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The Role of Air–Sea Coupling in Seasonal Prediction of Asia–Pacific Summer Monsoon Rainfall

Jieshun Zhu[1] and Jagadish Shukla[1,2]

[1]Center for Ocean-Land-Atmosphere Studies (COLA)

[2]Department of Atmospheric, Oceanic, and Earth Sciences

George Mason University (GMU)

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Backgrounds

- **1981-** *Charney and Shukla* provided a scientific basis for monsoon prediction beyond the 2-week limit of deterministic predictability;

- **1993-** *Bengtsson et al.* conducted dynamical seasonal predictions by adopting the so-called **Tier-2** approach;

  Advantage: *Avoiding large systematic errors of fully coupled models + Computational efficiency*

- **2000s- Tier-1** prediction systems become more popular (*Palmer et al. 2004; Saha et al. 2006;…*), but Tier 2 is still being used at several centers (IRI, *Barnston et al. 2010*), and as a tool for climate downscaling.

Disadvantage of Tier-2 approach: Lacking air-sea interaction

- ***The importance of air-sea interaction is pointed out by many studies (****Wang et al. 2005; Wu and Kirtman 2005,…****). Over the monsoon regions, vital role of air-sea interaction is further emphasized by studies (****Fu et al. 2002; Wu and Kirtman 2004, 2005, 2007; Wu et al. 2006; Wang et al. 2005; Cherchi and Navarra 2007; Chen et al. 2012; Hendon et al. 2012; Hu et al. 2012…****);***

- **Few studies have compared the tier 1 and tier 2 systems in a prediction mode (***Kug et al. 2008; Kumar et al. 2008***): Less controlled experiments.**

Model and Experiments

Tier-1 vs. Tier -2: *6-month hindcasts starting from April (1982-2009)*

- **Forecast Model: NCEP CFS version 2**

1) Atmosphere: T126, L64
2) Ocean (MOM4): 0.5°x0.5° (0.25° lat, 10°S-10°N), L40
3) Coupling: every half hour

- **Experiment design (Coupled vs. Uncoupled)**

1) An identical AGCM is used in Tier-1 and Tier-2 predictions
2) **Tier-1**: Coupled run based on CFSv2

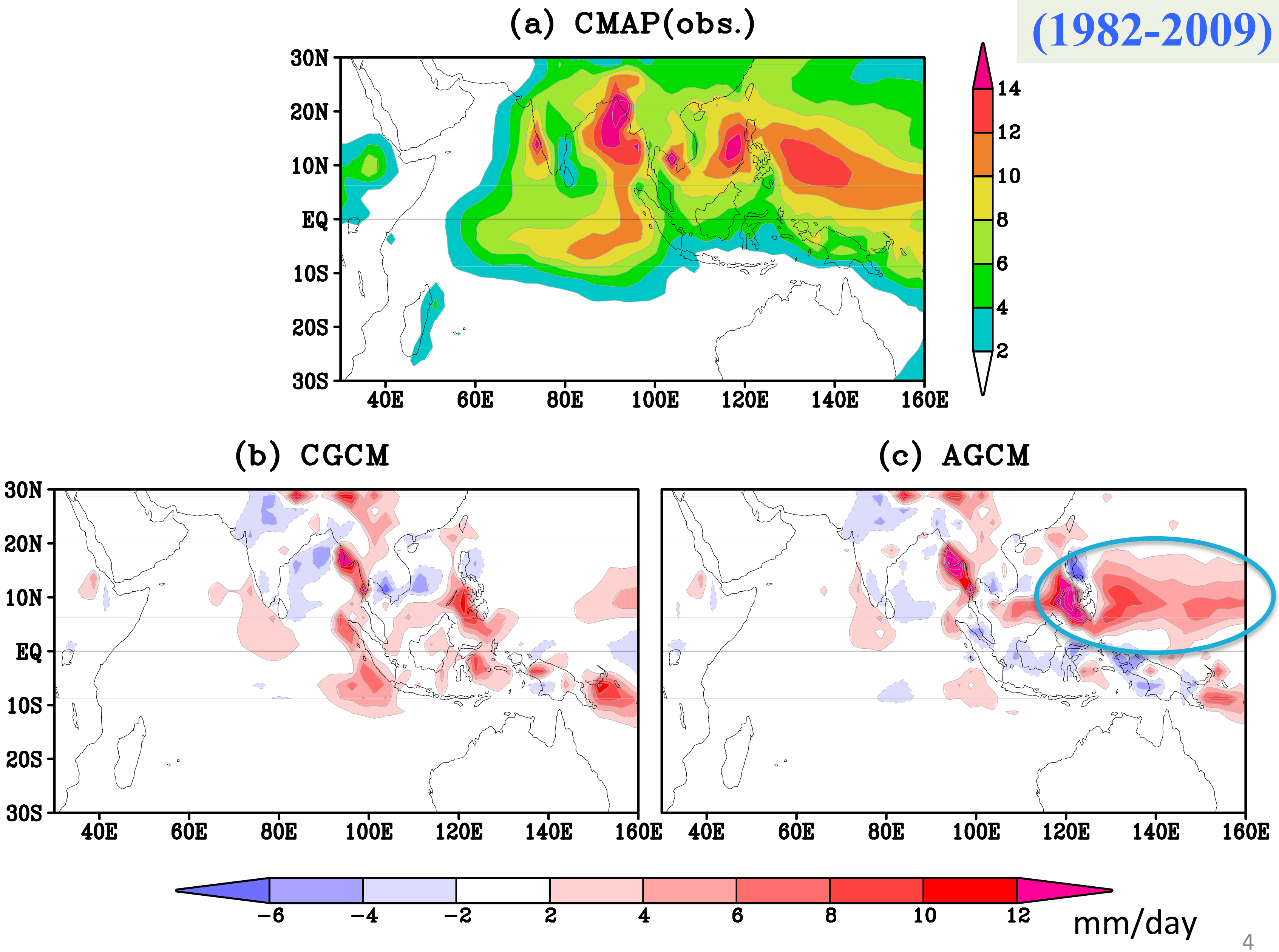
   Tier-2: Daily mean SSTs from Tier-1 are prescribed as boundary conditions

- **Initialization Conditions (1982-2009)**

1) **Tier-1**: Ocean IC: **Instantaneous states from ECMWF ORA-S4**
2) **Tier-1/2**: Atmosphere/Land IC: **CFSR** (4-member, Apr 1-4)

Climatological JJAS Rainfall (Bias)

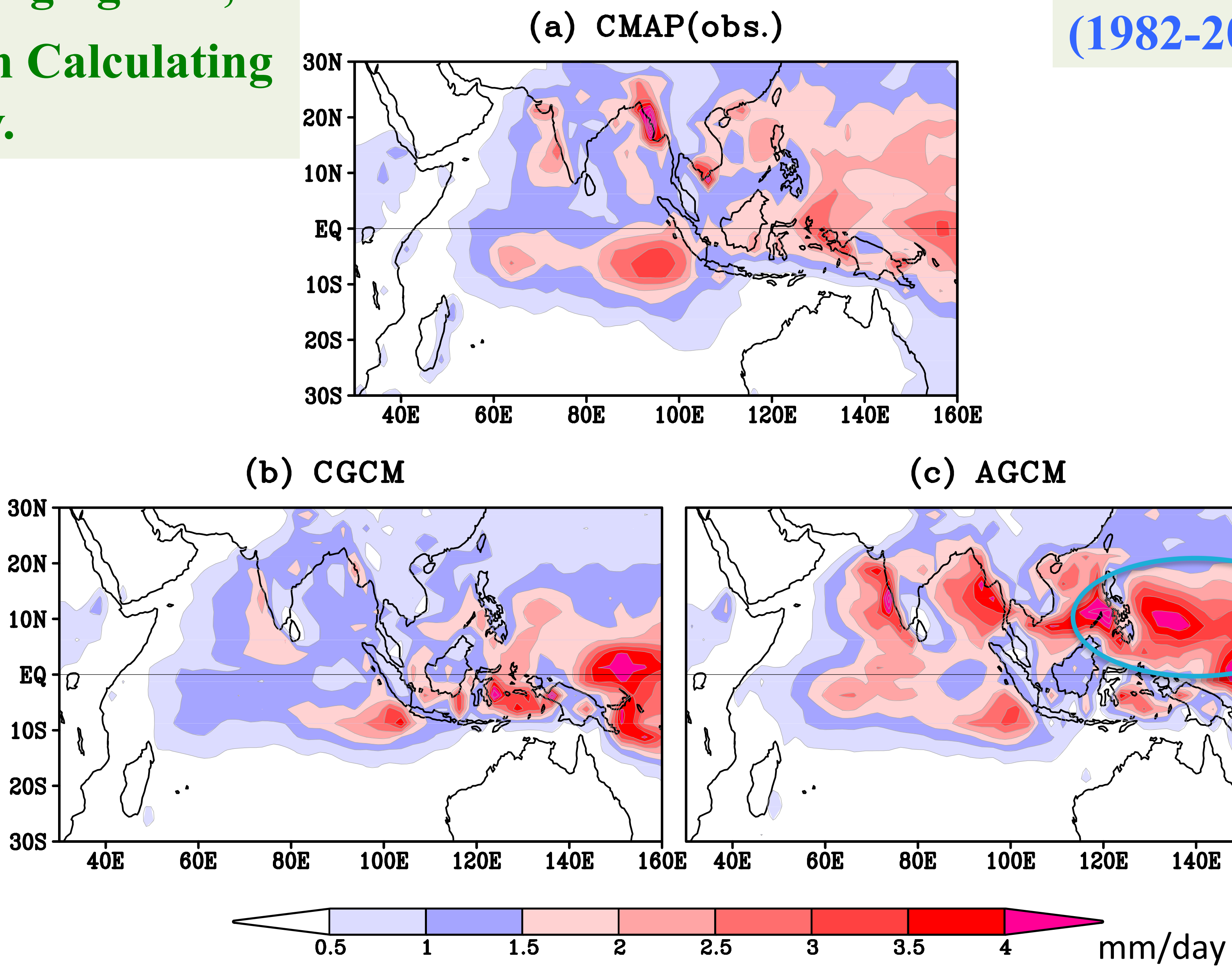
(1982-2009)



Standard Deviation (1)

Averaging first, Then Calculating Sdev.

(1982-2009)

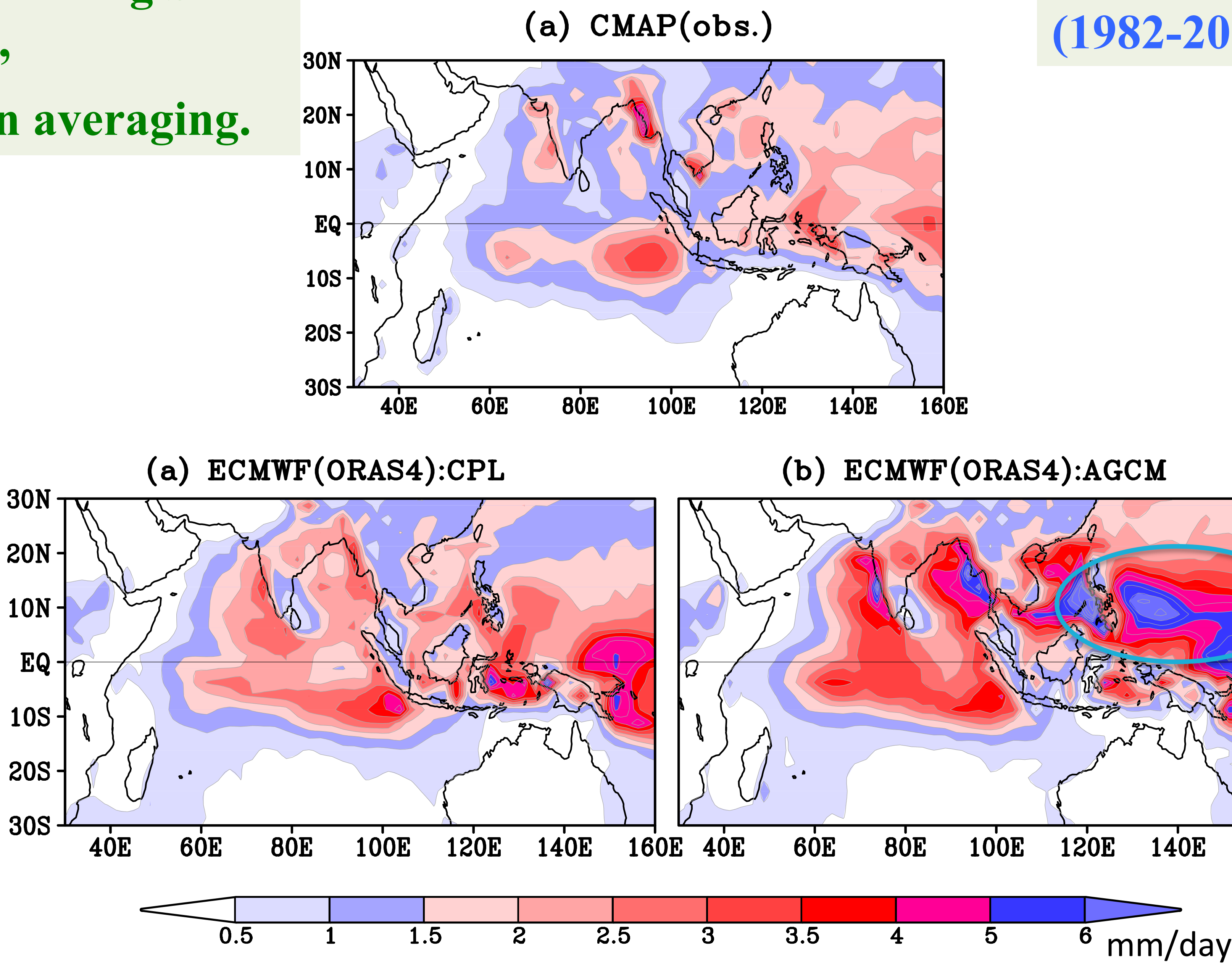


Standard Deviation (2)

Calculating Sdev first,

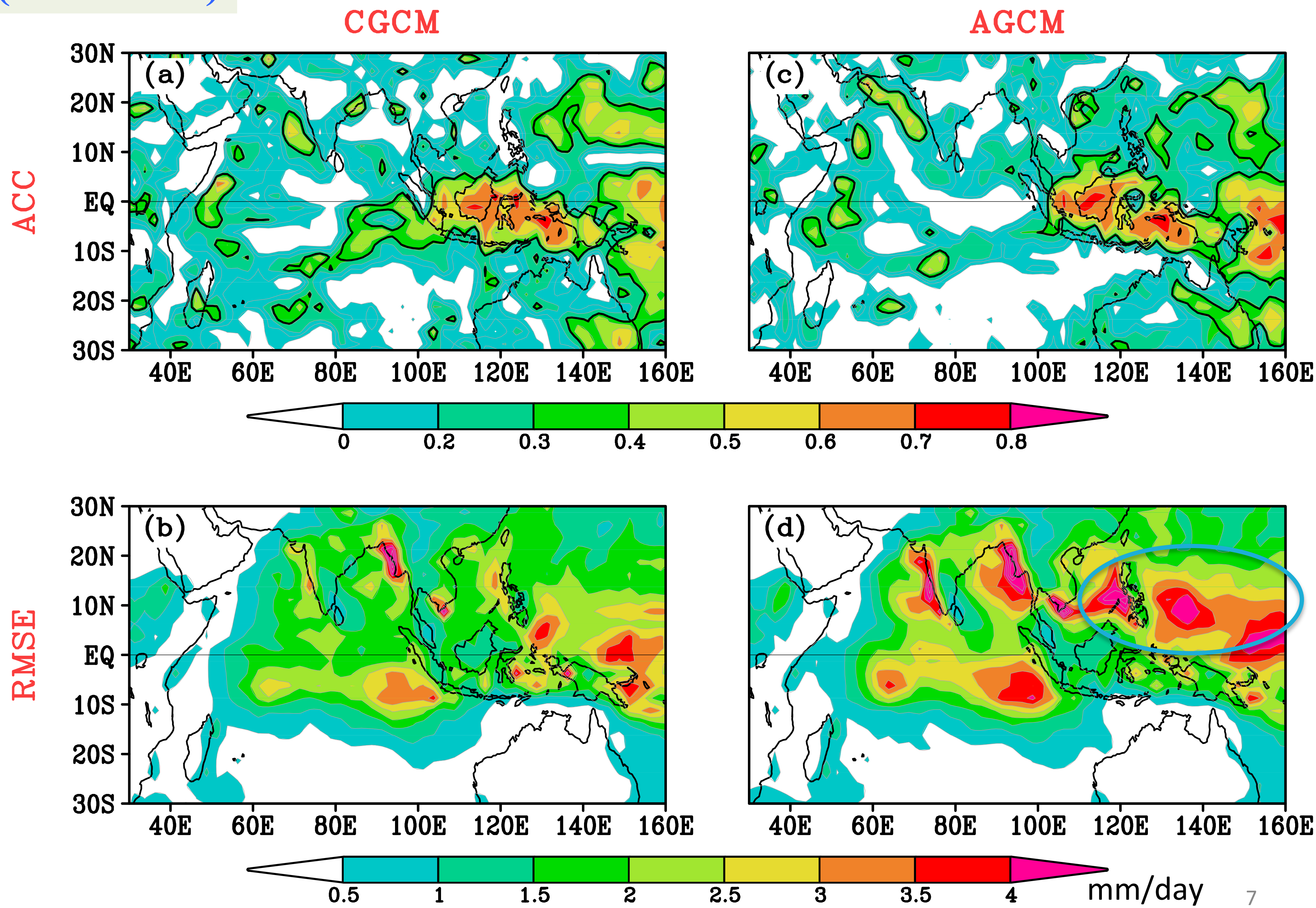
Then averaging.

(1982-2009)

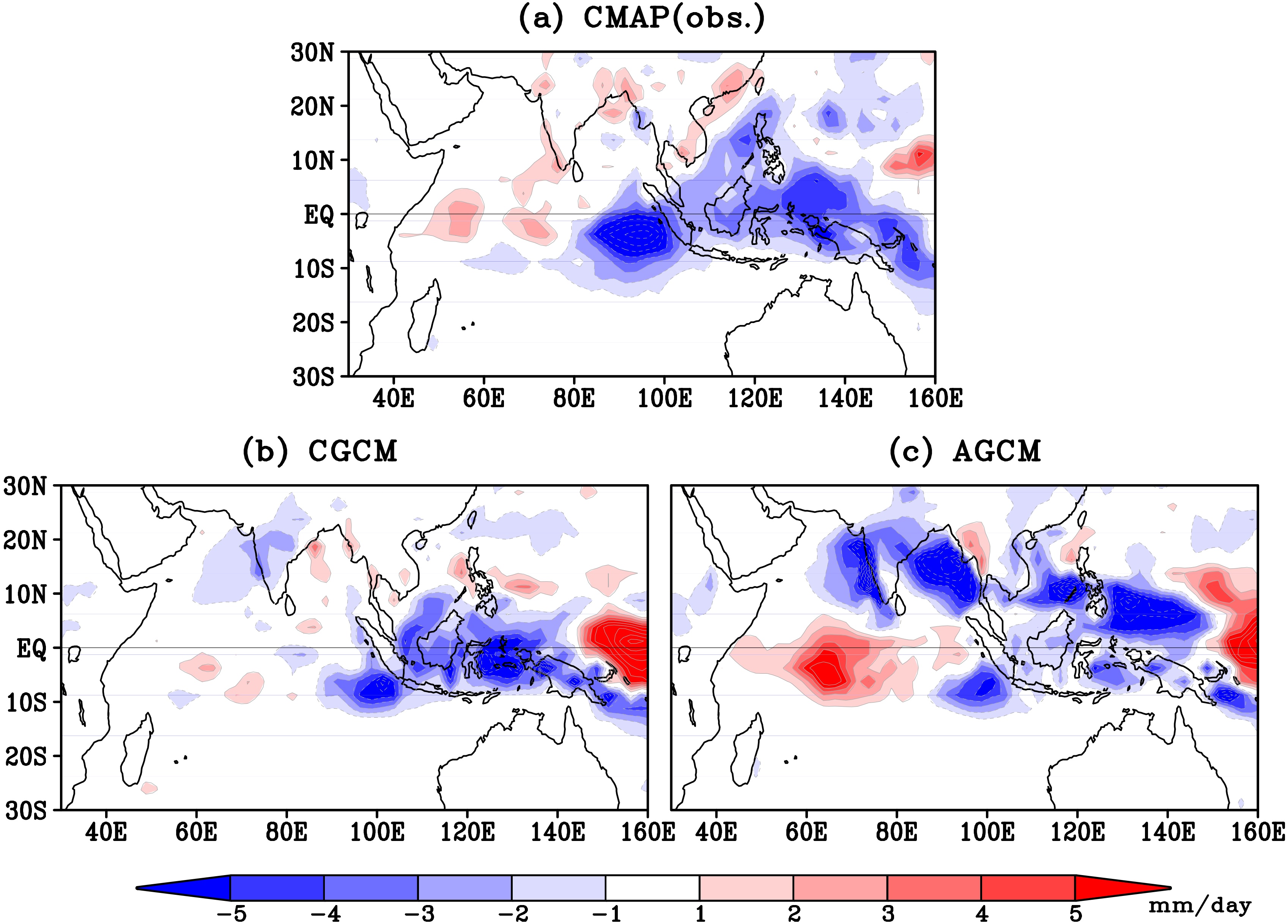


(1982-2009)

Prediction Skill of JJAS Mean Rainfall



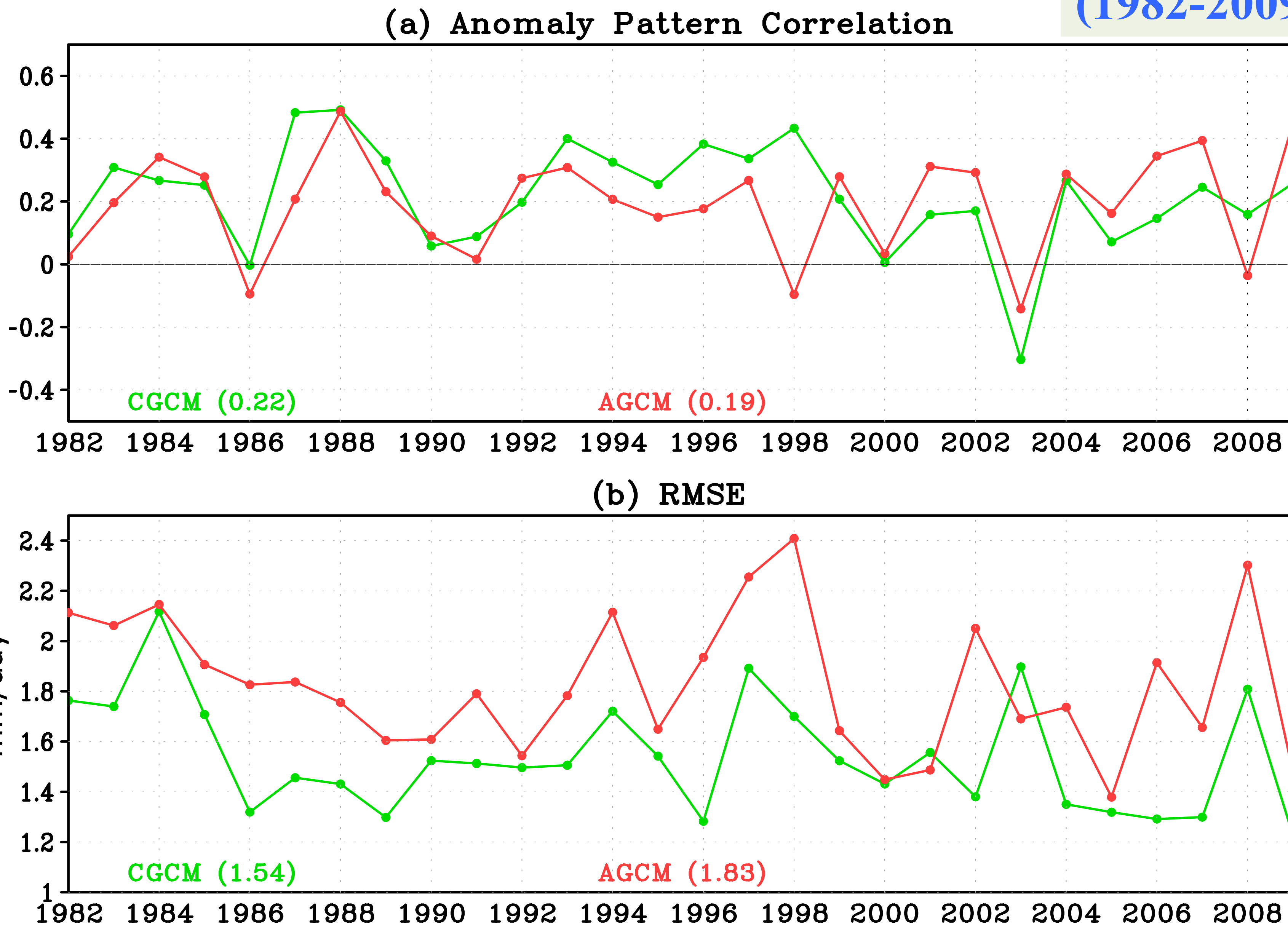
JJAS Rainfall Anomalies in 1997



Skill of JJAS Mean Rainfall Prediction

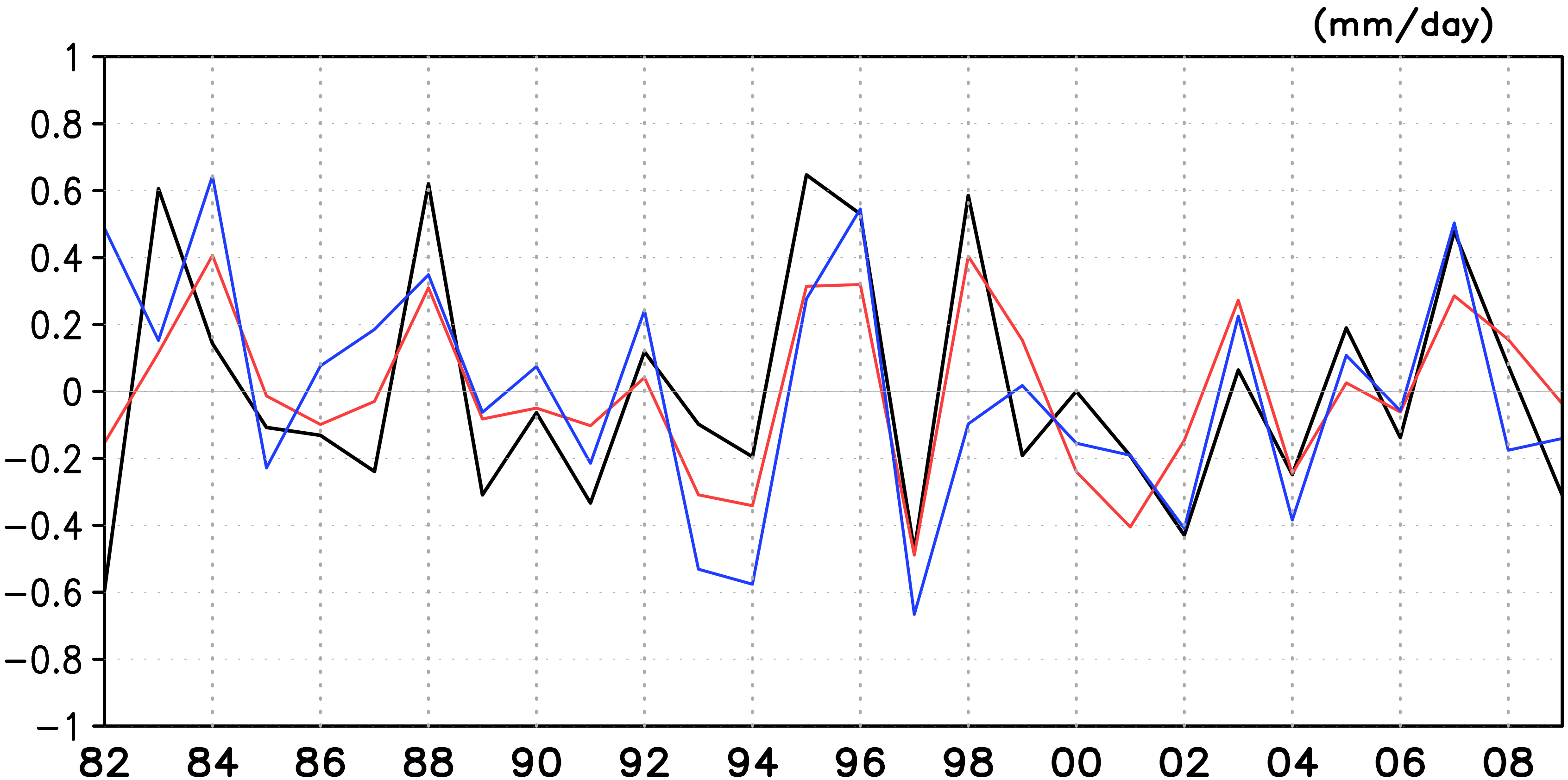
(30E–160E, 30S–30N)

(1982-2009)



Seasonal Forecasts (1Apr IC) with CGCM(CFS) & AGCM(GFS)

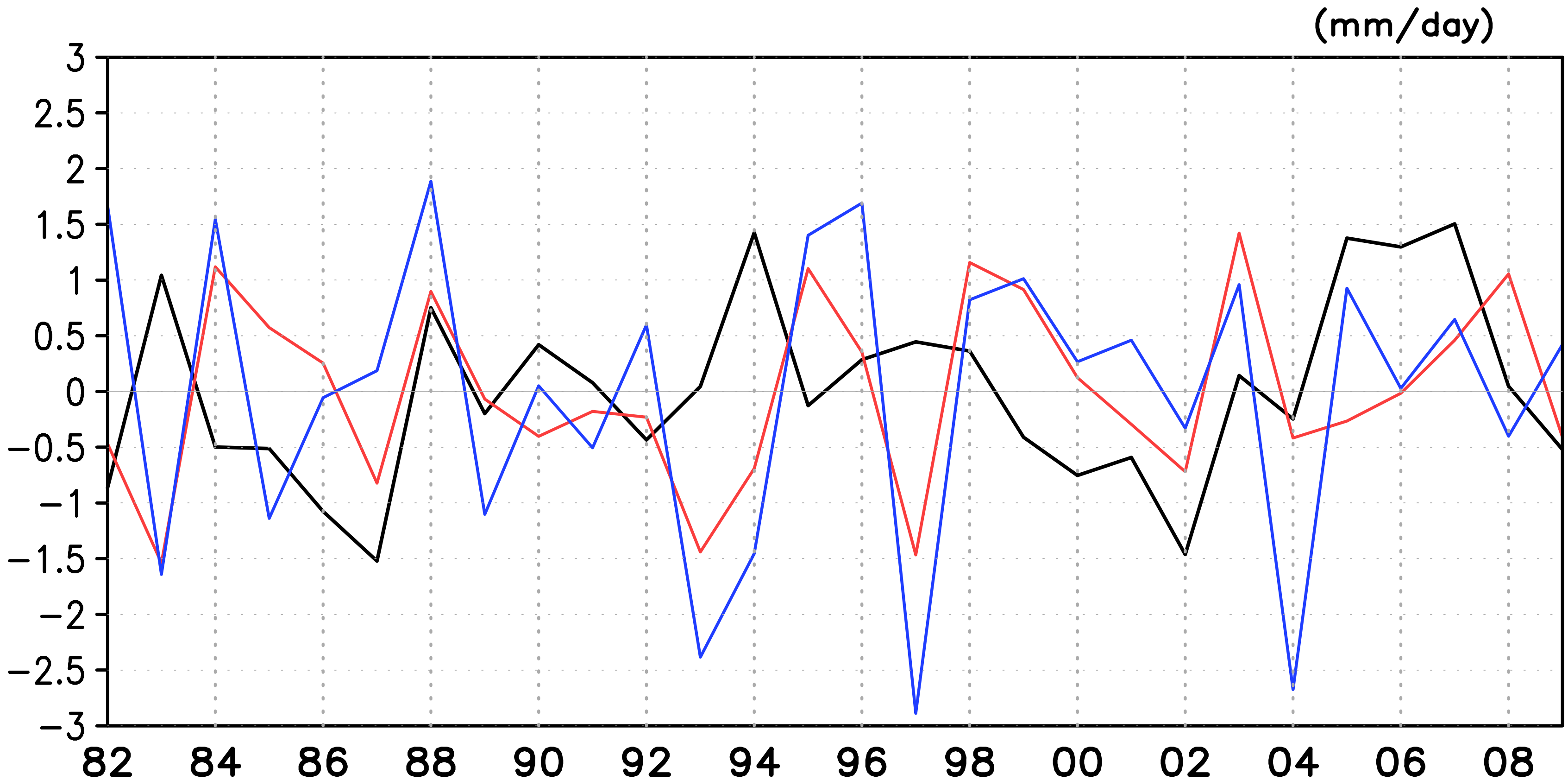
ISMR (40E–120E,10S–35N)



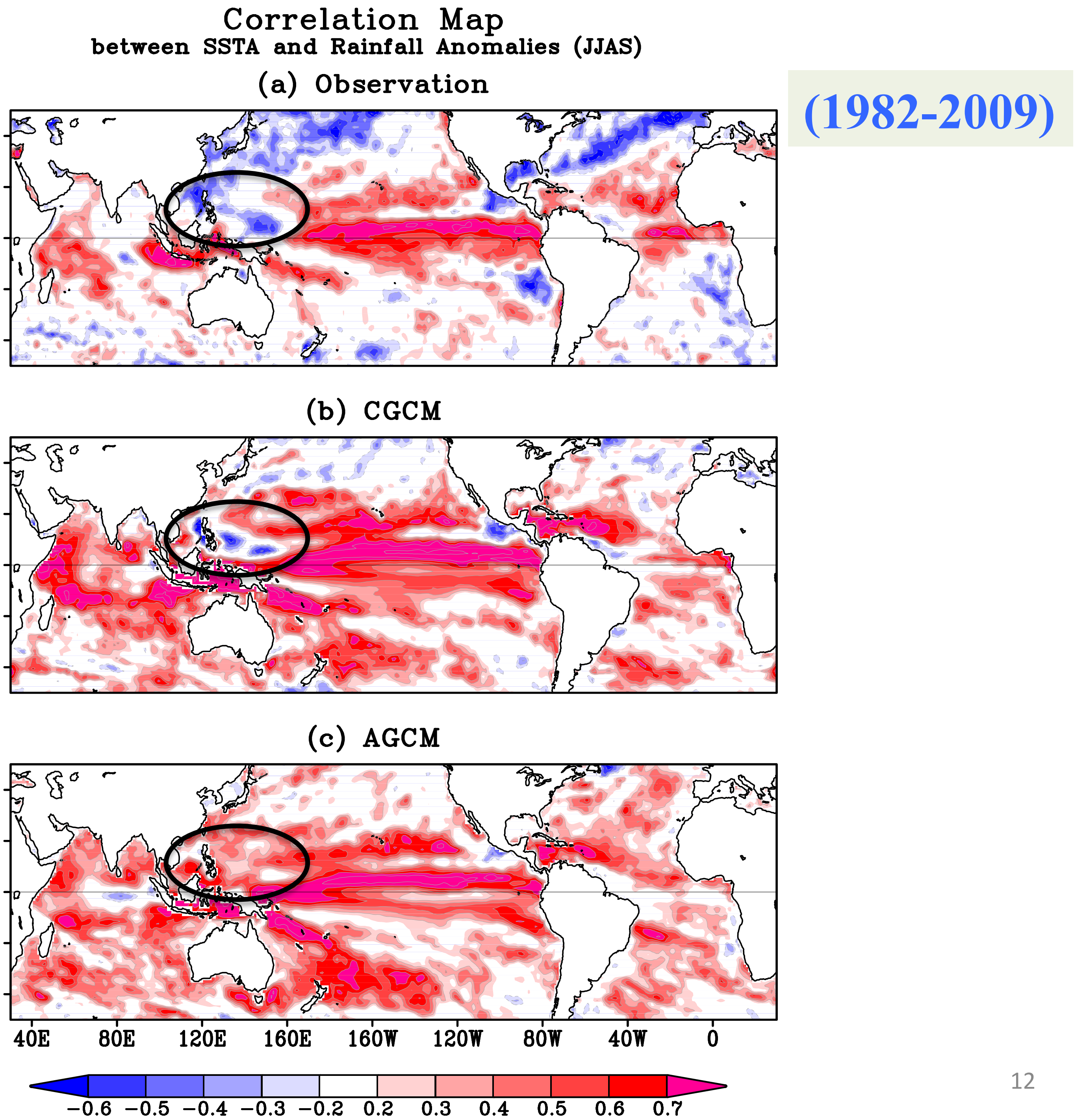
	Observation	CFS(ORA–S4)–Coupled	GFS(ORA–S4)–AGCM
MEAN	5.1	5.6	5.5
StdDev	0.35	0.24	0.34
ACC		0.75	0.51
RMSE		0.23	0.34

Seasonal Forecasts (1Apr IC) with CGCM(CFS) & AGCM(GFS)

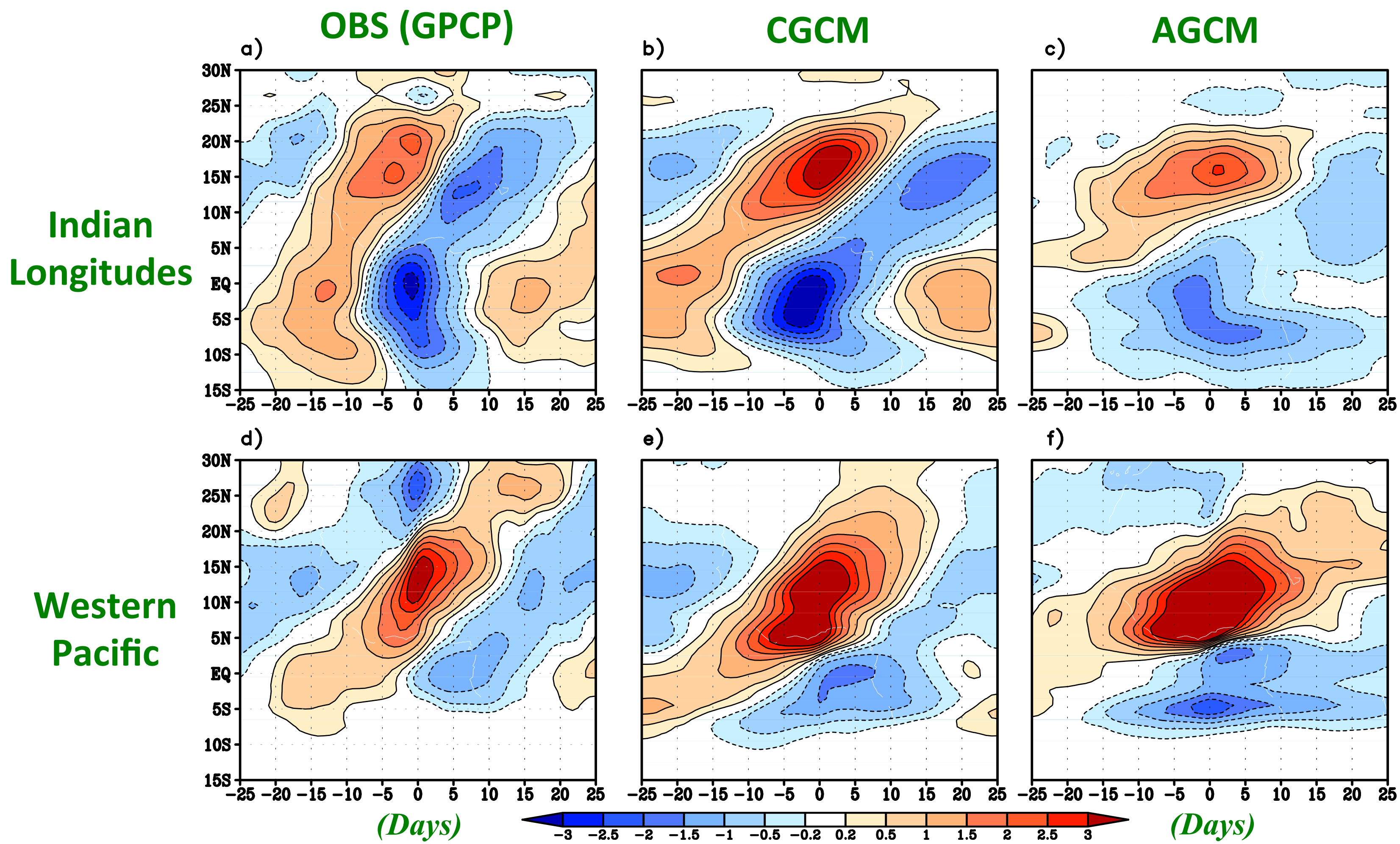
ISMR (70E–90E,10N–25N: Land)



	Observation	CFS(ORA–S4)–Coupled	GFS(ORA–S4)–AGCM
MEAN	7.2	6.3	6.5
StdDev	0.82	0.81	1.30
ACC		−0.01	−0.09
RMSE		1.16	1.60


Correlation Map
between SSTA and Rainfall Anomalies (JJAS)
(a) Observation
(1982-2009)
(b) CGCM
(c) AGCM
40N
20N
EQ
20S
40S
40E
80E
120E
160E
160W
120W
80W
40W
0
−0.6 −0.5 −0.4 −0.3 −0.2 0.2 0.3 0.4 0.5 0.6 0.7

The effect of coupling on boreal summer intraseasonal oscillations (BSISO)



Shukla, R. and J. Zhu*, 2013: Simulations of boreal summer intraseasonal oscillations with CFSv2 over India and western Pacific: Role of air-sea coupling***. To be submitted to GRL.***

Summary

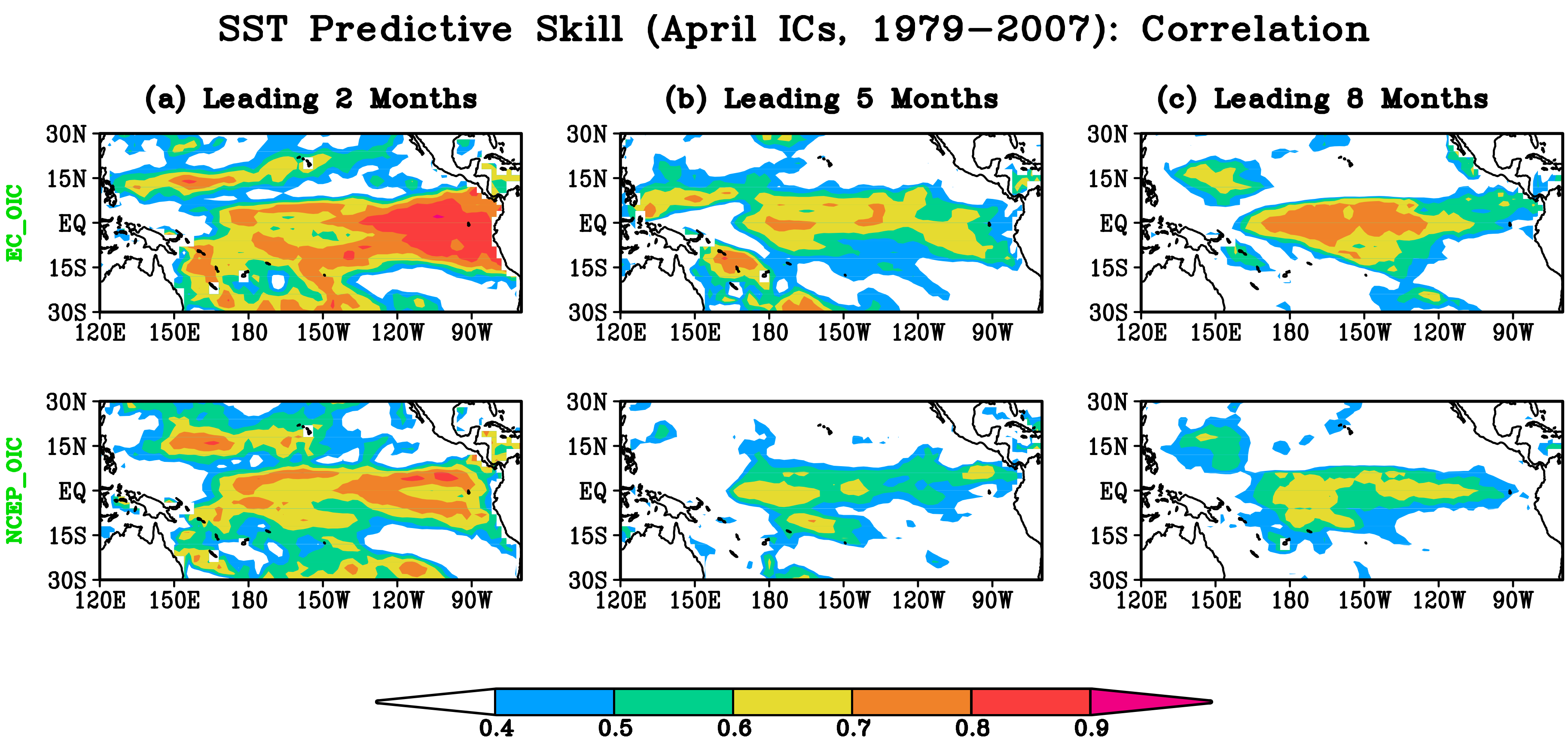
1) In the absence of air–sea coupling, Tier-2 predictions produce **higher rainfall biases** and **unrealistically high** rainfall interannual variations;

2) The prediction skill, as measured by anomaly correlation, does not show significant differences between the two types of predictions, but **RMSEs are significantly larger** for the AGCM (Tier-2) predictions compared to the CGCM (Tier-1) predictions;

3) The reduced RMSE skills in the Tier-2 predictions are due to the lack of a coupling process in AGCM-alone simulations, which, particularly, results in **an unrealistic SST-rainfall relationship** over the TWNP region;

4) Coupling also improves **BSISO** simulations.

Suggesting that coupled ocean–atmosphere models are the more promising tools for operational prediction over the Asia–Pacific region.



Zhu et al. (GRL, 2012)

Climatological JJAS Rainfall (Bias)