Wave Analysis Guidance for Tropical Cyclone Forecast Advisories

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1. INTRODUCTION

The Automated Tropical Cyclone Forecasting System (ATCF) has been in use at the Tropical Prediction Center/National Hurricane Center (TPS/NHC) since 1990 (Sampson and Schrader 2004). ATCF is a graphical system and its primary functions include plotting raw data or "fixes" used to analyze current and historical track positions, computation and display of forecast information from numerical weather prediction models, forecasting and message creation (Fig. 1). One of the messages forecasters generate is the tropical cyclone advisory. These advisories are then distributed worldwide through standard meteorological distribution methods (e.g., the Global Telecommunications System). Although the primary information in the advisory is the current and forecast position, intensity (1 minute maximum wind speed) and wind radii (34-, 50- and 64-kt), there is information regarding seas in and around the tropical cyclone (Fig. 2). Currently, two parametric wave models are used for wave analyses in the advisories, one based on empirical models (see Wu et al., 2003) and the other developed by Dr. Steve Lyons of the Weather Channel. The purpose of this study is to demonstrate the feasibility of running the 3rd generation WAVEWATCH III (WW3) wave model in time for use in the advisory wave analysis.

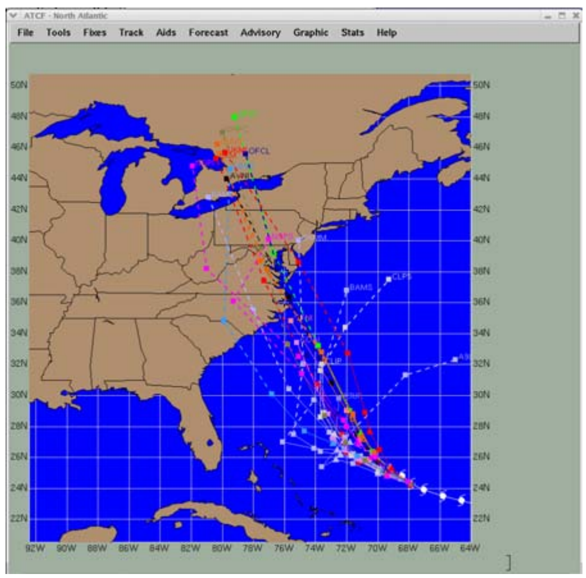

Figure 1. Typical ATCF display. In this example, historical track is shown as a white line connected by hurricane symbols. Forecast positions for different objective aids (from numerical weather prediction models and other techniques) are shown as different colored lines emanating from the most recent historical position.

ZCZC MIATCMAT5 ALL
TTAA00 KNHC DDHHMM CCA

TROPICAL STORM ERNESTO FORECAST/ADVISORY …
.
.
.
ESTIMATED MINIMUM CENTRAL PRESSURE 1003 MB
MAX SUSTAINED WINDS 40 KT WITH GUSTS TO 50 KT.
34 KT....... 80NE 0SE 0SW 0NW.
12 FT SEAS..120NE 120SE 0SW 0NW.
WINDS AND SEAS VARY GREATLY IN EACH
QUADRANT. RADII IN NAUTICAL
MILES ARE THE LARGEST RADII EXPECTED
ANYWHERE IN THAT QUADRANT.
.
.
.
FORECASTER MAINELLI/KNABB
NNNN

Figure 2. An excerpt from tropical storm Ernesto advisory for 0300 UTC SAT AUG 26 2006. The radii of 12- ft seas (bold) are included for the compass quadrants NE, SE, SW, NW.

Wave models are run at most major NWP centers around the globe (Bidlot et al. 2002), resulting in different wave forecasts for any one tropical cyclone. In the case of global NWP models, the intensity is often underestimated. Mesoscale NWP models have a better chance of forecasting the intensity correctly, owing to the greater spatial and temporal resolution, but often the global models are better at track forecasting. Specialized nested tropical cyclone model such as the Geophysical Fluid Dynamic Laboratory (GFDL) model generally perform well. Tolman et al. (2004) used the model (GFDL) blended into a background wind field to drive the third generation WW3 wave model. This system is run at the Centers for Environmental Prediction (NCEP) and produces high-resolution wave analyses along the GFDL model track. It is one of a suite of tools used at the Tropical Prediction Center/National Hurricane Center (TPC/NHC) for determination of maximum significant wave height and radii of 12-ft seas.

Others have uses parametric tropical cyclone models blended into background winds from NWP models to better specify winds around tropical cyclones, and hence produce a better wave forecast. Cox and Cardone (2000) also used a parametric topical cyclone model based primarily on 35- and 50-kt wind radii gleaned from the NHC advisories. Desjardins et al., (2004) used these same methods at the Canadian Hurricane Center (CHC), blending a parametric hurricane wind model into the CHC NWP model, and driving the 3rd generation Wave Model (WAM) with these hybrid winds.

2. WAVEWATCH III

WAVEWATCH III (Tolman and Chalikov 1996) is a third generation wave model developed at NOAA/NCEP. The model solves the spectral action density balance equation for wavenumber-direction spectra. The implicit assumption of these equations is that the medium (depth and current) as well as the wave field varies on time and space scales that are much larger than the corresponding scales of a single wave. For this study the computation of the drag coefficient was limited base on evidence the growth rate of the waves is too large in hurricane conditions (see Chao et al., 2005).

3. METHOD

In this study we used parameters specified as part of the bogus messages generated on the ATCF. The bogus estimates of intensity (wind speed), radius of maximum winds, radii of 64-, 50- and 34-knot winds, and tropical cyclone size are used to create a wind field that closely represents the official forecast. The warning messages are interpolated to a spherical grid using the Dalaunay tessellation method to produce wind fields that adhere to the parameters specified in the bogus. These wind fields are then used to force WW3, using a 6-hour wind fields interpolated to 1-hour intervals. The wave model grid used is a 0.25 by 0.25 degree (~27km) implementation for the Western North Atlantic and Gulf of Mexico. The resultant wave analyses produced are then consistent with the official forecast position from the NHC tropical cyclone. Initially no background wind field was used for the area outside the TC. In a second set of simulations (not shown here) the TC wind analyses and forecasts are blended into the analysis of Navy Operational Global Atmospheric Prediction System (NOGAPS; Hogan and Rosmond 1991).

4. TEST CASES

Preliminary testing was done by hind casting waves for the life cycles of hurricanes Katrina and Wilma of the 2005 Atlantic hurricane season. Figure 2 shows the wave fields generated by Katrina on Aug 28th, 12 GMT.

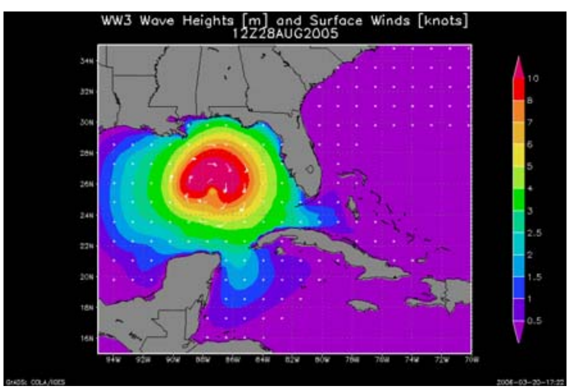

Figure 2. Simulation of waves for hurricane Katrina, Aug 28, 2006, 12GMT

Figure 3 shows the comparison of the WW3 wave heights compared to those measured by the NDBC buoy 42040. The storm passed within 50 nm of this buoy on Aug 25th, 2005. There is good general agreement, although there is some underestimation as the peak of the storm passed over the buoy.

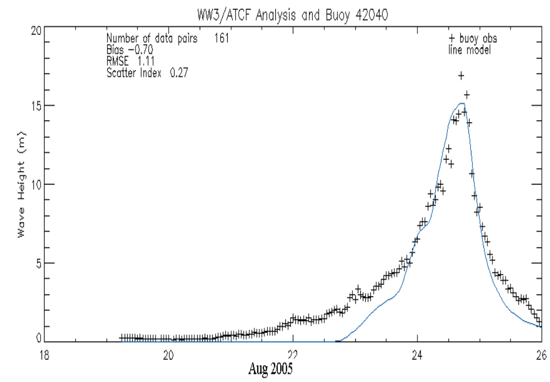

Figure 3. Comparison of WW3 and buoy wave heights at buoy 42040 during hurricane Katrina

Figure 4 shows results from a simulation of waves generated during hurricane Wilma. Figure 5 shows a comparison of the wave heights and buoy 42056 measurements as the eye of Hurricane Wilma passed within 60 nm of the buoy on Oct. 21, 2005. Here the result is not as good with the wave model overestimating the wave heights. The overestimation of wave height is due to the over specification of the winds in the advisory. This is seen in the wind speed comparison at buoy 42056, although part of the discrepancy is due to the fact that the buoy winds are averaged over an 8 min time interval (Fig. 6). Also, the wind structure in the bogus should contain higher maximum winds and a tighter vortex structure than those produced by NWP models normally used as input to WW3, so some over-prediction of the wave heights was expected. The wind speeds produced from the bogus data drop precipitously before the hurricane's arrival and after its departure. This is because the hurricane was imbedded in a zero wind speed background for these particular model runs. This has just recently been upgraded to include background winds from NOGAPS.

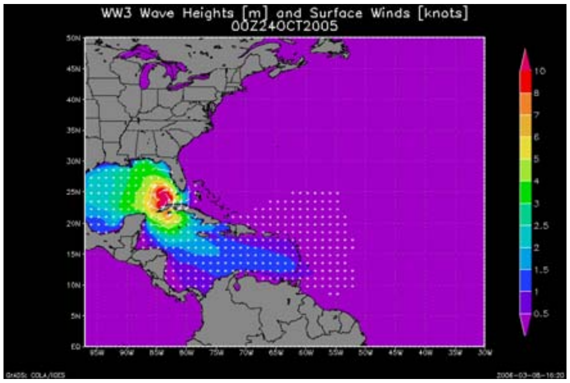

Figure4. Wave heights during hurricane Wilma, Oct 24, 2006, 00GMT

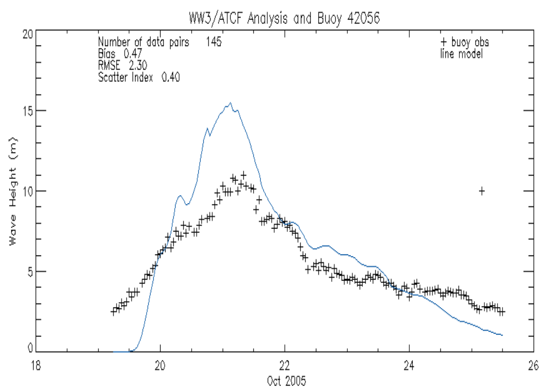

Figure 5. Comparison of WW3 and buoy wave heights at buoy 42056 during hurricane Wilma.

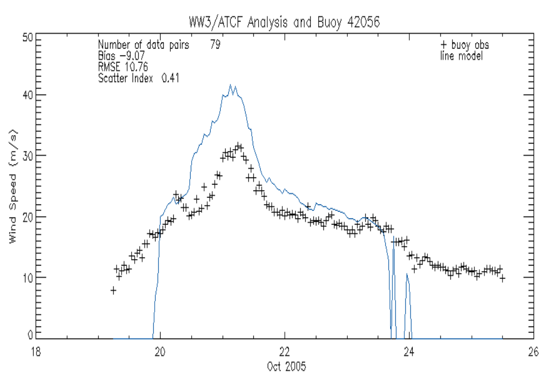

Figure 6. Comparison of ATCF wind speed derived from Hurricane Wilma advisories and at buoy 42056.

5. DISCUSSION

This is a pilot study to demonstrate that integration of the WW3 wave model into ATCF is feasible given the time constraints of the official forecast cycle at NHC. The current plan is to integrate the WW3 into ATCF and generate wave analyses consistent with the forecaster's best track that can be used in tropical cyclone advisory composition. The model would run on a 6-hour update cycle. Tropical cyclone wind structure from the bogus will be blended with winds from NOGAPS. Further verification of tropical cyclone generated waves with moored data buoys and satellite altimeter measurements will be done to insure that results are at least comparable with those of the two parametric models currently in use.

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