Improving the GFDL/URI Coupled Hurricane-Ocean Model for Transition to Operations

Semi-Annual Progress Report

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Executive Summary

This is the second semi-annual report for this program. During this time period, significant progress has been made toward our overall project objectives, which are to:

- To improve the ocean component of the GFDL/URI coupled model in the Atlantic basin and implement the ocean coupling into the GFDL model used for operational forecasting in the East Pacific
- To evaluate and transition to operations a new high resolution version of the GFDL/URI coupled model
- To test and implement operationally new air-sea flux parameterizations in the coupled model

The major accomplishment during the last six months of this project is the operational implementation of the new high-resolution GFDL/URI coupled hurricane-ocean forecast system at NCEP for the Atlantic and Eastern Pacific basins. After the final set of testing being presently conducted at NCEP, the model will most likely be approved for operations for the 2005 hurricane season. The primary development of the high-resolution model was done by the URI group and the final testing and tuning was done in collaboration with the GFDL hurricane group. The results of the new model performance using 130 cases from the 2004 hurricane season were presented at the 2005 IHC Conference.

Our group has configured a new coupled hurricane-wave-ocean model by implementing the URI coupled wave-wind model (CWW) into the GFDL/URI coupled hurricane-ocean model. Preliminary results of the model testing were presented at the 2005 IHC conference.

1 Personnel, Logistics and Facilities

There are four scientists committed to this project: Drs. Isaac Ginis, Biju Thomas, Il Ju Moon at URI and Dr. Alexandr Falkovich at EMC. Our group works in close collaboration with Morris Bender and Tim Marchok at GFDL and EMC scientists. The majority of the model development and computer-intensive numerical simulations and testing of the operational version of the GFDL/URI coupled model are performed on the GFDL and NCEP supercomputers.

2 Tasks Completed and Work in Progress

a. Development of the high resolution GFDL/URI hurricane model

During this time perion our group has completed the development of the high resolution version of the GFDL/URI coupled hurricane model and conducted a large number of test experiments in collaboration with the GFDL hurricane group. In the new model, the horizontal resolution has been doubled to 1/12 degree. Simultaneously, the GFDL hurricane group has implemented a new vortex initialization, including some modifications to the storm size parameterization procedure (see the corresponding GFDL semi-annual report for details). Our work on the flux parameterization described in the last year annual report, resulted in the improvements of the roughness lengths calculation of the 10 m wind in the GFDL high resolution model. All these changes have been included in the 2005 version of the GFDL forecast system, which is expected to be operational at NCEP this year.

Based on the test results of 130 cases selected in collaboration with Richard Pasch of TPC, the 2005 GFDL system delivers significant reduction in the track and intensity forecast errors at 3-5 days. Fig. 1 shows a summary of the track and intensity forecasts skill relative to the 2004 GFDL system and other models.

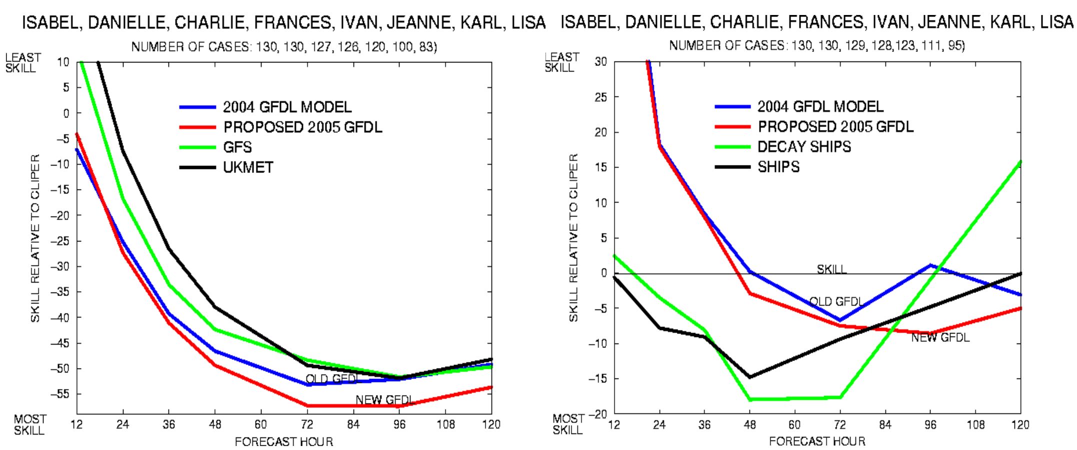


Figure 1. *Summary of the track (left) and intensity (right) forecast skill of the 2005 GFDL prediction system in comparison to the 2004 GFDL system and other models.*

b. Development of the coupled GFDL hurricane-wave-ocean model

During this time period we have coupled the GFDL hurricane model, the Princeton Ocean Model (POM) and the EMC WAVEWATCH III model with the URI wave boundary layer model, shown in Fig. 2. The configuration, size and resolution of the hurricane, wave and ocean model domains are shown in Fig. 3. The wave component of the coupled model, WAVEWATCH III (WW3) model, is a third-generation ocean surface wave model developed at NOAA/NCEP in the spirit of the WAM model. We have implemented a movable nested grid configuration into the WW3 in collaboration with Hendrik Tolman of EMC. The inner mesh of higher resolution follows the storm center, as it is done in the GFDL hurricane model. It is a necessary step for higher resolution versions of the coupled model to reduce significant computational requirements of the WW3 model. The key component of the new coupled hurricane-wave-ocean prediction model is the URI wave boundary layer (WBL) model. The roughness parameterization (Charnock's relation) currently used in the GFDL hurricane model is replaced by the wave-field dependent estimates of the roughness length z_0 estimated based on the WBL.

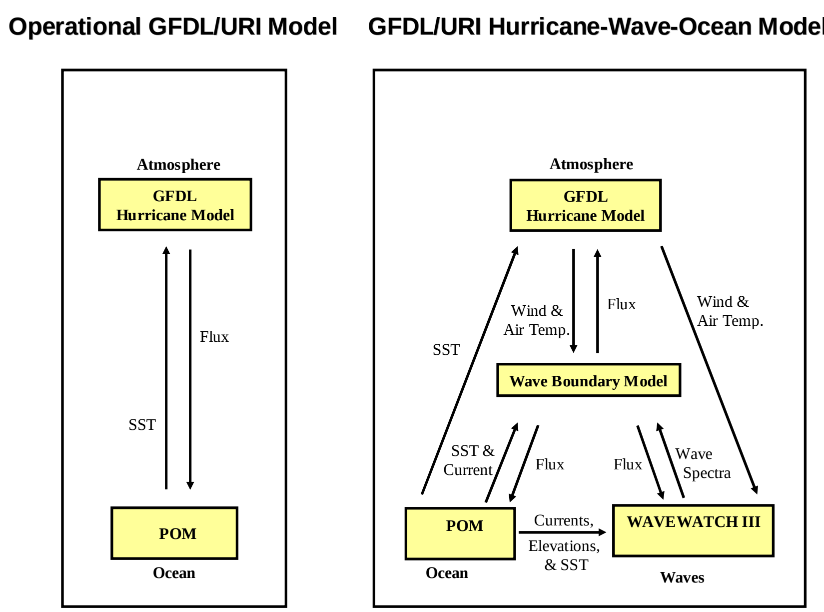
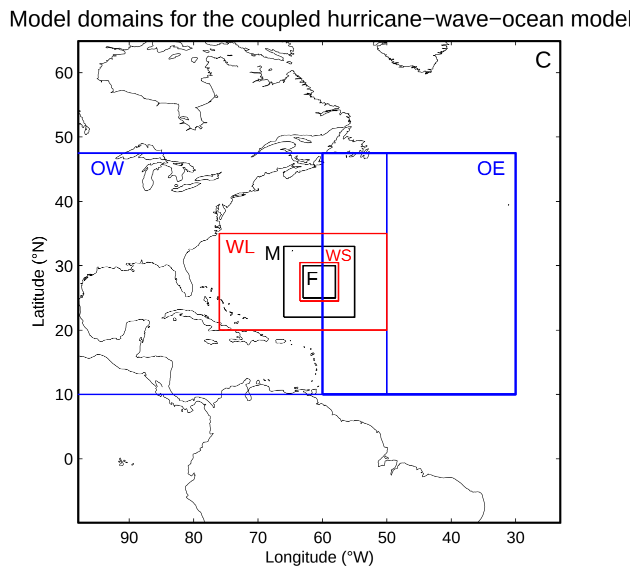


Figure 2. *Schematic diagrams of the present GFDL/URI operational hurricane model (left) and the new GFDL/URI coupled hurricane-wave-ocean system developed under the JHT funding.*

We have begun testing and evaluation of the new coupled system, but the first numerical experiments have already indicated very encouraging results. Fig. 4 shows the spatial distributions of the surface wind with and without wave coupling for a Hurricane Isabel forecast at 06Z Sep. 12, 2003. The wind structure in the coupled model is evidently in a better agreement with the HRD wind analysis indicating the maximum wind located in the northeast quadrant of the storm. More test simulations are underway and their results will be presented in the final report for this project.



- **GFDL model** (black): C (Coarse domain, 75°×75°, 1/2° resolution, relocatable)
  M (Medium domain, 11°×11°, 1/6° resolution, movable)
  F (Fine domain, 5°×5°, 1/12° resolution, movable)
- **POM** (blue): OW (Western ocean domain, 48.5°×37.6°, 1/6° resolution, fixed)
  OE (Eastern ocean domain, 30°×37.6°, 1/6° resolution, fixed)
- **WAVEWATCH-III** (red): WL (Large domain, 24°×15°, 1/12° resolution, relocatable)
  WS (Small, 6°×6°, 1/12° resolution, movable)

Figure 3. *Computational domain configuration, size and resolution of the hurricane, ocean, wave models in the GFDL coupled hurricane-wave-ocean system.*

c. *Investigation of the effect of different convective schemes.*

We have implemented the Emanuel convective parameterization scheme in the new GFDL high-resolution model and conducted sensitivity studies to compare it with the SAS convective parameterization scheme presently used in the operational GFDL model. Initial testing was done using idealized cases followed by evaluation with real-data cases. Overall, the Emanuel scheme has not yield a better forecast skill. It is concluded that the SAS scheme performs better in conjunction with the MRF boundary layer physics presently used in the GFDL model. Nevertheless, the GFDL model still suffers from a severe positive bias in sheared situations that reduces the model's overall intensity skill. It is anticipated that the inclusion of bulk physics may help reduce this bias. This will be evaluated more extensively in the coming months using the Ferrier microphysics schemes by the GFDL hurricane group.

d. Implementation of the HYCOM ocean model into the GFDL/URI coupled system

This task has not been originally planned in the present JHT project. It was initiated upon a request from EMC and replaced the original task of implementing a new land-sea mask in the GFDL coupled system. It is decided that the HYCOM model will be an ocean component of the future Hurricane WRF coupled system. The HYCOM ocean model has been implemented at EMC for the Atlantic basin by the EMC's ocean branch. Our group is presently configuring the HYCOM similar to the POM configuration used in the operational GFDL/URI coupled system. We will simulate ocean responses to historic hurricanes and compare the results with the POM simulations and observations when available. The main requirement for the ocean model from the hurricane perspective is very simple: it must realistically simulate the SST cooling generated by the tropical cyclone winds. We will initially use the ocean data assimilation system as it is presently used in the operational coupled GFDL/URI system. However, it will eventually be replaced by the data assimilation system being developed by the ocean modeling group at EMC. This work will be done in close collaboration Carlos Losano and Aleksandr Falkovich at EMC.

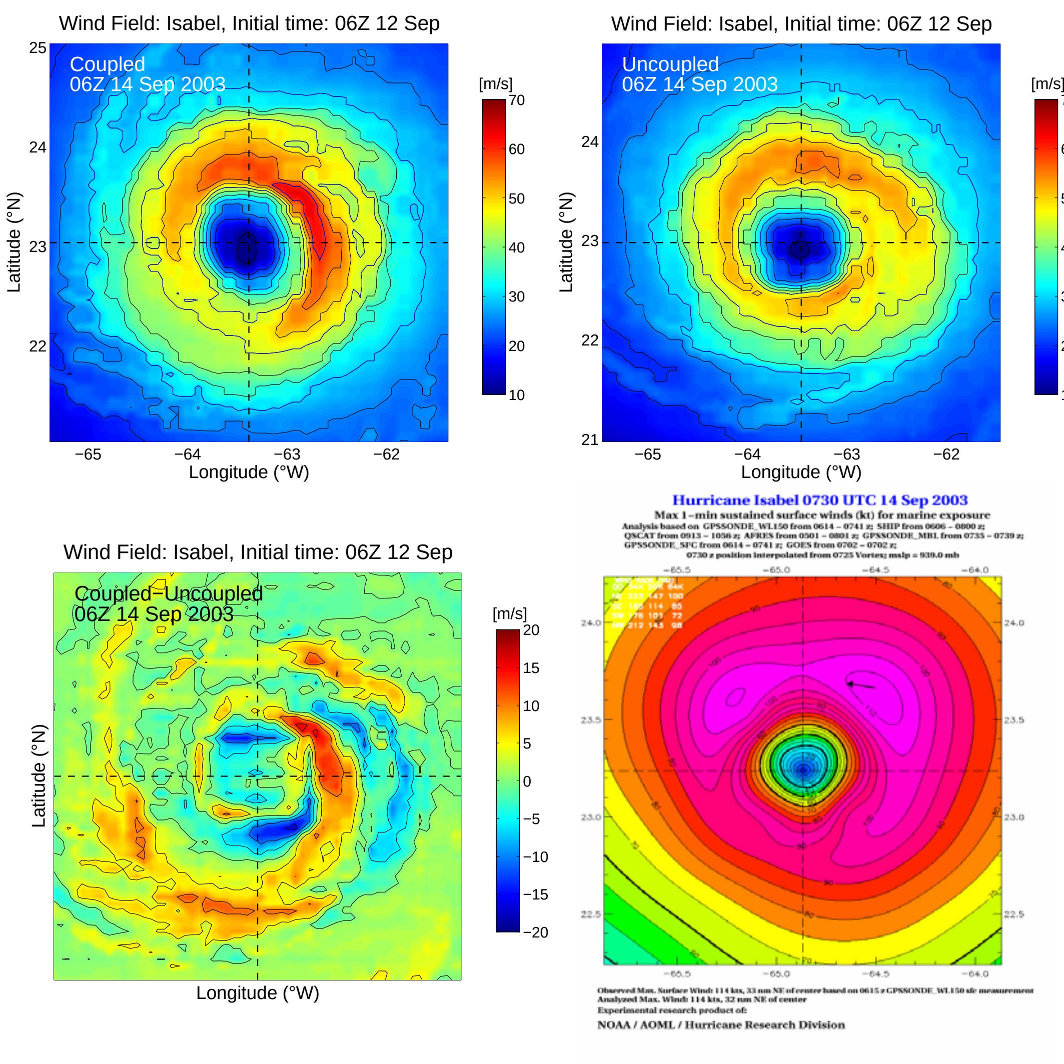


Figure 4. *Simulations of surface winds in Hurricane Isabel at 06 UTC 14 Sep. 2003 with (upper, left) and without (upper, right) wave coupling and the differences (lower, left). The observed wind at 730 UTC 14 Sep. 2003 from the HRD wind analysis is shown for comparison (lower right).*