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Propagation Dynamics of Successive, Circumnavigating MJO Events in MERRA2 Reanalysis

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Propagation speeds of strong circumnavigating successive MJO events are investigated in MERRA2 reanalysis. Coherent, statistically significant circumnavigating signals in parameterized latent heating and modeled adiabatic cooling associated with large-scale vertical motion are detected and tracked. The signals appear to be associated with propagation of a first baroclinic Kelvin wave, but they obviously moved at a rate much slower than the theoretical phase speed for a dry first baroclinic Kelvin wave. (∼45–50 m/s). The goal is to determine what factors primarily control the variable propagation speed of the MJO signal as a function of longitude.

Following theory of Neelin and Held (1987) and Emanuel et al. (1994), the climatological offset (i.e. cancellation) between column integrated diabatic heating and adiabatic cooling in MERRA2 is used to the estimate the wave propagation speed if a reduction of “effective static stability” governed the phase speed. The offset is robust from year to year at all longitudes. A first baroclinic mode based on applying the theory to reanalysis output would propagate between 20–25 m/s over much of the Western Hemisphere, between 20–35 m/s over the eastern Atlantic and Africa, and between 5–20 m/s over the tropical warm pool. The theoretically predicted velocities closely match the propagation speed of the circumnavigating convective signal seen in reanalysis over regions of the tropics where the weak temperature gradient (WTG) approximation is apparently inapplicable (i.e. where deep convection is not prevalent and the offset between diabatic heating and adiabatic cooling is small enough to allow a non-negligible temperature tendency). However, in places where deep convection is prevalent and the offset is large (greater than about 0.9), such as over the warm pool, the theory greatly overestimates propagation speed of the MJO signal. Rather, the moisture wave theory of Adames and Kim (2016), which assumes a WTG, accurately predicts the speed of the MJO signal. Thus, two distinct dynamic regimes, one in which gravity waves dominate and another in which moisture wave dynamics are more applicable, govern MJO propagation depending on where the signal is located.

In the East Pacific, the offset has seasonal dependence. It is small (about 0.7) during boreal winter, and a reduction of effective static stability adequately describes propagation of the MJO signal. During boreal summer, the offset approaches 0.9, meaning that the WTG dynamic regime is prevalent like over the warm pool. However, no known theory for MJO propagation can explain the propagation speed of the signal, 8–9 m/s. In the East Pacific, convection tends to have a second baroclinic vertical structure, and it is centered off the equator. This highlights the need for extension of moisture wave/moisture mode theories to incorporate the second convective vertical mode and convection that is not centered latitudinally at the equator.