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Project Title: Improving the Hurricane WRF-Wave-Ocean Coupled System for Transition to Operations
Recipient Name: The University of Rhode Island
Investigator: Isaac Ginis
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Reporting Period: 08/01/2007 - 01/31/2008

Work Accomplishments:

1. Tasks scheduled for Year 1:

a) Implementing the URI wave boundary layer model into the HWRF.
b) Improving internal momentum flux parameterization in the WW3 wave model for hurricane conditions.
c) Assimilating mesoscale oceanic features for improved HWRF model initialization.
d) Evaluation and operational implementation of the wave coupling in the HWRF.

2. Tasks accomplished this period

a) Implementing the URI wave boundary layer model into the HWRF

We have implemented the new formulation of drag coefficient, C_d, into the operational version of HWRF. The formulation, described in detail by Moon et al. (2007), is based on the theoretical model of Moon et al. (2004a-c) and derived from coupled wave-wind (CWW) model simulations of ten tropical cyclones in the Atlantic Ocean during 1998-2003. The implementation of the URI wave boundary layer (WBL) model will be done during the second half of the first year of this project when HWRF will be coupled with the WW3 wave model. In the meantime, we have been working on improvements to the WBL model by incorporating the observational results from the CBLAST field experiment (Black et al., 2007) and the recent estimations of drag coefficient distribution based on GPS sonde wind profiles by Powell (2007). In the improved WBL model, a new formulation for the nondimensional surface roughness (Charnock coefficient) has been derived in order to better match the model results with the observations. Figure 1 shows C_d vs. wind speed calculated with the improved WBL model at various sections relative to the storm center.. These sections represent composite distributions based on simulations of Hurricanes Noel (2007), Helene and Florence (2006), Katrina, Rita, Emily, Dennis (2005), Ivan and Frances (2004), and Isabel and Fabien (2003). The HRD wind analyses available at every 6 hours were used as the wind input into the model. The new parameterization is now more consistent with the Powell (2007) results but still cannot reproduce the extreme high and low values of C_d in his estimations.

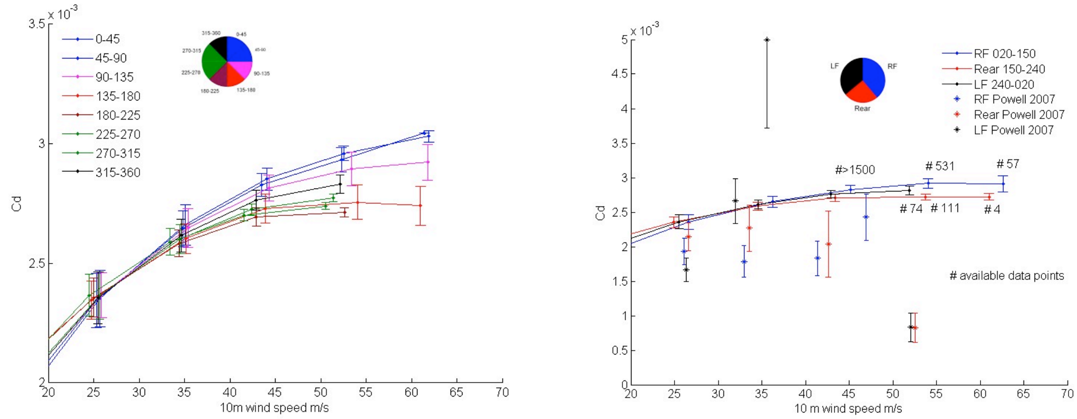

Figure 1. Drag coefficient (C_d) vs. wind speed. Left panel shows C_d in 8 sectors relative to the storm center. Each sector is 45^o where the zero degree direction is aligned with the storm movement vector. Right panel shows C_d in 3 sectors with the sizes corresponding to those in Powel (2007). Powell's data are shown for comparison.

b) Improving internal momentum flux parameterization in the WW3 for hurricane conditions.

It has been known that the WW3 wave model overestimates the significant wave height under very high wind conditions in strong hurricanes (Tolman et al., 2005; Chao et al., 2005). Moon et al. (2008) suggested that one of the reasons for the overestimation of the significant wave height is due to overestimation of the drag coefficient in high wind conditions. In preparation for coupling of WW3 with HWRF, we have implemented the Moon et al. (2007) drag coefficient formulation into WW3. We tested this formulation by comparing the model WW3 wave predictions with the SRA measurements during Hurricane Ivan (2004) in collaboration with Edward Walsh/NASA. We also investigated the effects of wind-wave-current interaction on the wave predictions by coupling WW3 with the Princeton Ocean Model. Details of this work are described in Fan et al. (2008), which will soon be submitted for publication. Examples of WW3 evaluation are shown in Fig. 2 and Fig. 3. Our test results indicate that the new momentum flux parameterization and the effects of wave-current interaction helped to improve the wave forecasts. We plan to transition these new formulations into HWRF after it is coupled with WW3 later this year.

c) Assimilating mesoscale oceanic features for improved HWRF model initialization.

The latest version of the feature-modeling ocean initialization procedure (Yablonsky and Ginis, 2008), which was designed to more accurately initialize the Loop Current and ocean eddies using satellite altimetry and *in situ* data in the Gulf of Mexico, has been transitioned to operations for both the HWRF and GFDL coupled hurricane-ocean models.

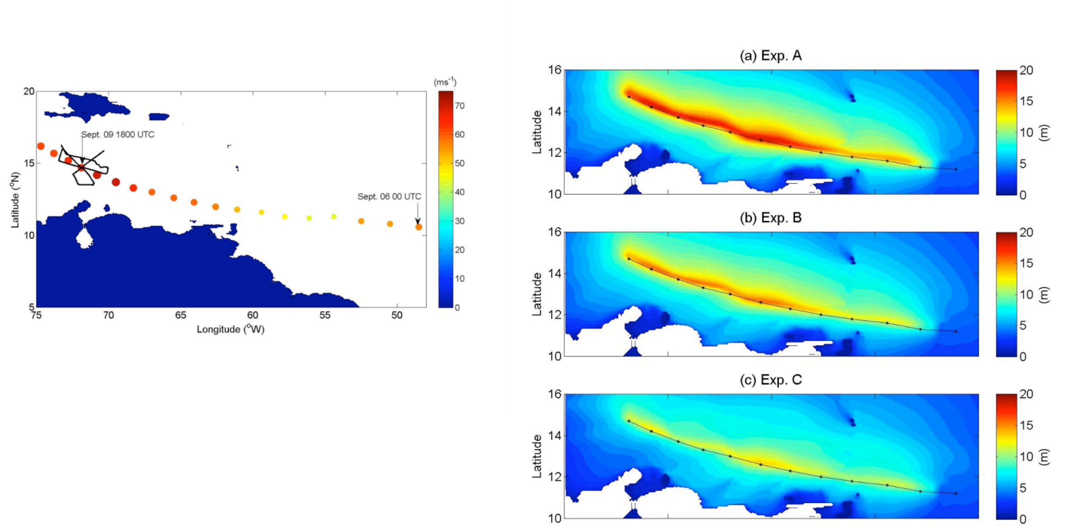

Figure 2. Left: Hurricane Ivan track from Sept. 6 0:00 UTC to Sept. 10 12:00 UTC. The color and size of the circle represent the maximum wind speed. Black lines represent the flight tracks during the SRA measurements. Right: Swath of maximum significant wave heights produced by WW3 using the original WW3 parameterization (Exp. A), the new parameterization (Exp. B), and the new parameterization with the wave-current interaction (Exp. C).

During the 2007 Atlantic hurricane season, the previous version of the feature-modeling ocean initialization procedure was used operationally in the GFDL and HWRF models. Unlike the latest version described in Yablonsky and Ginis (2008) and set to become operational in 2008, the previous version had the following limitations with regards to assimilating features in the Gulf of Mexico: (1) Only one warm core ring could be assimilated, not multiple rings, (2) cold core rings could not be assimilated, (3) the Loop Current had to connect to an adjacent warm core ring if the warm core ring was in close proximity to the Loop Current (in order to suppress unphysical interaction between these two features), and (4) *in situ* ocean temperature profiles could not be used to define the center temperature profile of the Loop Current and/or rings.

During the 2007 Atlantic hurricane season, satellite altimetry was used by the Tropical Prediction Center (TPC) to generate 26°C-isotherm maps (and oceanic heat content maps) for the Gulf of Mexico in real-time. Subsequently, TPC staff assimilated these 26°C-isotherm maps into the feature-modeling ocean initialization procedure by subjectively defining Loop Current and, when applicable, warm core ring perimeter points. Assuming the latest version of the procedure becomes operational in 2008, these maps will again need to be assimilated, but the assimilation method will need to change slightly to accommodate the new features in this latest version of the procedure. We will work with TPC staff to implement these changes before the start of the 2008 hurricane season.

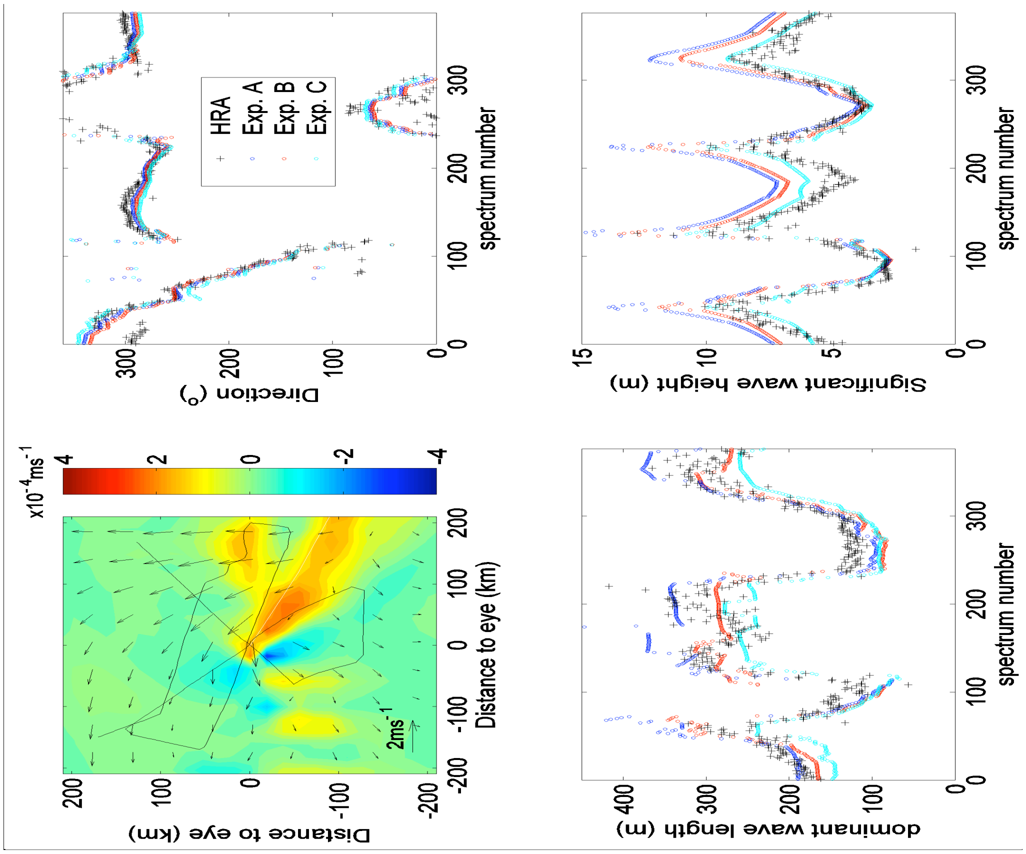

Figure 3. Upper Left: WW3 wave field divergence in the run with the new flux parameterization and wave-current interaction at Sept. 9 18:00UTC. The color scale indicates significant wave height in meters; arrow length represents mean wave length, and arrow direction shows mean wave direction. Upper right, bottom right, and bottom left: wave direction, dominant wave length, and significant wave height, respectively.

d) Evaluation and operational implementation of the wave coupling in the HWRF.

This task will be accomplished during the second half of the first year and during the first half of the second year.

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