Moisture Modes and the Madden-Julian Oscillation

David J. Raymond
Physics Department and Geophysical Research Center
New Mexico Tech
Socorro, NM 87801
raymond@kestrel.nmt.edu

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Recent observational and modeling work strongly suggests that deep convective precipitation over tropical oceans is extraordinarily sensitive to the integrated humidity in the tropospheric column, or more specifically the saturation fraction, which is equal to the precipitable water divided by the saturated precipitable water. This dependence and the tendency of convection to enhance locally surface heat fluxes and suppress outgoing longwave radiation gives rise to the development of convective clustering in a homogeneous environment. This clustering has been demonstrated in large-domain radiative-convective equilibrium calculations using cloud-resolving models. The resulting convective clusters are called "moisture modes".

On another front, progress has been made recently in the development of cumulus parameterizations for large-scale models which match the behavior of convection simulated in cloud-resolving models, particularly in the demonstrated sensitivity to tropospheric saturation fraction. In this paper I first demonstrate that a large-scale model using such a cumulus parameterization reproduces qualitatively the convective clustering demonstrated in cloud-resolving simulations. I then apply the large-scale model to a succession of more complex and realistic situations, demonstrating ultimately that traveling modes strongly resembling the Madden-Julian Oscillation develop in an aquaplanet beta-plane model with Reynolds sea surface temperatures. These modes have the character of moisture modes forced by nonlinear wind-induced surface heat exchange and possibly cloud-radiation interactions. They satisfy many of the criteria set forth by Zhang in his 2005 review of the Madden-Julian oscillation.