Monsoon IntraSeasonal Oscillation (MISO) in the Bay of Bengal: Effect of mixed layer and barrier layer on SST and convection

Weiqing Han
Department of Atmospheric and Oceanic Sciences
The University of Colorado at Boulder

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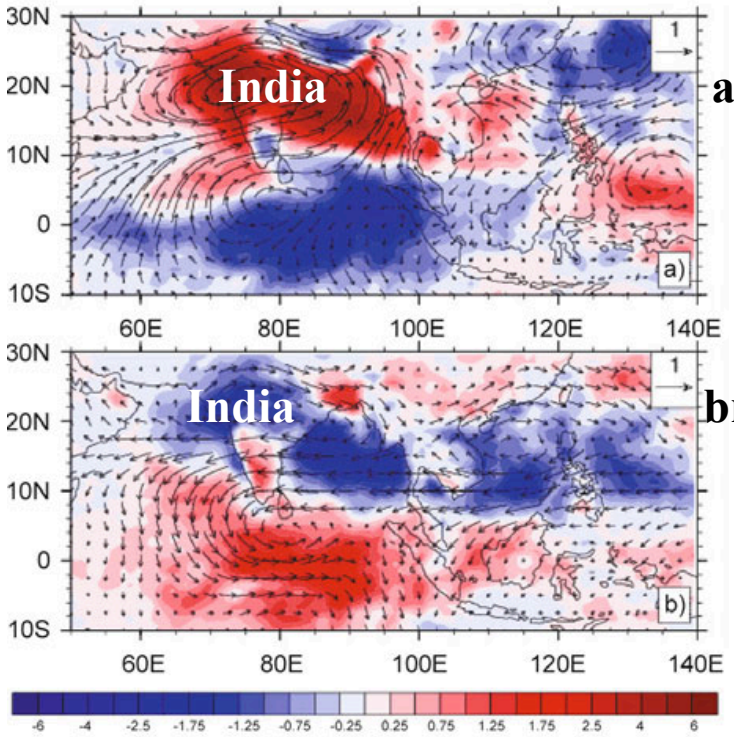
1. Background

Indian summer (**May-Oct**) **M**onsoon **I**ntra**S**easonal **O**scillation (**MISO**;10~90d):

Rain & wind



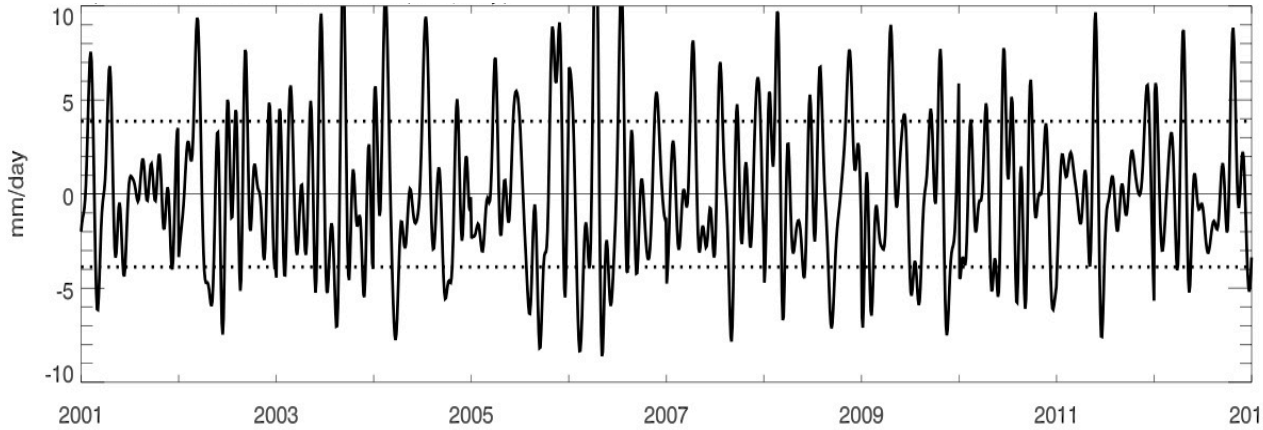
active (wet)

break (dry)

Associated with basin-scale wind & rainfall;

Large socio-economic consequences

10-90d all India rainfall for JJAS



Goal

Modeling studies: MISOs (i.e. summertime MJO)

– mainly atmospheric internal variability;

–air-sea interaction over Indian Ocean, however, is crucial for simulating/predicting MISO northward propagation (Goswami 2012, review);

Processes that determine air-sea interaction: not well understood.

The goal of this research:

Explore the influence of mixed layer depth (MLD) and barrier layer thickness (BLT) over the Bay of Bengal on sea surface temperature (SST) and precipitation variability of the MISO.

2. Approach

Combine observational analysis with OGCM experiments:

a) Analyze satellite observed winds + precipitation to identify the MISO events;

b) Perform OGCM Experiments (using HYCOM) to isolate forcing/ process that determine instraseasonal SSTa;

c) Examine the feedback of the ocean to MISO convection.

***Main Run (2000-2014)*: complete solution - simulates OBS**

Forcing fields: daily CCMP V1.1 (2000-2011) & ASCAT wind 2012-2014; CERES SWR & LWR; TRMM Multiple satellite precipitation; ERAI Tair and Specific humidity.

***No instraseasonal wind stress run*: Remove MISO wind stress-related oceanic processes (oceanic processes: upwelling, entrainment, advection);**

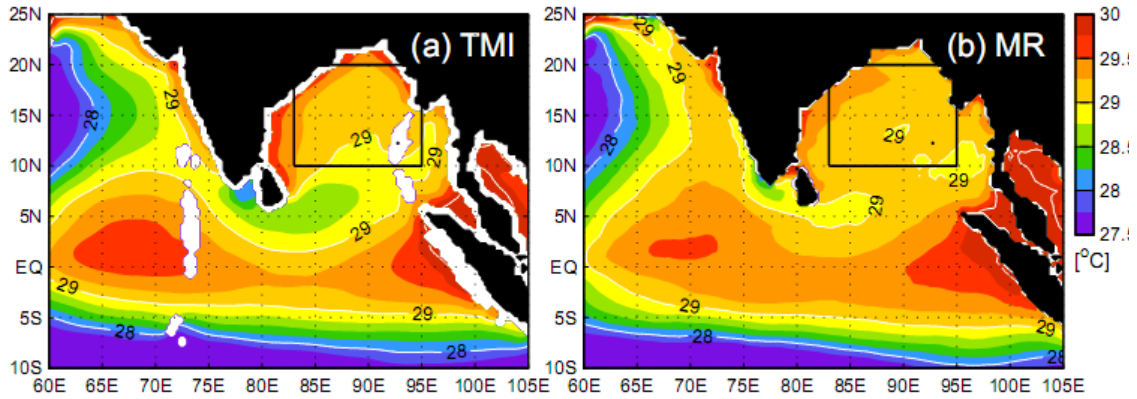
***No wind speed run*: remove MISO-related (Qsen + Qlat);**

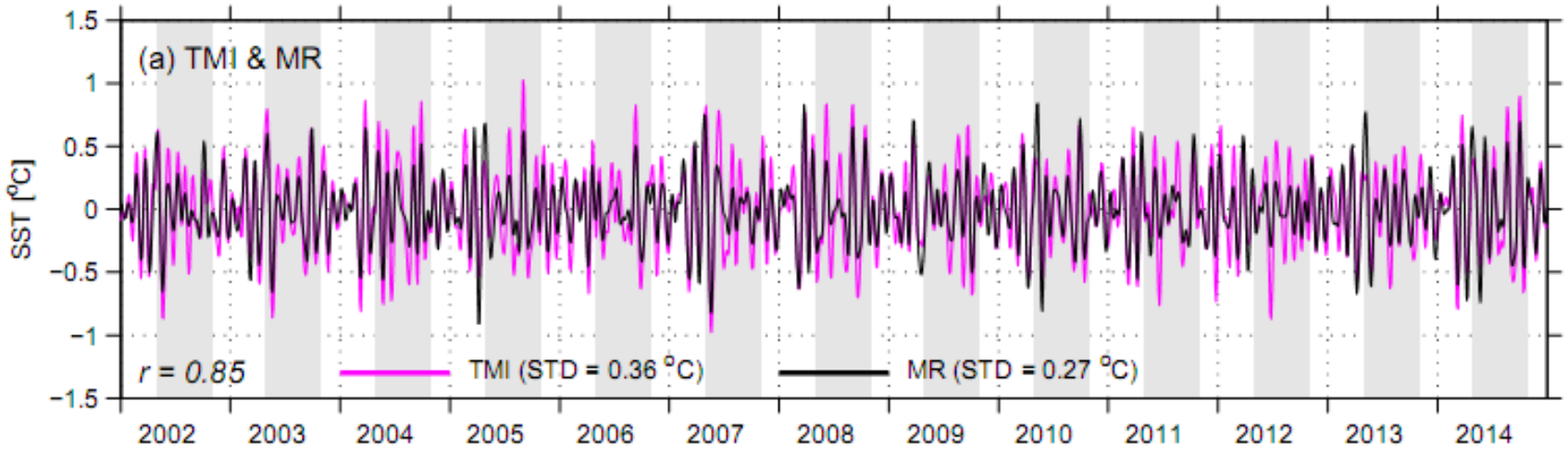
***No Short Wave Radiation run*: Remove MISO (SWR effect).**

3. Observed and simulated SST (May-Oct)

Mean SST

20-90d SST





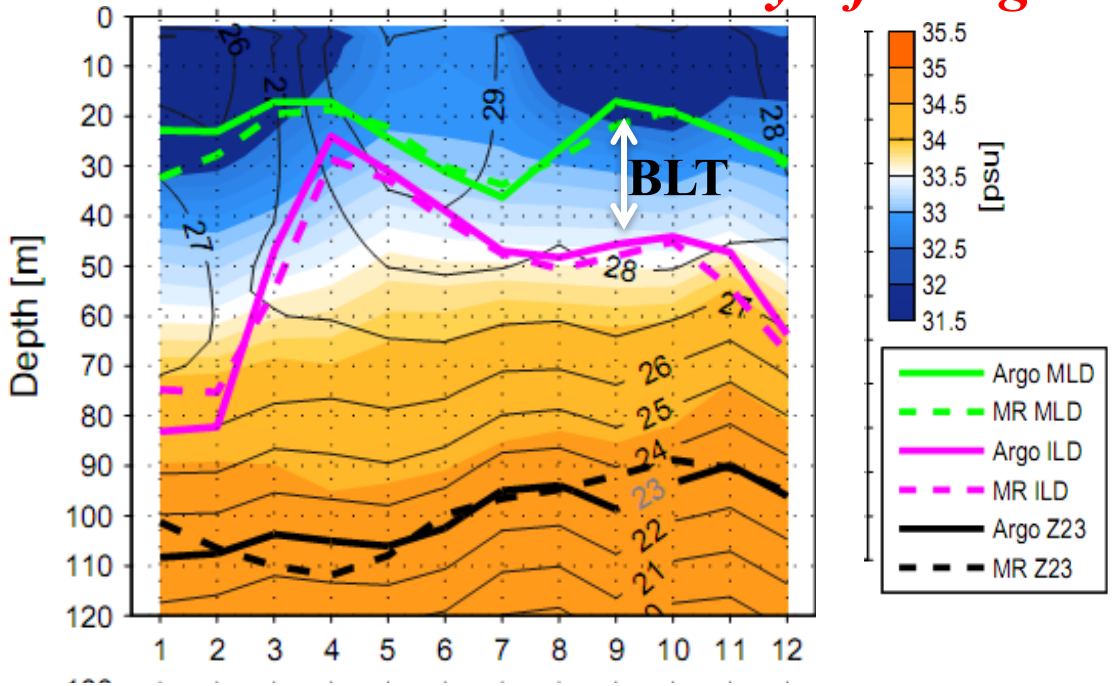
Obs/Model difference: (1) Skin vs bulk SST;

(2) Model: daily forcing: no diurnal cycle (~20% winter MJO in Thermocline Ridge region)

Observed/simulated MLD & BLT: 2005-2014 avg

Mixed layer depth (MLD);
Isothermal layer depth (ILD);
Barrier layer thickness (BLT): *(ILD – MLD)* ***(see Lukas and Lindstrom, 1991)***

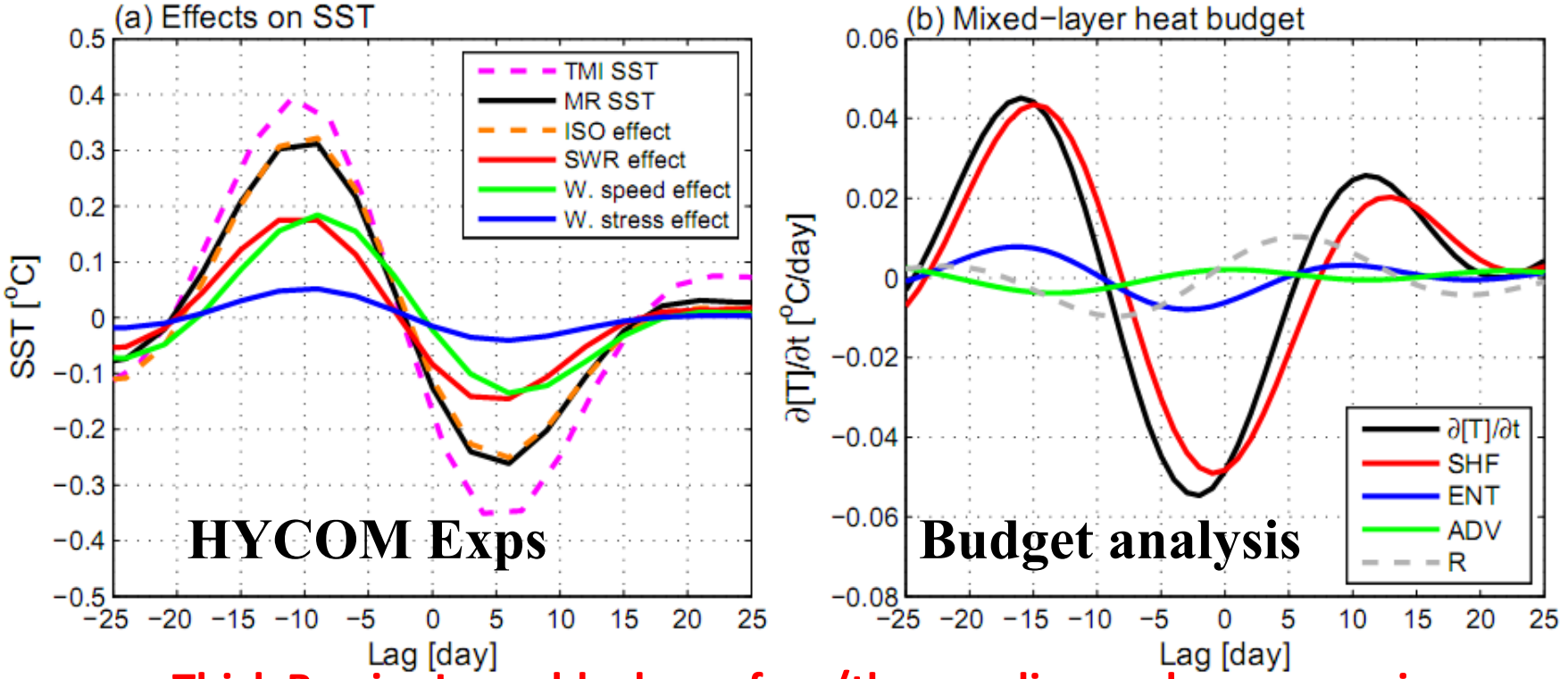
Seasonal evolution over Bay-of-Bengal



HYCOM well simulates mean & intraseasonal SST, MLD, BLT and Thermocline depth (Z23) – suitable for our present study

4. Air-Sea Interaction:
(a) processes controlling intraseasonal SST variability:
45 MISO events composite from May-Oct

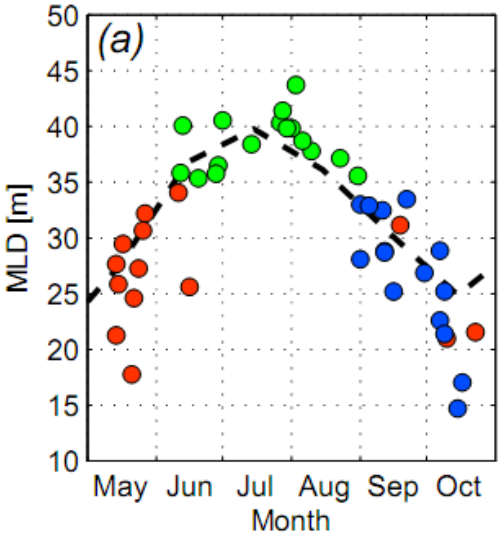
MR: complete run by daily forcing (2001-2014)
NoTAU: remove intraseasonal wind stress (**ocean processes: ent, upw & adv**)
NoSWR: remove (**shortwave radiation)**
NoWSP: remove intraseasonal wind speed (**turbulent heat fluxes: Qsen+Qlat**)

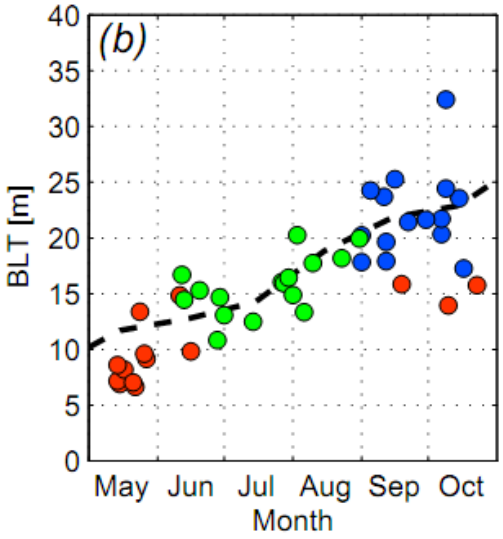


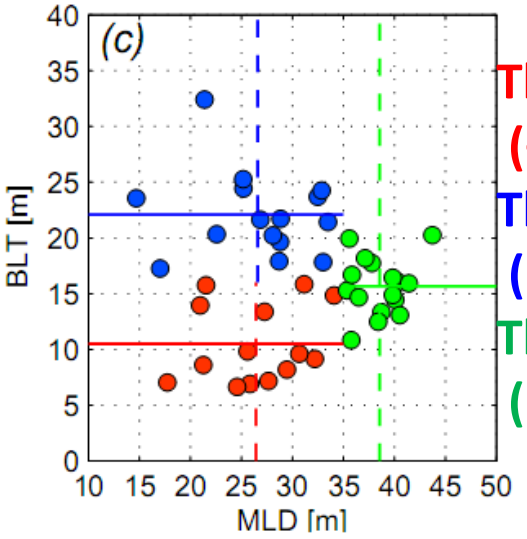
Thick Barrier Layer blocks surface/thermocline exchange, causing dominant effect of surface heat flux (SHF) on intraseasonal SSTa.

Air-sea interaction:

(b) Impact of MLD and BLT on MISO SSTa and rainfall:



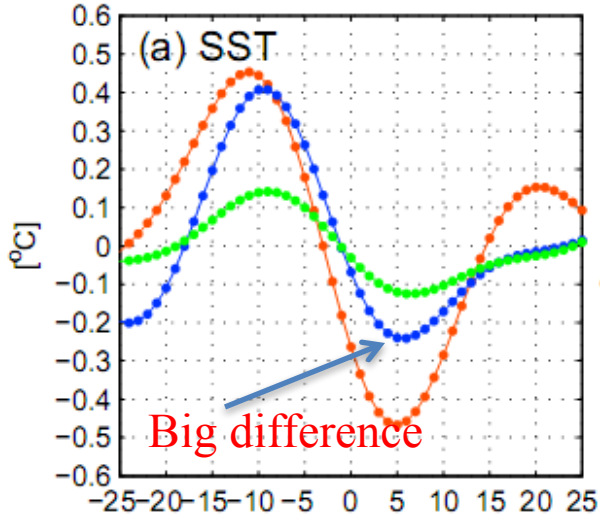


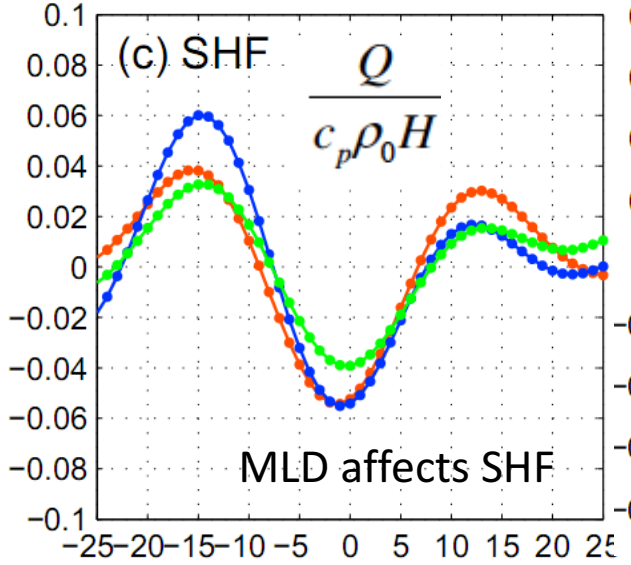


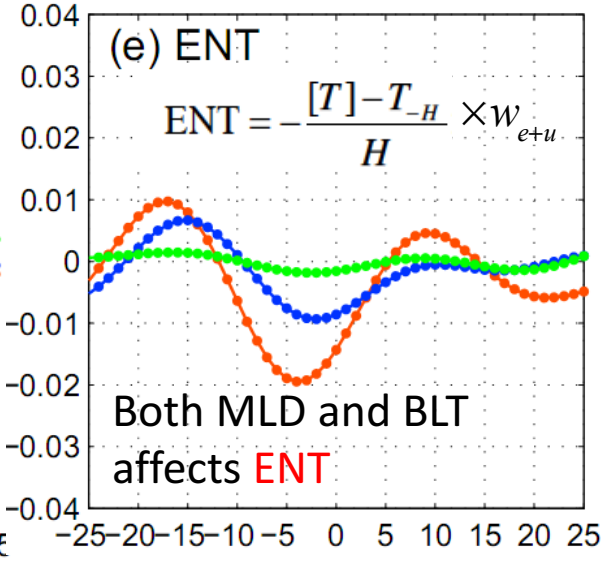
Thin BLT group (<17m, 14events)

Thick BLT group (>17m, 15)

Thick MLD group (>35m, 16)

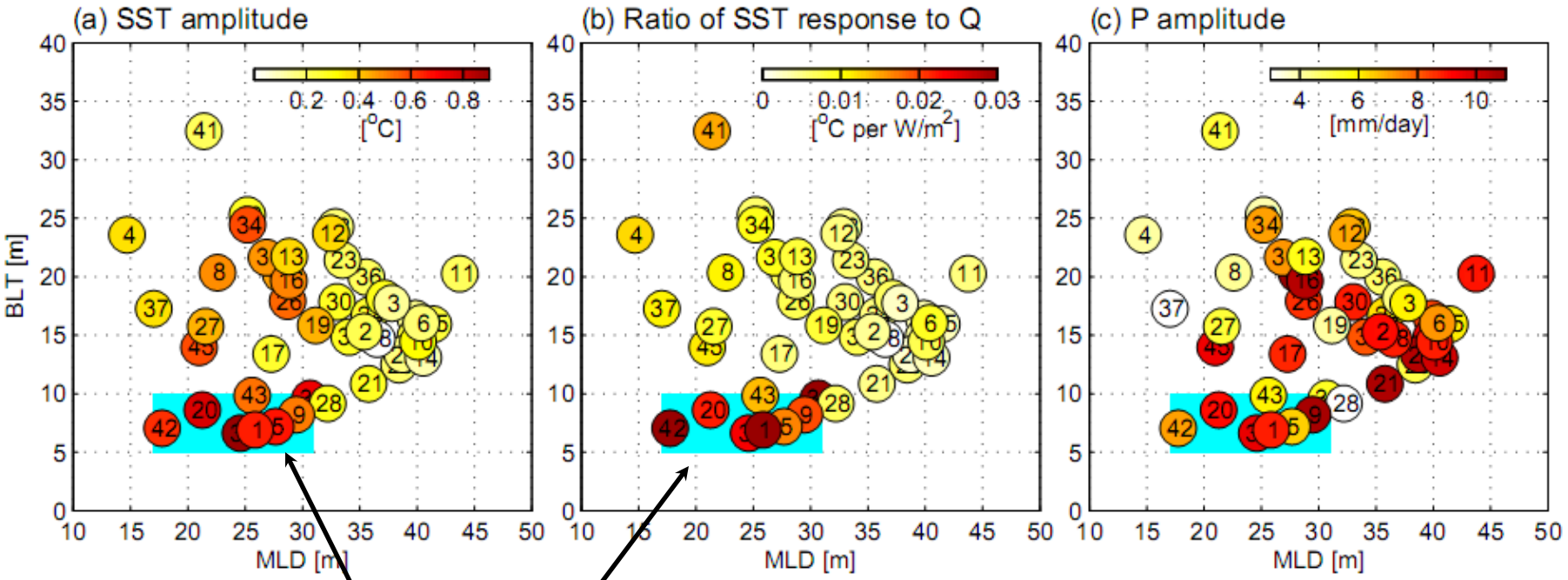






SST: Small BLT > Large BLT > Large MLD

(b) Impact of MLD and BLT on MISO SST and rainfall



When both MLD and BLT are small, the SST response to heat flux is enhanced.

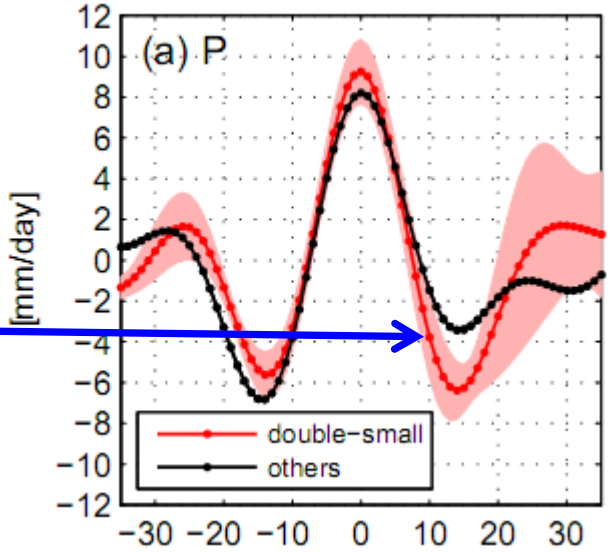
Most double-Small events occur in **May-mid June**

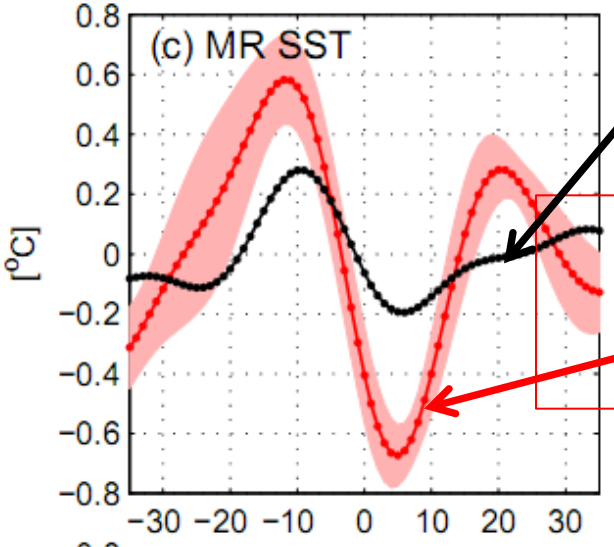
Impact on rainfall variability is relatively small for all 45 events during May-Oct.

Unique features of the double-small 8 events: May-June

Rainfall and SST anomalies are amplified under double-small condition
MLD<31m; BLT<10m

Large difference for the post-convection break

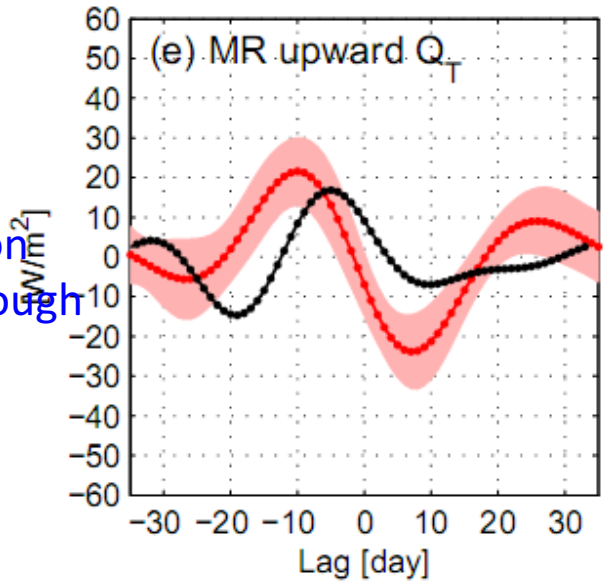


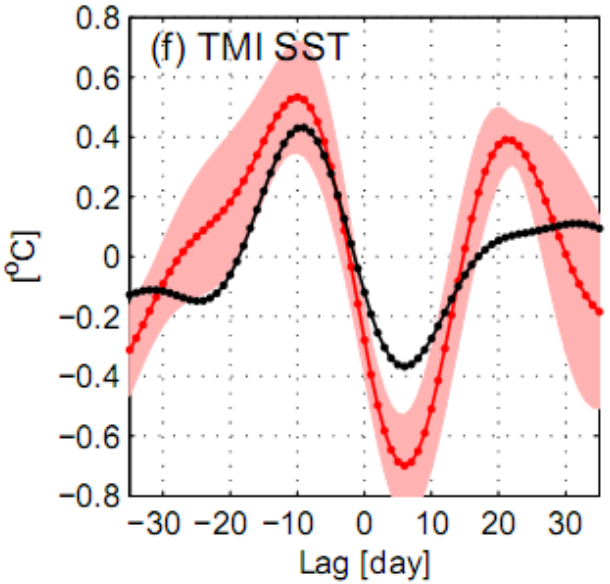


Prolonged but weak cooling

Short but Intensified cooling

Impact of SST on convection through turbulent Q

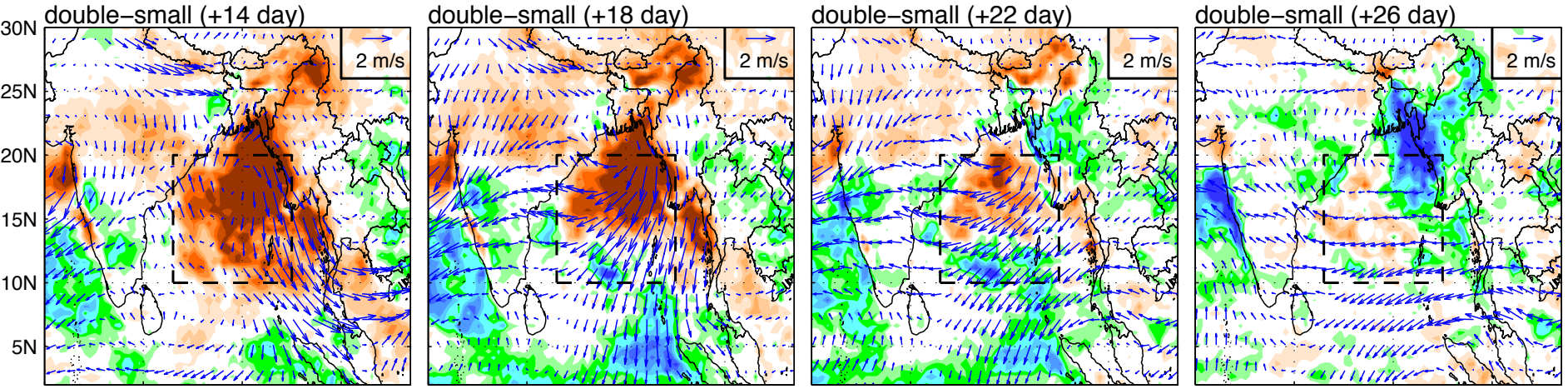




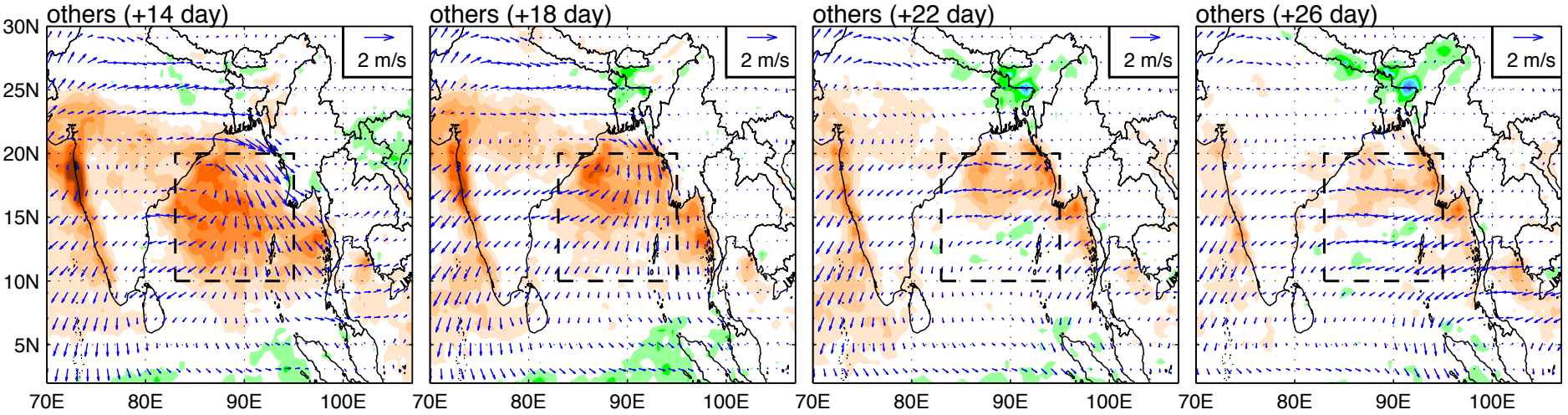
Vecchi & Harrison 2002

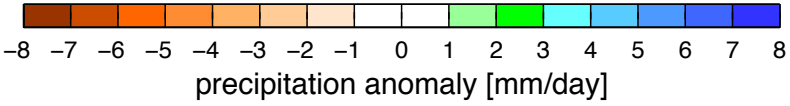
Confirmed by TMI observation

Thin MLD&BLT condition: intense but short break



Other: weak but prolonged break





5. Summary

- **Due to the thick barrier layer, intraseasonal SSTa over the Bay of Bengnal is primarily controlled by surface heat flux forcing;**

- **During May-June monsoon developing stage, the thin MLD and BLT over the Bay amplify intraseasonal SSTa amplitude, causing short-intense monsoon break in MISO convection compared to weak-prolonged break of the thick MLD and BLT cases;**

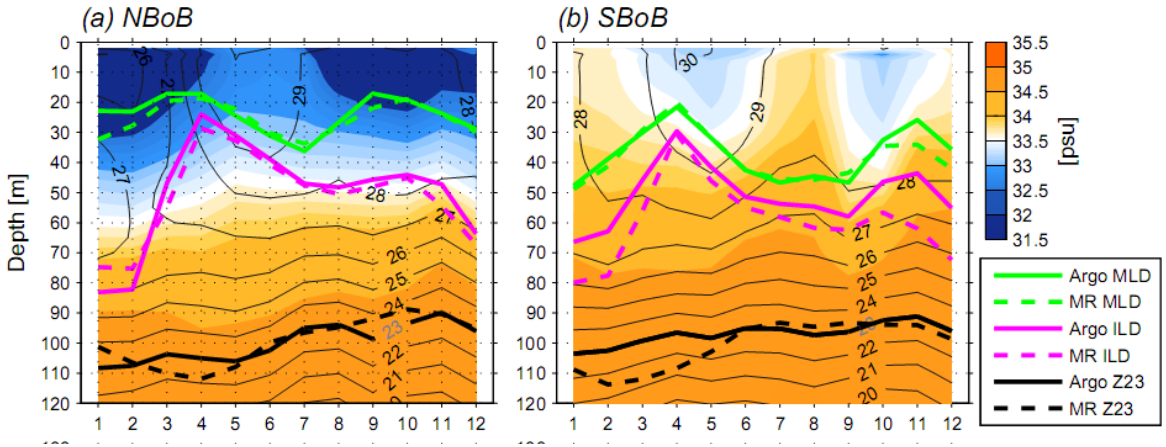
- **The strong wind & rainfall associated with the short-intense monsoon break (MISO dry phase) have large impact on different regions of India and Southeast Asia.**

Observed and simulated MLD, BLT & thermocline depth

Mixed layer depth (MLD): **depth at where density increase equivalent to 0.5C temperature decrease;**

Isothermo layer depth (ILD): depth at where T decreases by 0.5C;

Barrier layer thickness (BLT): *ILD - MLD*



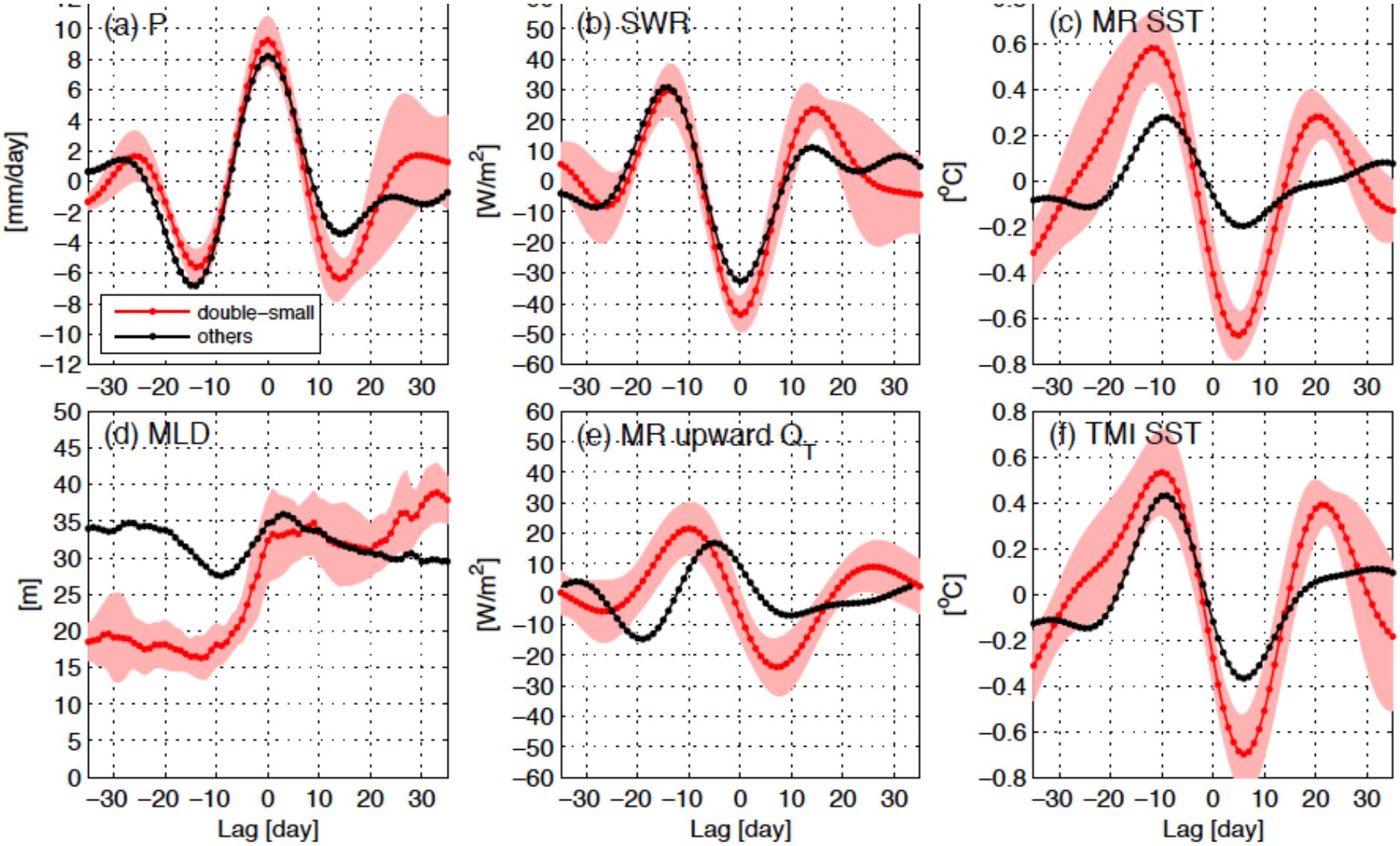
HYCOM realistically simulates MLD, ILD, BLT, and Z23 from Argo observation 2005-2014

HYCOM well simulates mean & intraseasonal SST, MLD, BLT and Z23 – suitable for our present study

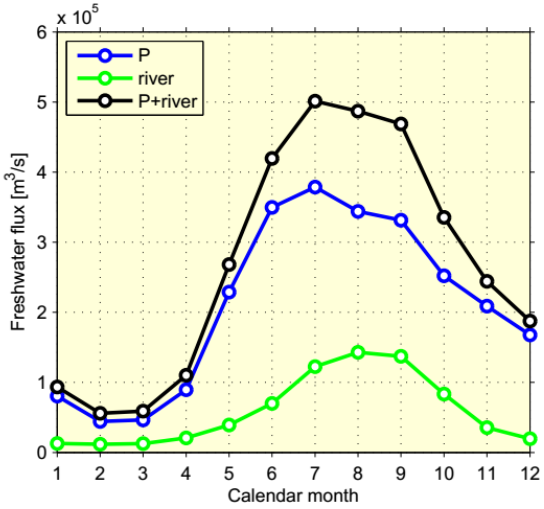
Unique features of the 8 double-thin events

Rainfall and SST anomalies are amplified under double-small condition

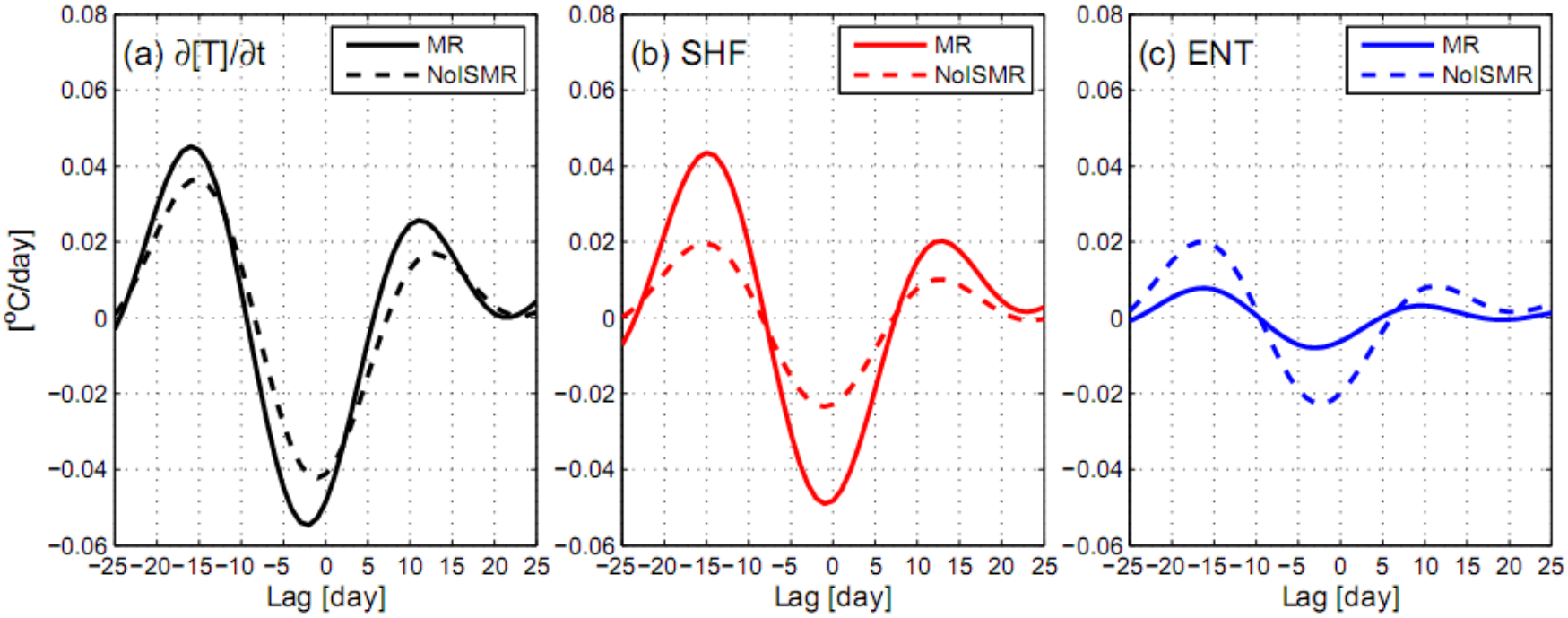
MLD<31m; BLT<10m



Impact of ISM freshwater flux on intraseasonal SST



MR: complete run by daily forcing (2001-2011)
NoISMR: keep rainfall/river to the JFM climatology



ISM freshwater flux can enhance intraseasonal SST through a shallow MLD, but BLT can suppress the entrainment.

$$\mathrm{SHF} = \frac{Q}{c_p \rho_0 H} \qquad Q = Q_{\mathrm{net}} - Q_{\mathrm{pen}}$$

$$\mathrm{ADV} = -[\mathbf{u} \cdot \nabla T]$$

$$\mathrm{ENT} = -\frac{[T] - T_{-H}}{H} \times \left(w_{-H} + \frac{\partial H}{\partial t} + \mathbf{u}_{-H} \cdot \nabla H \right)$$

$$\mathrm{ENT} = -\frac{[T] - T_{-H}}{H} \times w_{e+u}$$