Hurricane Forecasts with a Global Mesoscale-resolving Model on the NASA Columbia Supercomputer

Preliminary Simulations of Hurricane Katrina (2005)

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1. Introduction

It is known that General Circulation Models (GCMs) have insufficient resolution to accurately simulate hurricane near-eye dynamics and intensity. To overcome this limitation, the mesoscale-resolving finite-volume GCM (FV3GCM) has been experimentally deployed on the NASA Columbia supercomputer, and its performance is evaluated choosing Hurricane Katrina as an example in this study. In the August 2005 Katrina underwent two stages of rapid intensification and became one of the most intense hurricanes in the Atlantic. Six 5-day simulations of Katrina at both 0.25° and 0.125° show comparable track forecasts, but the latter significantly reduces uncertainty in landfall forecasts. Further study is needed to address the issues of model parameterization and more realistic average intensification rate. As connection parameterization (CP) is one of the major innovations in FV3, the 0.125° run with CP showed promising results.

2. The Finite-volume GCM

The finite-volume GCM (FV3GCM) is a next generation modeling system based on a state-of-the-art finite-volume dynamical core and the community built physical parameterizations and land surface model.

- Terrain following Lagrangian control-volume
- Vertical discretization of the basic conservation laws
- Mass
- Momentum
- Total energy
- Coriolis forces from semi-Lagrangian discretization
- Community conservative
- Gross oceanic: true
- Absolute vorticity correctly transported with mass and vorticity within the Lagrangian layers
- Computationally efficient

2003-2006: The 0.25° FV3GCM

Improved and enabled global high-resolution (23 km) climate simulations and predictions of hurricanes/typhoons tracks and strength. As of February 2006, 10-day forecasts can be done within one hour with 480 CPUs.

2005-2006: The 0 125° and higher FV3GCM

14 km global resolution is making assessment of regional impact of climate change easier. To our knowledge, the FV3GCM is the first to simulate the formation of mesoscale vortices in a global environment.

3. Model Validation

Numerical simulations of mesoscale vortices at 0 125°, unless stated, are conducted to demonstrate the model’s capability of simulating scale interactions between high mountains and nonlinear flow, between coastal surfaces, forcing and synoptic scale flow, and hurricane convection and large-scale flow.

4. Results

4.1 Track Predictions

Five-day track predictions of Hurricane Katrina initialized at 1200 UTC 25 August, 2005. The light blue, red, and blue lines represent the tracks from 0.25°, 0.125° simulations and 0.125° simulation with no CP. Each dot represents the center position at 3-hour time increments. The block line represents the advisory track with 6-hour time increment from the NHC. (Shen et al., 2006b)

4.2 Intensity Predictions

Intensity evolution of Hurricane Katrina. (a) Minimum Sea Level Pressure (b) Maximum 10m Surface Winds (MSW) with solid lines and Maximum Potential Intensity (MPI) with points along the corresponding tracks. Each dot represents the intensity at 3-hour time increments (Shen et al., 2006a)

4.3 Near-Eye Wind Distributions

Comparison of observed near-eye wind distributions from the National Hurricane Center with simulated near-eye wind distributions from various models. The intensity of Hurricane Katrina is shown to be underestimated in the simulations (Shen et al., 2006a)

4.4 Asymmetry of Spiral Bands

Simulated total precipitable water with the 0.125° FV3GCM initialized at 1200 UTC 25 August, 2005, at (a) 10th forecast with convection parameterization and (b) 6th forecast without convection parameterization (Shen et al., 2006b)

5. Concluding Remarks

In this work, we present preliminary simulations of hurricane Katrina’s intensity and near-eye wind distributions obtained with the mesoscale-resolving FV3GCM on the NASA Columbia supercomputer.

- Relatively low data internalization rates are observed in the 0.125° runs. Possible reasons for the over-intensification are: 1) uncertainties of cumulus parametrizations, 2) lack of feedback from sea surface temperature changes associated with air-sea interaction and also longer time for model storms over ocean, and 3) lack of non-hydrostatic effects.
- To address the above issues, we are developing a global non-hydrostatic cloud and eddy-resolving Earth modeling system which should include Ocean, Atmosphere, and Land components.

References

