2A.3 Distinct Structure and Intensity of Hurricanes Katrina and Ophelia (2005) in Coupled WRF-HYCOM Model

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1. INTRODUCTION

Although previous studies have shown that a large area of warm water provides a favorable condition for intensification of hurricanes, storm development and intensity over the warm ocean vary in a broad range. Various factors contribute to the storm intensity including the atmospheric environment conditions and internal dynamics of each individual storm. In the 2005 hurricane season, Hurricanes Ophelia and Katrina both developed over the warm water near the east coast of South Florida. However, they evolved differently with distinct structure and intensity. Katrina became one of the most intense Category 5 hurricanes in the Gulf of Mexico, whereas Ophelia remained a relatively weak Category 1 hurricane over several days near the Gulf Stream. In this study, we aim to investigate the relationship between the hurricanes and their environment and examine the structures of the hurricanes developed over the warm water. We examine the sensitivity of the storm intensity to various environmental conditions to shed some lights on why they both move over the warm water, one intensified quickly and the other did not.

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2. COUPLED ATMOSPHERE-OCEAN MODELING SYSTEM

2.1 Atmospheric Model

The atmosphere model in the coupled modeling system is the Advanced Research version of Weather Research and Forecasting (ARW) model (Skamarock et al. 2005). The ARW model is a fully compressible, nonhydrostatic, terrain-following hydrostatic pressure vertical coordinate model designed to simulate mesoscale atmospheric circulations. For studying hurricanes and coastal storms, we use the vortex-following nested grids developed at the University of Miami. In this study, we used nested domains with 36, 12, and 4km resolutions for Hurricane Katrina, and 12, 4, and 1.3 km resolutions for Hurricane Ophelia, respectively.

2.2 Ocean model

The ocean circulation models used in the coupled system are the U. Miami/NRL Hybrid Coordinate Ocean Model (HYCOM, Bleck et al. 2002) and the simple one-dimentional upper ocean model with the PWP mixing scheme (1DPWP, Price 1986). The ocean model grid resolution is 1/24 degree for HYCOM and the same grid resolution as the ARW for 1DPWP.

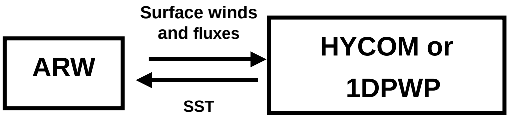

Fig. 1 Schematics of the coupled atmosphere-ocean modeling framework.

2.3 Initial conditions

The initial and lateral boundary conditions of ARW for Katrina are from the NCAR's ensemble Kalman Filter (EnKF) data assimilation. In this experiment, 26 ensemble initial conditions were generated by randomly perturbing the GFS analysis at 0000 UTC 26 August 2005. The National Centers for Environmental Prediction (NCEP) 1°×1° global analysis fields at 6-h intervals are used for Ophelia. The model was initialized at 0000 UTC 9 September 2005.

The initial condition for HYCOM is from the global HYCOM data assimilation system. The 1DPWP model is initialized with the satellite observed SST and combined with the monthly temperature and salinity profiles.

3. RESULTS

3.1 Track and Intensity

The model simulated tracks, the maximum surface wind speed and the minimum sea-level-pressure (MSLP) are compared with the best track data from the National Hurricane Center (NHC) for Hurricane Ophelia. Hurricane tracks are mostly affected by the environmental steering flow. The comparisons (Fig. 2a) of the uncoupled and coupled model simulations indicate that the effects of the coupled ocean on the simulated tracks are small. However, the coupled model improves the simulated storm intensity significantly compared to that of the uncoupled simulation. It is mostly because of the storm induced cooling due to vertical mixing and upwelling in the upper ocean in the coupled model, whereas the SST remains constant through out of the simulation in the uncoupled ARW.

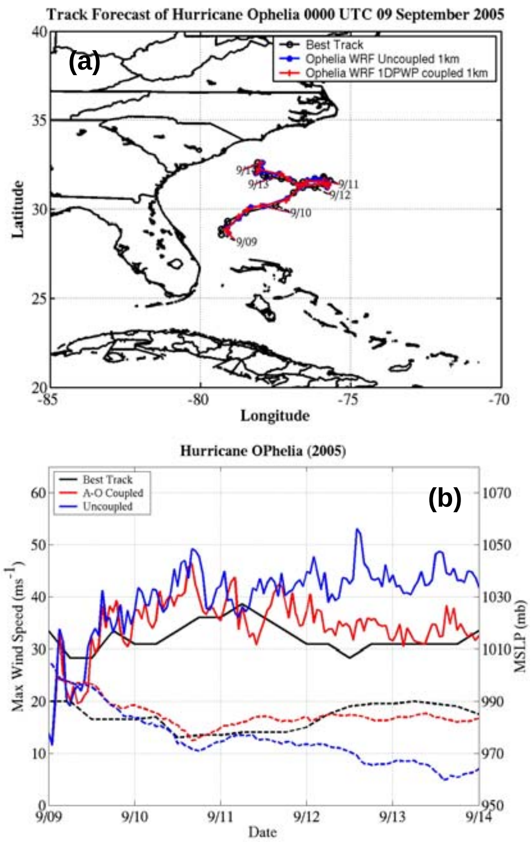

Fig. 2 Model simulated (a) storm tracks and (b) simulated MSLP (dashed lines) and maximum wind speed (solid lines) from the coupled model (red), uncoupled ARW model (blue) of Hurricane Ophelia in comparison with the NHC best track data (black) over a 5-day period from 0000 UTC on 9–14 September 2005.

Fig. 3 displays the initial SST for Ophelia from the TRMM TMI/AMSR-E and the SST anormaly at 0000 UTC 14 August 2005. The storm-induced cooling is very obvious after 5 days. This cooling makes the intensity more closed to the observation.

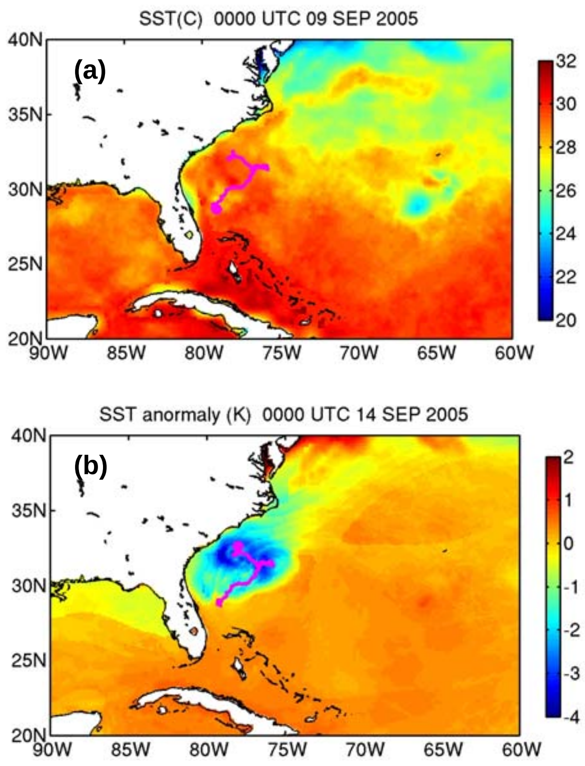

Fig. 3 (a) Initial SST fields for Ophelia from TRMM TMI/AMSR-E data. (b) The coupled model simulated SST anormaly at 0000 UTC 14 September 2005. Storm track are overlaid on each of SST maps.

3.2 Structure of Hurricane Ophelia

Fig 4 shows the azimuthal average radar reflectivity for coupled and uncoupled at 1900 UTC 11 September 2005. The coupled model produces a shallow and weaker eyewall. Fig. 5(a) shows the observed radar reflectivity at 3.6 km and the vertical cross section along the black solid line. The eyewall is asymmetric and eye is relative big. From the cross section, we can see the height of eyewall is less than 12km and the storm is a very shallow storm. Fig. 5(b) shows horizontal radar reflectivity at 3 km height and the cross section along the black solid line from the coupled model. Compared the coupled results to the observation, we can see the results capture the main feature of storm. It also produces the asymmetric and shallow eyewall, the relative big eye.

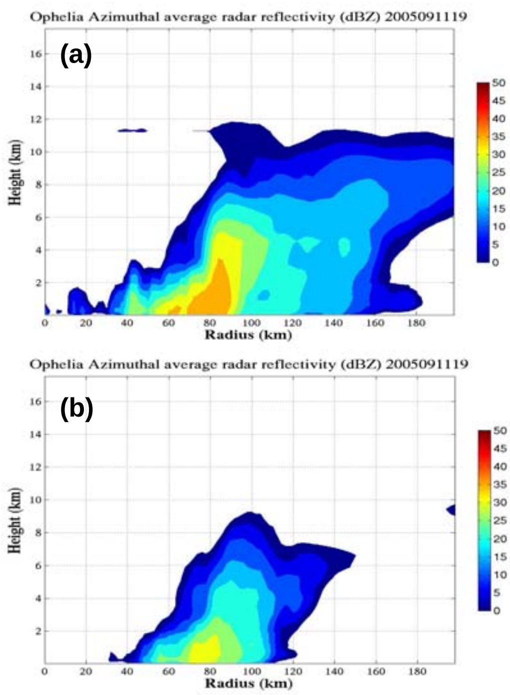

Fig. 4 The azimuthal average radar reflectivity of Ophelia at 1900 UTC Sep. 2005, (a) uncoupled model, (b) coupled model

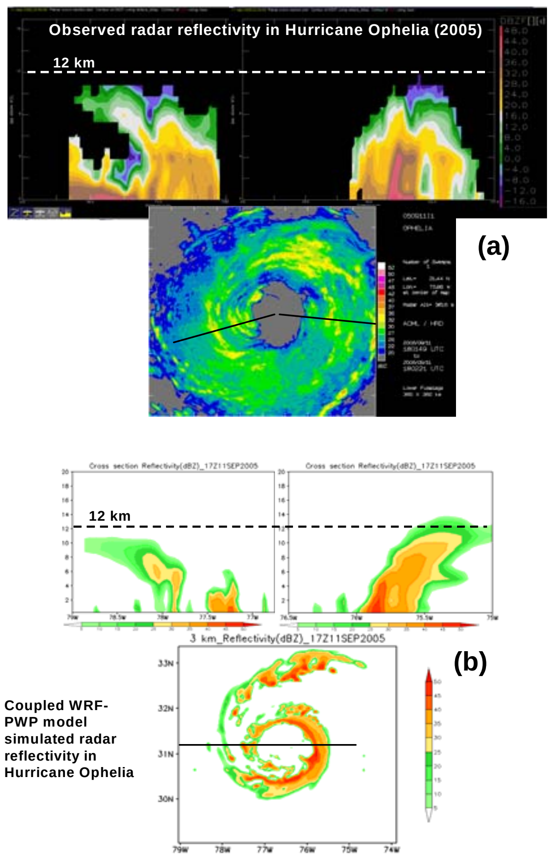

Fig. 5 (a) Observed radar reflectivity from the RAINEX. (b) Simulated radar reflectivity from the coupled model

3.3 Coupled ARW-HYCOM forecast of Hurricane Katrina

The coupled ARW-HYCOM simulated surface wind field in Katrina shows the hurricane eye is much larger than that of HWIND estimated wind (Fig. 6). It is most likely due to the 4-km grid resolution, which may be too coarse to resolve the strong gradient near the eyewall in an intense hurricane like Katrina.

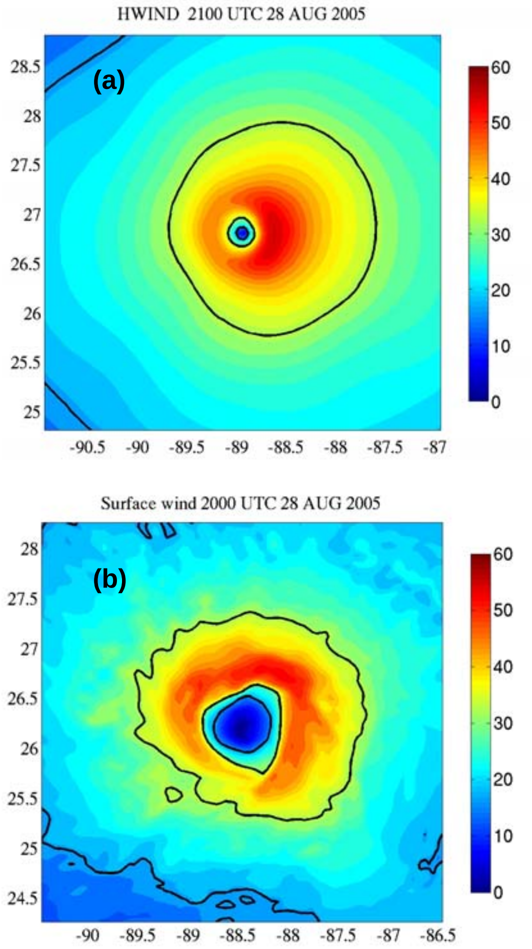

Fig. 6 (a) Hwind at 2100 UTC, 28 August 2005. (b) WRF surface wind at 2000 UTC, 28 August 2005.

The coupled ARW-HYCOM was able to simulated the complex ocean features that are a combination of the pre-storm ocean circulation including the Loop Current and warm eddy (Fig. 7a) and the storm-induced cooling and currents (Fig. 7b).

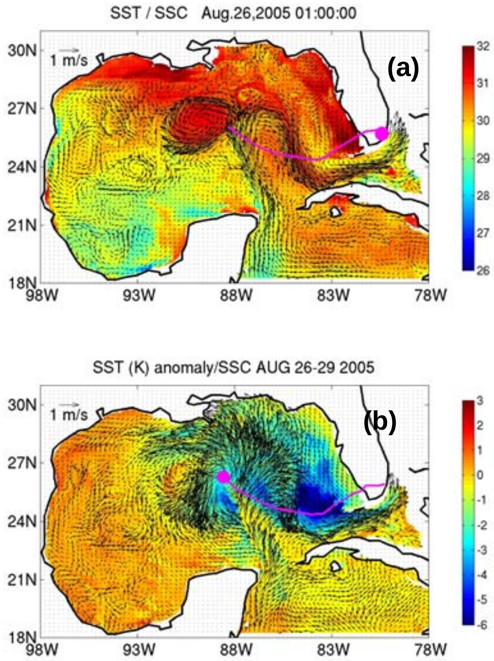

Fig 7 (a) Coupled model simulated SST and ocean surface current in Hurricane Katrina at 0001 UTC 26 August 2005. (b) Coupled model simulated SST cooling and ocean surface current in Hurricane Katrina at 2100 UTC 28 August 2005

4. SUMMARY AND FUTURE WORK

The coupled ARW-Ocean modeling system is tested in simulations of Hurricane Katrina and Ophelia. The model simulated hurricane intensity and structure are improved in the coupled model. A fully coupled atmosphere-wave-ocean model will be tested in the near future.

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