Assessing the impact of accurately representing river freshwater and turbulent fluxes on monsoon variability in a seasonal forecast model

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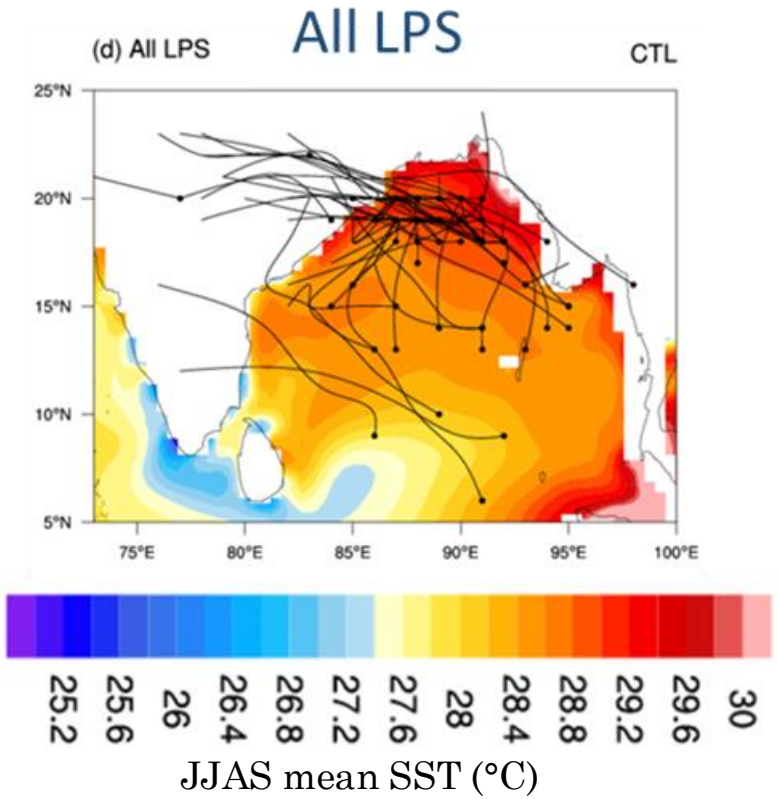
Joint plenary S4 - Model processes improvements

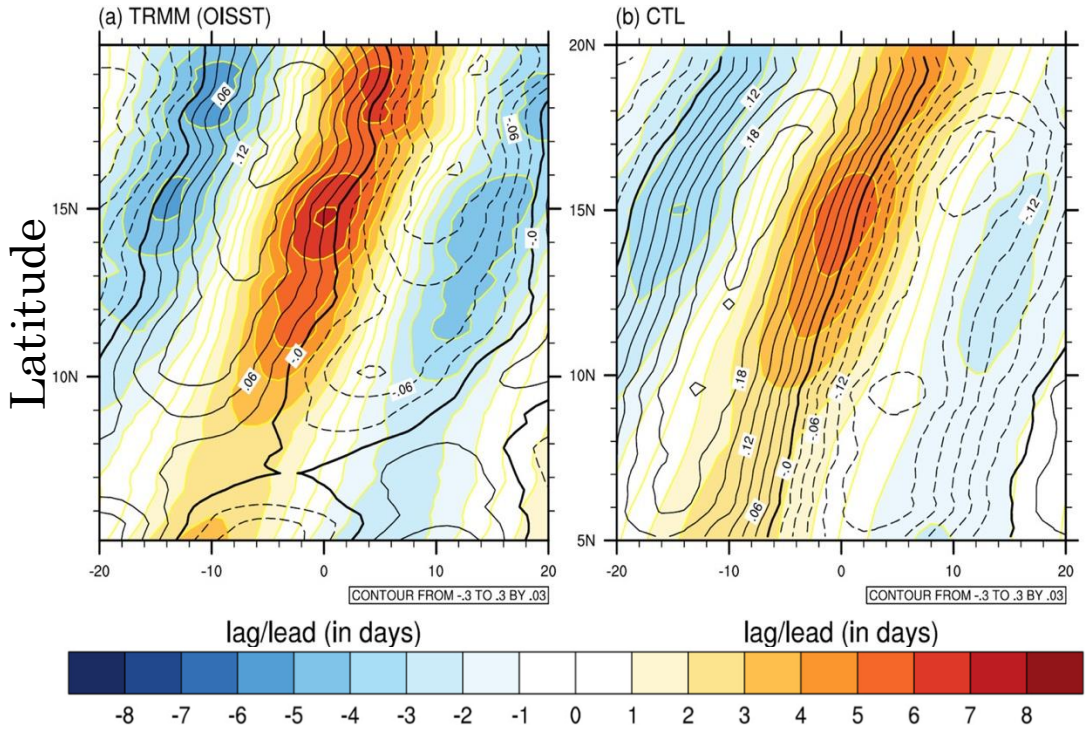
Problems in coupled models at S2S scales

Srivastava et al. (2017)

- Under-estimation of synoptic variability in the Bay of Bengal.
- Slower northward propagation of Monsoon intra-seasonal oscillations in CFSv2.



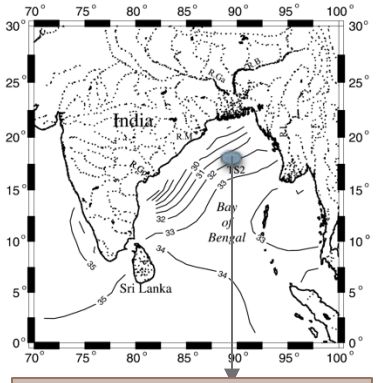
JJAS mean SST (°C)



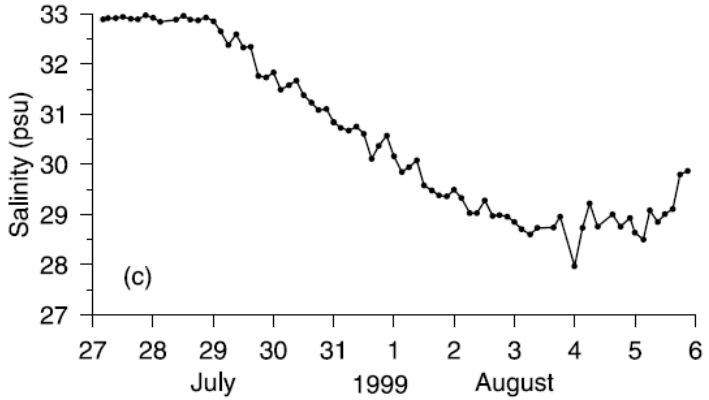
Hovmöller plot of 10-90 day filtered rainfall (mm/day, shading) and SST anomaly (°C, contours) for strong ISO events

Sub-seasonal scale processes limit the seasonal forecast skill!

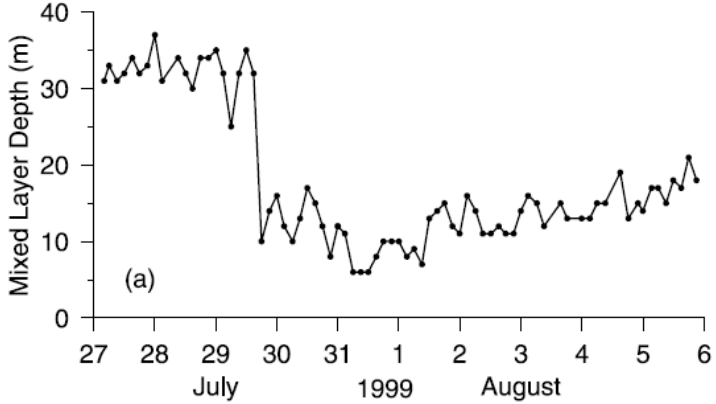
Observational evidence of the impact of rivers on upper ocean variability:
Bay of Bengal Monsoon Experiment (BOBMEX)



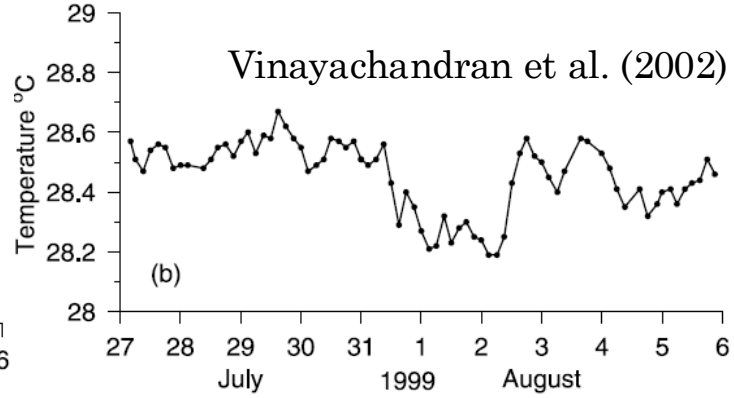
Location of ORV Sagar Kanya



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



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

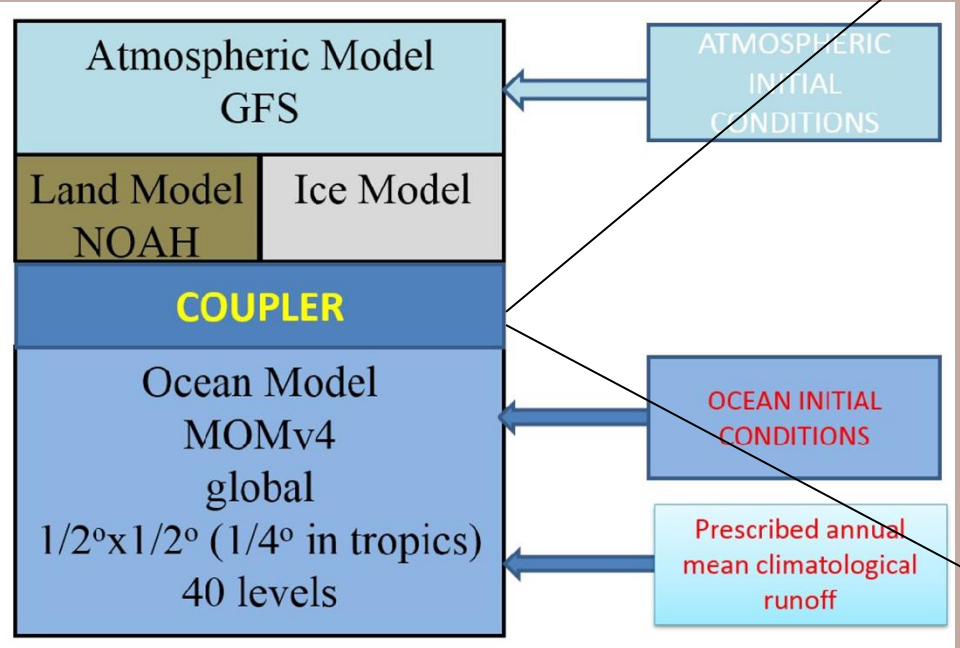


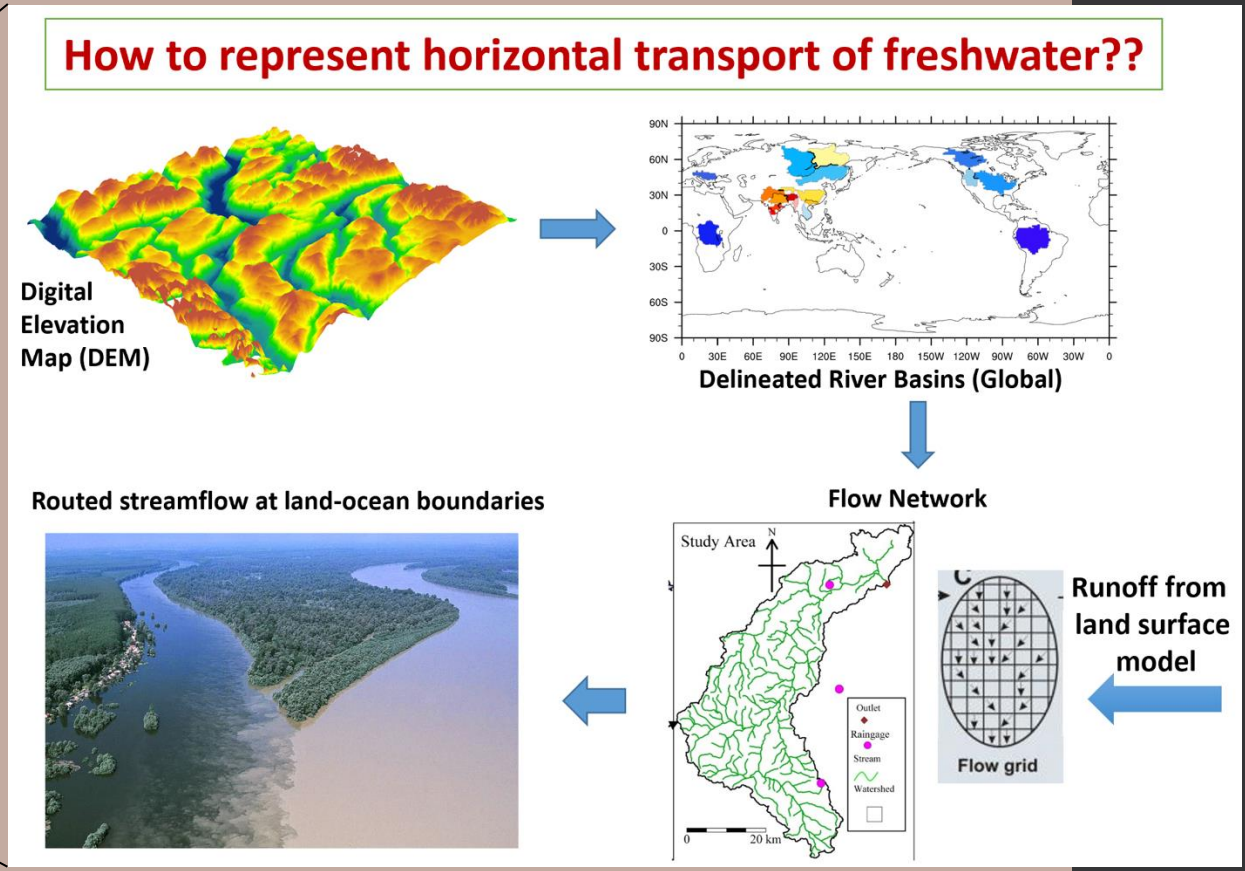
Vinayachandran et al. (2002)

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.**

Missing rivers in CFSv2

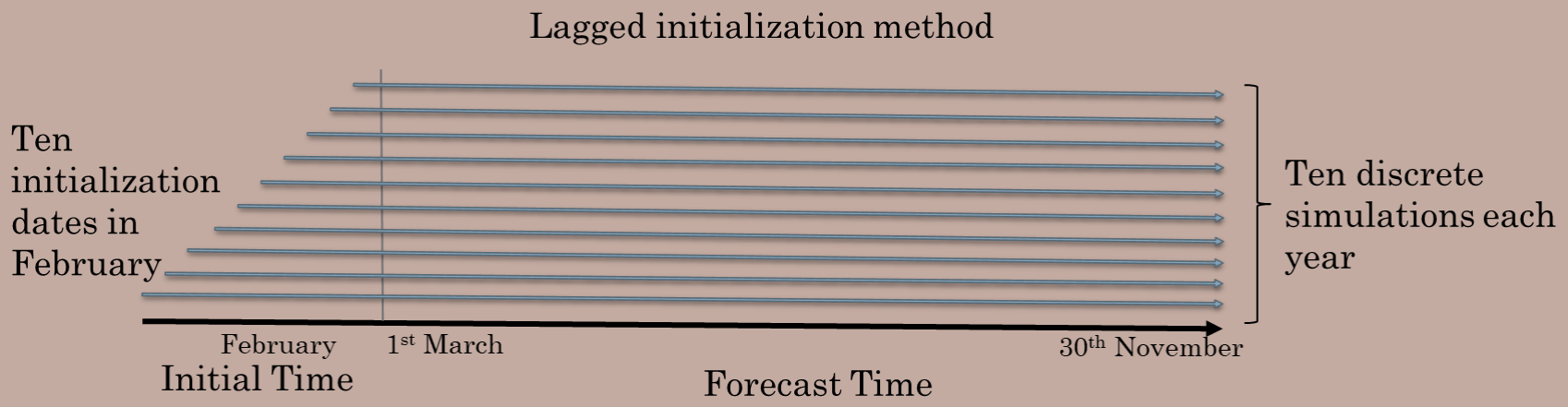




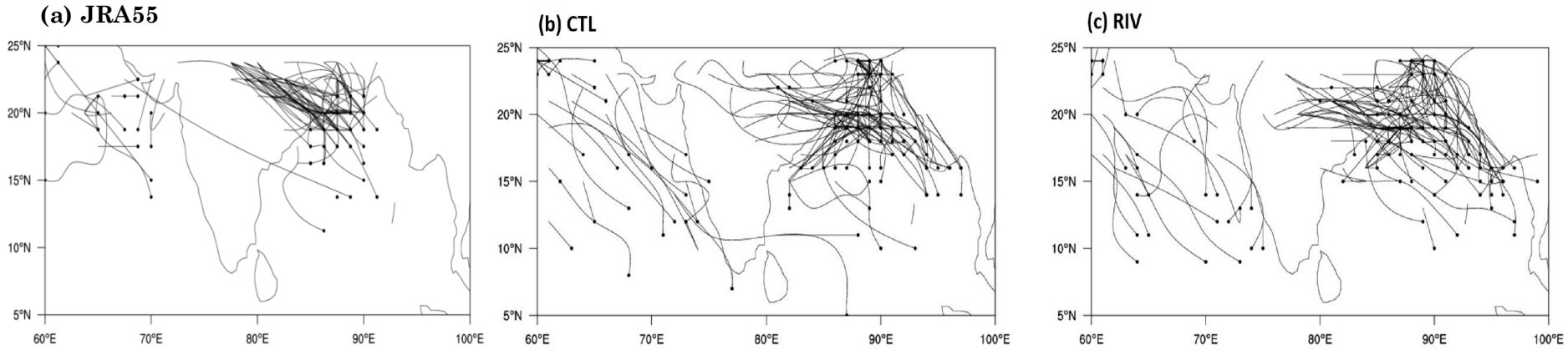
Hindcast Time period:

1981-2017

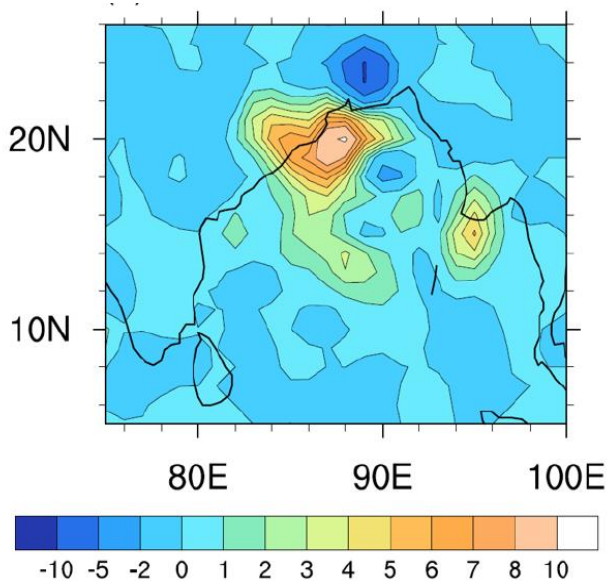
10 ensembles



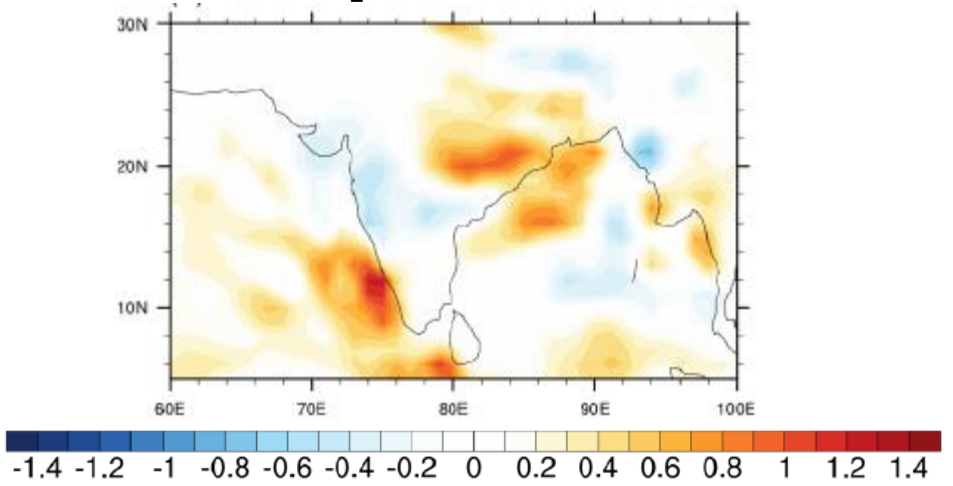
LPS Track Density



RIV-CTL track density



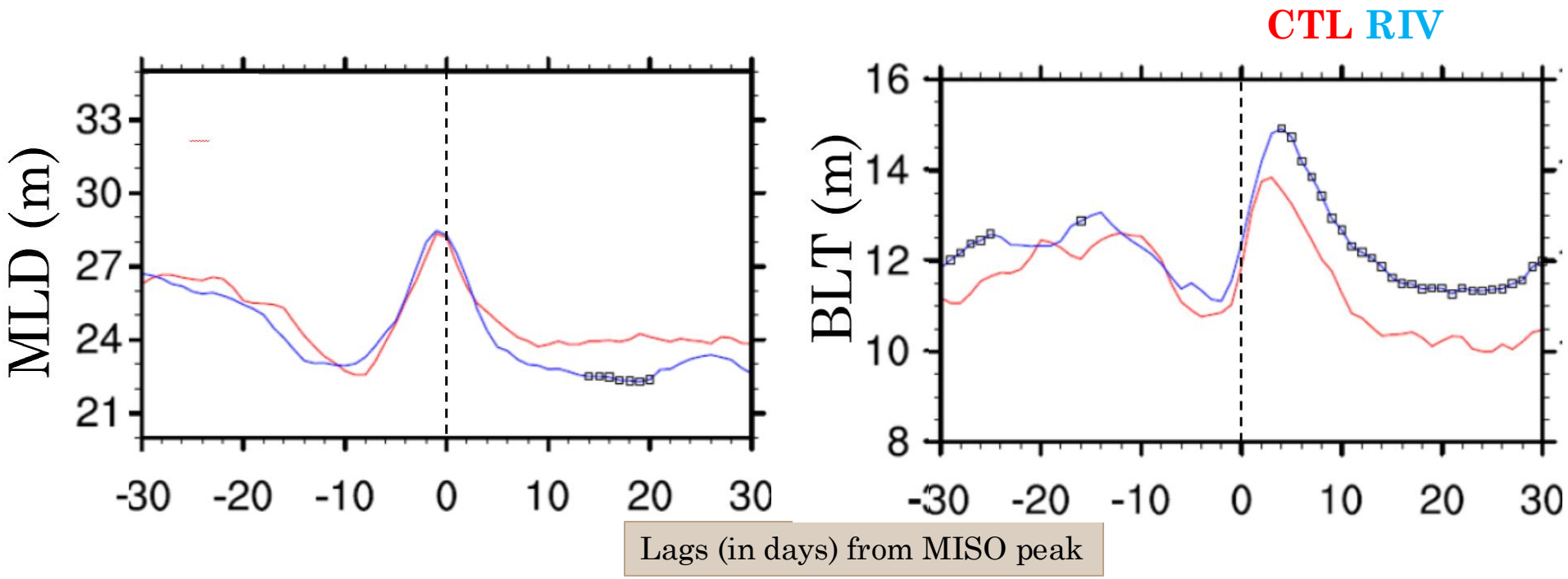
RIV-CTL LPS days composite rainfall



Enhanced LPS activity and associated rainfall in RIV.

The lag composites of various terms wrt to MISOs active phase.

Category 3 events: Small MLD Large BLT group (MLD<28m; BLT>11m)

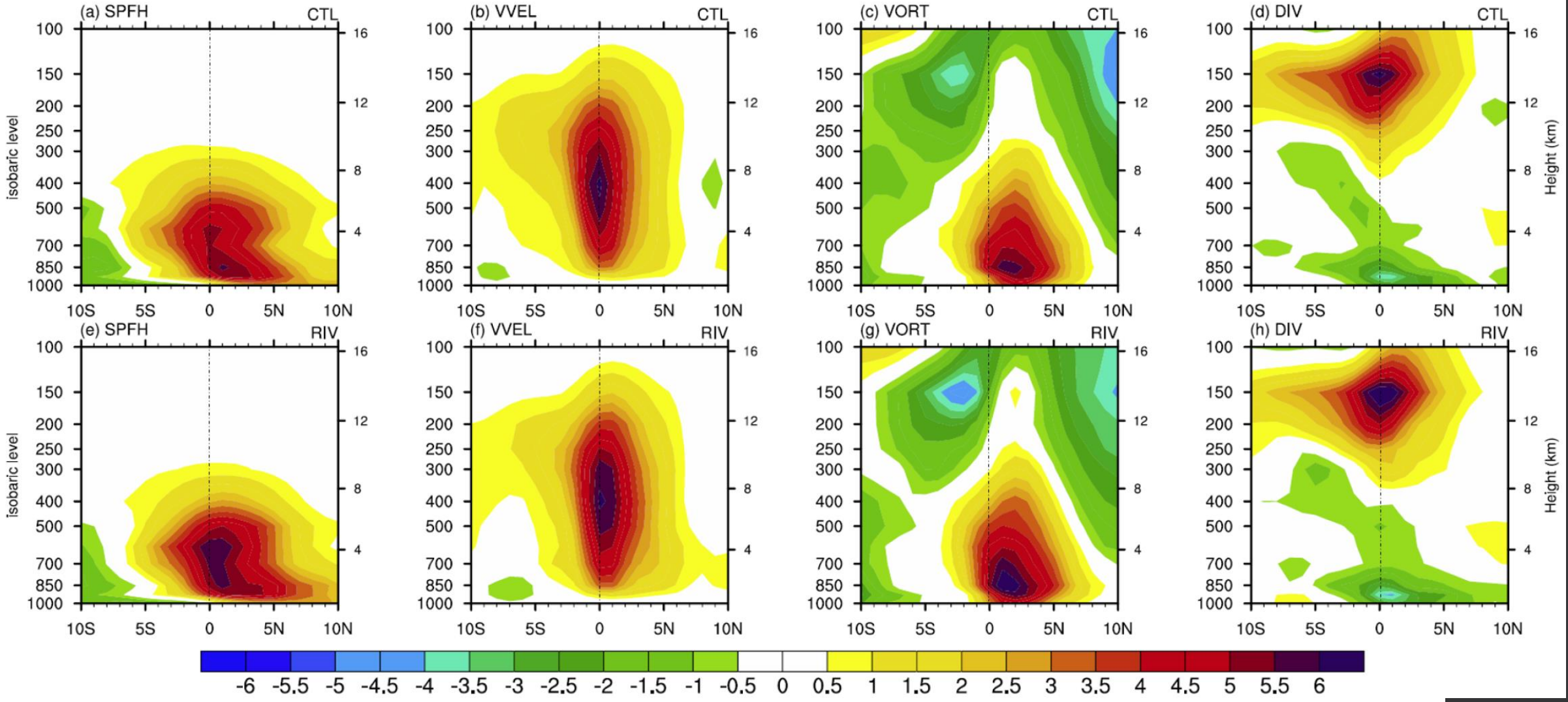


lag-0 implies peak rainfall over Central India

- MLD is shallower post convection and barrier layers are thicker in RIV.
- 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 MISO convection

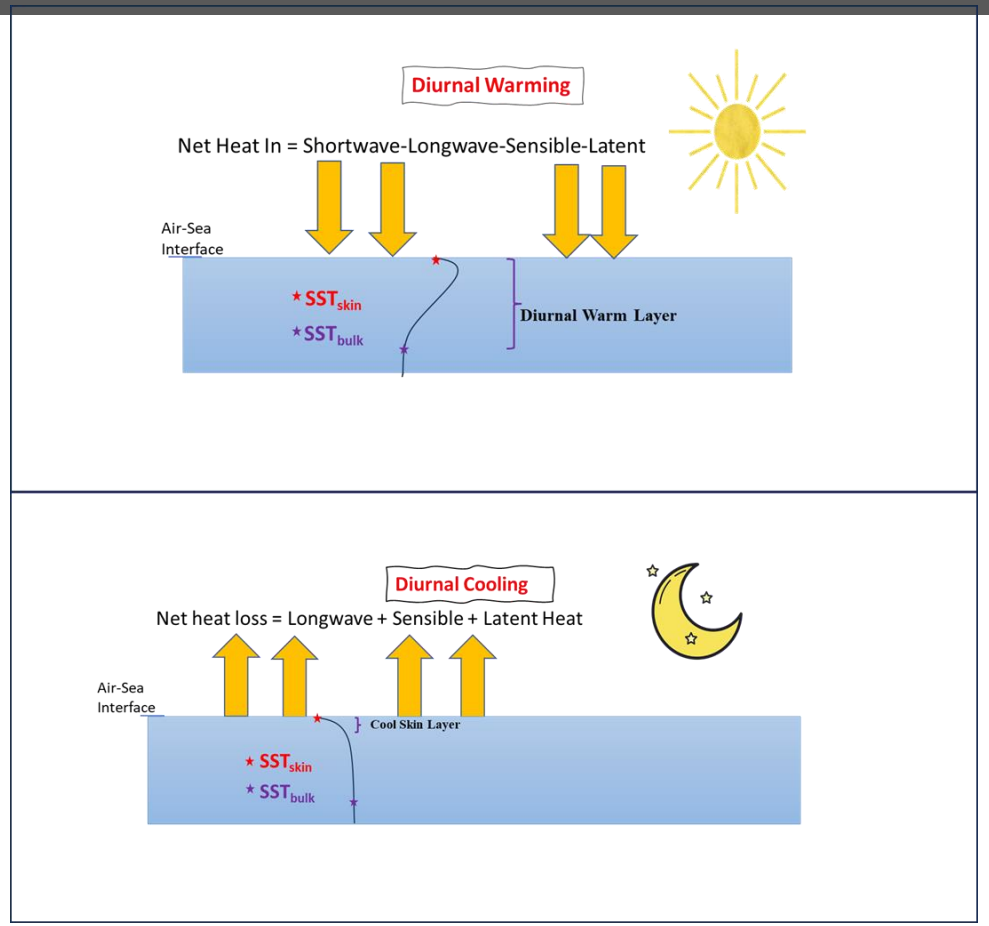


- Stronger vorticity and specific humidity ahead of the convection center associated with the MISO convection.
- **Stronger northward propagating MISO pulse.**

Improving Air-Sea Interactions in a Coupled Model

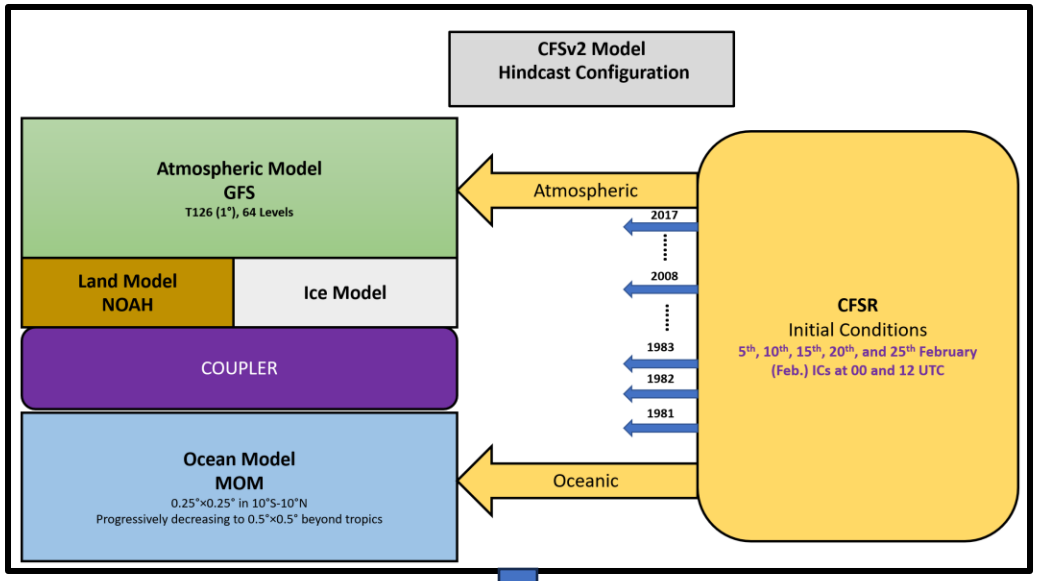
Maheswar Pradhan, ***Suryachandra A. Rao, Amitabh Bhattacharya, and Sridhar Balasubramanian***

Design of Experiments



CTL (default CFSv2): No diurnal skin temperature and fluxes using NCAR algorithm

SEN (revised CFSv2): Have diurnal skin temperature variability and fluxes using COARE 3.0 algorithm



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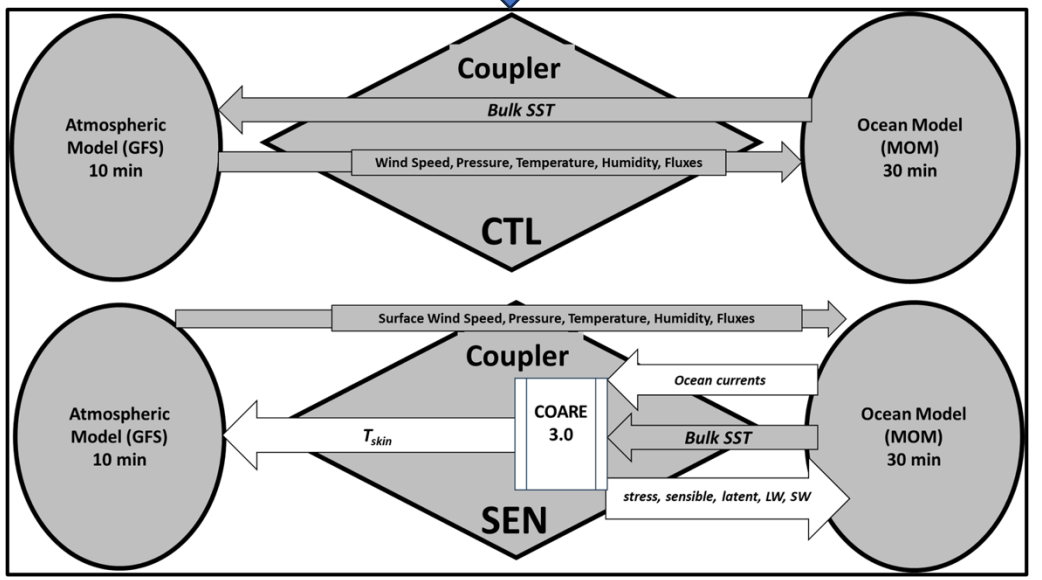
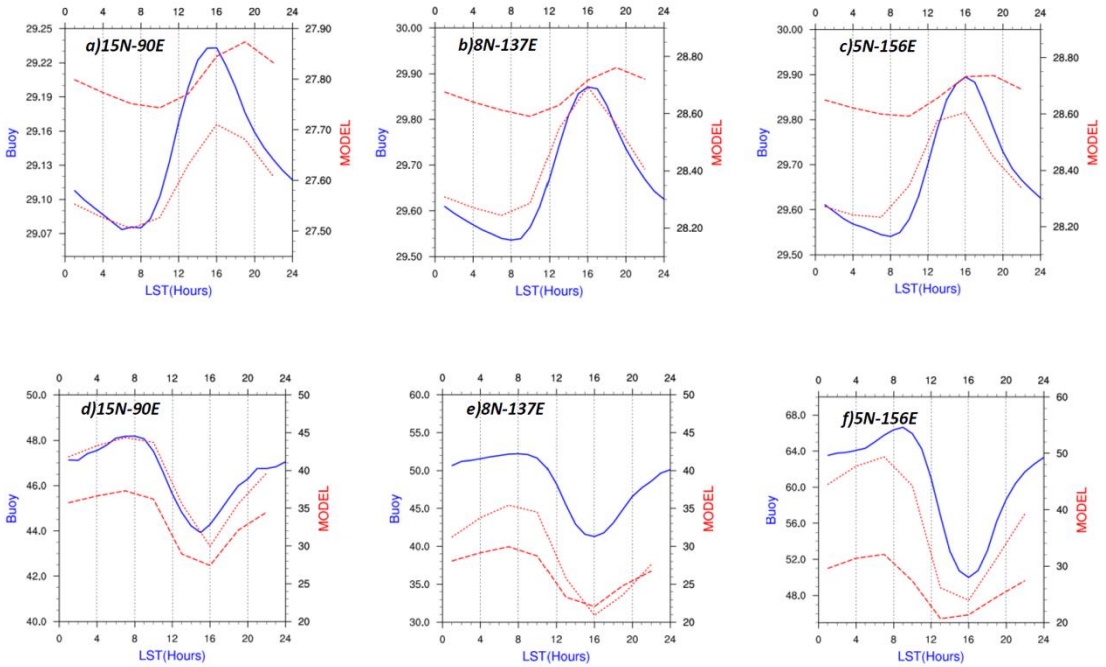
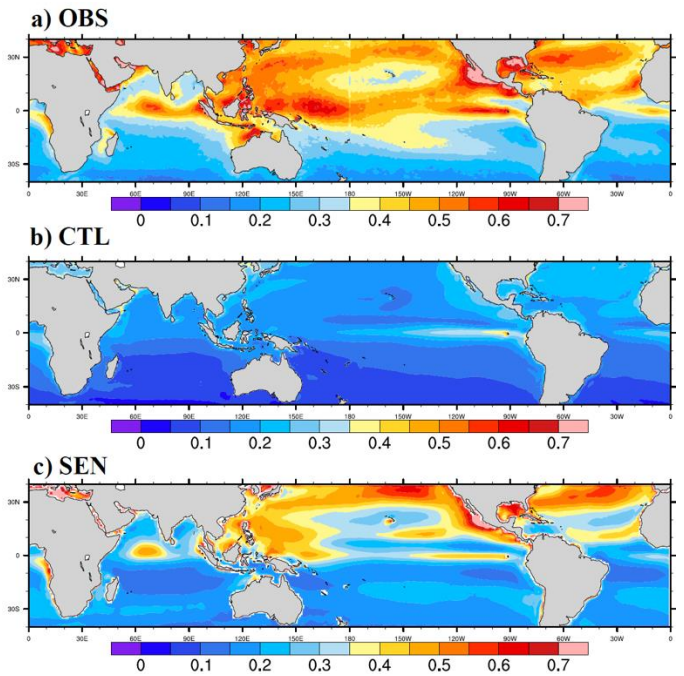


Pradhan et al., 2022, 2024
https://doi.org/10.3389/fclim.2021.792980
https://doi.org/10.1007/s00382-023-07053-6

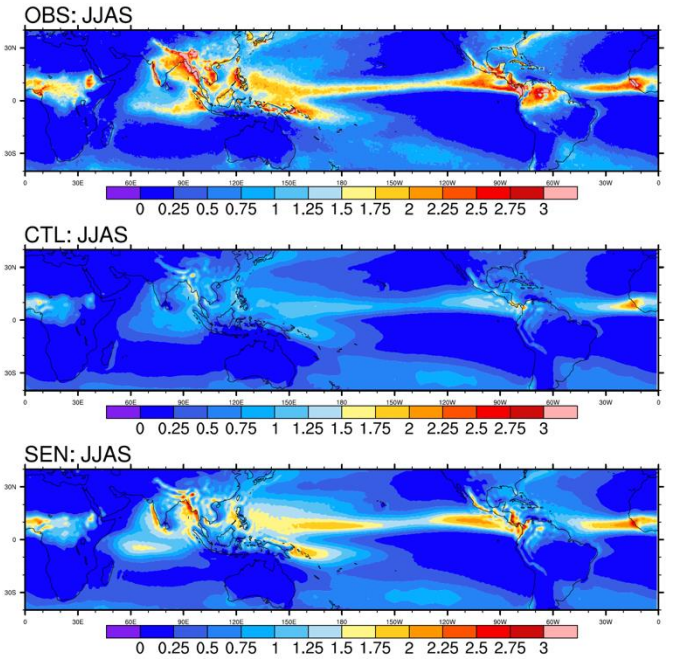
Impact on Diurnal Ocean Extremes



Variation of SST and MLD w.r.t. Local Solar Time (LST)



dSST: Seasonal (JJAS) Mean diurnal range

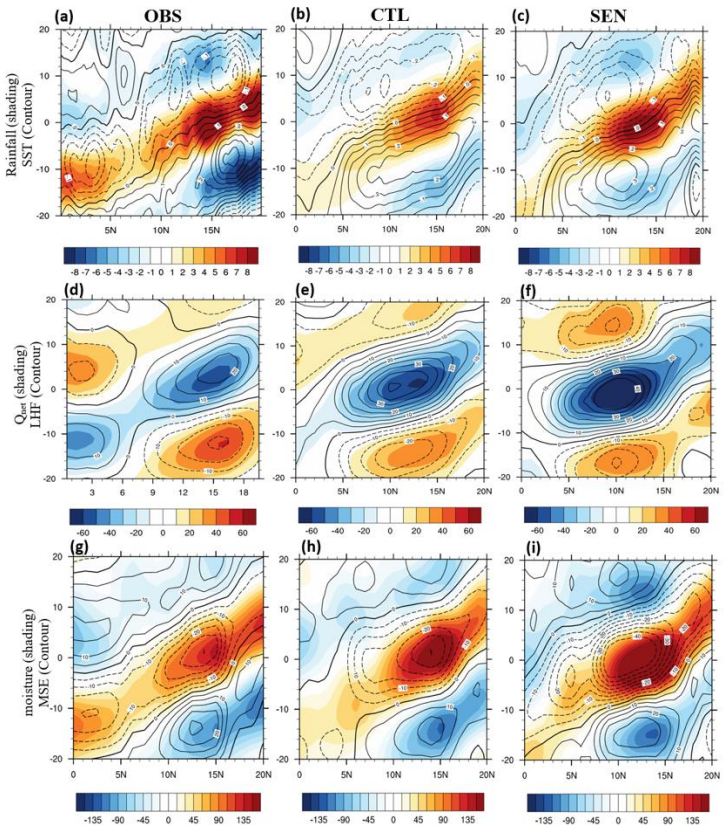


dPrate: Seasonal (JJAS) Mean diurnal rain

- Comparison of model simulations against the in-situ observation suggest that both the phase and amplitude of diurnal SST variability is improved by including skin temperature parameterization.
- The amplitude difference between early morning deep MLD and afternoon shallow MLD is significantly improved in SEN run compared to CTL run.
- Enhancement in dprate in SEN run compared to CTL run is as large as 0.5-1.0 mm/hour over most tropical Oceans and Indian landmass regions during southwest monsoon season.

Impact of the skin temperature and revised flux scheme is not limited to the surface ocean but is also seen at the upper ocean mixed layer and atmospheric convective processes at a diurnal scale.

Impact on MISO

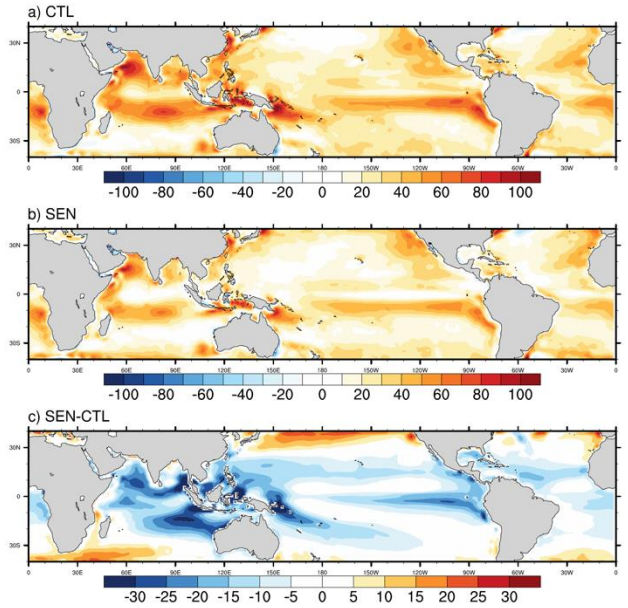


20-90 day filtered anomalies (active phase)

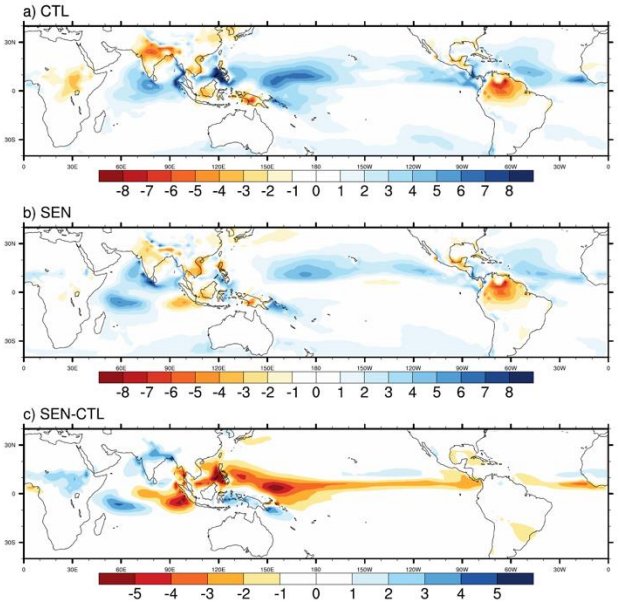
During break spell

- Shallower MLD
- Reduced LHF (due to calm winds)
- Higher Q_{net} into the ocean (due to higher solar insolation and reduce LHF)
- Higher diurnal SST warming (due to all above)
- Enhanced recharge of MSE and moisture to favour a stronger active following break.

Impact on Seasonal Mean Biases

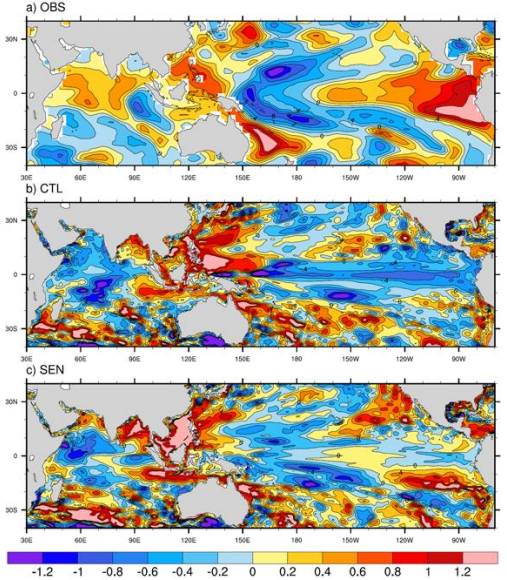


Reduced overestimation in LHF

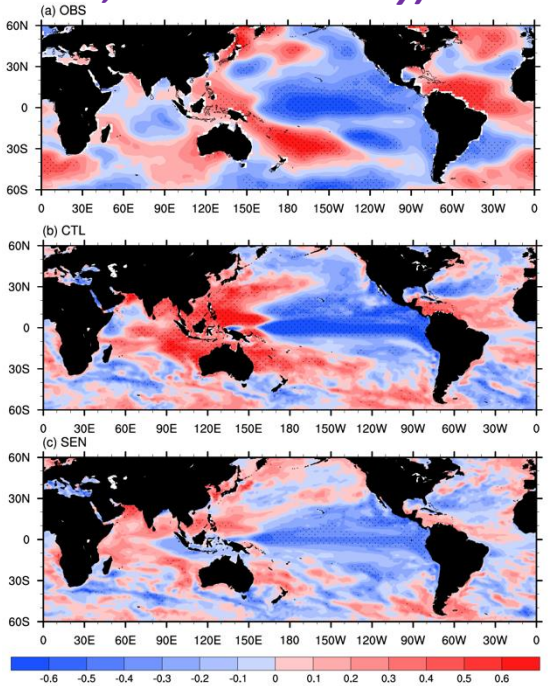


Reduced bias in Rainfall

Impact on ENSO, IOD, Monsoon



Better SST skewness (Improved ENSO, IOD nonlinearity)



Better SST-ISMR correlation

These model development activities have improved the seasonal prediction skill of ISMR by ~30-40%!

Thankyou!

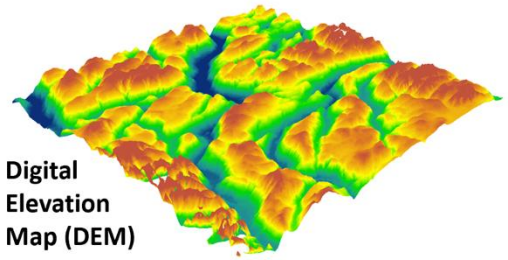
Any questions?

Get in touch:
ankur@tropmet.res.in
ankur.iitmpune@gmail.com

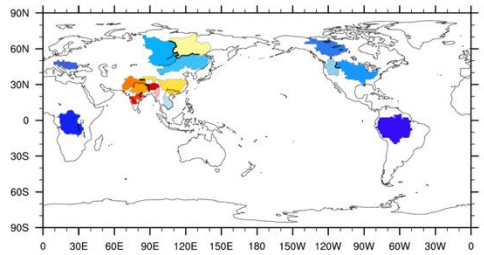
Additional Slides

Adding rivers to CFSv2

How to represent horizontal transport of freshwater??

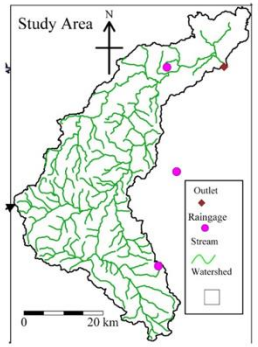


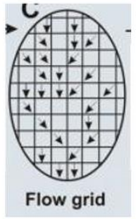
Digital Elevation Map (DEM)



Delineated River Basins (Global)

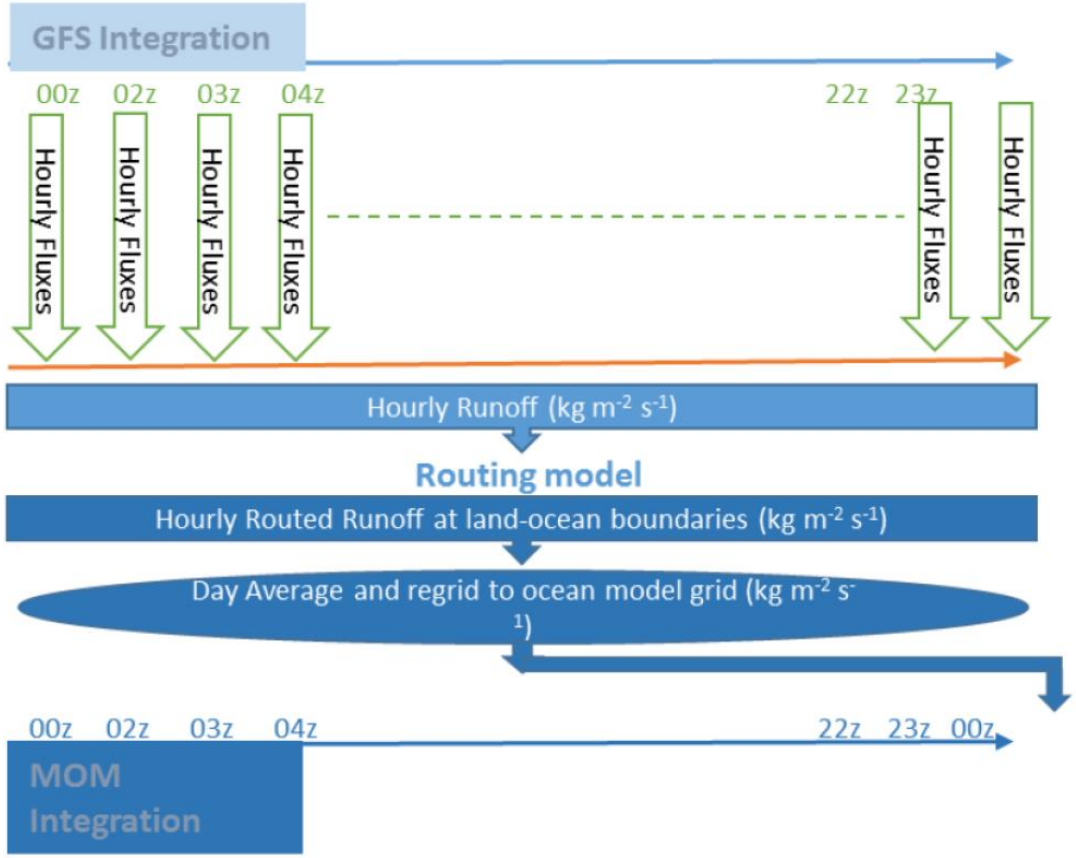
Flow Network





Runoff from land surface model

Routed streamflow at land-ocean boundaries



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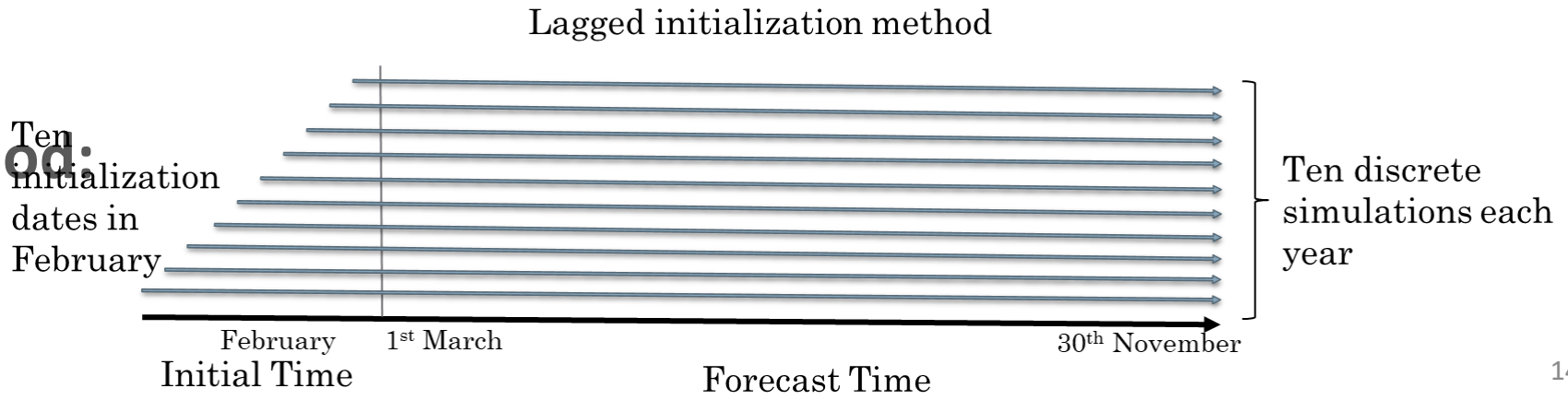
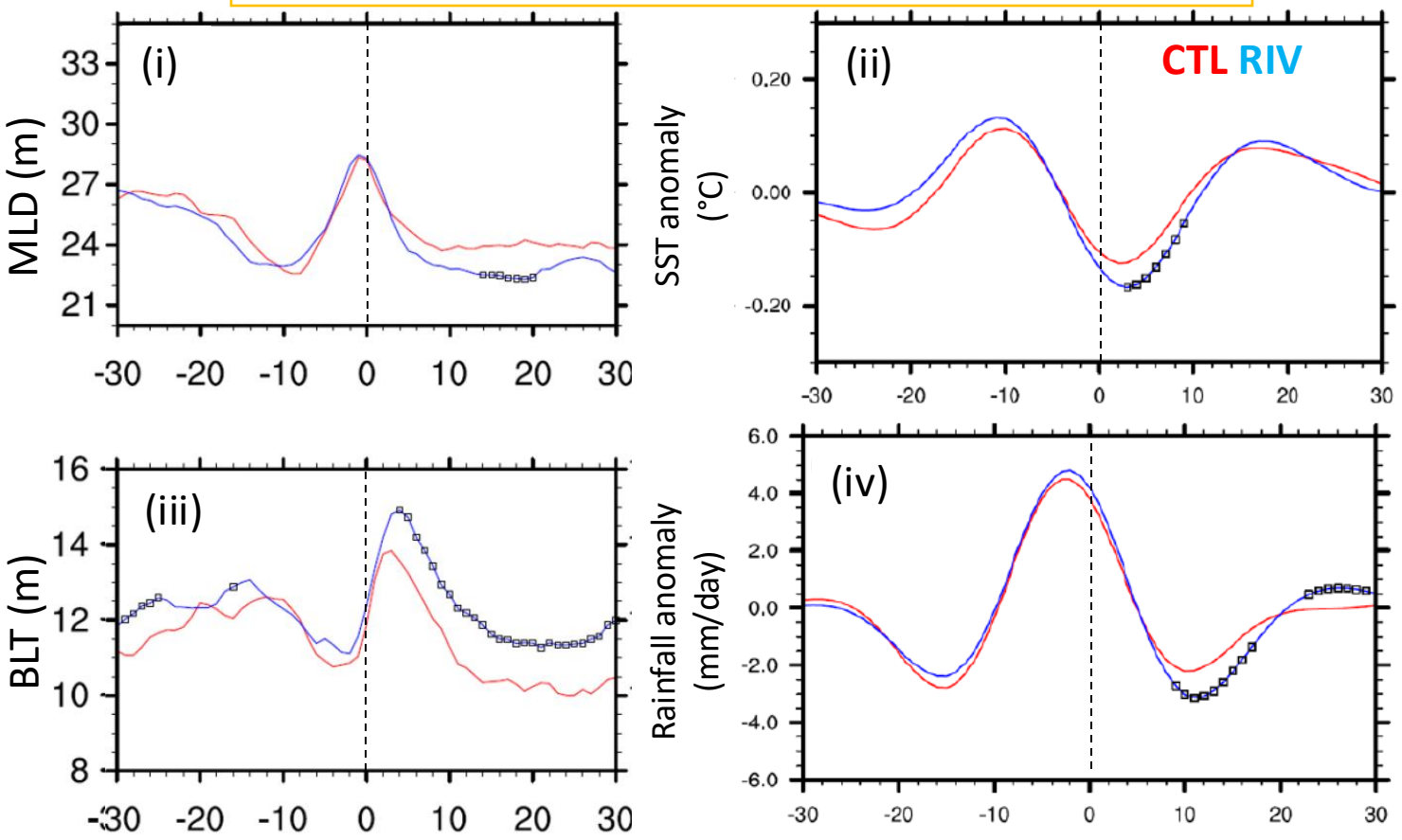


Upper ocean stratification

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

Category 3 events: Small MLD Large BLT group (MLD<28m; BLT>11m)



- 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.