Surface Winds in 2008 Hurricane Ike: Observations and High-Resolution Model Forecast

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Hurricanes and Air-Sea Coupled Modeling

1. Introduction

In 2009, the National Hurricane Center (NHC) documented that over the last few decades, tropical cyclone (TC) track forecasts have improved significantly, largely as a result of improvement of large-scale numerical weather prediction (NWP) models and satellite observations, whereas relative little progress has been made in forecast of hurricane intensity and structure.

To predict TC intensity and structure, it is necessary to use high-resolution cloud-resolving models like the 5th generation Pennsylvania State University (PSU)-NCAR Mesoscale Model (MM5) and the Weather Research Forecast (WRF) model. In the same way, since air-sea interaction is a key factor controlling TCs intensity, fully coupled atmosphere-ocean models like the University of Miami Coupled Model (UMCM) and the Coupled Weather Research Forecast (CWRF) model are necessary.

The goal of this research is to evaluate and verify coupled and uncoupled model forecasts during Hurricane Ike with all available observations, but first, a study of how accurate are these observations is needed to best verify these models and later on determine the intensity of a TC.

2. Methodology

a. Data

Although Hurricane Ike lifetime was from September 1-14, 2008, the period of study chosen was 5 days (September 8-13) when the high-resolution model forecasts were available. The data used in this study are:

- H-Wind analysis based on airborne data from the NOAA P3 aircraft.
- National Data Buoy Center (NDBC) moored buoys and ships as surface stations data.

Figure 1. Surface level observations consisted of maximum wind speed data from six NDBC moored buoys and eleven selected ships from NHC Report for Ike.

b. Model

Initialized on September 8, 2008 at 1200 UTC, for 5 days forecast with 1-hr interval.

- Uncoupled: MM5 and WRF
- Coupled:
  - UMCM- composed from the MM5, Wave- Watch 3 (WW3), and 3 dimensional Price- Weller-Pinkel (3DPWP) upper ocean model)
  - CWRF- do not include a wave model

Figure 2. Storm Tracks. It is important to recall that this model have very high resolution (~1-2 km) in the inner most domain. Map Source: Google Earth

3. Surface Wind Analysis

Comparison of Observations:

- H-Wind Analysis Swath:
  - to observe the wind structure and spatial distribution of the storm
- Numerical Comparison Analysis
- Scatterplots Analysis

Evaluation of the Models:

- Spatial projection of the model track into the best track (recorded by NHC) represent the storm relative case and gives the idea of how different is the structure predicted by the models from the observations.
- Swaths:
  - Comparison between H-Wind Analysis and each model
- Time Series Analysis **(Fig.3)**
- Scatterplots Analysis

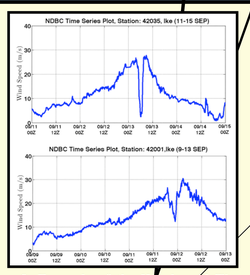
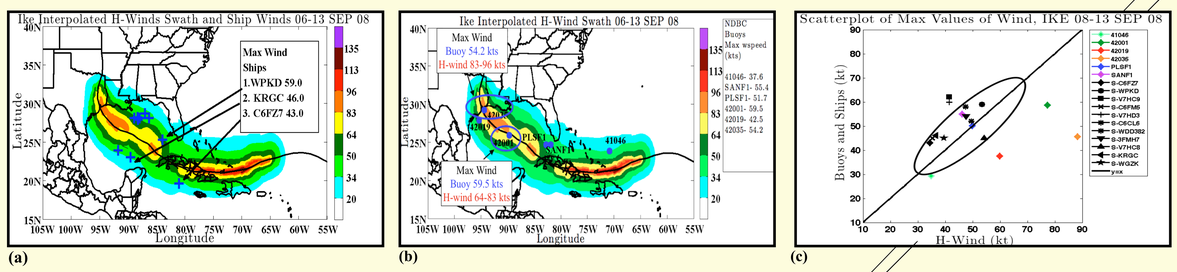


Figure 3. Example of the Windspeed Time Series for two buoys (42001 and 42035) located very close to the best track that recorded when Hurricane Ike's Eyey was passing by.

4. Results

a. Comparison of Observations

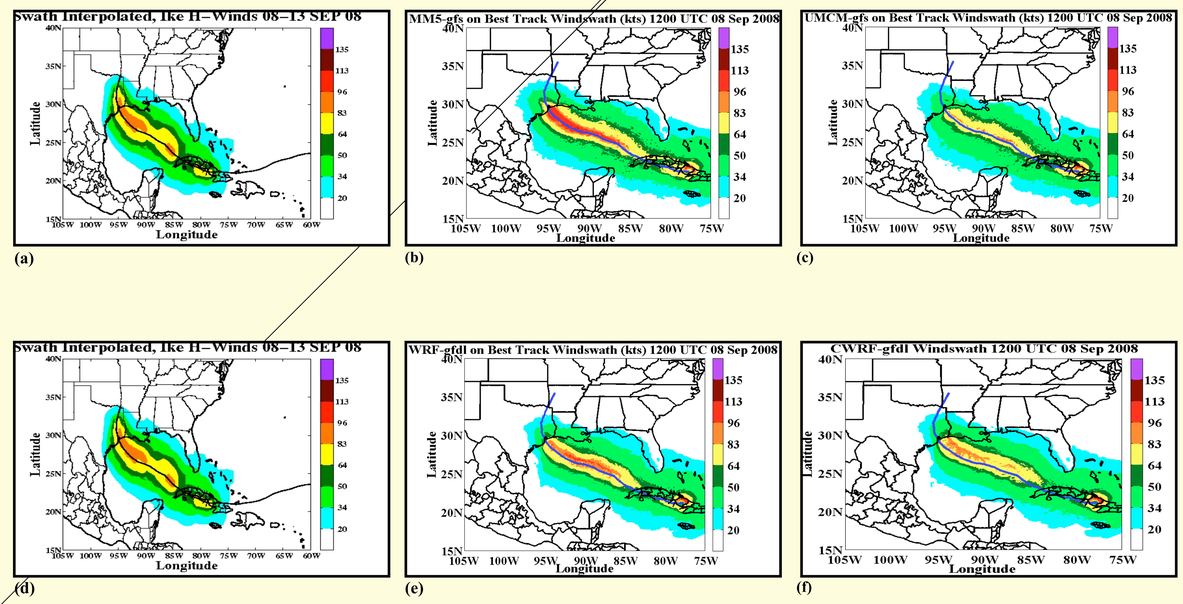


(a) (b) (c)

Figure 4. Maximum winds of H-Winds are compared with ships **(Panel a)** and NDBC buoys **(Panel b)**. The tendency found by this study was that H-Wind recorded the wind speed higher than buoys, and very similar to the ships. It is confirmed by the scatterplot shown in **Panel c**. Ships observations data has better linear relationship with H-Wind, although some buoys stations are near the perfect straight line. H-Wind output was 3-hr interval, so interpolation was used to create the smooth swath shown in the figure. Therefore it had an effect on the results and can be the possible reason for the discrepancy between the buoys and H- Wind.

b. Evaluation of coupled and uncoupled model performance

1. Swaths



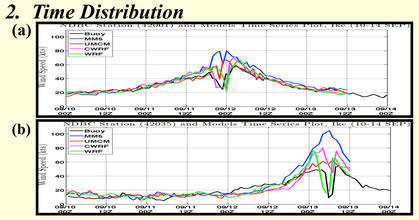
(a) (b) (c) (d) (e) (f)

Figure 5. Wind swath of all models were created to compare the structure and spatial distribution of Ike's surface winds with the H-Wind swath **(Panels a and d)**. MM5 **(Panel b)**, UMCM **(Panel c)**, WRF **(Panel e)** and CWRF **(Panel f)** swaths are plotted. The structure of each models are very similar, showing asymmetry on the winds on each side of the track. In spatial distribution MM5 and UMCM covered more area than WRF and CWRF. In intensity, MM5 swath shows higher winds than the others, but also WRF shows higher winds than CWRF. This is because CWRF and UMCM are the coupled ocean model, they have the atmosphere ocean interaction and the temperature of the ocean is fundamental to the forecast of winds. For this case, the temperature of the ocean probably was cooler and the winds did not increase significantly.

A visible difference between UMCM and H-Wind swath is when Ike made landfall that UMCM did not predict higher winds. In general, coupled models did better job predicting the surface wind within the eye of Ike. Outside the center of the storm, all models did a good work forecasting the winds.

4. Results (cont.)

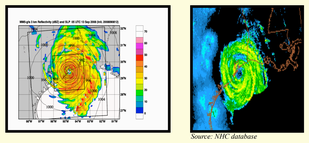
2. Time Distribution



(a) (b)

Figure 6. Time series plots from 42001 and 42035 NDBC station are compared to the models. **Panel a** shows that the models were close to the buoy, only differing when the eye passed the buoy. Although some models predicted higher than the buoy, H-Wind recorded higher values of wind speed in comparison with the buoys **(Panel 4b)**.

Figure 7. In contrast, **Panel 6b** shows that some models did not forecast a well defined Eye on Ike. An example is the MM5, it is confirmed in this figure. Model (confined eye) vs. NEXRAD radar image (bigger eye).



Source: NHC database

3. Scatterplots

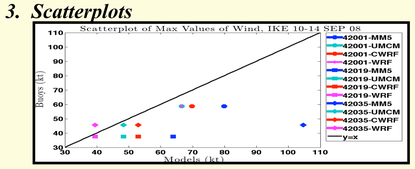


Figure 8. Maximum values of wind speed for each buoy and models. This graph shows that WRF did a good prediction on the 42019-buoy location and the UMCM and CWRF on 42035-buoy location. It is important to notice that for 42001 station, UMCM and WRF values of maximum winds were very close, that is why we cannot differentiate one from the other. In general the models overestimated the maximum winds recorded by the buoys.

5. Summary

From the observations, results seems to indicate that H-Wind may have overestimated the wind in the inner core, while underestimated in the outer regions in Hurricane Ike. Although there are some significant differences in model predicted maximum wind speeds compared to the observations, models captured the asymmetric structure in Hurricane Ike. The uncoupled models, both MM5 and WRF, overpredict surface winds compared to the observations, largely due to the lack of coupling to the ocean. Hurricane-induced cooling in the coupled models of UMCM and CWRF reduced the surface wind forecast bias. However, because of the error in model track forecasts, the comparisons between model with observations at given locations are difficult to make. The comparison with the buoy data are not representative unless the track error can be corrected in future analysis.

6. Future research

- Comparing all observations during Hurricane Ike to provide more complete evaluation on how the H-Wind analysis compared with *in situ* observations.
- Examine the model forecasts with observations in time and space to better understand the evolution and spatial variability of the surface wind related to storm structure changes.
- Develop a methodology to better quantify uncertainties in observational errors and model forecasts.

7. Acknowledgments

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