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Nonlinear moisture modes with stratiform precipitation

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A model similar to the quasi-equilibrium tropical circulation model (QTCM) with two vertical modes has been developed to examine the effect of stratiform precipitation on nonlinear moisture modes.

Moisture mode owes its existence to the feedback between environmental free-tropospheric humidity and deep convection. Linear moisture mode is unstable if there are enough moist static energy (MSE) sources that overcompensate for MSE export. In the nonlinear regime, the moisture mode is primarily governed by prognostic humidity equations combined with a damped response of momentum and temperature. Nonlinear wind-evaporation feedback contributes to large-scale selection and westward movement, whereas nonlinear advection leads to eastward movement.

When these two effects are combined, the model with only a single vertical mode blows up; including the two effects simultaneously requires stratiform precipitation and the second-baroclinic mode, which exports MSE efficiently with its top-heavy heating as indicated by observations. Under a certain parameter choice, the nonlinear moisture modes with a wavenumber of 2-4 move eastward along the equator at about 1 m/s, although its detailed time evolution exhibits somewhat chaotic behavior and clear off-equator signals.

The implication of the present results for modeling of the Madden-Julian Oscillation is discussed.