Sensitivity of Tropical Cyclone Convection to the Initial Entropy Deficit

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The spinup timescale of tropical cyclones (TCs) is an important forecast issue that is not well understood or accurately predicted. An axisymmetric model is used to investigate the spinup timescale of idealized TC vortices with varying moist entropy deficits between the boundary layer and free troposphere. The spinup timescale is inversely related to the mean vertical mass flux in the convecting region. Contoured frequency by altitude diagrams demonstrate a decrease in the mean vertical mass flux throughout the troposphere for drier simulations. Possible mechanisms that reduce the mean vertical mass flux include entrainment of low-entropy air into the boundary layer due to Ekman suction, entrainment into the eyewall by turbulent mixing, and convective downdrafts.

Convective motions are further analyzed in an isentropic framework by considering the conservation of moist entropy. This approach is similar to the isentropic analysis by Pauluis and Mrowiec (2013). Isentropic averaging separates higher entropy, upward-moving air parcels from lower entropy, subsiding air parcels, allowing for a systematic way to analyze moist entropy changes along the secondary circulation of the eyewall. The isentropic analysis of the mean vertical mass flux, and the associated streamfunction, show a decrease in the moist entropy within the deep convective updrafts. Separation of mean upward and downward mass transport is completed using a two-stream approximation. This method is used to show the large decrease in the mean upward vertical mass flux throughout the boundary layer and free troposphere for the drier simulations. These analyses demonstrate the role of dry air entrainment in reducing upward vertical mass fluxes, lowering the detrainment height of convection, and increasing the spinup timescale.

Forward and backward parcel trajectories from the locations of the convective updrafts are utilized to evaluate the relative importance of dry air entrainment directly into the eyewall from the mid-level environment versus dry air entrainment into the boundary layer from Ekman suction in reducing the moist entropy of eyewall air parcels.