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

Tim Li

IPRC and Dept. of Meteorology, Univ. of Hawaii

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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?
Filtered All Indian Rainfall Index–SST Correlation and Moisture Flux Composite (Wet Minus Dry) at 1000hPa, 1950–1997

2–3 year

3–7 year

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
Local processes (IO SSTA & moisture transport) prior to the monsoon season

Large-scale overturning circulation

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?

A simple explanation of this in-phase relationship is that both the Indian and Australian monsoons are controlled by ENSO.
Velocity potential difference fields
The result suggests that Indian Ocean SSTAn may play an 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 $\rightarrow$ WP circulation anomaly (Boreal summer/fall)

EP SSTA $\rightarrow$ 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)

Composite for 25 cases

W. Indian Ocean Warming Case (6, WISST>0.5)

El Nino Only Case (5, WISST <0.2)

Dashed : WISST (40-65E, 10S-10N)
El Niño 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
SSTA composites (wet minus dry I-AM)

Non-ENSO years

ENSO-years
2. TBO structure and origin