Interaction of rivers with the upper-ocean: A climate modelling perspective towards better S2S forecasts

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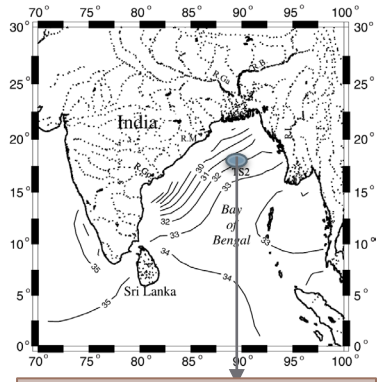
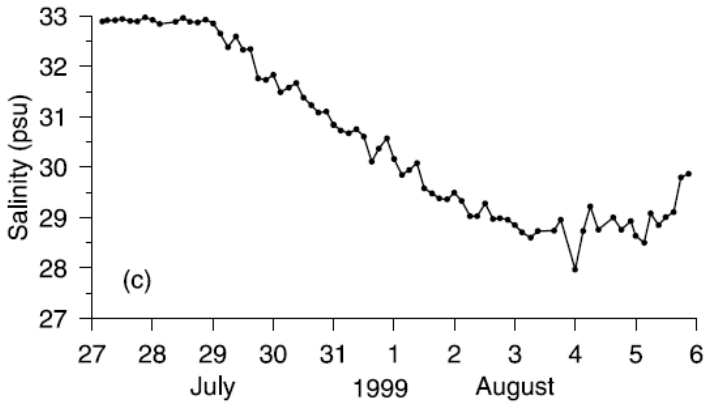
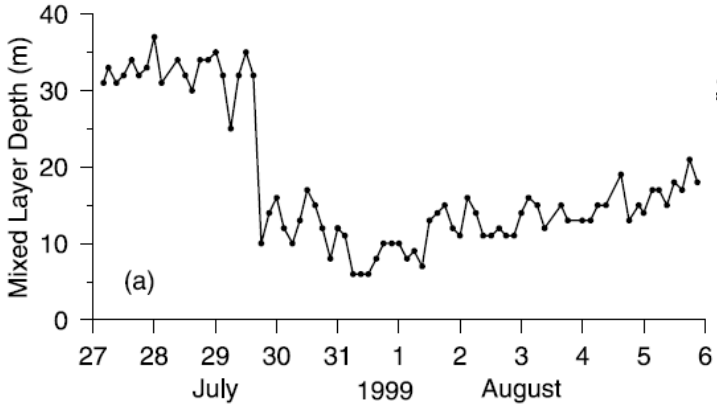
Observational evidence of the impact of rivers on upper ocean variability:
Bay of Bengal Monsoon Experiment (BOBMEX)



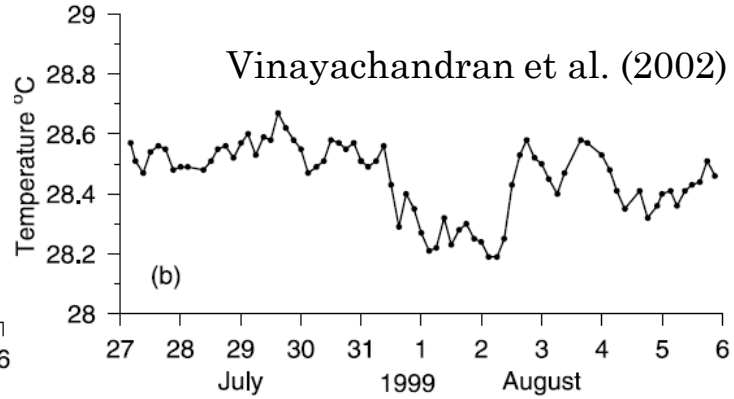
Location of ORV Sagar Kanya



- Spectacular arrival of a freshwater plume
- Salinity fell by about 4 psu



- MLD decreased from ~30 m to ~10 m.

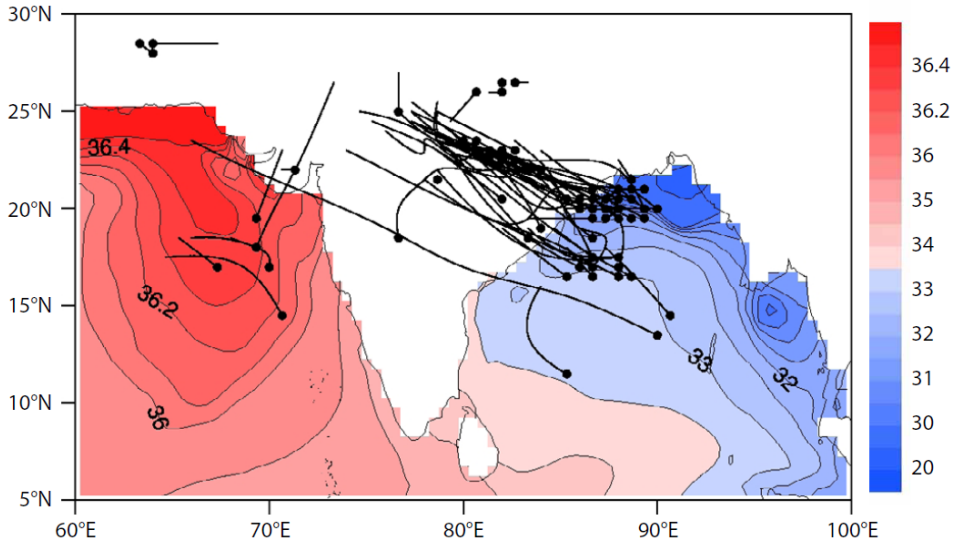


Vinayachandran et al. (2002)

The mixed layer temperature remained in the range of 0.5°C.

- The amount of rainfall received at observation site could not explain the observed freshening.
- **Surface salinity in the northern Bay of Bengal (at 15° N) varies coherently with the rainfall over Ganga-Brahmaputra catchment area on intra-seasonal time scale and with lag of about 60 days.**

Interaction with the Indian Summer Monsoon

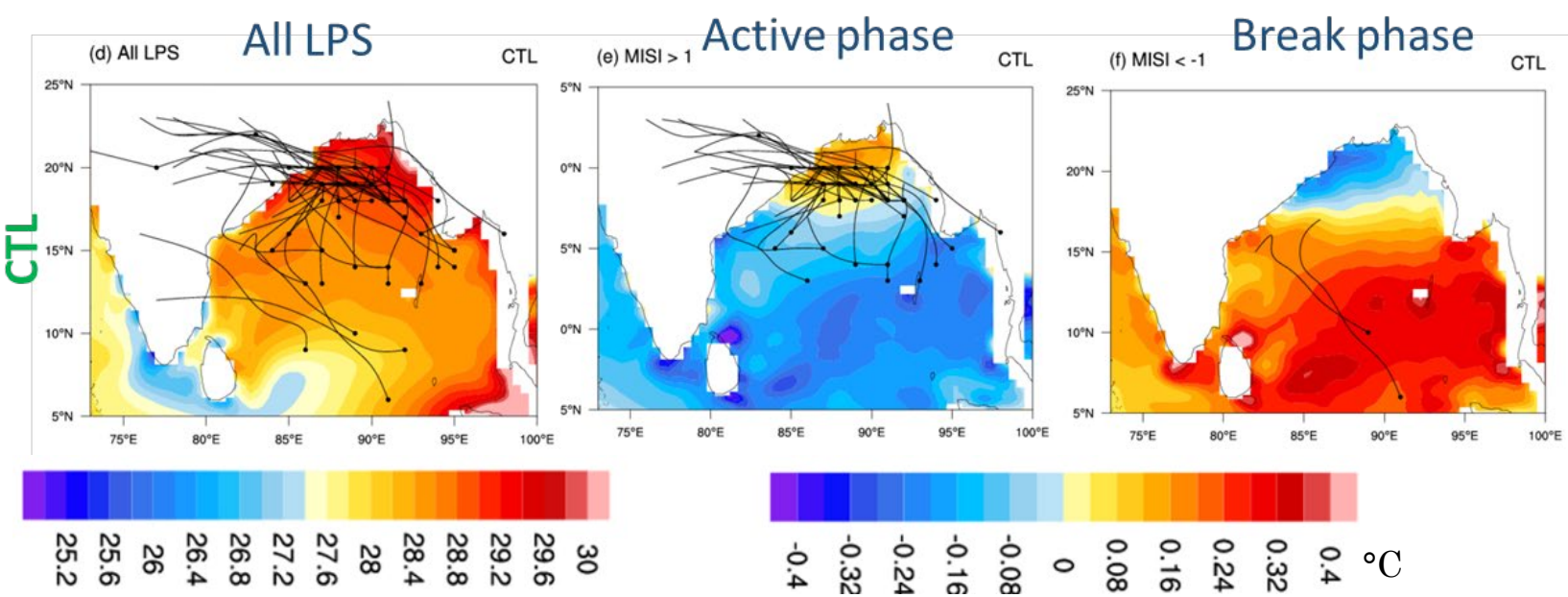


Observed genesis (black dots) and tracks (curves) of low-pressure systems forming during the boreal summer monsoon season (JJAS), and climatology of sea-surface salinity (shading).

- Enormous freshwater discharge from the Ganges-Brahmaputra, Irrawaddy, and several other major rainfed rivers makes the northern BoB one of freshest regions of the world ocean.
- BoB plays an important role in determining monsoon precipitation by facilitating the genesis of monsoon lows and depressions and controlling the air-sea interactions associated with the monsoon intra-seasonal oscillations.

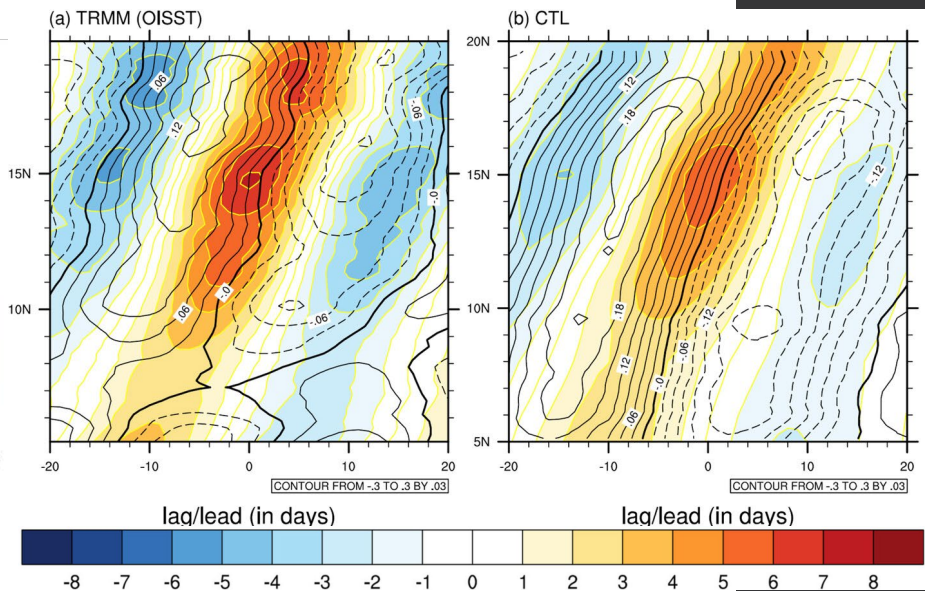
Problems plaguing CFSv2 at S2S scales

Srivastava et al. (2017)



JJAS mean SST (°C)

Active/Break days composite SST anomaly (°C)



Hovmöller plot of 10-90 day filtered rainfall (mm/day, shading) and SST anomaly (°C, contours) for strong ISO events

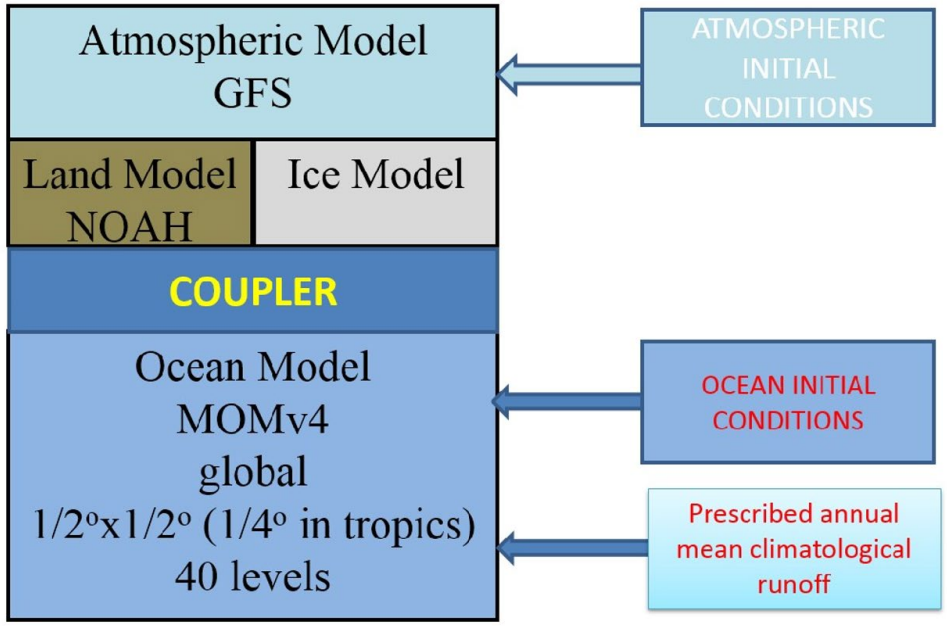
- Under-estimation of synoptic variability in the Bay of Bengal.
- Too few systems with restricted inland propagation.
- Slower northward propagation of Monsoon intra-seasonal oscillations in CFSv2.
- Associated biases in precipitation and air-sea interactions.

Indian Ocean Dynamics need to be improved in coupled models.

How can we improve coupled models?

- Improve the existing model physics and parameterization.
- Add new processes which are not yet represented in the model.

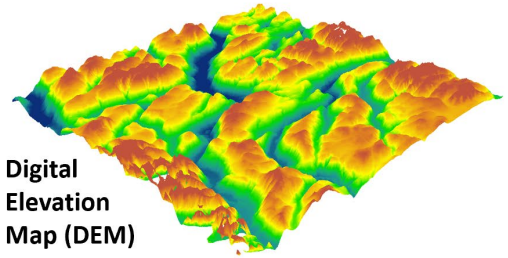
Missing rivers in CFSv2



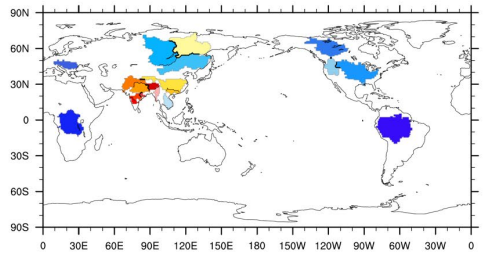
Prescribing river-runoff is not a good strategy, specially for coupled models such as the CFSv2.

Adding rivers to CFSv2

How to represent horizontal transport of freshwater??

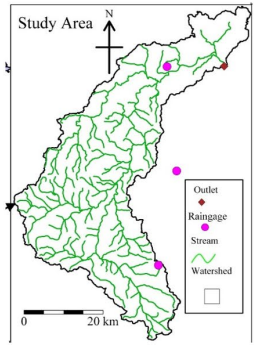


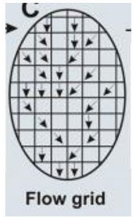
Digital Elevation Map (DEM)



Delineated River Basins (Global)

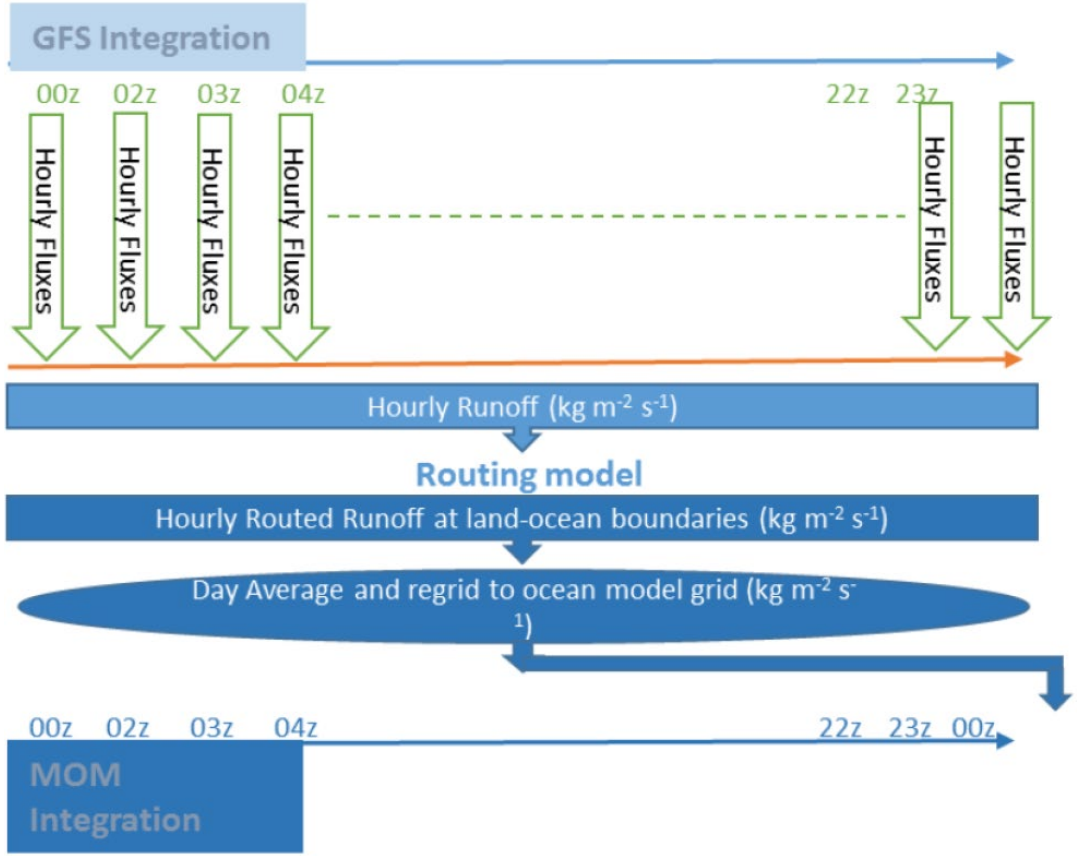
Flow Network





Runoff from land surface model

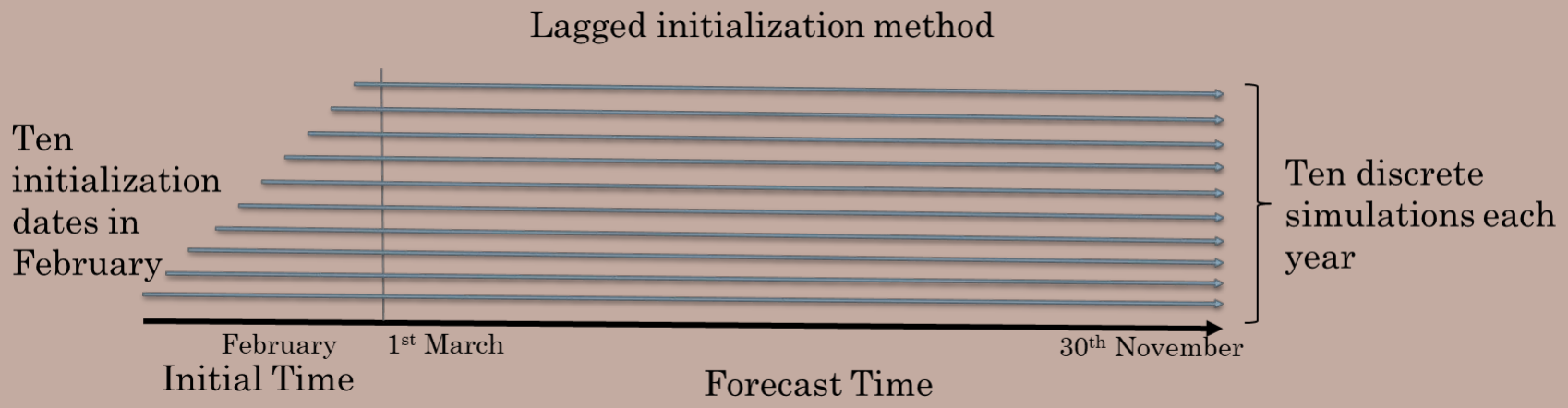
Routed streamflow at land-ocean boundaries

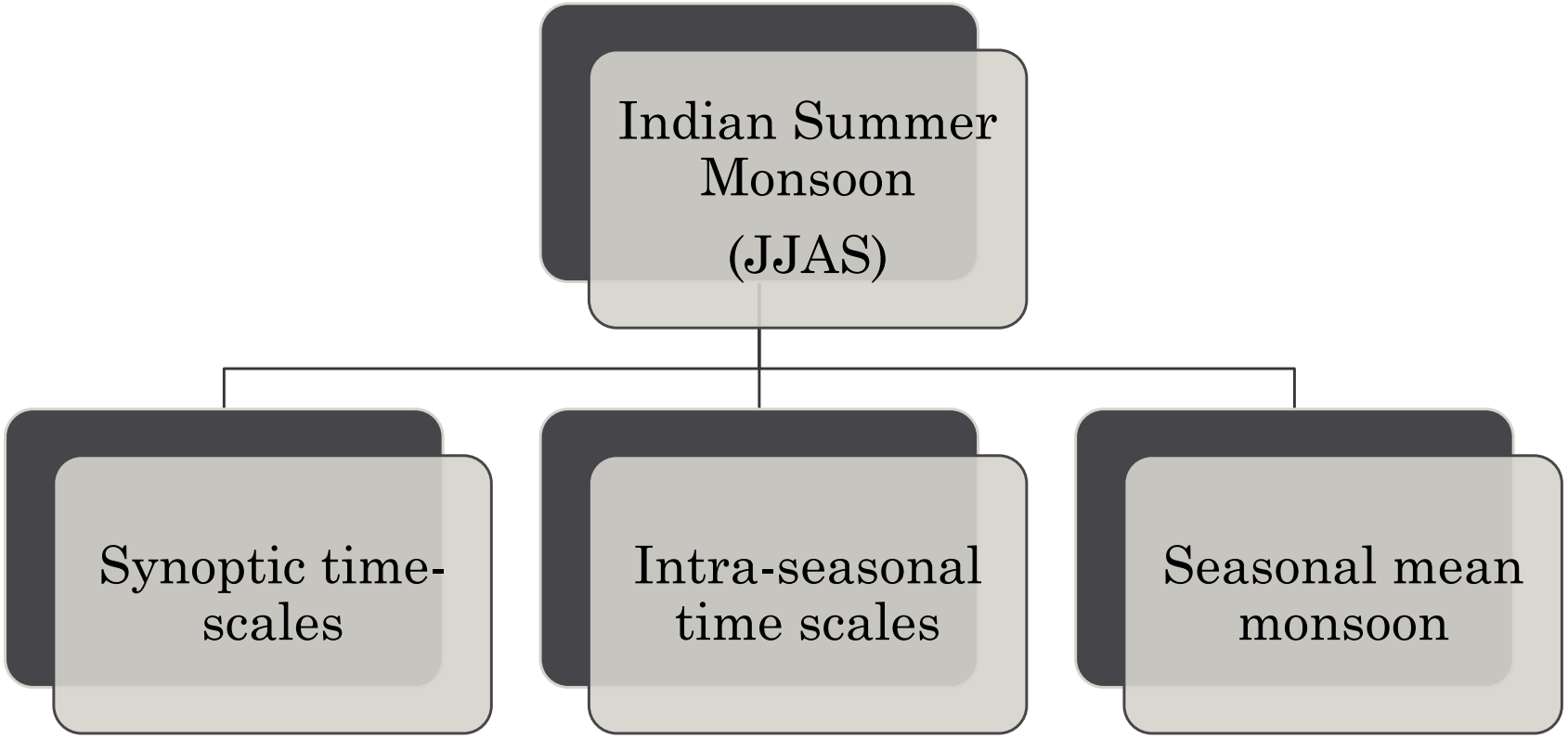


Hindcast Time period:

1981-2017

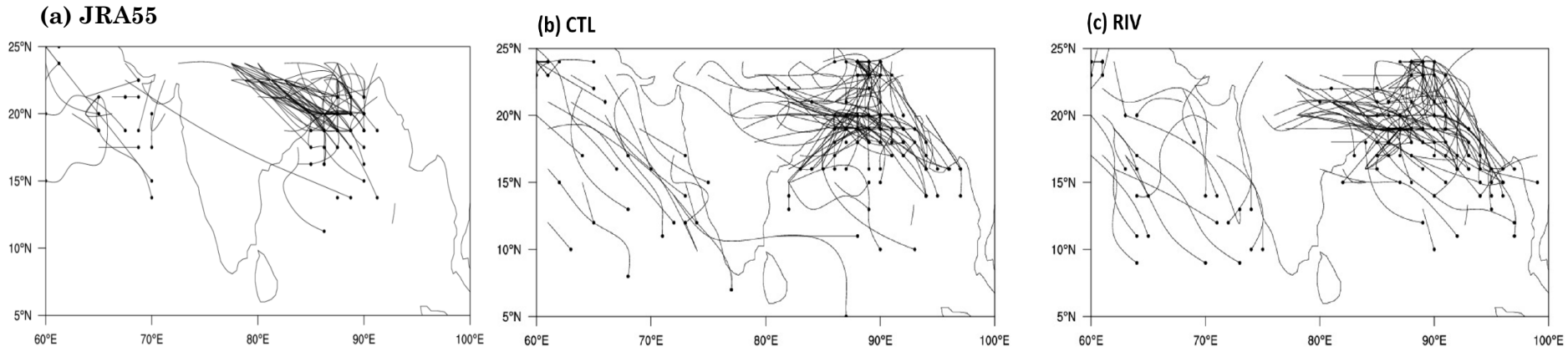
10 ensembles



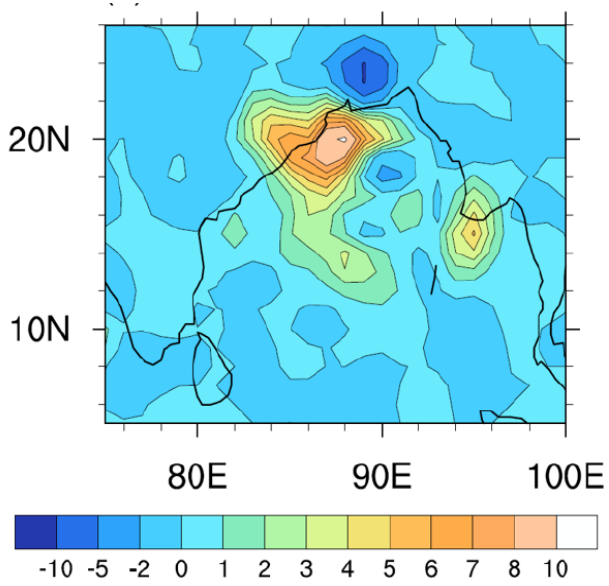


Srivastava et al. (2022, 2023a, 2023b)

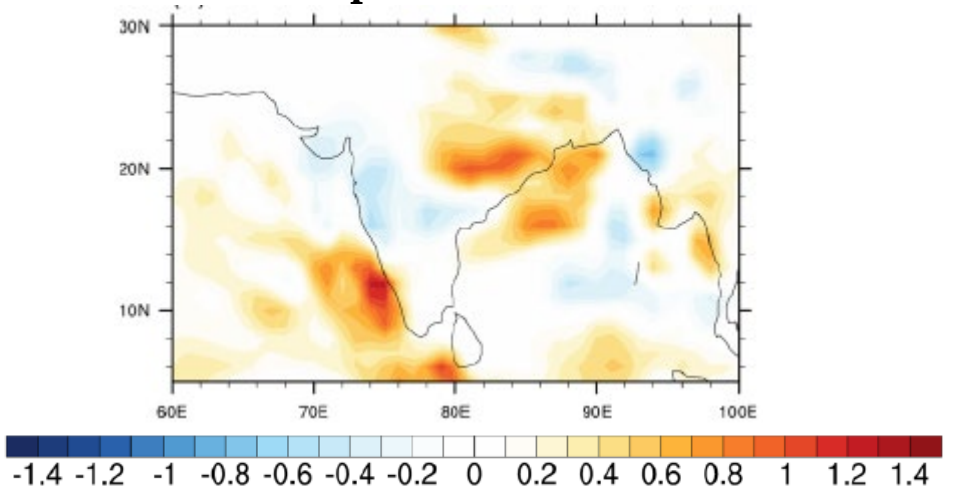
LPS Track Density



RIV-CTL track density



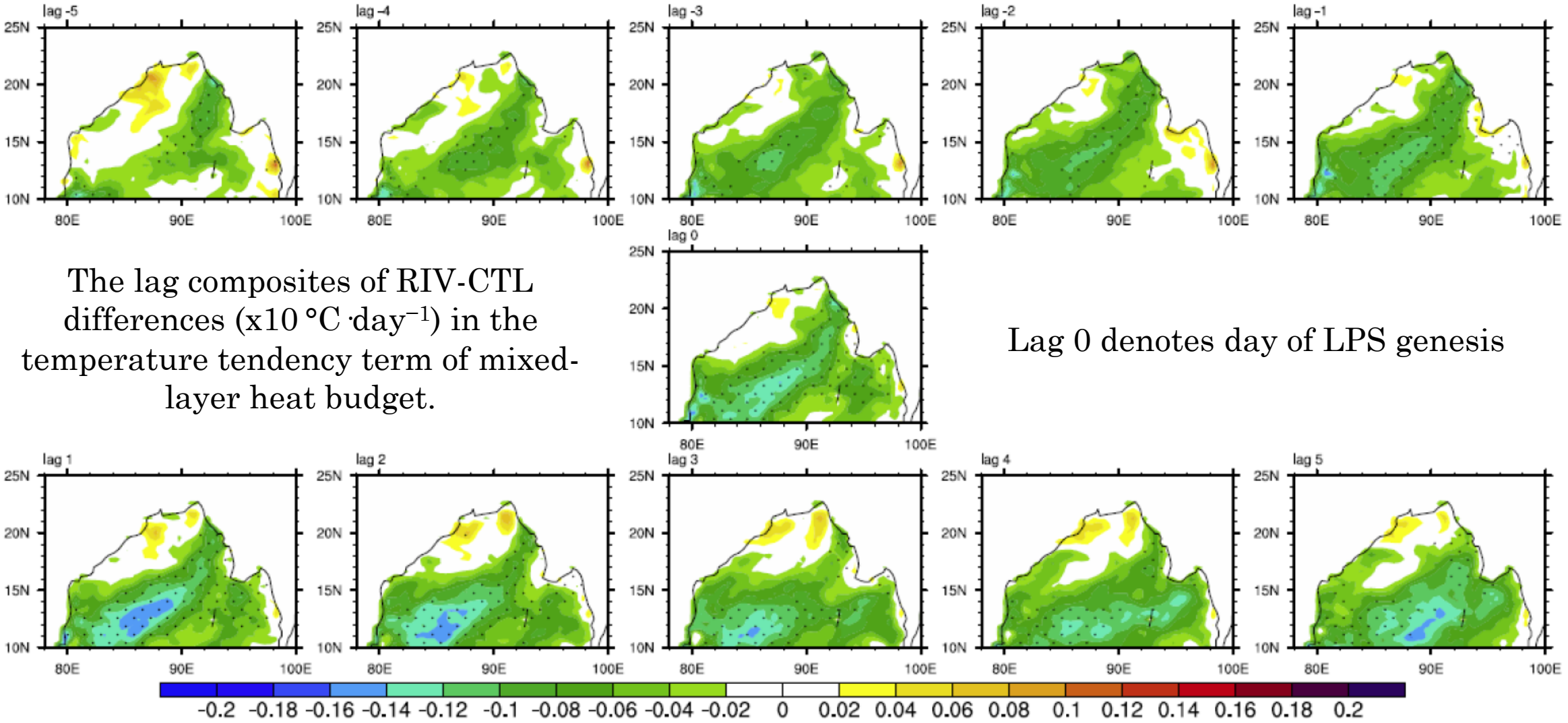
RIV-CTL LPS days composite rainfall



- Defined as the number of tracks crossing a particular grid point.
- The track density is higher in RIV run in the north-western BoB and the adjoining parts over the Indian landmass.
- Enhanced rainfall over landmass compared to CTL run of the order of 1-1.5 mm day^{-1}.

Enhanced LPS activity and associated rainfall in RIV.

Mixed Layer Temperature Tendency

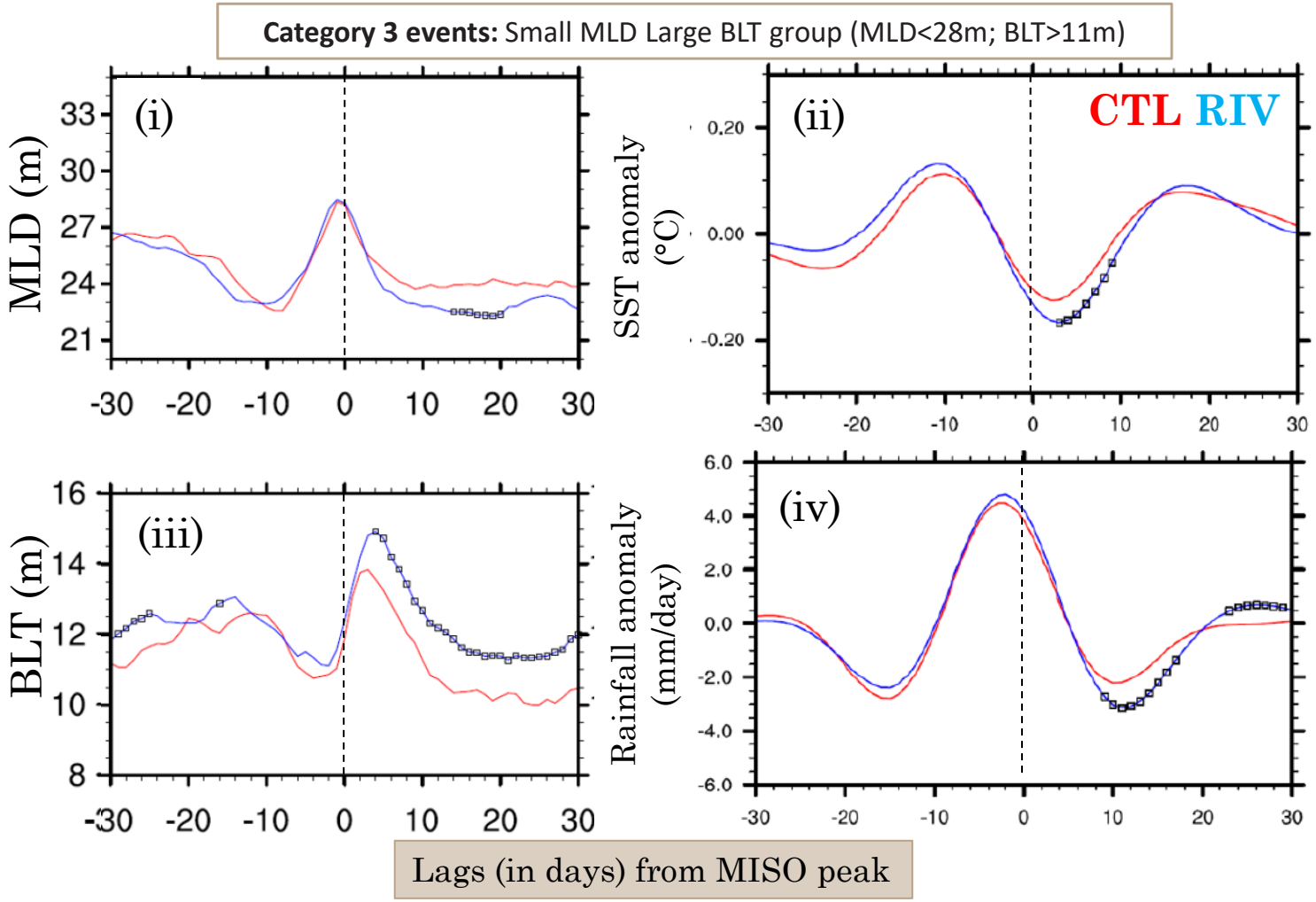


The lag composites of RIV-CTL differences (x10 °C $\cdot$day^{-1}) in the temperature tendency term of mixed-layer heat budget.

Lag 0 denotes day of LPS genesis

- North-west oriented temperature gradients, strengthen post LPS genesis.
- Crucial for LPS simulation.
- Enhance moisture availability to the system.
- Primarily governed by the asymmetric SHF term.

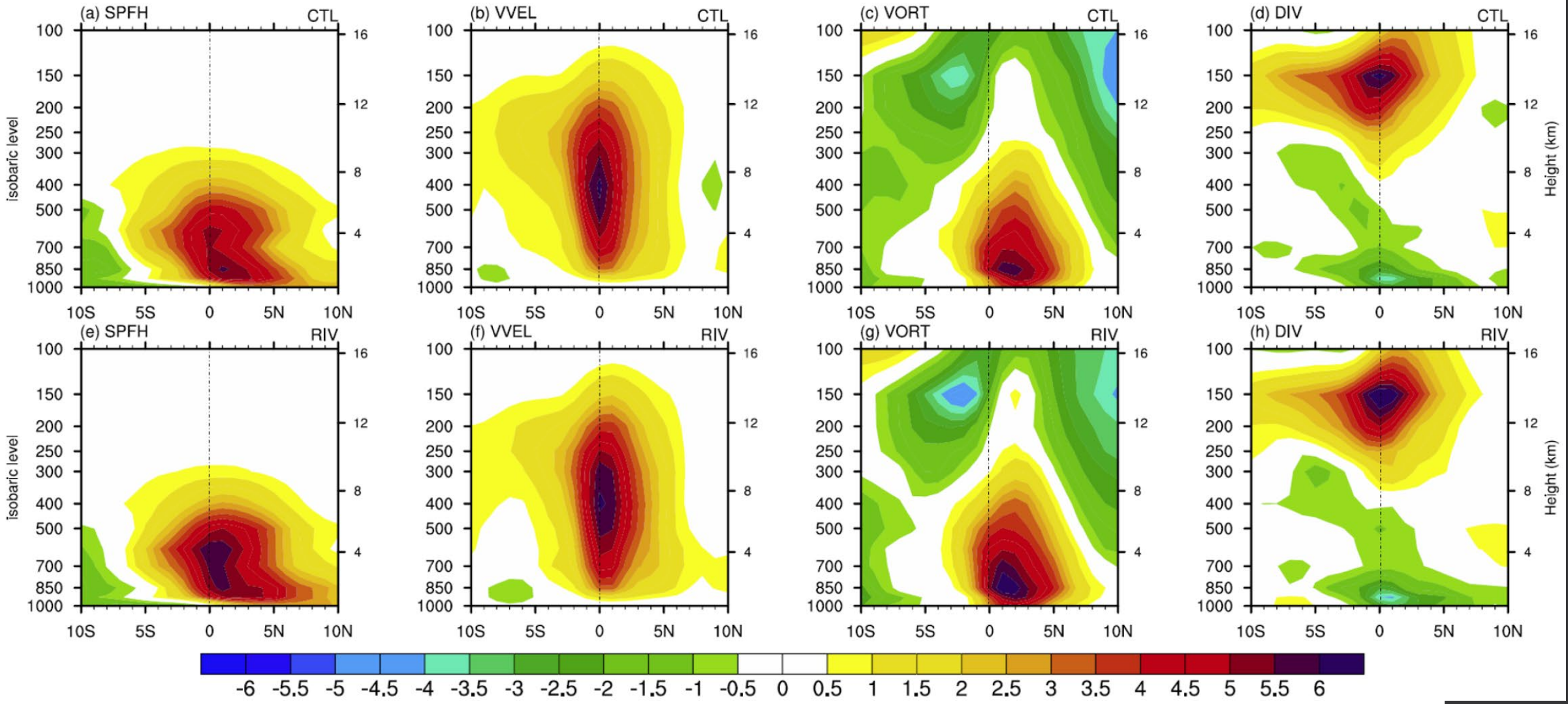
The lag composites of various terms wrt to MISOs active phase, lag-0 implies peak rainfall over Central India



- For thick BL events, MLD is shallower post convection and barrier layers are thicker in RIV.
- Minor differences between CTL and RIV in the pre-convection period.
- The SST anomalies are cooler during convection indicating a stronger active spell (rainfall anomalies are greater though not statistically significant).
- Shoaling of mixed layers post convection, and formation of thick barrier layers cause intense post-convection break.

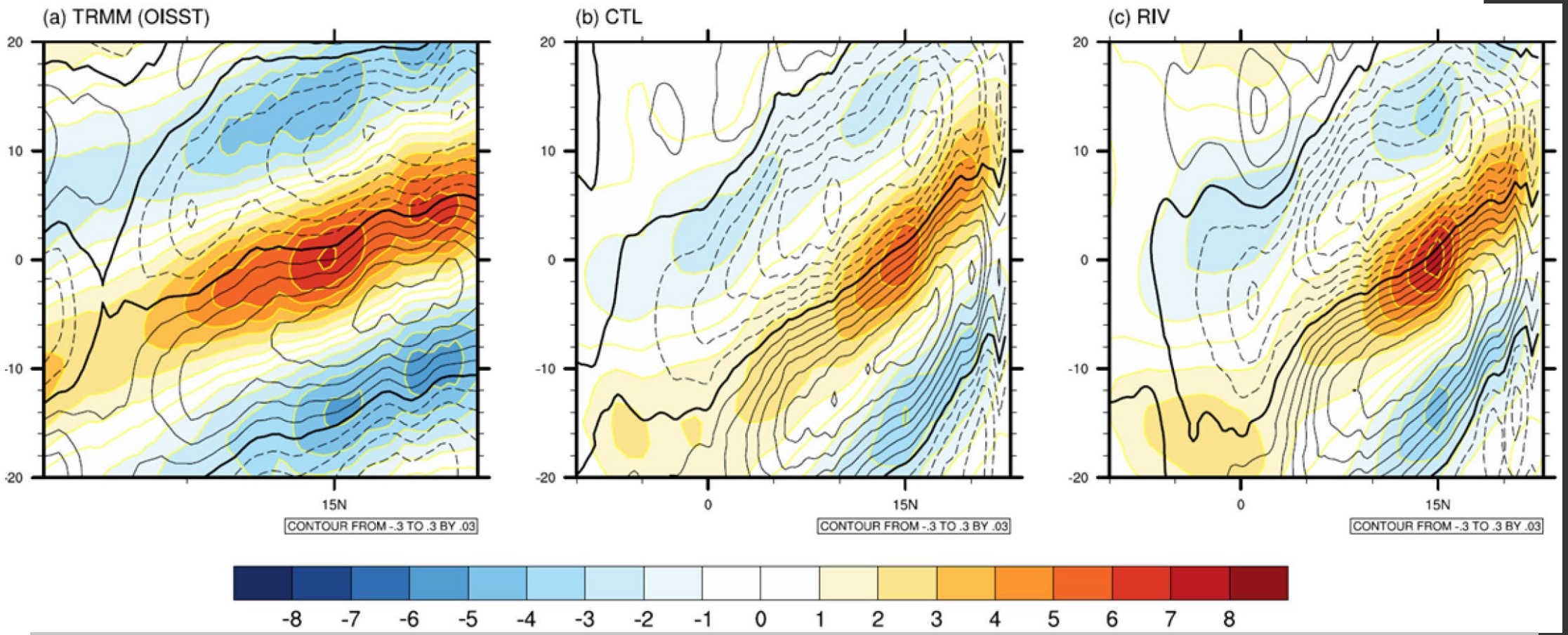
Composite vertical structure

Fields are composited wrt centre of convection



- Improved upper ocean variability leads to enhanced air-sea interactions in the Bay.
- Stronger vorticity and specific humidity ahead of the convection center associated with the MISO convection.
- **Stronger northward propagating MISO pulse.**

Coherently propagating MISO events



- **The northward propagating convection band has stronger positive anomalies in the RIV run.**
- The positive SST anomalies preceding an active phase are well organized in the RIV run.
- The subsequent cooling of SSTs is also stronger which is due to the stronger low-level cyclonic circulation associated with the MISO event.
- **The MISO propagation speed is slower in CTL, which has improved in RIV.**

Mechanism

Freshwater from rivers

Improved upper ocean stratification

Post convection shoaling of mixed layer and formation of thick barrier layers

Changes to mixed layer heat budget

Enhanced air-sea interactions restricted to shallow mixed layer

Enhanced specific humidity and vorticity profiles north of MISO convection center

Stronger MISO associated circulation

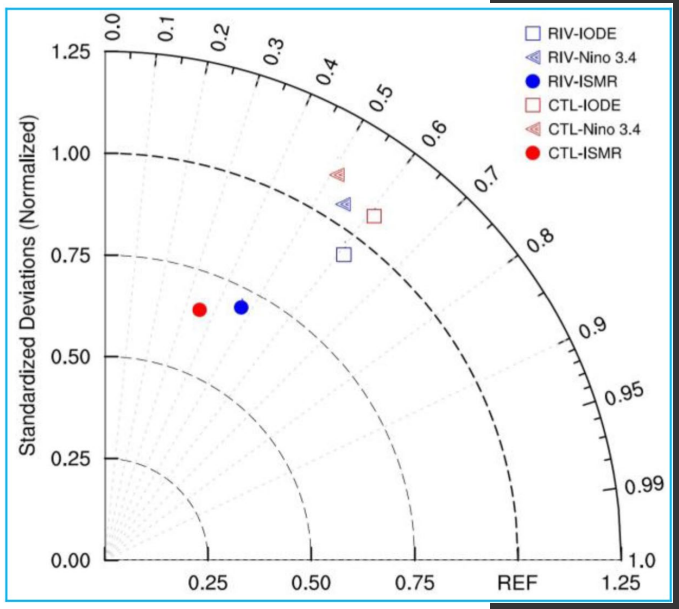
Stronger asymmetric surface heat flux forcing

Enhanced temperature gradients in Bay of Bengal

Frequent LPS genesis

Longer-lived LPS with greater inland propagation

Better representation of convection at synoptic to intra-seasonal time-scales



Get in touch at: **ankur@tropmet.res.in**

Thankyou.