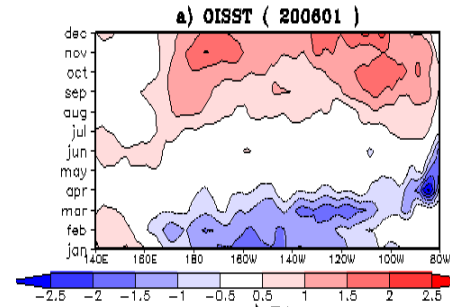
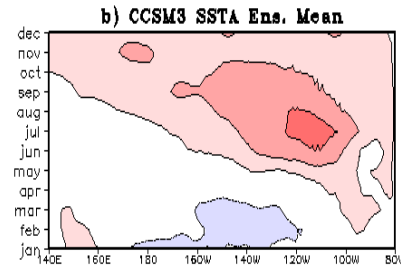
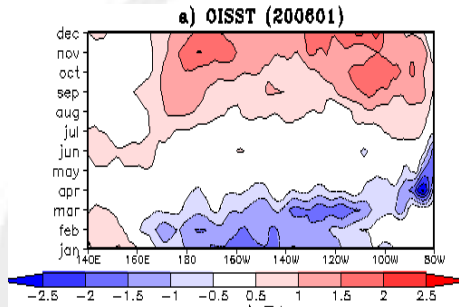
CCSM 3.0 Prediction Experiments

- **CCSM3.0: (CAM3 T85L26 + POP 1.4 gx1v3 L40)**
- **Testing IPCC Class Model on the Seasonal-to-Interannual Prediction Problem**
- **Using Ocean Initial Conditions from MOM3 in POP**
 - GFDL MOM3 Ocean Data Assimilation (ODA) System (Rosati and Harrison, 2002)
 - Variation Optimal Interpolation Scheme (Derber and Rosati, 1989)
 - No attempt to find optimal method in atmospheric perturbations in hindcast ensembles
 - Identical in the ocean initial state for each ensemble member each year
- **Retrospective Forecast : 1982 -1998 initialized in January and July**
Interpolation to the POP grid from the GFDL ocean January and July initial states
- **An ensemble of six hindcasts : a total of 204 hindcasts**

Results

CCSM3.0 Jan 2006 IC

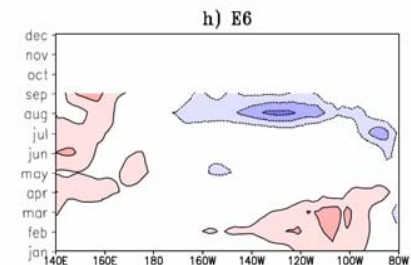
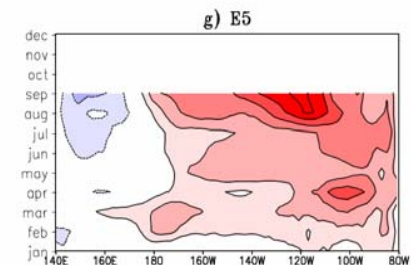
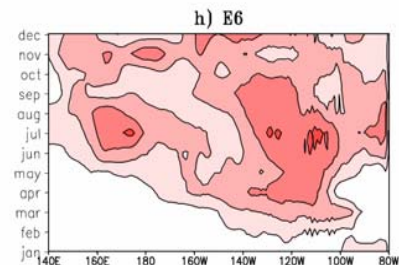
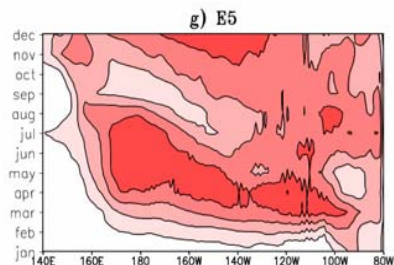
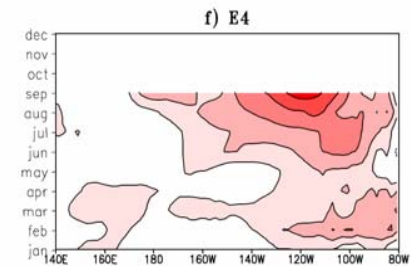
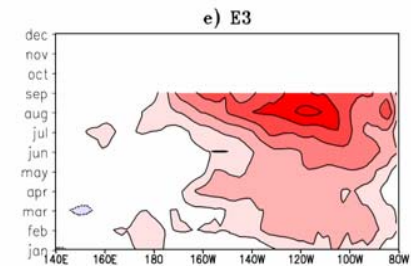
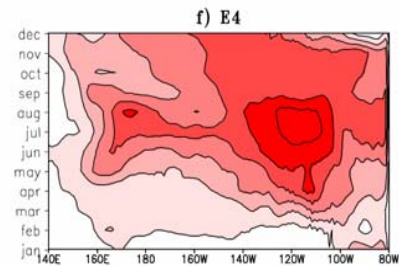
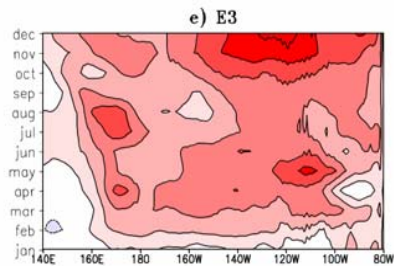
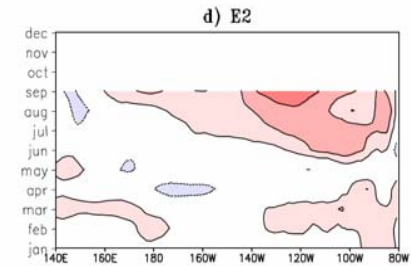
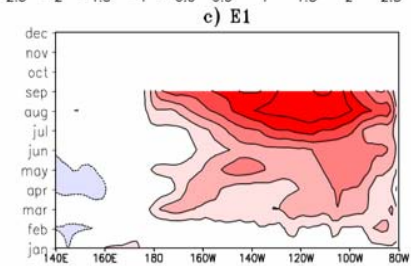
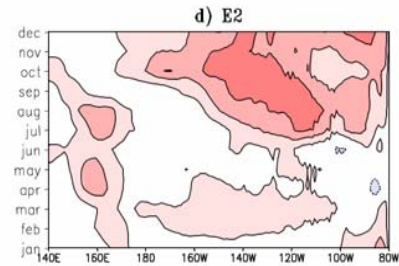
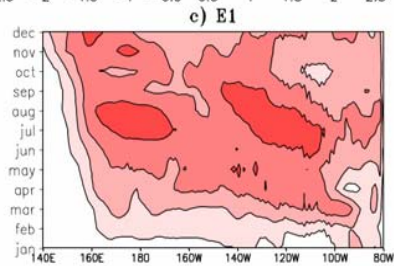
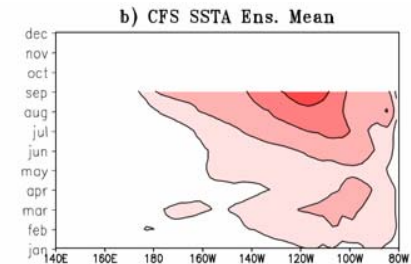
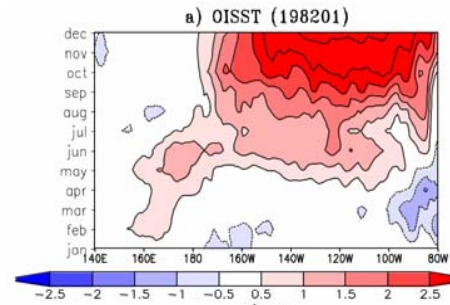
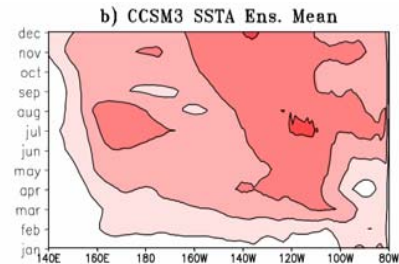
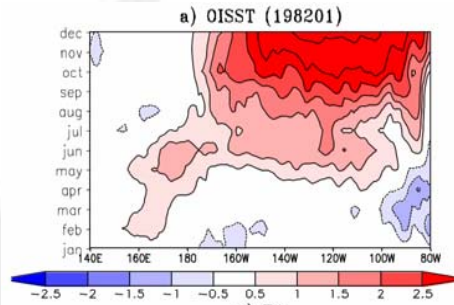
COLA Jan 2006 IC



Results

CCSM3.0 Jan 1982 IC

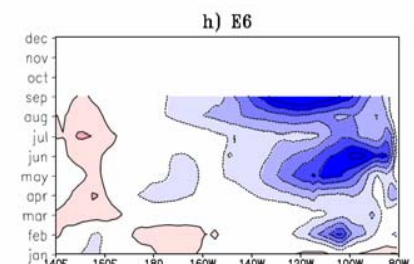
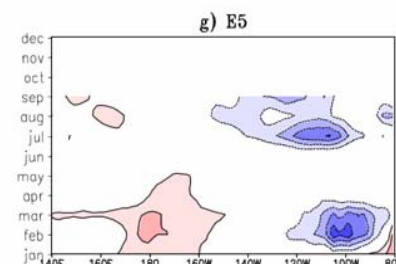
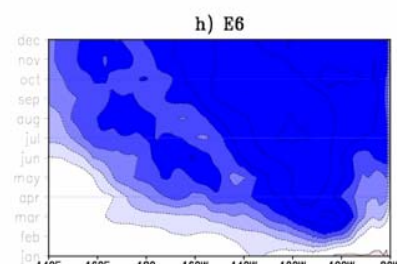
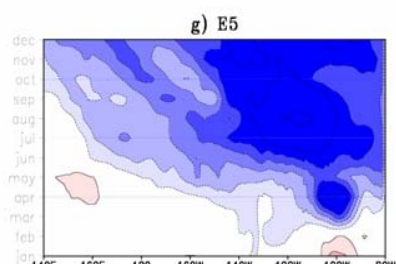
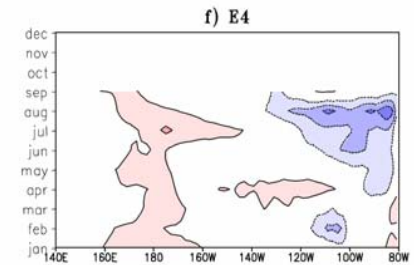
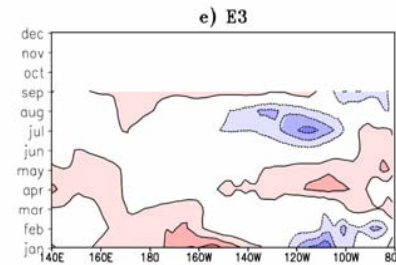
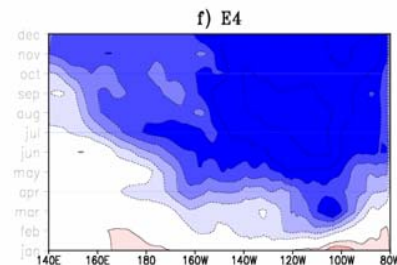
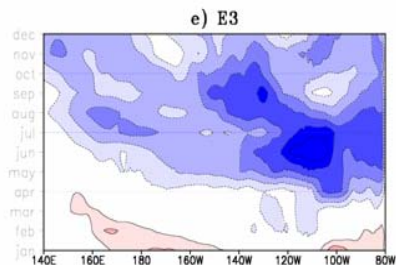
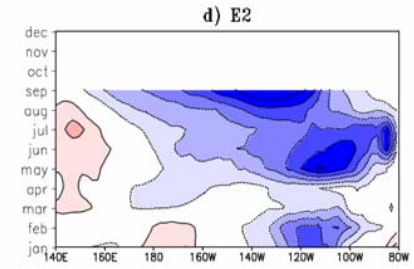
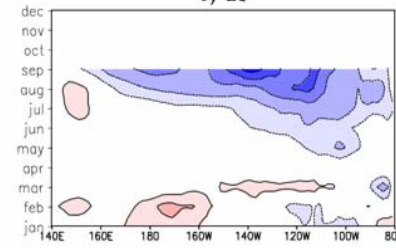
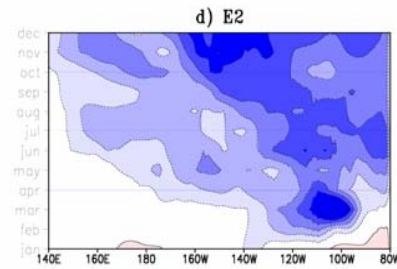
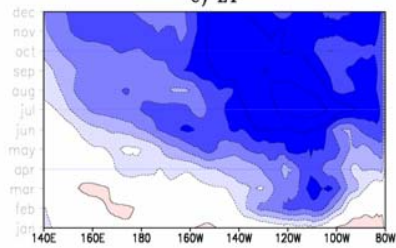
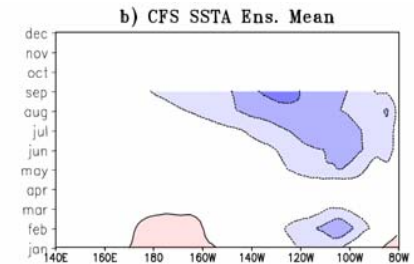
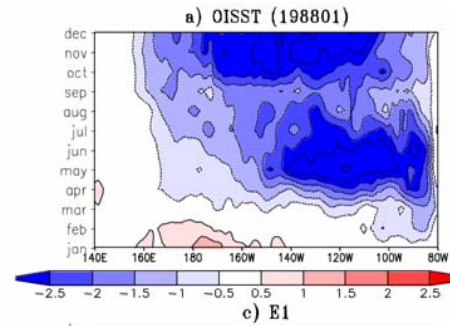
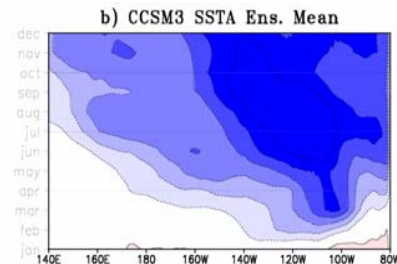
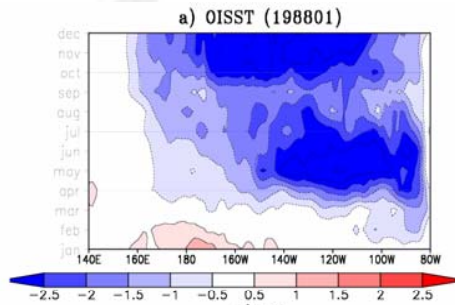
CFS Jan 1982 IC



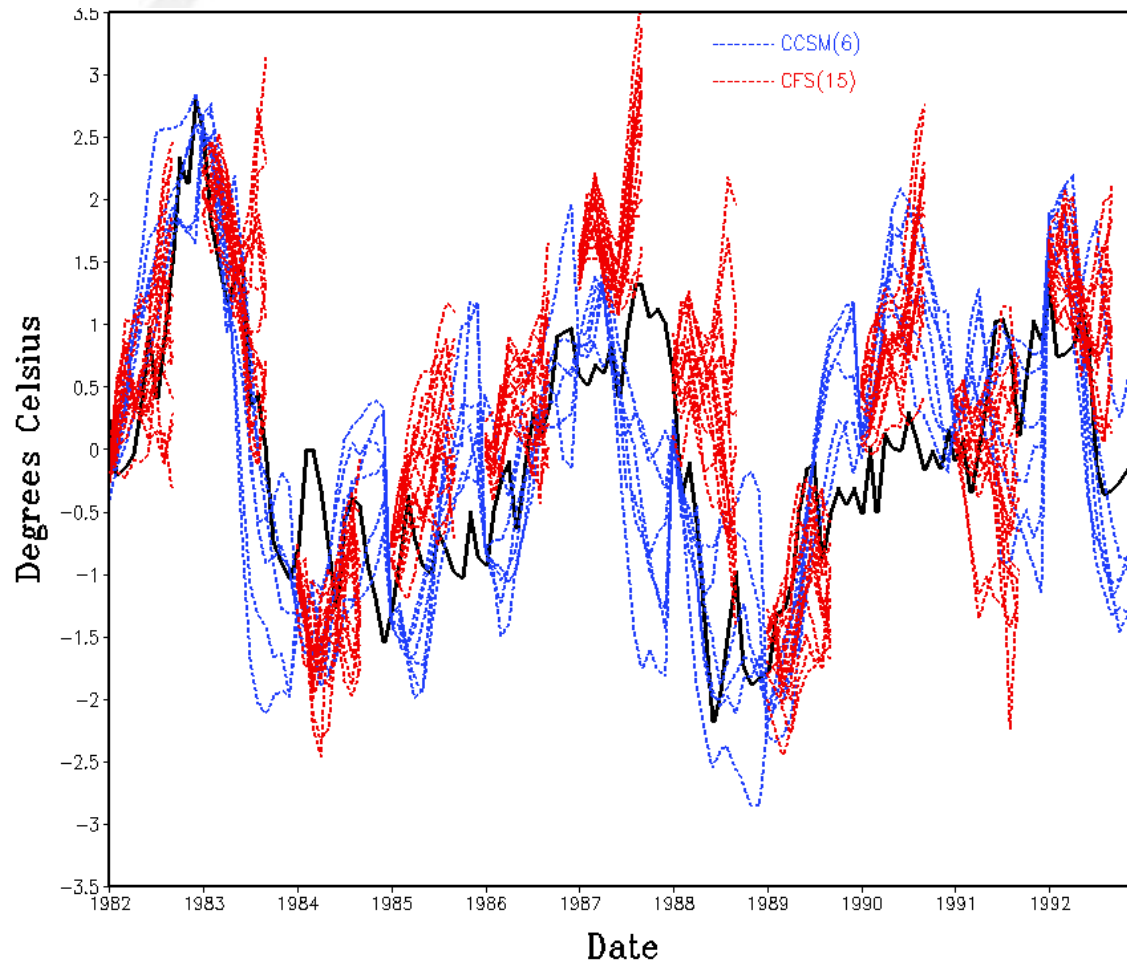
Results

CCSM3.0 Jan 1988 IC

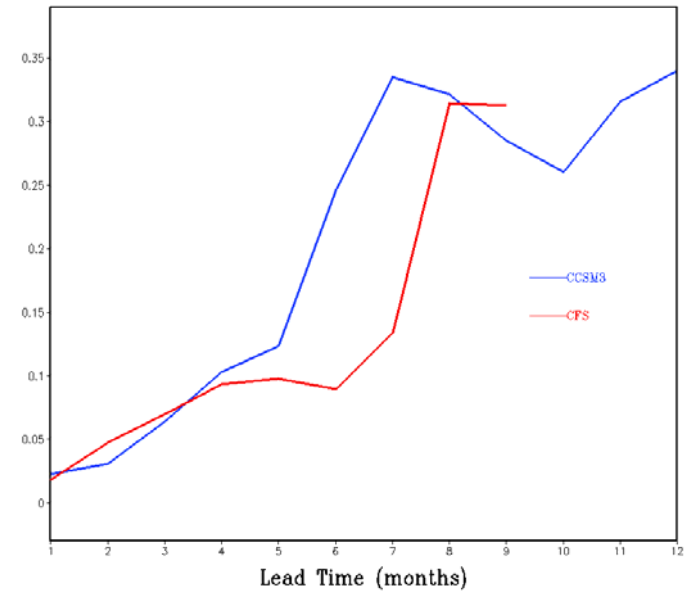
CFS Jan 1988 IC



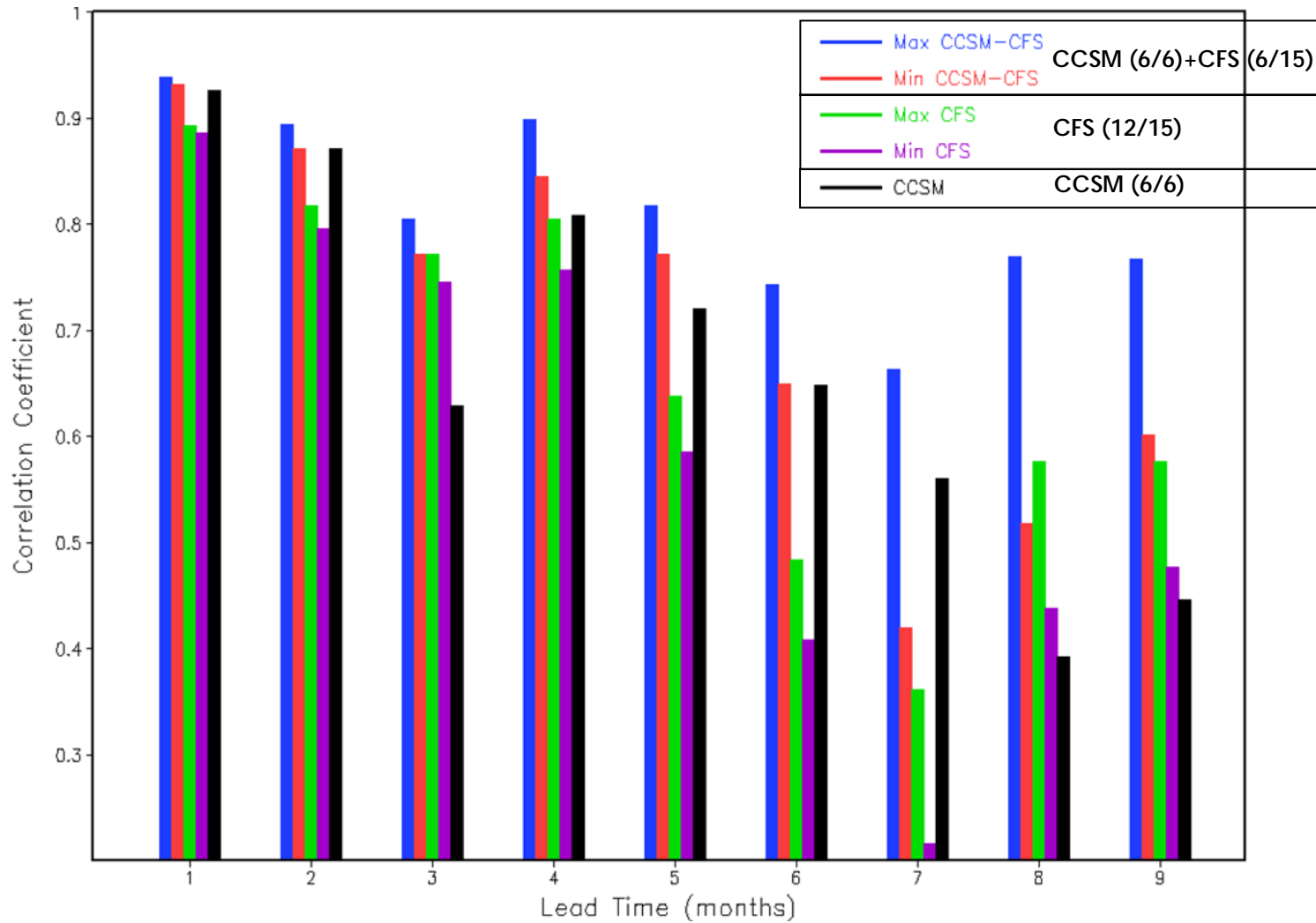
NINO3.4 Index



Ensemble Spread



Maximum NINO3.4 Skill





Seasonal Predictability Studies

- Demonstrated that **ocean-atmosphere interactions** and **land-atmosphere interactions**, with **high-frequency noise** and **low-frequency climate change**, play important roles to **enhance climate predictability**
- Showed that **better models** (improved mean) can lead to **better predictions**

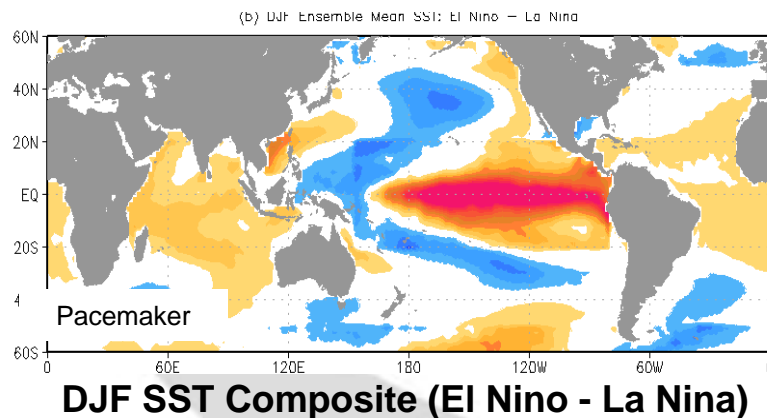
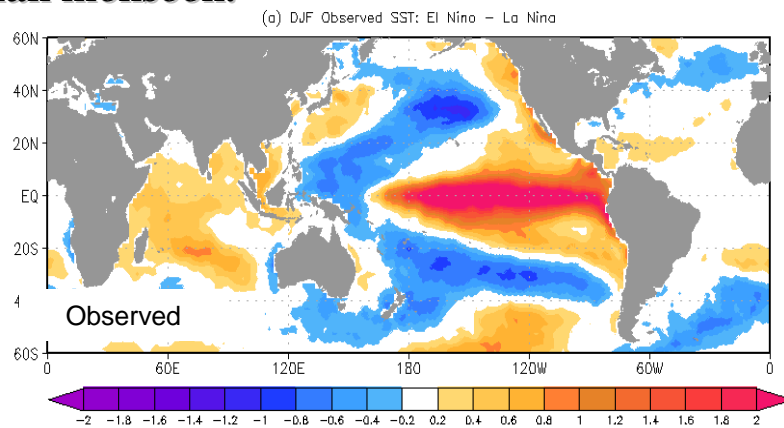
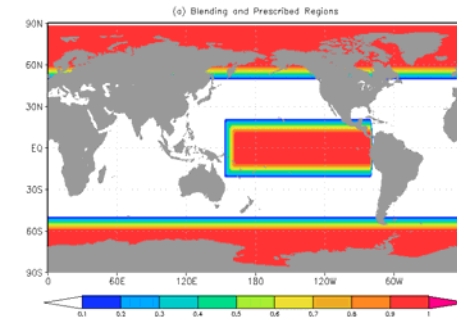
Pacemaker Strategy:

Overcoming Shortcomings of Coupled Models

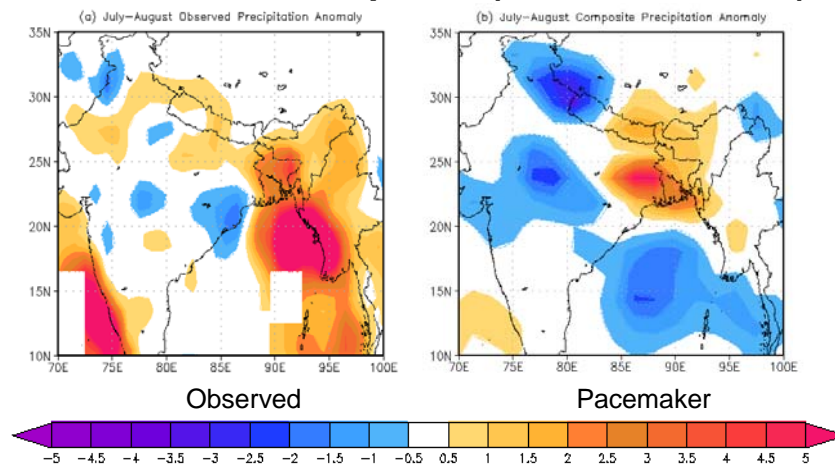
The “pacemaker” strategy permits a consistent air-sea energy balance while simultaneously including the time sequence of climate-driver events, such as ENSO.

Teleconnections from the eastern tropical Pacific to remote tropical and extratropical regions are well represented in pacemaker runs, e.g., phenomena that are at once driven by and independent of ENSO, like the Asian monsoon.

Pacemaker design:
specified SST regions
(COLA AGCM)

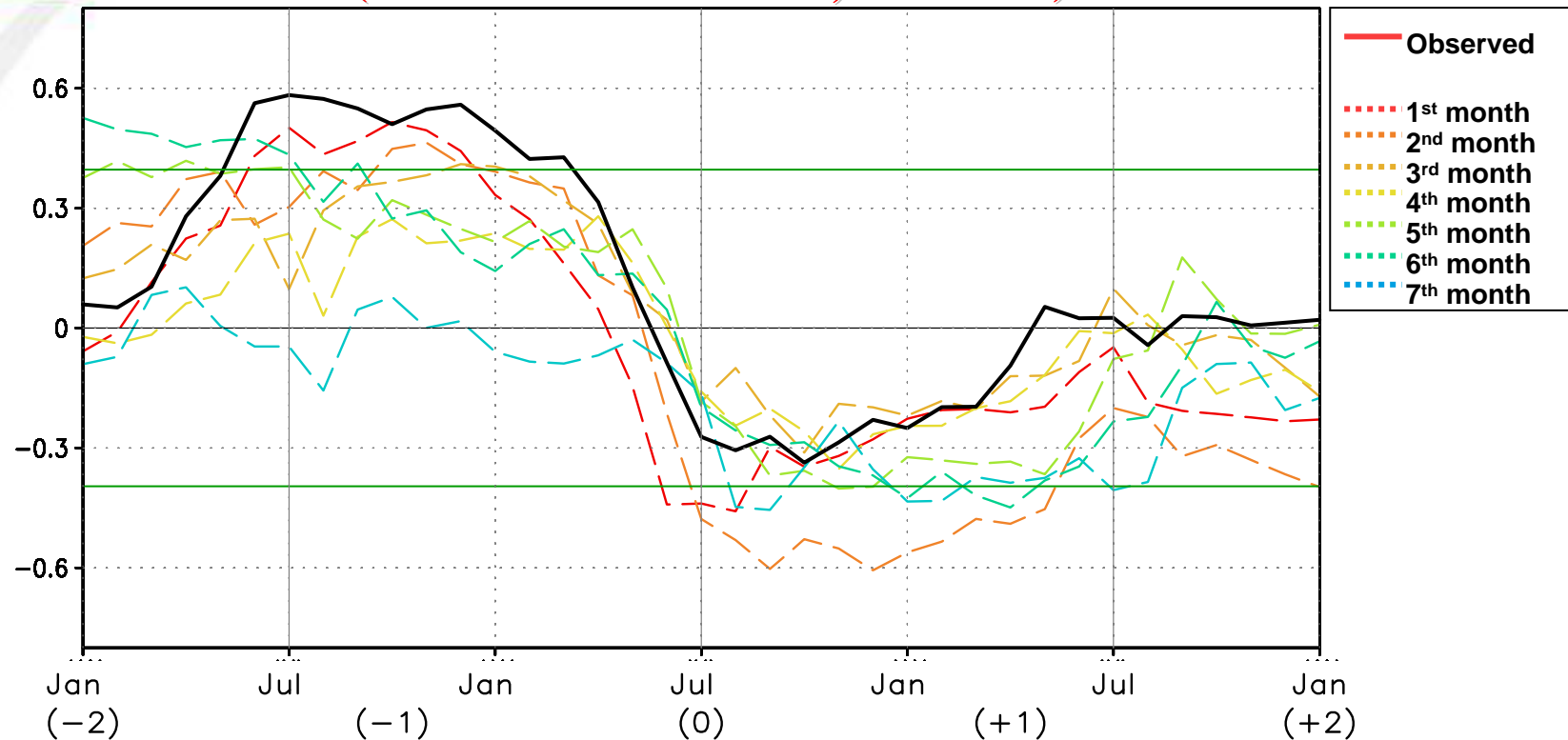


JJA Rainfall Composite (El Nino - La Nina)



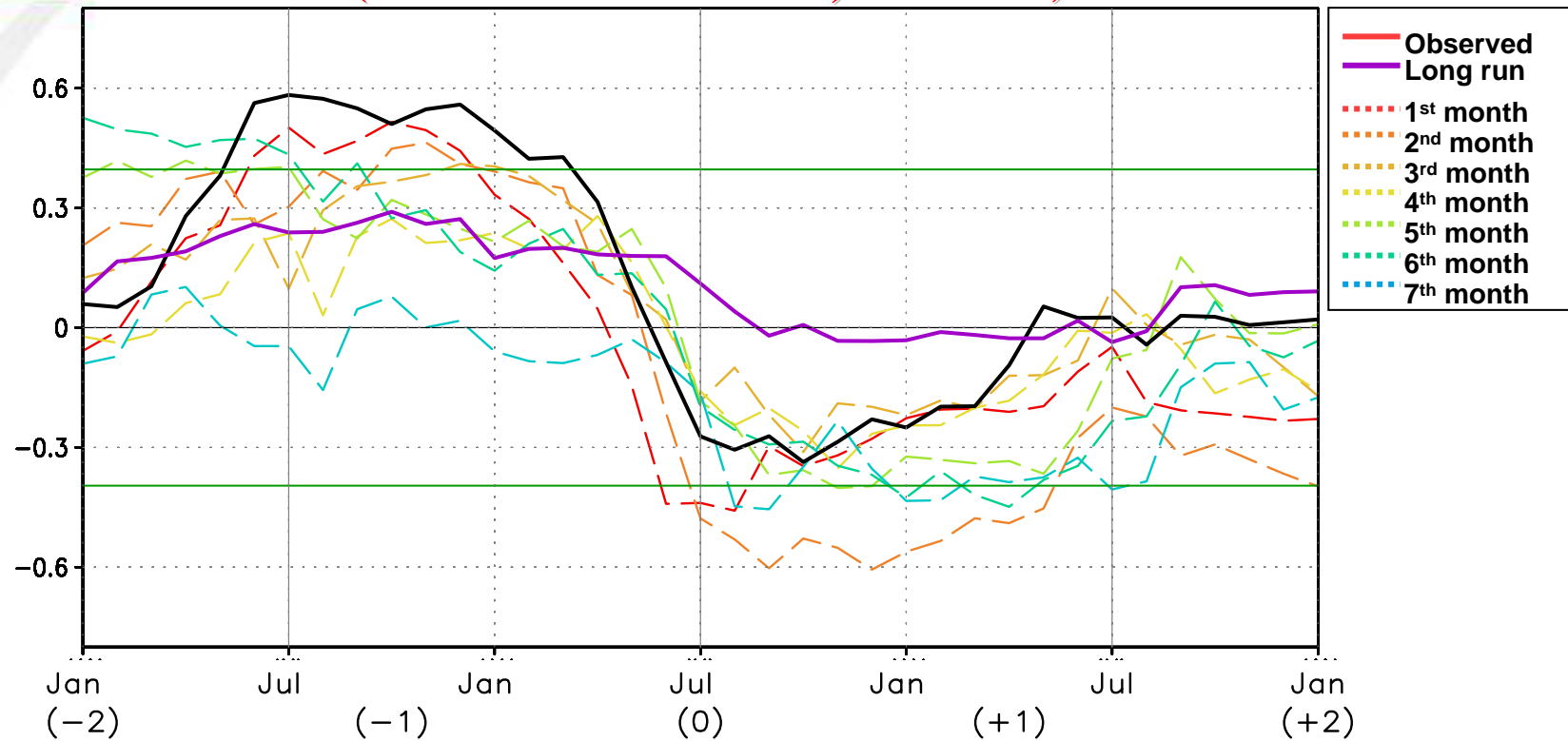
Cash et al. 2007

Lead-lag Correlation (CFS) (JJMS Extended IMR, NINO3.4)



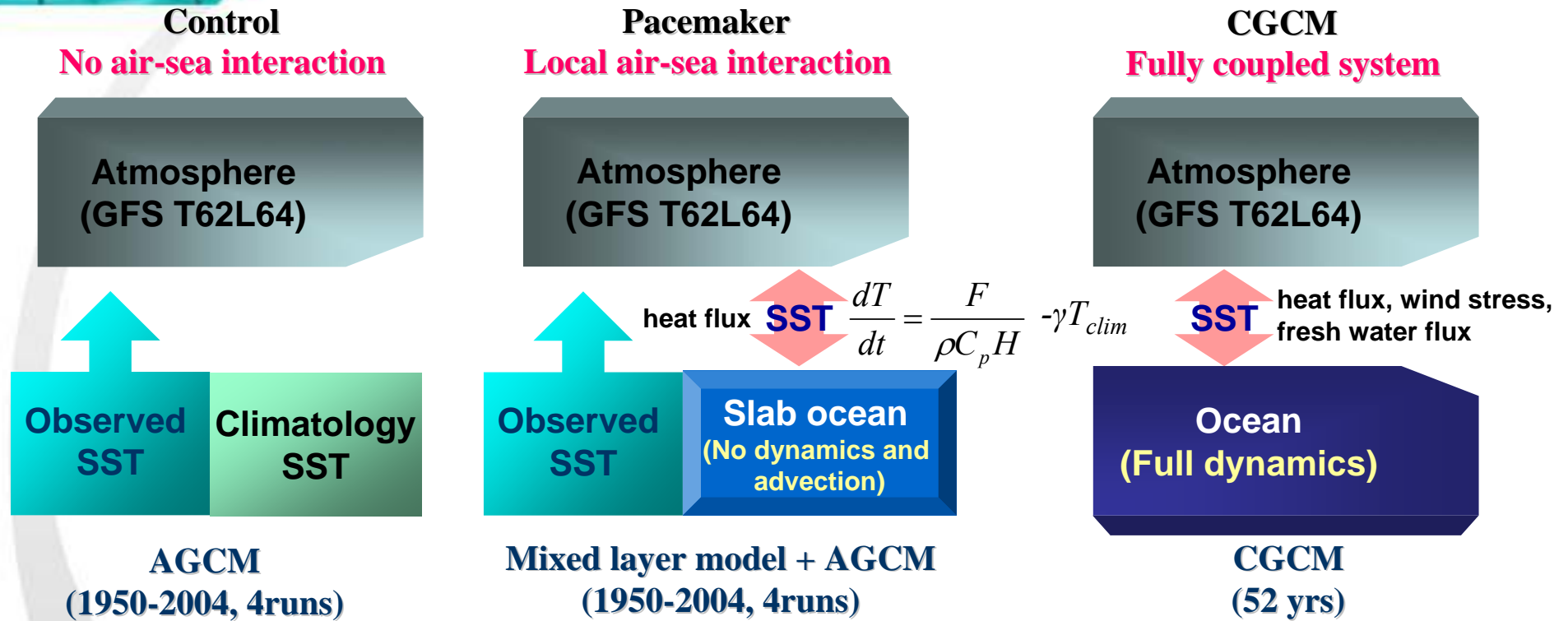
- **Extended MR (Indian Monsoon Rainfall Index):**
Total rainfall over 60-100°E, 5-25°N during JJAS
- For retrospective forecasts, reconstructed data with respect to **lead time (monthly forecast composite)** is used.
- **Green solid line denotes 95% significance level**

Lead-lag Correlation (CFS) (JJMS Extended IMR, NINO3.4)



▪ Purple line: CFS free long run during 52 years

Model and Experimental Design

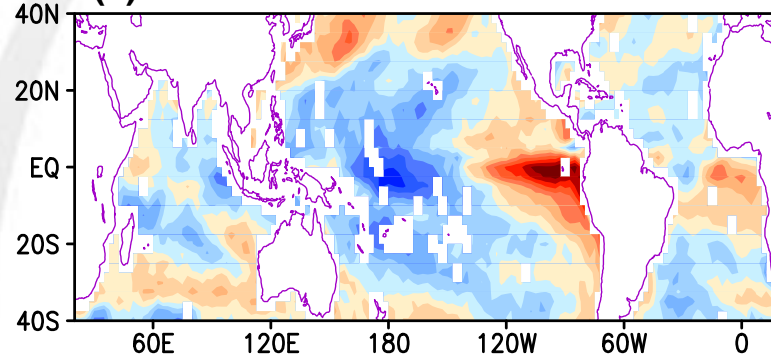


Experiment	Extratropics	Tropics	Mixed-layer depth	Period	Member
Pacemaker	Slab ocean mixed-layer with weak damping of $15W/m^2/K$	Observed interannual SST	Zonal mean monthly Levitus climatology except Eastern Pacific (reduced as 1/3)	55 yr (1950-2004)	4
Control	Climatological SST	Observed interannual SST	none	55 yr (1950-2004)	4
CGCM	MOM3			52 yr	1

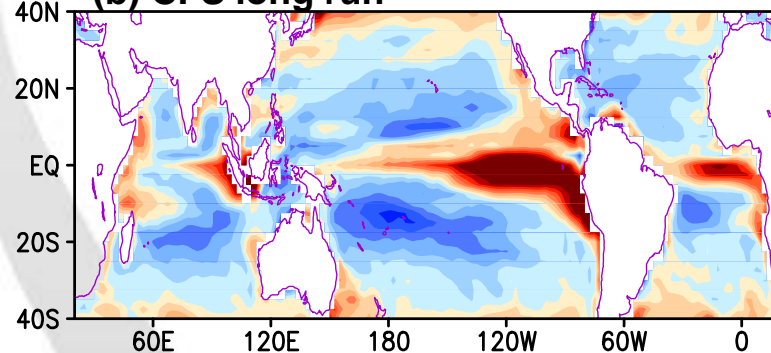
ENSO forcing in Experiments

Correlation bet. SST and Latent heat flux

(a) Observation

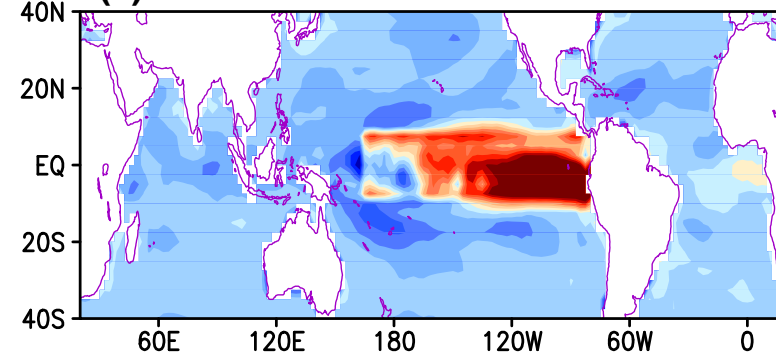


(b) CFS long run



GSSTF ver. 2 Surface latent heat flux during 1988-2000

(c) PACE

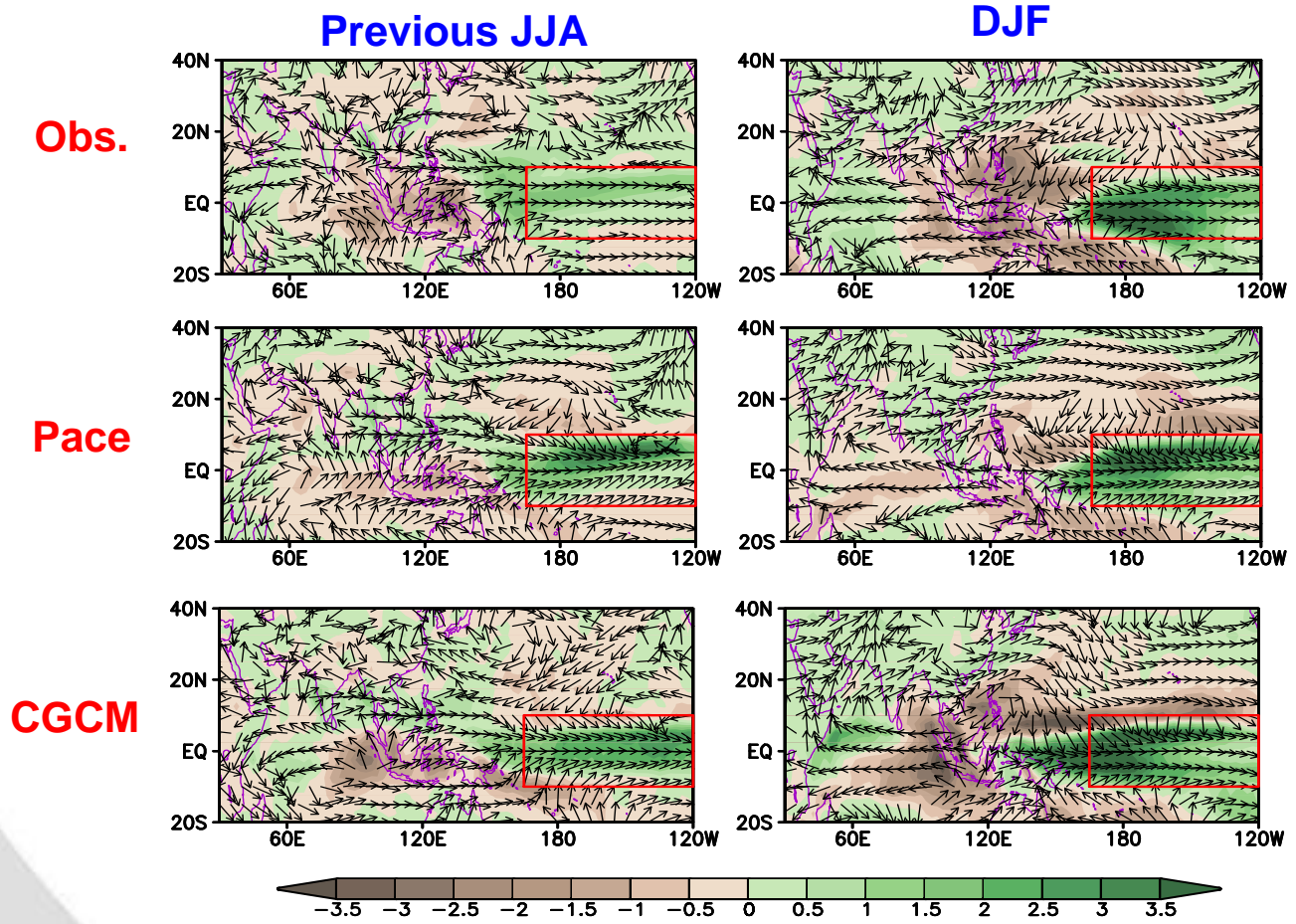


Positive: Ocean forces the Atmosphere
Negative: Atmosphere forces the Ocean

- In CGCM, the relationship between SST and latent head flux **in the western Pacific** shows the **excessive ocean forcing atmosphere**. It may be related with too coherent oceanic response, since the space and time scales of atmospheric internal dynamics (stochastic forcing) are too coherent (Kirtman and Wu, 2006)

Regressed Map by DJF NINO3.4 Index

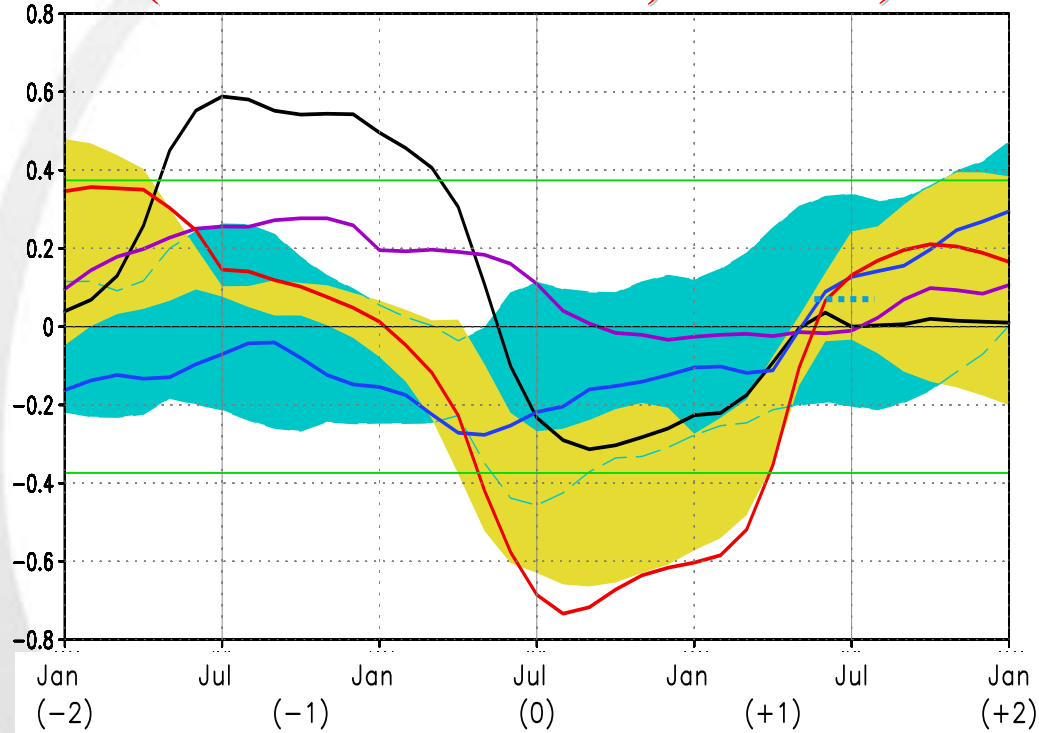
Rainfall and 850 hPa wind



▪ Red box denotes pacemaker region.

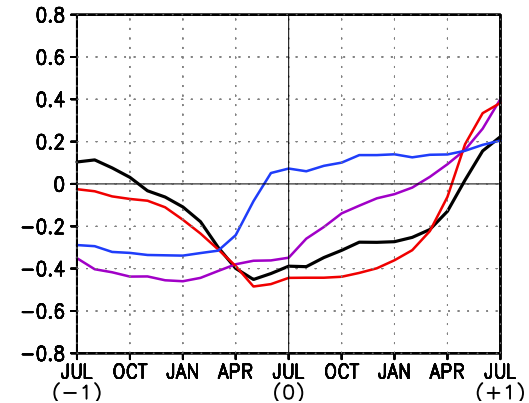
Lead-lag Correlation

(JJMS Extended IMR, NINO3.4)

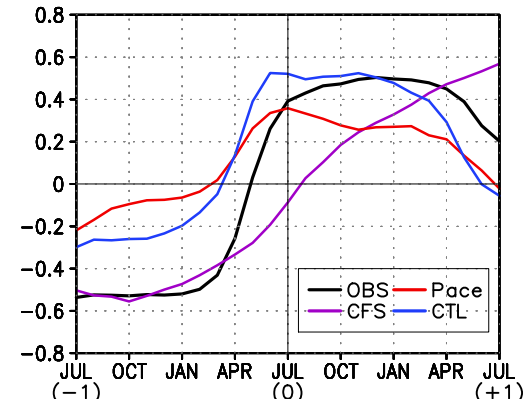


• Shading denotes ensemble spread among 4 members.
 Note that correlation for ensemble mean is not the average of correlations for four members.

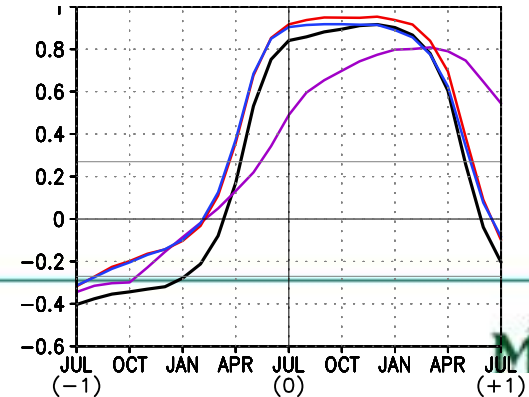
Indian Summer Monsoon index



Western North Pacific Summer Monsoon Index



1ST mode of Seasonal EOF in Monsoon region



Seasonal Prediction and Predictability Studies

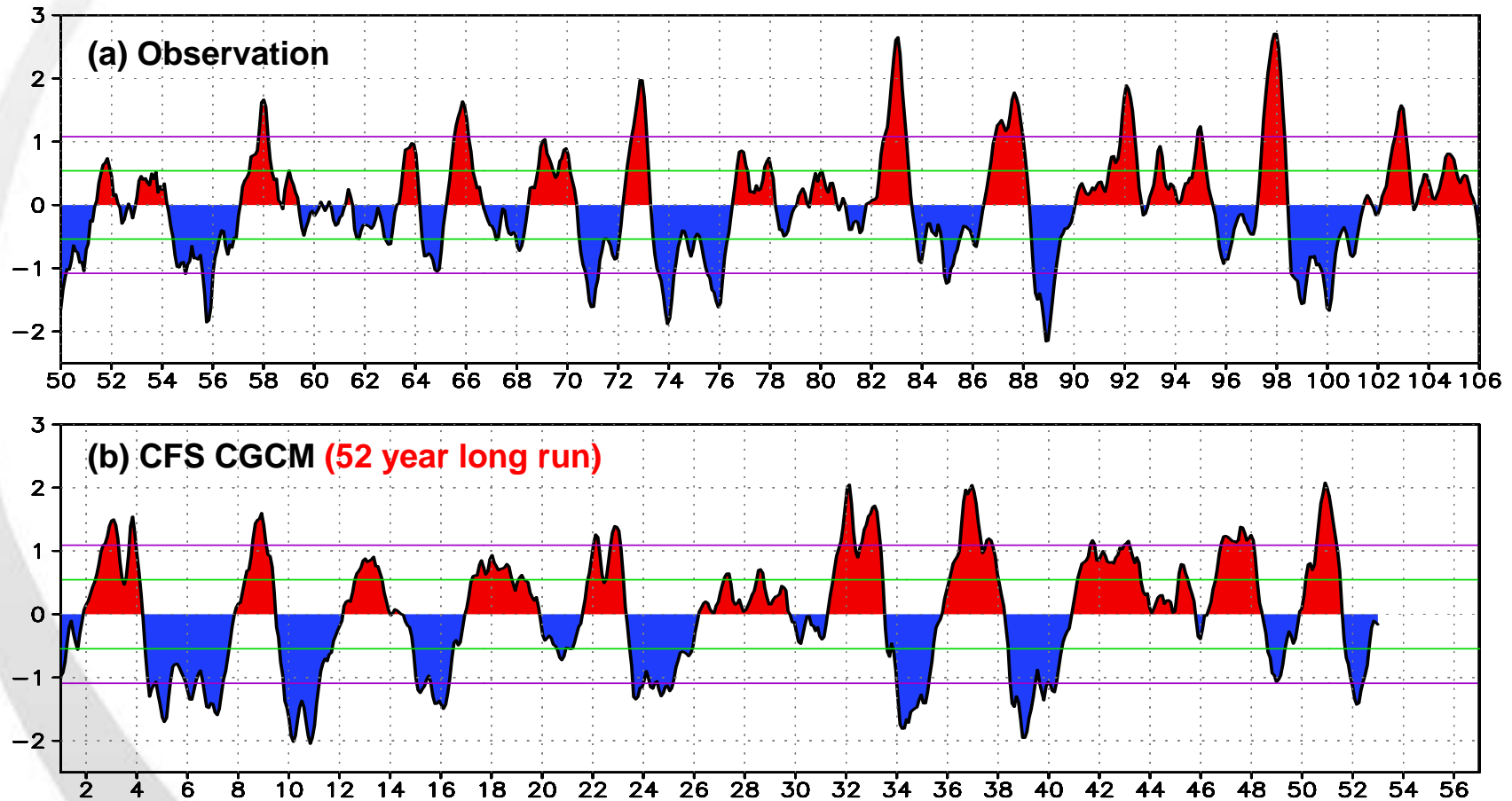
- This pacemaker experiments show CGCMs do not always simulate all of the relevant physical processes more realistically than simpler models, and often the CGCM representation of some relevant phenomena is worse than that of simpler models.
- **Forecast experiments based on predictability study**
 - Regionally coupled prediction system such as “pacemaker” (CFS, COLA, CCSM, GFDL GCM)
 - Bias corrected hindcast experiments (COLA AGCM-POSEIDON, CFS)
- **CGCM forecast system**
 - [Scale Interactions-Weather within Climate-Stochastic Effects-Weather Noise](#)
 - ENSO-WWB-MJO, Western Pacific and Indian Ocean, Decadal Predictability/Variability-ENSO, Basin Interactions, Multi-Mode Interactive Ensemble (CFS, CCSM)
 - [ENSO Prediction Research](#)
 - Coupled Initialization, Initial Condition Sensitivity, Model Errors



THANK YOU!

ENSO Characteristics in CFS CGCM

NINO3.4 Index during 1950-2005



ENSO Characteristics in CFS CGCM

Standard Deviation of SST Anomalies over Tropics

