Systematic Errors in the Simulation of Mean and Variability of the *Asian Summer Monsoon* in Climate Models

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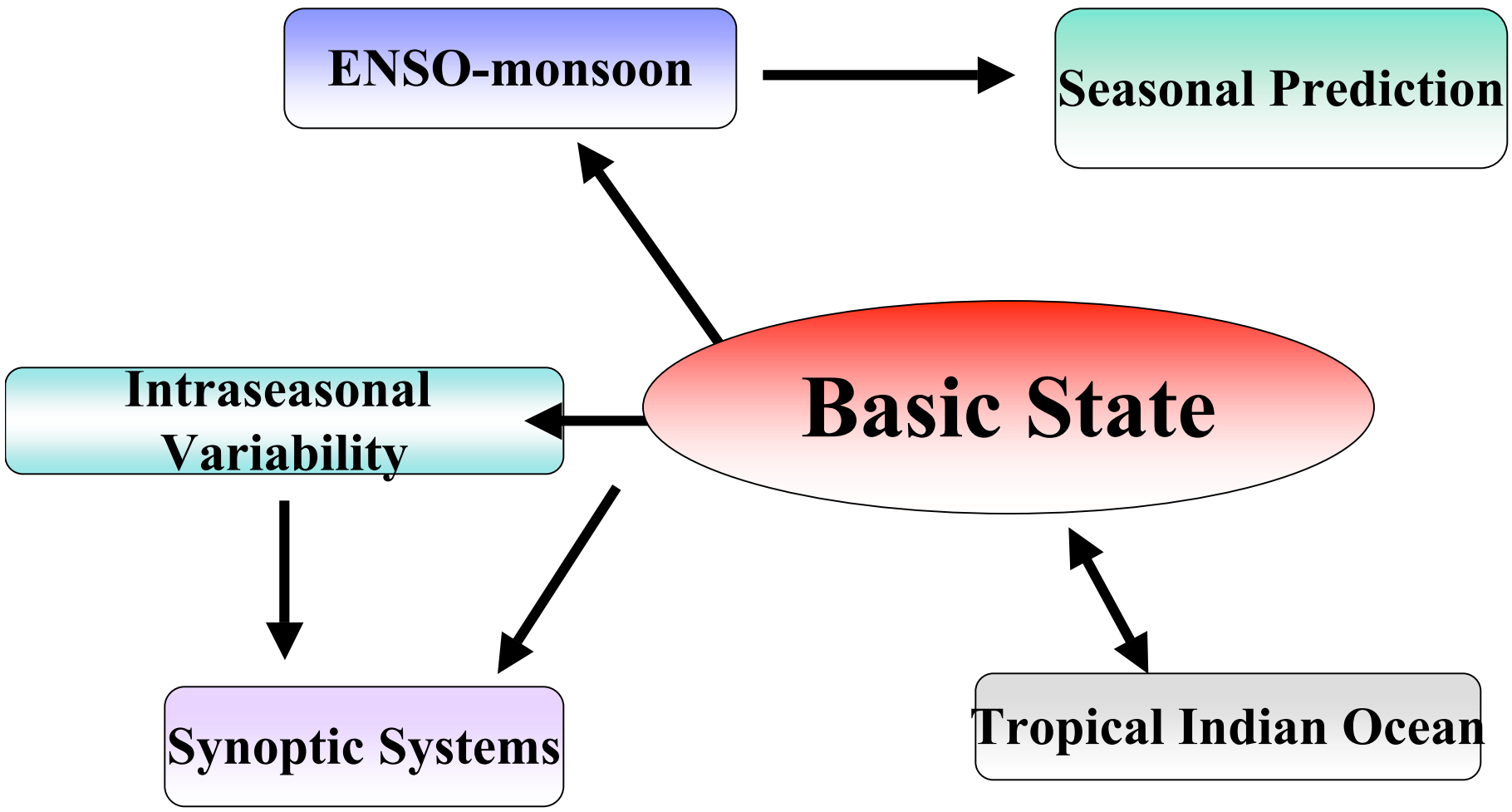
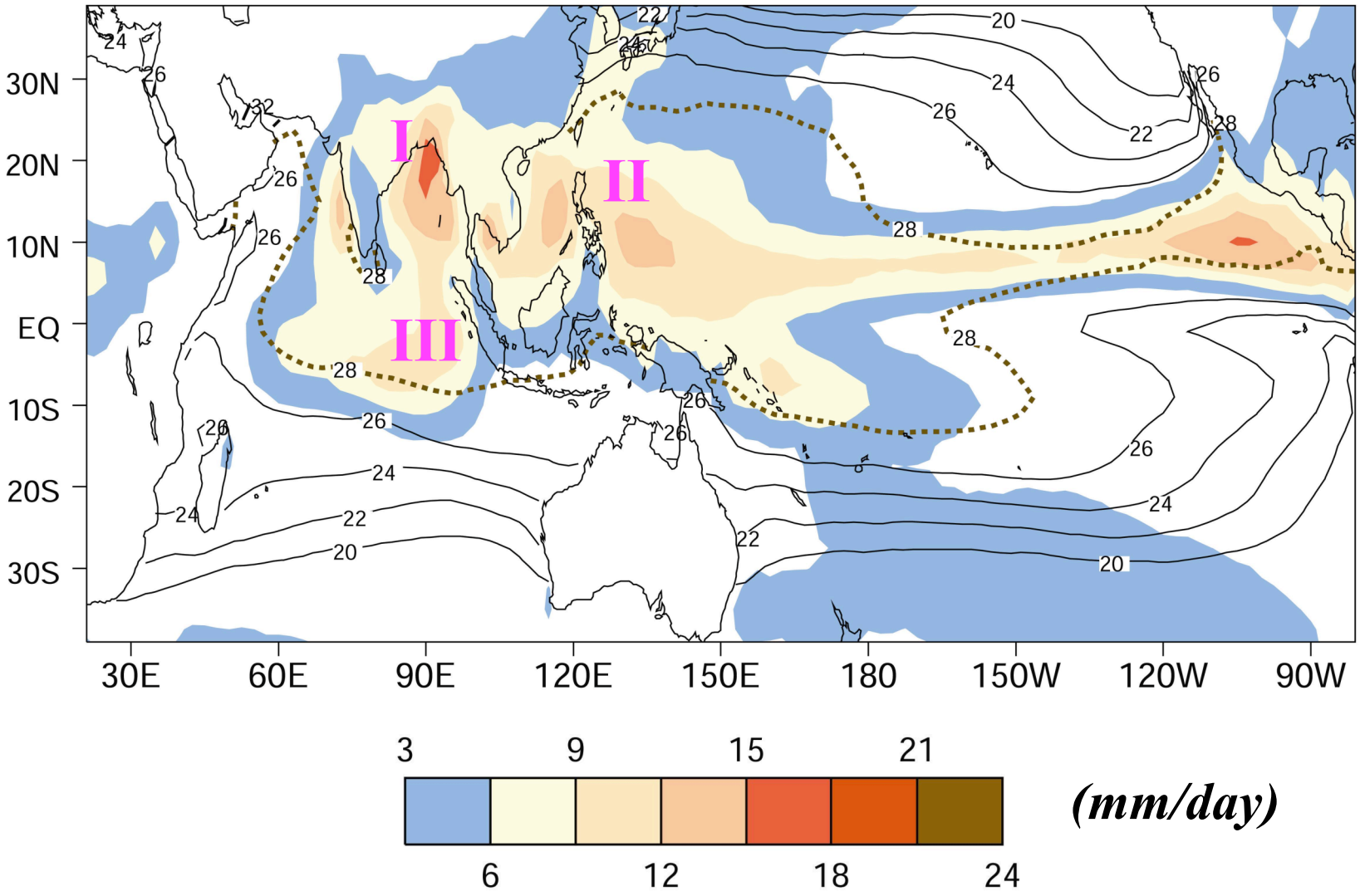
Livermore, California

Contributing authors…..

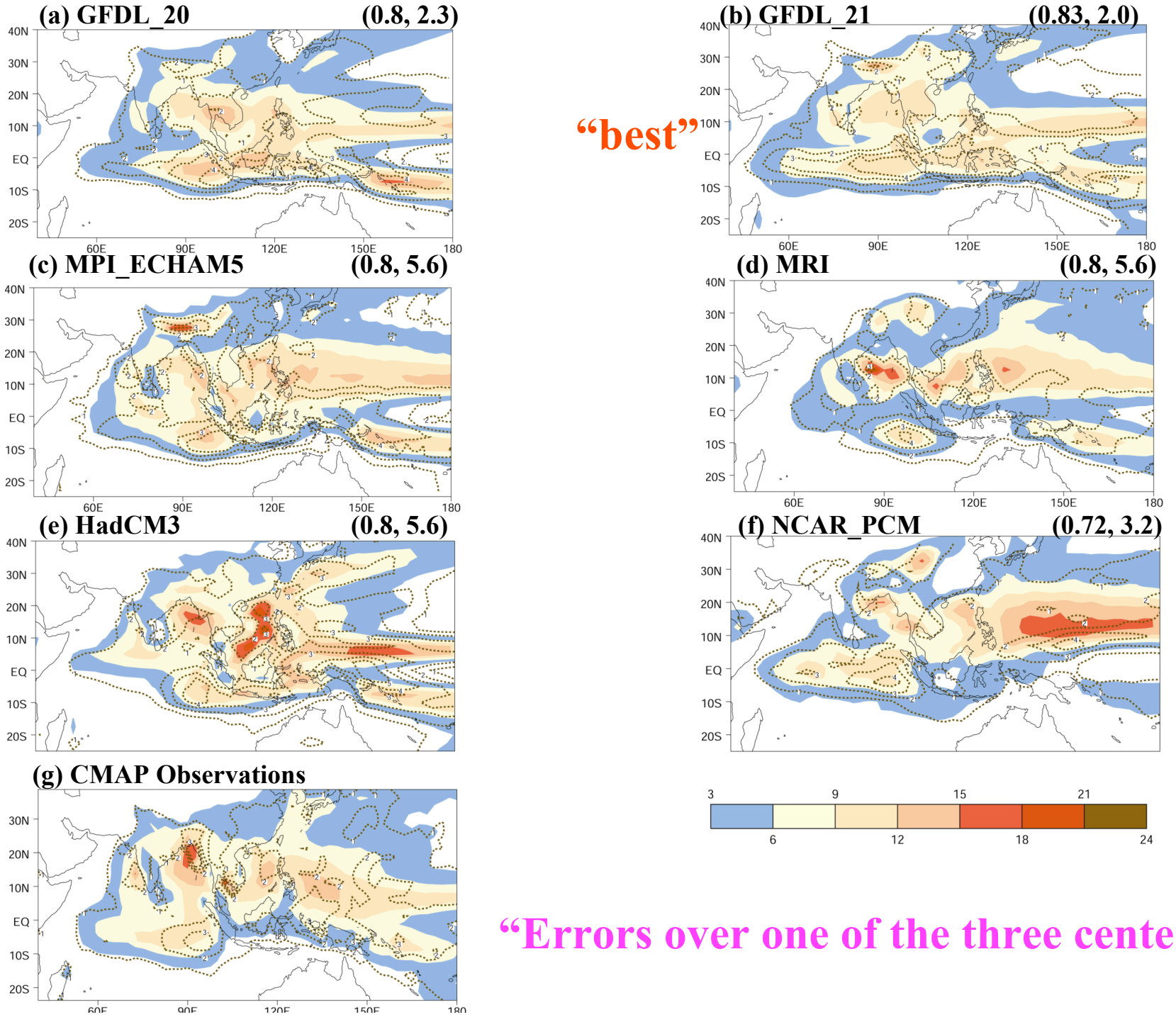
- **Andy Turner and Julia Slingo** (Reading)
- **Yune-Yi and Bin Wang** (IPRC, Hawaii)


ENSO-monsoon
Seasonal Prediction
Intraseasonal Variability
Basic State
Synoptic Systems
Tropical Indian Ocean

JJAS – Precipitation and SST Climatology



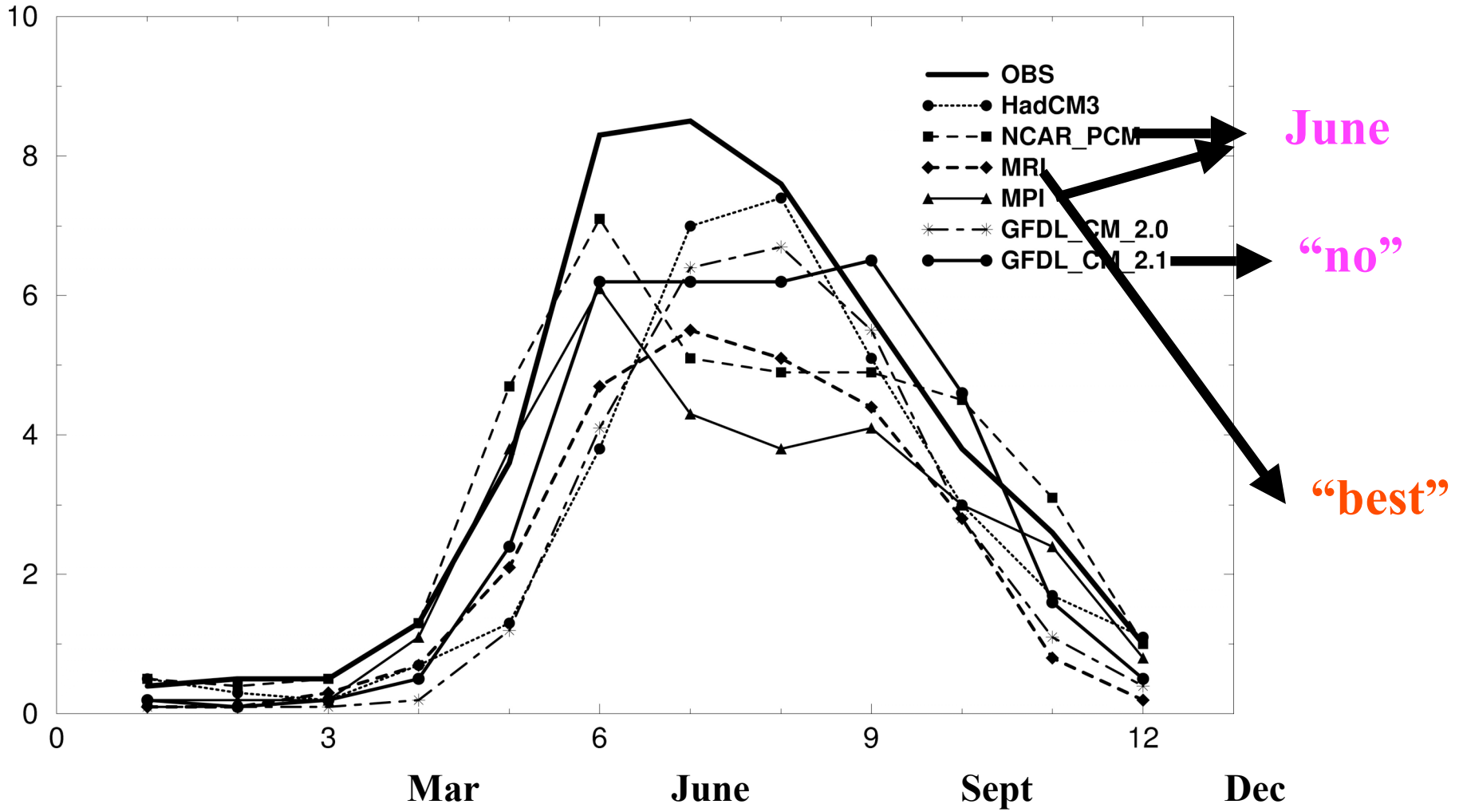
"Three regional heat sources"



"best"

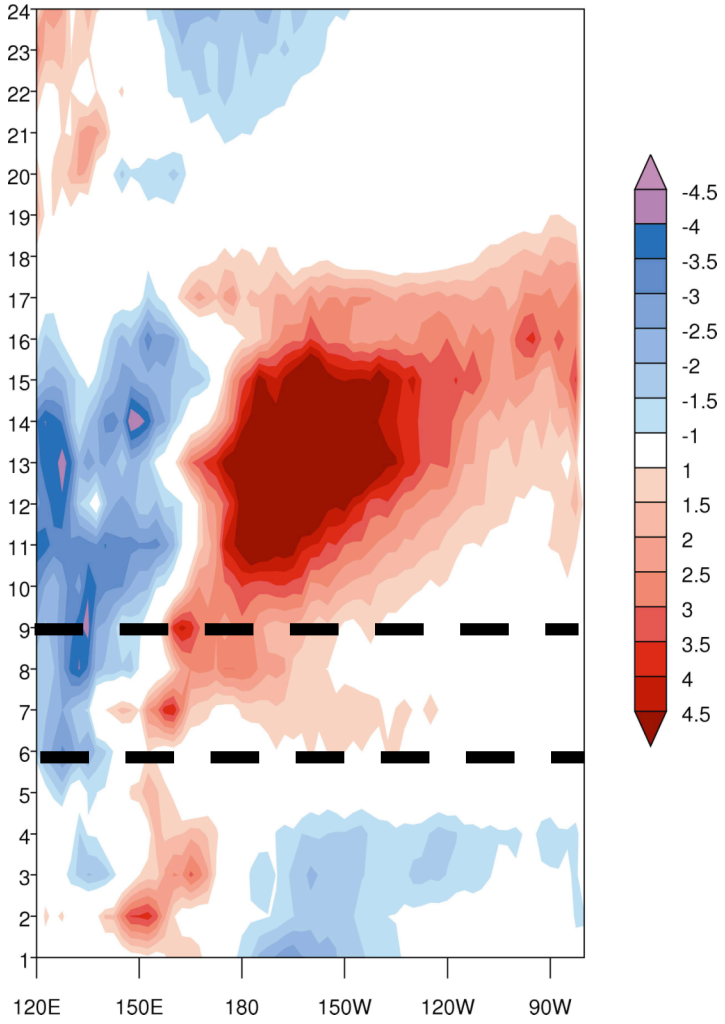
"Errors over one of the three centers"

Annual Cycle of Precipitation (60-100°E, 10-25°N)



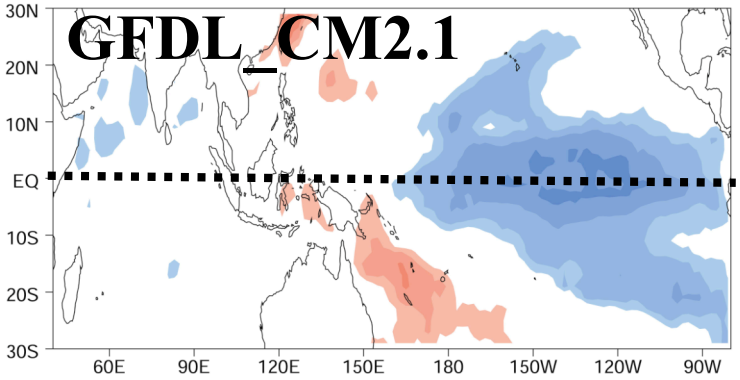
ENSO-monsoon association

Evolution of anomalous Precipitation during El Nino

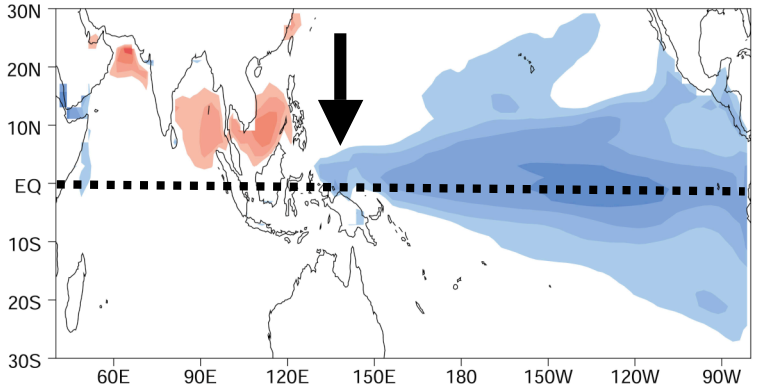


Correlations between AIR and SST (JJAS)

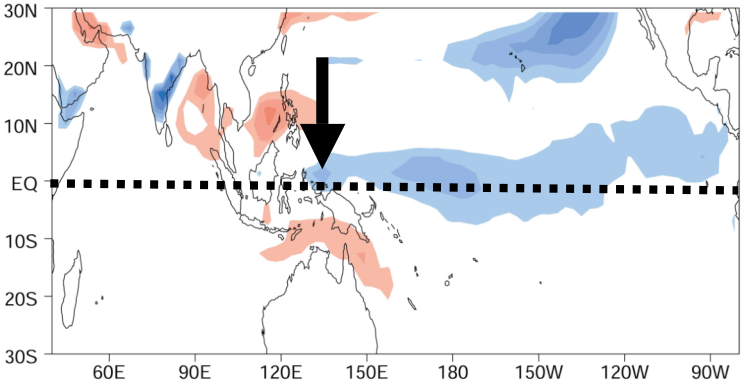
Observation



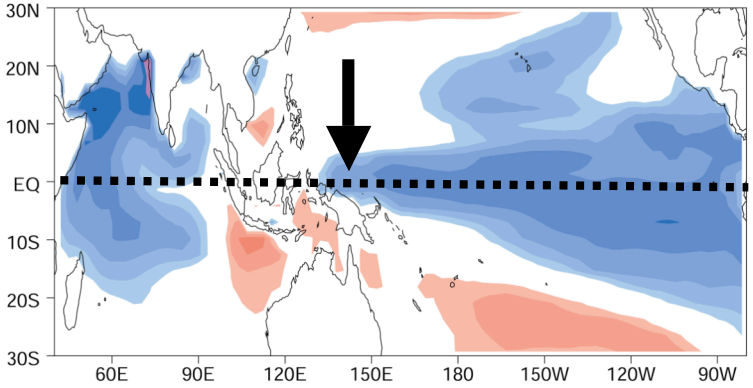
GFDL_CM2.1

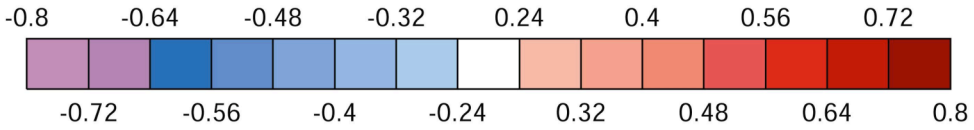


NCAR_PCM



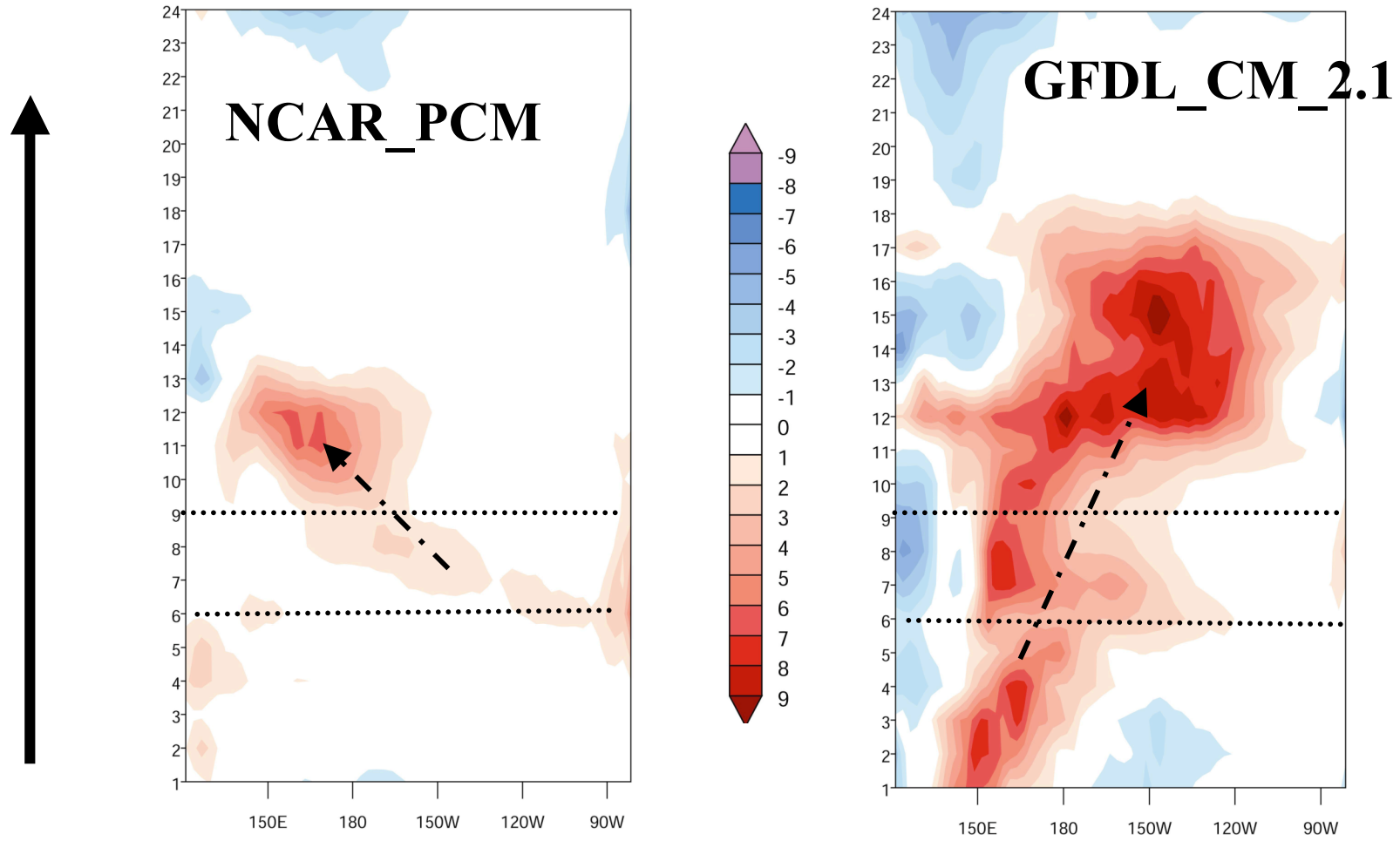
MRI (flux-corrected)





"warm SST anomalies penetrate into the equatorial Pacific"

Precipitation Anomalies during composite El Nino – Eq. Pacific



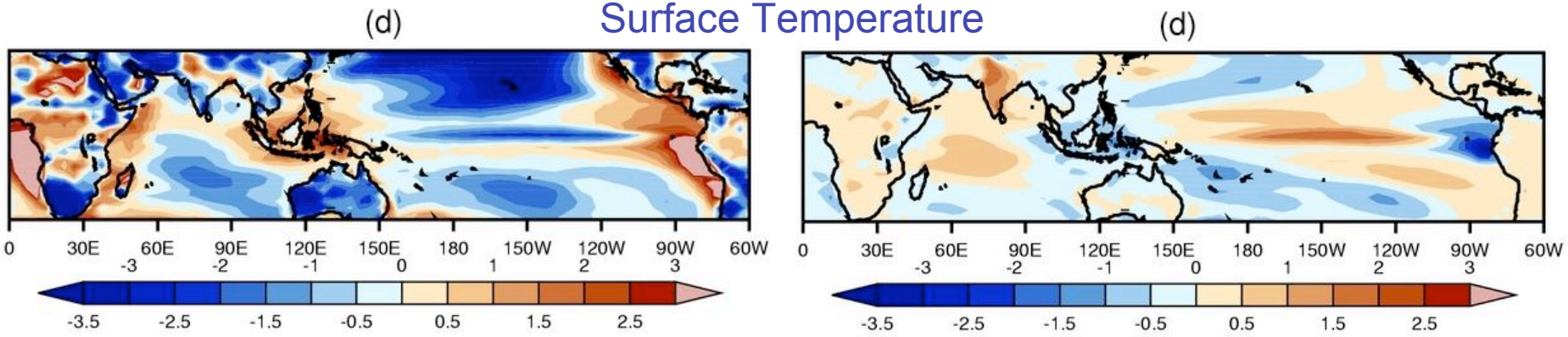
"models that failure to capture ENSO-monsoon relationship fail to capture the anomalous diabatic heating patterns in the Pacific"

HadCM3: Changes to mean state using ocean heat flux adjustment

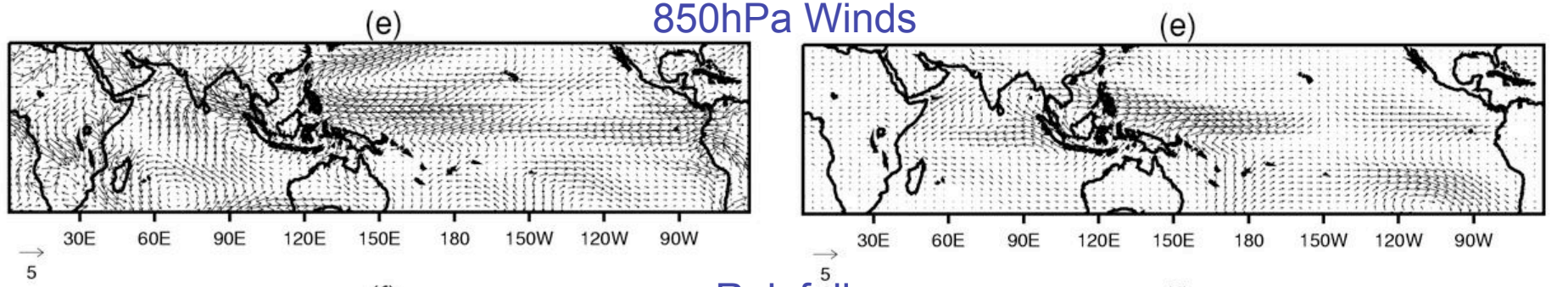
Original Biases

Changes with flux adjustment

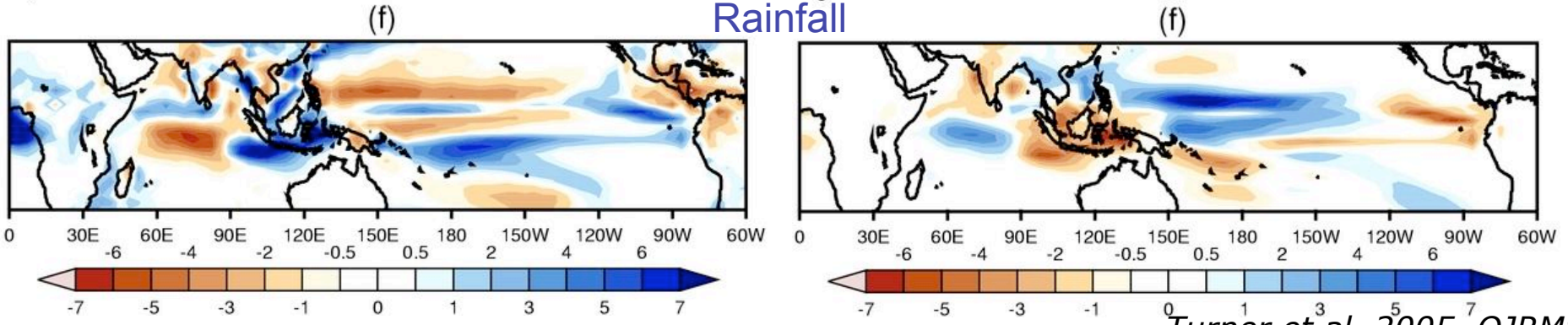
Surface Temperature



850hPa Winds



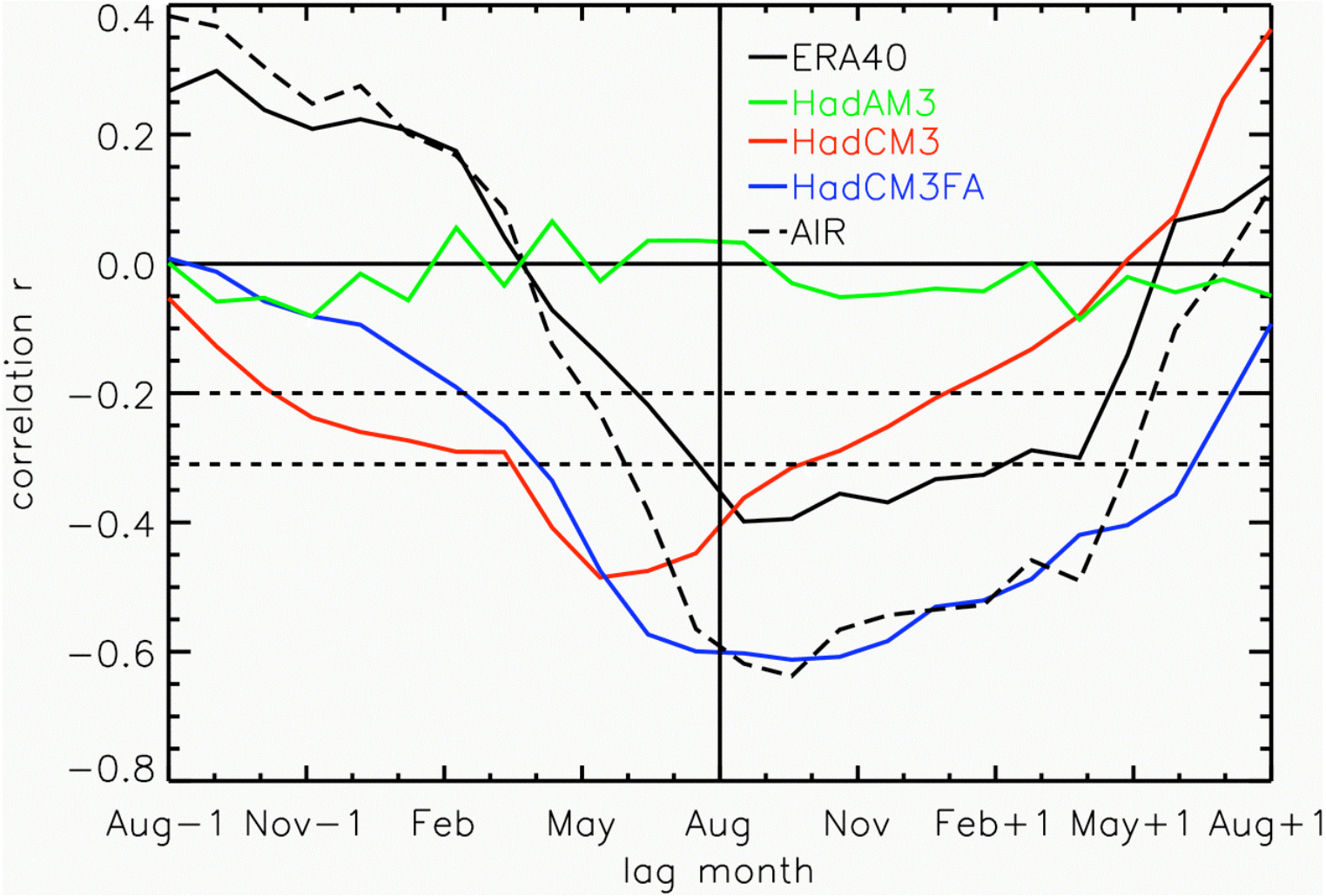
Rainfall



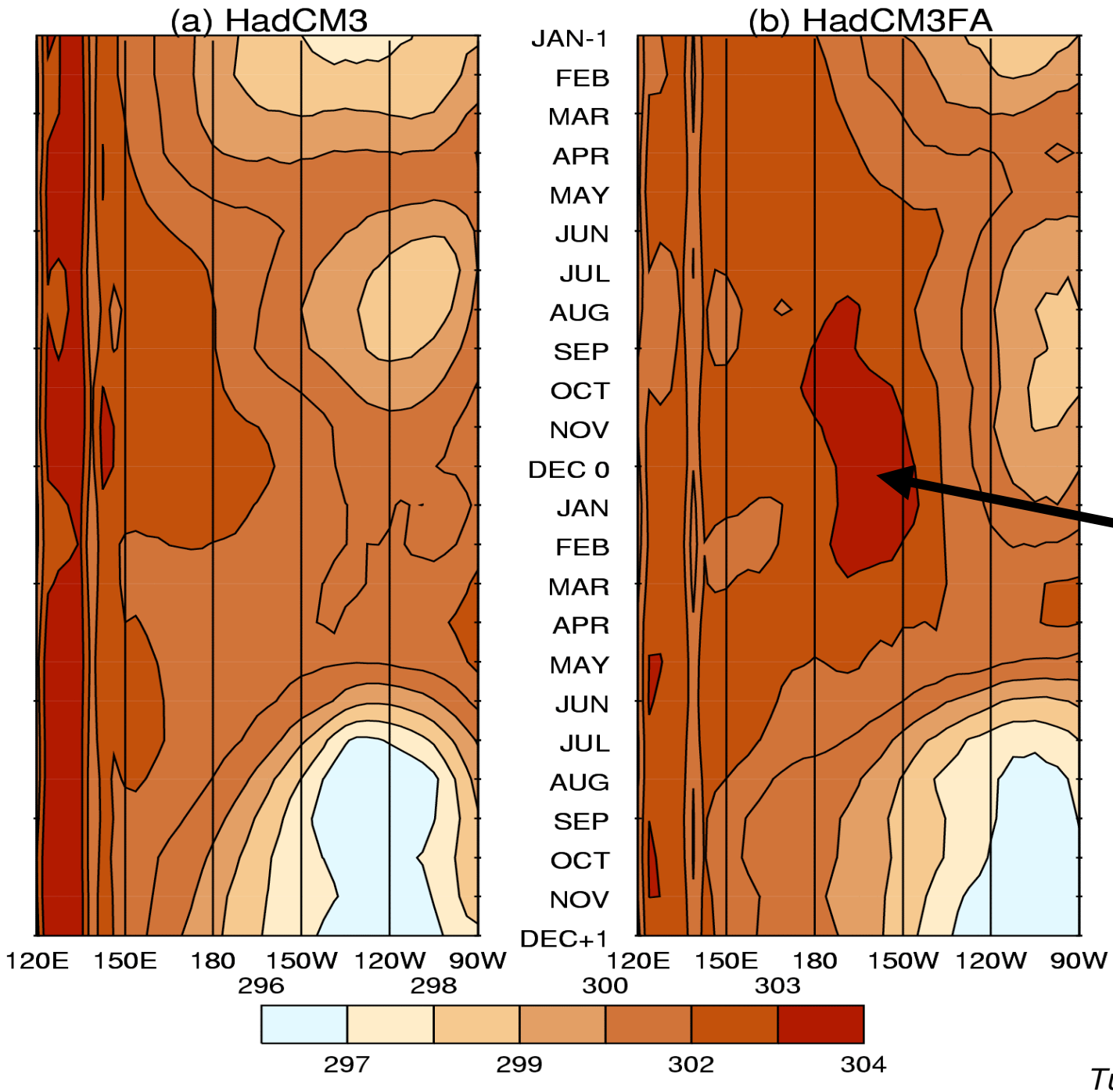
Turner et al. 2005, QJRMS

ENSO-Monsoon Teleconnections

Summer All India Rainfall (AIR) lag-correlated with Nino-3 SSTs



Turner et al. 2005, QJRMS

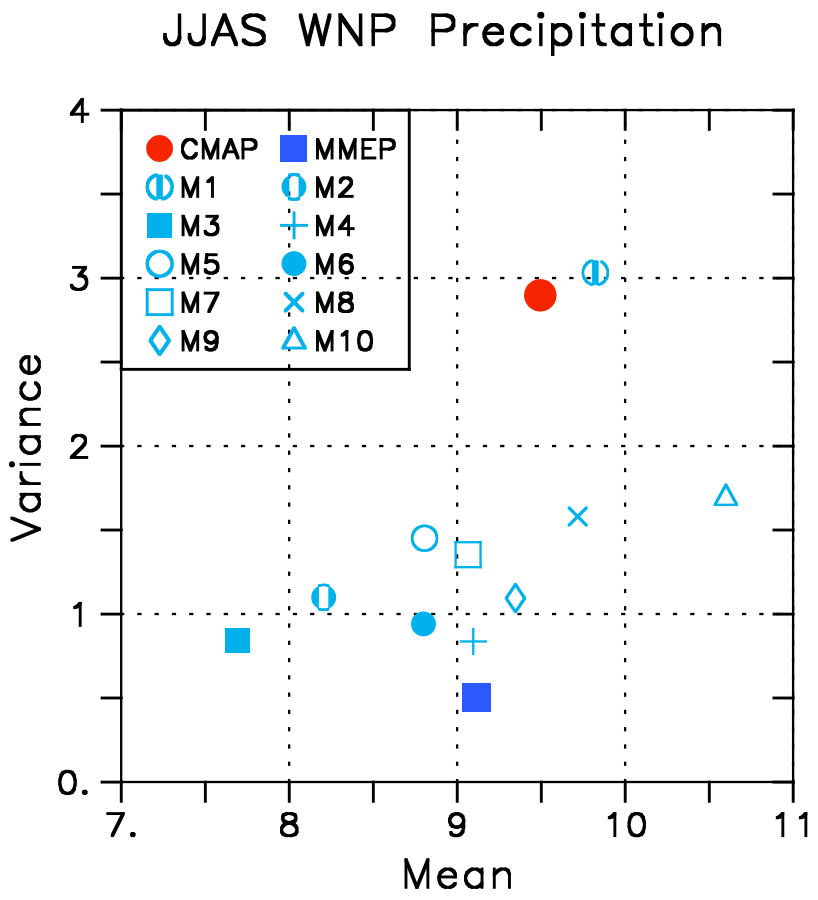


Evolution of SST through composite El Nino

Note that warmest water moves into the central Pacific with improved basic state

Turner et al. 2005, QJRMS

Performance on Annual Modes and its Linkage with Seasonal Prediction



➢ Figure shows the **climatological mean** of JJAS precipitation and **its variance** for 21 years over the WNPM region—obtained from CMAP, the MME and the individual coupled model predictions.

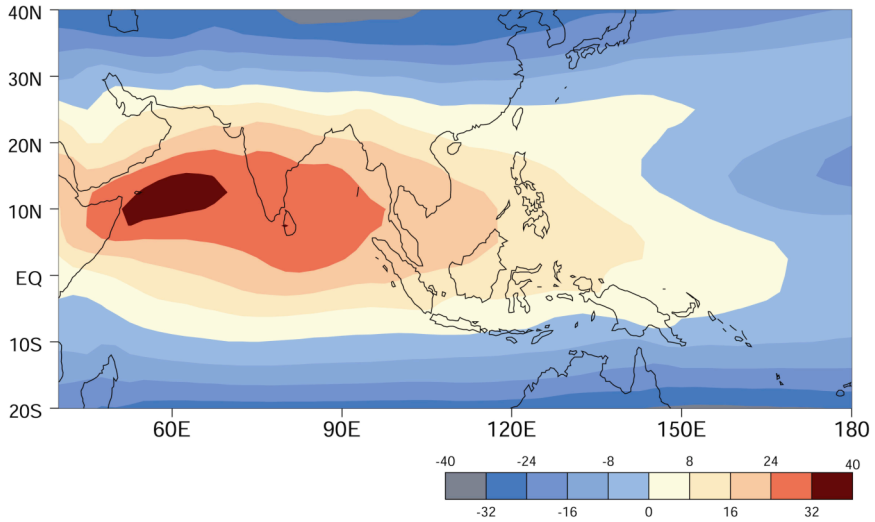
➢The majority of coupled models **has not only smaller climatological mean but also much less interannual variability of seasonal anomalies than the observation**, except few models, such as M1 which has comparable mean and variance to observation. Note that the amplitudes of variances in most coupled models are less than half that of the observed.

Yune-Yi and Wang (2007)

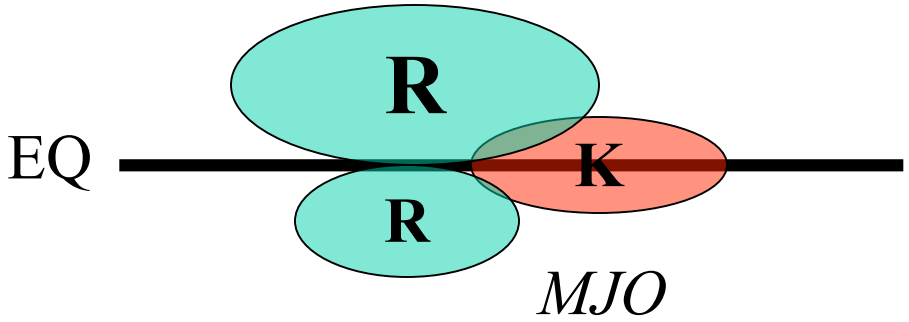
"poor simulation of mean monsoon leads to similar errors in interannual variations"

Mean Monsoon and Intraseasonal Variability

Zonal Vertical Shear



Lau and Peng (1990)
Wang and Xie (1997)
Annamalai and Sperber (2005)

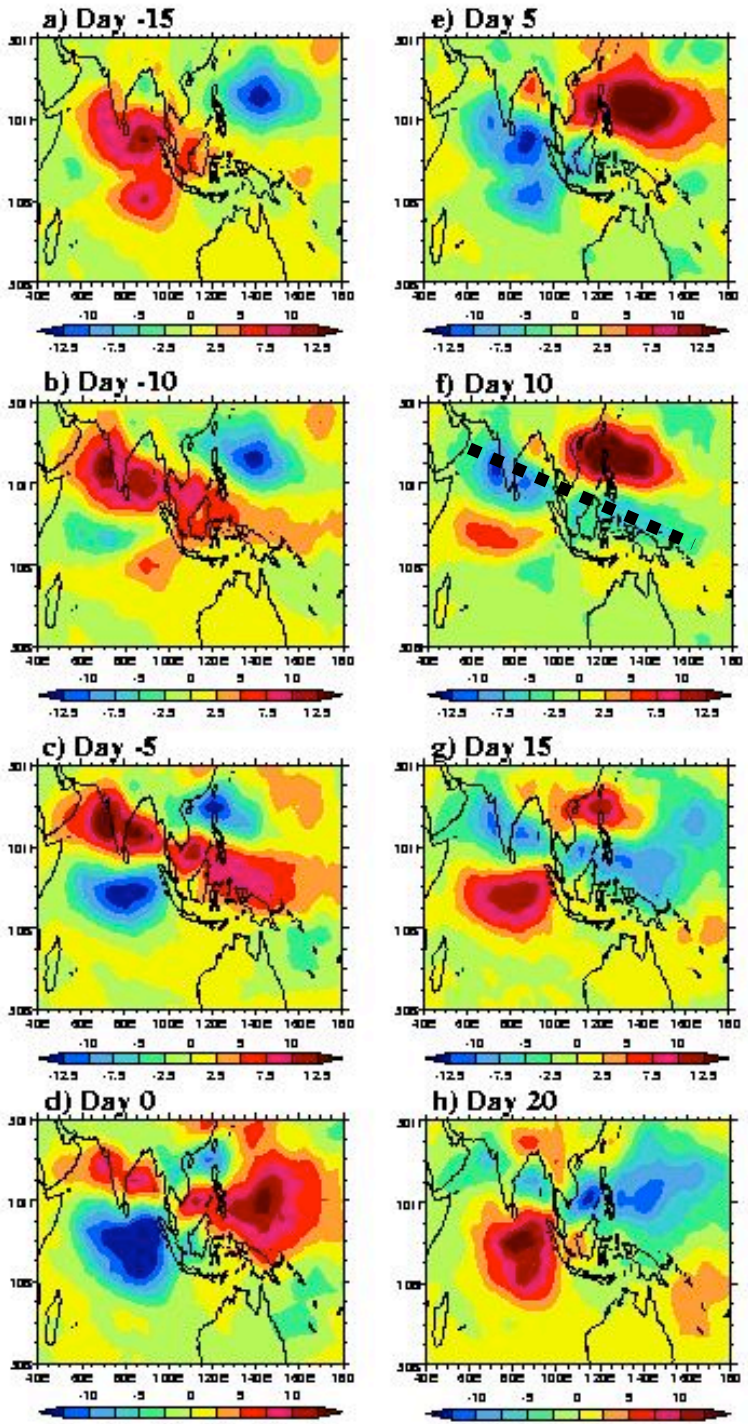


Initiation

CsEOF

Annamalai and Sperber (2005)

Amplification



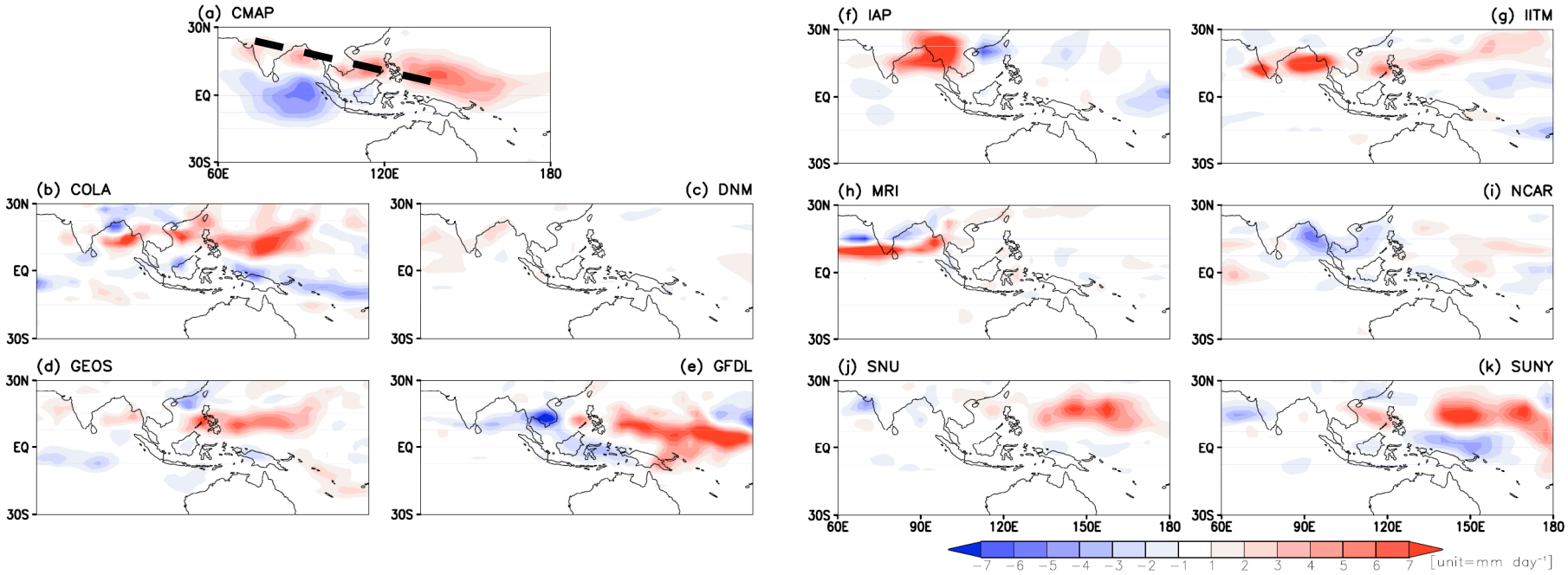
Poleward - India

Eastward – W. Pacific

Quadra-pole

Poleward – W. Pacific

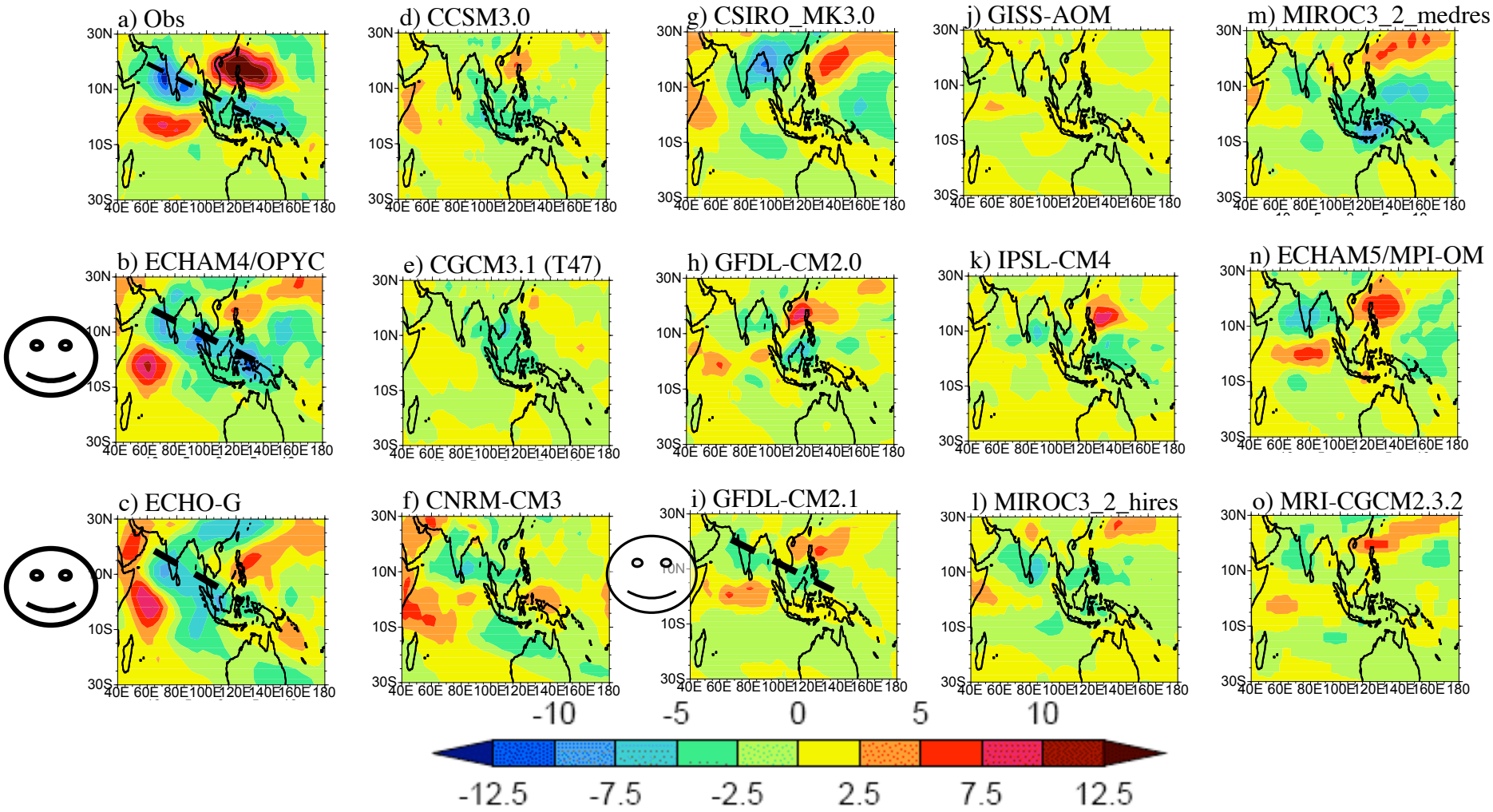
Tilted rainband in AGCMs



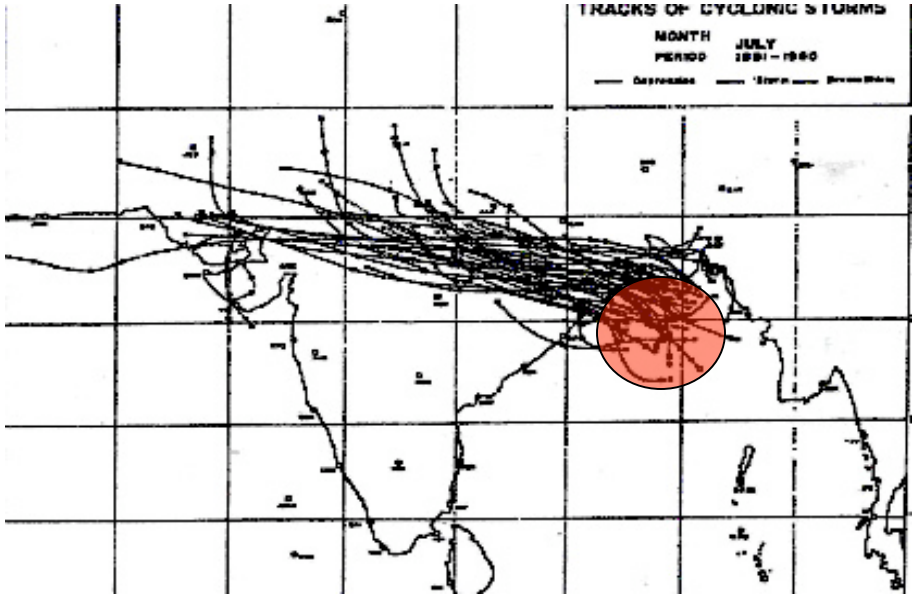
"Typically, AGCMs poorly represent the BSISV tilted rainband (Waliser et al. 2003, *Clim. Dynam.*, 21, 423-446)"

BSISV in Coupled Models: The Tilted Rainband (Day 10)

(Sperber and Annamalai 2007)

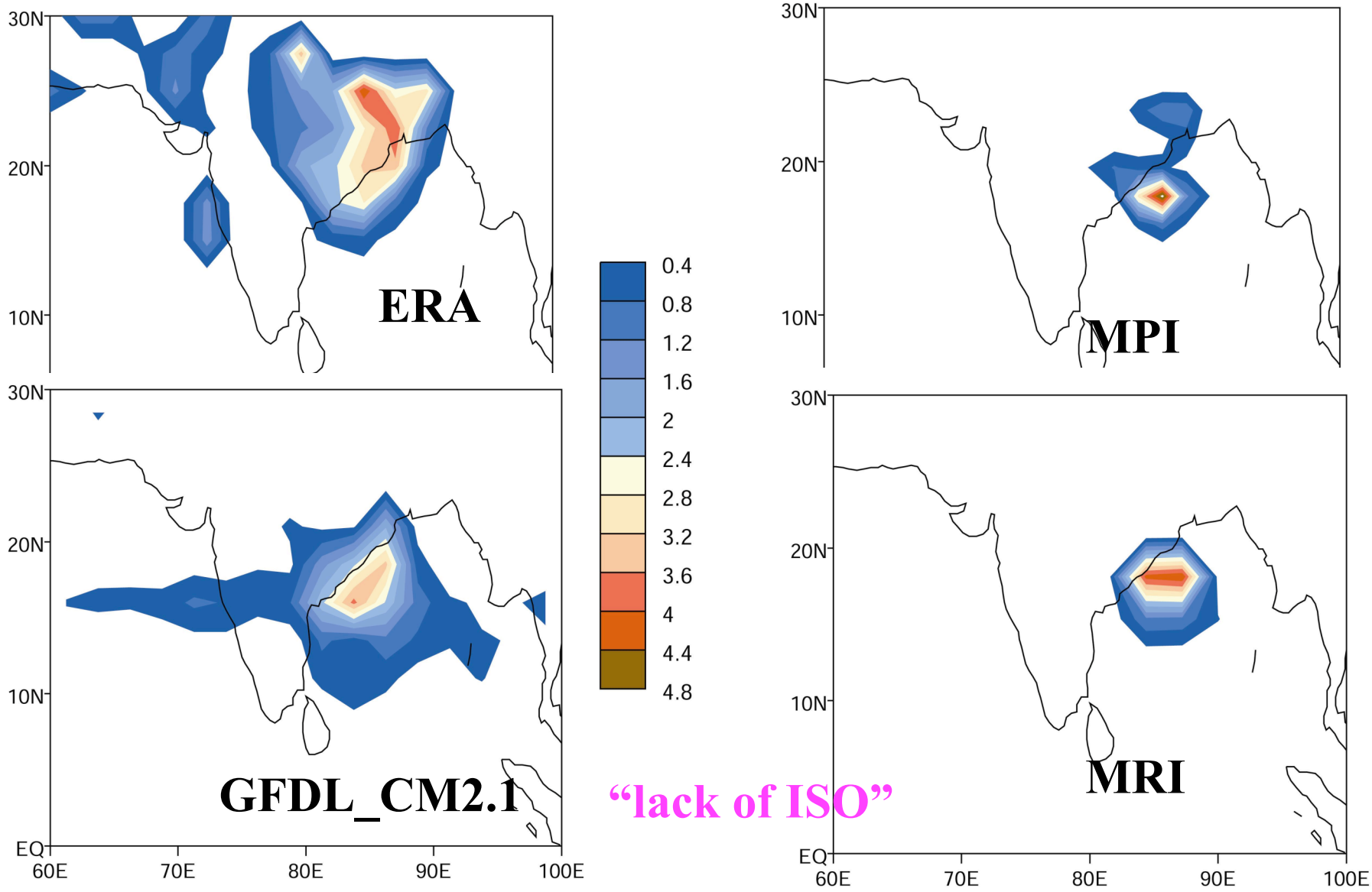


Mean Monsoon and Synoptic Systems



Role of the basic flow

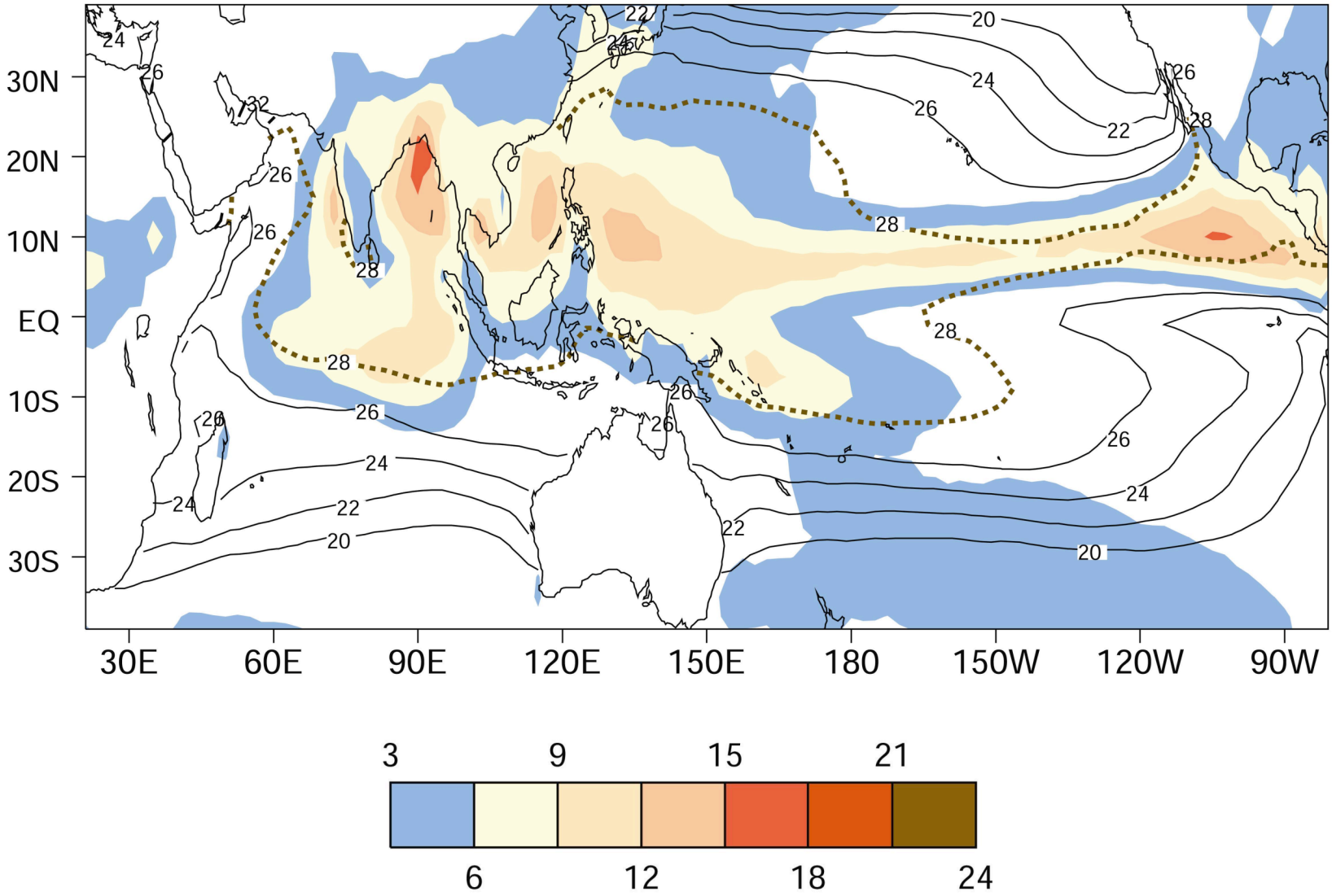
Feature density of monsoon depressions



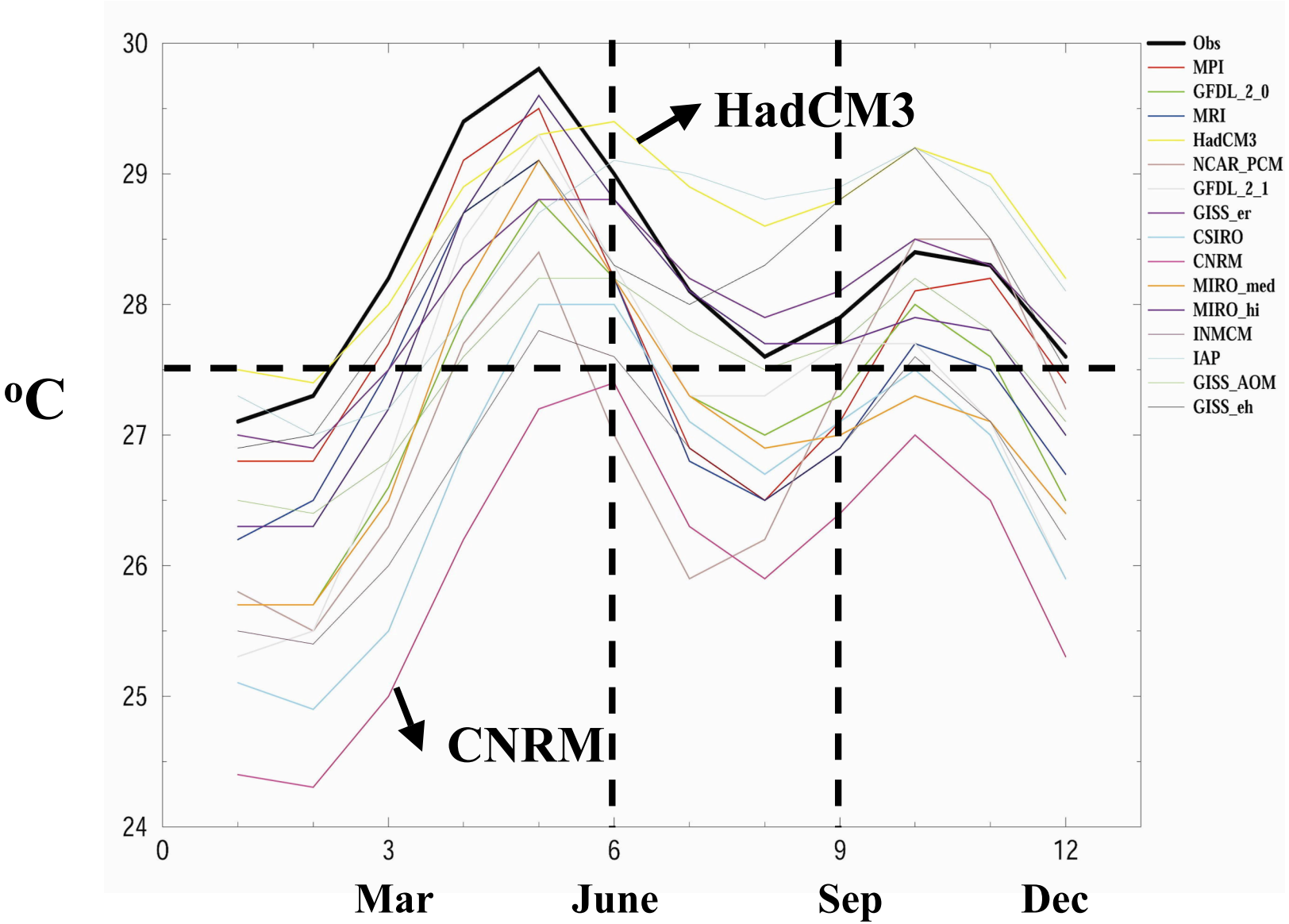
"lack of ISO"

"In models, depressions are concentrated over the ocean" – The mean monsoon trough is located "southwards" in the models

Mean Monsoon Simulation – Role of the Indian Ocean



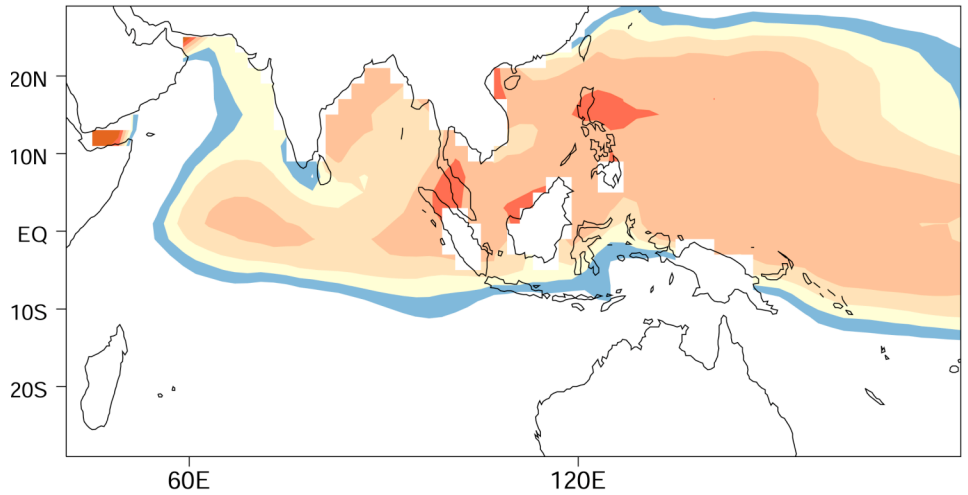
Annual Cycle of SST (80-100°E, 10-25°N)



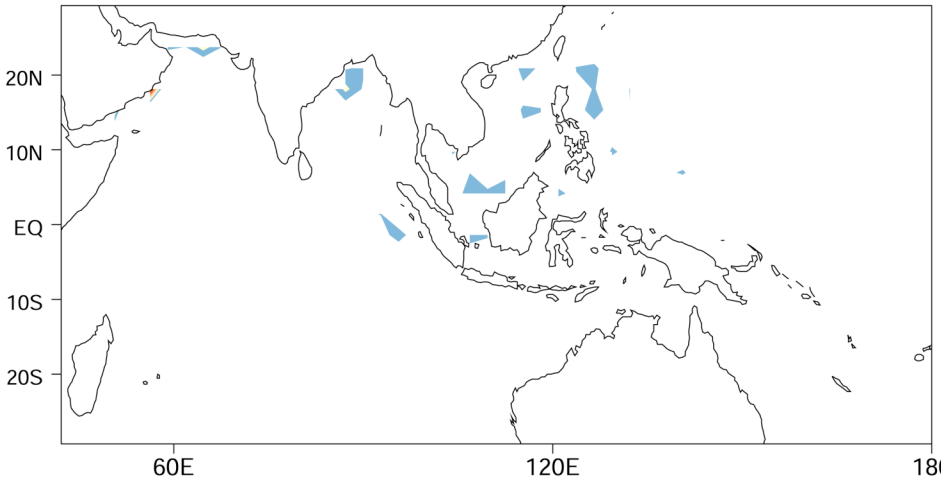
Simulated SST over Bay of Bengal is "weak" – cold bias

SST Climatology (JJAS)

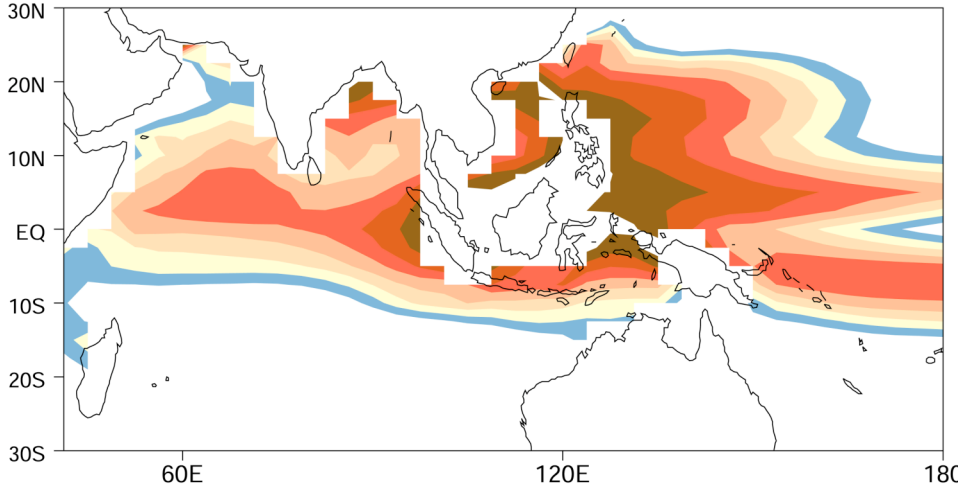
OBS

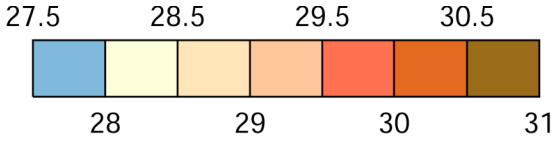


CNRM



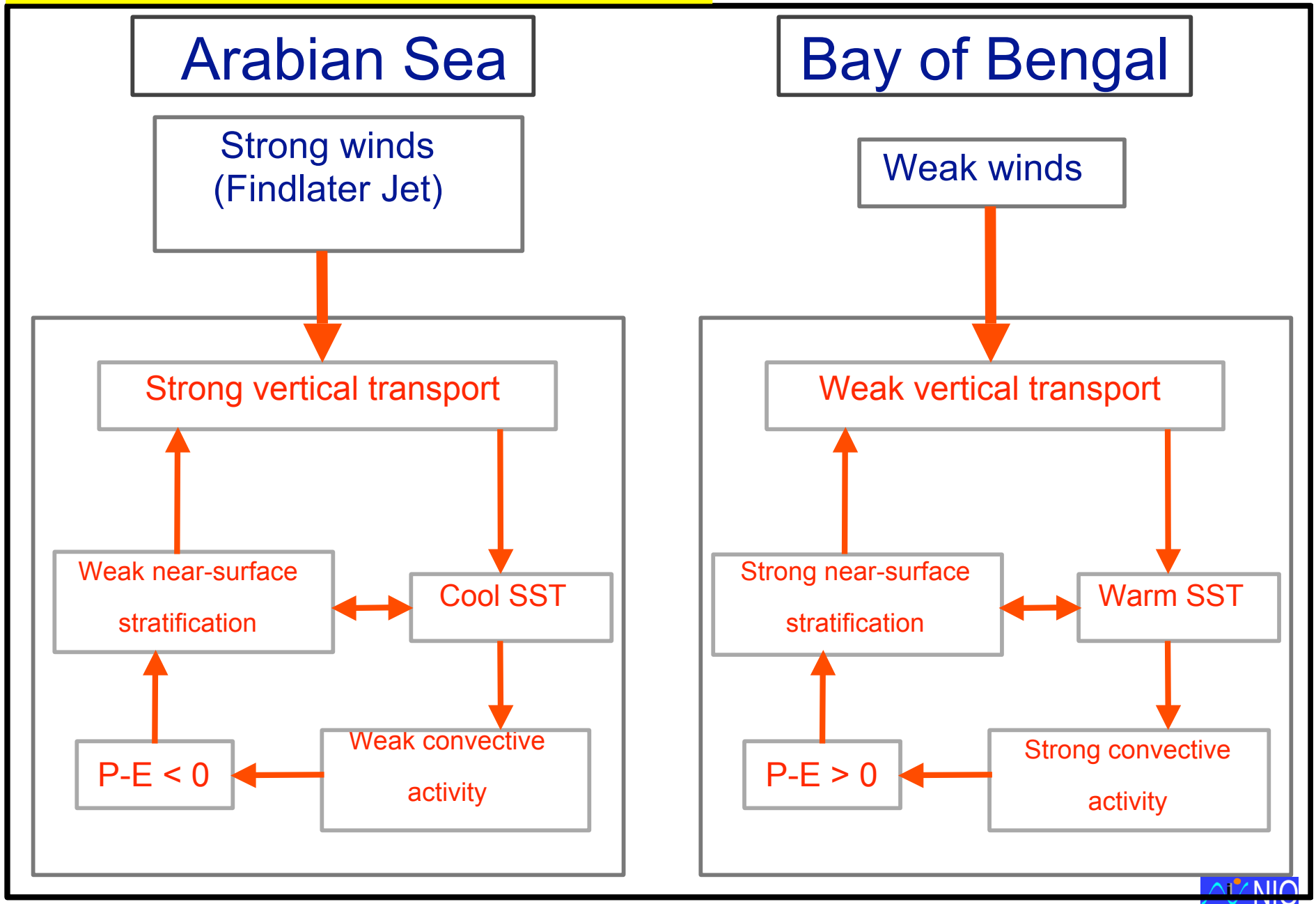
HadCM3



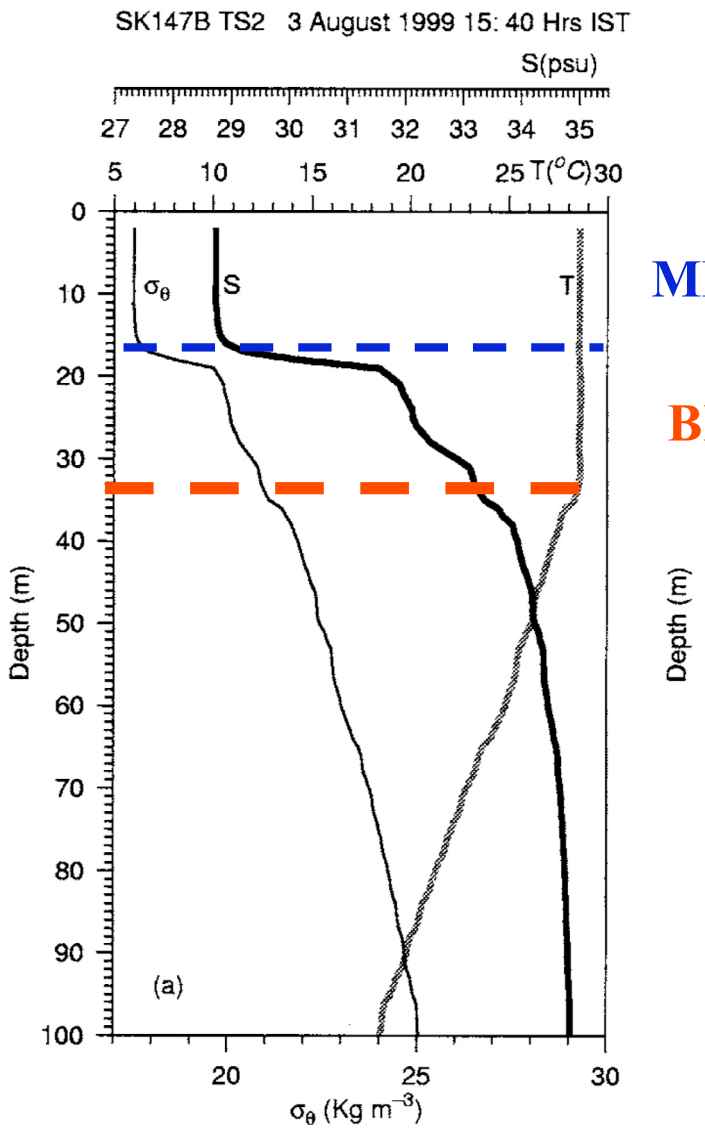


The monsoons: An oceanographer's view …

Shenoi et al (2002)

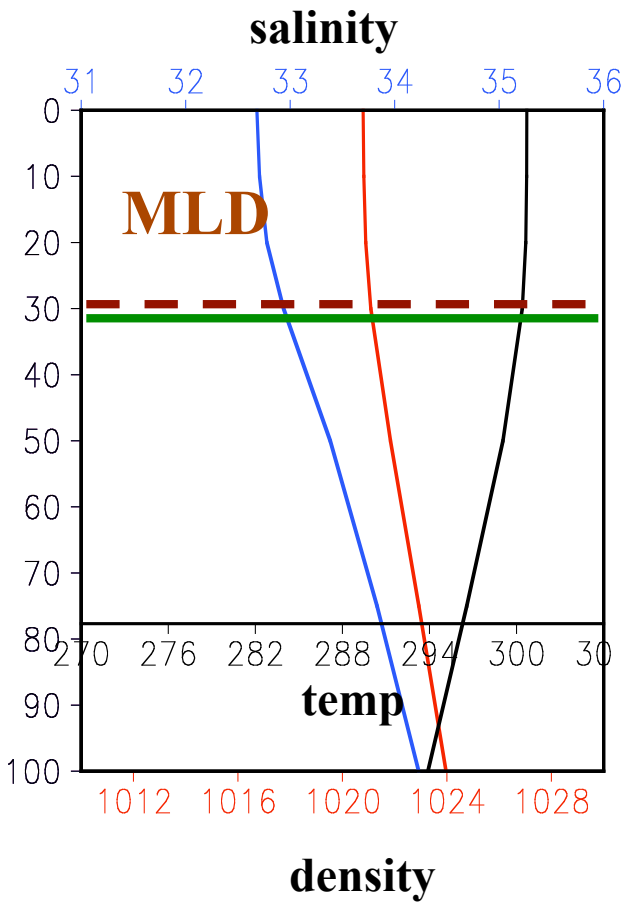


North Bay

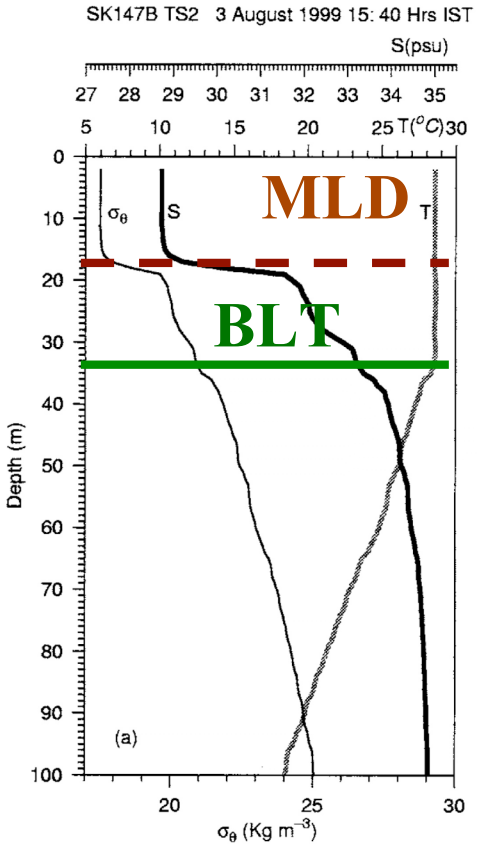


Courtesy: Murty (NIO)

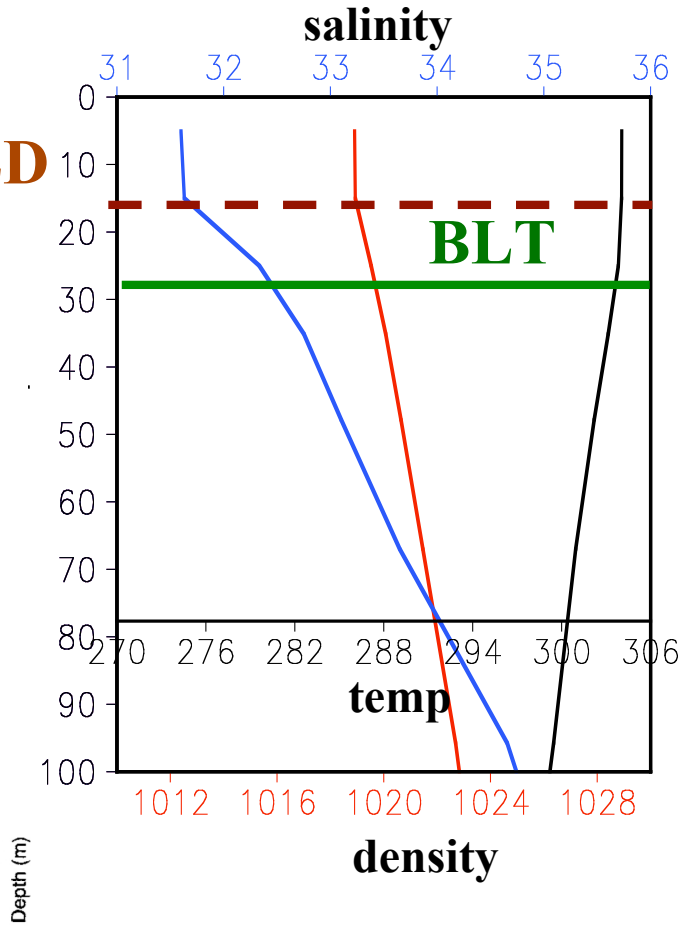
CNRM



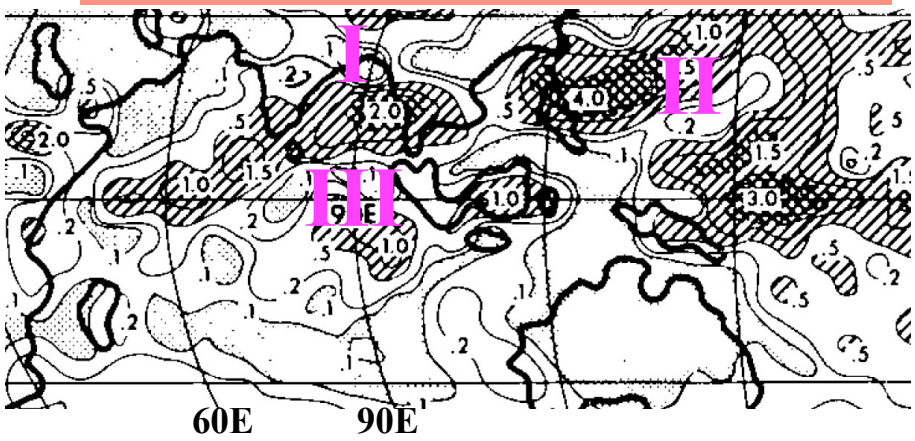
Observations



HadCM3

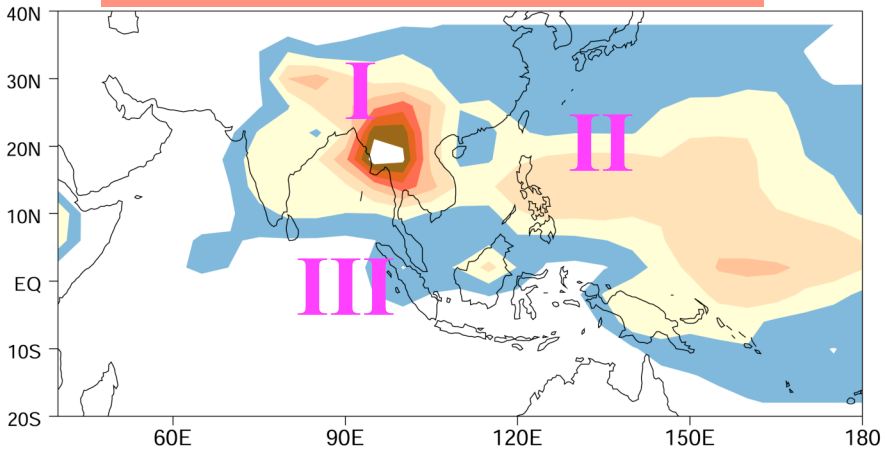


AGCM (~270 km, 11 levels)



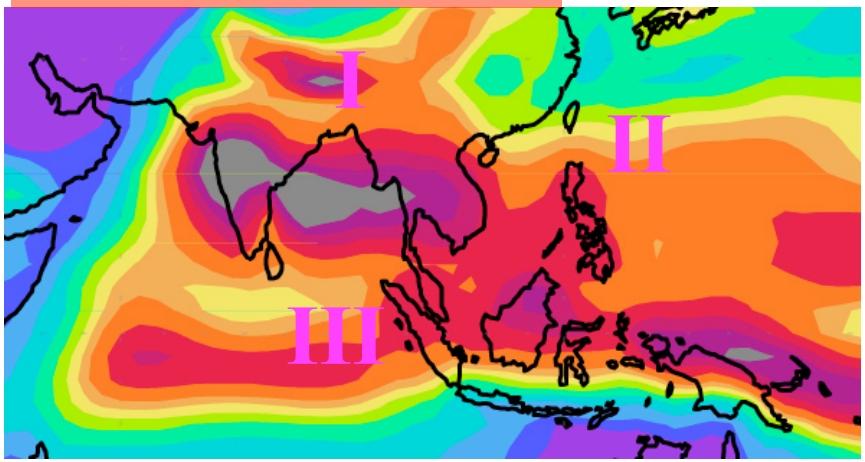
Manabe (1975)

AMIP-2 GFDL_DERF



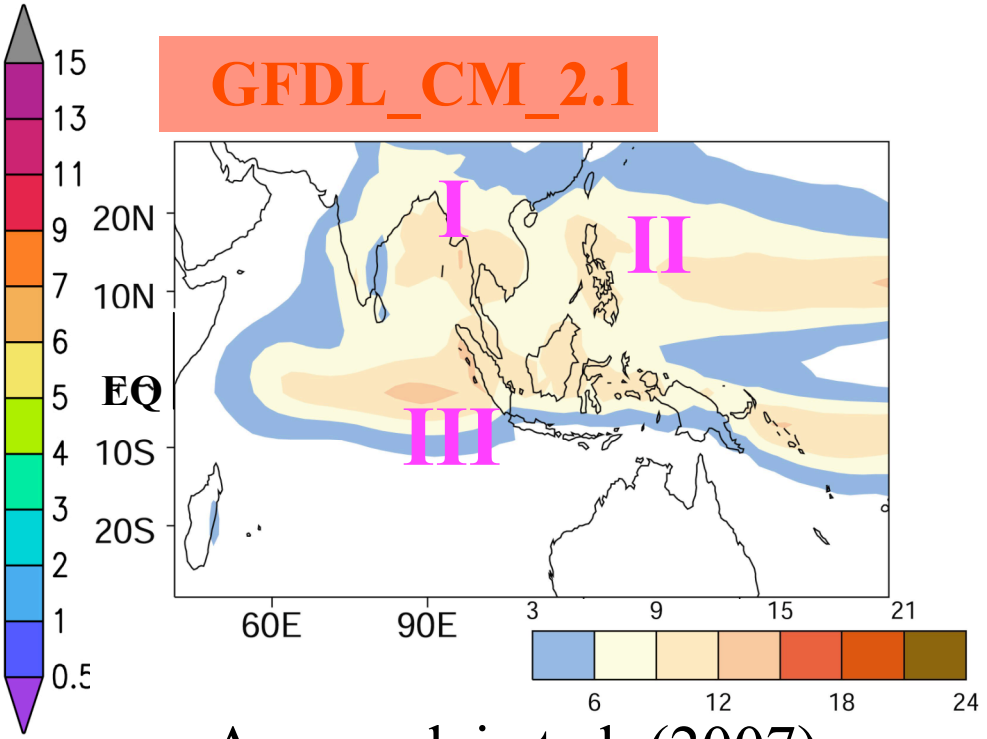
Sperber (1999)

AGCM (AM2.1)



Anderson et al. (2004)

GFDL_CM_2.1



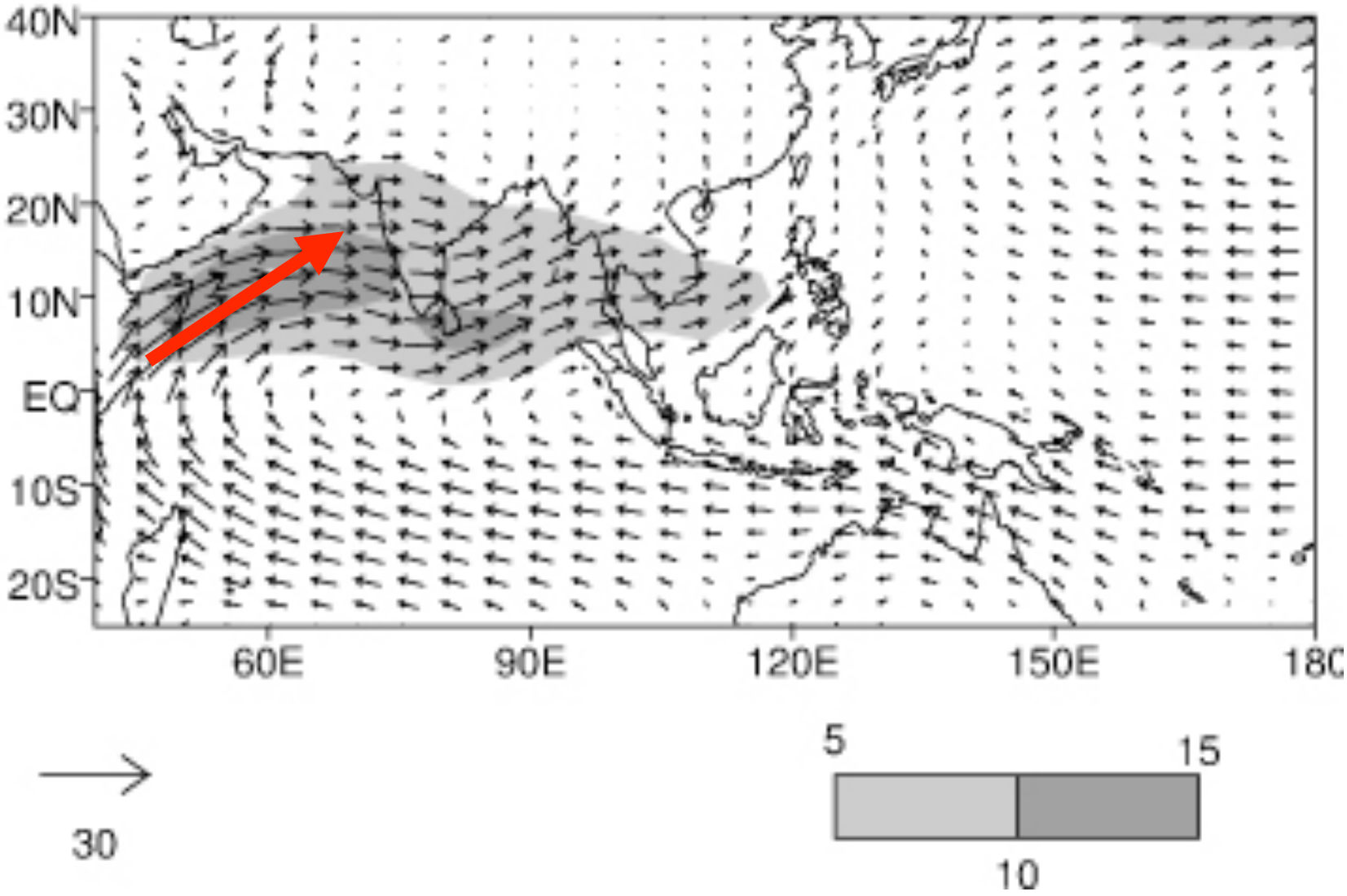
Annamalai et al. (2007)

Summary

- *Simulation of "monsoon basic state" is a necessary condition but a sufficient condition [ENSO-monsoon; ISOs (equatorial mode)]*

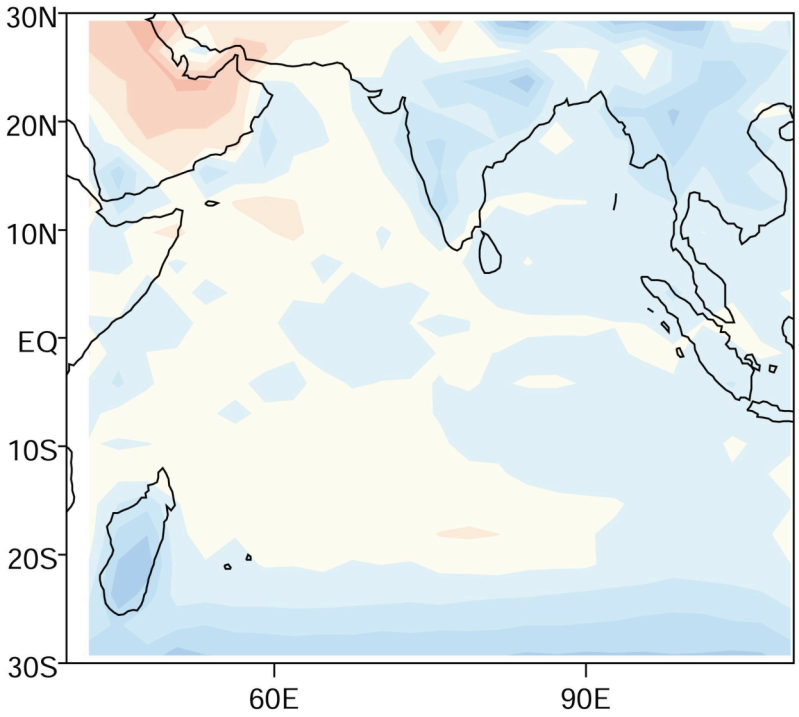
- *Future model development – Indian Ocean processes*

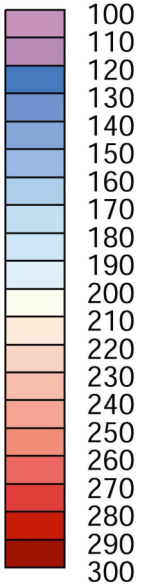
850hPa Winds



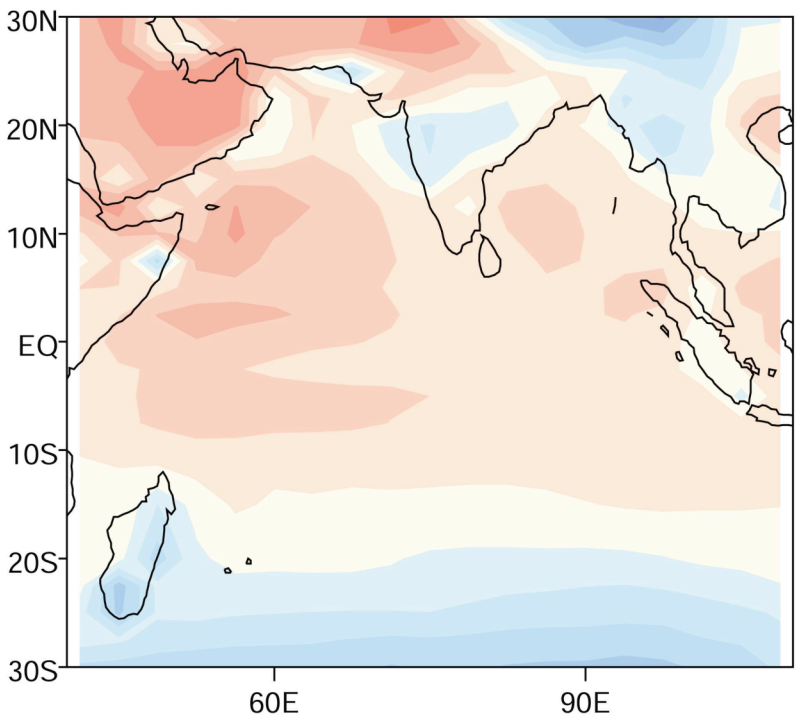
Q – net heating

CNRM_CM3



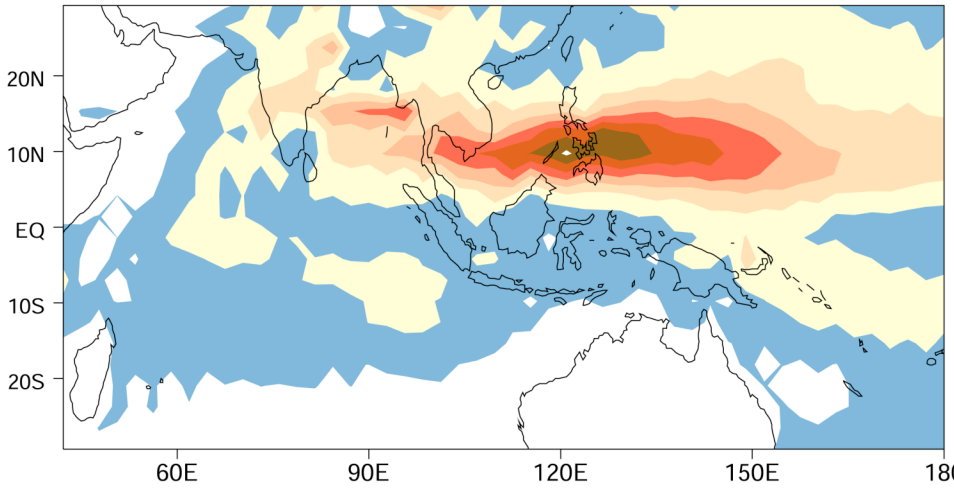


HadCM3

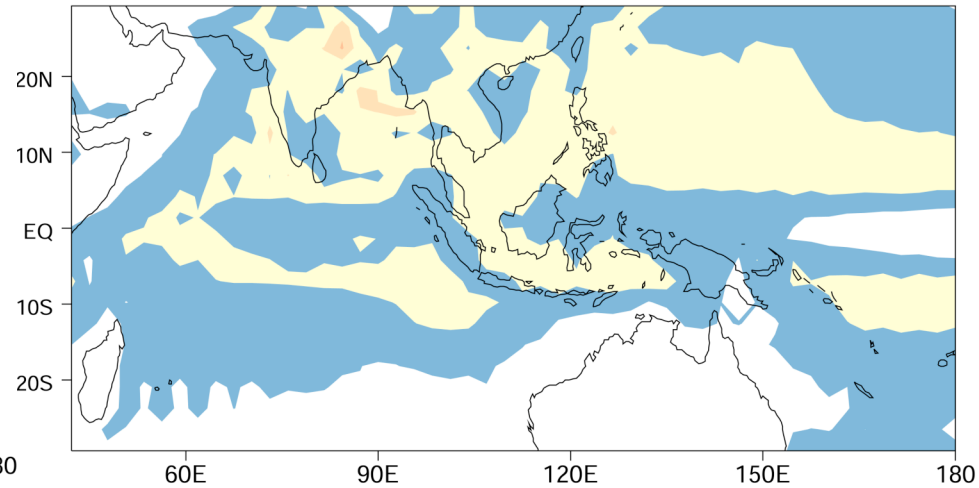


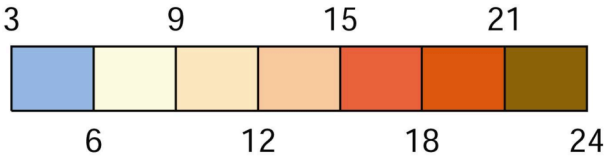
CNRM

Forced run

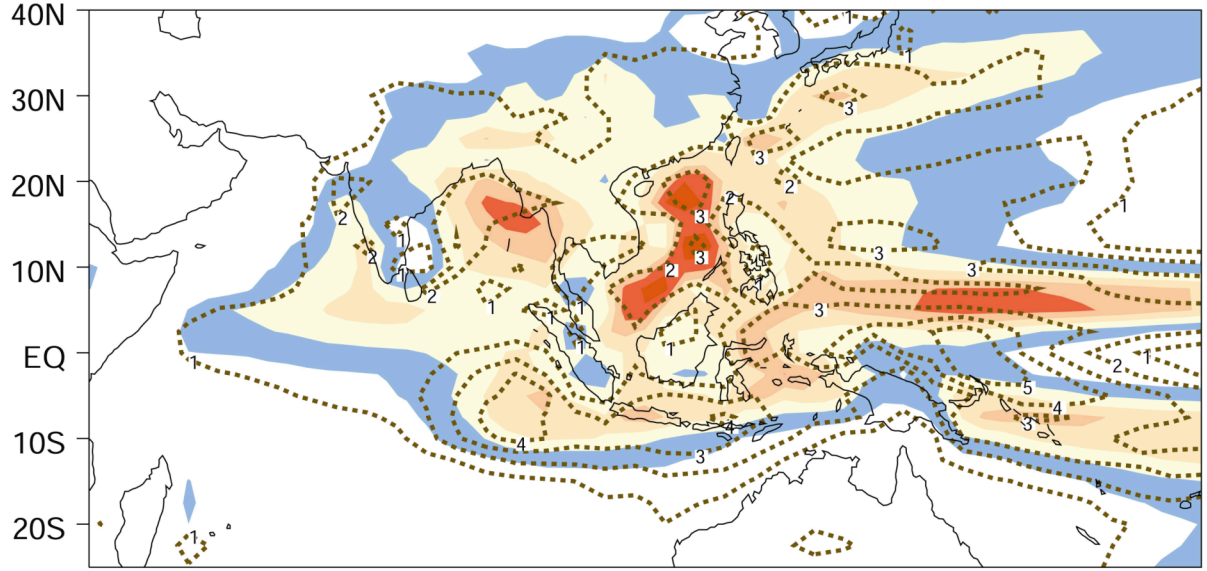


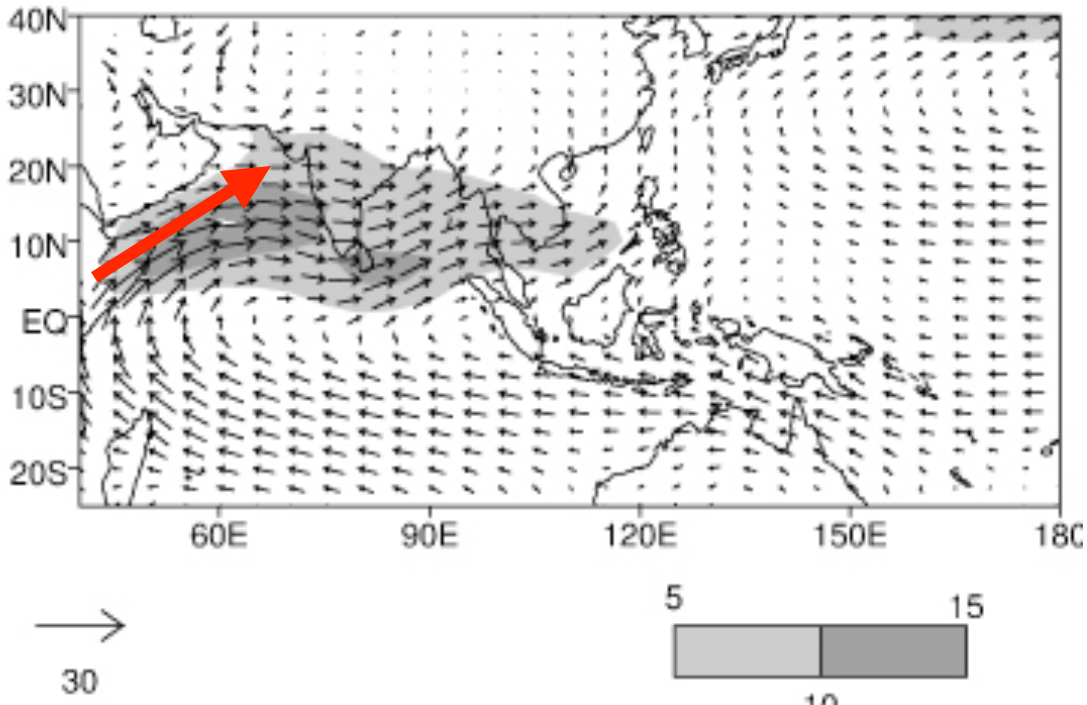
Coupled run





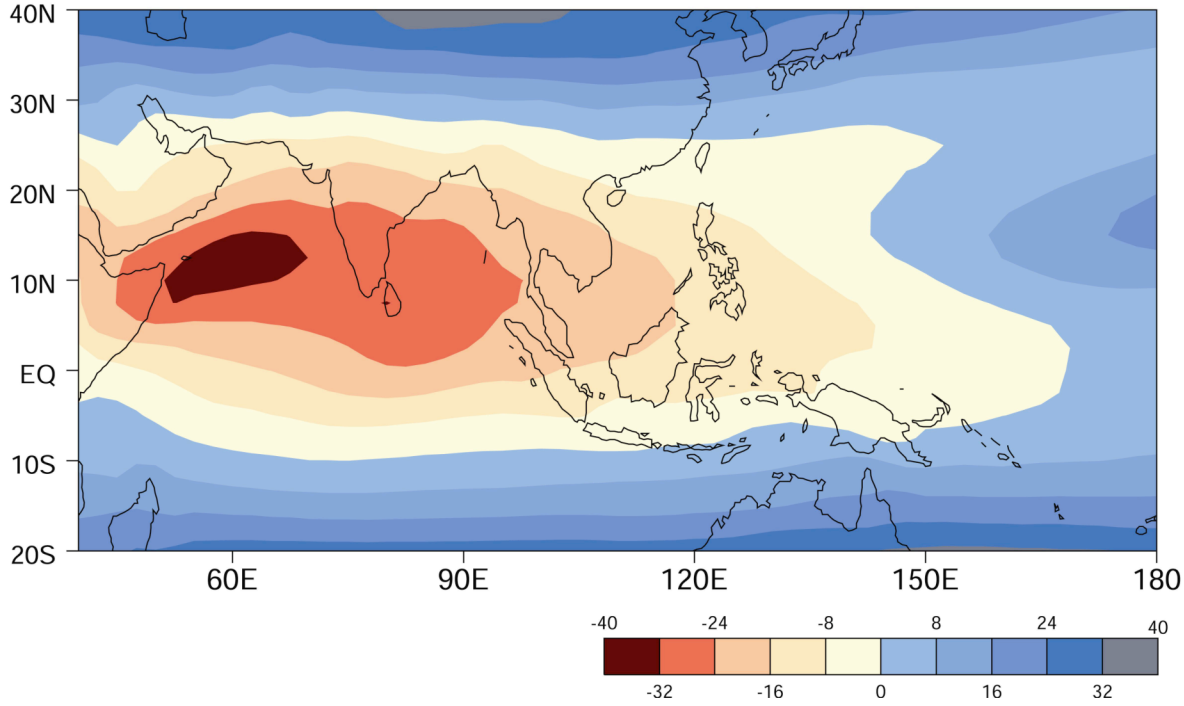
HadCM3





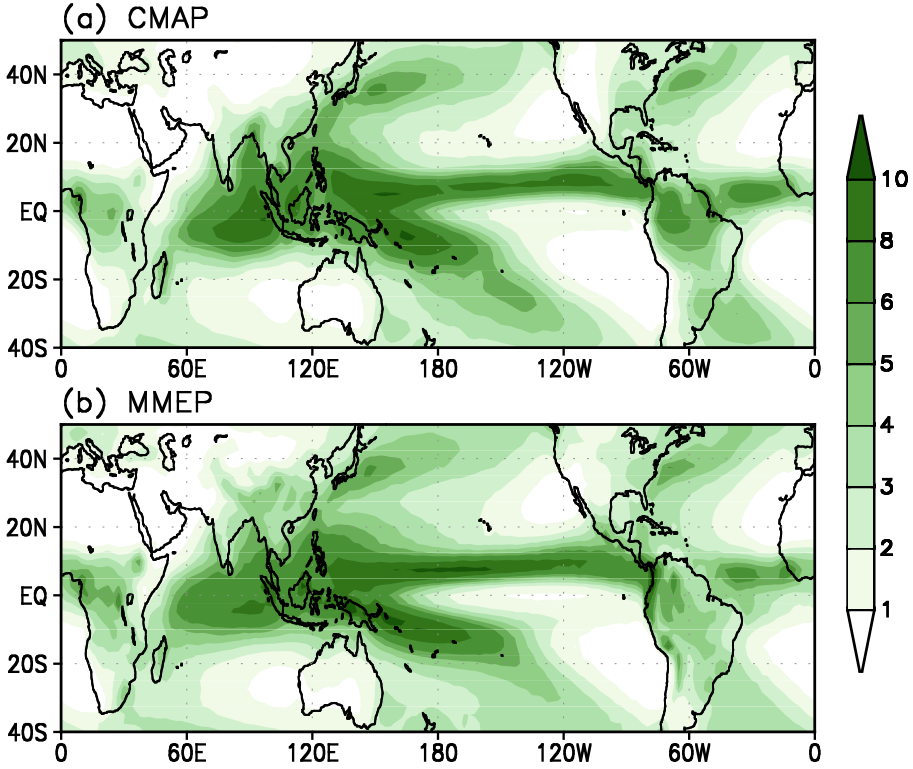
850hPa Winds

Vertical Shear
(U200 *minus* U850)



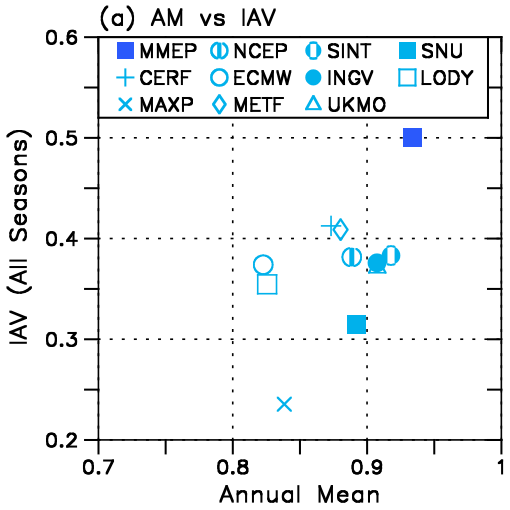
Performance on Annual Modes and its Linkage with Seasonal Prediction

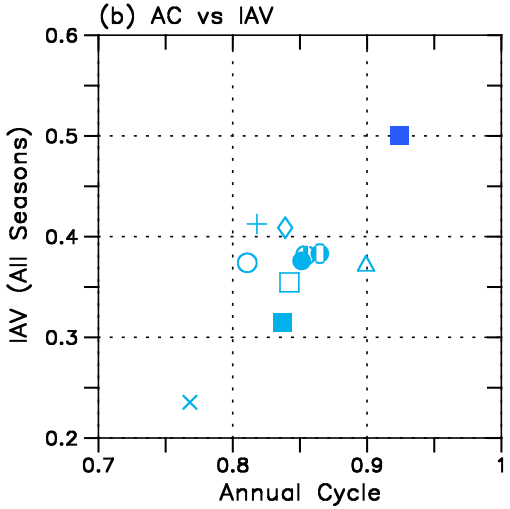
Annual Mean Precipitation



Performance on Annual mean, Annual Cycle, and Seasonal anomalies

Pattern Correlation Skill over the Global Tropics (0-360E, 30S-30N)

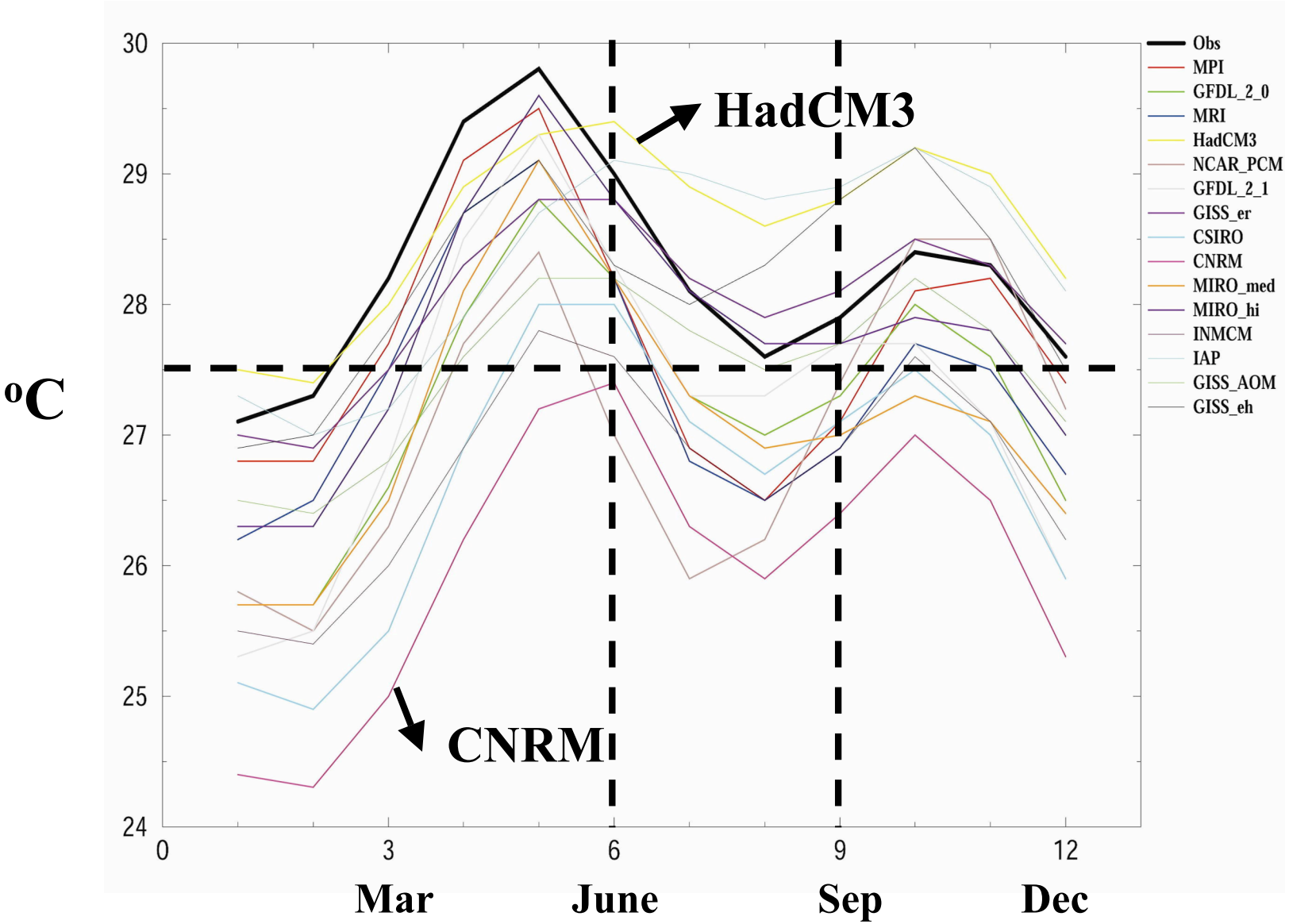




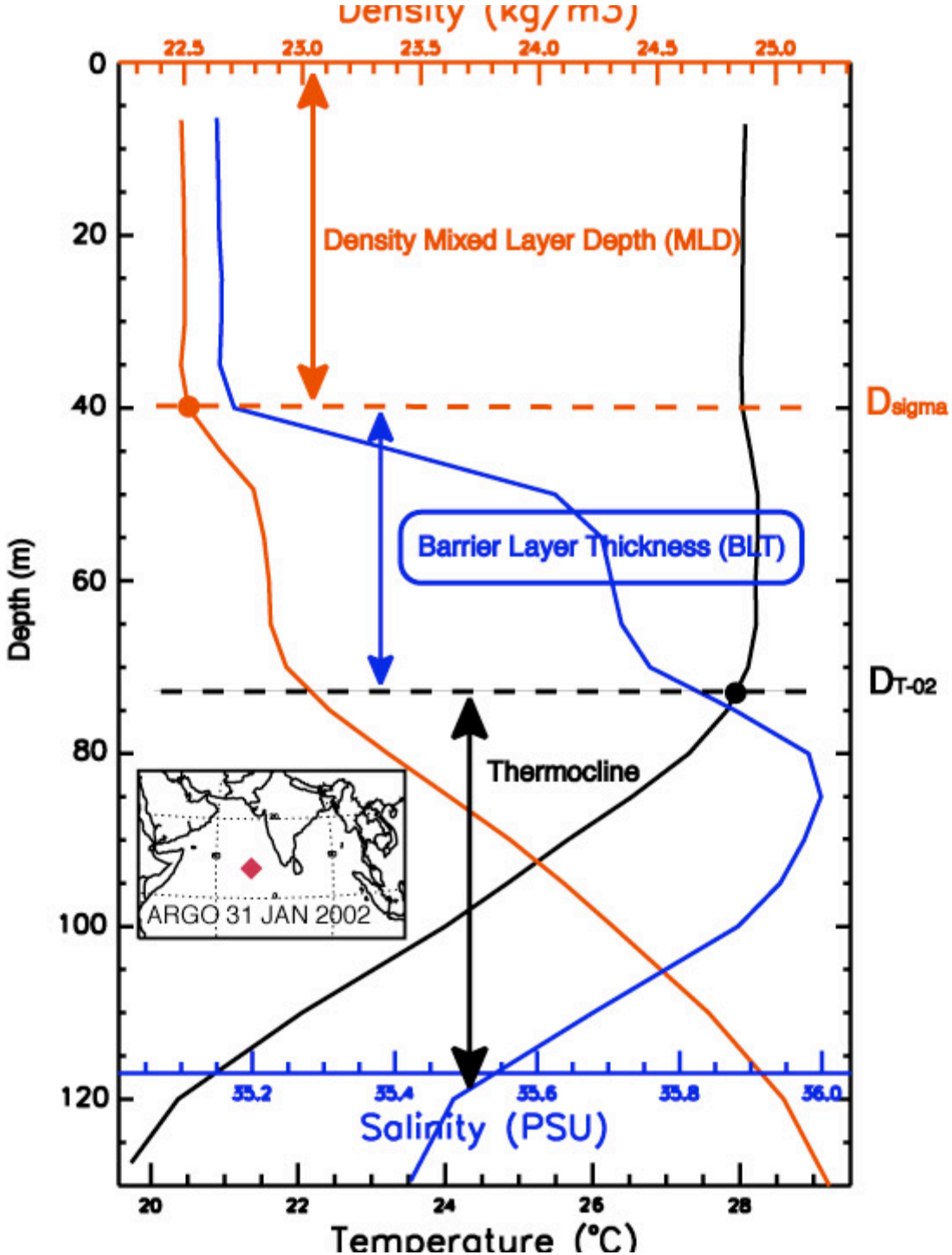
The models' performance in simulating and forecasting seasonal mean states is closely related to the models' capability in predicting seasonal anomalies.

Yune-Ji and Bin Wang (2007)

Annual Cycle of SST (80-100°E, 10-25°N)

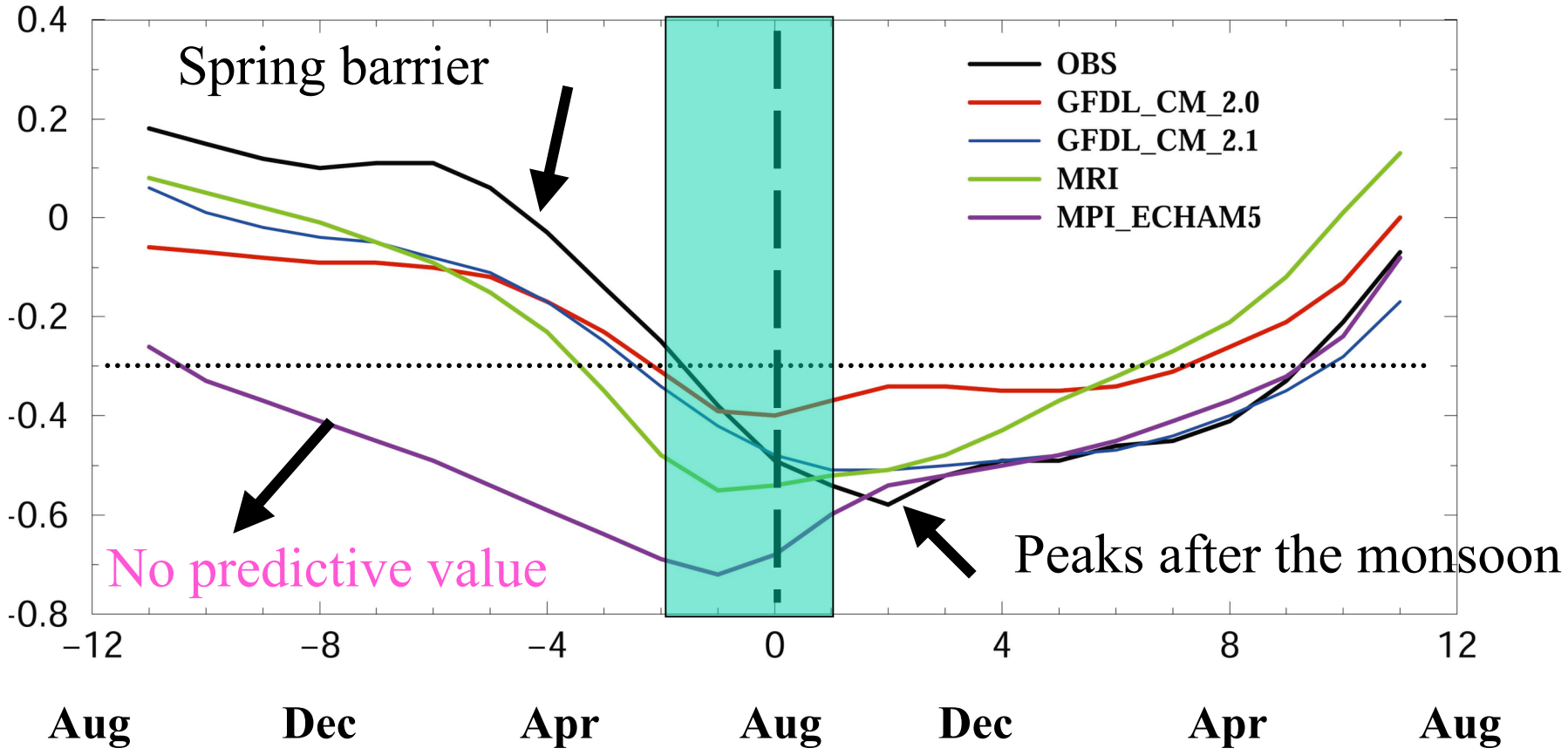


Simulated SST over Bay of Bengal is "weak" – cold bias


Density (kg/m3)
22.5
23.0
23.5
24.0
24.5
25.0
0
20
40
60
80
100
120
Depth (m)
Density Mixed Layer Depth (MLD)
Dsigma
Barrier Layer Thickness (BLT)
DT-02
Thermocline
ARGO 31 JAN 2002
35.2
35.4
35.6
35.8
36.0
Salinity (PSU)
20
22
24
26
28
Temperature (°C)

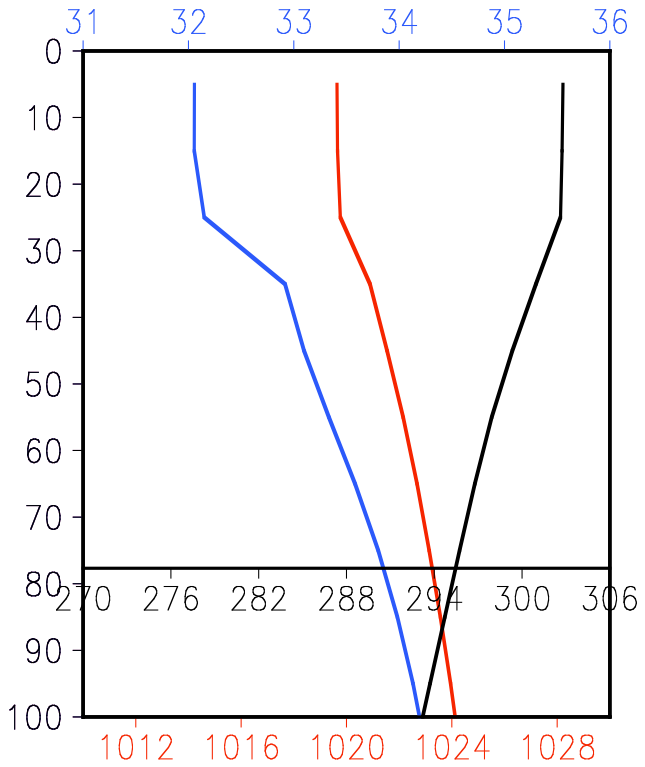
20c3m Integrations

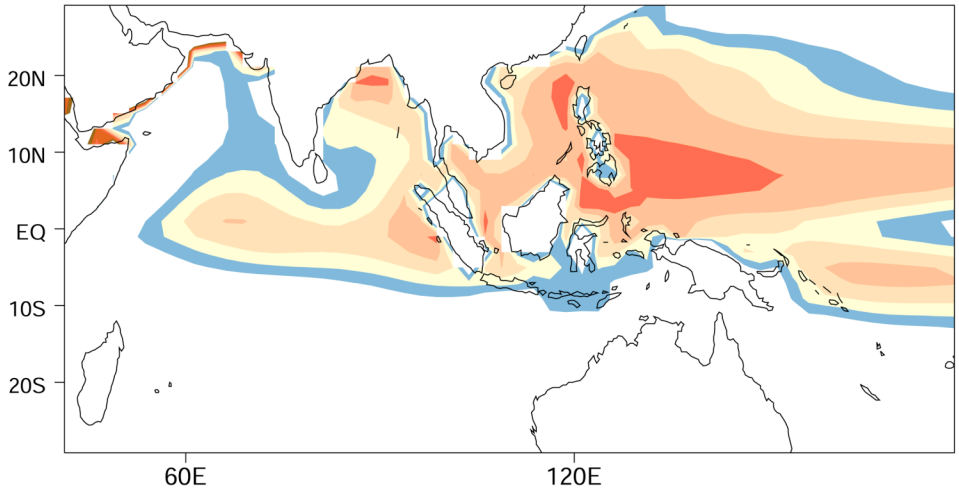
Lead/lag relationship between AIR and NINO3.4 SST



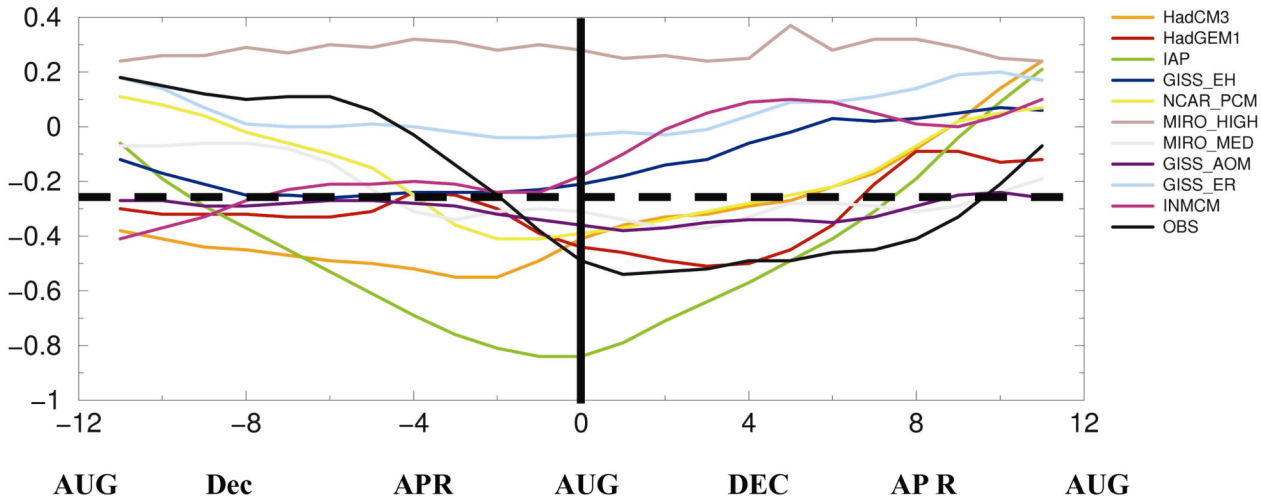
"except in CM_2.1 the phasing of the relationship is incorrect. However, the intensity of ENSO is too strong in GFDL_CM2.1"

GFDL

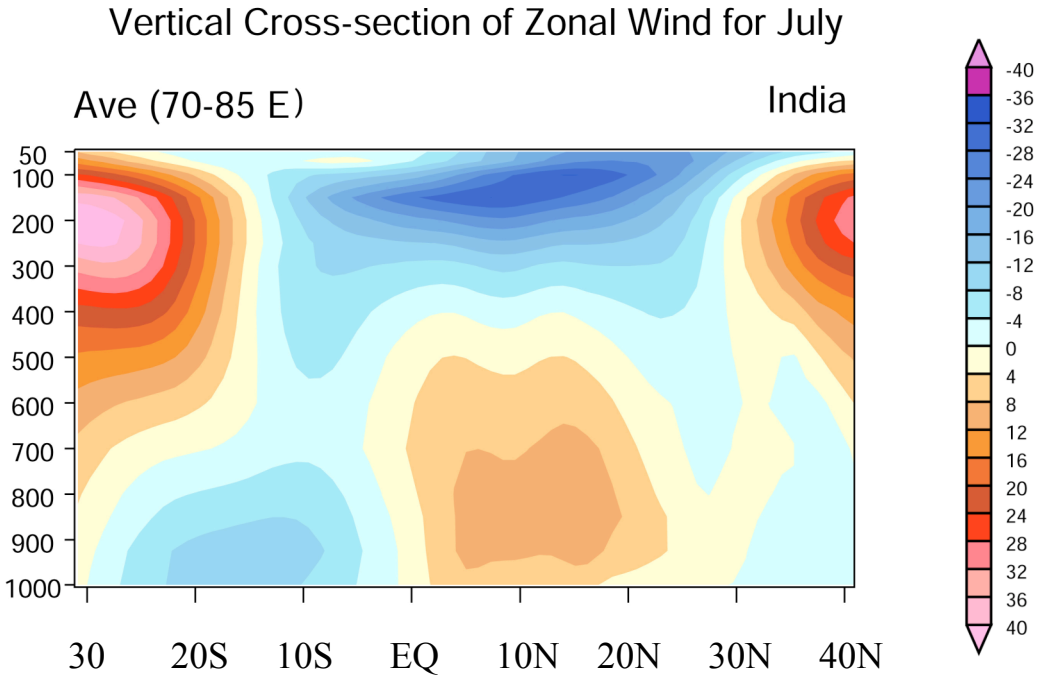

31
32
33
34
35
36
0
10
20
30
40
50
60
70
80
90
100
270
276
282
288
294
300
306
1012
1016
1020
1024
1028


20N
10N
EQ
10S
20S
60E
120E

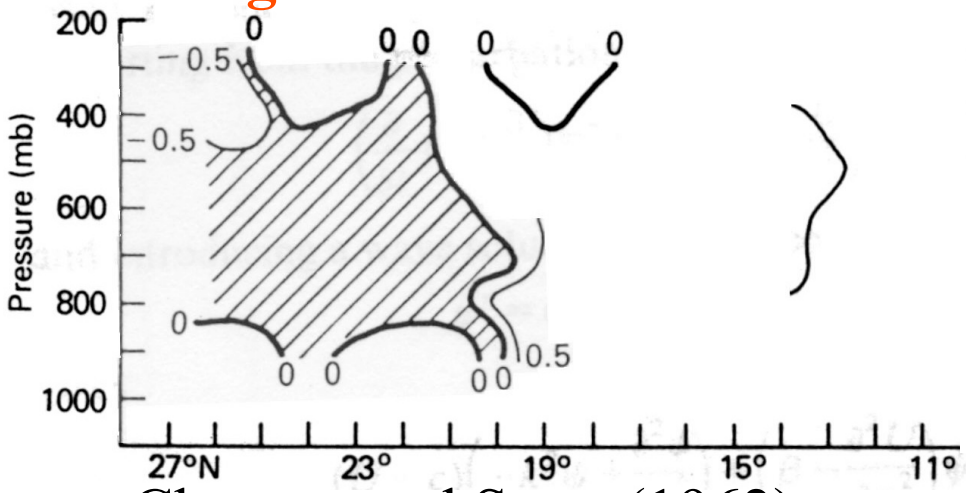
ENSO-monsoon association…..



“realistic simulation of both ENSO and monsoon are required”

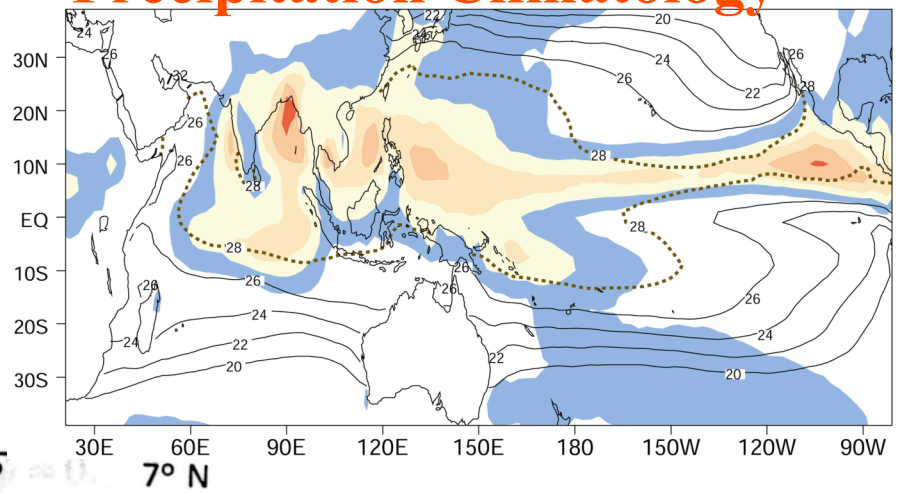


PV gradient



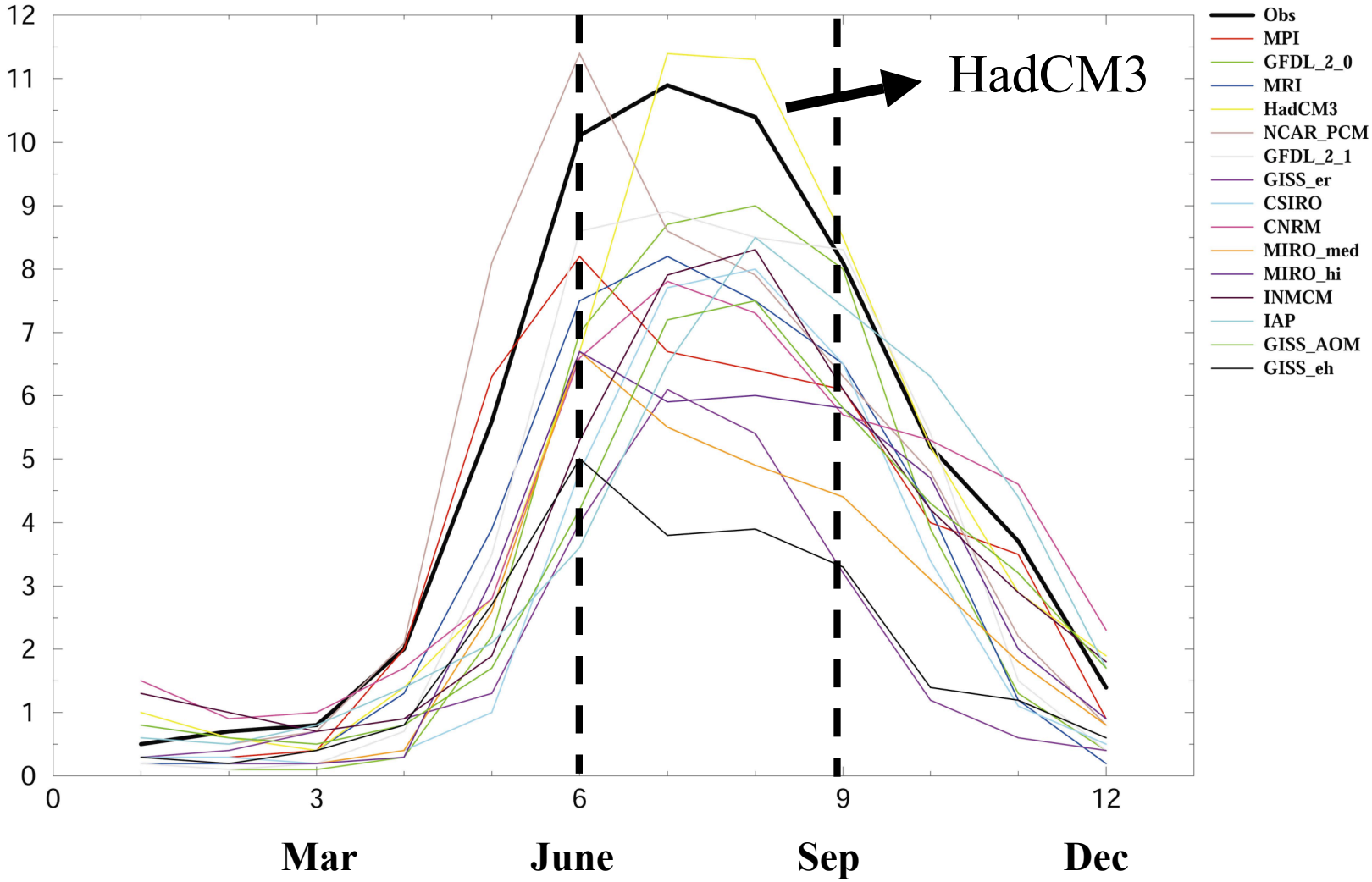
Charney and Stern (1962)

Precipitation Climatology



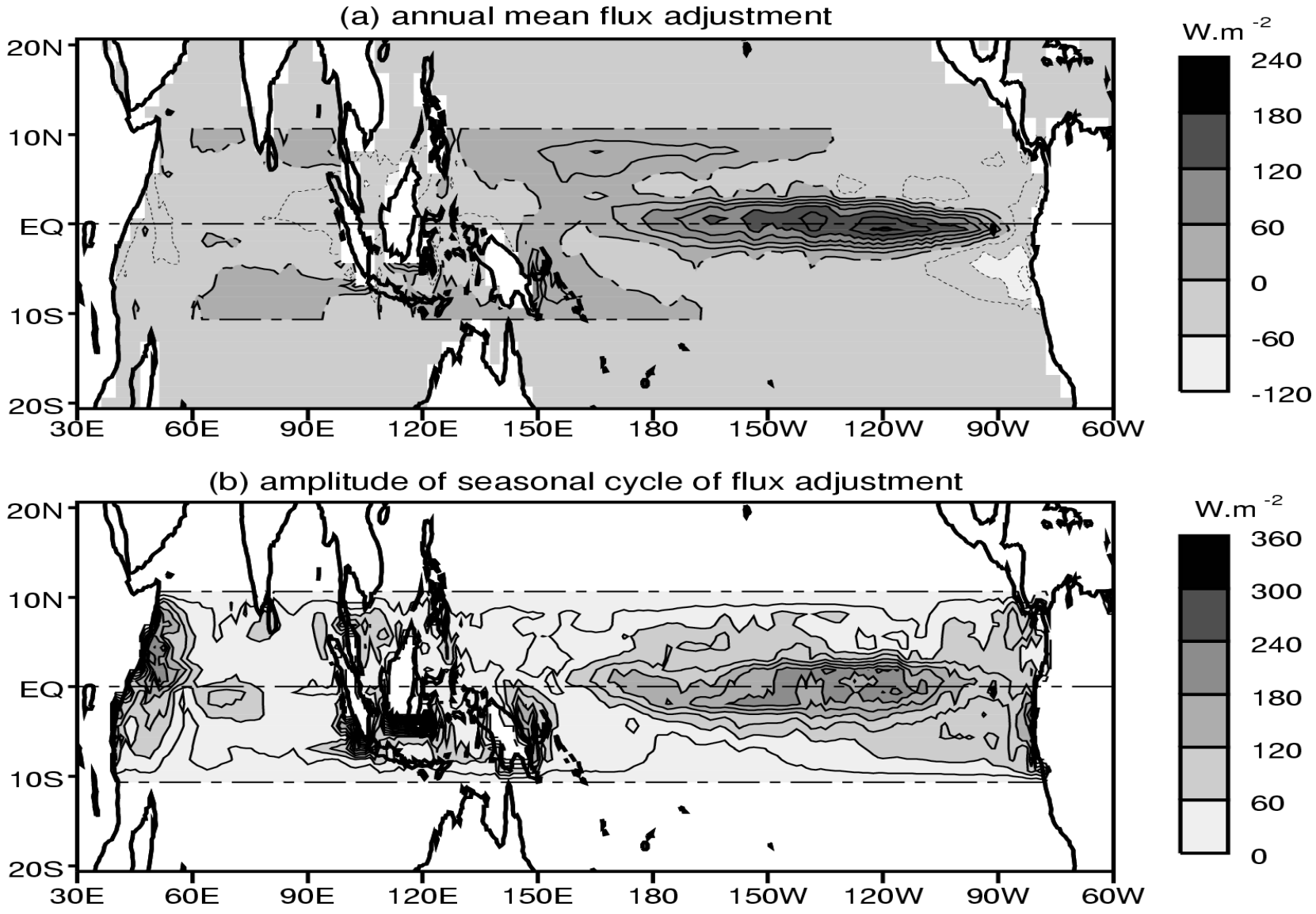
Dickinson and Molinari (2000)

Annual Cycle of Precipitation (80-100°E, 10-25°N)



"Except HadCM3, all coupled models simulate weak monsoon"

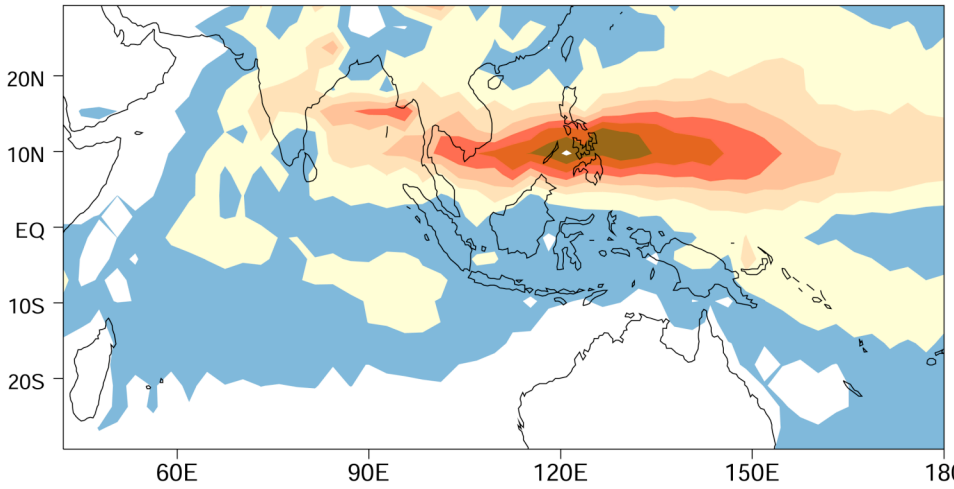
Flux correction applied between 10^0N and 10^0S



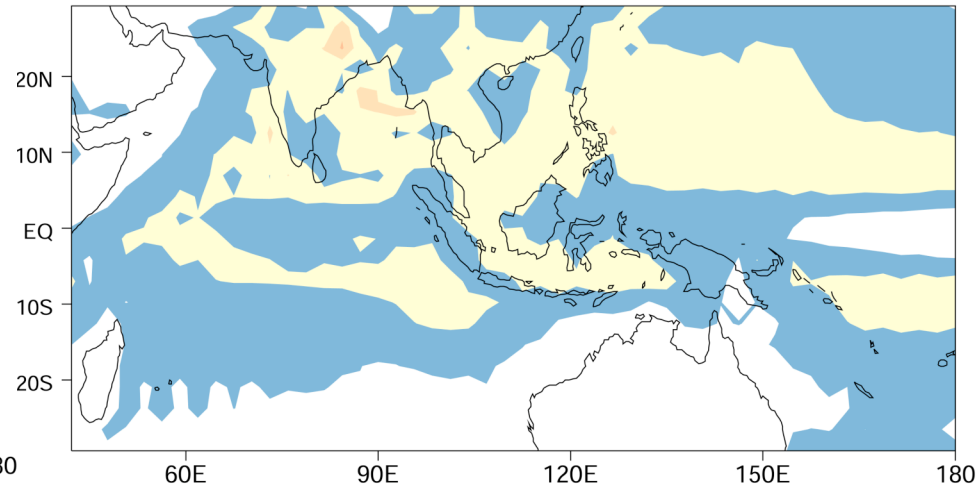
Turner et al. 2005, QJRMS

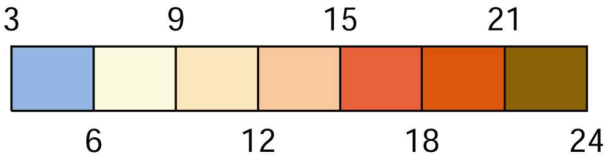
CNRM

Forced run

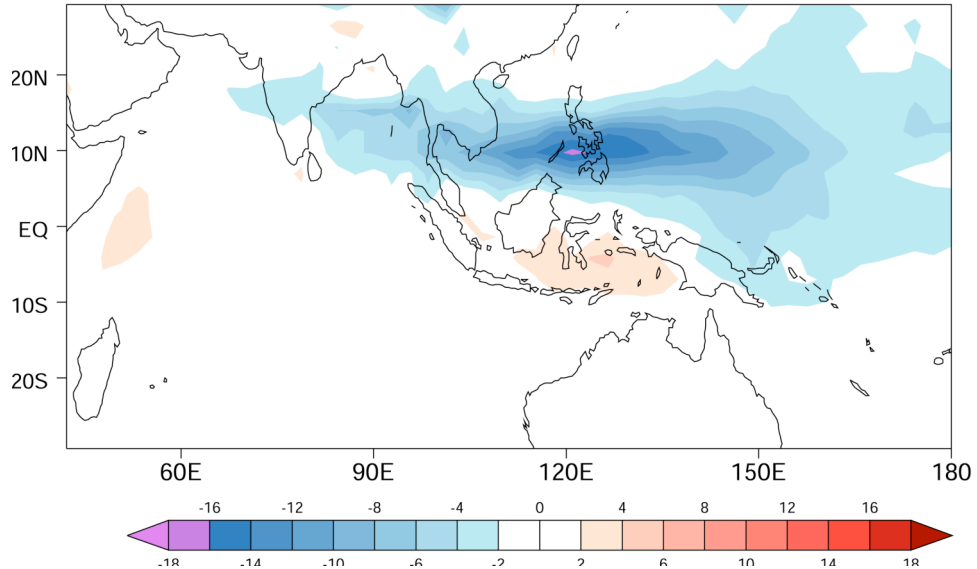


Coupled run



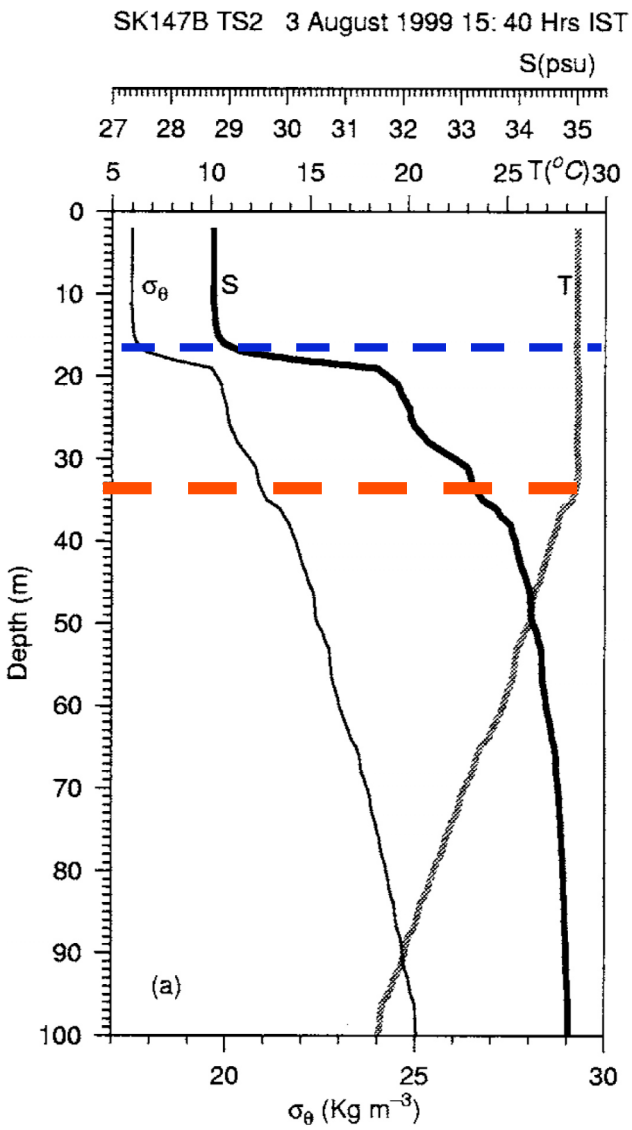


Difference (Coupled *minus* Forced)



"Simulated precipitation too weak in the Coupled run"

North Bay

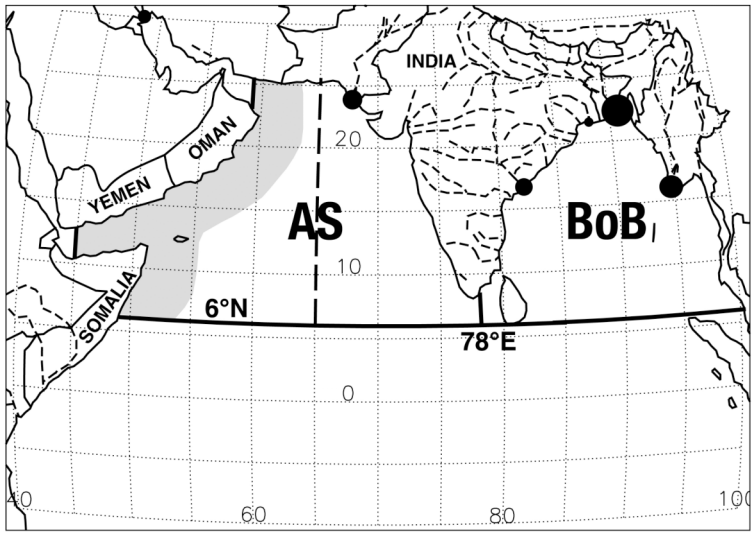


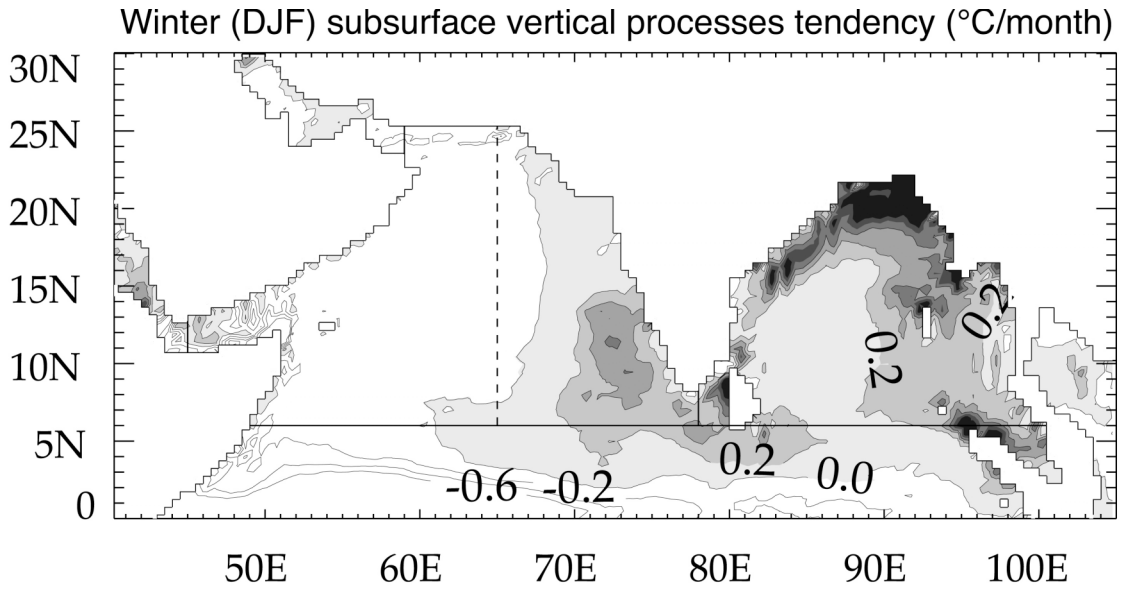
MLD

BLT

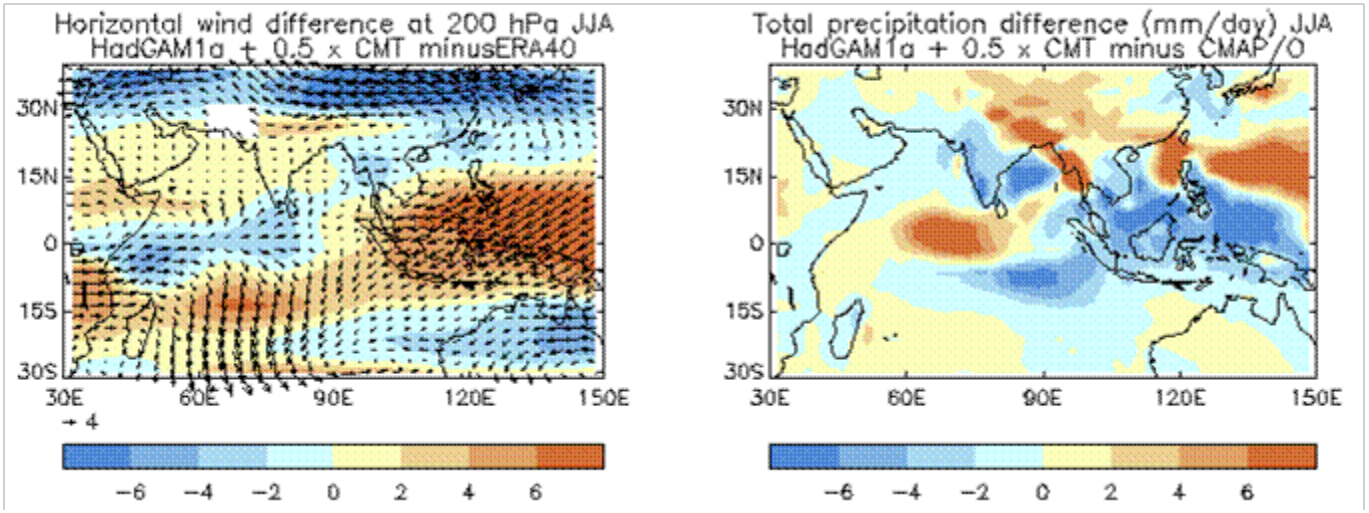
Courtesy: Murty (NIO)

River discharge



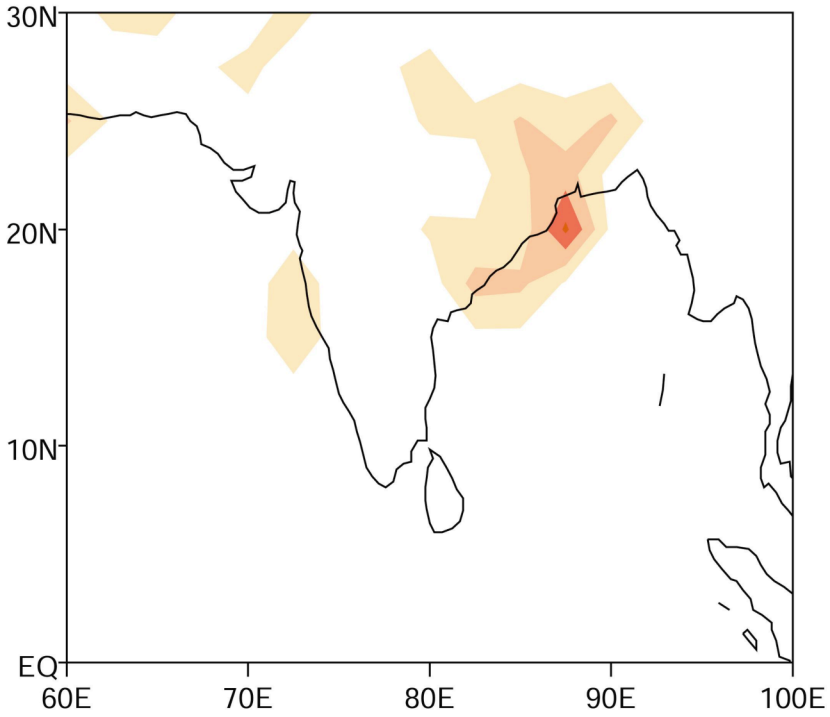


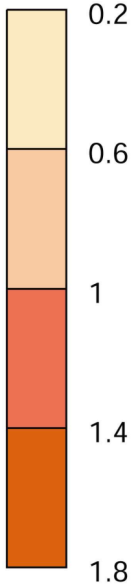
Montegut et al. (2007, J. Climate)


Horizontal wind difference at 200 hPa JJA
HadGAM1a + 0.5 x CMT minusERA40
30N
15N
0
15S
30S
30E
60E
90E
120E
150E
→ 4
−6 −4 −2 0 2 4 6
Total precipitation difference (mm/day) JJA
HadGAM1a + 0.5 x CMT minus CMAP/O
30N
15N
0
15S
30S
30E
60E
90E
120E
150E
−6 −4 −2 0 2 4 6

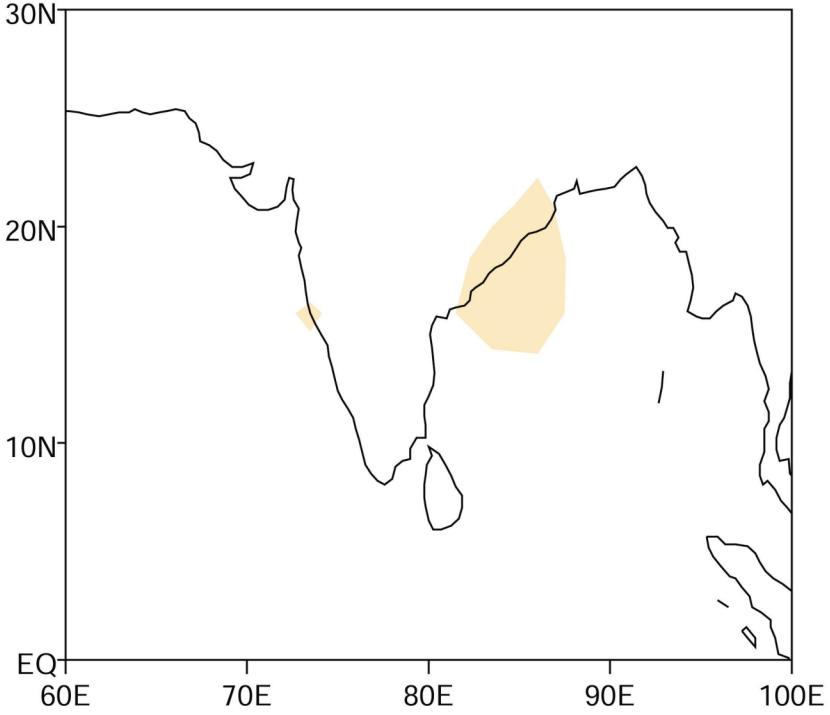
Genesis density of storms/monsoon depressions

ERA-40





GFDL_CM2.1



"too few storms generated – phase of the ISO"