Sensitivity of Tropical Cyclone Spin-up Time and Size to the Initial Entropy Deficit

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Tropical cyclogenesis and the subsequent development of the vortex are sensitive to the initial entropy deficit, the difference in entropy between a boundary layer parcel and the entropy of the free troposphere. We seek to study how the initial entropy deficit affects the spinup timescale and the size of a tropical cyclone (TC) in an axisymmetric model. The model experiments are initialized with the same vortex but with different initial entropy deficits, ranging from 0 to 100 J kg^{-1} K^{-1}. Larger initial entropy deficits imply less initial moisture above the boundary layer.

The spin-up timescale and TC size are both diagnosed through changes in the integrated kinetic energy of the low-level vortex out to a radius of 300 km and a height of 1.5 km. We define the spin-up time to be when the integrated kinetic energy of the low-level vortex doubles from its initial value. The spin-up time increases with increasing entropy deficit. The relationship is nonlinear, with the largest changes in spin-up time at lower entropy deficits (0 - 30 J kg^{-1} K^{-1}). The scaling between spin-up time and the entropy deficit is strongly related to the mass flux at a height of 1.5 km, averaged over the spin-up time and 300 km area. Decreasing mass flux with increasing entropy deficit results in less radial import of angular momentum in the boundary layer, resulting in both a slower intensification and a faster decrease in the tangential winds with radius, despite similar maximum intensities across all the experiments.

Analysis of the energetics reveals there is less efficient conversion of available potential energy to kinetic energy in the experiments with higher entropy deficits. Entrainment of low-entropy air into the boundary layer and turbulent mixing of low-entropy air into convective updrafts leads to a loss of buoyancy and the destruction of available potential energy. Less available potential energy is then converted to kinetic energy, resulting in a longer spin-up timescale and a smaller TC.