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A GRID SENSITIVITY STUDY FOR VERTICAL SIGMA LEVELS IN IDEALIZED HURRICANE SIMULATIONS.

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1. INTRODUCTION

In the course of studying the development of idealized hurricanes using the PSU/NCAR mesoscale model, MM5, a relationship between vortex stability and vertical resolution became apparent. In this study, the nature of these instabilities will be investigated. Possible contributors are numerical (Anthes, 1972), internal to the vortex (Montgomery and Kallenbach, 1997), or may be caused by the boundaries of the model domain.

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) makes use of a 15 km horizontal resolution. The inner grid (103 X 103 points) uses a 5 km horizontal resolution. 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. The number of vertical sigma levels is varied as discussed below.

3. ARTIFICIAL VORTEX CONSTRUCTION

An artificial vortex is constructed using the technique described in Kimball and Evans (2002). In the current study, the boundary temperature and moisture soundings and sea level pressure are taken at 12 UTC 19 July 1997 over the Gulf of Mexico. The sea surface temperature (SST) is constant and uniform and has a value of 28°C. An f-plane, defined at 20°N, is used. The initial vortex has a radius of maximum winds (RMW) of 135 km and a maximum wind value of 20 ms^{-1}.

4. EXPERIMENTS

The sigma distributions of two earlier experiments clustered the sigma levels at the lower and upper regions of the atmosphere. These are shown in Figure 1, as distribution A (35 levels) and distribution E (24 levels). Three other distributions have been identified for the sigma sensitivity study. Using these, B through D, we seek to evaluate the effects on the solution by varying both the number of sigmas in the lower atmosphere and the distribution in the middle.

Experiment	Vertical distribution	Timestep (s)
1	35 (A)	15
2	24 (B)	15
3	35 (A)	10
4	35 (B)	10

Table 1 List of experiments with sigma distributions and timesteps.

5. RESULTS

So far, 4 experiments have been run (Table 1). Two 35 level cases at 2 different timesteps were run for a total of 7 days of simulation. Two additional cases using 24 level sigmas (distribution B) were also run for the above 2 timesteps. Unfortunately, the storms in all 4 cases did not reach steady state intensity. This can be seen in Figure 2 where the minimum center pressures are plotted.

Originally, it was suspected that the problem was caused by too large a timestep (15 s). However, reducing the timestep to 10 s did not improve the results. Further study into the 4 results, in particular looking at the tracks of the hurricanes (Figures 3 and 4) and at the cloudwater and rainwater concentrations (not shown), indicated that there was a problem at the boundaries of the nested mesh. The problems were attenuated by reducing the timestep, which seems to indicate a number of possibilities for the instabilities. In each simulation, the vortex makes several trochoidal oscillations before filling, even though it is located on an f-plane in quiescent flow and hence would not be expected to move from its original position. These loops are possibly related to growth of truncation and roundoff errors (Anthes, 1972), but they have not been shown to cause the hurricane decay seen here. In addition, real hurricanes have been observed to make looping motions (Holland and Lander, 1993) and researchers have speculated that these could be related to internal vortex instabilities (Montgomery and Kallenbach, 1997). The behaviors viewed in the cloudwater and rainwater concentrations, however, indicate that one or more moisture variables may not be advected properly across the boundary of the nested grid. The investigation into this potential problem continues.

Looking at Figure 2, a difference in the 35 and 24 level simulations can readily be seen. The storms in the 24 level cases do not become as intense as the 35 level cases before decay commences. Further study into the sensitivity of the sigma levels must be delayed until the

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lateral boundary condition problems are understood, since those errors may mask some of the effects of the different sigma distributions.

6. REFERENCES

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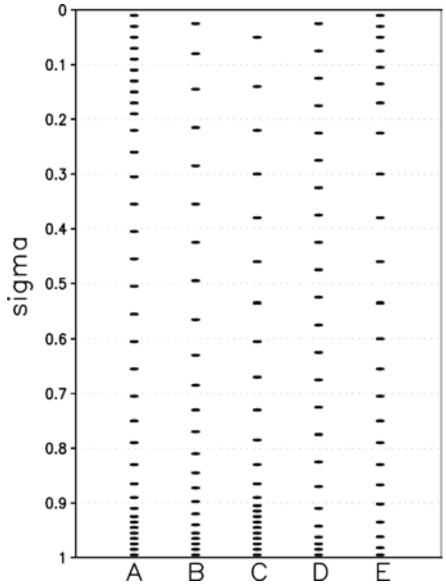

Figure 1 Vertical distributions of sigma levels.

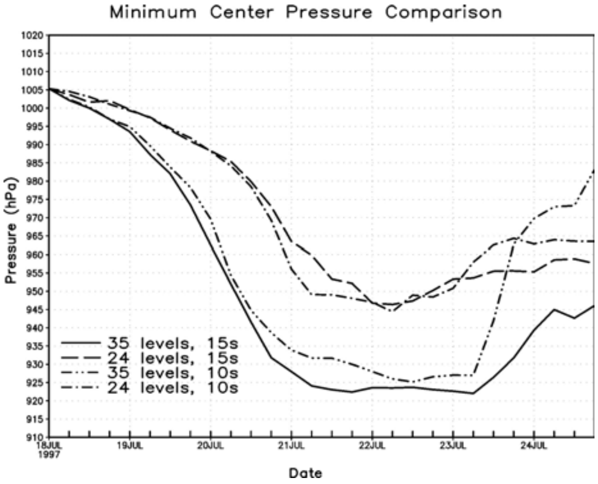

Figure 2 Minimum surface pressure (hPa) timeseries.

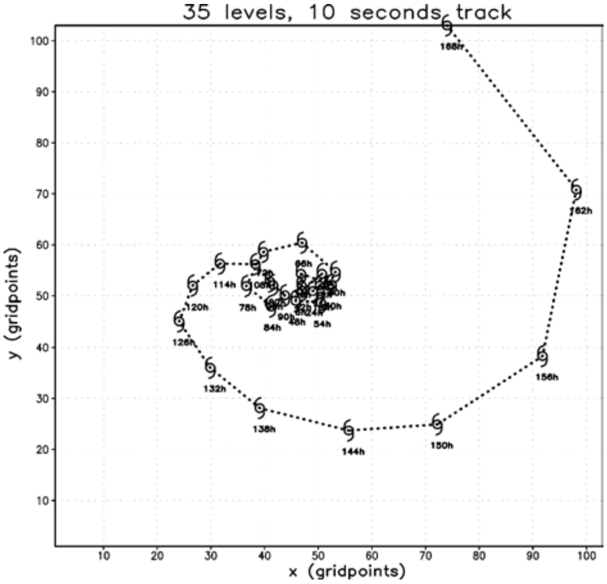

Figure 3 Hurricane track of experiment 3. The hurricane symbol indicates the position of the hurricane at 6h intervals.

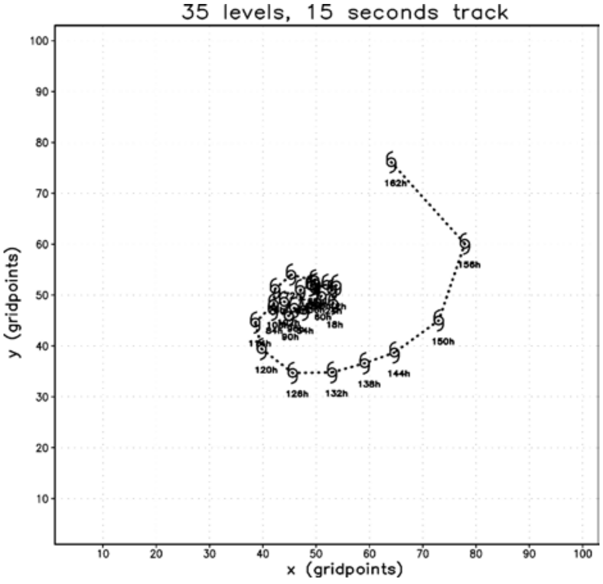

Figure 4 As figure 3, but for experiment 1.