# Local vs. Remote SST Forcing in Shaping the Asian-Australian Monsoon Variability

**Tim Li**

**IPRC and Dept. of Meteorology, Univ. of Hawaii**

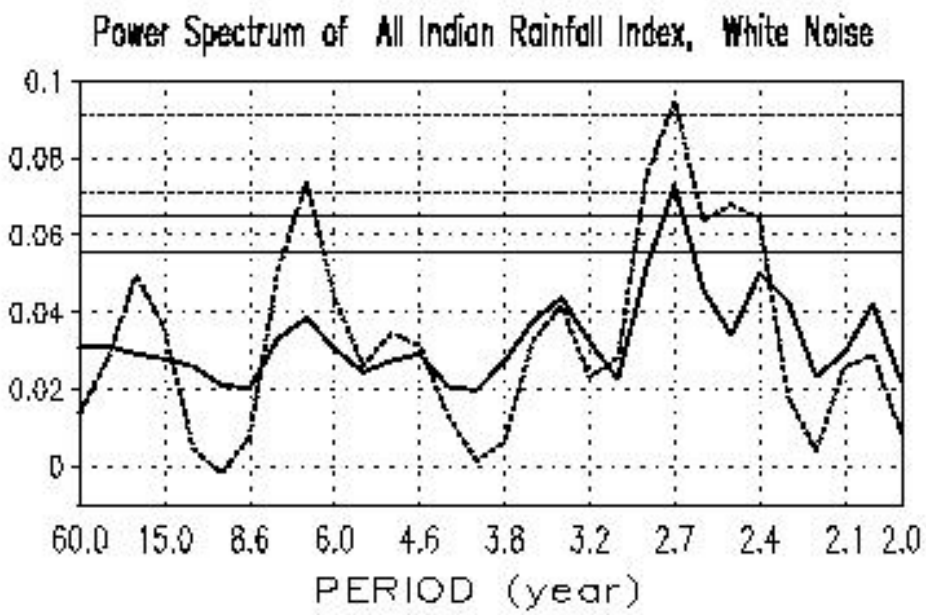
Acknowledgement. B. Wang, C.-P. Chang, P. Liu, X. Fu, Y. Zhang, Kug

# Outline

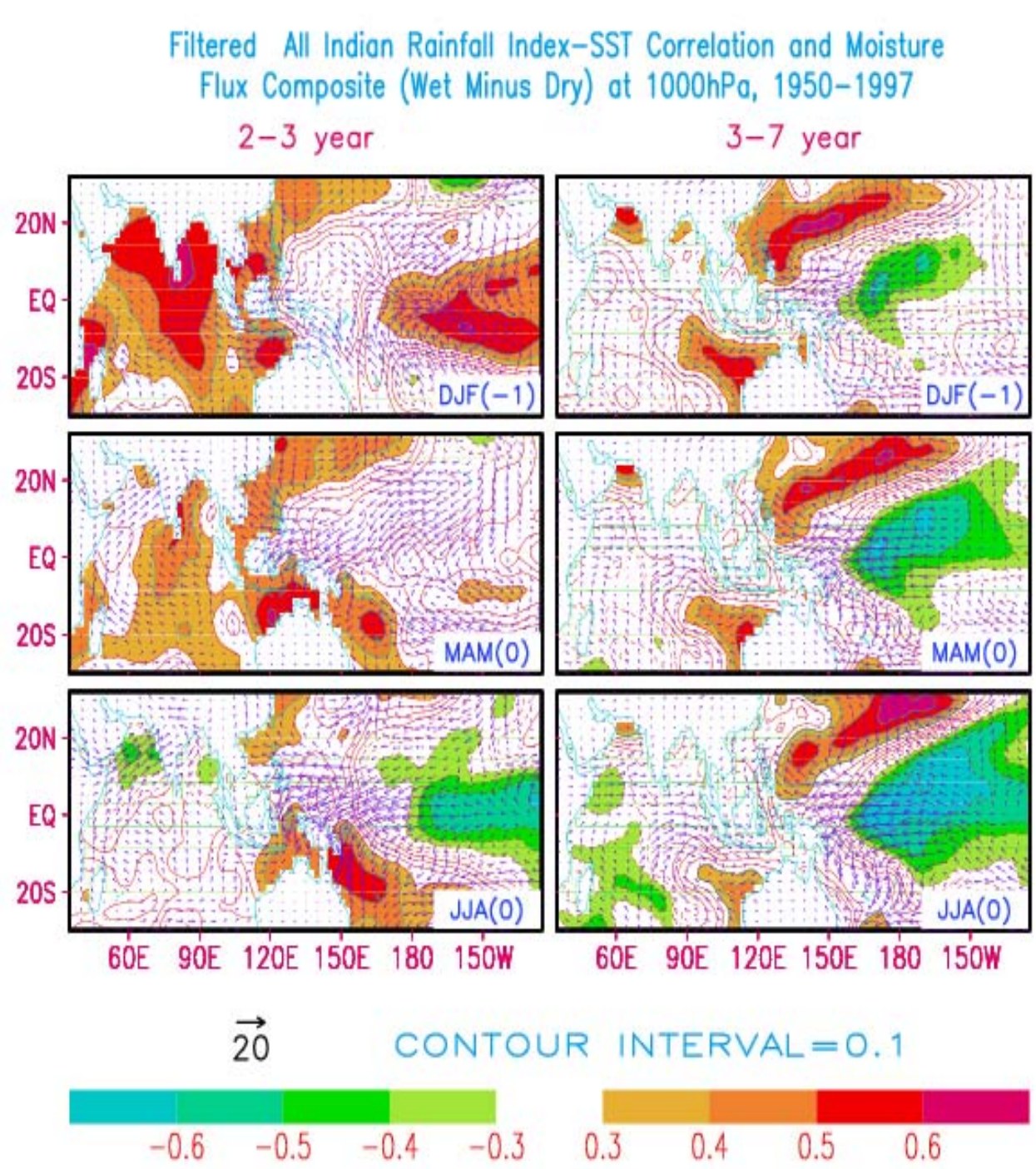
- Variability of Indian monsoon
- Indian-Australian monsoon in-phase relationship
- TBO structure and origin
- Relative role of remote vs. local SSTA forcing:
  - An AGCM study

Indian Ocean SST has been long thought to play a weaker role in Indian monsoon rainfall than does the EEP SST.

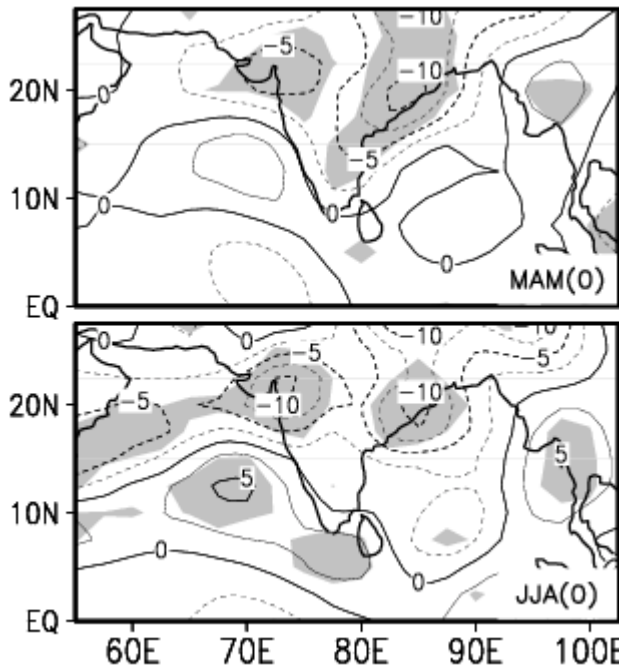
In the first part we show that on the quasi-biennial time scale the AIR has significant positive correlations with IO SSTA and local moisture transport in preceding spring and winter.



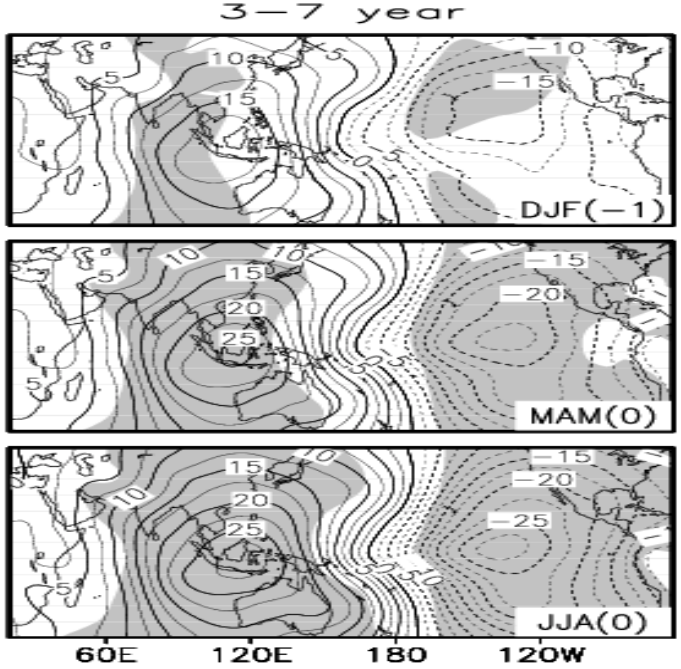

Q: What processes are responsible for the QB and LF interannual variabilities of the Indian monsoon rainfall?

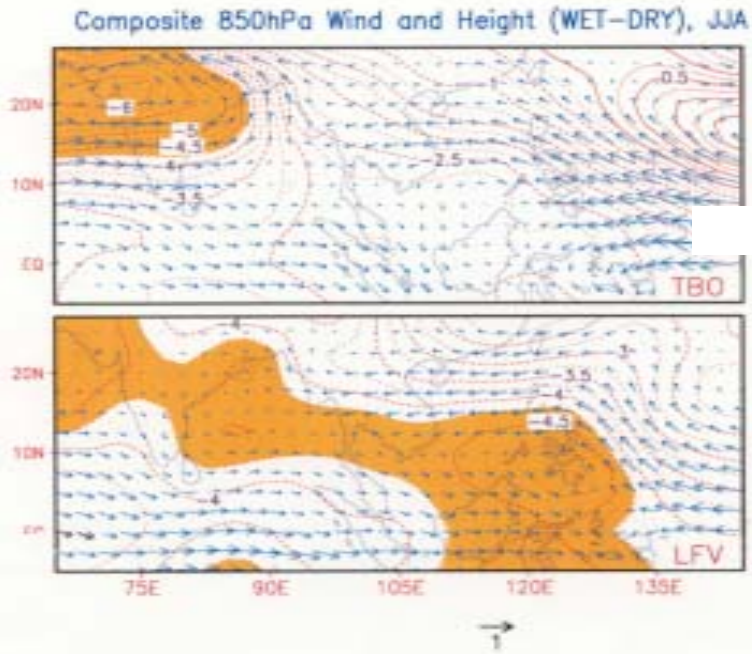


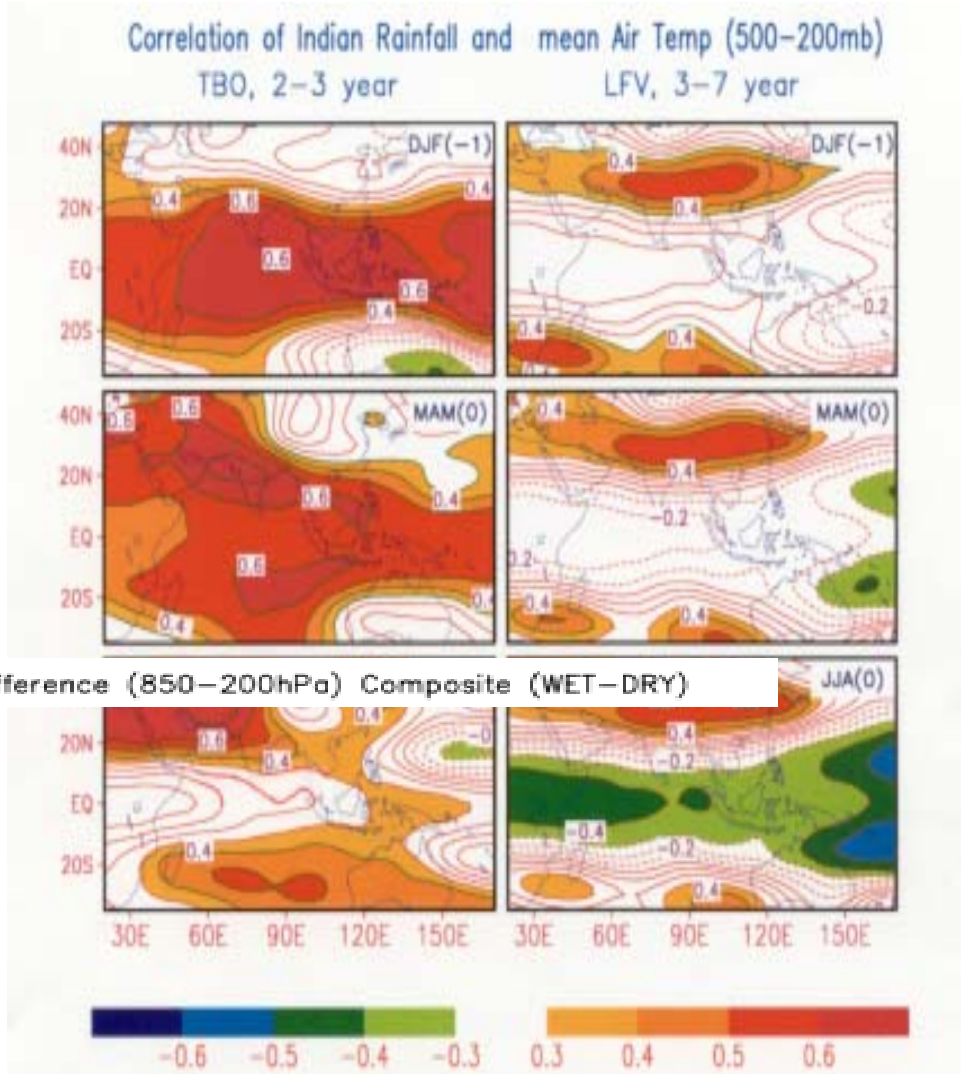

**1000hPa moisture flux convergence (2-3 yr)**

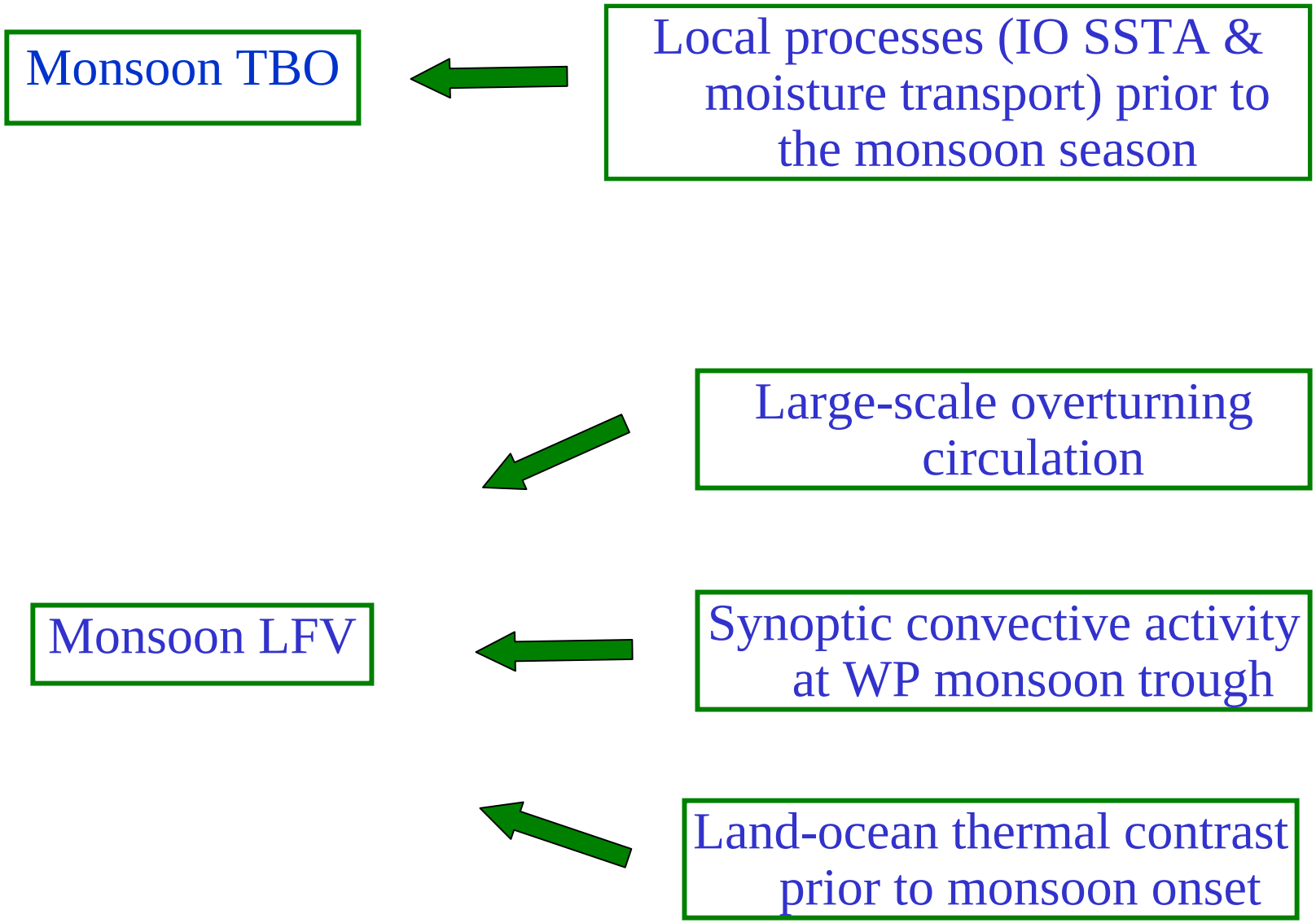


1. Large-scale east-west circulation
2. Land-ocean thermal contrast
3. Synoptic wave activity/monsoon trough in WP




Monsoon TBO
Local processes (IO SSTA & moisture transport) prior to the monsoon season
Large-scale overturning circulation
Monsoon LFV
Synoptic convective activity at WP monsoon trough
Land-ocean thermal contrast prior to monsoon onset

# 2. Indian-Australian monsoon in-phase relationship

*Why does a strong (weak) Australian monsoon often follow a strong (weak) Indian monsoon?*

From Unfiltered data

| India WET → Australia WET | India DRY → Australia DRY | India DRY → Australia WET | India WET → Australia DRY |
|---|---|---|---|
| 10 | 9 | 1 | 3 |

| Australia WET → India WET | Australia DRY → India DRY | Australia DRY → India WET | Australia WET → India DRY |
|---|---|---|---|
| 3 | 7 | 8 | 6 |

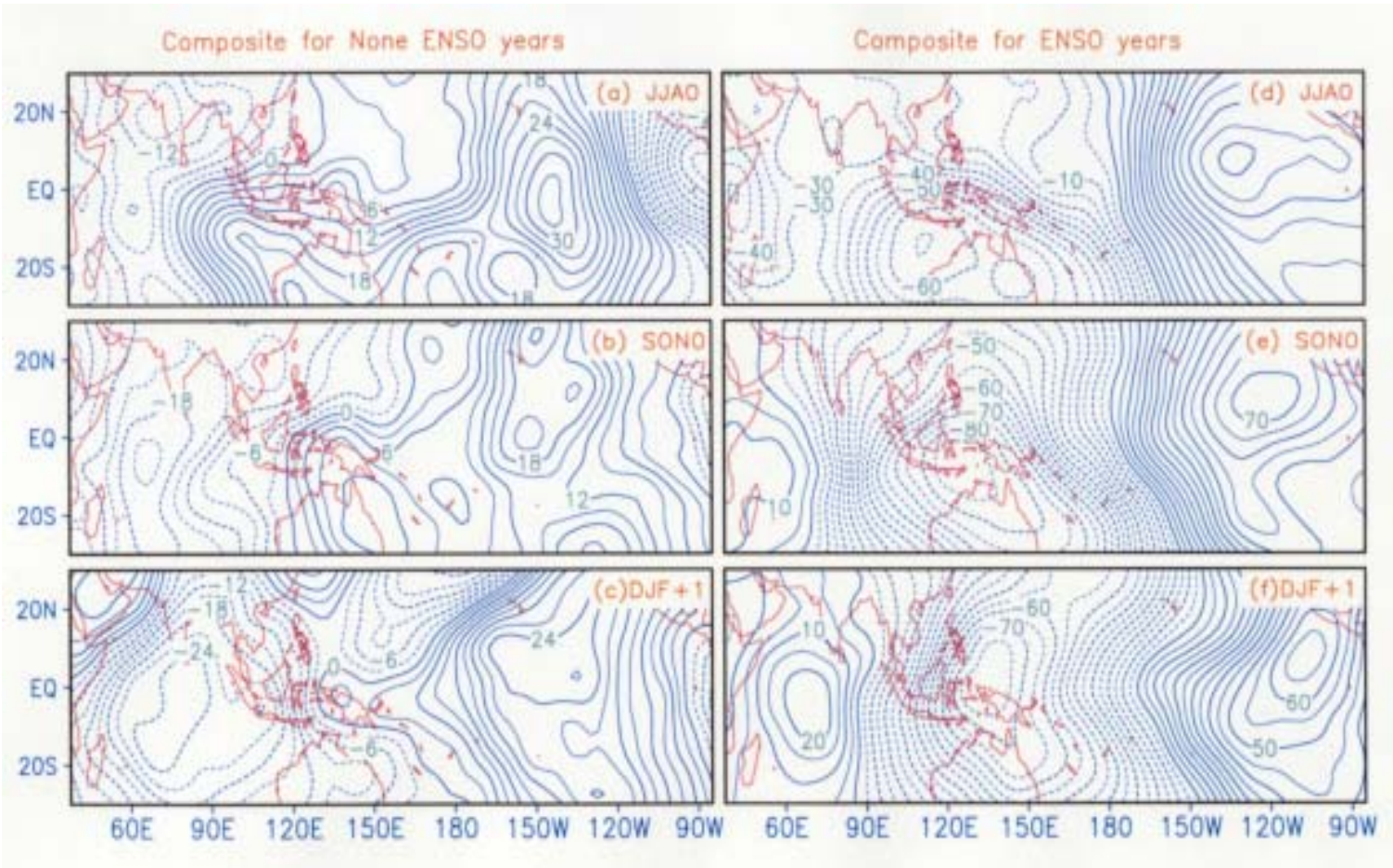
A simple explanation of this in-phase relationship is that both the Indian and Australian monsoons are controlled by ENSO.

$I_{wet} \Longrightarrow A_{wet}$

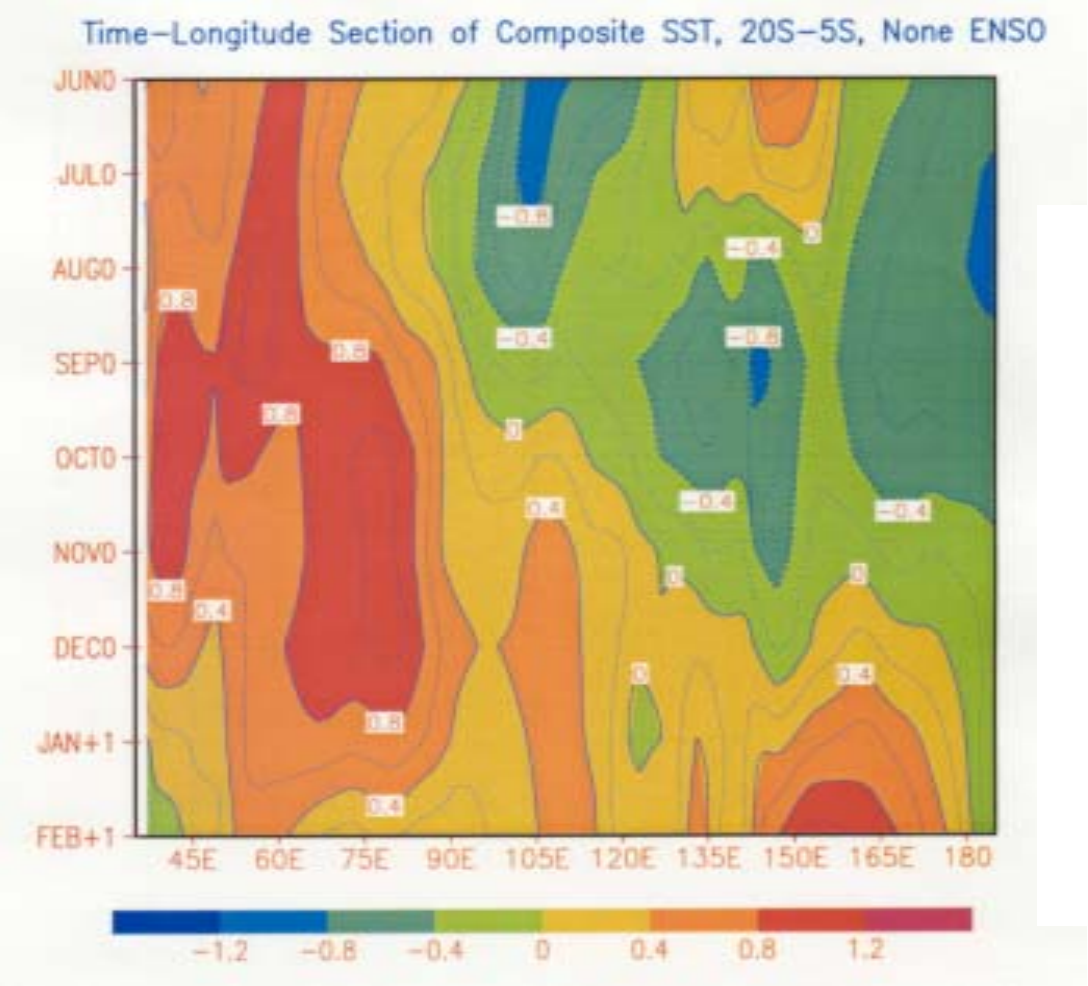
| La Nino | Normal |
|---|---|
| 1954 1956 1971 1973 1975 | 1978 1980 1983 1990 1994 |

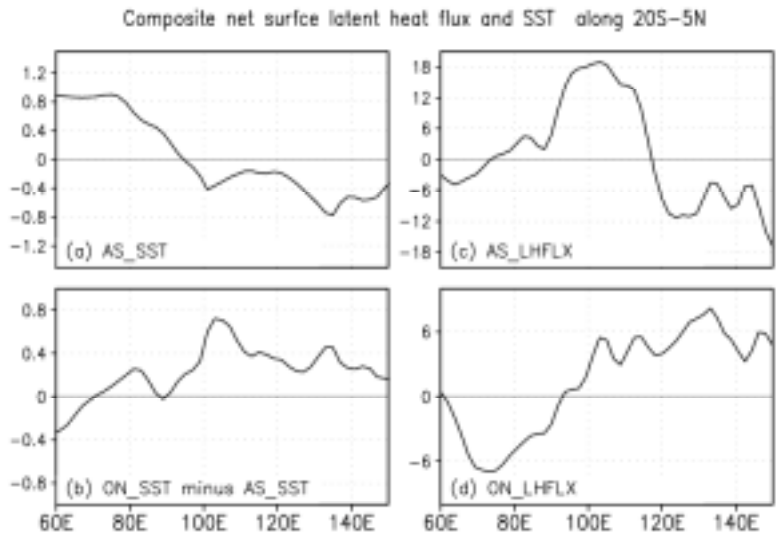
$I_{dry} \Longrightarrow A_{dry}$

| El Nina | Normal |
|---|---|
| 1951 1965 1982 1986 1987 1991 | 1968 1985 1992 |

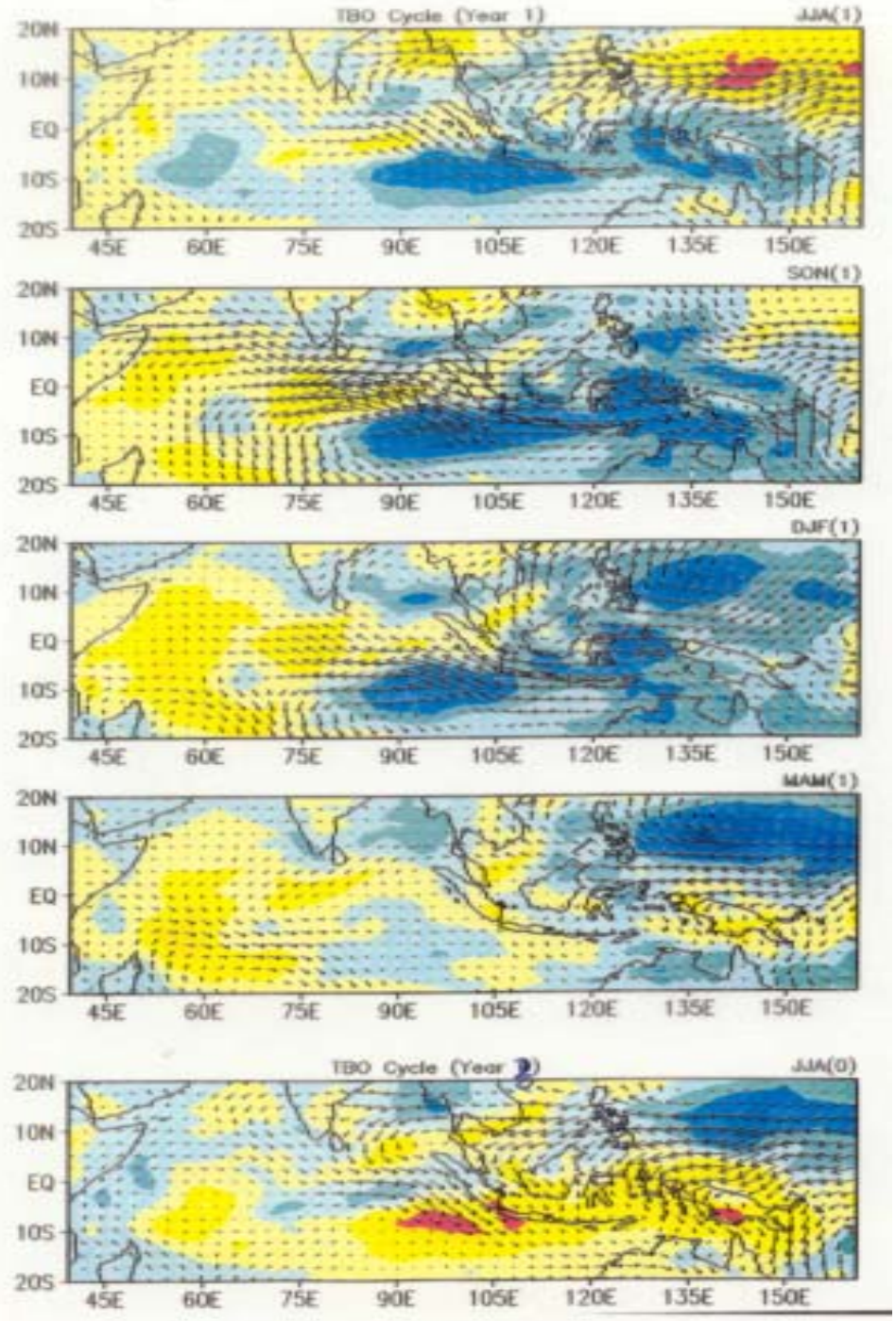



**Velocity potential difference fields**




The result suggests that Indian Ocean SSTA may play a active role in bridging the Indian and Australian summer monsoons.




# 3. Seasonally evolving TBO pattern and its origin

Seasonal-sequence EOF analysis using NCAR/NCEP reanalysis data (1950-1999)

Shading: rainfall

Vector: 925mb wind

200mb wind: first baroclinic mode structure

*Data: seasonal mean (DJF, MAM, JJA, SON) fields of*

- Precipitation, SLP, SST
- 925mb U and V
- 200mb U and V
- 850mb geopotential height

**What is the origin of the TBO in the monsoon region?**

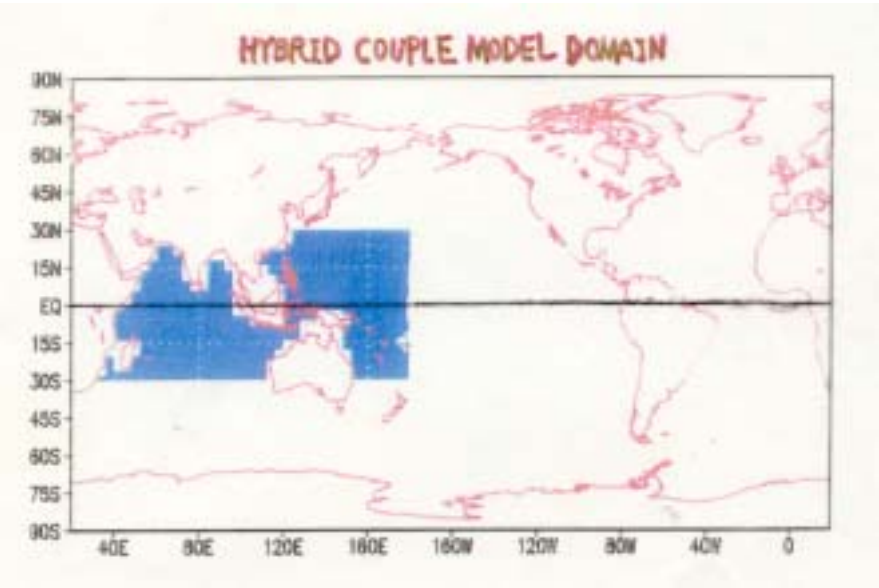
Hypothesis 1:

TBO is forced by remote forcing from the eastern equatorial Pacific.

Hypothesis 2:

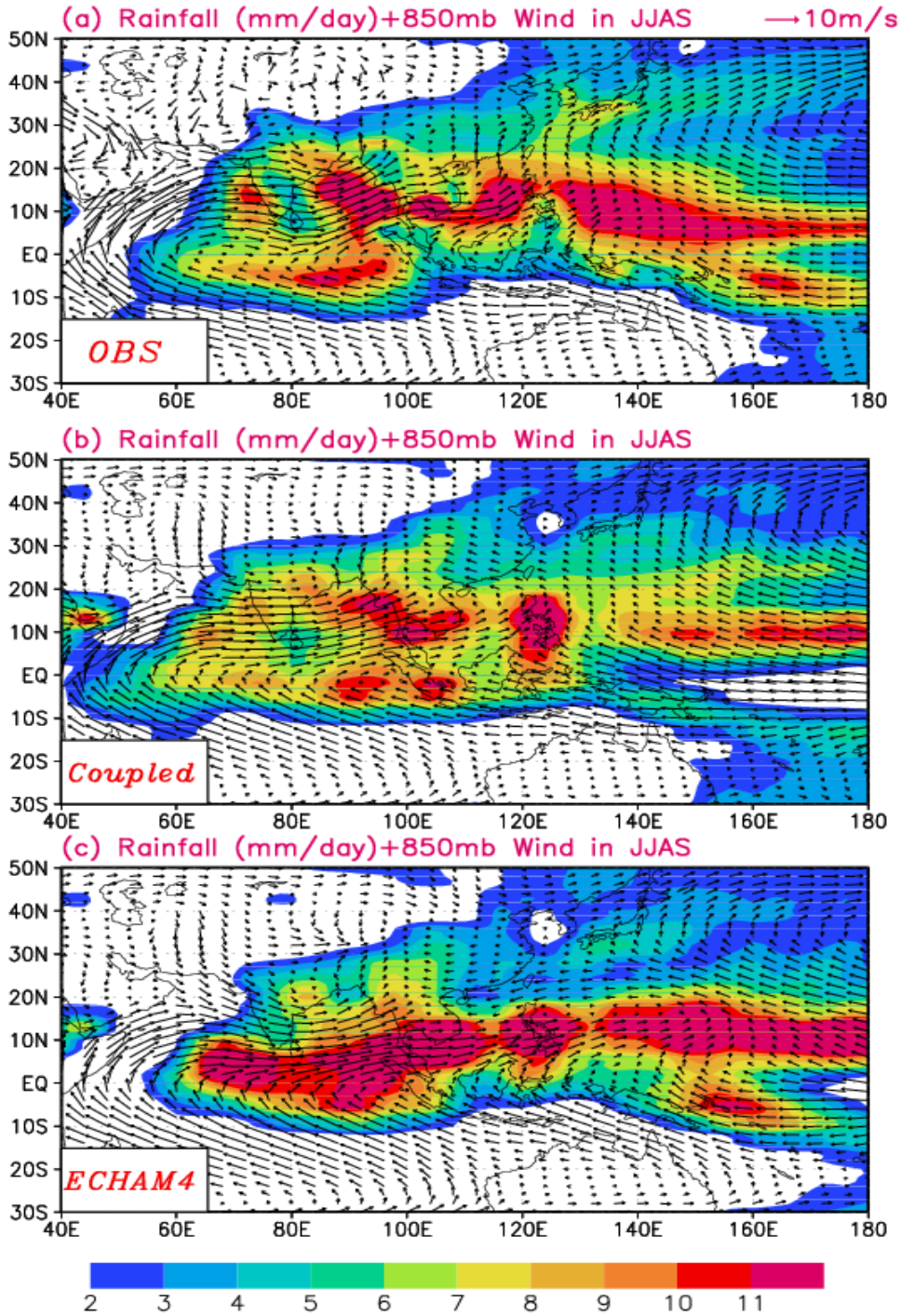
TBO is an air-sea coupled mode in the monsoon region.

*Implication: The QB component of ENSO may result from the inter-basin teleconnection between the monsoon/warm ocean and eastern Pacific.*

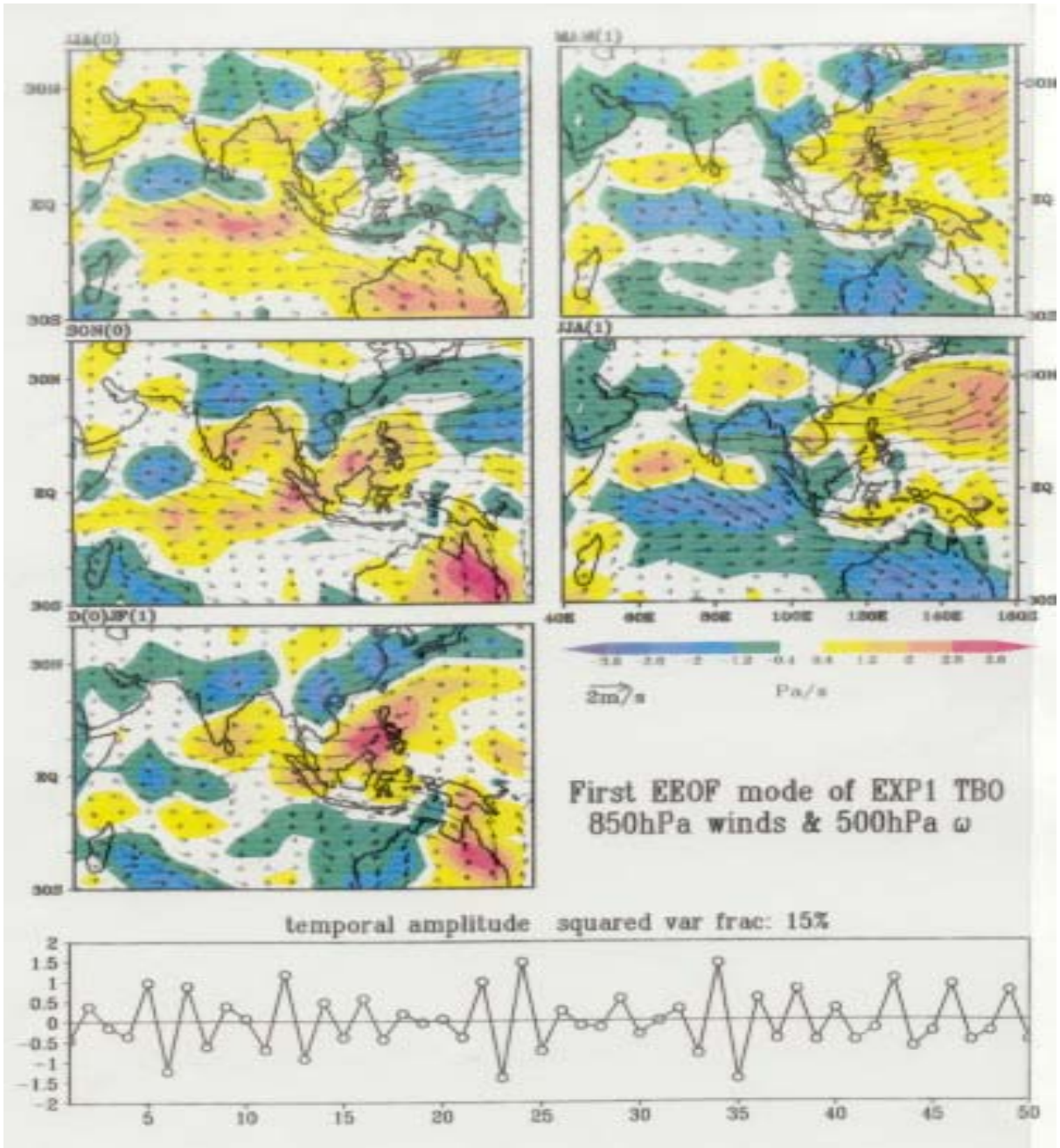



IPRC Hybrid coupled GCM:

ECHAM4 AGCM coupled with 2.5-layer UH intermediate ocean model (Wang et al. 1995)



Coupled ECHAM4-ocean model 50-yr simulation



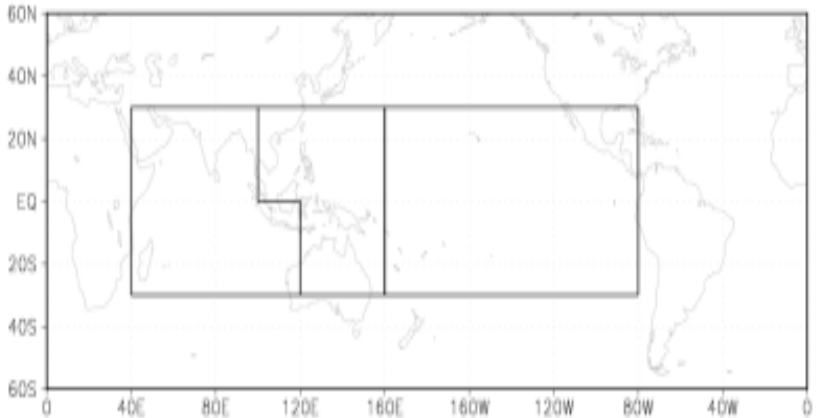
**The hybrid coupled GCM experiments suggest that**

TBO is originated from the monsoon-warm ocean interaction. The QB component of ENSO may result from the interaction between the monsoon/IO and Pacific.

→Analogy to the PNA pattern (internal atmospheric dynamics vs. external forcing)

The TBO is an inherent monsoon mode, while the El Nino forcing may magnify the signal.

# 4. Relative role of remote vs. local SSTA forcing in shaping the A-A monsoon anomalies



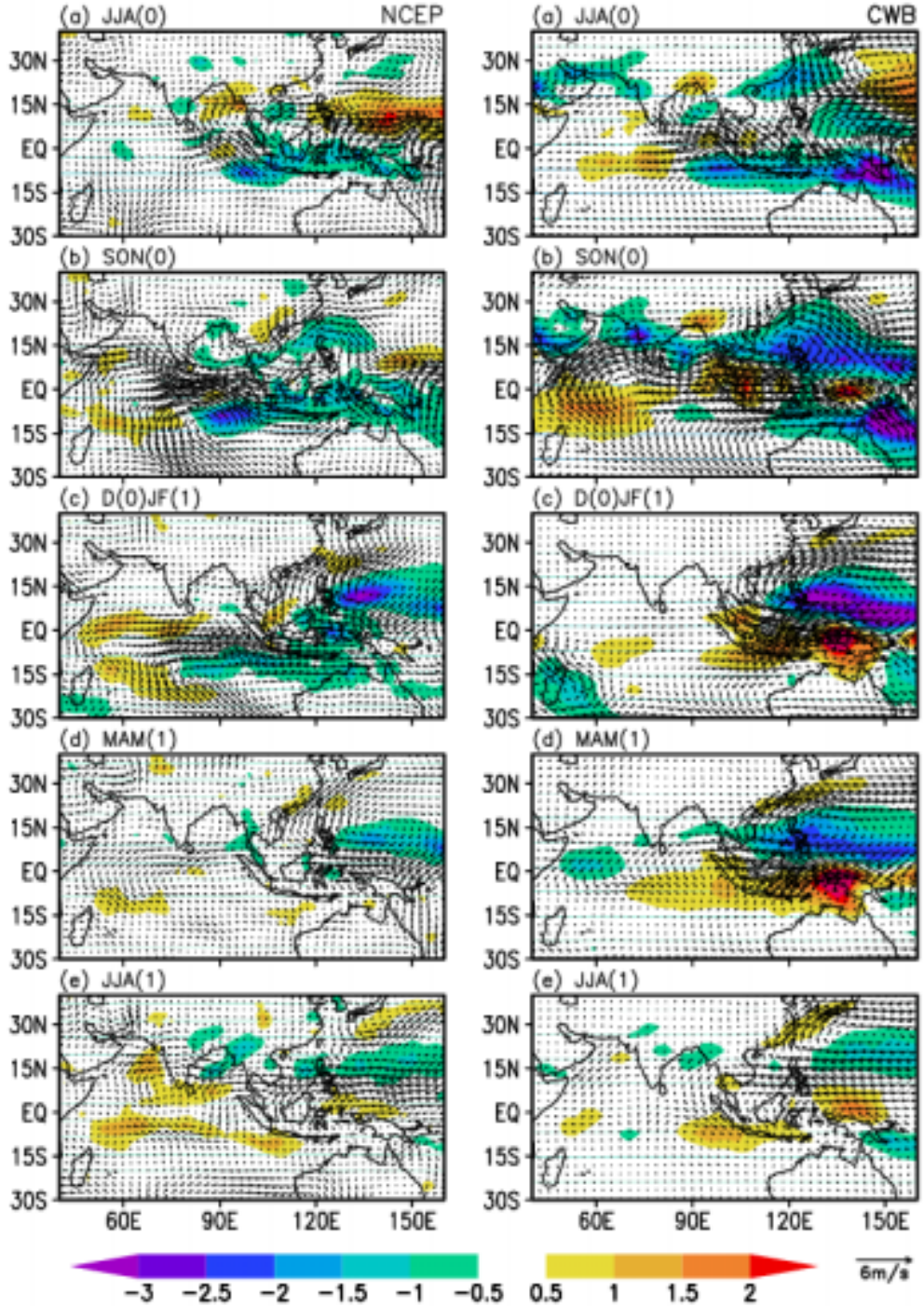

Exp1: Eastern Pacific SSTA only

Exp2: Western Pacific SSTA only

Exp3: Indian Ocean plus eastern Pacific SSTA

Exp4: All three regions

Exp5: Global SSTA



Major results:

A seasonal-dependent teleconnection character:

IO SSTA → WP circulation anomaly (Boreal summer/fall)

EP SSTA → IO circulation anomaly (Boreal winter)

Square: EP SSTA only

Triangle: EP plus IO SSTA

Circle: WP SSTA only

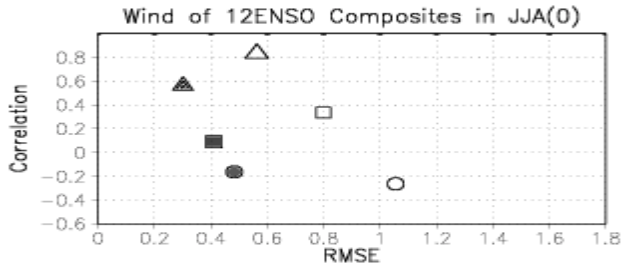
Open symbols: WP domain

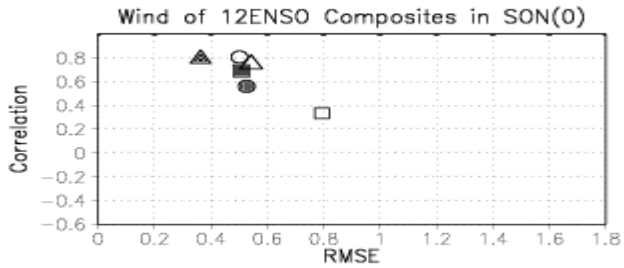
Close symbols: IO domain

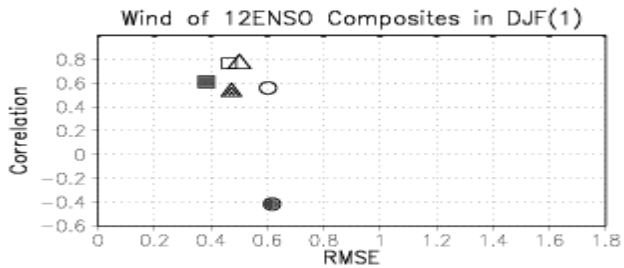
Conclusion:

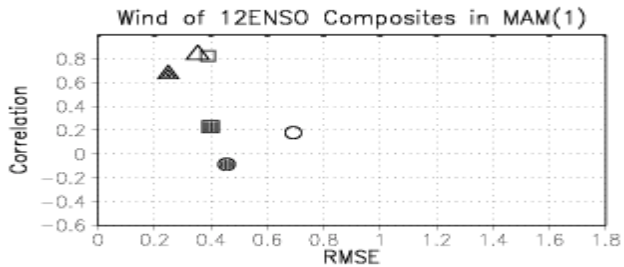
IO SSTA has significant impacts on WP winds in JJA(0) and SON(0)

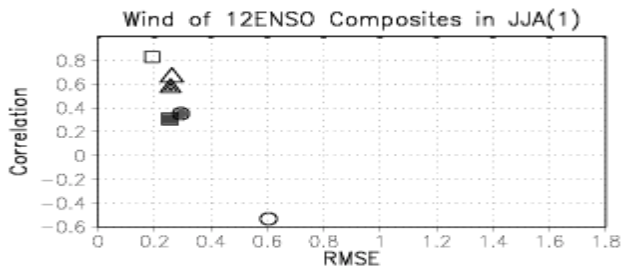
EP SSTA has a much greater impact on IO wind in boreal winter than boreal summer.



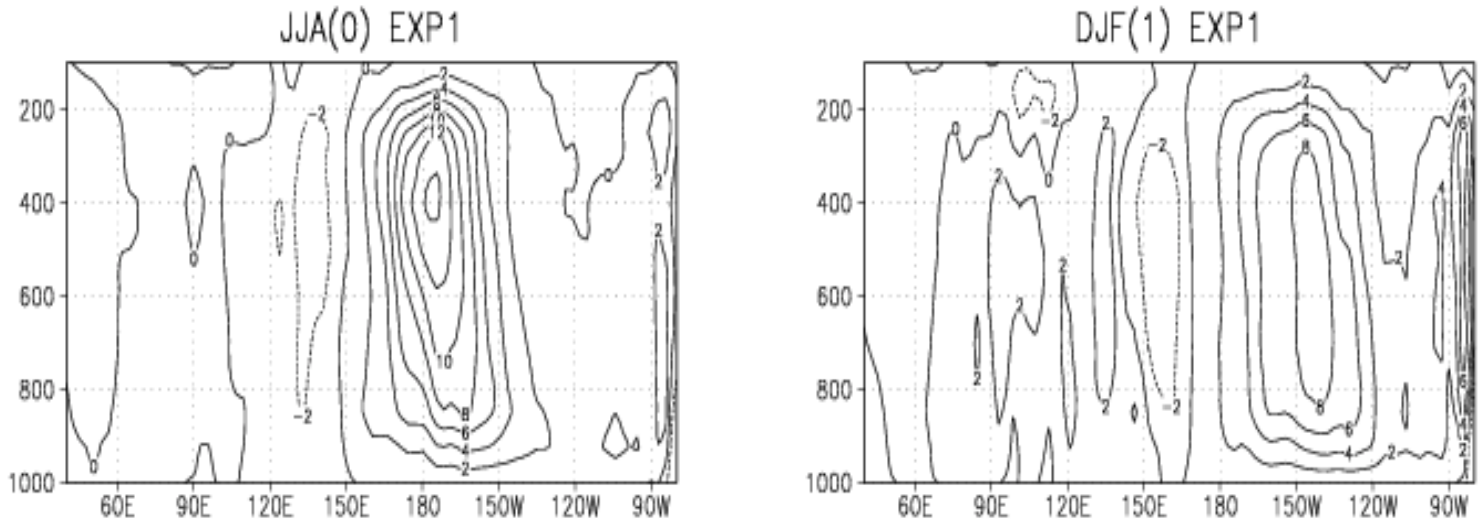



Q: Why does the El Nino have a greater impact on IO wind in boreal winter than boreal summer, even though the El Nino forcing itself might be stronger in summer ?




In boreal summer, SSTA amplitude weaker, but shifting to the west

→Stronger ascending motion in the central equatorial Pacific

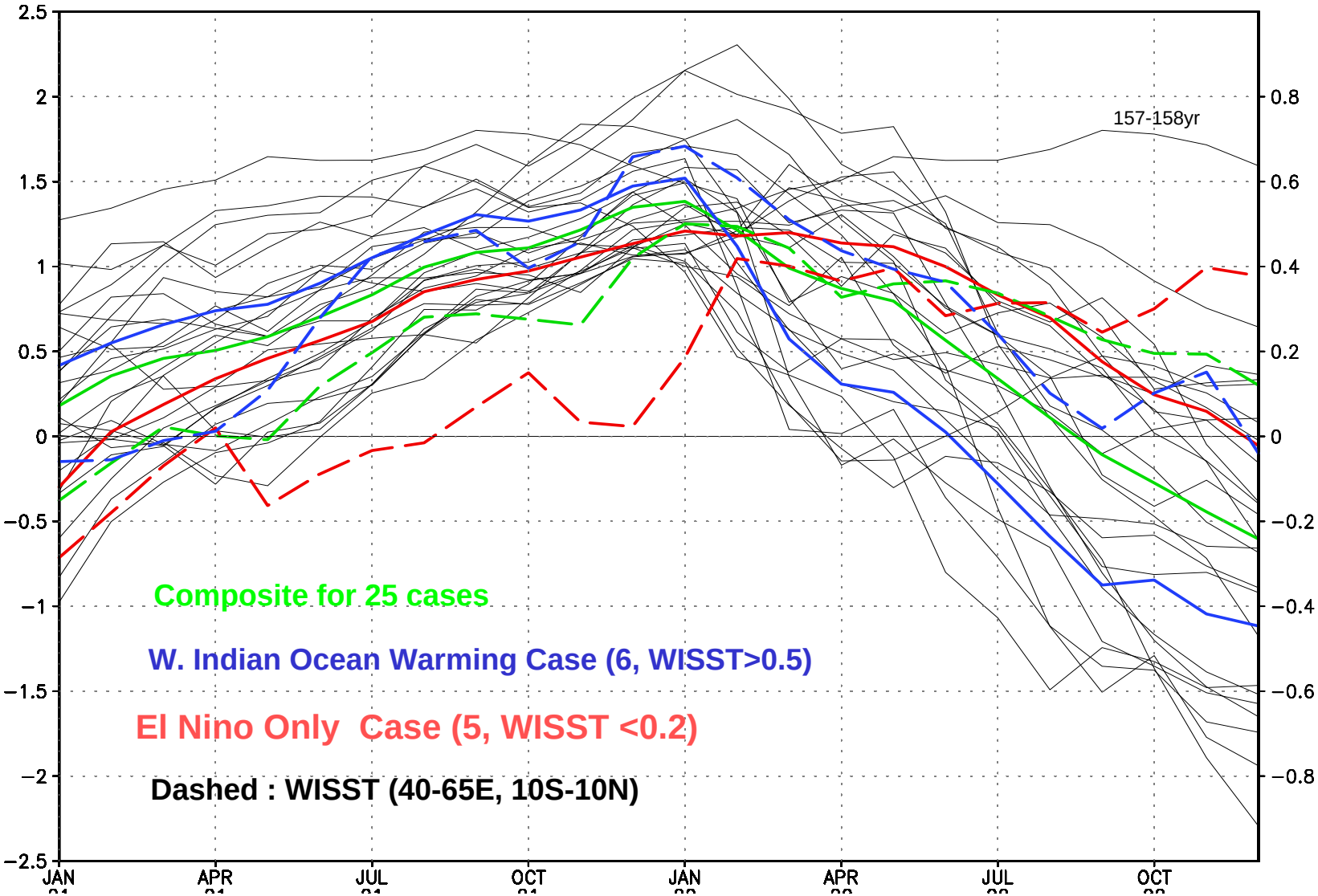
Speculation: The weaker response in IO may be attributed to the seasonal shift of the thermal equator – an asymmetric basic state.

# Conclusions

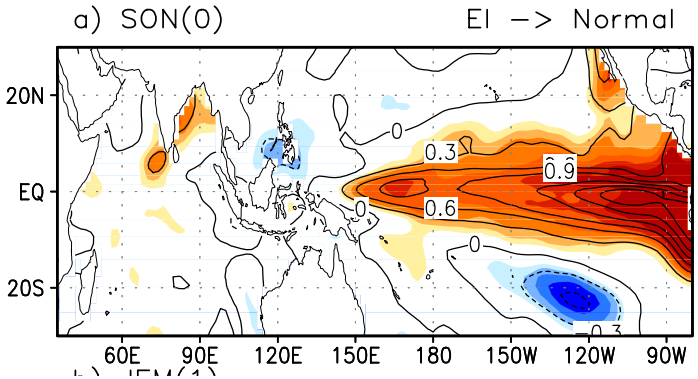
- Quasi-biennial variability of Indian monsoon is attributed to local SST and moisture transport in IO, while lower-frequency variability results from remote forcing in the Pacific.
- TBO structure and origin: TBO might be originated from local air-sea interactions while ENSO may amplify the biennial signal.
- Asian-Australian monsoon in-phase relationship: in addition to remote ENSO forcing, eastward expansion of Indian Ocean SSTA may contribute to the in-phase relationship.
- Remote vs. local SSTA forcing in shaping the A-A monsoon anomaly: numerical experiments reveal a seasonal dependent inter-basin teleconnection character between the tropical IO and Pacific Ocean.

# SINTEX CGCM Analysis

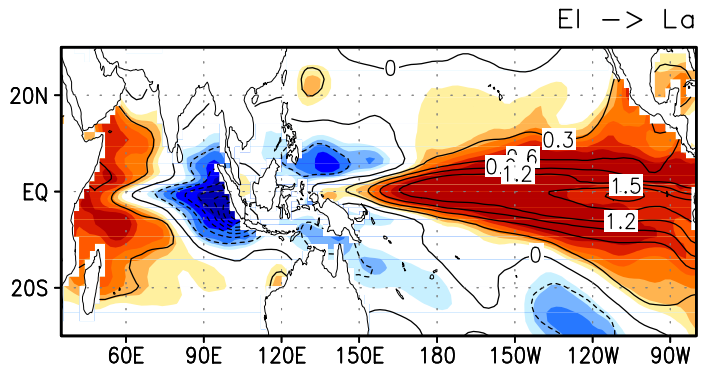
## NINO3.4 SST for El Ninos (25 cases)



## El Nino only Case

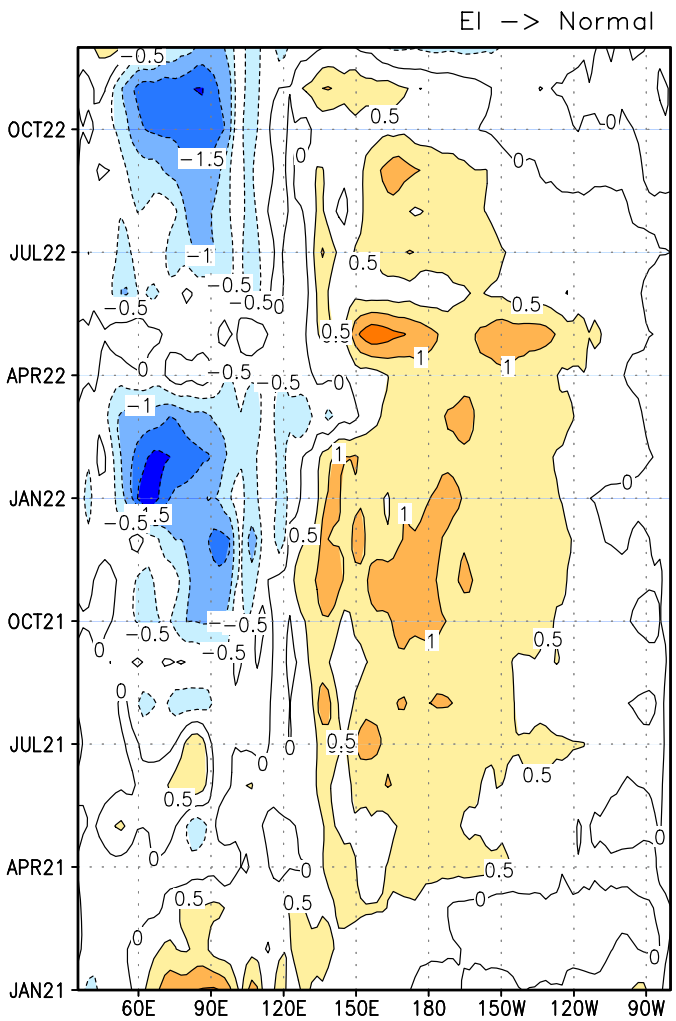



## Indian Ocean Warming Case

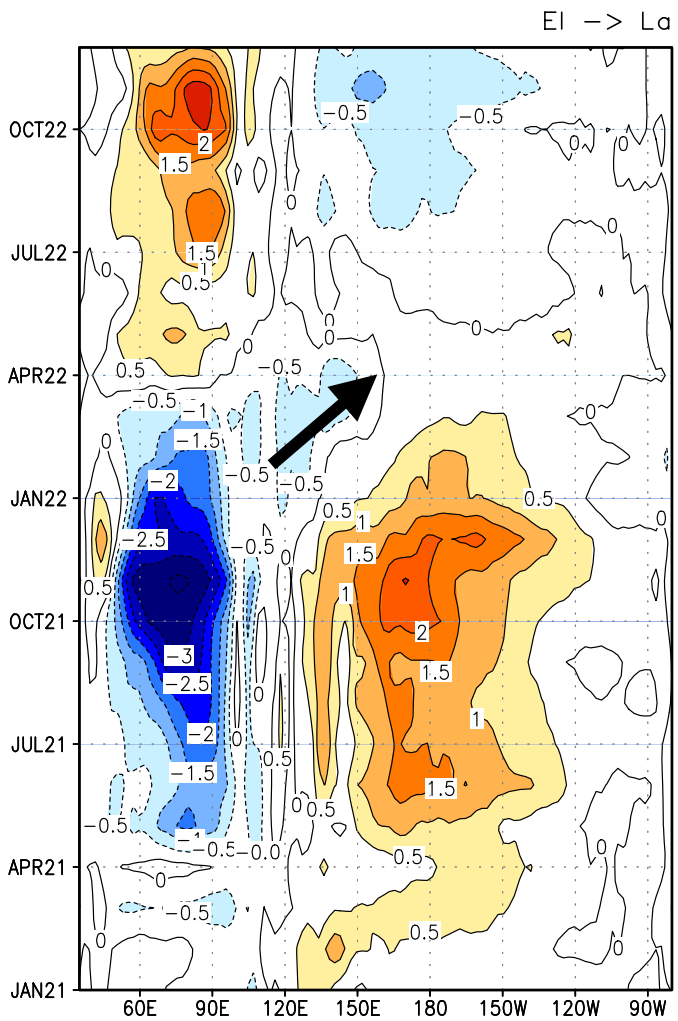


# Wind anomalies along Equator (1S-1N)

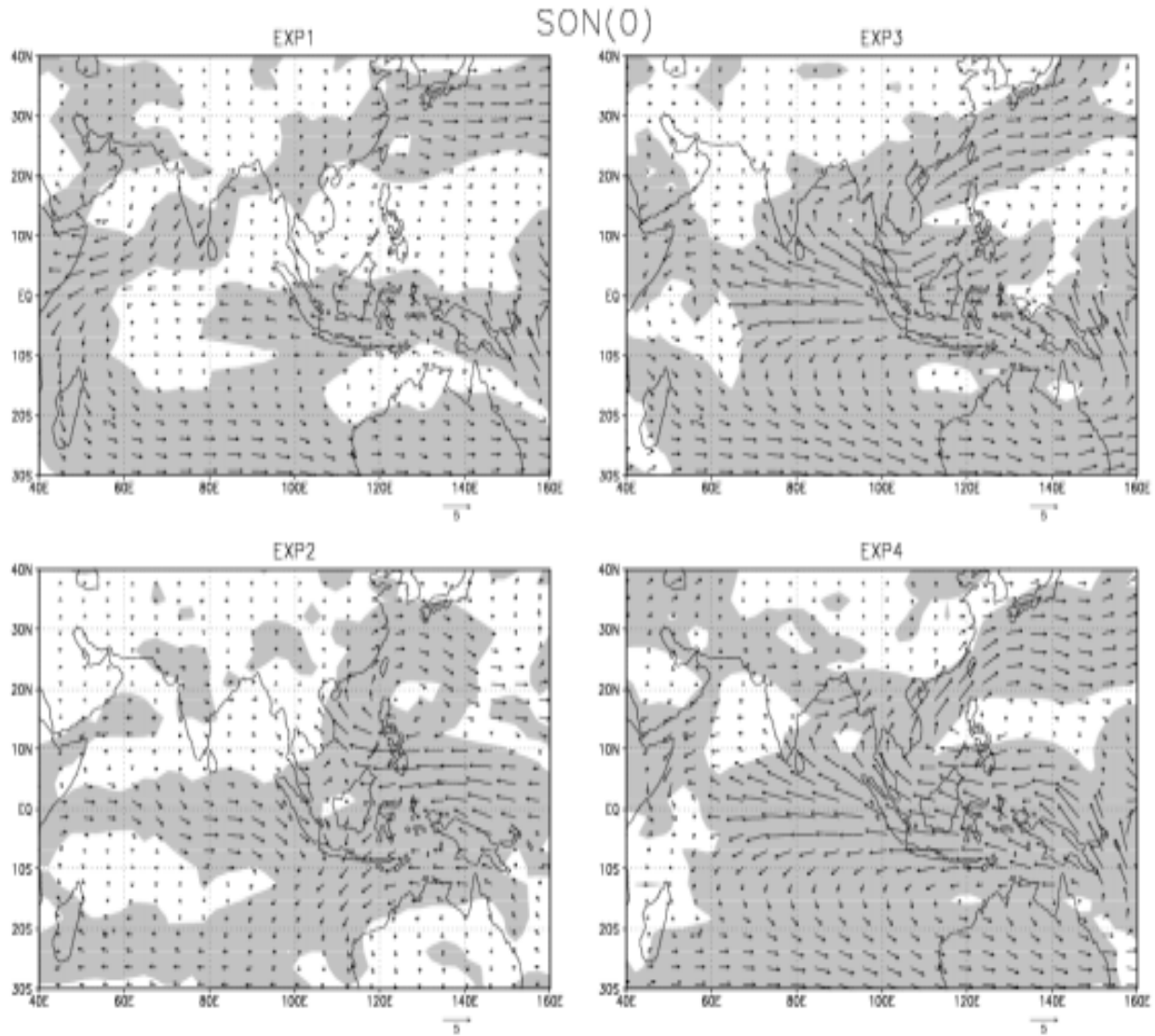
## El Nino only Case




## Indian Ocean Warming Case



# Initiation of Philippine Sea Anticyclone anomaly in SON(0)



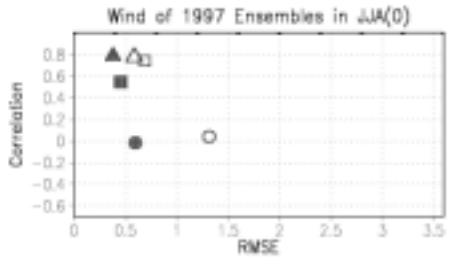
Square: EP SSTA only

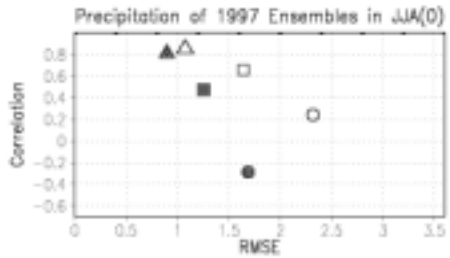
Triangle: EP plus IO SSTA

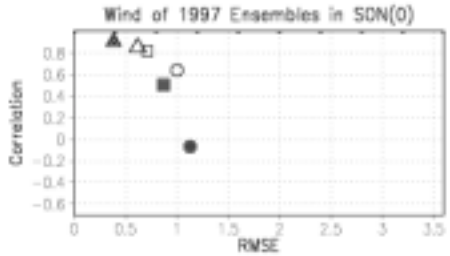
Circle: WP SSTA only

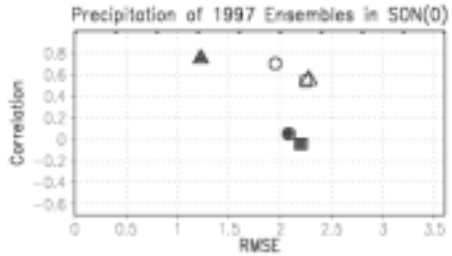
Open symbols: WP domain

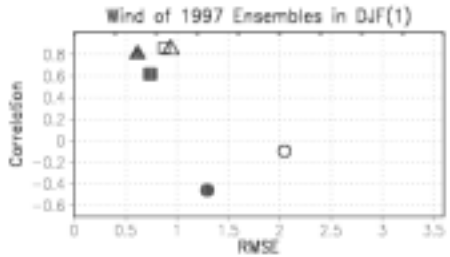
Close symbols: IO domain

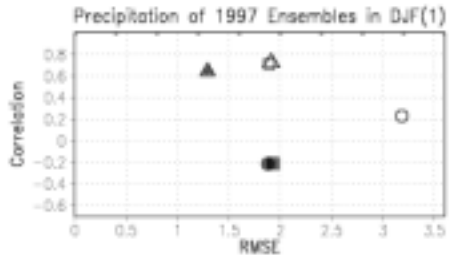


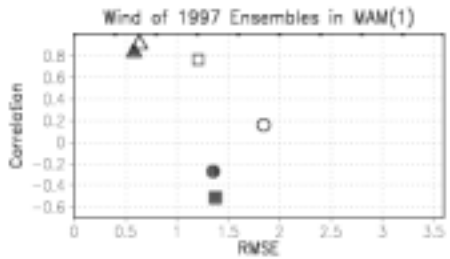



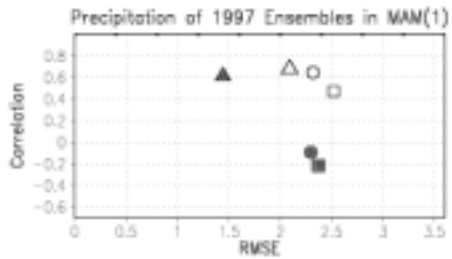



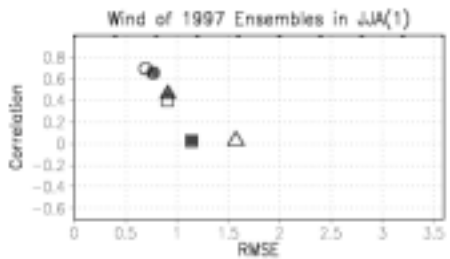



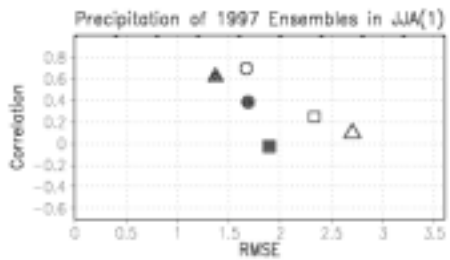



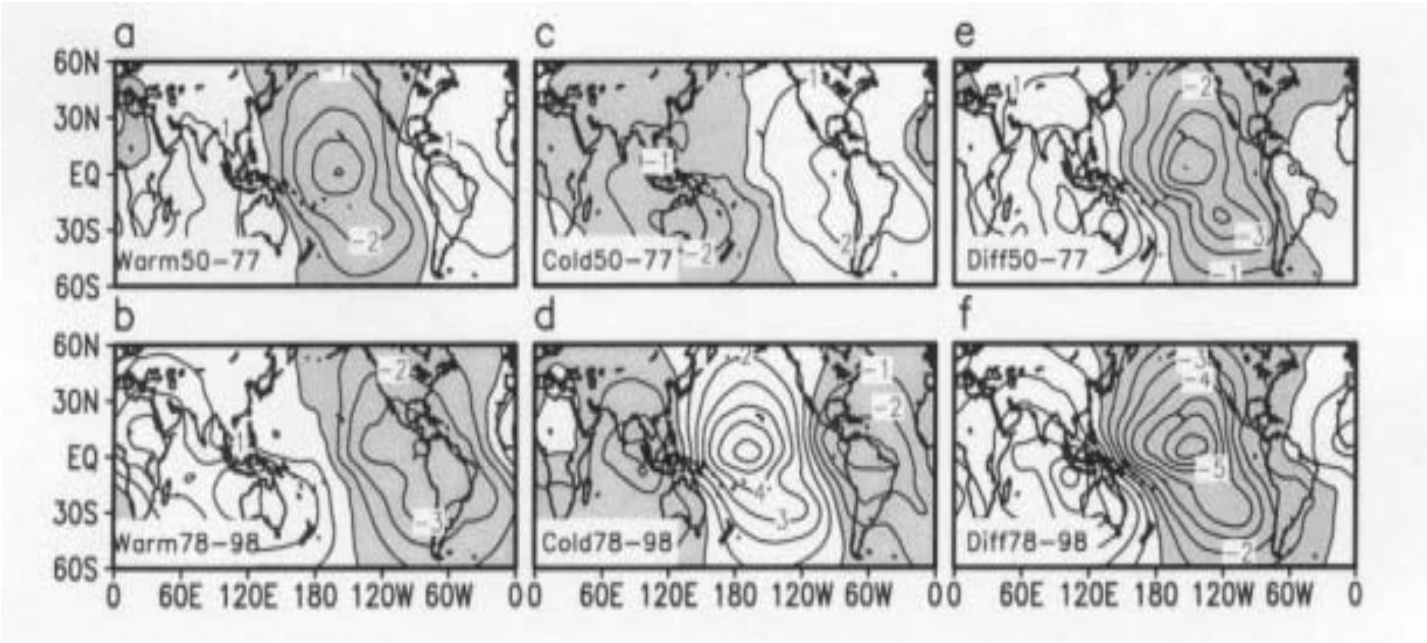



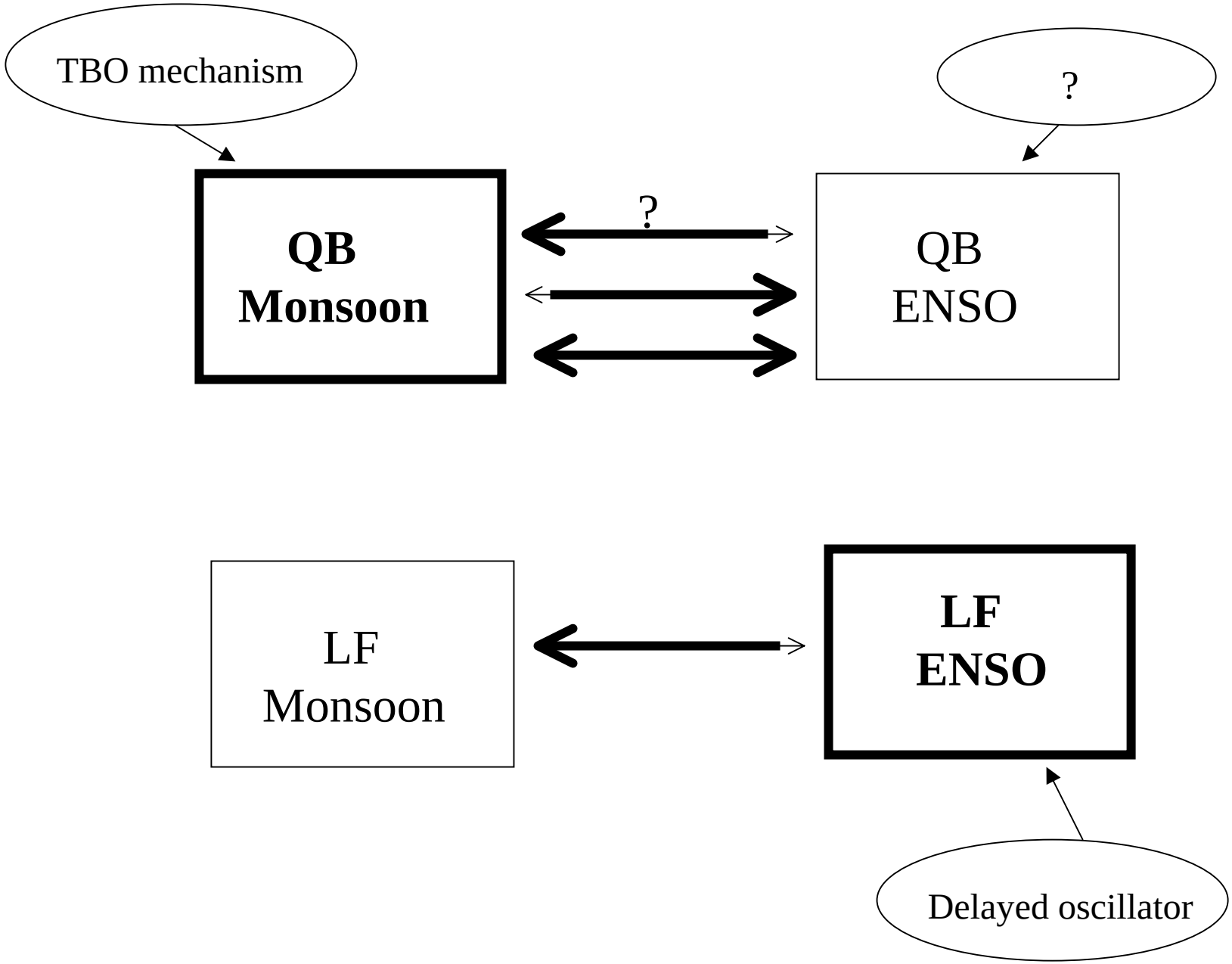
## Issue III: Interdecadal change of the monsoon-ENSO relationship

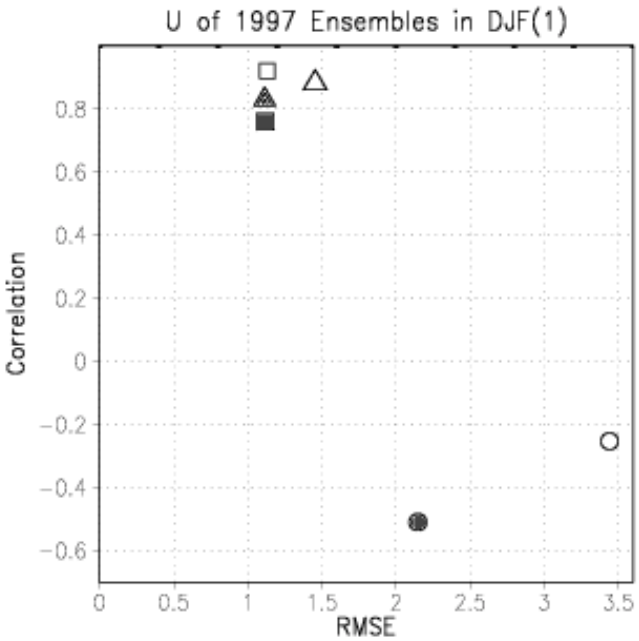
- *Why is the negative monsoon-ENSO correlation broken in recent decade?*

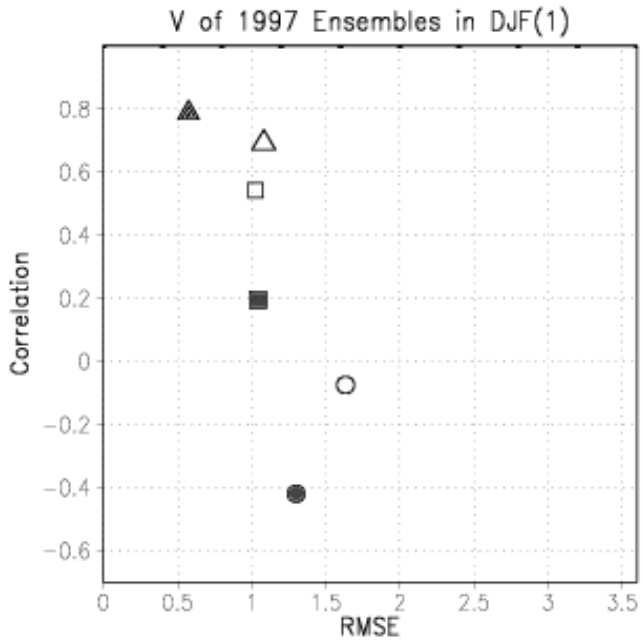
*Hypothesis:*

*— Eastward shifting of El Nino convection*




TBO mechanism
?
QB
Monsoon
?
QB
ENSO
LF
Monsoon
LF
ENSO
Delayed oscillator


U of 1997 Ensembles in DJF(1)
Correlation
RMSE
0.8
0.6
0.4
0.2
0
−0.2
−0.4
−0.6
0
0.5
1
1.5
2
2.5
3
3.5


V of 1997 Ensembles in DJF(1)
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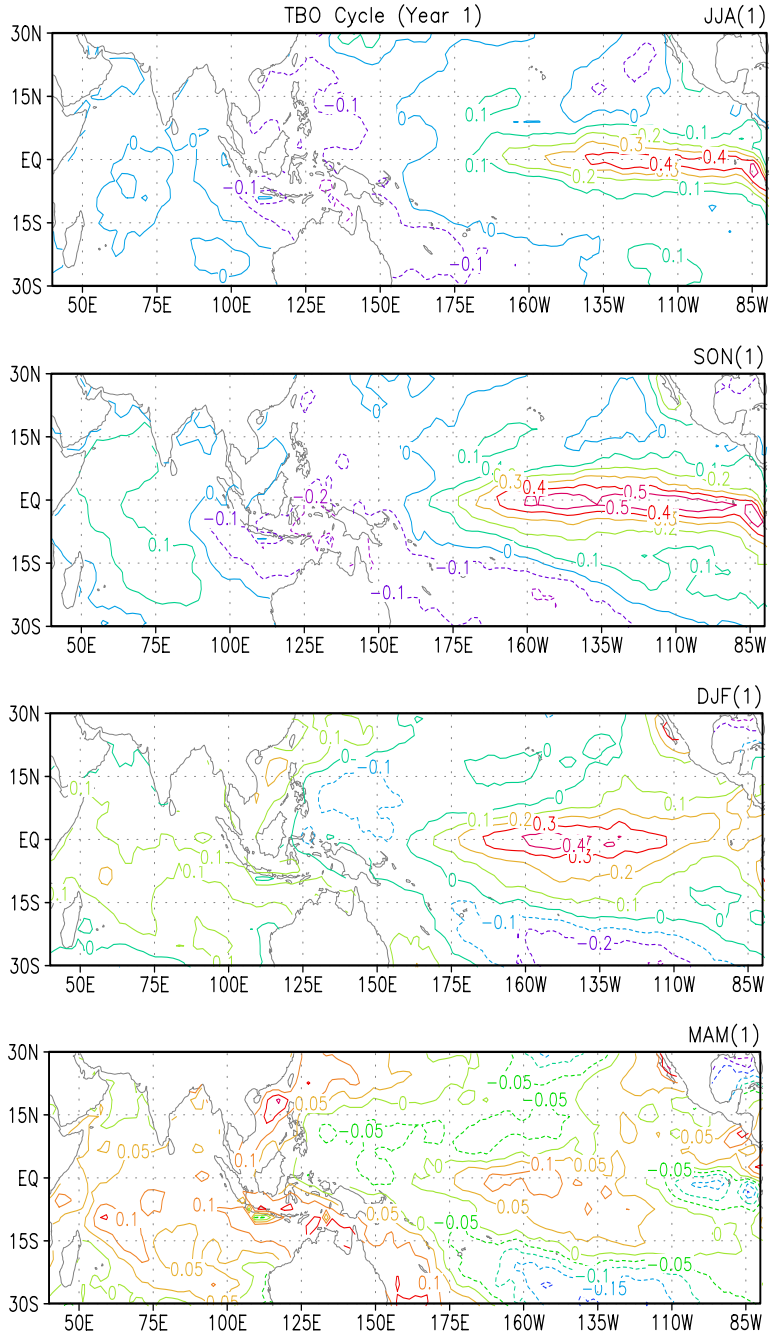
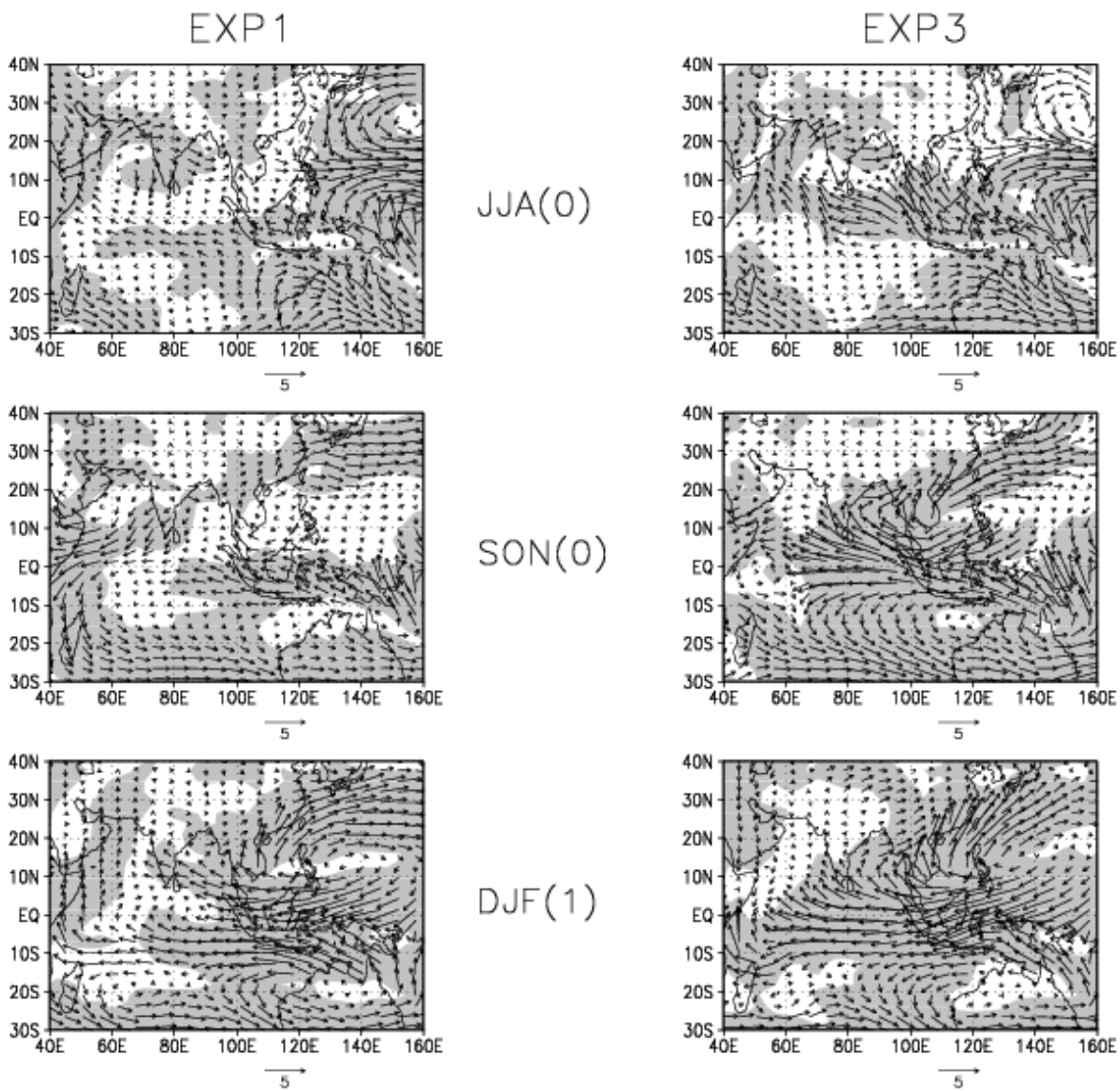
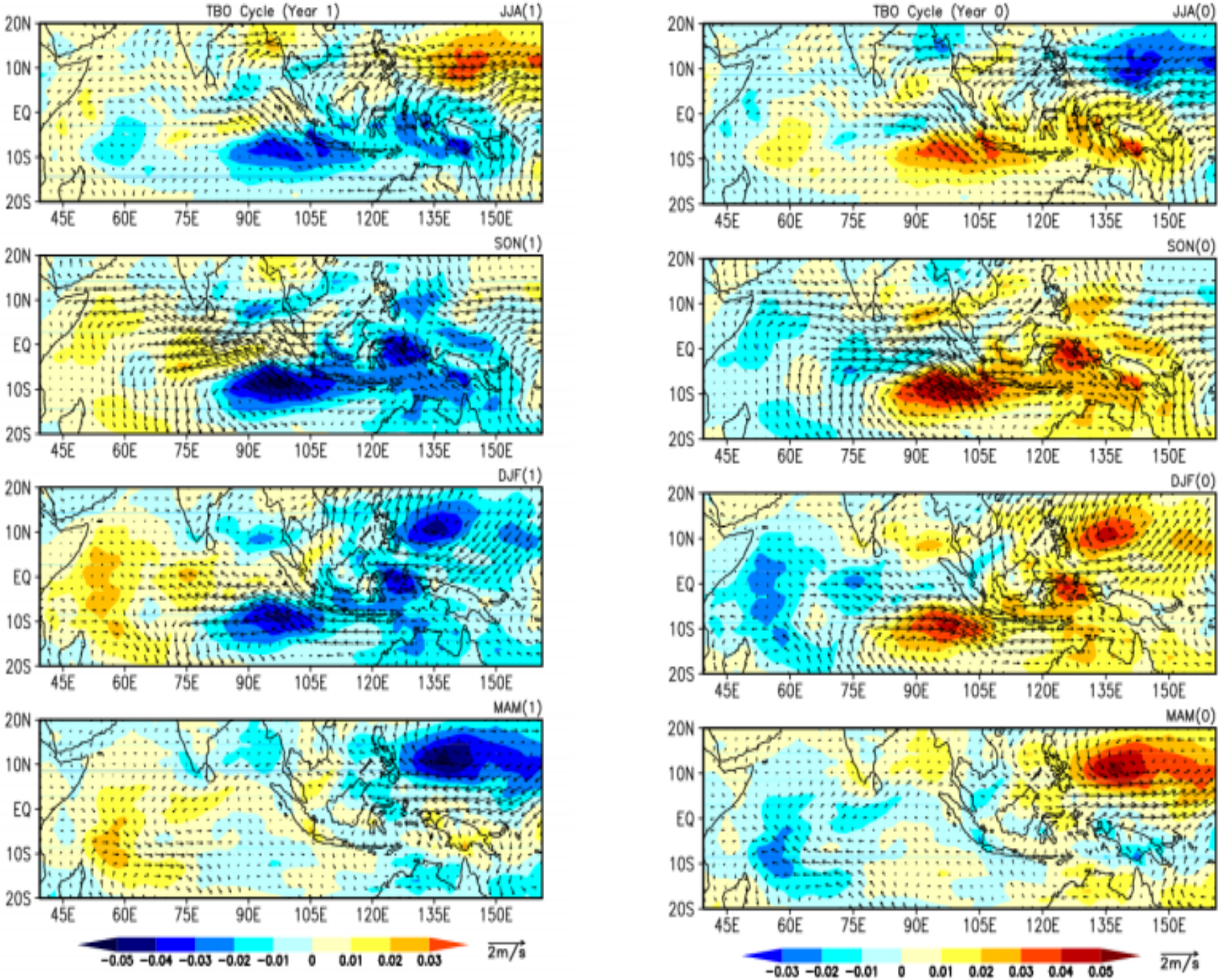
RMSE
0.8
0.6
0.4
0.2
0
−0.2
−0.4
−0.6
0
0.5
1
1.5
2
2.5
3
3.5


TBO Cycle (Year 1)
JJA(1)
SON(1)
DJF(1)
MAM(1)
30N
15N
EQ
15S
30S
50E
75E
100E
125E
150E
175E
160W
135W
110W
85W

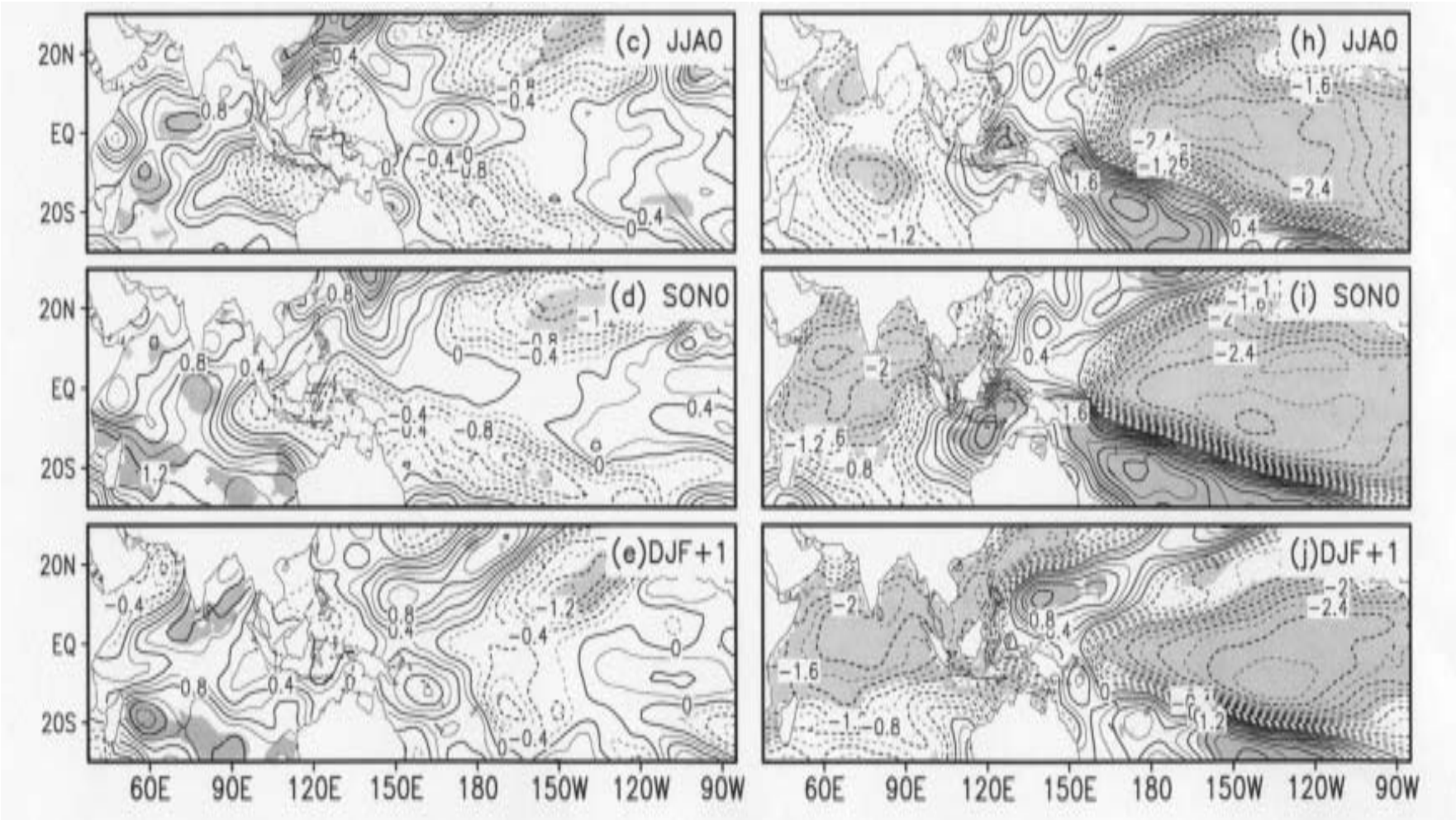

EXP1
EXP3
JJA(0)
SON(0)
DJF(1)
40N
30N
20N
10N
EQ
10S
20S
30S
40E
60E
80E
100E
120E
140E
160E
5


TBO Cycle (Year 1)
JJA(1)
SON(1)
DJF(1)
MAM(1)
TBO Cycle (Year 0)
JJA(0)
SON(0)
DJF(0)
MAM(0)
20N
10N
EQ
10S
20S
45E
60E
75E
90E
105E
120E
135E
150E
−0.05 −0.04 −0.03 −0.02 −0.01 0 0.01 0.02 0.03
−0.03 −0.02 −0.01 0 0.01 0.02 0.03 0.04 0.05
2m/s

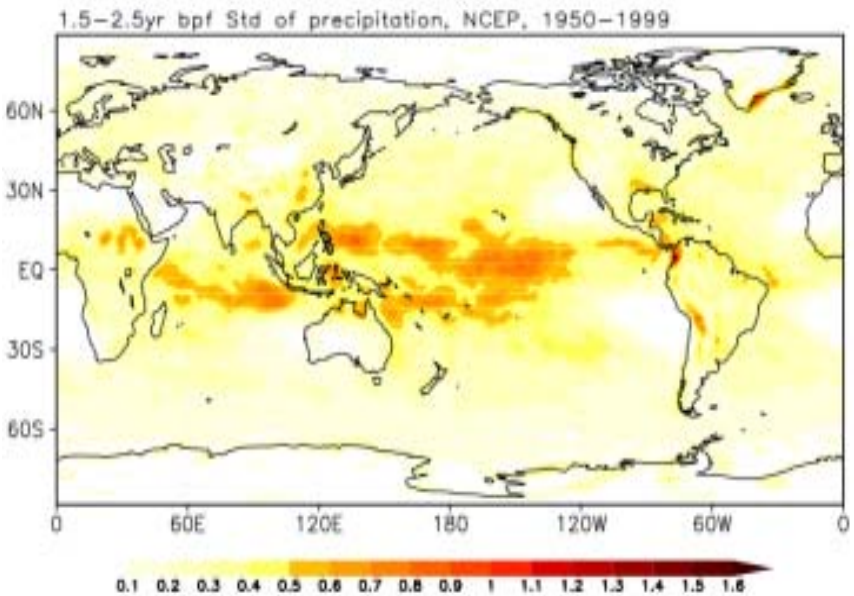
# SSTA composites (wet minus dry I-AM)

Non-ENSO years

ENSO-years



# 2. TBO structure and origin




Time filter