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Large-Scale Mid- and Upper-Tropospheric Vertical Motions and MJO Convective Onset

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Reanalysis (ERA-Interim) is used to demonstrate that anomalies of large-scale vertical motion with ∼30 day variability at Addu City, Maldives, exist to the west of the Indian Ocean prior to the occurrence of widespread, organized convection associated with convectively active Madden-Julian Oscillation (MJO) events during DYNAMO/AMIE. The upward motions are associated with large negative anomalies of 150 hPa velocity potential, extend as low as 700 hPa, and apparently circumnavigate the globe several times. Sustained, widespread, organized convection does not initially develop until 0–2 days after large-scale upper-tropospheric upward motion anomalies arrive over the Indian Ocean. Over low-precipitation regions where they are not reinforced by latent heating, the magnitude of the equatorial anomalies is as large as 0.03 Pa s^{-1}.

Using large-scale forcing data derived from a sounding array in conjunction with ground-based radar, typical profiles of environmental heating, vertical motion, and moisture advection are computed for periods prior to those during which deep convection is prevalent and those during which moderately deep cumulonimbi do not form into deep clouds. In both environmental regimes, convection with tops between 3 and 7 km are present. Drying by horizontal advection is also ubiquitous. During periods when moderately deep cumulonimbus do not tend to grow into deep convection, vertical moisture advection is insufficient on the large-scale to overcome drying by horizontal advection. Prior to sustenance of deep convection,vertical advection of moisture in the mid- to upper-troposphere overcomes drying by horizontal advection such that the total (horizontal + vertical) moisture advection throughout the troposphere is positive. In order to do so, upward motion in the middle- and upper-troposphere, in excess of the median by as much as 0.03 Pa s^{-1}, is necessary.

The large-scale upward motions connected to equatorially trapped, eastward propagating divergent zonal wind anomalies in the upper-troposphere are sufficiently large to permit positive total moisture advection through a deep layer in the middle to upper troposphere. Formation and maintenance of deep convection and large stratiform regions are already known to be sensitive to mid-tropospheric, and possibly upper-tropospheric, humidity. Hence, the deep positive moisture advection associated with circumnavigating large-scale vertical motions probably allows deep convection and large stratiform regions to develop on the large-scale, signifying MJO convective onset. Although a relationship between upper-tropospheric velocity potential/divergence anomalies and MJO onset has long been suspected, we have proposed a novel and plausible mechanism through which such anomalies are directly related to MJO convective onset.