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Large-Eddy Simulation of Extreme Updrafts in the Tropical Cyclone Inner Core

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Extreme updrafts (stronger than 10 m/s) have been observed in the tropical cyclone core region, which has profound implications to tropical cyclone intensification and structure change. Since extreme updrafts in the tropical cyclone are difficult to observe, their features and the associated mechanisms for formation and influences on tropical cyclones remain poorly understood. With increasing tropical cyclone simulations conducted with horizontal grid spacing less than 1 km, it is possible that the numerical model can simulate the coherent structures and extreme updrafts in tropical cyclones. In this study, we examine the eyewall extreme updrafts simulated in the WRF-LES framework. The two simulations are conducted with the highest horizontal resolutions of 111 m and 37 m. The simulated updrafts (downdrafts) stronger than 2 (-2) m/s only occur at 5% of the grid points in the inner core region. It is found that the frequency of the extreme updraft exhibits three maxima at the lower, middle, and upper levels, respectively. All the extreme updrafts are associated with the enhanced eyewall convection in the northern quadrant of the simulated tropical cyclone. The extreme updrafts are related to different types of small-scale features at the lower, middle and upper levels. While the extreme updrafts at the lower levels occur with the tornado-scale vortex, at the upper levels two counter-rotating horizontal rolls are elongated generally along the tangential flow, sharing the strong in-between updrafts. The horizontal rolls are centered around the altitude of 14 km with a vertical extension of 2-3 km. The outflow and inflow of the enhanced eyewall convection provide strong vertical wind shear, leading to Ri<0.25. At the middle levels, the extreme updrafts are associated with small-scale features that are associated with the convective cells in the enhanced eyewall convection.