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EFFECTS OF SEA SPRAY IN THE SIMULATION OF HURRICANES USING LES-BASED PARAMETERIZATIONS

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1. INTRODUCTION

This study examines the behavior of simulated, idealized hurricanes in response to parameterized effects of sea spray. Hurricanes produce copious amounts of spray, and recent studies of spray behavior indicate that it can have potentially large effects on the air-sea exchanges of sensible heat, latent heat, and momentum. Parameterizations of spray effects on some of these surface fluxes have been developed and tested, but there is still a great deal of uncertainty as to how these parameterizations should behave at very high wind speeds, and ultimately on how the spray affects the hurricane. The uncertainties result from the complexity of the problem and from the lack of adequate observations in the lower boundary layers of hurricanes.

The current study is part of a larger project that is using Large-Eddy Simulation (LES) to simulate explicitly the behavior of spray in hurricane boundary layers. The results of our LES simulations of hurricane boundary layers will be discussed in a companion paper at this conference (Kelly et al., 2004). This paper describes the use of the LES results to tune spray parameterizations and then to explore the effects of spray on modeled hurricanes. The idealized hurricanes are simulated using the Penn State/NCAR Mesoscale Model (MM5). The poster will show results of the LES simulations, discuss how these results are used to alter the spray parameterizations of the hurricane model, and show sensitivity studies of the effects of the modified spray parameters on the modeled storms.

2. METHODOLOGY

An axisymmetric control hurricane is created from the output of a real-data simulation of Hurricane Floyd (1999). Twenty four hours of output are averaged, and the axisymmetric storm is placed in an idealized zero-flow environment on an f plane. The sea surface temperature is 28.5 C everywhere and remains constant. The temperature and wind fields are rebalanced. We then activate the spray parameterization of Fairall et al., (1995), which modifies the surface fluxes of sensible and latent heat. We also use a simple parameterization of spray momentum flux based on the same spray source function used in the Fairall parameterization.

Sensitivity tests are performed by altering the spray source function to increase or decrease the amount of spray generated for a specific surface wind speed. The effects of including momentum flux in the spray parameterization are explored. In some simulations we add horizontally uniform and unidirectional wind shear. The purpose of the shear is to create asymmetries in the core structure and hence to determine whether the effects of spray are dependant upon the degree of core symmetry.

Finally, results of LES simulations performed with sea spray and for wind speeds comparable to those of the control hurricane are used to modify the parameterizations of surface fluxes of sensible and latent heat and of momentum. These LES results are used to modify the spray parameterization used in MM5. Simulations are run again with the new flux parameterizations, and the effects of the modifications upon the simulated hurricane cases are studied.

3. RESULTS

Sensitivity studies show that the effects of spray on the simulated storms are complex. Initially, the spray tends to increase the air-sea flux of moist enthalpy leading to intensification of the storm. However, the relative effects of spray on storm intensity are greater for hurricanes of moderate intensity than for very intense storms. This seems somewhat counterintuitive, since the spray flux increases very rapidly with increasing wind speeds. The results suggest that storms that are close to their maximum potential intensity (MPI) do not intensify further due to the parameterized spray, while storms that are well below the MPI intensify due to the increases enthalpy fluxes.

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The momentum effect of the spray, essentially the force required to accelerate the spray drops to horizontal terminal velocity, acts to reduce the surface winds. By doing so, it also decreases the magnitude of the enthalpy fluxes. Further, the spray modifies the structure of the boundary layer, further affecting the net surface fluxes. As a result of the interplay of these processes, it is not straightforward to predict the changes in storm intensity due to spray. Most simulations intensify initially when spray is added, and increasing the spray simply increases the intensity change. However, some simulations subsequently weaken, and some show little long-term differences in intensity despite large variations in the amount of spray generated. We are exploring the mechanisms responsible for these behavior patterns.

As of this writing, the LES-based parameterizations have not yet been installed and tested in the MM5 hurricane simulations. However based on the results of the LES cases we expect that the spray and surface flux parameterizations in the hurricane model (MM5) will need to be altered. Early results indicate that spray stabilizes the boundary layer, reducing both surface winds and the surface fluxes. We will report on this phase of the research at the conference.

4. REFERENCES

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