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INVESTIGATING CONVECTIVE ELEMENTS IN A HIGH RESOLUTION SIMULATION OF HURRICANE OPAL (1995)

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1. INTRODUCTION

Numerous studies have investigated the intensity and track of Hurricane Opal in 1995, an event that eluded forecasters at that time. It is now possible with advanced computing power to also explore the convective scale behavior of the hurricane. This is of particular interest because Hurricane Opal was a prolific producer of tornadoes (22), nearly four times the mean for a Gulf landfalling system. Many of these tornadoes were linked with mini-supercells in an outer hurricane rainband. Additional tornadoes were generated in the "core" region of the hurricane within eyewall convection.

High resolution simulations of Hurricane Opal using MM5 with an inner grid of 1.1 km horizontal resolution have been completed and are being analyzed. In addition, the COMMAS model is being used to carry out finer scale simulations with idealized initial conditions taken from the MM5 simulation instead of composite soundings as done in McCaul and Weisman (1995, 2001). Objectives include studying the behavior and structure of model generated convection in the outer rainbands of a hurricane.

2. RESULTS

Investigation of the MM5 simulation results reveals rainband structures similar to observations, including convective elements in the outer hurricane rainband. These elements exhibited structure and behavior analogous to mini-supercells, with persistent rotating updrafts. Fig. 1 shows a cross-section through a convective element in the simulation, showing a strong low-level updraft and the attendant hydrometeor field. The relative vertical vorticity in this updraft exceeds 0.01 s^{-1} in magnitude. Cell dimensions were similar to those observed and the position and orientation of the outer rainband was reasonably well represented.

The simulated convective environment that these cells formed in was conditionally unstable, featured by bands of dry air entrained into the otherwise saturated and relatively stable environment. The CAPE in the environment of the outer rainband was modest (800-1500 JKg^{-1}) yet showed considerable variability on the smallest scales, varying by as much as an order of magnitude over ten kilometers. Most outer rainband cells formed over the warmer waters before moving onshore, and then maintained strength as they progressed inland along the Florida Panhandle coast. Simulated cells lacked organized downdrafts, and updrafts rarely exceeded 12 ms^{-1}. Linearly organized individual cells in the outer rainband appear to be associated with elongated bands of both horizontal (enhanced local vertical shear) and vertical vorticity. Large values of shear were generally confined to the lowest 5 km, with 0-3 km helicity values over 400 m^2s^{-2} and BRNSHR of 50 m^2s^{-2}. Using the criteria of Stensrud *et al*. (1997), tornadic supercells are likely.

Fine-scale structure was identified in the dynamical character of the hurricane core, which displayed significant gradients of vertical motion on small spatial scales, with updrafts rooted in the boundary layer as illustrated in Fig. 2. These bands of ascent were convergent toward the hurricane eye, and appeared to be initiated by low-level shearing instabilities. Bands were ubiquitous around the core of the storm, but showed greatest organization in the right front quadrant. Similar structure was noted in observations of other strong hurricanes by Gall (1998). The dynamical character of the banded features in this simulation is currently under study. Mesoscale vortices were also observed in the simulation within the radius of maximum winds. These vortices acted to concentrate local wind maxima, distorting the otherwise concentric eyewall.

Visualization efforts have yielded insightful results about the character of the dynamical

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processes. Fig. 3 was extracted from an animation of the enstrophy field, which showed considerable organization and structure. Shaded regions are indicative of high values of vertical shear, as the horizontal components of vorticity dominate the enstrophy field. Boundary layer rolls assist in the transport of sensible and latent heat fluxes that support the formation of ascending bands (Fig. 2). The dynamics of these features are currently under investigation.

3. REFERENCES

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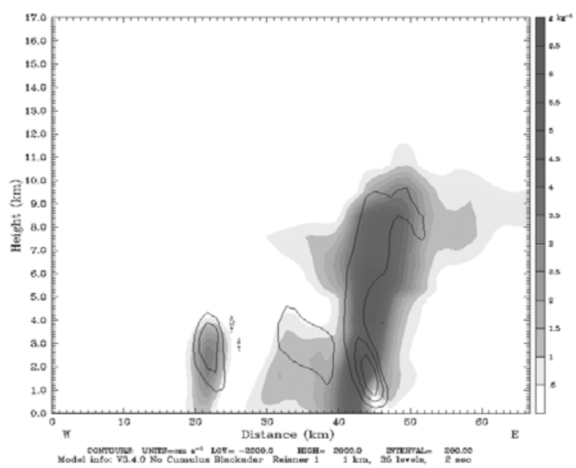

Fig. 1. Cross-section through a simulated tropical cyclone convective element in an outer hurricane rainband. The shading indicates hydrometeor mixing ratio concentration, overlain with contours of vertical velocity in 2 ms^{-1} intervals.

4. ACKNOWLEDGEMENTS

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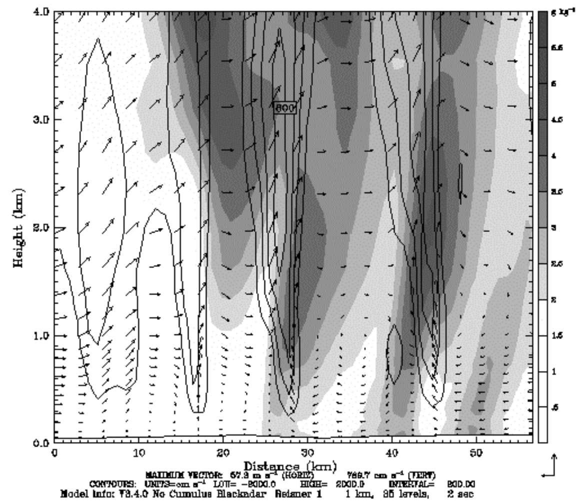

Fig. 2. Cross-section of the lowest four km ahead of the hurricane track showing ascent greater than 2 ms^{-1}, along plane relative circulation vectors, and rainwater mixing ratio.

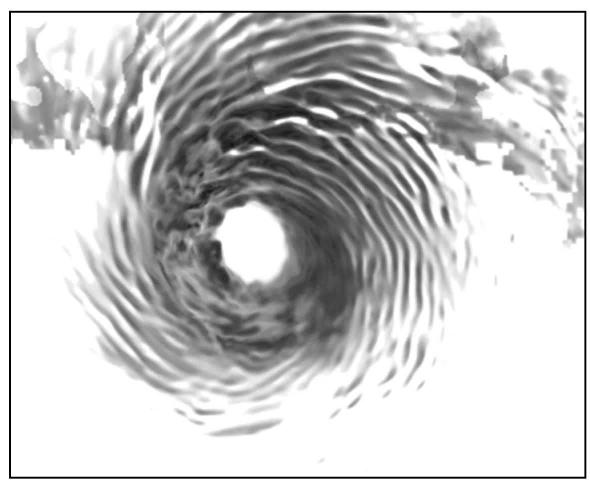

Fig. 3. Enstrophy near the surface for Hurricane Opal simulation using a volume rendering technique. Shaded regions indicate large values of enstrophy, which are organized in bands. Also, enhancement in enstrophy near the figure top is associated with frictional drag along the coastline.