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A comparison of isotope-derived moisture budgets for the Madden-Julian Oscillation between satellites and GCMs

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A number of competing theories to explain the initiation mechanism, longevity and propagation characteristics of the Madden-Julian Oscillation (MJO) have been developed from observational analysis of the tropical climate and minimal dynamical models. A major hindrance in forwarding a single theory for the MJO is the failure of GCMs to produce realistic MJO-like events that could be used as test cases to isolate processes and boundary conditions necessary for MJO development. Here we present a diagnostic analysis of the footprint the MJO leaves on the isotopic composition of atmospheric moisture using paired satellite retrievals of H$_{2}$O and HDO from the boundary layer and mid troposphere. Because the isotopic composition of humidity is sensitive to moist processes that cannot be directly inferred from traditional meteorological fields, the isotopic analysis provides observational evidence of processes that dynamical models have hypothesized to be critical for MJO development but have thus far remained unobserved. The isotopic diagnosis shows that 2 weeks prior to the peak of MJO convective activity, the atmosphere is composed of anomalously high proportions of moisture from evaporation that has undergone little distillation. During this early initiation period, there is a shallow isotopic lapse rate, which is interpreted to reflect vertical transport of evaporated moisture that populates the mid troposphere with cloud burn-off, which has undergone minimal fractionation. As shallow convection develops, the evaporative moisture source is no longer observable and is replaced by easterly moisture convergence with an isotopic signature of more depleted moisture and moisture which has undergone significant rainout. At the peak in convective activity the moisture source bifurcates, showing evidence once again of a dominant evaporative source and a second source associated with evaporation from falling hydrometeors. The re-emergence of the evaporative moisture source likely arises from a positive feedback between rainfall intensity and wind strength, which ultimately enhances evaporation. The isotopes therefore depict a well-defined moisture sequence for the MJO, which does not appear when comparable analysis is performed on smaller convective systems that develop in the same region but do not mature into MJO's. The transition and utilization of different moisture sources is hypothesized to critical to the development of the moisture-convection feedbacks that allow the MJO to sustain deep convection without quickly exhausting itself. A similar set of diagnostic analysis is performed on a suite of GCMs, which have variable representations of the MJO and isotope tracers. A comparison between model and the satellite-derived moisture budgets are used to assess how weaknesses in moisture sources feeding the MJO might influence the representation of the MJO in these models.