Linking Asian monsoon to Indian Ocean SST in the observation: Possible roles of Indian Ocean Basin Mode and Dipole Mode

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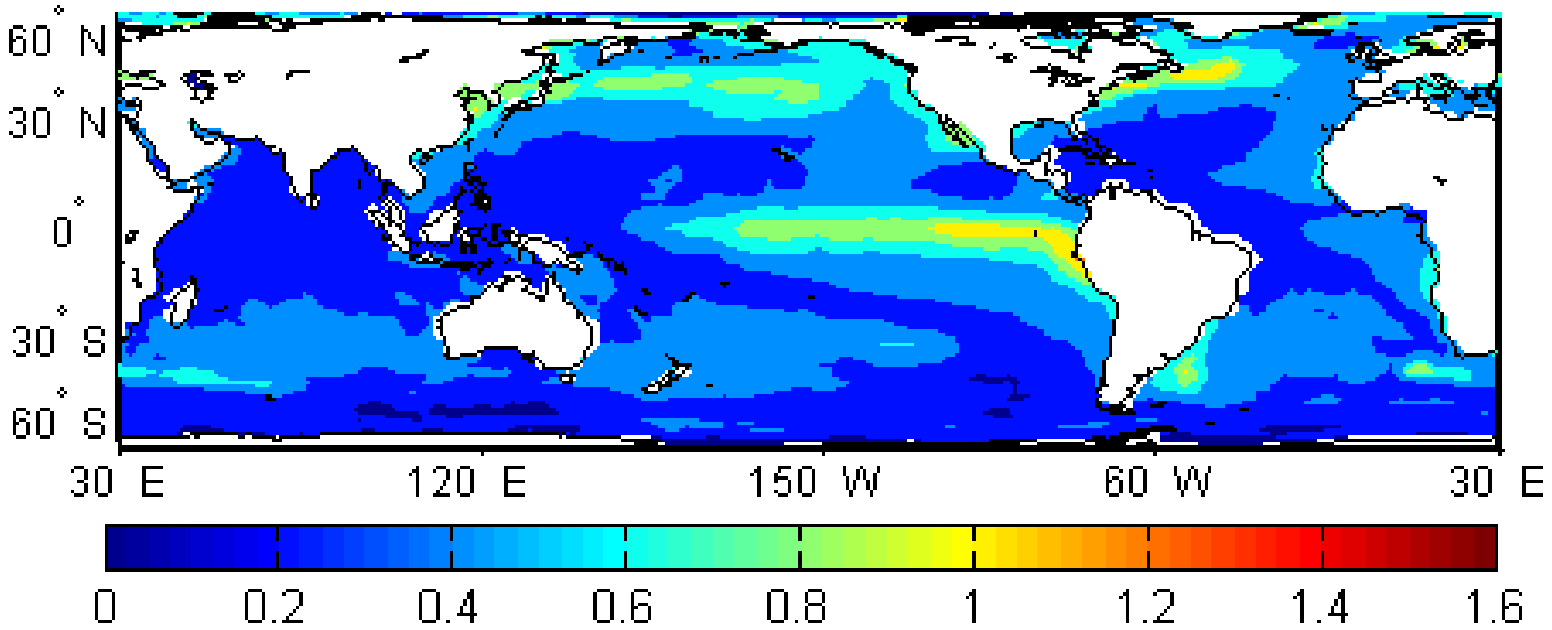
Outline

- Background
- Data and method
- Maximum Covariance Analysis (MCA)
- Physical mechanism of the IOBM and IODM impact on the Asian Monsoon
- Summary

Background

The STD of SST anomaly in tropical Indian Ocean is very smaller than it in tropical east Pacific during recent 100 Years (1903-2002)

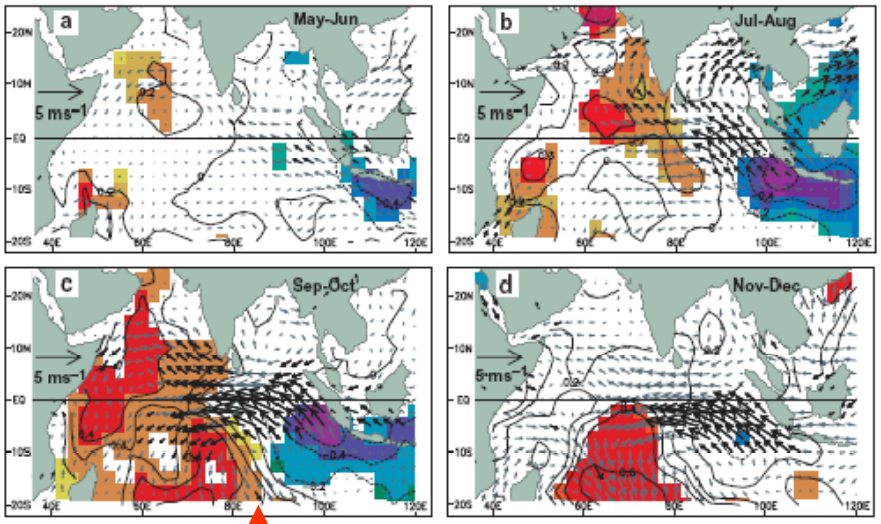


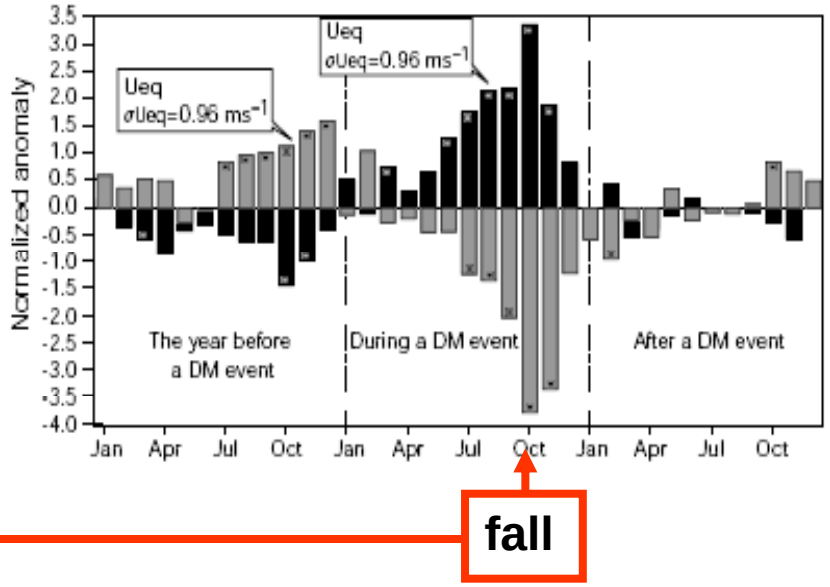
Whether the impact of the Indian Ocean SST anomaly on Asian Monsoon is important or not?

If it is important, Can we forecast the monsoon anomaly based on the observation SST anomaly in Indian Ocean?

Background

Saji et al. 1999: the IO Basin Mode (IOBM) can explain above 30% of the total variance of the TIO SSTA and the dipole mode explains about 12% of that; Dipole mode is independent of ENSO.

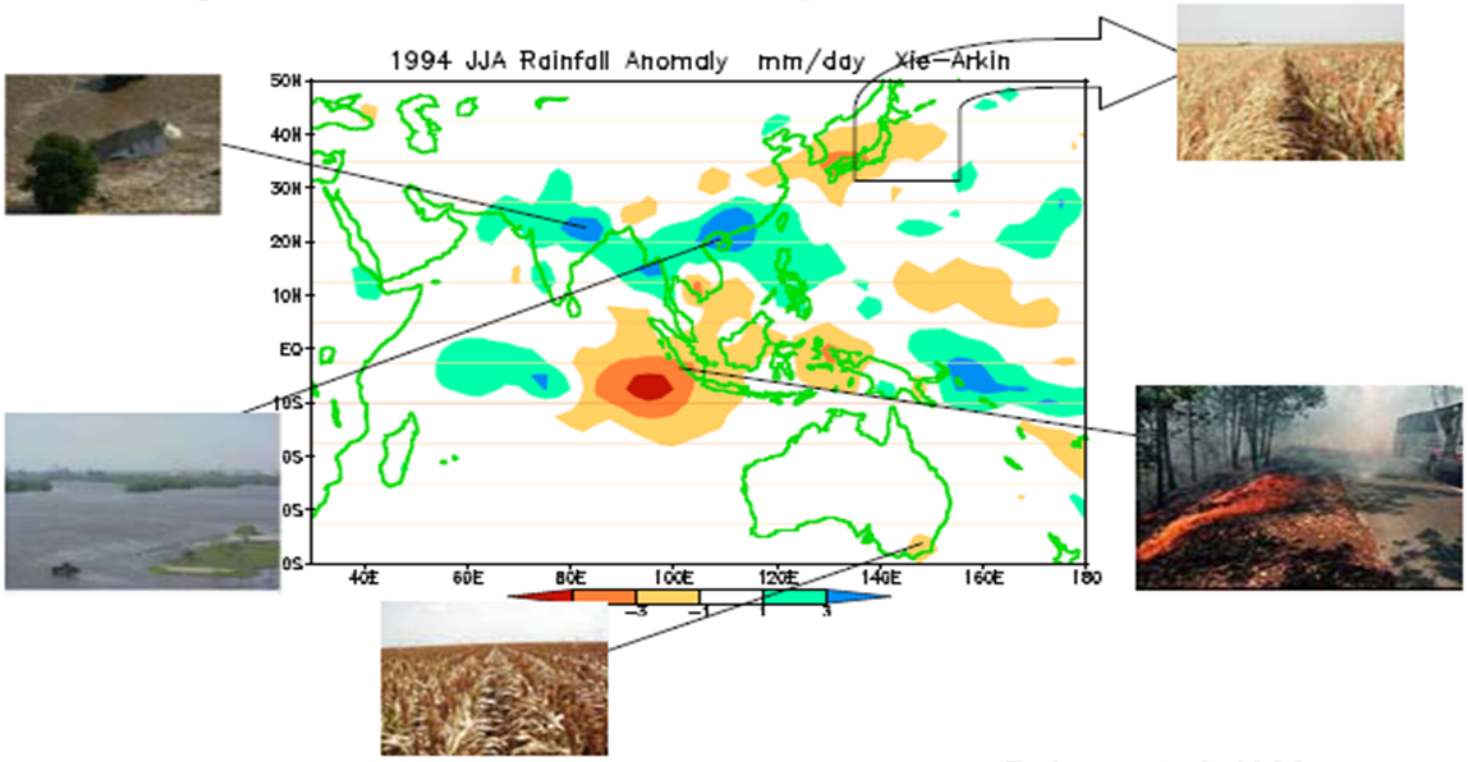




Behera et al. 1999; Slingo and Annamalai 2000; Ashok et al. 2001; Li and Mu 2001; Behera and Yamagata 2003; Guan et al. 2003; Li et al. 2003; Saji and Yamagata 2003; Lau and Nath 2004; Kripalani et al. 2005

Background:

1994 Anomalous Indian Ocean Conditions – A dry and hot summer in Japan

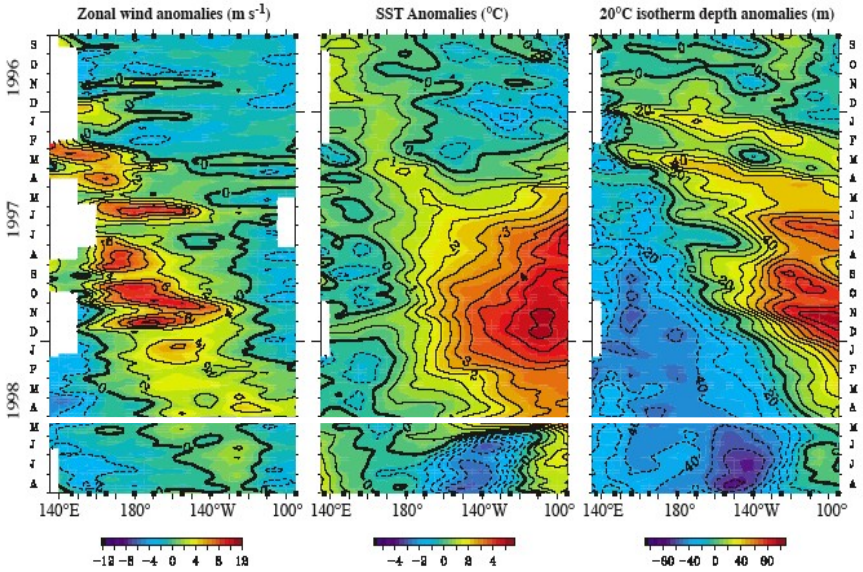


Behera et al. 1999

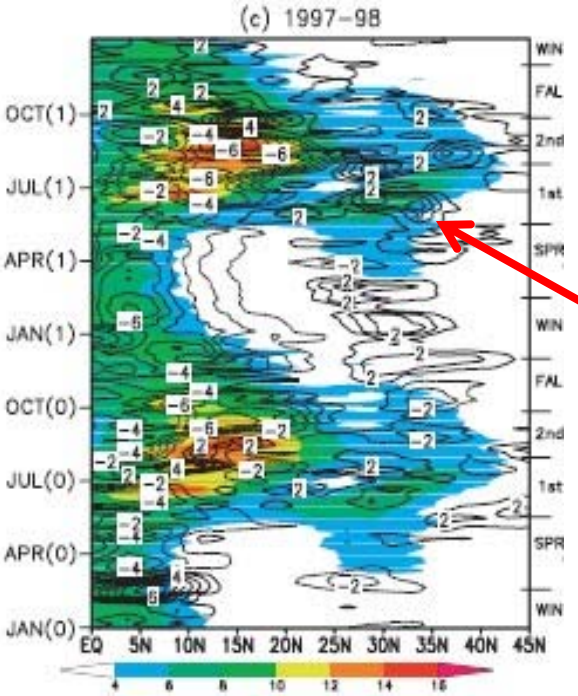
Question: Whether we get the impact of the Indian Ocean SST anomaly on atmosphere based on the contemporary observation data or not?
Which is chicken, Which is egg?

Background:

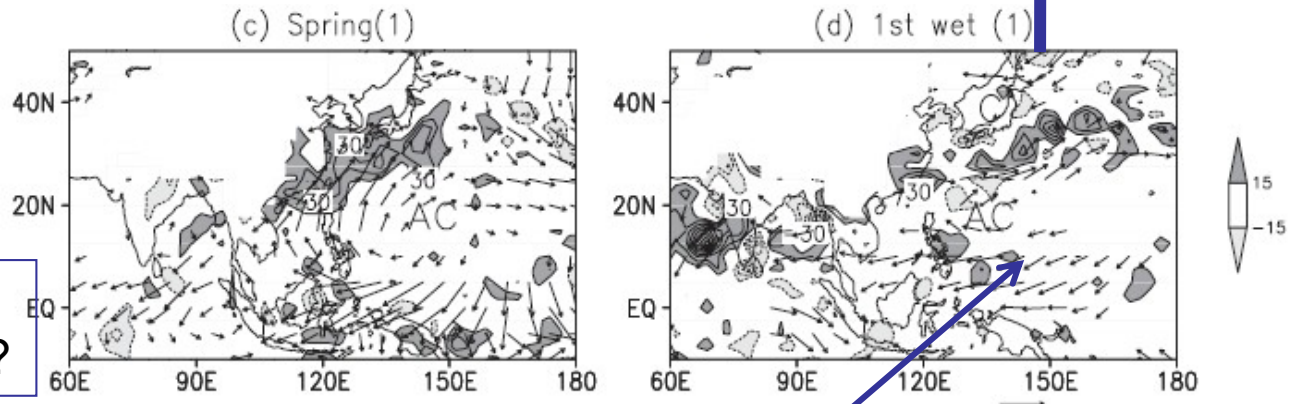
Precipitation anomaly over 110-150E



From McPhaden (1999)



Q: Why the precipitation anomaly is still very larger in east Asia, after the El Nino disappears in May1998?

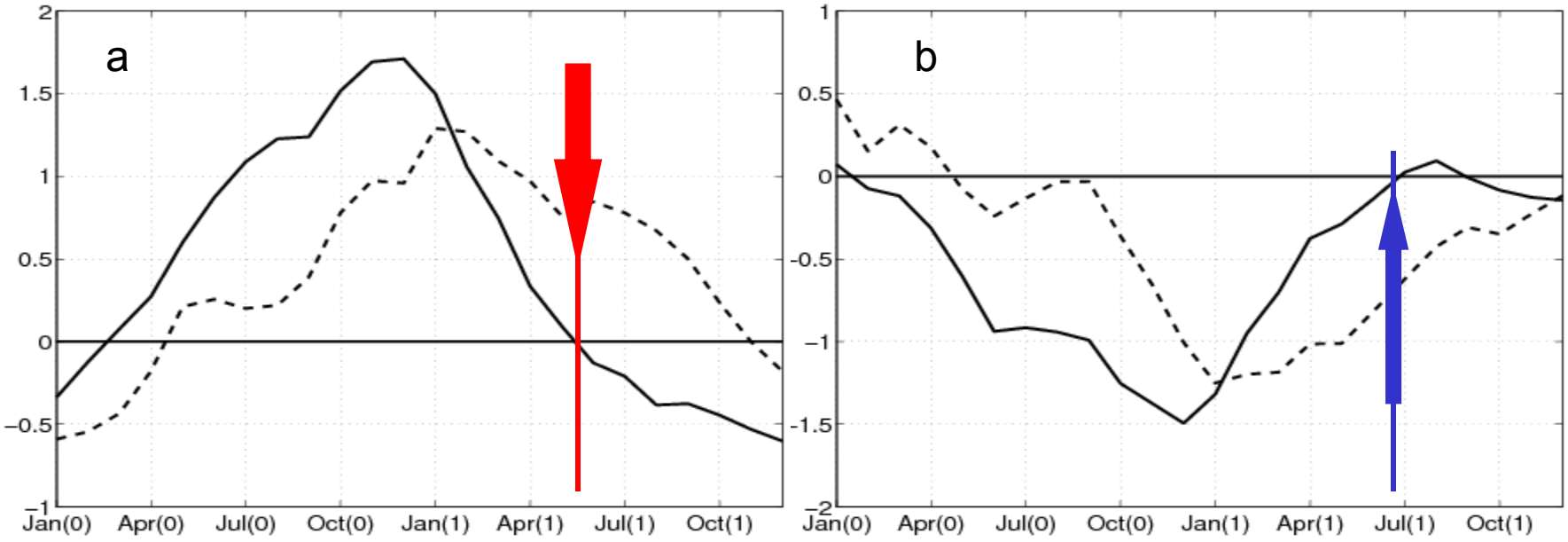


Why is the AC still in WP after El Nino disappears ?

(Chou et al.2009)

Background: IOB & IOD

Yoo et al. (2006) showed that the dominant mode of IO SST is often characterized by uniform warming or cooling and exerts a larger impact on monsoon variability than the tropical IO dipole does.

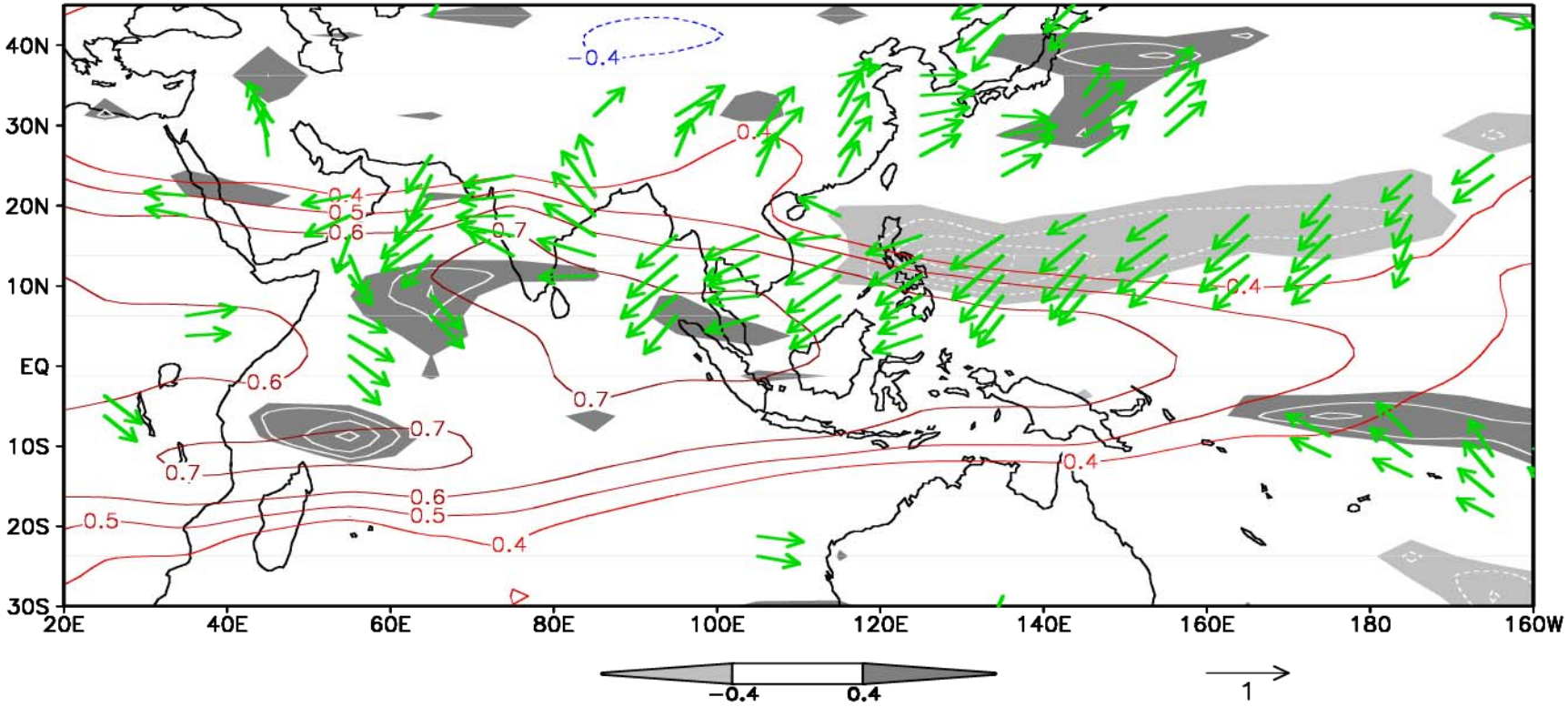


While IOBM persists into the following summer and its impact on the Asian Summer monsoon like a discharging capacitor(Yang et al. 2007)

Background

How does IO warming force NW Pacific anticyclone?

IO warming → Warm Kelvin wave into the WP
→ Northeasterly winds to the north under friction
→ Divergence over NW Pacific ←→ Suppressed convection



Tropospheric temp,
surface wind & rainfall

(Xie et al.,2008)

Science Issue

- **Which mode (IOB or IOD) plays more important role in Asian monsoon anomaly and in which season?**
- **What are the physical mechanisms behind the effects of the IOB or the IOD?**

Goal：

1.To reveal the relative importance of those two modes in a consistent method.

2.To find useful seasonal prediction signal about the Asian Monsoon.

Data and method

- The NCEP-NCAR reanalysis Data (20ºS-50ºN and 40ºE-160ºE) :

geopotential height at 200 hPa (hereafter H200),

horizontal wind and specific humidity at 850 hPa,

vertical velocity (omega) at 500 hPa,

precipitation rate

- The monthly SST data (HadISST dataset) over the TIO region (20ºS-20ºN, 40ºE-110ºE).

All data are in the period of 1950-2004, except for the atmosphere heat source that is for 1958-2000.

Maximum Covariance Analysis (MCA) (Czaja and Frankignoual 2002)

Remove the ENSO signal from the atmosphere variation by the linear regression of the Niño3 SST index (leading 2 month)

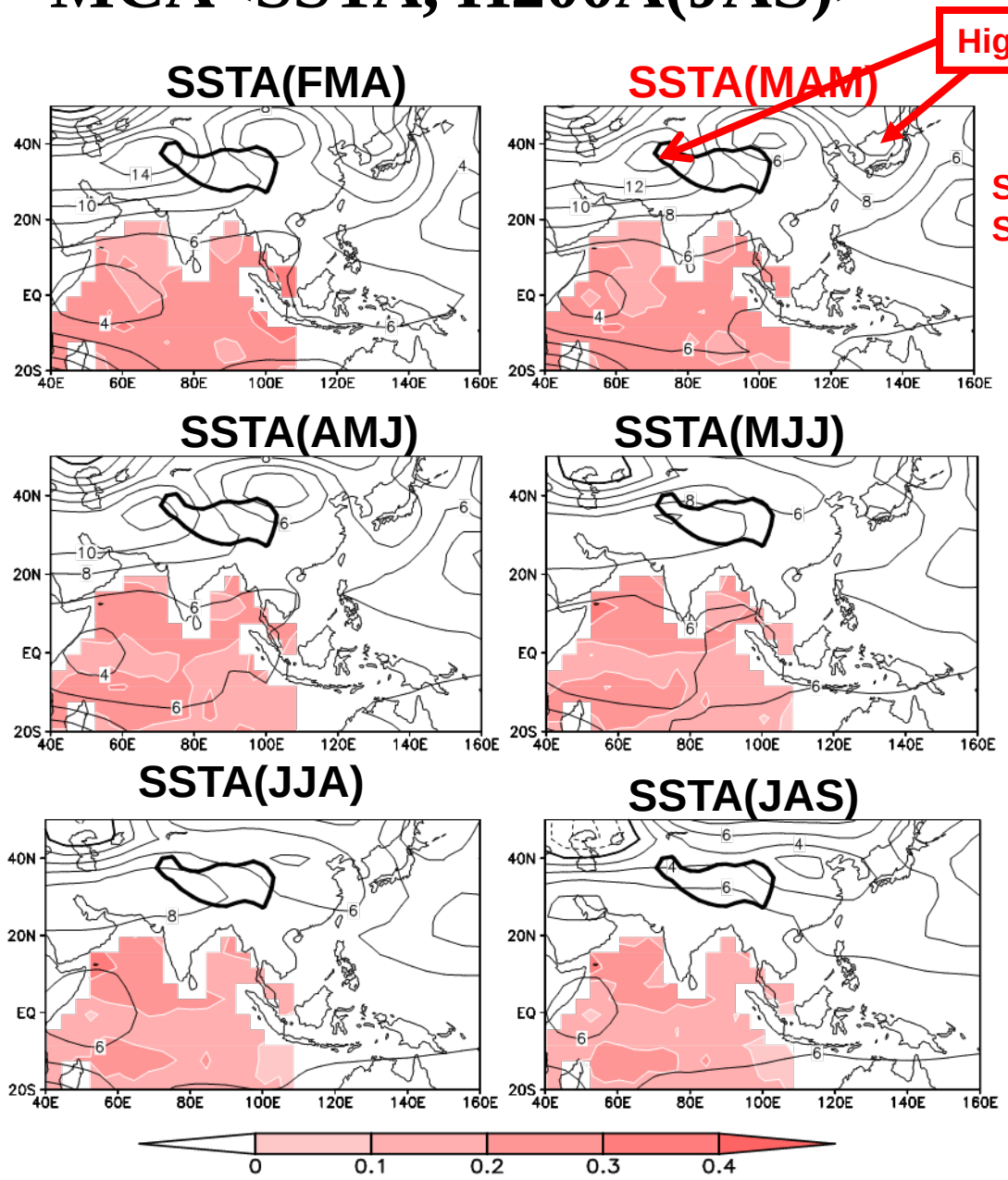
Mode 1: MCA<SSTA, H200A(JAS)>

coherent patterns

SSTA (color)

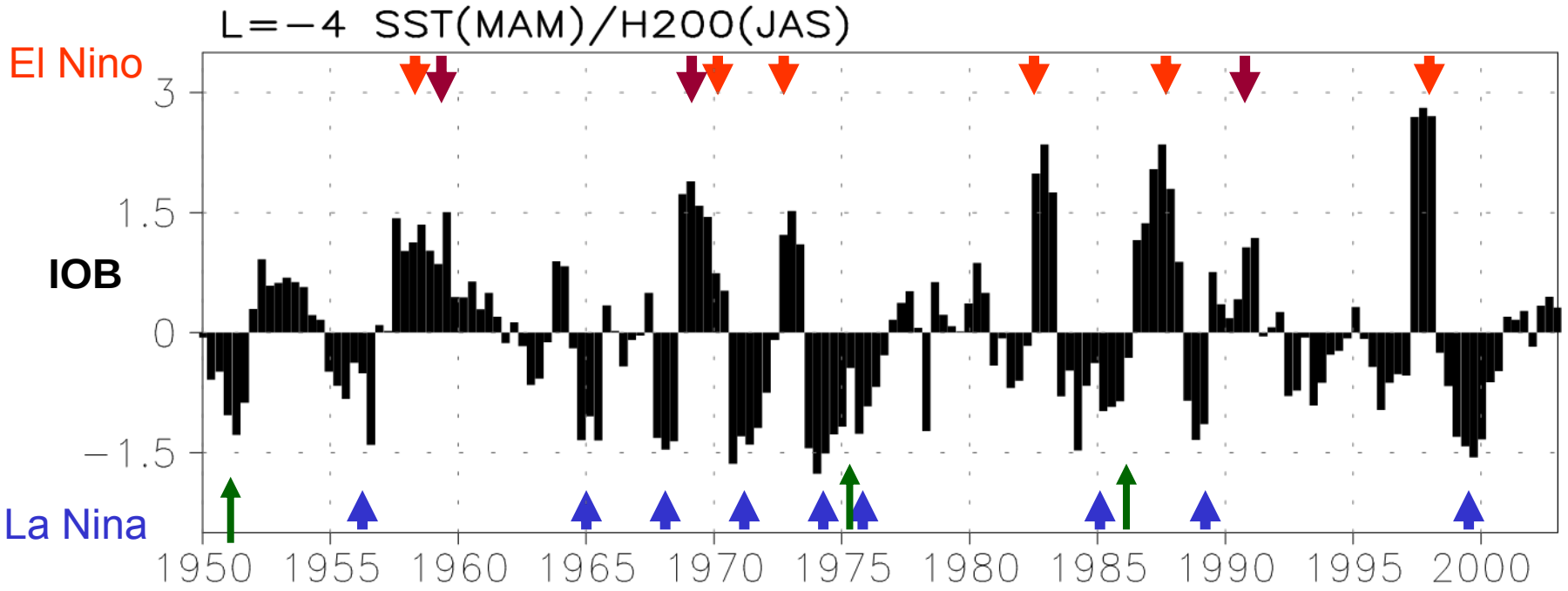
H200A (JAS)

- **SSTA: IOBM warming can persist from the spring to summer .**
- **H200A in summer: SAH positive anomaly**



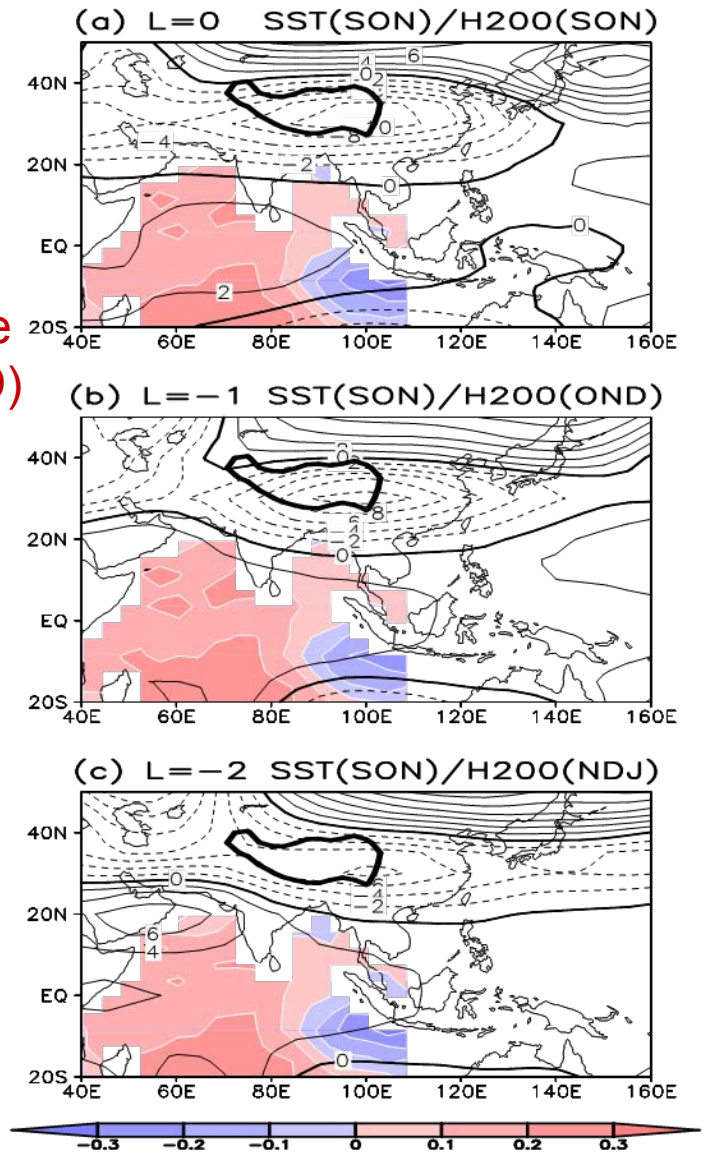
SC:>25000
SCF:>90%

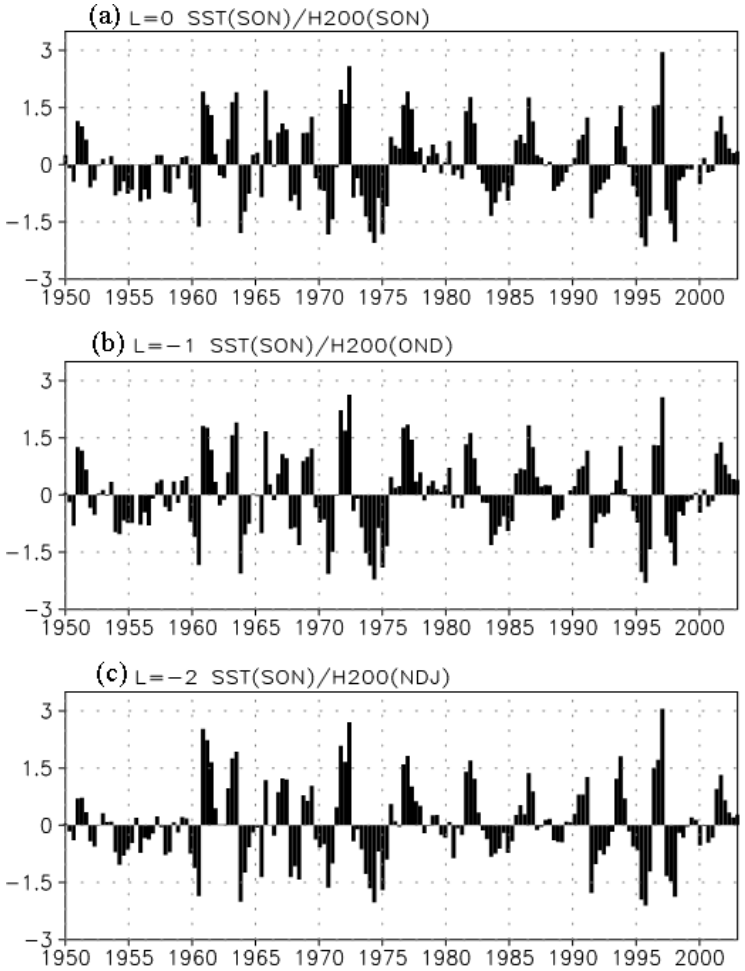
SSTA Time series in MAM of the first mode by MCA (IOBM Index)



The 7 warmer years (1958, 1970,1973,1983,1987,1988 and1998), and **9 cooler years** (1956,1965,1968,1971,1974, 1976, 1985,1989 and 2000) are the next year of the El Nino and La Nina respectively (the only exceptions are the 3 warm years [1959, 1969, 1991] and 3 cool years [1951, 1975,1984]).

IOD Mode (SVD)





The IOD appears almost before ENSO peak

The 6 positive IOD years (1963, 1972, 1977, 1982, 1991and 1997), and 5 negative IOD years (1964,1971,1974, 1975, 1998) are the first year of the El Nino and La Nina respectively (the only exceptions are the 1 Positive IOD year [1961] and 2 negative IOD years[1960, 1996]).

MCA results

- The SCF of the first mode is up to 4 times large as that of the second mode.

- For first MCA mode, the Maximum SC: spring (MAM)SST and Asian Summer Monsoon in second year of the El Nino (La Nina); Positive Phase (SST Warm) is corresponding to the stronger Asian Summer Monsoon **(IBOM)**

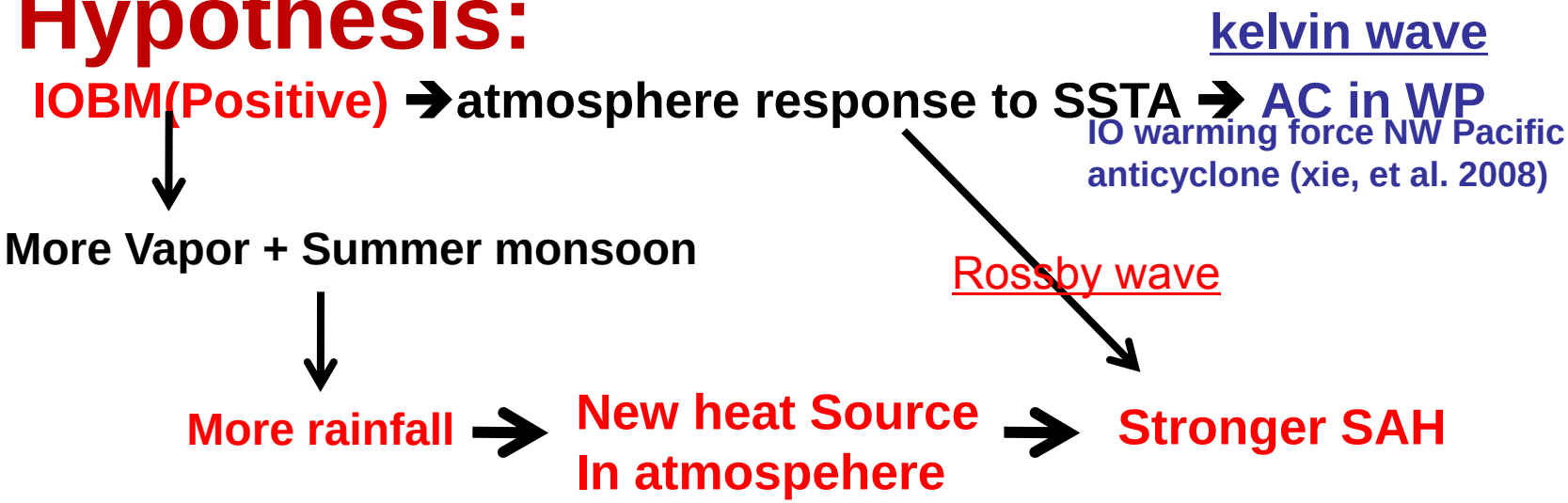
- For second MCA mode, the Maximum SC: late fall SST and Asian Winter Monsoon in first year of the El Nino (La Nina) year; Positive Phase (east cold and west warm) is corresponding to the weaker Asian winter monsoon **(IODM)**

How understand the MCA result, which is only statistical result or not?

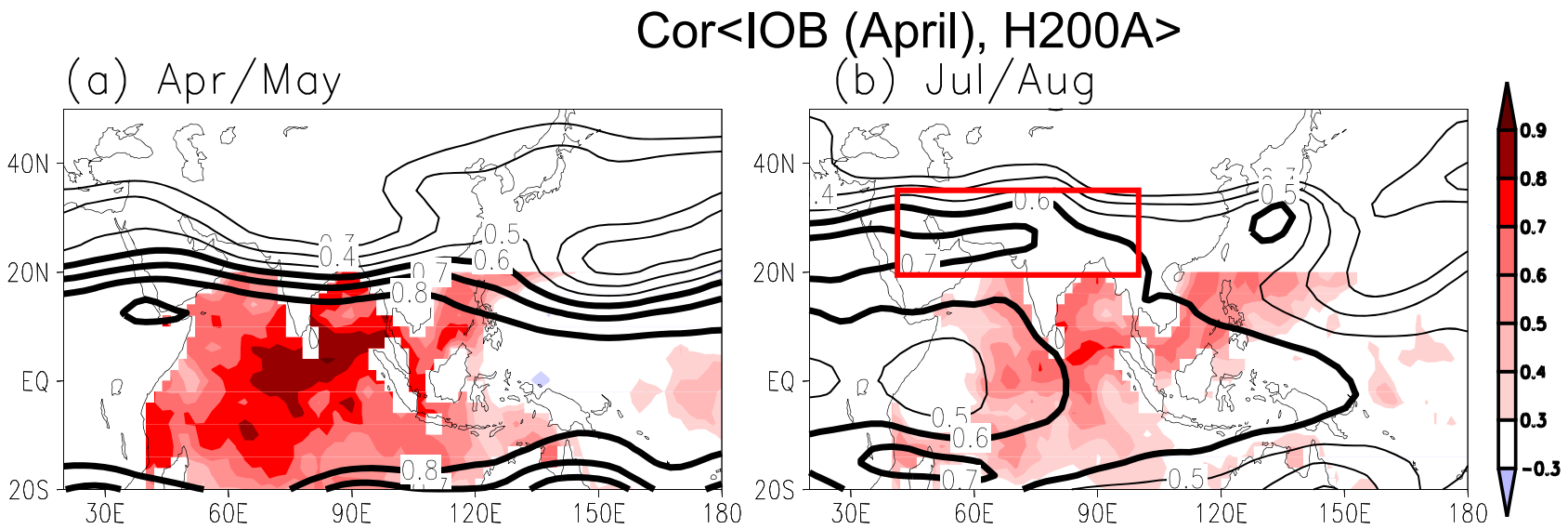
Why the IO warm ->stronger Asian Summer Monsoon?

Physical mechanism of the first mode – IOB mode

Hypothesis:



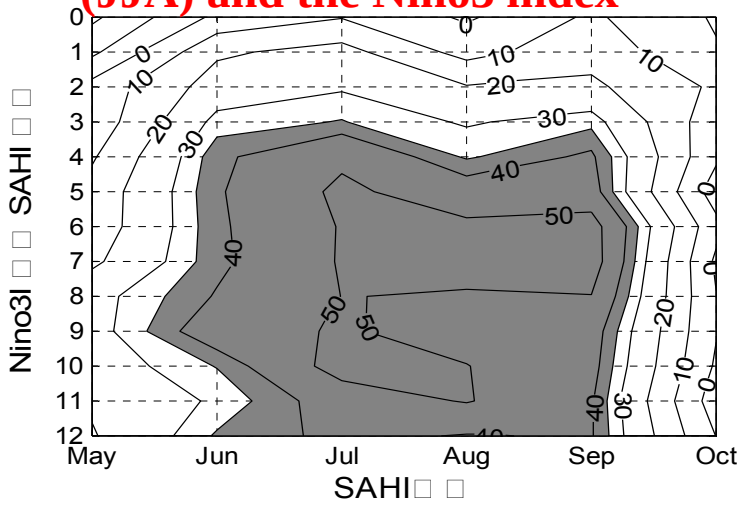
Some evidences for the Hypothesis



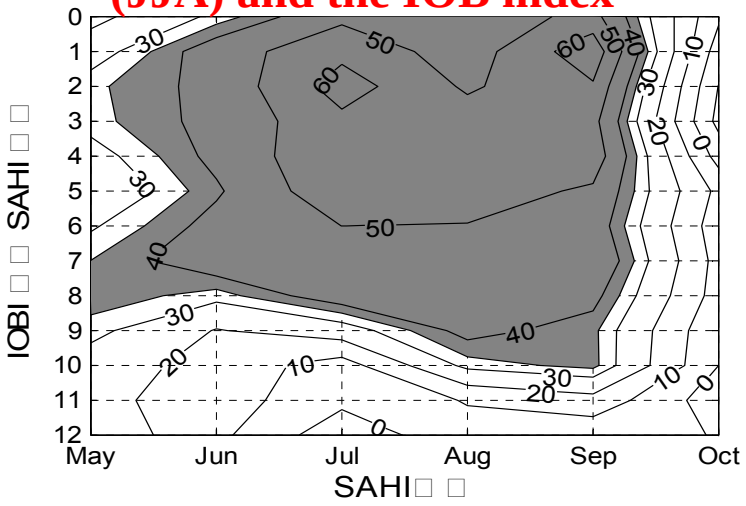
The extended Matsuno-Gill pattern responds to increased latent heating over the TIO: positive correlations over the off-equatorial areas are a pair of Rossby wave packets, and an equatorial Kelvin wave over the Marine continent (Yang et al. 2007).

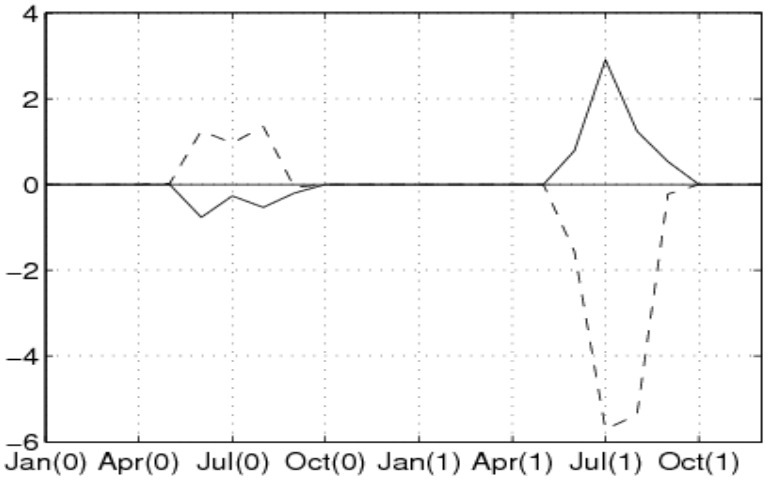
The box denotes the region for the SAH index definition.

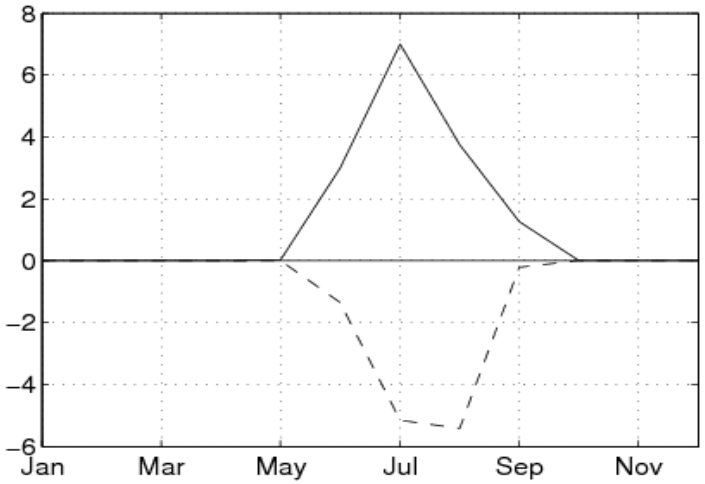
South Asian high Index (JJA) and the Niño3 index



South Asian high Index (JJA) and the IOB index





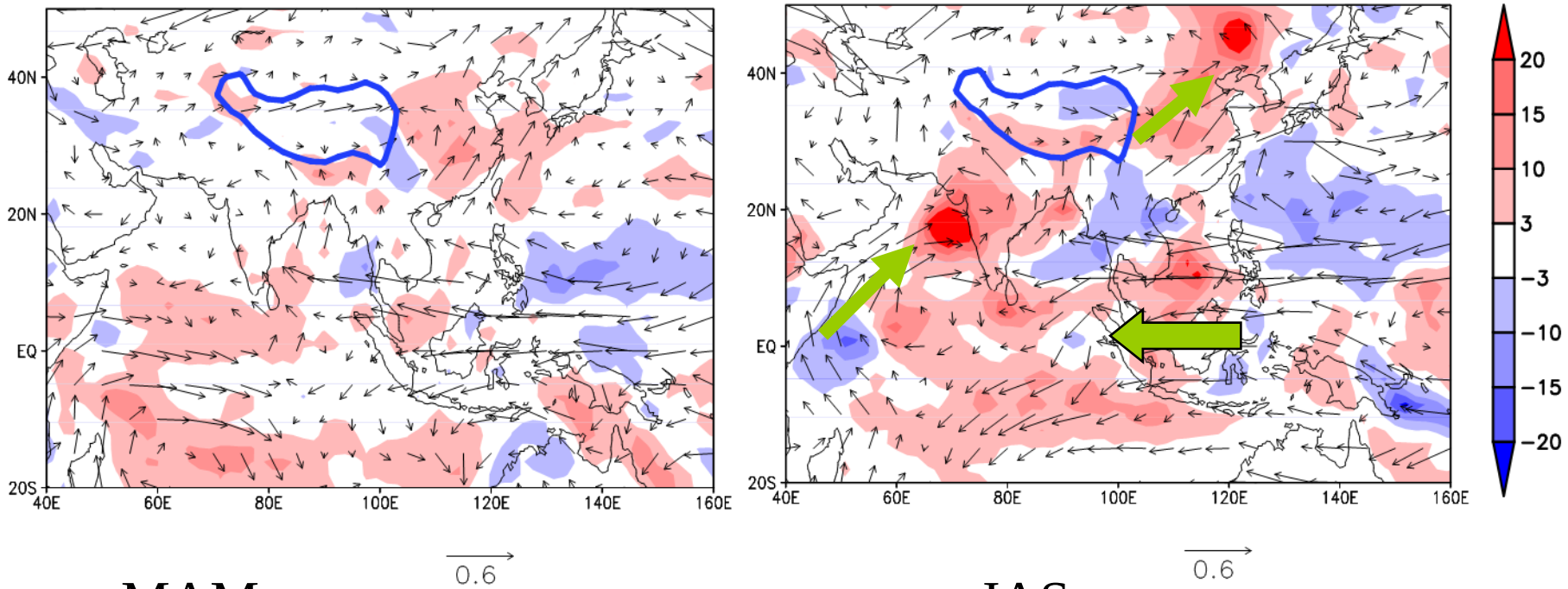


composites of SAHI in the years and the following years of El Niño (solid line),La Niño(dashed line)

composites of SAHI in the years and the following years of warm IOB (solid line) and cool IOB (dashed line)

IOBM➔Surface wind and rainfall

Reg<IOBM index, UV(850) anomaly and precipitation rate anomaly>



MAM JAS

SAH, SA monsoon

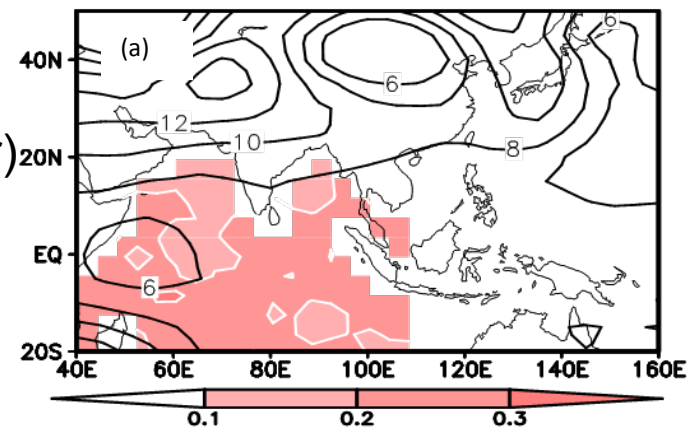
UV850(vector) , Prec(shaded)

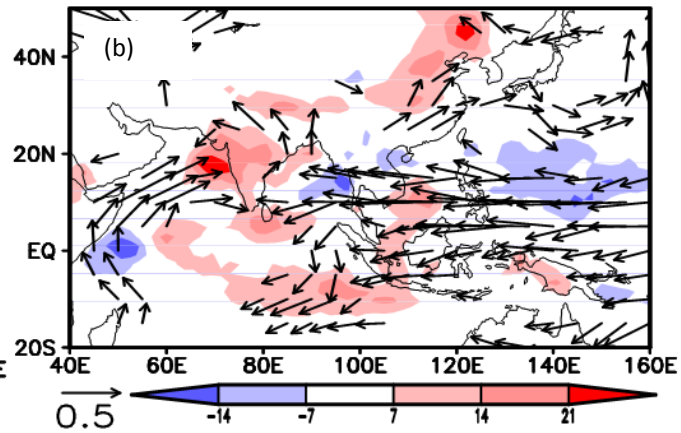
Subtropical High, JSH, EA monsoon

Northward moisture transport and additional heating

Reg(IOBM index, atmosphere anomaly in JAS)

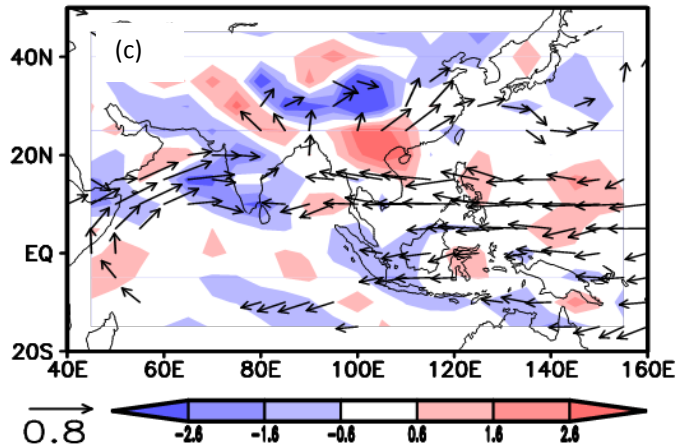
SSTA (color)
GH200

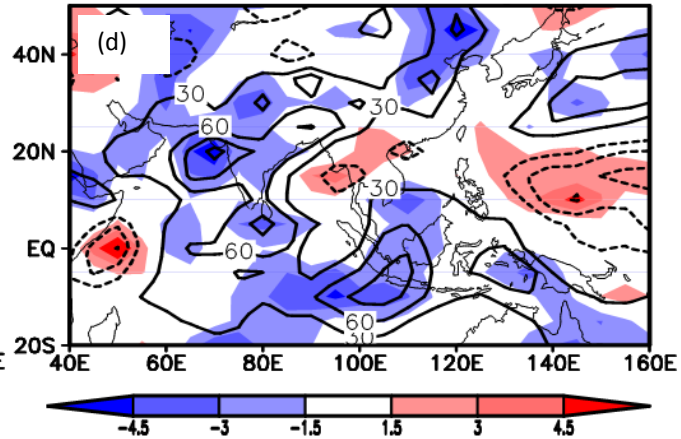




Wind
rainfall

Vq850(vector),
Div(Vq850)
(color)





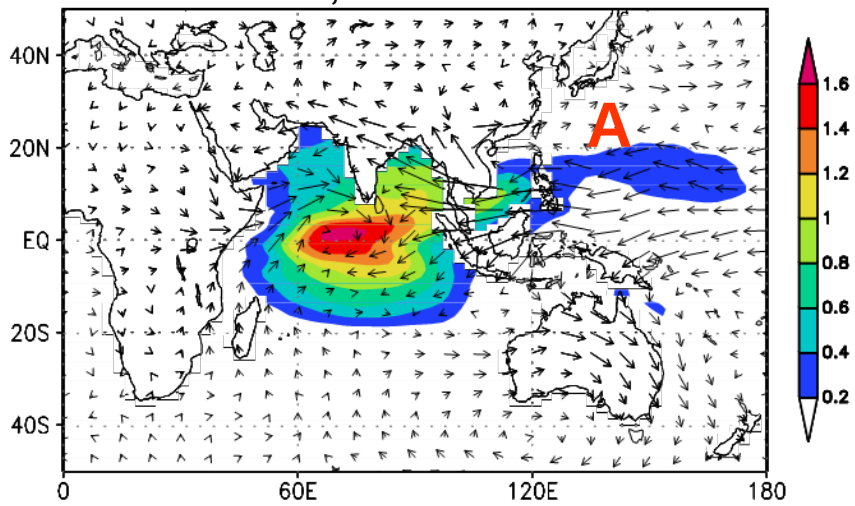
Omg500
(color),
DiaHeat
ing(cont
our)

The Positive SAH anomaly likely a Rossby wave response to a diabatic heating over the South Asia and the TIO.

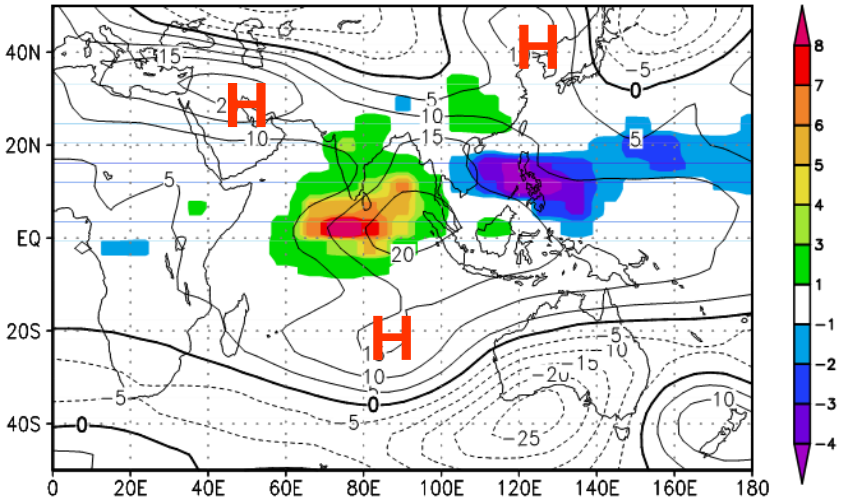
The AC anomaly on WP in JAS is the result of the Kelvin wave response

Further Evidence 3: Ensemble mean from FOAM experiment (JJA)

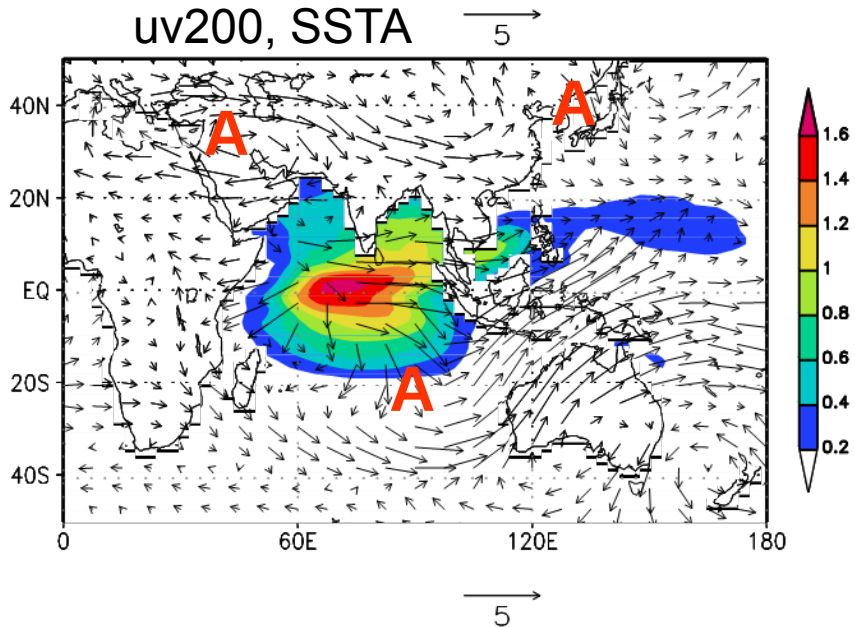
uv850, SSTA



H200, precipitation

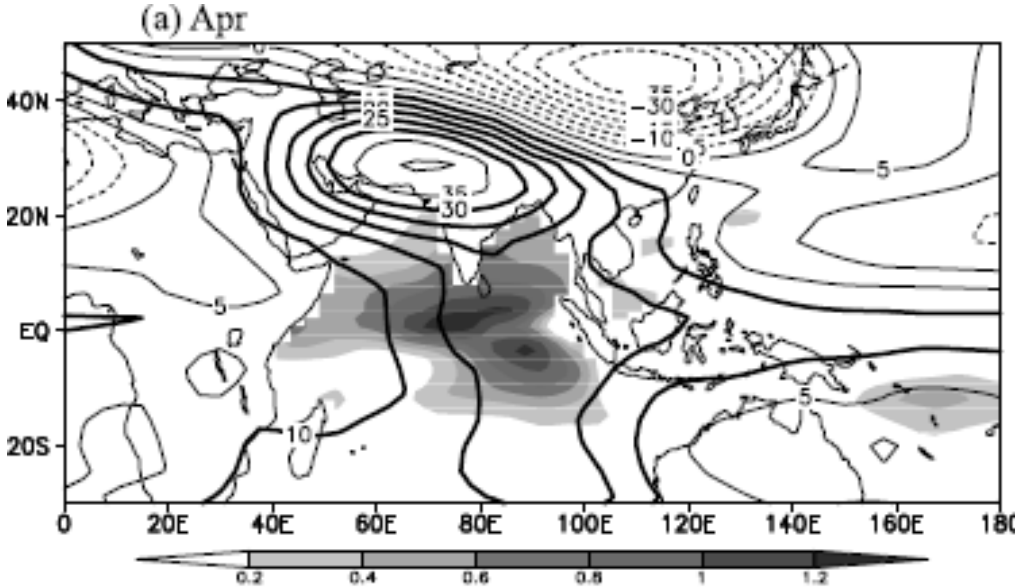


uv200, SSTA

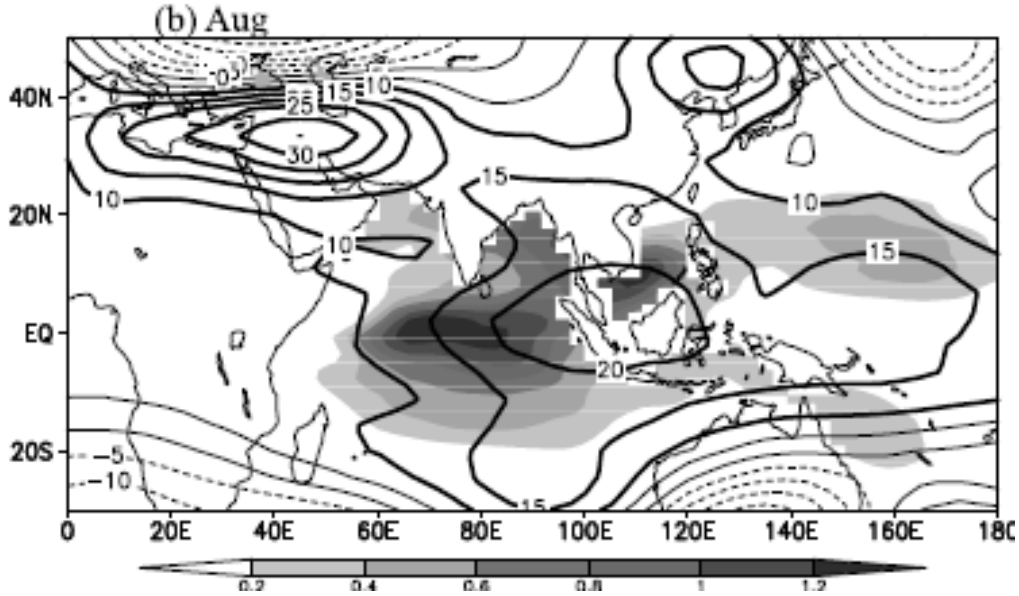


The FOAM model results are consistent with those of the observational analyses.

Ensemble mean from FOAM experiment

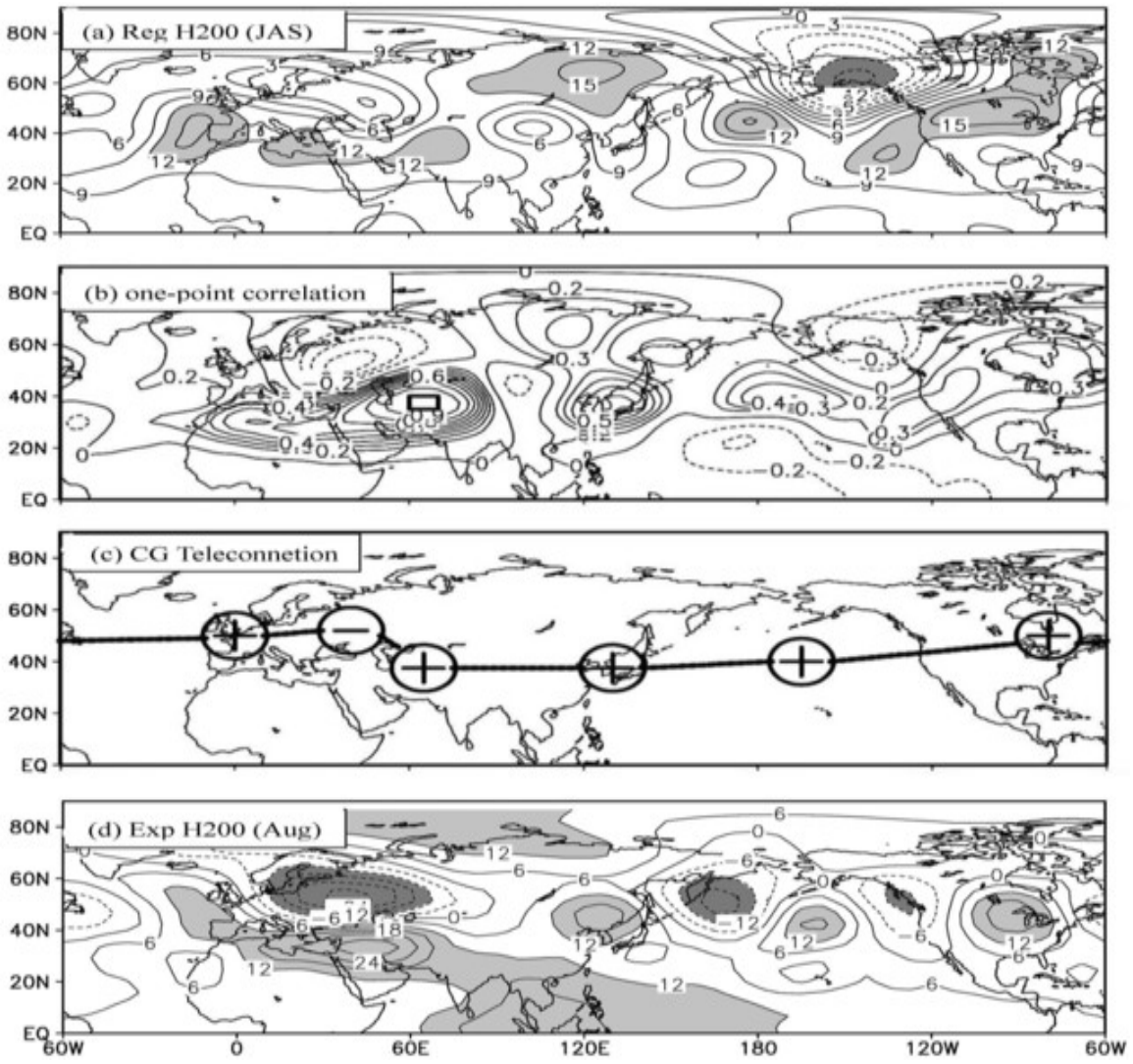


The response of H200 to initial SST (in April) positive anomaly



The response of H200 to initial SST (in Aug) positive anomaly

Circumglobal Teleconnection (CGT)



IOBM &CGT

SAH & CGT

CGT
(Ding and Wang,2005)

T

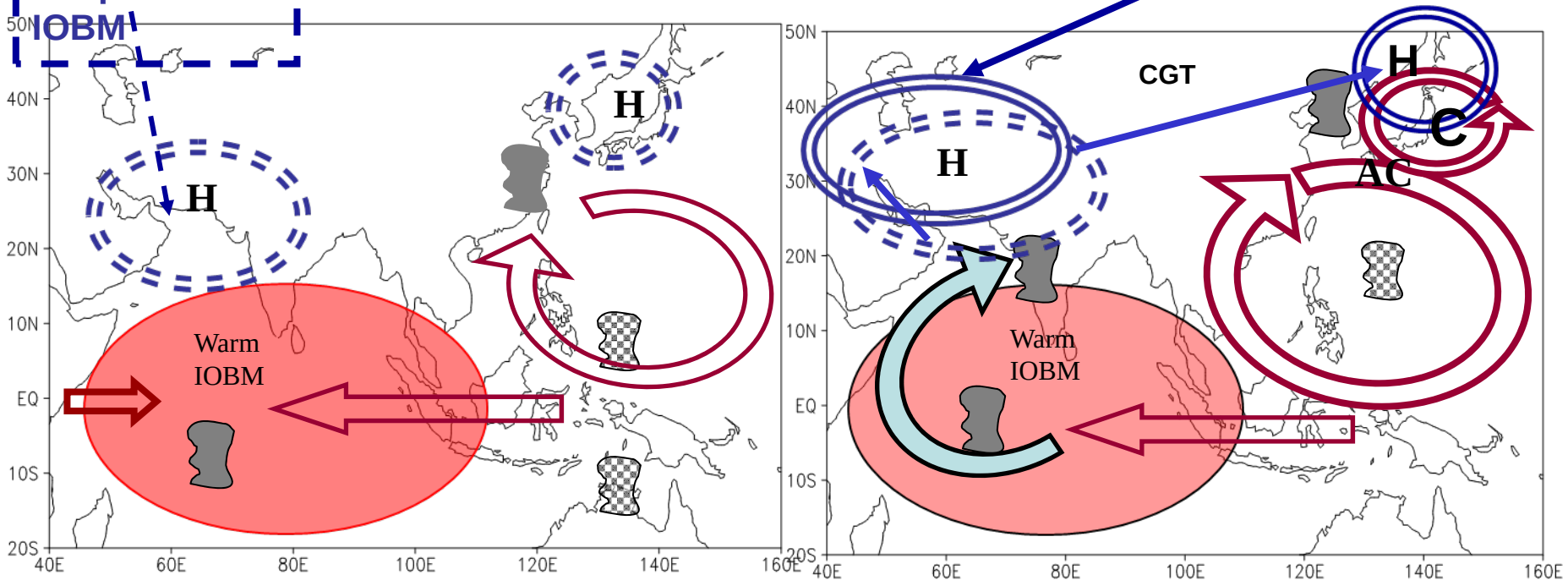
The response of H200 to initial SST (in Aug) positive anomaly

Sketch about IOB impact

Matsuno-Gill pattern

Response to IOBM

Response to new heat source



Spring

Summer

upper level height

Warm SST

Negative Precipitation

Low level wind

Positive precipitation

Impact of the IOBM

- In summer the southwesterly transports more moisture from the warm Indian Ocean towards the south Asian even causing more precipitation over east Arab Sea-west India and forming a new heating source in atmosphere and stronger Asian summer monsoon; enhances SAH;
- In spring and summer, corresponding to IOBM warm, an anomalous anticyclonic circulation forms over the subtropical Northwest Pacific, and impacts on the East Asian Monsoon;
- Impacts of the IOBM on atmosphere can extend farther by CGT

How understand the MCA result, which is only statistical result or not?

Why the IOD in late fall ->weaker Asian Winter Monsoon?

Physical mechanism of the second mode – IOD mode

Hypothesis:

IODM(Positive) ➔atmosphere respond to negative SSTA

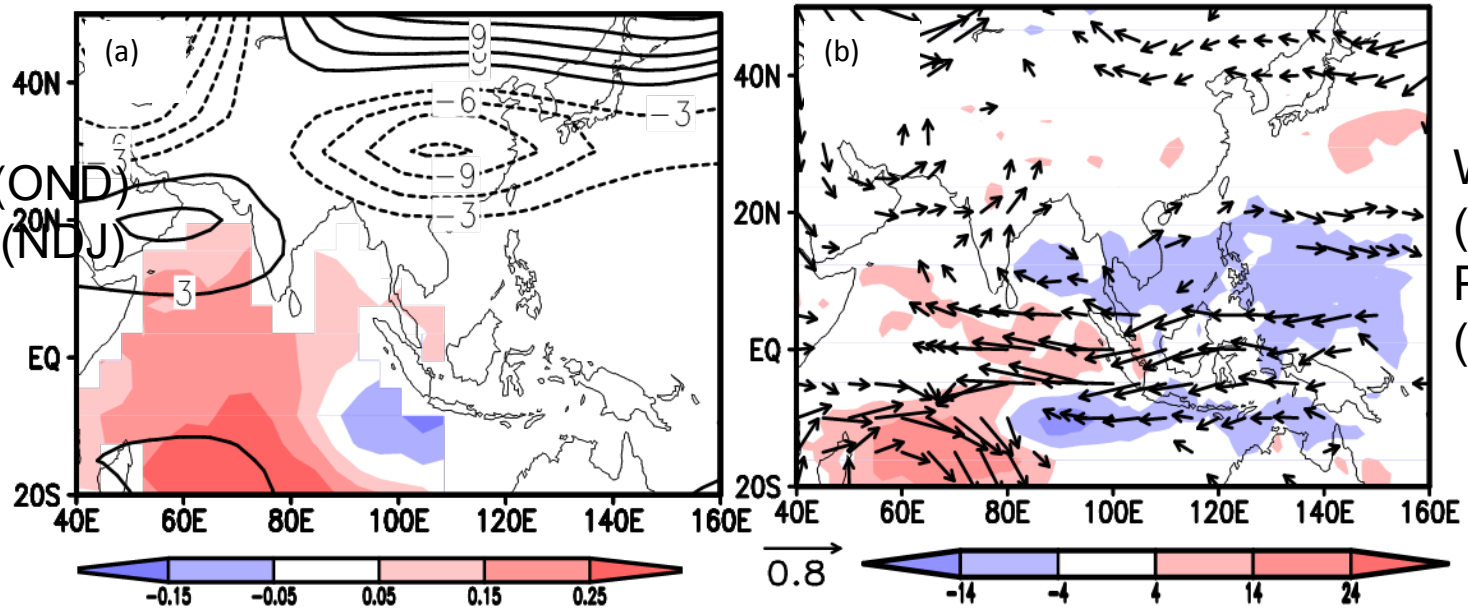
Less Vapor + Asian winter monsoon

Less rainfall In Australia

Weaker Australia High

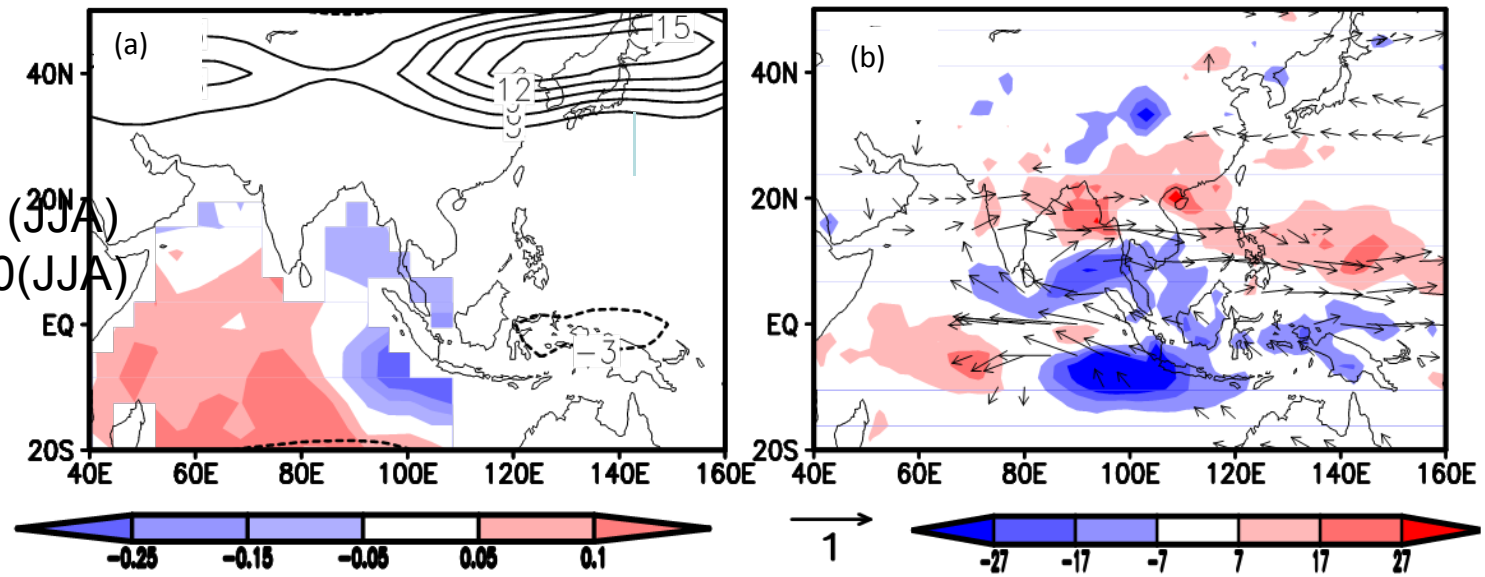
This hypothesis need to be proved in future

SST (OND)
H200(NDJ)



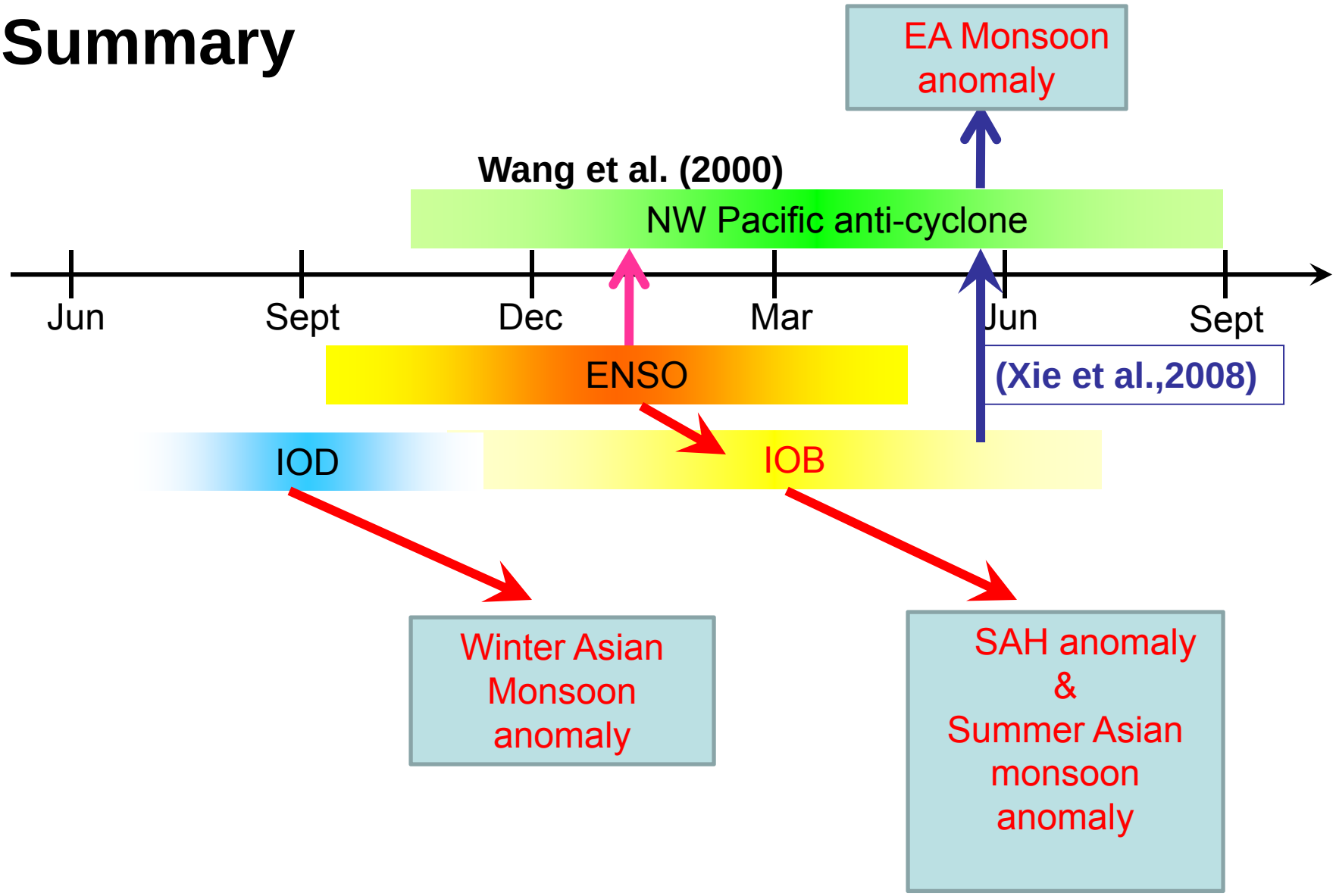
Wind 850 (NDJ)
Precipitation (NDJ)

SST (JJA)
H200(JJA)



Wind 850 (JJA)
Precipitation (JJA)

Summary


EA Monsoon anomaly
Wang et al. (2000)
NW Pacific anti-cyclone
Jun
Sept
Dec
Mar
Jun
Sept
ENSO
(Xie et al.,2008)
IOD
IOB
Winter Asian Monsoon anomaly
SAH anomaly & Summer Asian monsoon anomaly


Thank you!
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