# Deepwater Hindcast of Hurricane Rita

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## 1. Introduction

Since September 2004, Horizon Marine, in partnership with Accurate Environmental Forecasting (AEF), has been providing an Eddy Forecast service using a unique ocean modeling technology developed at AEF. The same ocean modeling technology that has been used in the Eddy Forecast service and that has been validated by our successful forecasts of Eddy Ulysses and Eddy Vortex can be applied in a hindcast mode to provide a reliable and accurate simulation of ocean currents associated with the Loop Current and its eddies. In addition to that, the ocean model can be extended to include the effects of hurricane winds on ocean currents. This extension is based upon well-established technology previously developed at the University of Rhode Island and NOAA and used operationally by the National Weather Service. Thus, the ocean model can presently be used to accurately simulate the strong ocean currents that were caused by both Eddy Vortex and by Hurricanes Katrina and Rita.

Our partners from AEF have significant expertise in modeling and forecasting hurricanes. They have been providing real-time hurricane forecasting services to large insurance and re-insurance companies for nearly ten years. Their knowledge and expertise in numerical modeling of hurricane-force winds allows us to provide you with an accurate assessment of the ground-level winds that occurred during Hurricanes Katrina and Rita at any specific site in the Gulf of Mexico.

Finally, AEF recently acquired access to wave modeling technology developed at the University of Rhode Island in collaboration with NOAA. Isaac Ginis, a professor at the University of Rhode Island and CEO of AEF, has been leading an active research program in air-sea interactions under hurricane conditions. A unique, high-resolution wave model created by his group, based on the well known WAVEWATCH III model, has been adapted to run on the AEF computer system, thus enabling us to provide an accurate assessment of waves created by Hurricanes Katrina and Rita at any specific site in the Gulf of Mexico .

## 2. Data Sources and Methods

<u>Surface Winds</u>

The surface winds are based on real-time objective wind analyses of maximum sustained one-minute wind speed from NOAA's Hurricane Research Division (HRD). HRD's analyses are created by compiling all available observations relative to the storm center. Some of these observations are taken from Air Force and NOAA aircrafts, ships, buoys, satellites (QuikScat, TMI, ERS-2, SSMI), and the Coastal Marine Automated Network (CMAN).

The conversion factor between one-minute average and one-hour average wind speed for hurricanes in the Gulf of Mexico is approximately 0.77. Note that this factor depends somewhat on latitude, wind speed, and surface roughness. It is appropriate for deepwater sites in the Gulf but is not appropriate for near-shore sites or other regions outside of the Gulf.

Wave Model

The surface waves are simulated by a high-resolution version of the WAVEWATCH III enhanced by a new air-sea flux parameterization. Recent observational studies have shown that drag coefficients over the ocean actually level off at wind speeds higher than 32 m/s. They also show that young waves produce less drag than fully formed seas. The enhanced WAVEWATCH III includes an improved algorithm for the Charnock coefficient where the coefficient varies with both wind speed and wave age (Moon et al, 2003; Moon et al 2004). This change results in more accurate prediction of surface waves before, during, and after the passage of a tropical storm. Note that the model is tuned towards deepwater waves and results in depths shallower than 25 m - where waves are shoaling - may not be accurate.

Ocean Model

The ocean currents were simulated using the Eddy Forecast System (EFS) (Coholan et al, 2005.) The EFS uses an existing high-performance, high-resolution ocean model for the prediction component combined with a completely unique, feature-based initialization component. The essential underlying idea of a feature initialization approach is to extend limited real-time information with a historical knowledge of the typical structure and evolution patterns of LCEs (Robinson and Gangopadhyay, 1997). This is analogous to “vortex bogusing” used so successfully in hurricane forecasting. This initialization procedure allows the use of all available oceanographic data, not just satellite altimetry.

The prediction component of the EFS uses the “MIT model” to solve the incompressible Navier-Stokes equations using hydrostatic, quasi-hydrostatic, or non-hydrostatic approximations with rigid-lid or free-surface options (Marshall, et al, 1997). The numerical integration scheme ensures that the evolving velocities are divergence free by solving the Poisson equation for the pressure with Neumann boundary conditions and then using this pressure to update the velocities. The model is also designed for parallel computation. The model is well tested; it has been employed to study numerous phenomena whose scales range from centimeters up to many thousands of kilometers. For EFS, the numerical model is configured for a spatial resolution of 3 km and runs on a cluster of 10 computing nodes. A 30-day forecast run takes 2 hours of computing time.

The EFS was forced with the HRD hurricane wind analysis. The resulting ocean currents include both the variability associated with the Loop Current, Loop Current eddies, and the ocean currents resulting from the hurricane itself. The model domain stretched from 22 to 30 N and 82 to 94 W and includes water depths greater than 30 m.

## 3. Results

Rita tracked through the Gulf of Mexico in September 2005 (Figure 1) and encountered the Loop Current, Eddy Walker, and Eddy Vortex. Hurricane Rita ranks as the fourth most intense Atlantic hurricane and the most intense observed in the Gulf of Mexico with a minimum pressure of 895 mbar and maximum sustained winds of 80 m/s (~180 mph) (Figure 2). Rita intensified over the Loop Current and, to a lesser extent, over Eddy Vortex.

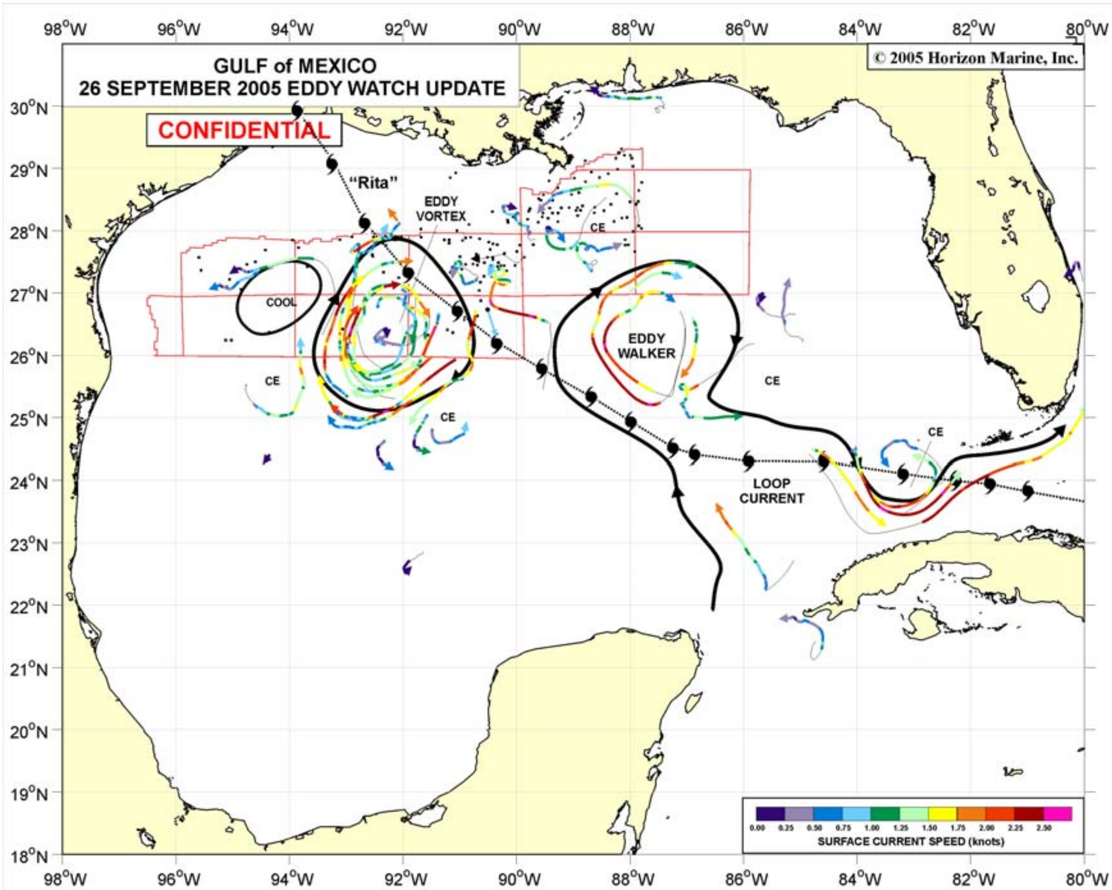


**Figure 1.** Trajectory of Hurricane Rita and Eddy Watch Report for 26 September 2005.

The largest waves were located just to the right of Rita's track (Figure 3). Western Green Canyon encountered significant wave heights up to 19.4 m. Note that the maximum wave height can likely be twice the significant wave height.

The strongest hurricane-induced currents were located to the right of Rita's track, and the strongest total currents (hurricane and Loop/eddy) were along the western side of Eddy Walker (Figure 4). Here the eddy currents were in line with the hurricane forcing, and the maximum currents reached 3.2 m/s (~6.4 kts).

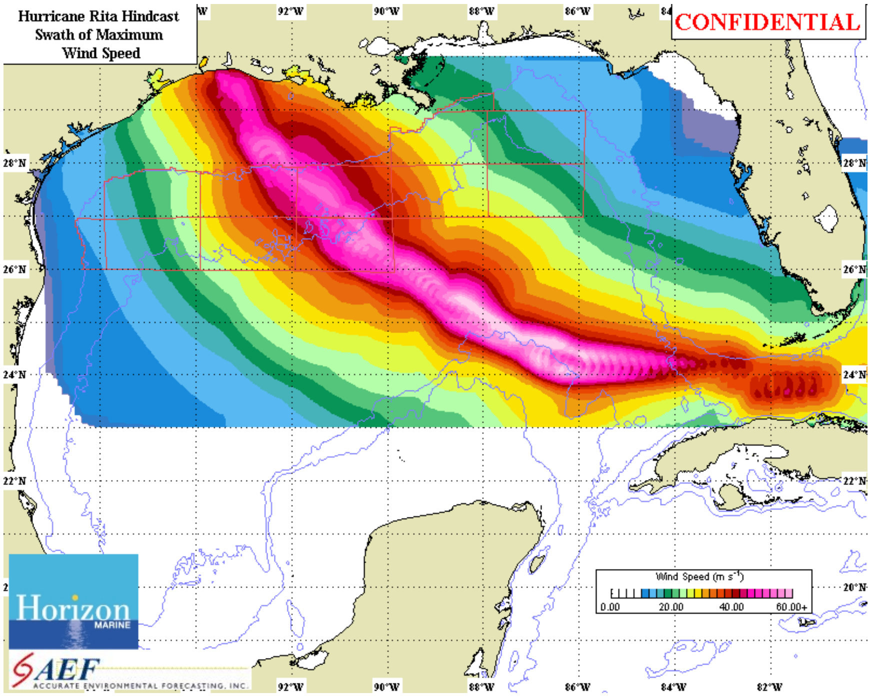


**Figure 2.** Swath of Maximum Wind Speed from Rita.

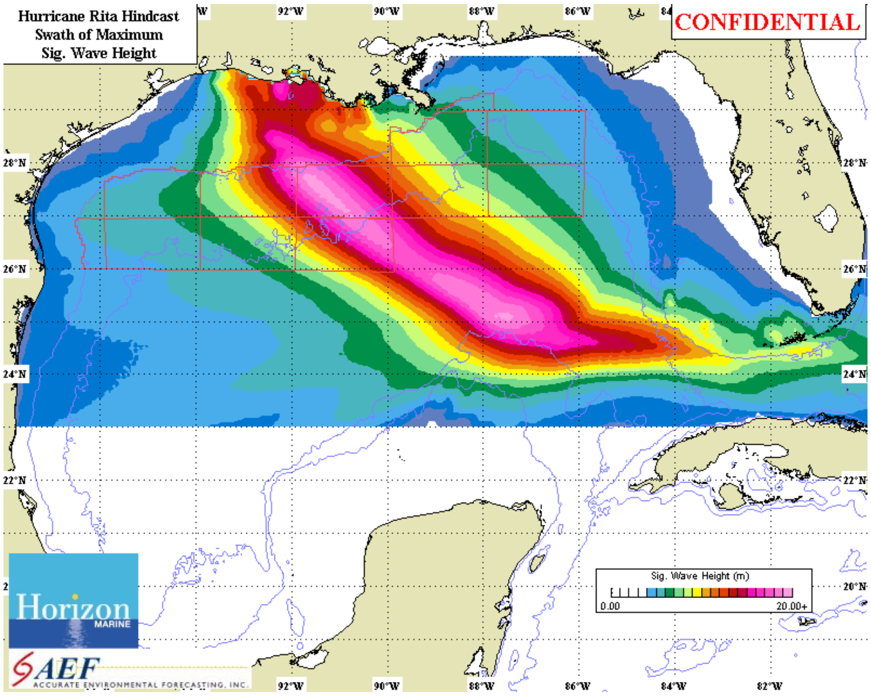


**Figure 3.** Swath of Maximum Significant Wave Heights for Hurricane Rita.

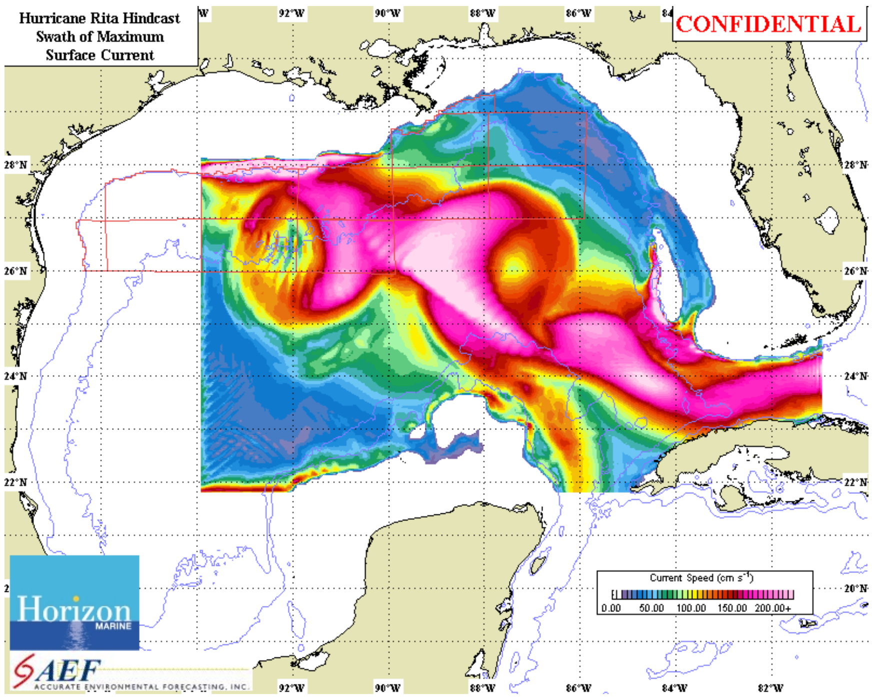


**Figure 4.** Swath of maximum combined Hurricane and Loop/eddy surface currents during Hurricane Rita.

## 4. Comparison to observed wind and waves

NOAA buoy #42002 located at 25.17°N, 94.42°W was the only deepwater site in the Gulf to measure wind and waves during the passage of Rita. The model (hindcast) results compare very well in both timing and amplitude to the buoy observations.


**Figure 5.** Comparison of NOAA buoy #42002 wind speeds with hindcast (model) wind speeds.

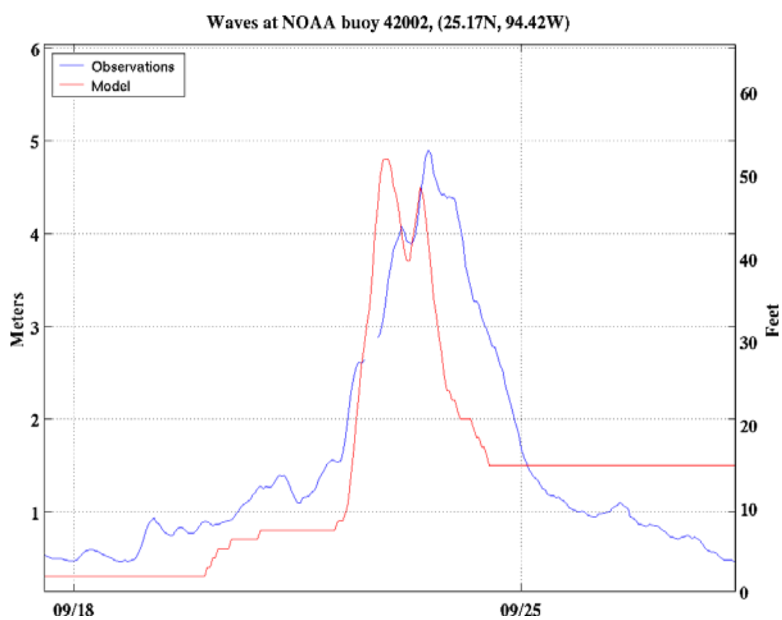


**Figure 6.** Comparison of NOAA buoy #42002 significant wave heights with hindcast (model) significant wave heights.

## 5. Comparison to observed currents

Six Far Horizon Drifters (FHDs) located near Rita's path collected data during the hurricane. The locations of the drifters relative to the hurricane track are shown in Figure 7.

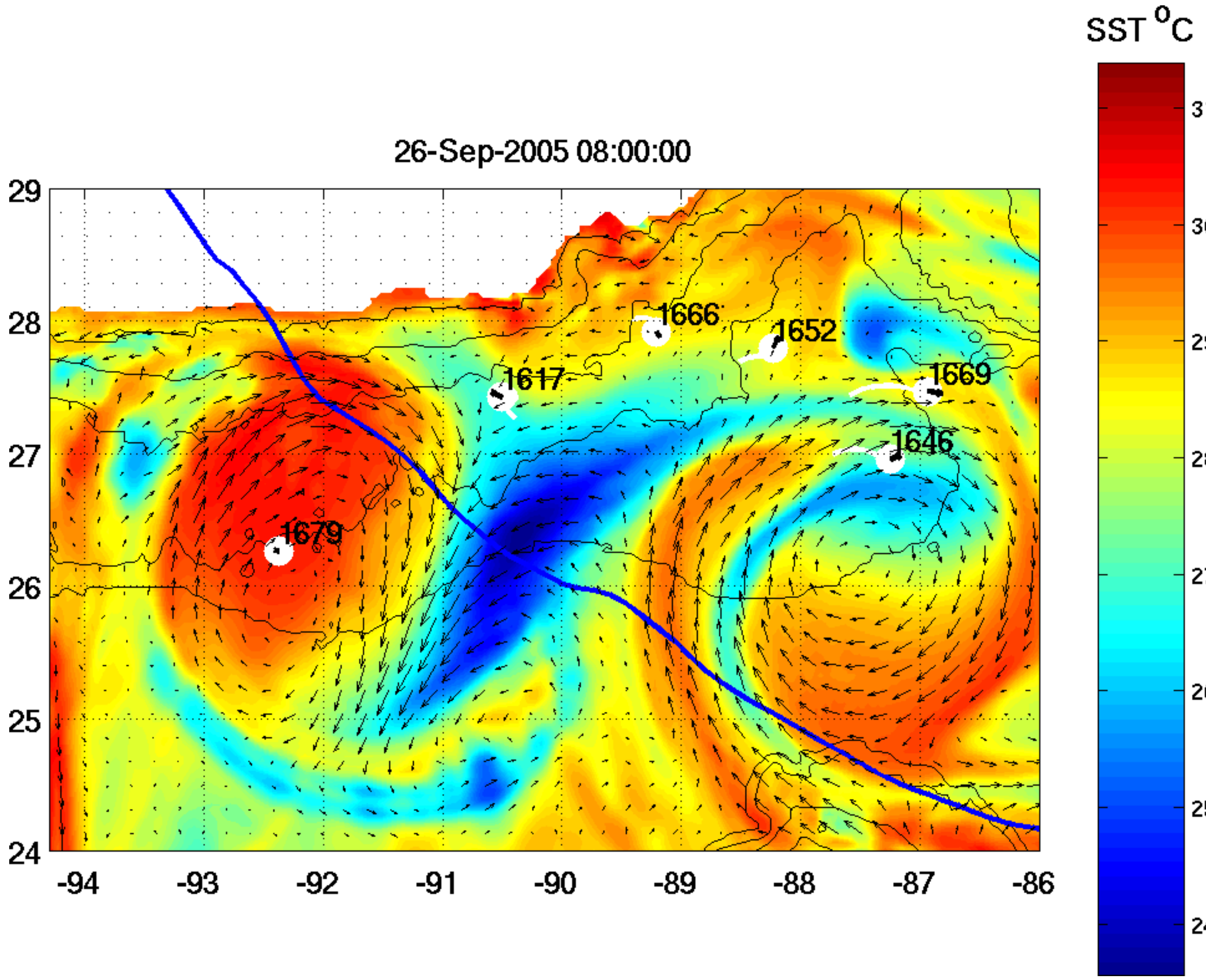


**Figure 7.** This figure shows the hindcast surface temperature and currents on 26 September 2005 at 0800 UTC. Note the warm waters and strong anticyclonic currents associated with Eddies Walker and Vortex. Also shown are the locations of six Far Horizon Drifters.

The model currents along the drifter tracks were extracted to compare the drifter currents to the hindcast model. This allowed for a direct comparison of the hindcast model to the observed current speed and direction (see Figures 7a-f.) The model currents closely match the maximum observed speed and direction. In addition, the model also reproduces much of the near-inertial variability observed during the week after the event.

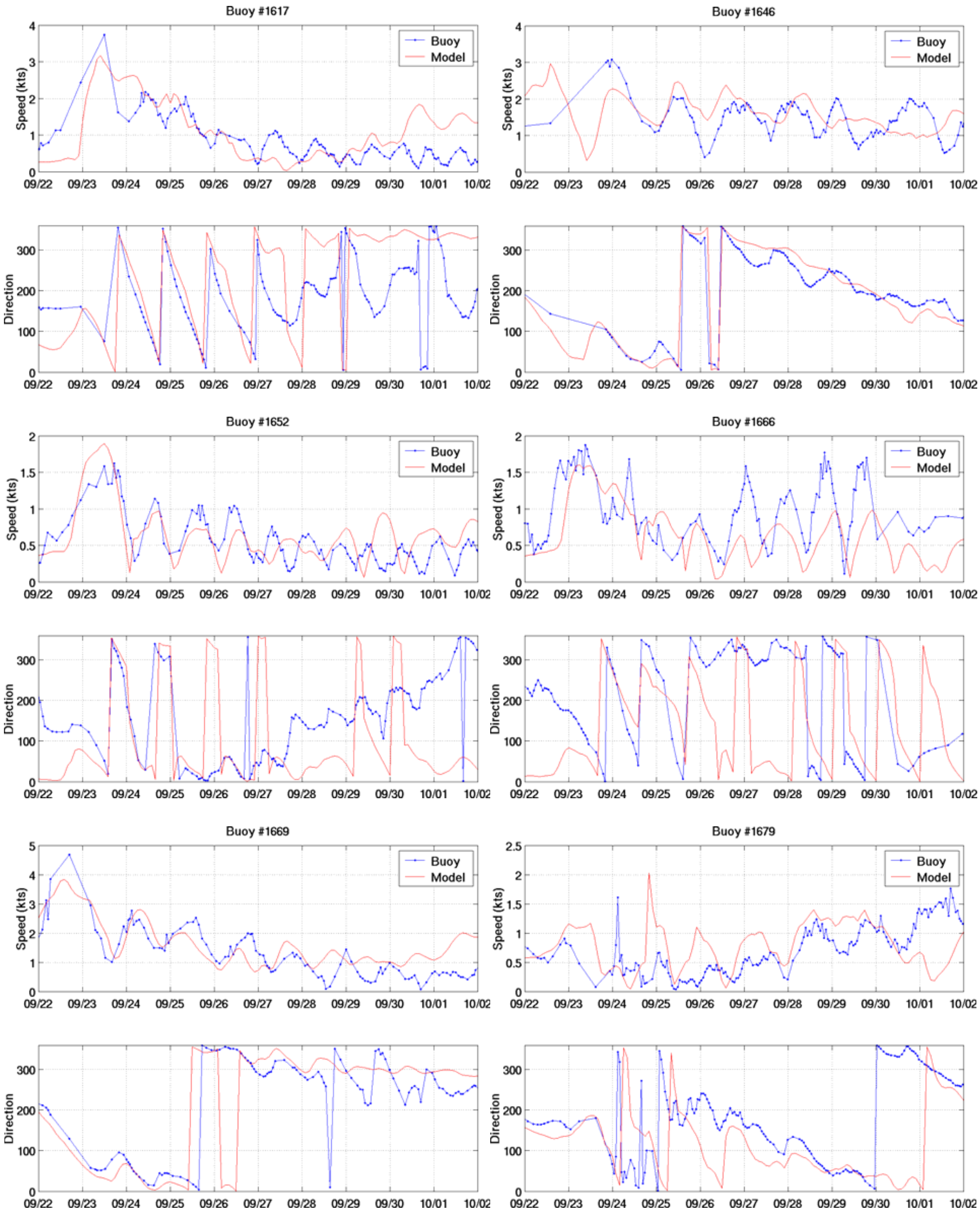


**Figure 7a-f.** Comparison between FHD reported current speed and direction and hindcast model currents for Hurricane Rita.

## 6. Summary

This hurricane hindcast utilized state-of-the-art wave and ocean modeling techniques. The unique procedures account fully for the hurricane and Loop Current forcing of ocean currents. There has been absolutely no tuning of the model for this particular event or to the few available observations, yet the hindcast results compare extremely well with the limited independent observations. These comparisons provide confidence that the model provides a hindcast with meaningful skill in all regions of the Gulf of Mexico. It also suggests that this technique can be used to provide results of similar quality for other tropical storm events.

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