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SIMULATIONS OF HURRICANE ISABEL (2003) IN THE WRF, GFDL, AND ZETAC MODELS

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1. INTRODUCTION

The Weather Research and Forecast Model (WRF) is a next-generation, regional, nonhydrostatic model of the atmosphere presently under development by a number of agencies involved in atmospheric research and weather forecasting (NCAR-MMM, NCEP-EMC, FSL-FRD, AFWA, UOK-CAPS), along with a number of university scientists (Michalakes et al. 2001). NOAA is presently planning to replace the the GFDL Hurricane Prediction System with WRF or a similar model based on the WRF modeling framework. In earlier work, the first author found that a straightforward application of the WRF model did generate reasonable hurricane forecasts (Nolan and Tuleya, 2002). Here, we will look more closely at the predicted storm structure for a particular case, Isabel (2003). Isabel is useful for this purpose because it was a well-developed, strong storm, whose track was forecast remarkably well by both global and regional models.

2. MODELS AND INITIAL DATA

We will analyze forecasts of Hurricane Isabel (2003) from three independent, and quite different, models:

- The GFDL Hurricane Prediction System of 2003:
  A hydrostatic model, in σ (p/p_s) coordinates, with two nested grids of 1/2 and 1/6 degree resolutions; simplified Arakawa-Schubert (SAS) cumulus parameterization, and a Mellor-Yamada type PBL scheme, coupled to an ocean model (see Bender and Ginis, 2000, for an overall discussion of the model).
- WRF 1.3:
  A fully compressible nonhydrostatic model, in σ coordinates with high-order advection and time-stepping schemes (Wicker and Skamarock 2002). The NCEP 5-class microphysics, Kain-Fritsch cumulus, and MRF PBL schemes are used for this case.
- ZETAC:
  A fully compressible nonhydrostatic model developed at GFDL. It uses a terrain-following coordinate ζ (z/z_s), Lin bulk microphysics, Mellor-Yamada boundary-layer diffusion, GFDL interactive radiation, and finite-volume advection in all directions. No cumulus parameterization was used in the forecast presented here, but a refined Arakawa-Schubert (RAS) scheme will be used in future simulations.

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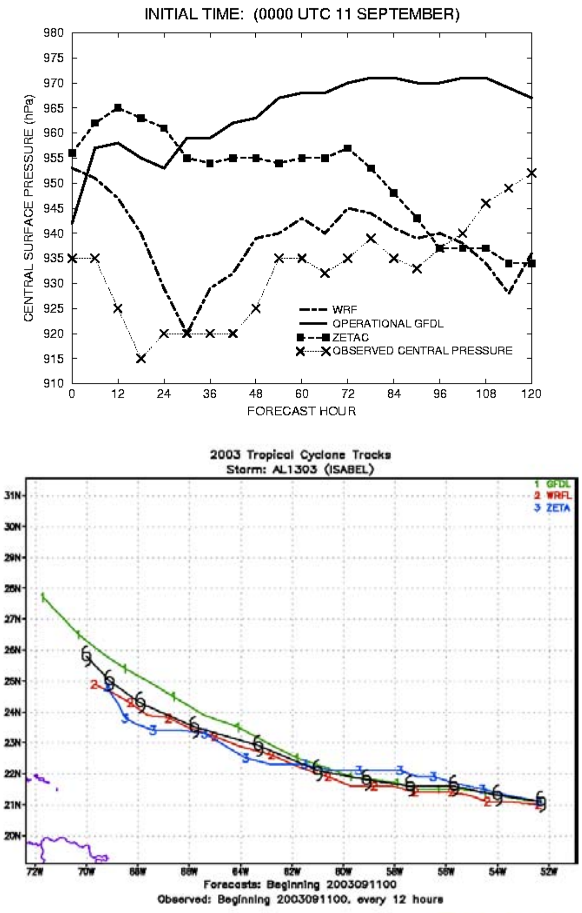

Figure 1: Minimum pressure and track forecasts.

Otherwise, all three models are run with the same 42 vertical levels, the same grid spacing (1/6th degree or 18 km, only in the inner nest for the GFDL model), and the same initial conditions. These initial conditions are those generated by the operational GFDL forecast system, *which includes a bogus vortex matched to observations in both position and intensity.* The WRF and ZETAC domains are 240x240 grid points, or 40x40 degrees, centered at 60W, 25N. For the GFDL model, the boundary conditions are supplied by the global GFS forecast; whereas for the WRF and ZETAC models, boundary conditions are supplied by the GFDL forecast outer grid (75x75 degrees). All simulations begin at 0Z on September 11th, 2003.

3. RESULTS

Figure 1 shows track and intensity (in terms of minimum surface pressure) forecasts from the three models, along with observations. The GFDL model had an excellent track forecast (label 1), but it could not reproduce the observed category 4 and 5 intensities. The WRF model track (2) is *very* close to the observed track. It also predicts the right intensity range, and seems to capture the magnitude and character of Isabel's observed intensity fluctuations. The ZETAC track forecast (3) is also quite good, though it took nearly 4 days to "spin up" to the observed intensity. This is likely due to the absence of cumulus parameterization and the 18 km grid spacing, such that resolved convection takes several days to fully develop in the core of the storm.

Figure 2 shows radial-height cross sections of the azimuthal velocity and total condensate (cloud water, rain, cloud ice, and snow) azimuthally averaged about the center of the storm at t = 84 h in the WRF forecast. Even at this resolution (18km), the hurricane structure seems quite realistic, with a radius of maximum winds at about r = 50 km and the commonly observed outward slope of the eyewall. Rather than just track and intensity, it is these structures that we plan to study closely. While *very* high resolution models (i.e., with horizontal spacings of 1-4 km) have shown considerable success in mimicking the structure of real hurricanes (e.g., Braun 2002), such resolutions are not in the foreseeable future of operational hurricane forecasting, even with multiple nesting capabilities. This leaves the question as to whether or not meaningful forecasts of hurricane wind field and precipitation structures, as desired by NOAA, can be achieved with a more "intermediate" resolution, such as 6-10 km.

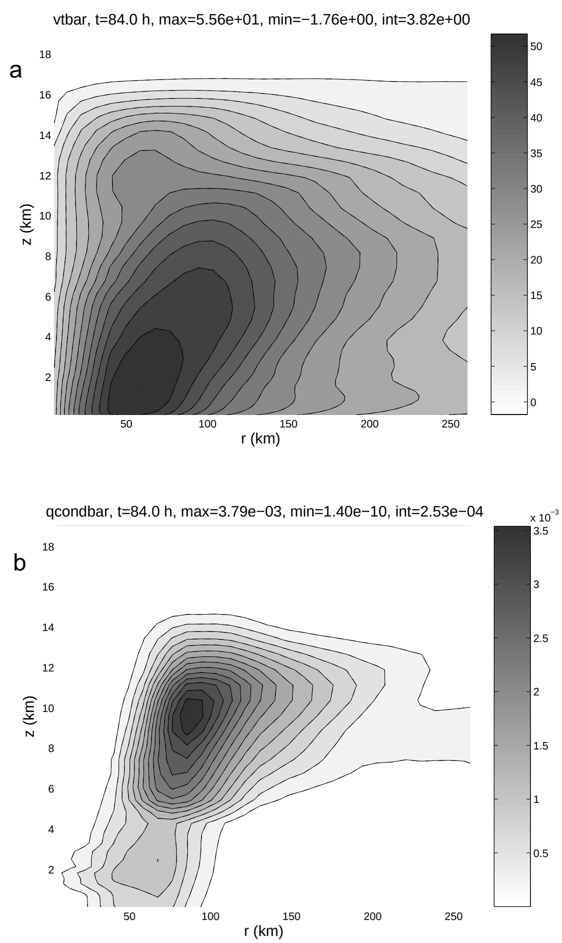

Figure 2: Azimuthal-mean profiles at t = 84 hours of the WRF simulation of Isabel (2003): a) azimuthal velocity (m/s); b) total condensate (kg/kg).

4. FUTURE WORK

Our analysis of the WRF model hurricane simulations will take a number of different directions in the near future. Higher resolution simulations, with grid spacings of 1/12th degree or 9km, will be perfomed and analyzed in a similar manner; even higher resolution simulations will follow. Isabel and other recent hurricanes such as Fabian (2003) were heavily sampled by NOAA hurricane research flights. Close comparisons of the wind and precipitation fields in the simulated and observed storms will help us to improve the physics parameterizations used in the model.

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