P1F.19 AN EVALUATION OF THE BOUNDARY CONDITIONS FOR NESTED DOMAINS FOR IDEALIZED HURRICANE SIMULATIONS

Sarah Aplin, F. Carroll Dougherty *, and Sytske K. Kimball
University of South Alabama, Mobile, Alabama

1. INTRODUCTION

A recent study completed for an idealized hurricane simulation over water at a constant surface temperature using the PSU/NCAR mesoscale model version 5, MM5, showed that the storm developed very differently as a function of the vertical spacing of the model sigma levels (Kimball and Dougherty, 2006). In addition, all the simulations, regardless of the sigma distribution, eventually filled and lost their hurricane characteristics, an unexpected result. The time and spatial resolutions had been carefully chosen to avoid stability bounds, yet the simulations became unstable. After some investigation into probable causes, this study was initiated to evaluate the boundary conditions on the nested domains.

2. MODEL CONFIGURATION

The Penn State/NCAR mesoscale model, MM5, is used with a two-way nested grid configuration. The coarse grid (200 x 200 points) horizontal resolution is 15 km; that of the inner grid (103 x 103 points) is 5 km. Convection is modeled explicitly on the inner mesh, while on the outer mesh the Betts-Miller scheme is used. Micro-physics is modeled using the Reisner graupel scheme and includes snow, super-cooled water, graupel, and ice number prediction equations. Time dependent boundaries are used on the nested grid and relaxation boundaries are used on the large-scale grid. Two different vertical sigma distributions are investigated (see next section). An artificial vortex is constructed via the method described in Kimball and Evans (2002). The boundary temperature, moisture soundings, and sea level pressures are based on a12 UTC 19 July 1997 Gulf of Mexico sounding. The sea surface temperature (SST) is constant and uniform and has a value of 28^0C. An f-plane, defined at 20^0N, is used. The initial vortex was created with a radius of maximum winds (RWM) of 135 km and a maximum wind value of 20 ms^{-1}. The first domain is chosen to be approximately 10 times larger than the initial vortex; the nested domain is approximately twice the size of the vortex.
*

* *Corresponding author address:* F. Carroll Dougherty, Department of Mechanical Engineering EGCB 212, 307 USA Boulevard South, University of South Alabama, Mobile, AL 36688; email: doughert@jaguar1.usouthal.edu.

3. SIMULATIONS AND VALIDATION

Two test cases have been created, with the one being the baseline case from the Kimball and Dougherty study. The baseline case has more levels (35 half-sigma levels), and the levels are clustered in meteorologically active regions such as the Planetary Boundary Layer (PBL) and the hurricane outflow layer. A similar distribution with 24 half-sigma levels is the second case.
In the absence of real observations, a baseline must be established for the idealized simulations. A number of authors have derived theoretical or climatological MPI's for hurricanes. A theoretical MPI, derived by Emanuel (1988), calculates the intensity based on the SST and the thermodynamic structure of the atmosphere. It was decided to use the 35-level simulation as a baseline case for this effort. Justifications for this are 1) it comes closer to the theoretical MPI, 2) it has more vertical levels, 3) it conforms with the traditional recommendation of a well-resolved PBL especially when employing the Blackadar PBL scheme, and 4) it resembles distributions used by others who successfully simulated real case hurricanes.

4. RESULTS AND DISCUSSION

Results from both simulations were evaluated by plotting the winds and the different moisture variables in both domains. For both simulations, the parameters on the nested domains are seen to be correctly convected in and out of the domain boundaries. On the large-scale domains, however, evidence of the disturbances reaching the boundaries and rebounding back into the field is seen as early as 24 hours into the simulation. These disturbances collected in the corners of the domain and eventually formed small vortices there. These vortices continued to grow until they formed super vortices around the initial vortex. In the 35 sigma level case, these false disturbances were entrained into the original vortex, causing it to fill and dissipate. In the 24 sigma level case, the super vortex formed, but the interaction between the false vortex and the original vortex was weaker, causing it to fill more slowly. This is consistent with the results found in the Kimball and Dougherty study, where the development of an idealized storm was clearly affected by the sigma level distribution. In all of the cases, incorrect solutions resulted because the relaxation boundary conditions were insufficient at the domain boundaries.

A second study to determine if making the domain larger would reduce or eliminate this problem has been initiated. If possible, the authors would like to replace the relaxation boundary conditions with non-reflective boundary conditions. In addition, since the disturbances appear to travel to the domain boundaries fairly quickly, there is a possibility that small errors may be convected into the domain for real simulations, since many simulations use updated boundaries only ever 12-14 hours.

5. SUMMARY

This new study evaluates the boundary conditions at the outer boundaries of the primary domain. Results show that many of the physical parameters such as the winds and many of the precipitation variables are convected outward to the edge of the domain, where the boundary values are held constant for an idealized simulation. In spite of the relaxation boundary conditions applied to the variables near the boundary, these parameters are seen to ‘stack’ up at the boundary of the domain, causing new recirculation regions that eventually rebound back into the simulation to affect the hurricane development.

6. ACKNOWLEDGEMENTS

This work is supported by NOAA Award No. NA06NWS4680008. This work was made possible in part by a grant of high-performance computing resources and technical support from the Alabama Supercomputer Authority.

7. REFERENCES

Emanuel, K.A., 1988: The Maximum Intensity of Hurricanes. *J. Atmos. Sci.,* **45**, 1143-1155.

Kimball, S.K. and F.C. Dougherty, 2006: The Sensitivity of Idealized Hurricane Structure and Development to the Distribution of Vertical Levels in MM5. ," *Mon. Wea. Rev.*, **7**, 1987-2008.

Kimball, S.K. and J.L. Evans, 2002: Idealized Numerical Modeling of Hurricane-Trough Interaction. *Mon. Wea. Rev.*, **130**, 2210-2227.