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Pathways to temperature variability in South Asia

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For improving climate projections, there is a need to understand the physical processes governing the variability of dynamically driven variables, like near-surface temperature. Studies have shown that some features like surface drying and anticyclonic upper level conditions are associated with enhanced surface warming. However, the different ways in which surface, radiative and atmospheric variables compound to cause a heatwave, and the relative magnitudes of these variables and their relationship with heatwave intensity has not been well understood. Further, the large scale dynamics governing such conditions, and the effects of slowly varying climate features like ENSO and AO, are unresolved.

Using the ERA5 reanalysis dataset, we are studying the drivers of variability of daily mean 2 meter temperature (T2m) anomaly over the northwest Indian heatwave hotspot region, in the entire premonsoon season (March to June). Our approach is to develop an interaction framework which identifies governing surface and weather regimes active during different months, and quantify how large-scale climate patterns modulate their frequency of occurrence. We are leveraging the decision tree classification framework to identify the dominant weather patterns explaining different quartiles of T2m anomaly, owing to its non-linear modeling capability.

During March and April, the T2m anomalies are accompanied by a vertically coherent temperature anomaly field, and typically last only for a day or two. The decision tree classification algorithm suggests that anomalous surface warming during this period is preceded by increased shortwave radiation corresponding to subsidence across the tropospheric extent. The decay of such an anomaly is marked by decreased downward shortwave radiation fluxes and increased downward longwave radiation fluxes, indicating the role of ventilation and cloud formation. The direction of sensible flux anomaly also changes between the two phases, directed from the atmosphere to the surface in the warming phase, and from the surface of the atmosphere in the decay phase. During May and June, the warming anomalies last for more than three days, and the sensible heat flux anomalies are directed toward the surface. Although shortwave anomalies peak along with T2m anomalies, there is also an increased convergence of dry static energy in the lower troposphere, between 600–900 hPa, in the region. Geopotential anomalies on the 350 K isentropic surface are anti-correlated with potential vorticity anomaly, establishing the role of Rossby wave packets as the dynamical drivers of temperature variability in this region.

Thus, we show how an interpretable machine learning algorithm like the decision tree could

potentially identify proximal drivers and compounding factors of heatwaves, provide a way to rank them by their importance, and eventually lead to a multiscale framework by incorporating longer term signals such as ENSO.