Northern Indian Ocean SST Gradients and Monsoon Intraseasonal Oscillations

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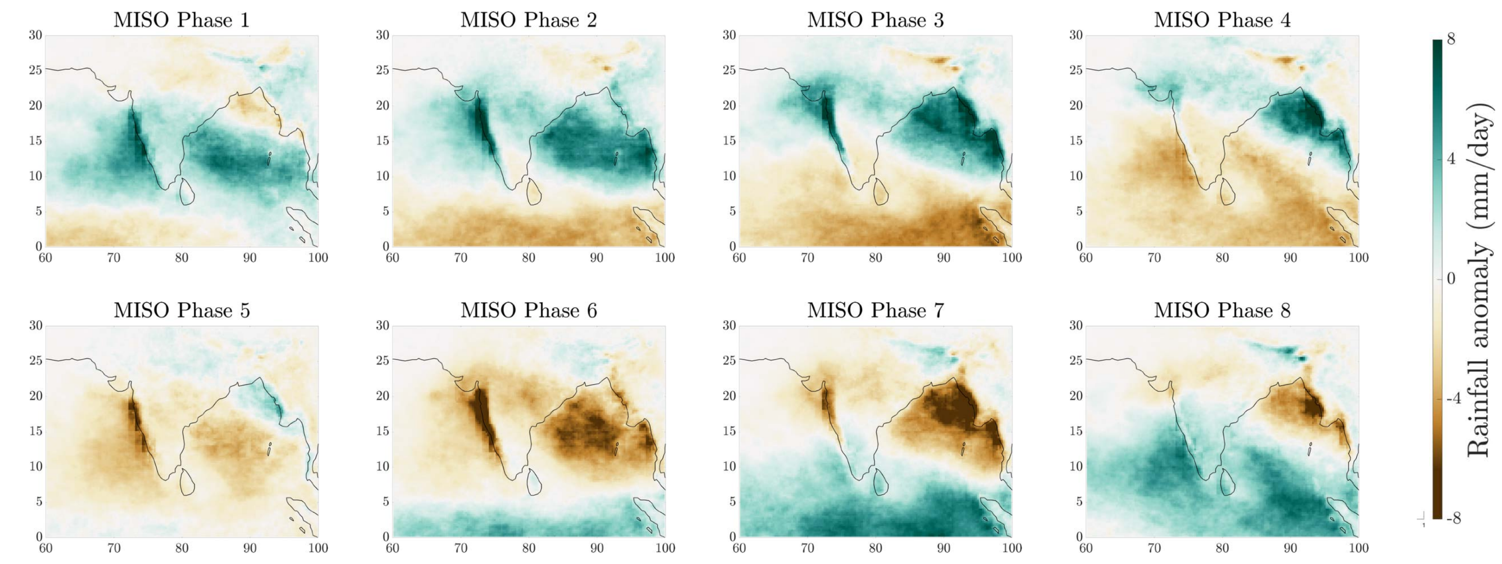
1: Background

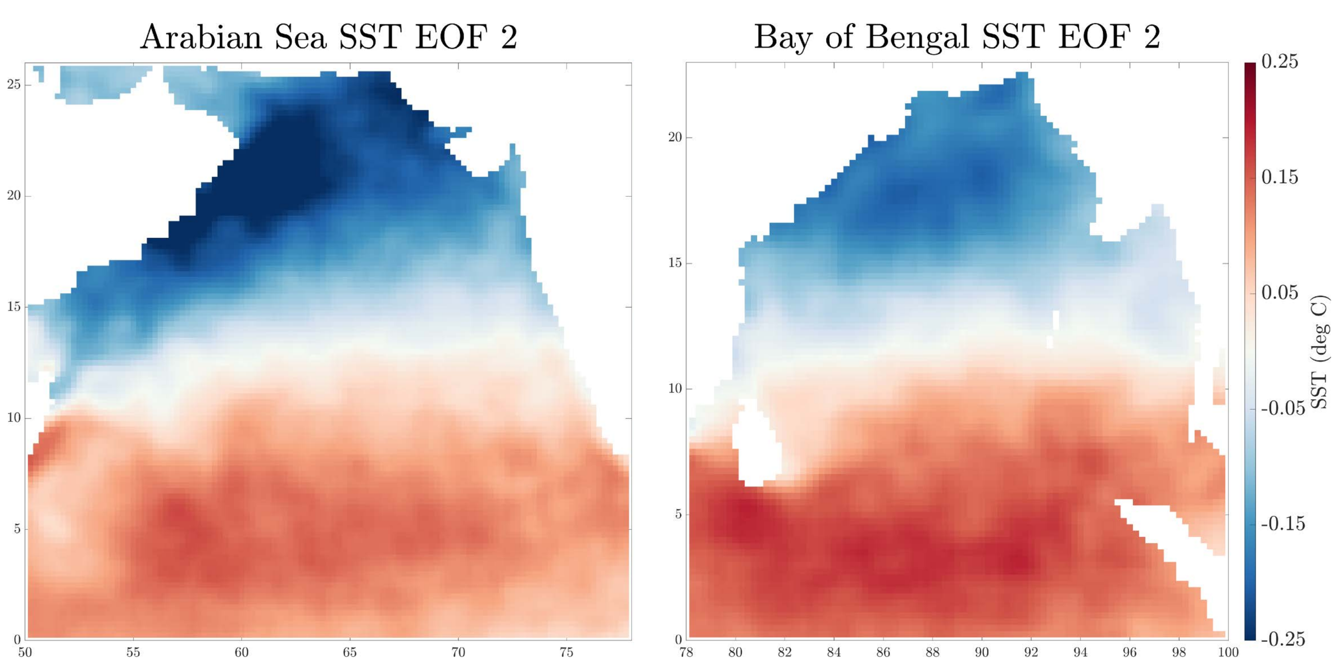
- The South Asian monsoon exhibits strong variability in the intraseasonal band (20-100 days) known as the monsoon intraseasonal oscillation (MISO). The oscillation manifests most directly as alternating active and break phases in rainfall over the Bay of Bengal (BoB) and Indian subcontinent.
- These rainfall oscillations are correlated with meridional shifts of the Somali low-level westerly jet, which transports moisture from the Arabian Sea to the BoB and South Asia.
- SST in the northern Indian Ocean also shows strong variability in the intraseasonal band. Active phases of MISO tend to be preceded by strong positive meridional SST gradients in the Bay of Bengal and Arabian Sea (Shankar et al. 2007).
- **Our question:** Is there a robust difference in rainfall and wind patterns between MISO events preceded by strong meridional SST gradients and those preceded by weak ones? Are differences in atmospheric behavior caused by the SST gradient anomalies or vice-versa?

2: Methods - MISO Event Identification

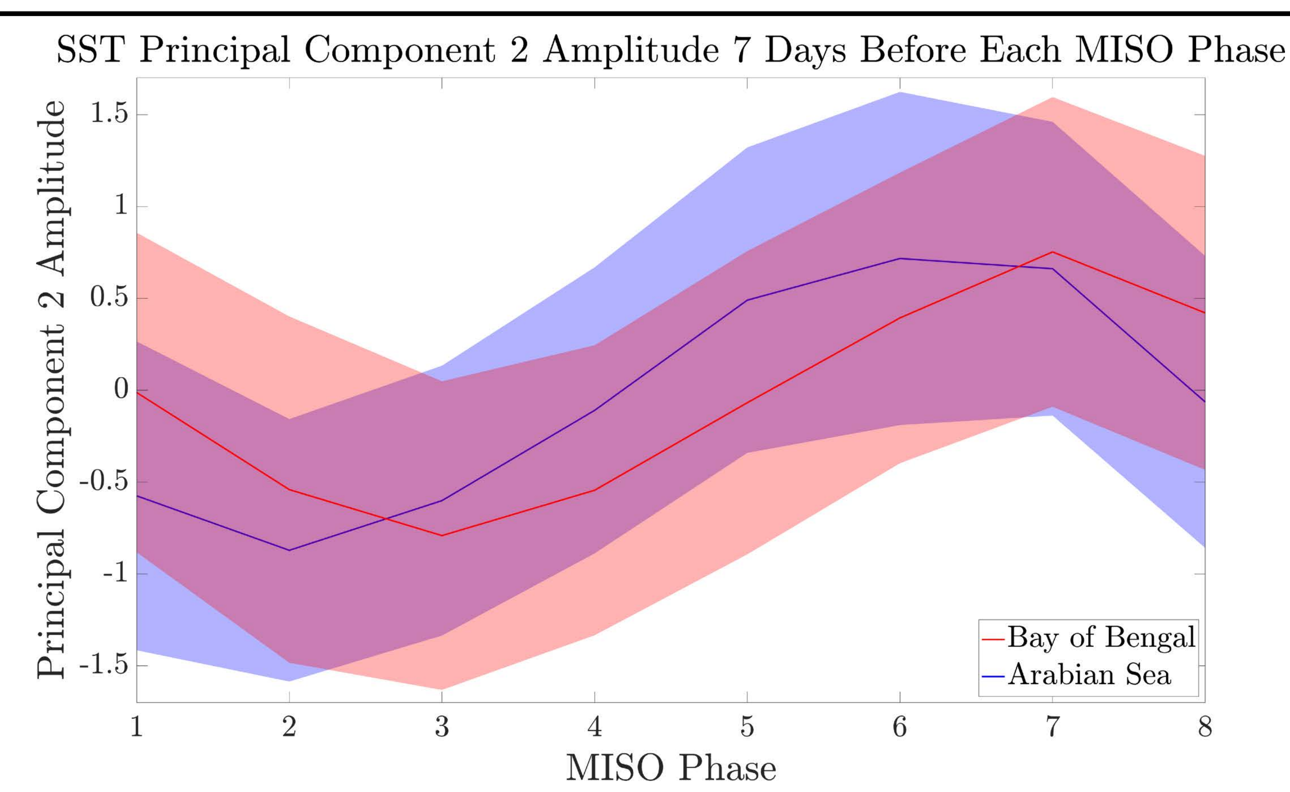


- The MISO index of Suhas et al. (2013) is given by the first two normalized extended EOF principal components of intraseasonal rainfall anomalies over the northern Indian Ocean. We identify a MISO event when the amplitude of the index is above 1 for at least eleven days.
- Above: Composite intraseasonal rainfall anomalies of each phase of the MISO index for 61 JJAS MISO events during 1998-2021 from TRMM rainfall data.

3: Methods - EOF Identification of Meridional SST Dipole



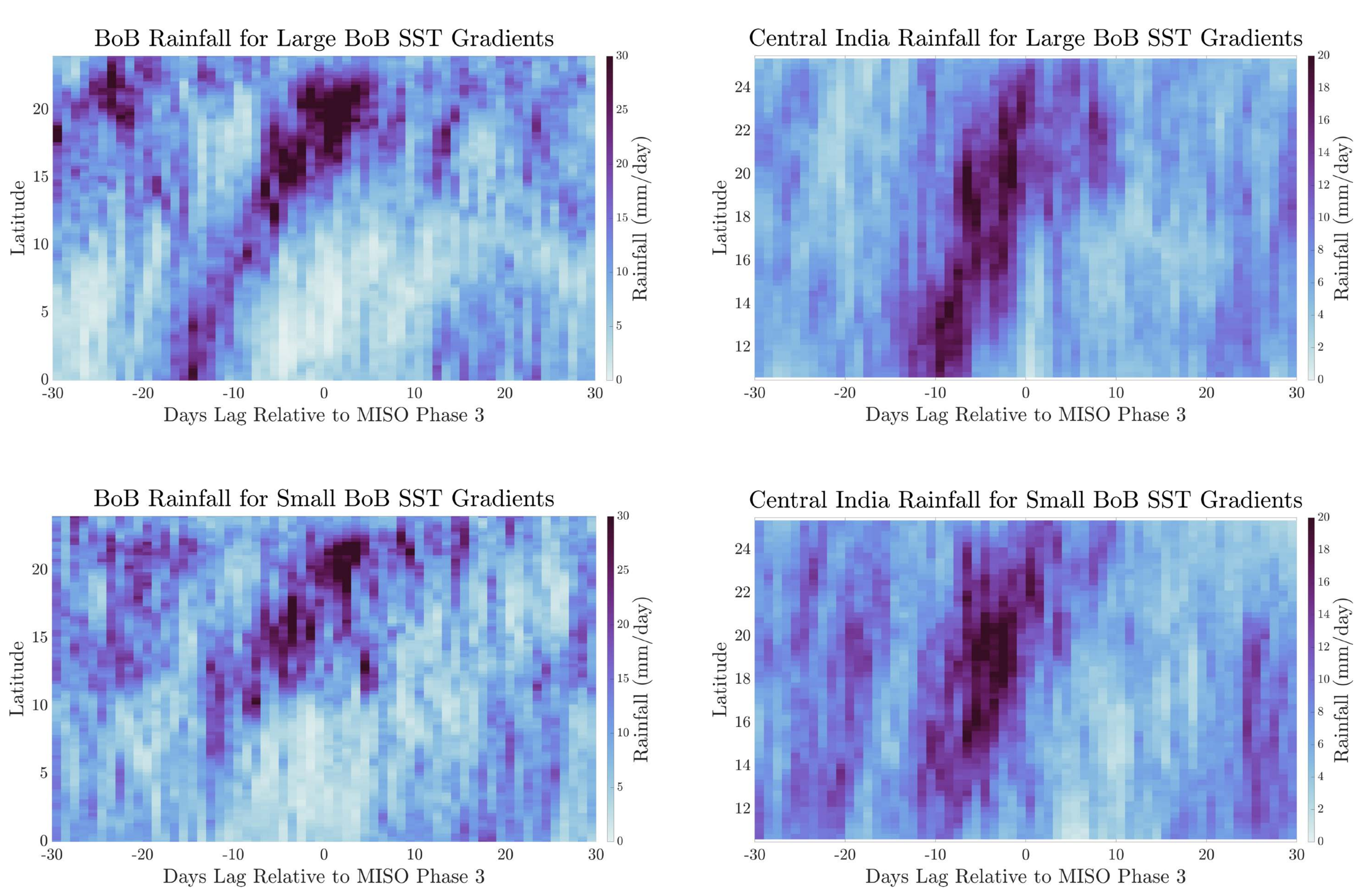
- We quantify the SST gradient in the northern Indian Ocean basins by the 2nd EOF of 20-100 day bandpass filtered SST with the annual cycle removed. We use 1998-2021 OISST data.
- These EOF have a north-south dipole pattern and we call the normalized principal component time series $\mathbf{SST2_{AS}}$ and $\mathbf{SST2_{BoB}}$.



- The SST2 indices for the Arabian Sea and Bay of Bengal are well-correlated with the MISO indices (~50% correlation), but also show variability independent of atmospheric forcing. Above: Composited SST2 amplitude with one-standard deviation shading.
- Other EOFs represent coherent patterns (monopole, zonal dipole, quadrupoles, etc.) that have smaller correlation with the MISO indices.

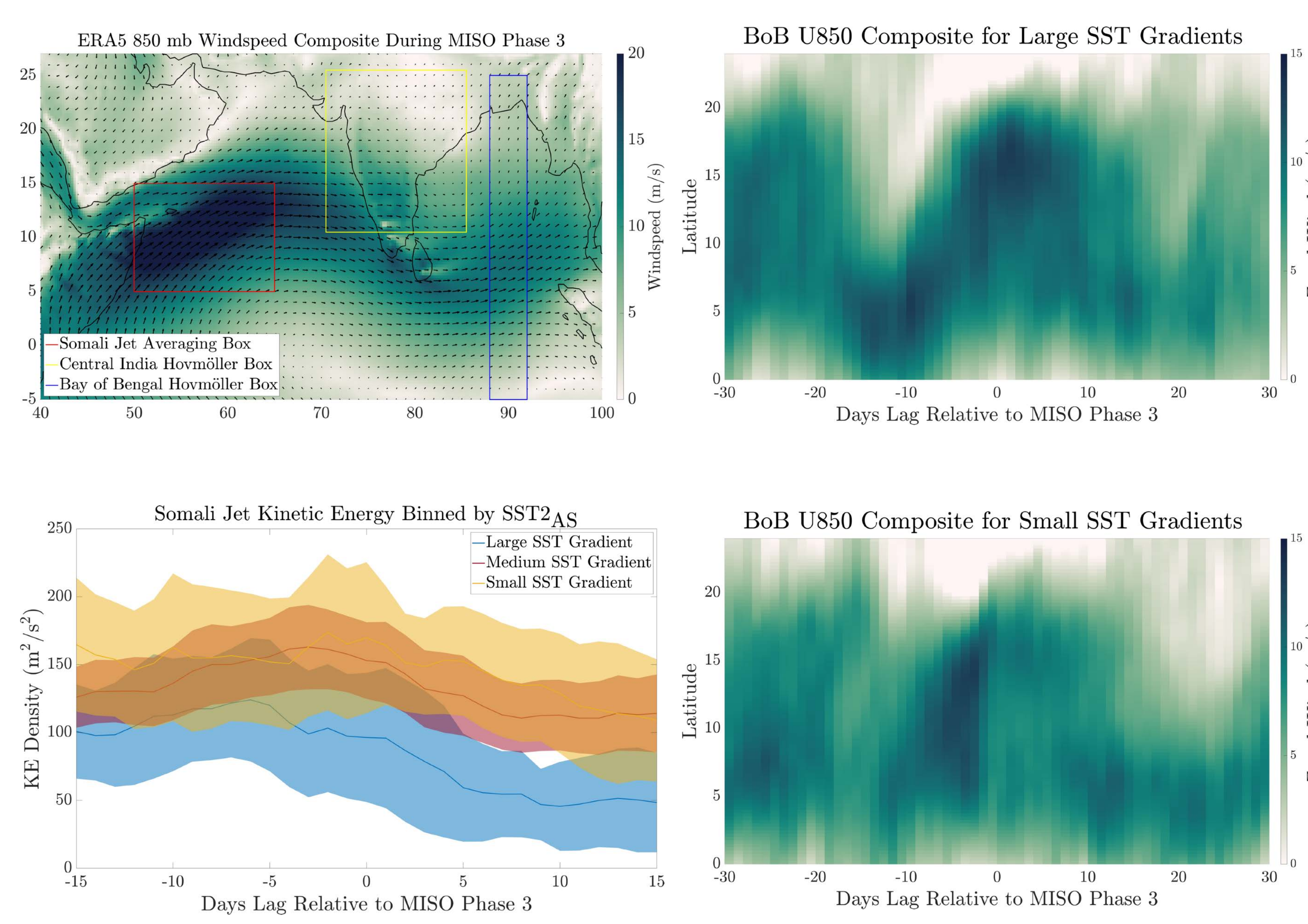
4: Results - SST Gradients and Rainfall

- Below: Composite rainfall over central BoB (left column) and central India (right column) binned by $SST2_{BoB}$. Longitudinal averages are taken over the blue and yellow boxes shown in the map in box 5. Large/small SST gradients are those that are +/- 1/2-standard deviation from the mean computed for MISO phase 3 events.
- During the active MISO phase, rainfall begins much farther north in the BoB when preceded by negative meridional SST gradients. The composite rainband is also more diffuse. These features are connected to the meridional movement of the Somali jet shown in box 5.
- Central India rainfall has a weaker dependence on $SST2_{BoB}$ in all phases. Total rainfall for large and small $SST2_{BoB}$ events are similar.
- Positive meridional SST gradients have enhanced break phases before the active phase. A strong break phase allows for more solar heating before the active phase.



5: Results - SST Gradients and the Somali Jet

- An integral part of MISO is the variability of the Somali jet that extends from the Arabian Sea to the Bay of Bengal in the lower free troposphere (see top left panel below). We observe differences in jet strength and behavior in events preceded by large versus small SST gradients.
- Active MISO phases preceded by more negative $SST2_{BoB}$ (i.e. stronger meridional gradients) show more meridional movement of the Somali jet, while for weaker SST gradients the jet tends to stay near the same latitude (see right column below).
- The meridional SST gradient in the Arabian Sea is instead correlated with the overall strength of the Somali jet, as measured by the kinetic energy of the 850 mb winds averaged over the western Arabian Sea (red box in top left panel).
- Bottom left panel: Large/small SST gradients are defined here as more than 1 standard deviation from the MISO phase 3 mean. Shading is 95% confidence interval.



6: Discussion - SST Independence by Phase

- Around the peak active MISO phases (e.g. phase 3) and the peak break MISO phases (e.g. phase 7), the meridional SST gradient behavior is dominated by the presence or absence of atmospheric forcing by a previous MISO cycle.
- For "shoulder" phases (e.g. phase 1 and phase 5), the gradient is less dependent on the previous cycle, and ocean dynamics may play a stronger role in setting the meridional gradient.
- In future work, we plan to separately quantify the MISO effect of SST gradient variability due to 1) atmospheric forcing and 2) ocean advection of freshwater and heat.

Summary

- We investigated how intraseasonal monsoon rainfall and low-level jet behavior are correlated with the strength of meridional SST gradients in the Bay of Bengal and Arabian Sea.
- Active-break cycles in rainfall over the BoB show robust differences depending on the 7-day leading SST gradient, but rainfall over central India is less correlated with the SST signal.
- The meridional SST gradient in the Arabian Sea is correlated with the overall strength of the Somali jet, while the BoB SST gradient is correlated with the amplitude of meridional oscillations in the jet. This jet behavior is central to the active-break cycles of the monsoon.

Primary References

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