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

Preliminary Simulations of Hurricane Katrina (2005)

B.-W. Shen1,2, R. Atlas3, O. Reale1,4, J.-D. Chern1,4, S.-J. Lin5, T. Lee6, J. Chang7,8, C. Henze7, K.-S. Yeh1,4

NASA-GFC; SAIC; NODAAOML; UMBC/GEST; NOAA/GFDL; NASA/MSI; NASA/ARC; NCS

1. Introduction

It is known that General Circulation Models (GCMs) have insufficient resolution to accurately simulate hurricane near-eye structure and intensity. To overcome the limitation, the mesoscale-resolving finite-volume GCM (NGCM) has been experimentally deployed on the NASA Columbia supercomputer, and its performance is evaluated choosing hurricane Katrina as an example in the study. In late August 2005, Katrina underwent two stages of rapid intensification and became the sixth most intense hurricane on the Atlantic. Six 5-day simulations of Katrina at both 0.25° and 0.125° show comparable track forecasts, but the 0.125° run provides much better intensity forecasts, producing the center pressure with the most bias error. The NGCM at 0.125° simulates better near-eye wind distributions and a more realistic average intensity ratio. As convection parameterization (CP) is one of the major limitations of GCM, the 0.125° run with CP allowed produces very encouraging results.

2. The Finite-volume GCM

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

- Territorial following Lagrangian control-volume vertical discretization of the basic conservation laws.
- Mass
- Momentum
- Total energy
- AQI horizontal flux from semi-Lagrangian discretization
- Commutator conservative
- Glider oceanic flow
- Absorbing working correctly transported with mass within the Lagrangian layer
- Computationally efficient

3. Model Validations

Numerical simulations of real-scale simulations at 0.125°, unless stated, are conducted to demonstrate the model's capability of simulating scale interactions between high mountains and nonlocal flow, between coastal surface forcing and synoptic scale flow, and baroclinic conversion and large-scale flow.

5-day forecasts of total precipitable water initialized at 0000 UTC 1 September 2006 with the 0.125 degree NGCM showing a polar front at the equator.

3.1 Hawaiian Wakes

Simulations of the Hawaiian Wakes initialized at 0000 UTC 1 September 2004 at 36 simulation (a) and 48 simulation (b) to show an upstream stagnation point vortex shedding and gap flows (Shen et al., 2006a).

3.2 The Catalina Eddy

Surface winds and vertical vortices validated at 0000 UTC 4 September 2004 (a) NCEP 384 GFS analysis, and (b) 72 simulation (Shen et al., 2006a).

3.3 A Mei-Yu Front accompanied by a Drifting Mesocyclone

Surface winds and vertical vortices validated at 1200 UTC June 8, 2003 (a) NCEP GFS 254 analysis, (b) QuickSCAT using 0.5° data, and (c) 48 simulations with the 0.125° NGCM (Shen et al., 2006a).

3.4 Atlantic Hurricanes (Frances, Ivan, and Jeanne, 2004)

High resolution five-day track predictions of hurricanes (a) Frances initialized at 0000 UTC 1 September, (b) Ivan initialized at 0000 UTC 12 September, and (c) Jeanne initialized at 0000 UTC 23 September. The blue (red) lines represent the tracks from 0.125 (0.25) degree simulations, while the black lines represent the best track from the National Hurricane Center. Each dot represents the center position at 6-hour time increments (Shen et al., 2006a).

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 black line represents the advisory track with a 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., 2006b).

4.3 Near-Eye Wind Distributions

Simulated total precipitable water with the 0.125° NGCM initialized at 1200 UTC 25 August, 2005, at (a) 9th forecast with convection parameterization and (b) 9th 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 NGCM on the NASA Columbia supercomputer.

- Relatively larger intensification rates are observed in the 0.125° runs. Possible reasons for the over-intensification are 1) uncertainties of cumulus parameterizations, 2) lack of feedback from sea surface temperature changes associated with sea-ice 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