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Seasonal variability in the South Asian monsoon dynamics

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Here, we analyze seasonal changes in the dynamics and thermodynamics of the South Asian summer monsoon (SASM) in atmospheric reanalysis data using a threshold-independent index of monsoon onset we have recently introduced (Walker and Bordoni 2016). We seek to evaluate the extent to which emerging theoretical frameworks are consistent with the observed monsoon. Climatological composites reveal that at monsoon onset, an abrupt strengthening and northward migration of the maximum in sub-cloud equivalent potential temperature accompany the rapid northward movement of the monsoon rainbelt. These changes are driven by changes in near-surface specific humidity, rather than changes in near-surface temperature, whose gradient actually decreases at monsoon onset. These findings are inconsistent with the traditional paradigm of the monsoon as a sea breeze circulation and confirm the convectively coupled view of the SASM circulation as an energetically-direct overturning circulation as more fundamental for the understanding of monsoon dynamics.

Providing further support to this emerging view, we show that the SASM sector mean circulation at monsoon onset undergoes a rapid transition from an equinox circulation with a pair of tropical overturning cells, to a solstice circulation dominated by a strong cross-equatorial monsoonal cell and negligible overturning cell in the northern hemisphere. This transition corresponds to a transition in the leading order momentum budget, from an eddy-dominated equinox regime to a highly nonlinear monsoon regime which approaches conservation of angular momentum. These transitions are similar to those seen in idealized zonally symmetric studies of aquaplanet monsoons, suggesting that eddy-mean flow feedbacks identified in those studies may be acting in the SASM sector, and may contribute to the abruptness of the SASM onset. Our findings highlight the importance of nonlinear dynamics in the seasonal evolution of the SASM circulation and suggest that some fundamental aspects of the observed monsoon can be understood in the absence of land-sea contrast or other zonal asymmetries.