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The role of midlatitude dry air during the withdrawal of the Indian monsoon

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The Indian summer monsoon (ISM) supplies over 75% of the country's annual precipitation, profoundly impacting lives of over a billion people. Significant variability in the timing of its onset and withdrawal has a direct impact on the agricultural sector and other users of water resources. Previous studies have shown that a wedge of mid-tropospheric dry air emanating from the midlatitudes is present over India during early summer, which is much shallower in the vertical toward the southeast of India. Following the strengthening of low-level monsoon winds during the onset, the dry air retreats from the southeast due to increased moistening by shallow cumulus congestus clouds, driving the north-westward progression of the ISM. The withdrawal of the ISM is observed to progress in a southeast direction during September–October, but there is a lack of a conceptual model. In this study, we use observations and the ERA5 reanalysis to understand the dynamics and thermodynamics of the withdrawal. We find that a mid-level dry intrusion re-appears over the northwest of India around mid-September. Vertical profiles associated with this dry air show how the most unfavourable environment for deep convection occurs in the northwest, where the withdrawal occurs first. As the withdrawal progresses, the wedge of dry air deepens throughout its horizontal extent and descends. This stabilises the troposphere, suppressing deep convection and ultimately driving the withdrawal toward the southeast. By mid-October, the dry air engulfs most of India, causing the ISM to withdraw from the entire country. Thus, the strengthening of the mid-level dry advection from the midlatitudes can explain the withdrawal of the ISM, and the mechanism driving the local withdrawal can be considered as the reverse of that at play during the progression of the onset. This work establishes a new paradigm for the withdrawal of the Indian monsoon in terms of midlatitude interactions, which could be tested for other monsoon regions.