Challenges in Prediction of Summer Monsoon Rainfall: Inadequacy of the Tier-2 Strategy

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SCIENTIFIC BASIS for climate prediction

The climate predictability is determined by variations of the ocean and land surface conditions. (Charney and Shukla 1981, Shukla 1998, Shukla et al. 2000).

Two –tier climate prediction system

Bengtsson, L., U. Schlese, E. Roeckner, M. Latif, T. Barnett, and N. Graham, 1993: A two-tiered approach to long-range climate forecasting. *Science*, 261, 1026-1029.

Under the influence of slowly varying boundary forcing, the atmospheric model should be able to capture the predictable portion of tropical rainfall.

Poor simulation of Indian monsoon rainfall
(Sperber and Palmer 1996
Gadgil and Sajani 1998)

Wang, Kang, Lee 2004, J. Climate

Conclusion:

The state-of-the-art atmospheric general circulation models (AGCMs), when forced by observed sea surface temperature (SST), are unable to simulate with any accuracy Asian-Pacific summer monsoon rainfall.

CLIVAR/international monsoon panel AGCM intercomparison

AMIP type ensemble simulation

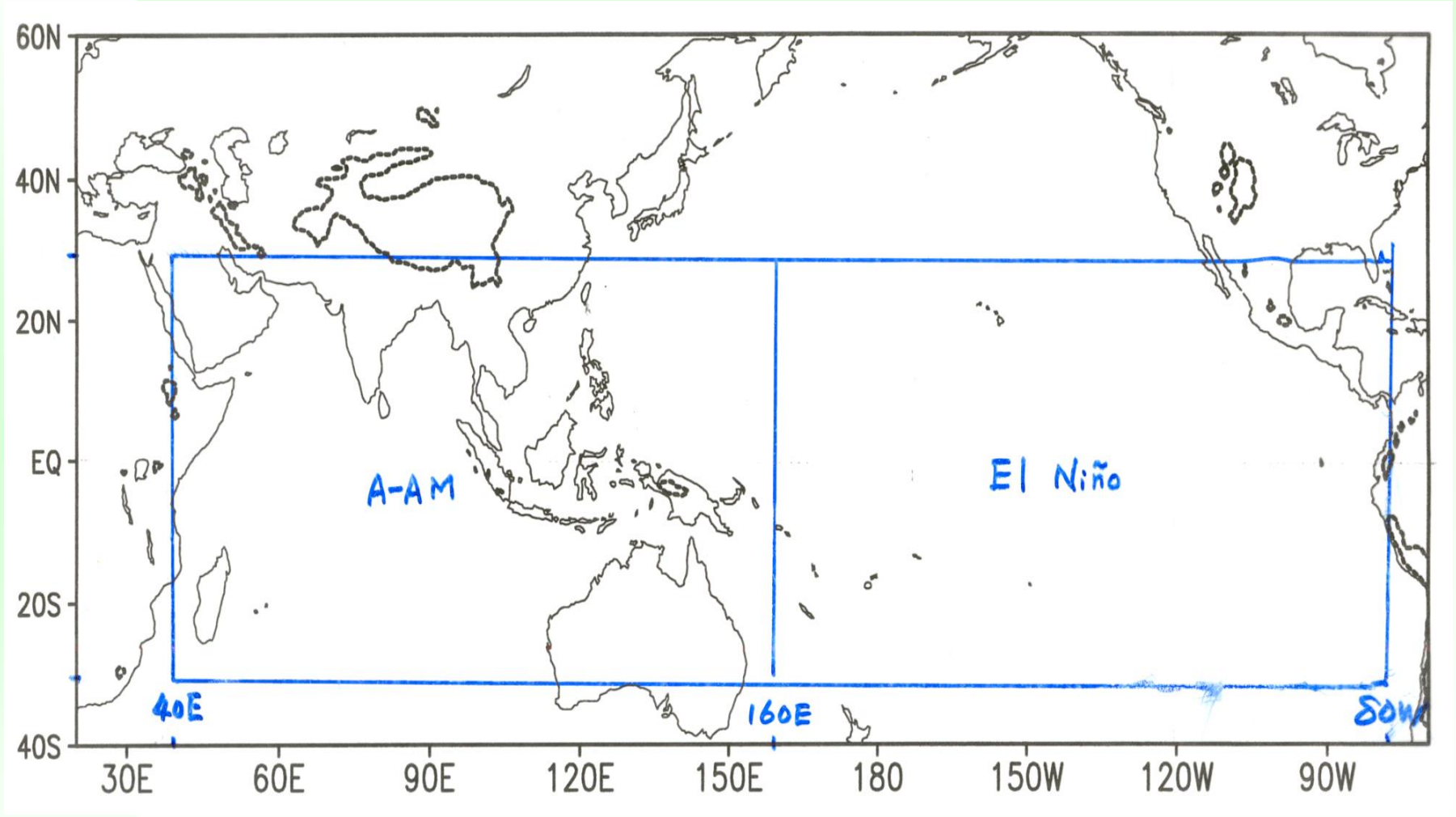
Observed SST

Observed SST and sea ice as LB forcing

11 AGCMs

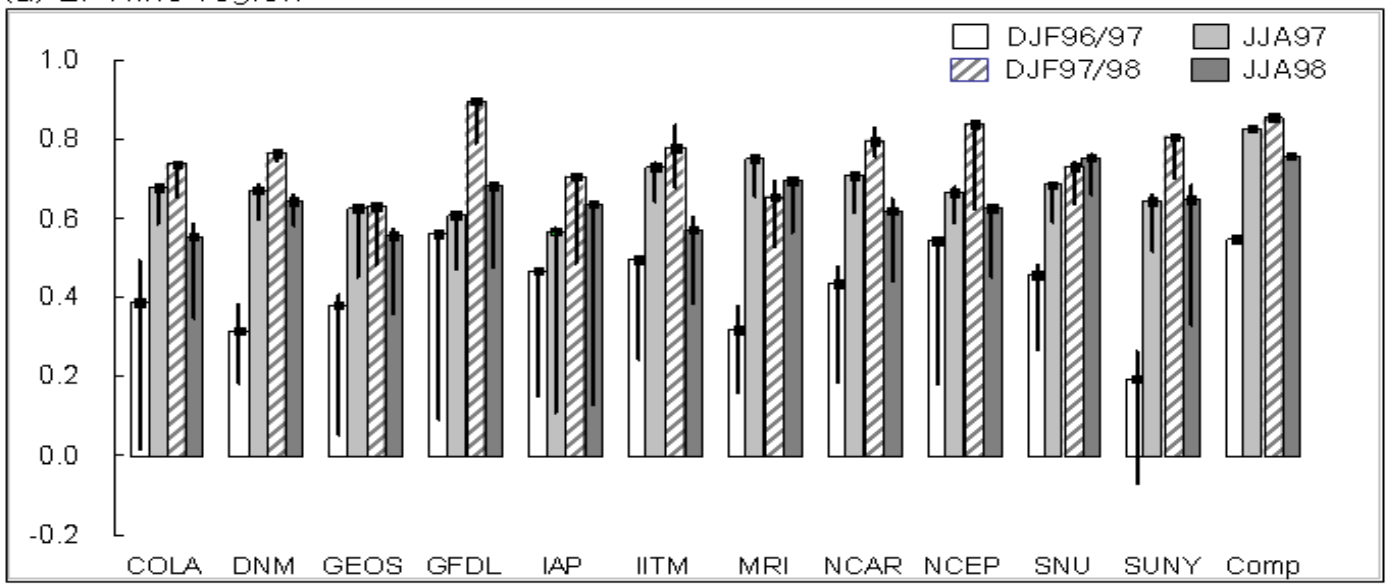
10-member ensemble

2-year period (9/1996-8/1998)

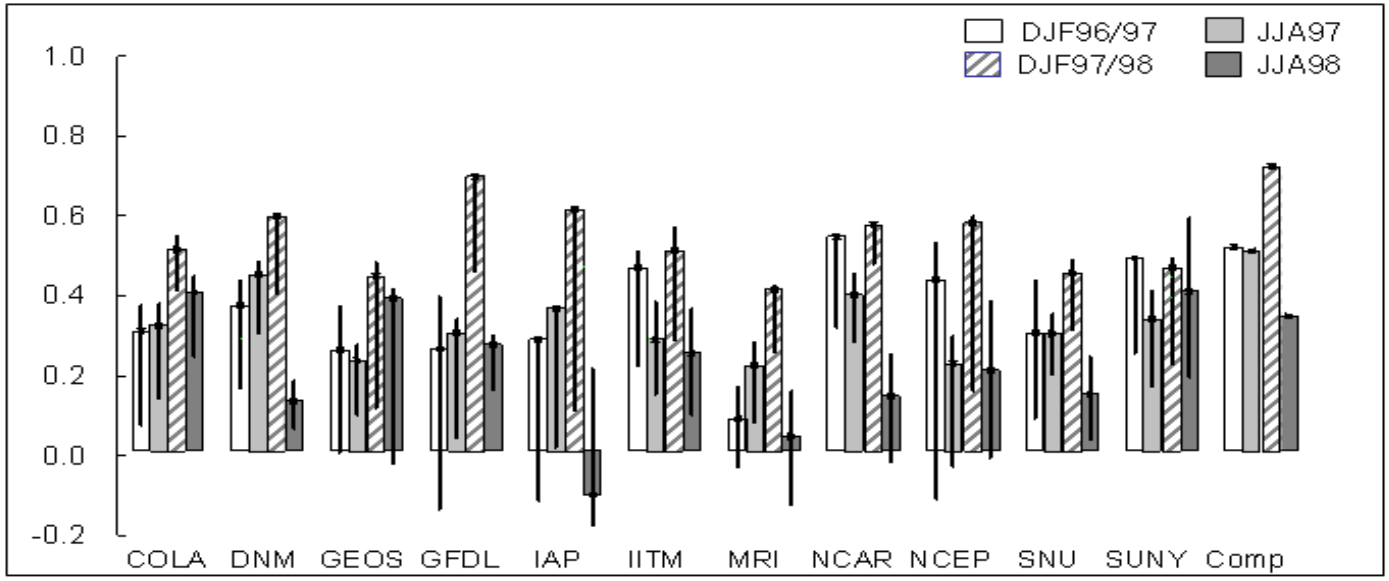

60N
40N
20N
EQ
20S
40S
30E
60E
90E
120E
150E
180
150W
120W
90W
A-AM
El Niño
40E
160E

Pattern Correlation Coefficients

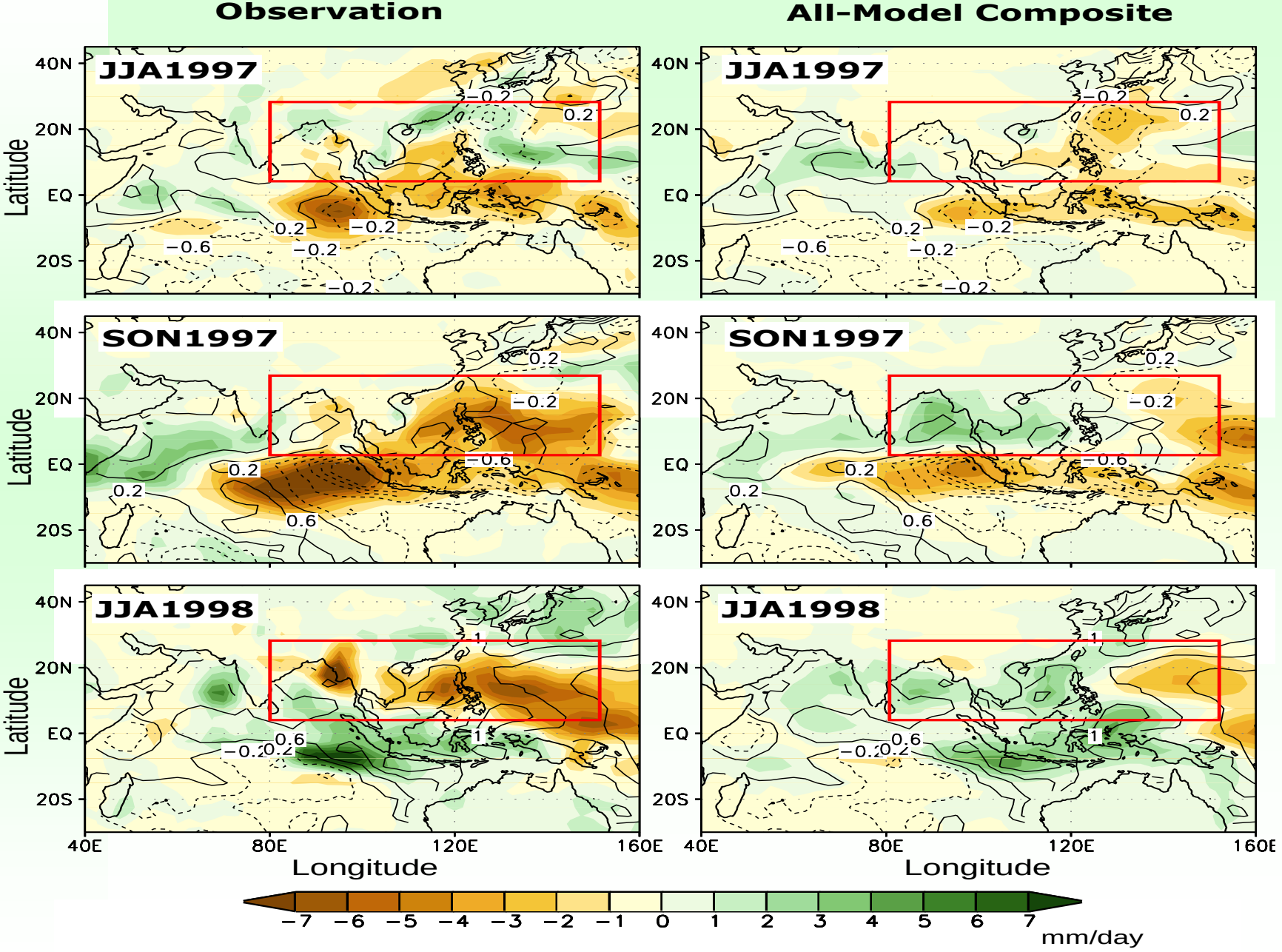
(a) El-Nino region



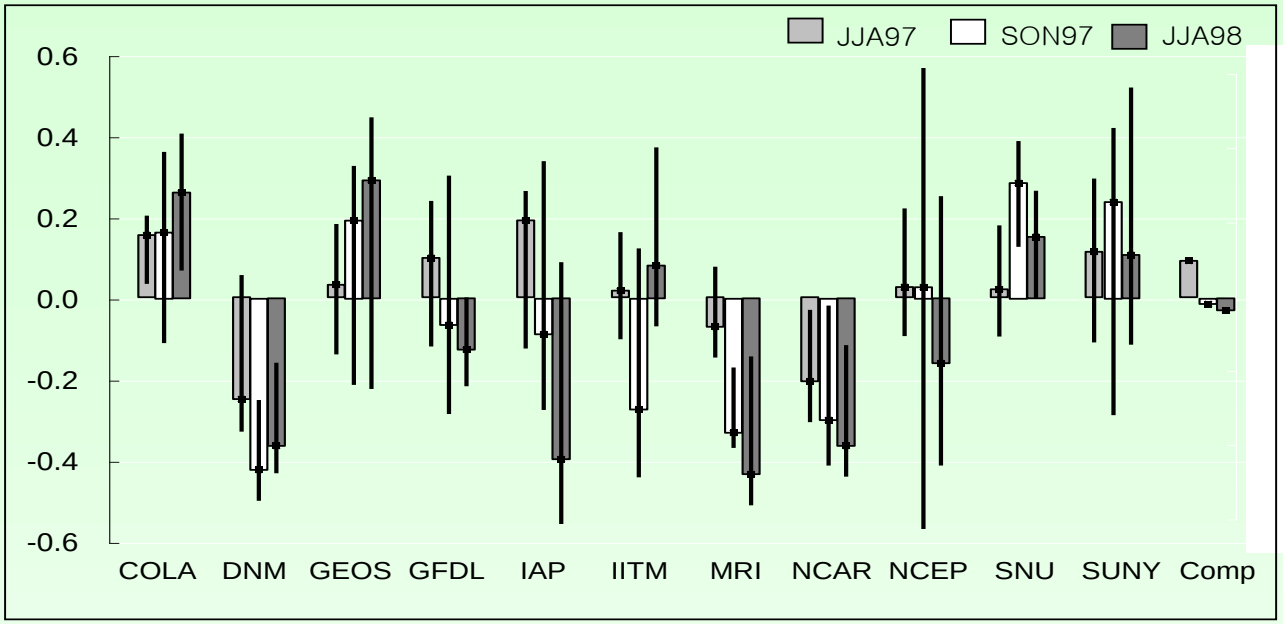
(b) Monsoon region



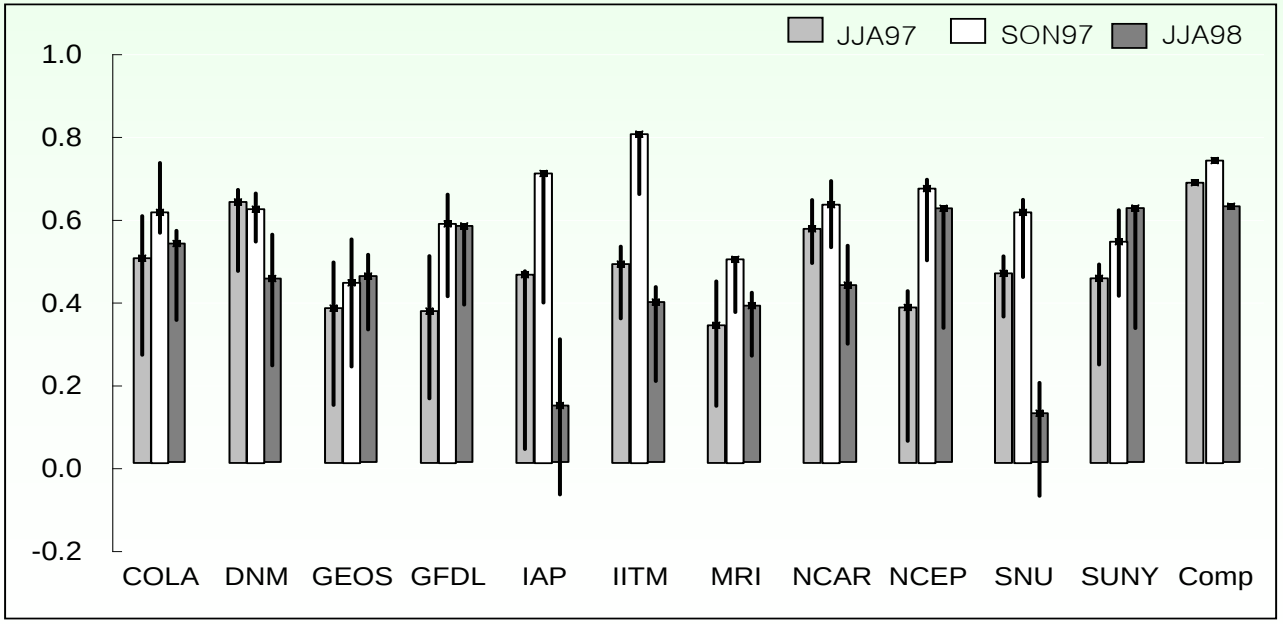
Precipitation (shading) and SST (contour)



(a) Southeast Asian and WNP region



(b) The rest of the A-AM domain



A question of fundamental importance to climate simulation and prediction:

Why are all AGCMs, when given the observed lower-boundary forcing, unable to simulate summer monsoon precipitation anomalies? Even with the extremely strong 1997/98 forcing!

Bad model climatology?
Bad tropical teleconnection?
Bad model physics?
Or something else!

Correlation coefficients between the local SST and precipitation anomalies that are observed (CMAP) or derived from the all-model comp (Comp) and from each model ensemble means. The computation was carried out for JJA97, SON97, and JJA98 and the three seasons as a whole using monthly mean data.

	CMAP OBS	Comp	COLA	DNM	GEOS	GFDL	IAP	IITM	MRI	NCAR	NCEP	SNU	SUNY
JJA 97	-0.15	0.59	0.42	0.49	0.38	0.19	0.02	0.15	0.49	0.43	0.39	0.36	0.33
SON 97	-0.33	0.71	0.59	0.7	0.5	0.35	0.45	0.49	0.44	0.66	0.37	0.34	0.37
JJA 98	-0.45	0.56	0.19	0.77	0.24	0.52	0.59	0.44	0.5	0.51	0.57	-0.12	0.38
TO-TAL	-0.35	0.58	0.33	0.65	0.32	0.42	0.42	0.37	0.47	0.51	0.47	0.04	0.35

A major finding

All models tend to yield positive SST-rainfall correlations in the summer monsoon that are at odds with observations.

HYPOTHESIS

Treating monsoon as a slave to prescribed SST results in the models' failaure.

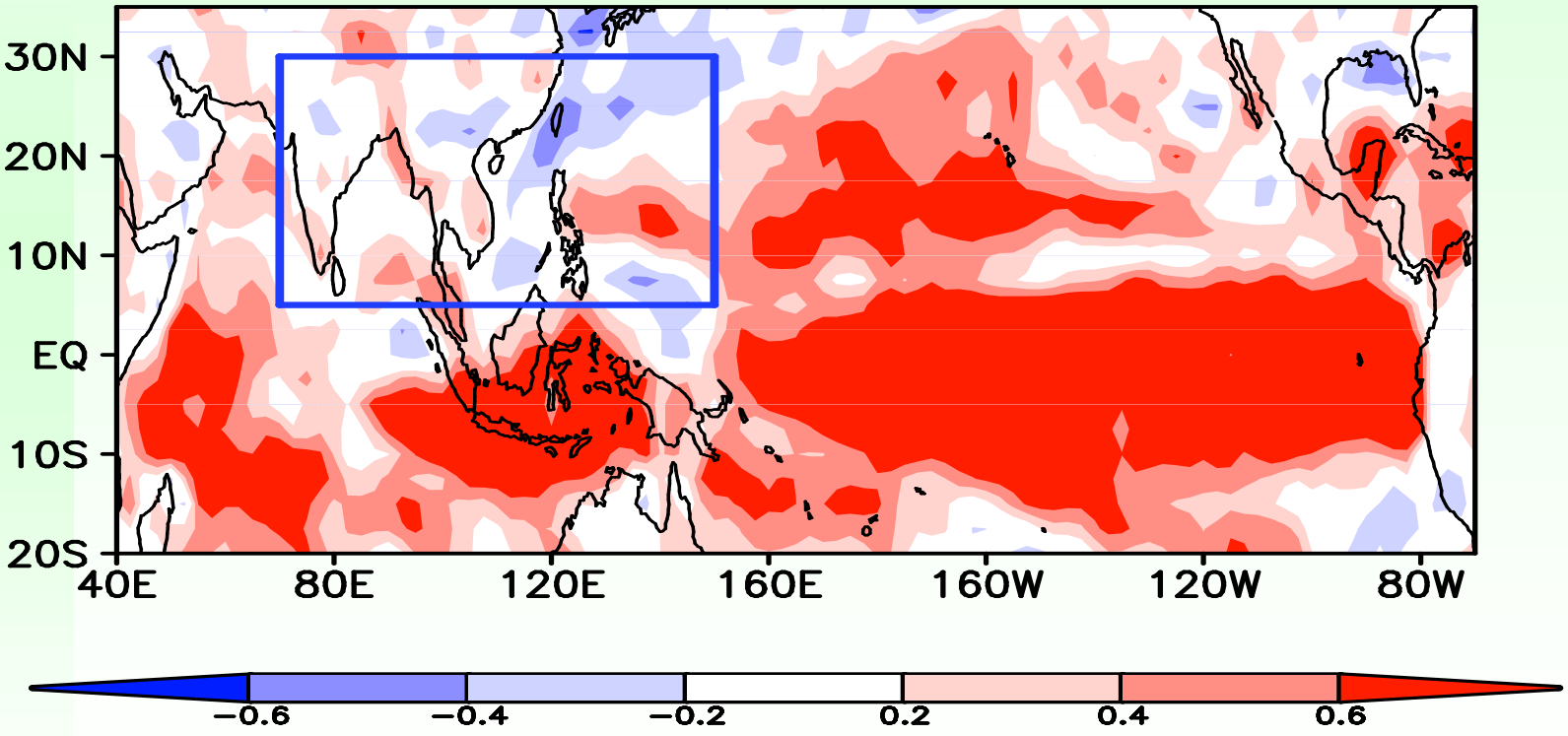
Or strategy is fundamentally wrong.

How well are the Asian summer monsoon rainfall hindcasted in the MME prediction?

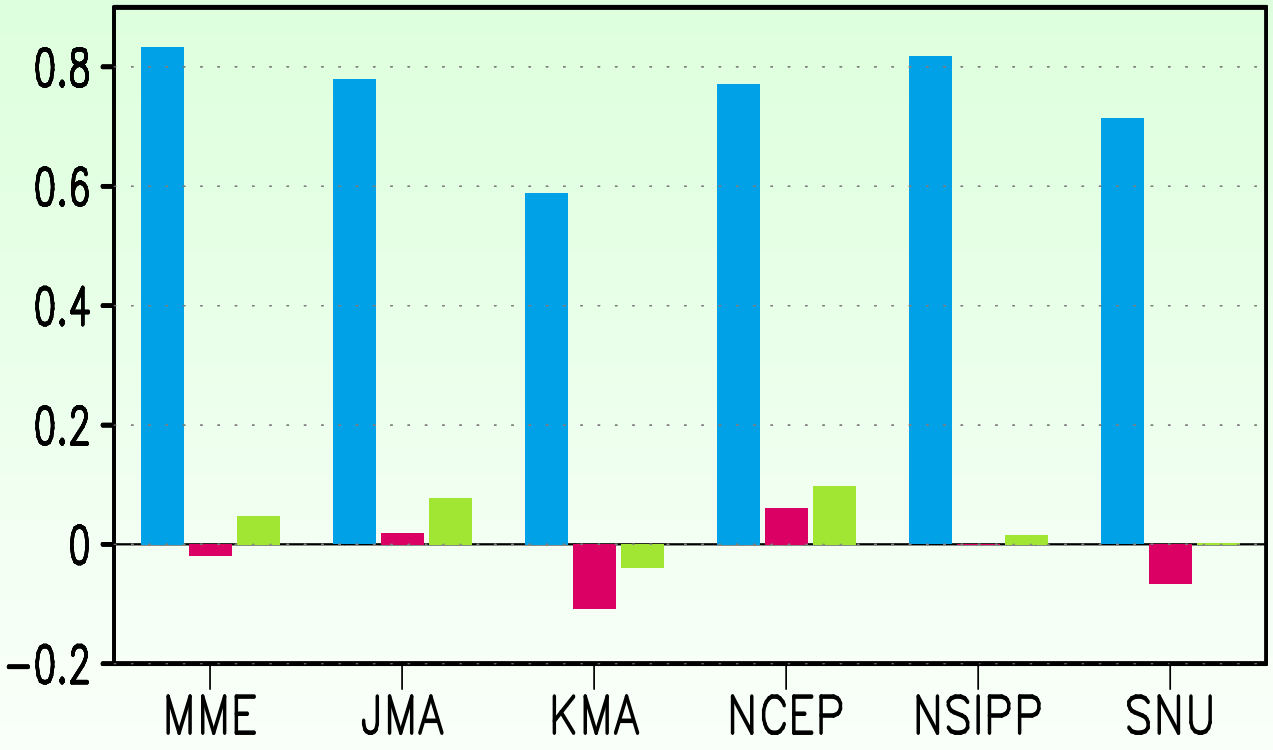
APCN 5 participating models:
NCEP, NSIPP, JMA, KMA, SNU
MME: Multi-Model Ensemble

AMIP type ensemble hindcast
6 to 10-member ensemble
21-year period (1979-2001)

Correlation Coefficients between the observed and MME hindcasted June-August precipitations (1979-1999)



Area averaged correlation coefficient skills



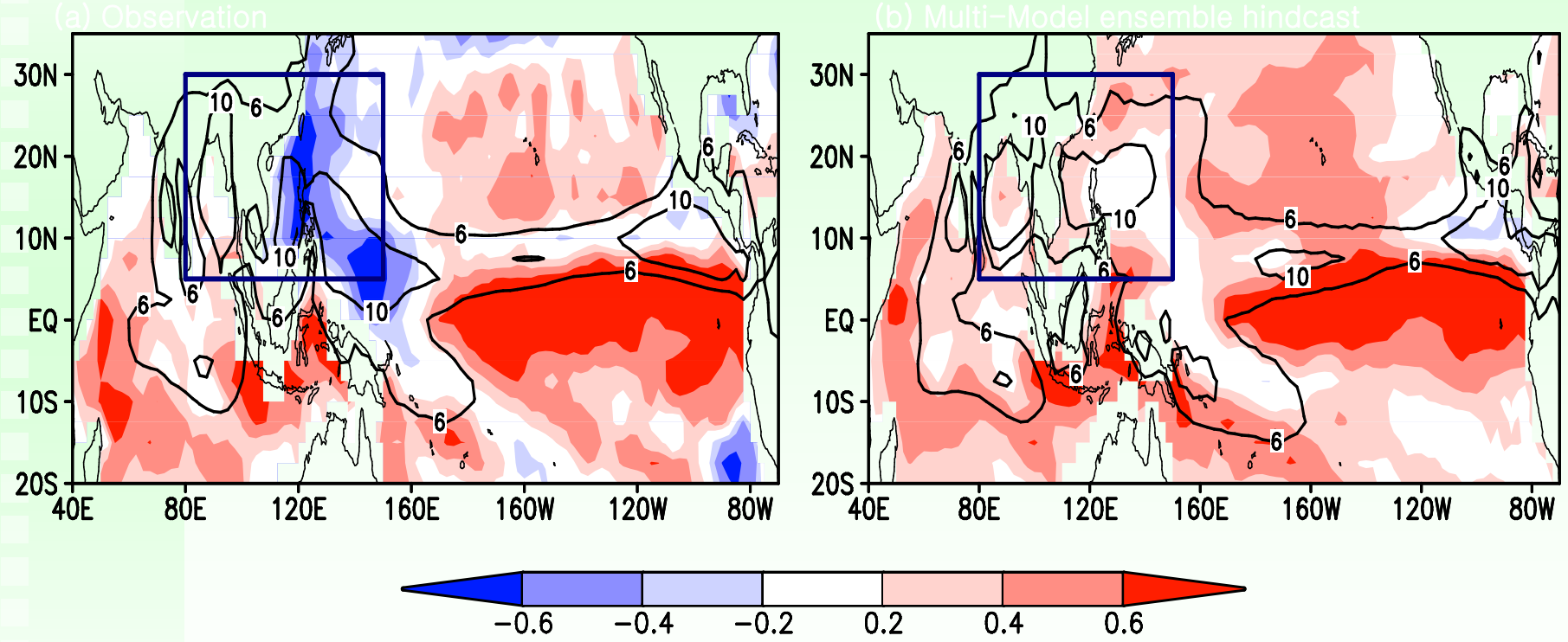
El Nino region (10°S-5°N, 80°W-180°W)

WNP (5-30°N, 110-150°E)

Asian-Pacific MNS (5-30°N, 70-150°E)

Obs. SST-Rainfall Correlation

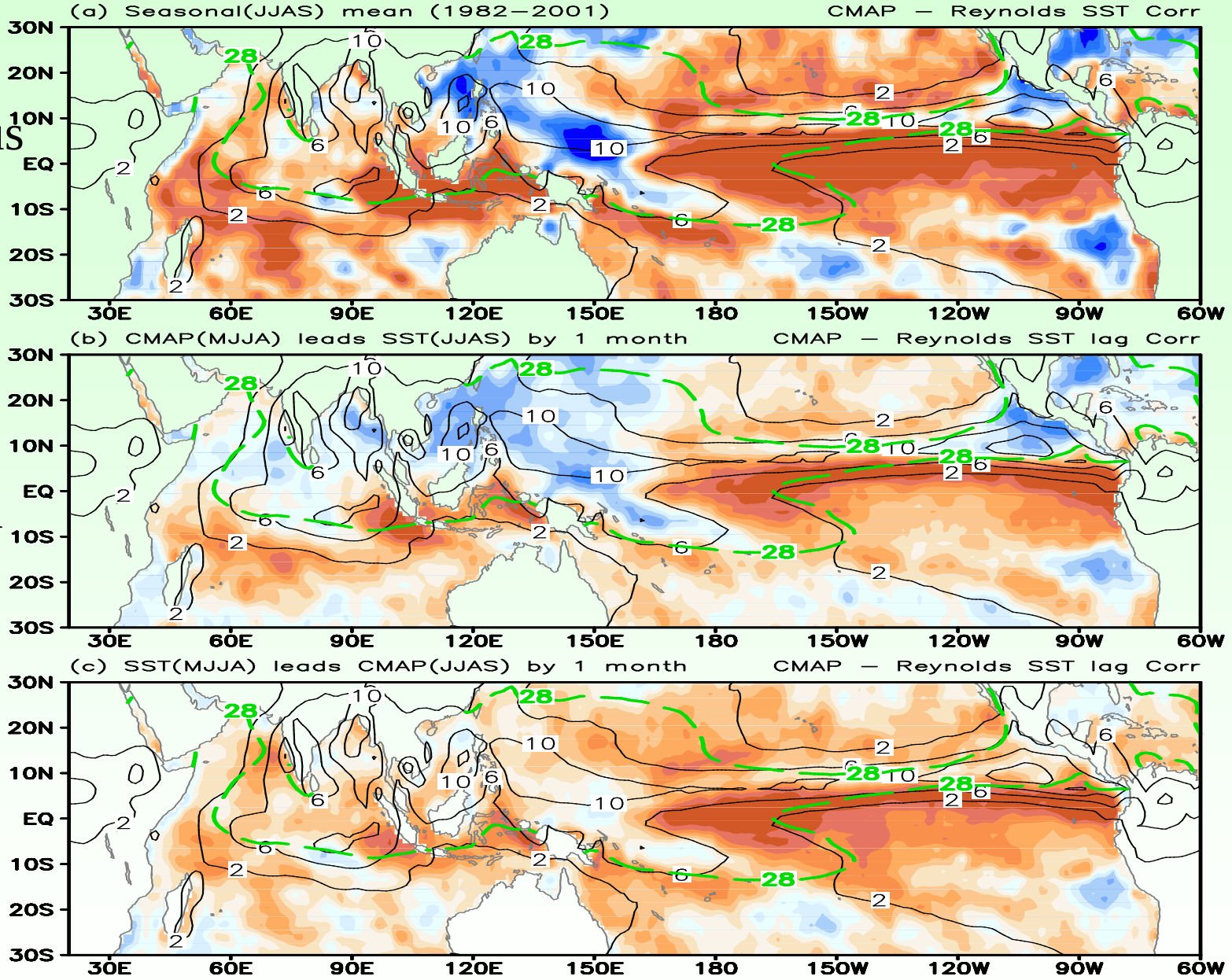
MME SST-Rainfall correlation



Simultatious

Rainfall Leads SST by 1-month

SST leads Rainfall by 1-month



Observed

Coupled model Experiments

IPRC Hybrid Coupled Atmosphere-Ocean Model

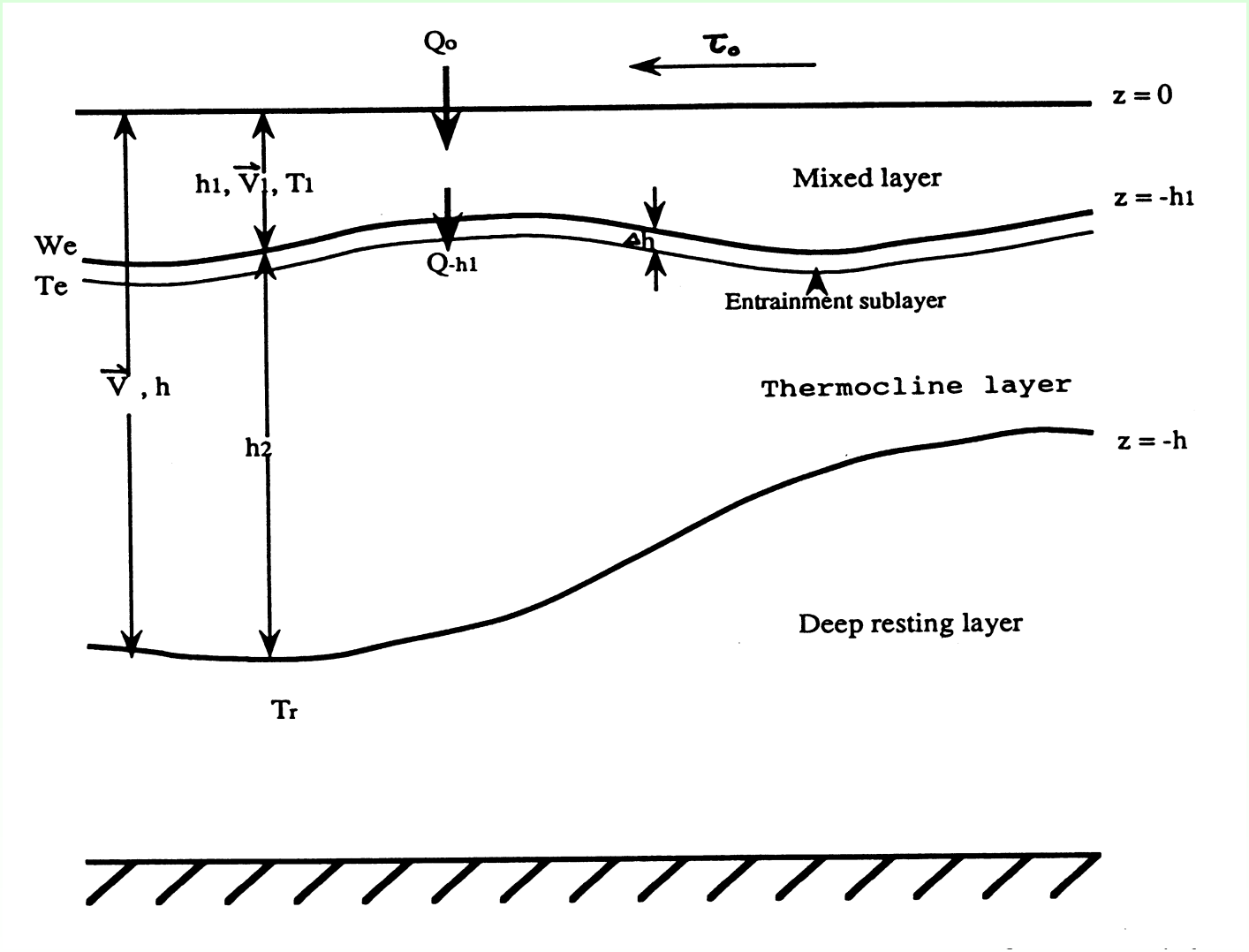
Atmosphere: ECHAM4 T30 AGCM

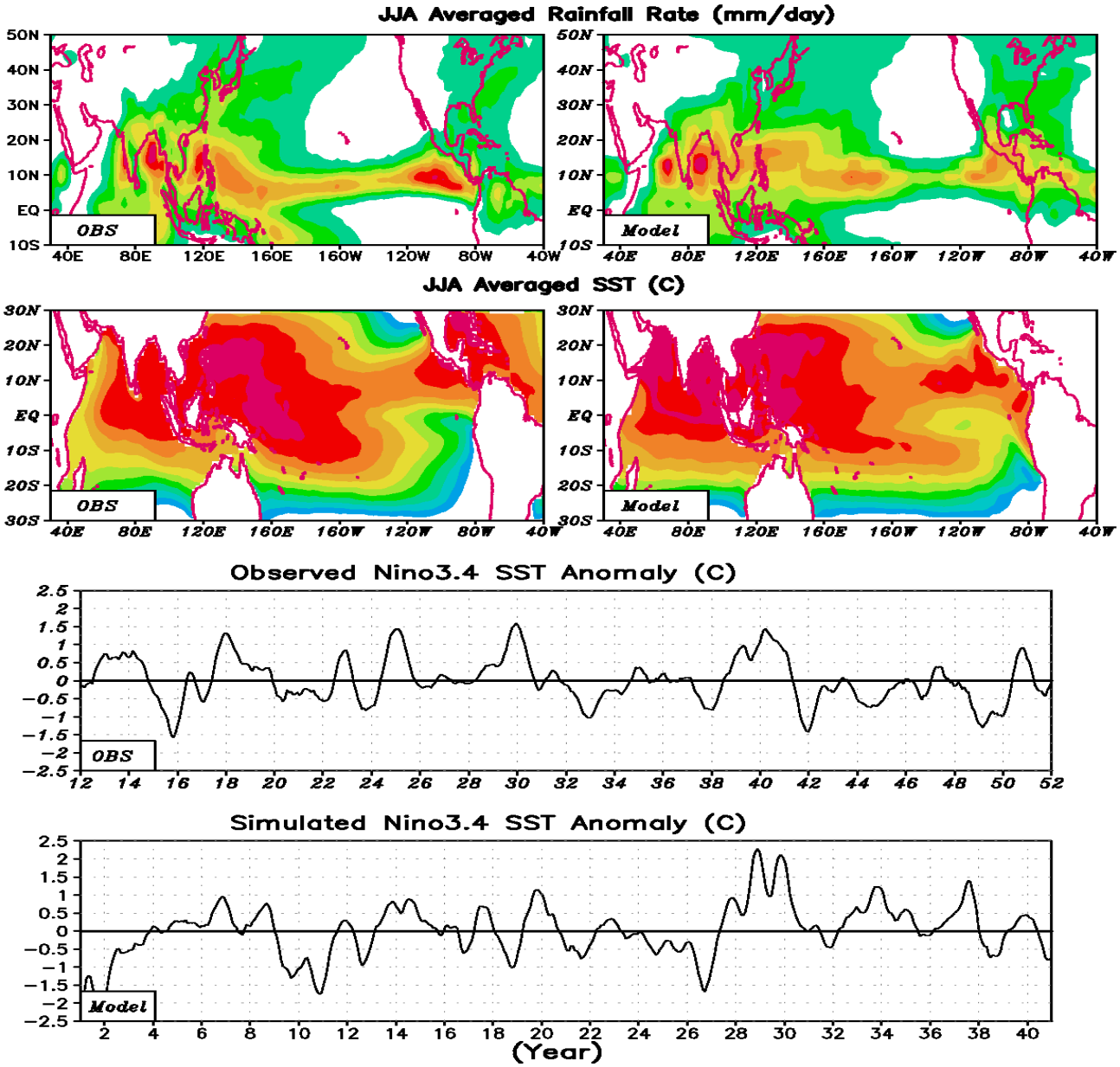
Ocean:WLF intermediate ocean model (0.5x0.5)
(Wang et al. 95, Fu and Wang 2001)

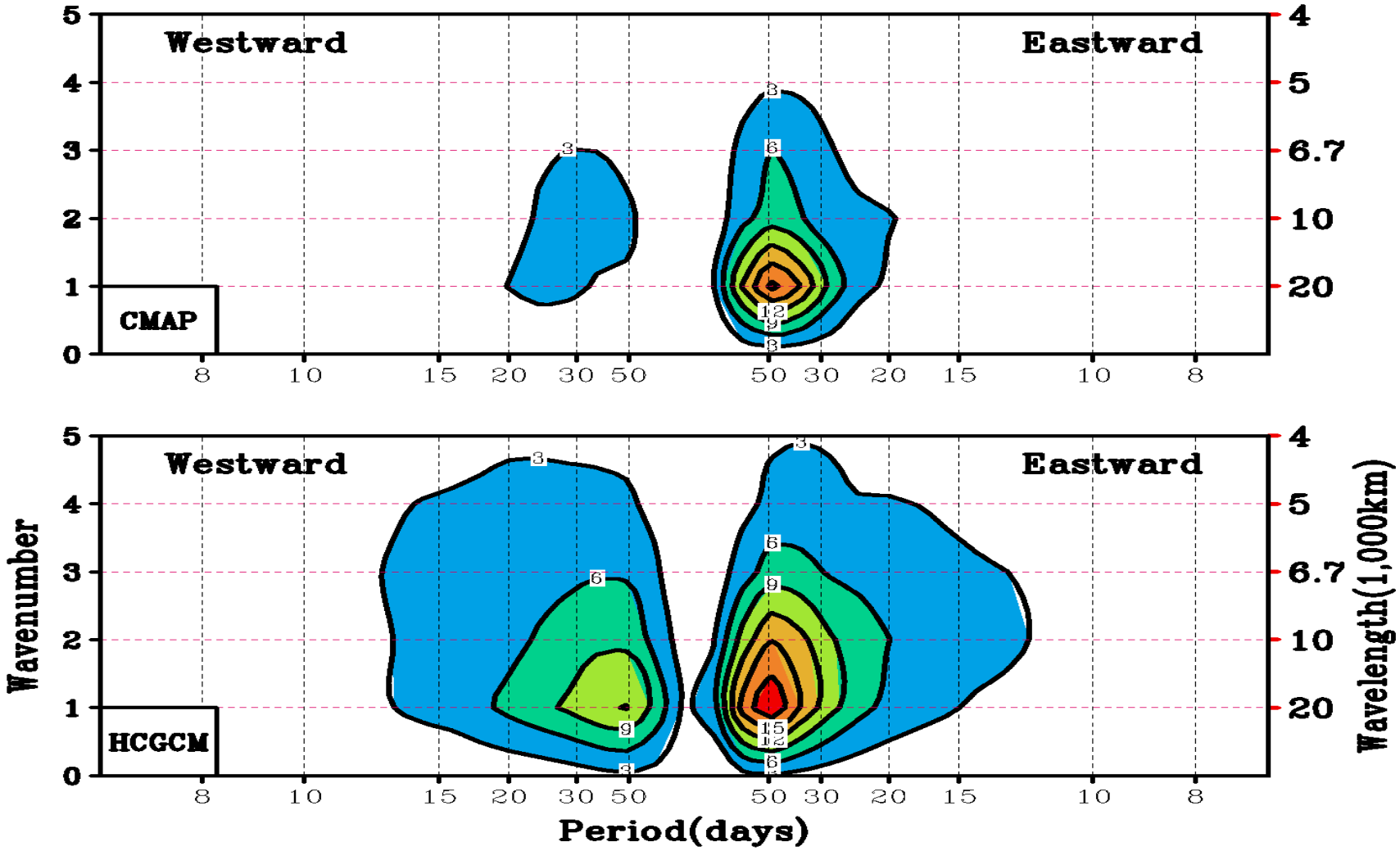
50 year integration

Contour indicates 95% significant level

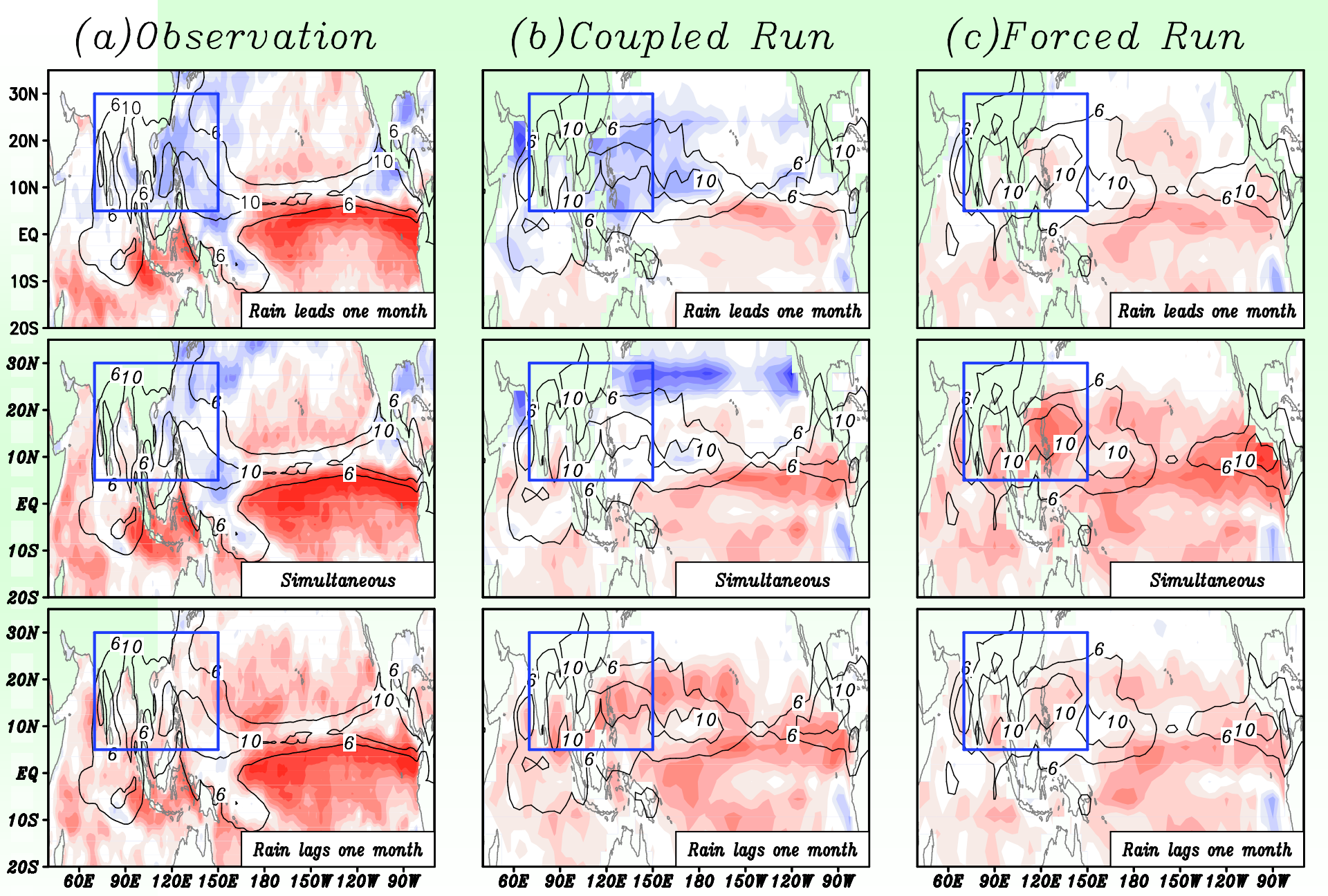
WLF intermediate ocean model (0.5x0.5)




JJA Averaged Rainfall Rate (mm/day)
OBS
Model
JJA Averaged SST (C)
OBS
Model
Observed Nino3.4 SST Anomaly (C)
OBS
Simulated Nino3.4 SST Anomaly (C)
Model
(Year)



Wavenumber-frequency spectra of MJO in boreal winter (NDJFMA) averaged from 10°S to 5°N


(a)Observation
(b)Coupled Run
(c)Forced Run
Rain leads one month
Simultaneous
Rain lags one month
30N
20N
10N
EQ
10S
20S
60E 90E 120E 150E 180 150W 120W 90W
−0.7 −0.6 −0.5 −0.4 −0.3 −0.2 −0.1 0.1 0.2 0.3 0.4 0.5 0.6 0.7

Summary

SSTA in heavy precipitating summer monsoon region is largely a result of atmospheric forcing. Treating monsoon as a slave to prescribed SST results in the models' failure.

An AGCM, coupled with an ocean model, simulated realistic SST-rainfall relationships; however, the same AGCM fails when forced by the same SSTs that are generated in its coupled run.

Neglect of atmospheric feedback makes the forced solution depart from the coupled solution in the presence of initial noises or tiny errors in the lower boundary.

Coupled ocean-atmosphere processes are extremely important in the heavy precipitating monsoon convergence zones where the atmospheric feedback to SST is essential.

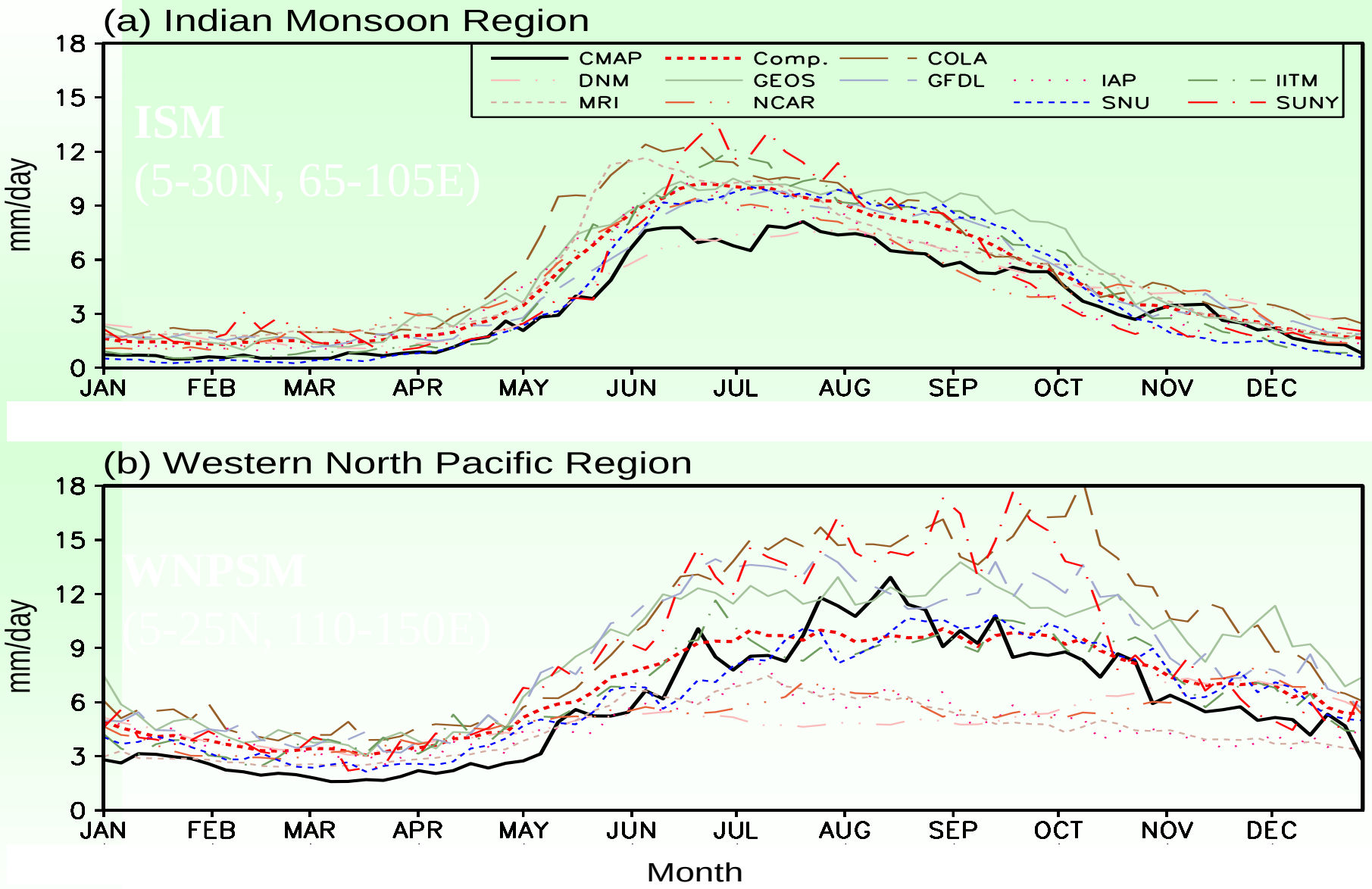
Implications

The present finding calls for reshaping of current strategies for predicting monsoon climate and validating AGCMs.

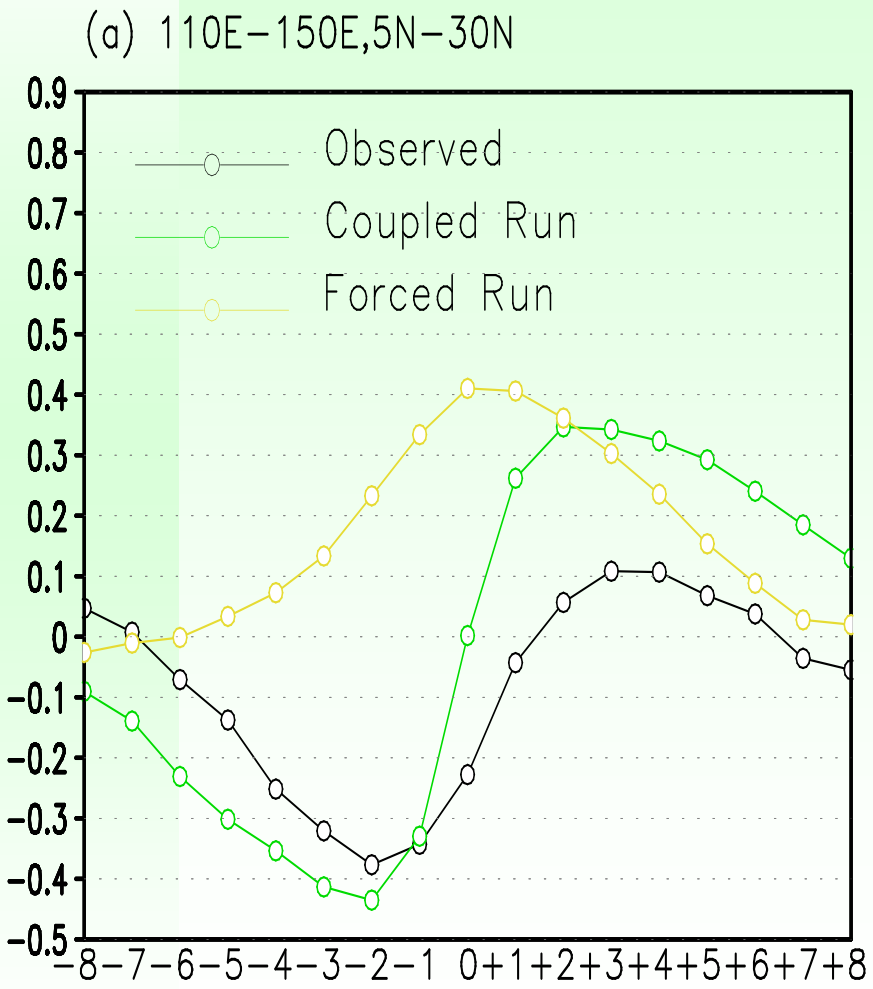
The Tier 2 approach where AGCM is forced by pre-forecasted SST is inadequate for predicting summer monsoon rainfall, especially in the Asian-Pacific region.

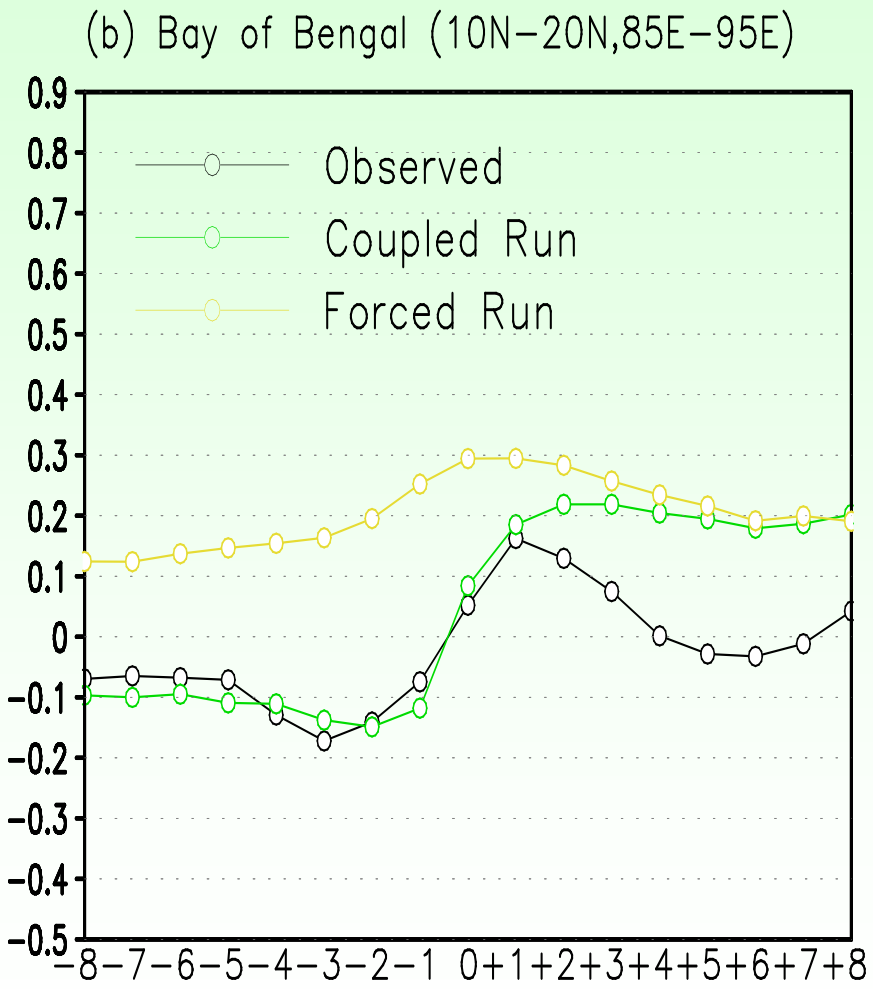
The AMIP approach is inadequate in validating AGCM or determining upper limit of predictability of summer monsoon.

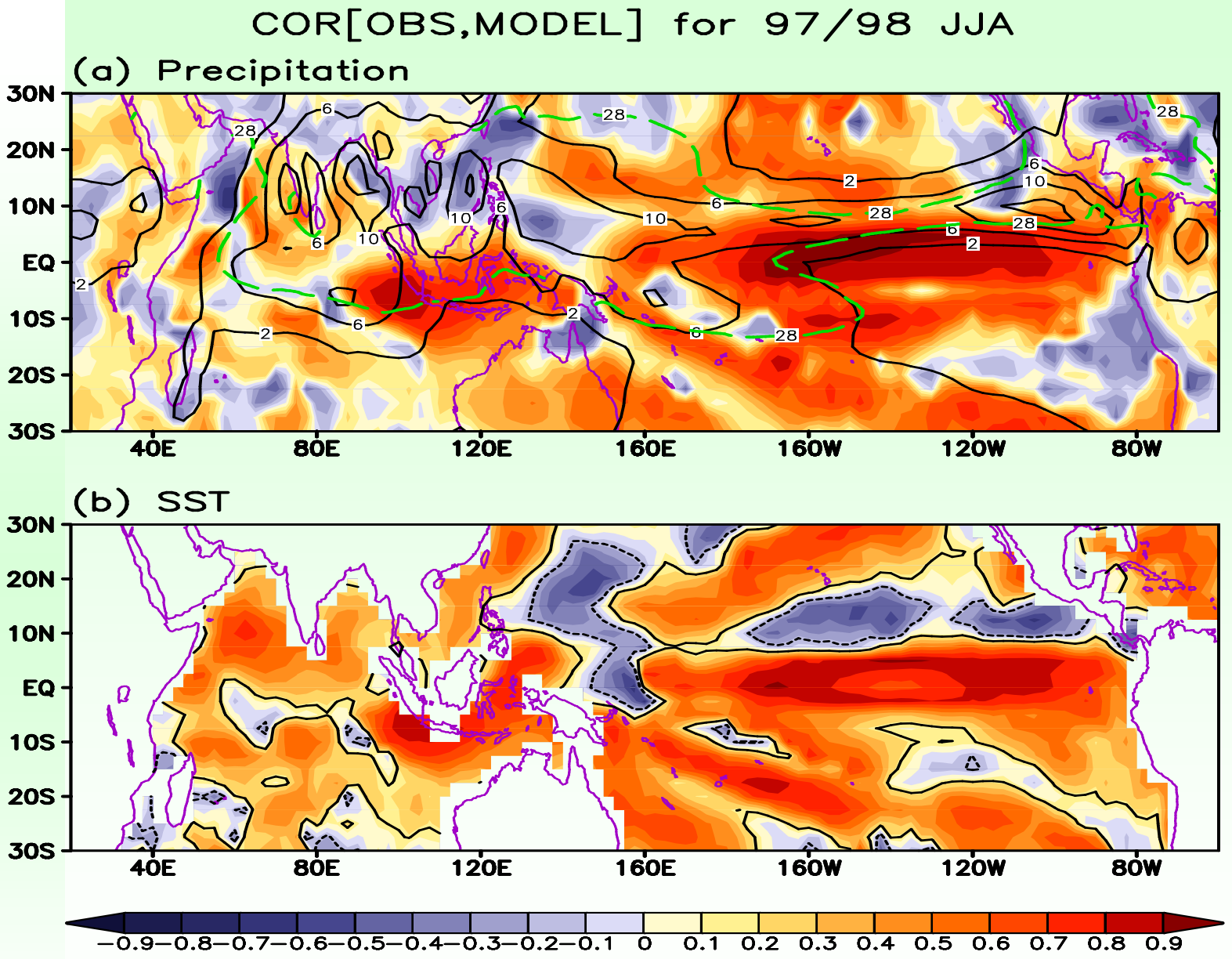
Climatological Pentad Mean Precipitation



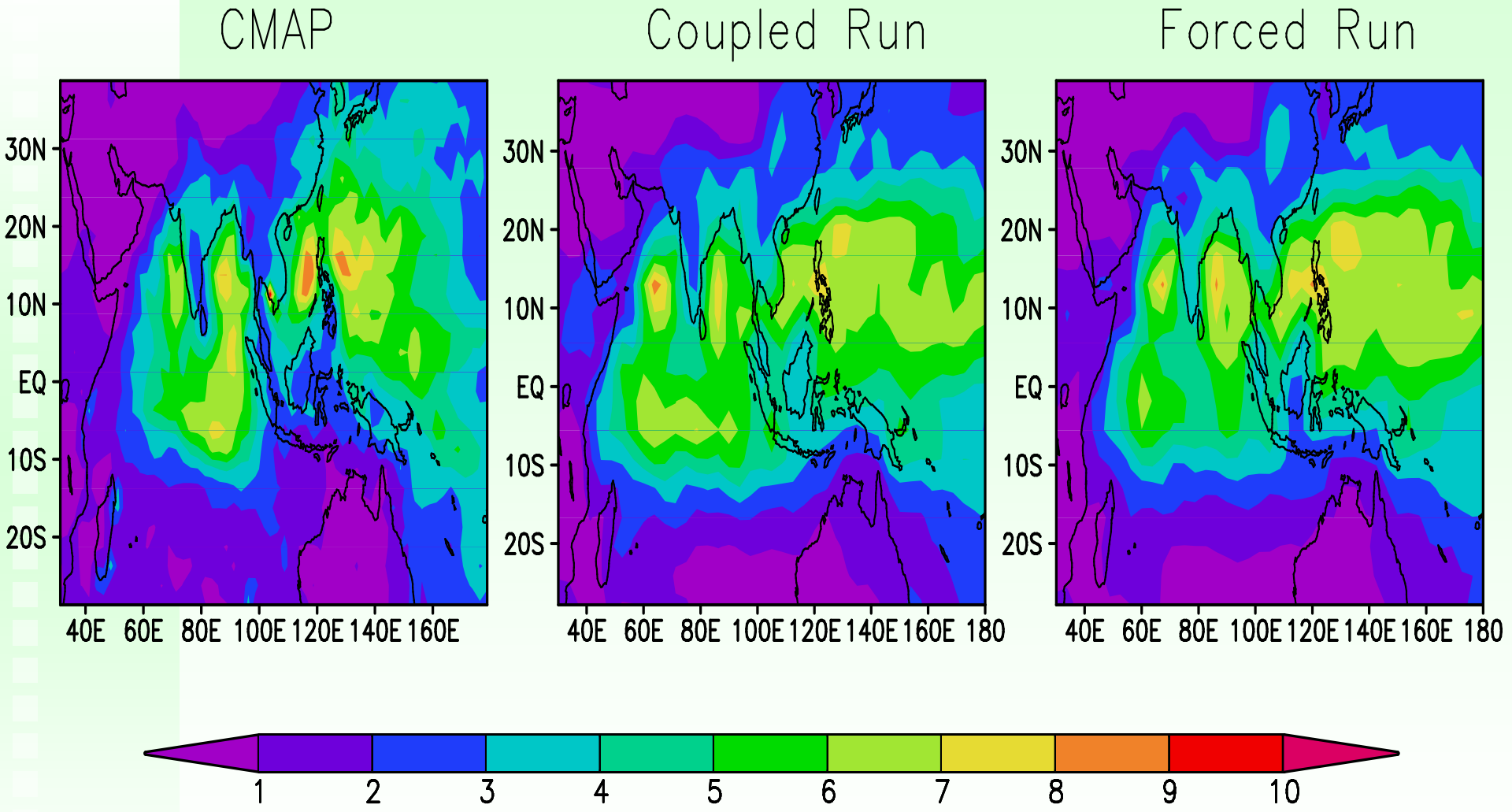
AGCMs simulate climatology poorly over the WNP heat source region


(a) 110E–150E,5N–30N
Observed
Coupled Run
Forced Run
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
–0.4
–0.5
–8 –7 –6 –5 –4 –3 –2 –1 0 +1 +2 +3 +4 +5 +6 +7 +8


(b) Bay of Bengal (10N–20N,85E–95E)
Observed
Coupled Run
Forced Run
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
–0.4
–0.5
–8 –7 –6 –5 –4 –3 –2 –1 0 +1 +2 +3 +4 +5 +6 +7 +8



color shading denotes the correlation coefficients and the contours denote climatological seasonal mean rainfall rate (1979-98 CMAP climatology), and the green dashed line denotes the contour of seasonal mean 28°C SST (1971-2000 OISST climatology). (b) The same as in (a) except for the correlation coefficients between observed SST and simulated precipitation anomalies during JJA 1997 and 1998. The contour denotes the significance level with 99% confidence level (0.17).


CMAP
Coupled Run
Forced Run
30N
20N
10N
EQ
10S
20S
40E 60E 80E 100E 120E 140E 160E
40E 60E 80E 100E 120E 140E 160E 180
1 2 3 4 5 6 7 8 9 10