NOAA Joint Hurricane Testbed (JHT) Year 1 Final Report

Date: Aug. 3, 2010
Project title: *Advanced Applications of the Monte Carlo Wind Probability Model*
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Project dates: Aug. 2009-Jul. 2011

1. Long-Term Objectives and Specific Plans to Achieve Them

Under previous JHT support a program for estimating the probability of occurrence of 34, 50, and 64 kt winds was developed by NESDIS and CIRA. A Monte Carlo (MC) method was utilized to combine the uncertainty in the tropical cyclone track, intensity and wind structure forecasts. The MC probability program has been run in NHC and CPHC operations since 2006.

In the current two-year project, four new applications of the MC model are under development. These include (1) Landfall timing and intensity distributions; (2) Methods for using the MC model to enhance WFO local products; (3) Probabilities integrated over coastal segments; (4) Automated guidance for issuing coastal watches and warnings.

The current project also includes four refinements to the MC model code. These include (1) A procedure to adjust the model time step for fast moving and small storms; (2) Modification of the azimuthal interpolation routine that occasionally leads to inconsistent probability values for 34, 50 and 64 kt winds; (3) Evaluation of the spatial interpolation method that sometimes results in inconsistencies between the gridded and text probabilities; (4) Evaluation of the underlying wind radii model utilized by the MC model.

The timeline for Year 1 of this project is provided in the Appendix.

2. Accomplishments

The accomplishments below are described for each of the four new applications and four code refinements. Results were also presented at the Interdepartmental Hurricane Conference in March, 2010.

<u>Application 1, landfall timing and intensity distributions.</u>

The MC model code was modified to create a new output file that includes the track, intensity and wind radii of all 1000 realizations at every time step. A separate post-processing routine was developed that calculates the landfall timing and intensity distributions for a set of user defined points. Because this application requires a forecaster to select points of interest along the coast, a prototype graphical user interface called Hurricane Landfall Probability Applications (HuLPA) was developed for demonstration of these capabilities. HuLPA is java-based, but a similar application could be developed

in the ATCF framework. Figure 1 is a screen capture of the HuLPA application run on a Windows system. Because of the use of java, the program also runs on Linux systems. The user selects from a set of storm cases (Hurricane Gustav initialized at 00 UTC on 31 August 2008 in this example), and then the program displays the NHC forecast track and intensity. The user then selects the coast points of interest (San Luis Pass to Fort Walton Beach in this example), and then the application of interest (landfall timing and intensity distribution in this example). The user can modify the selected points or forecast case and re-run the application.

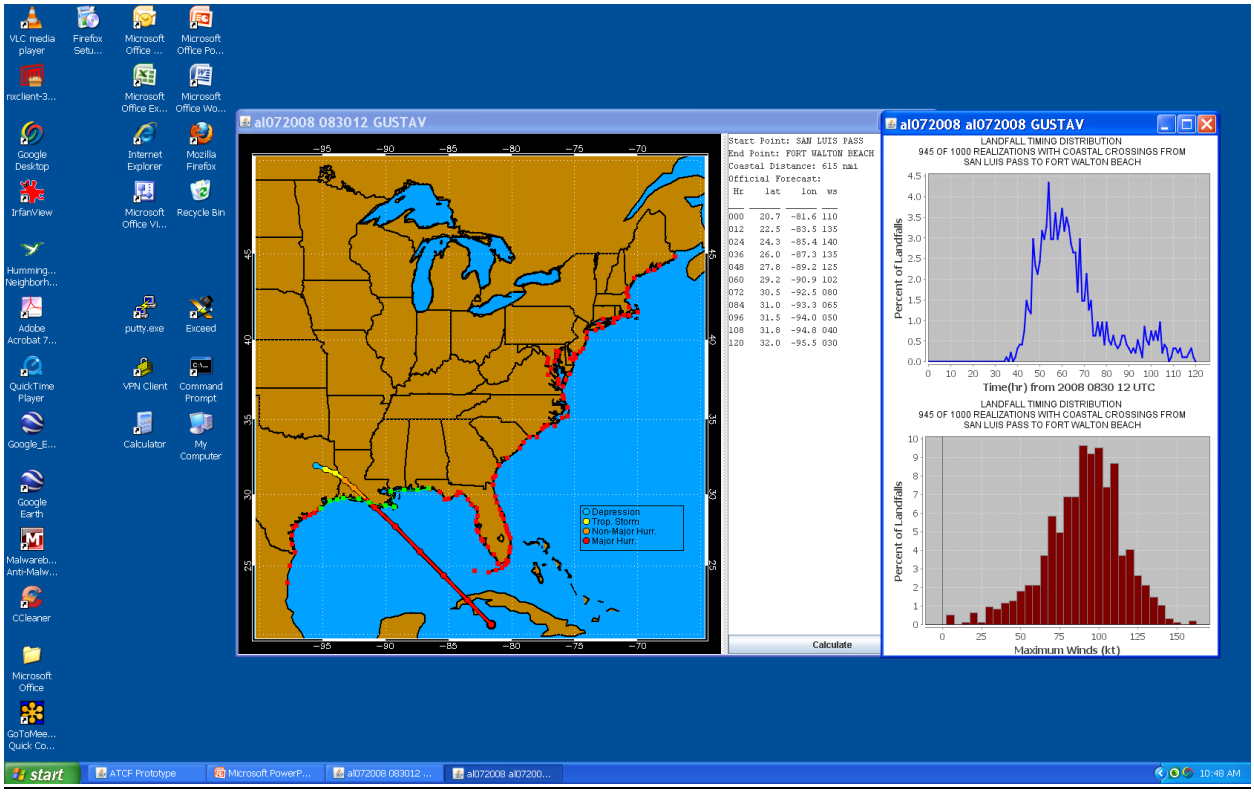

Figure 1. Screen capture of the HuLPA program for a case from Hurricane Gustav (2008).

Application 2. WFO local applications.

The work for this application was completed in the first half of Year 1 as reported in the Year 1 mid-year report. In coordination with Pablo Santos from the Miami, FL WFO and Dave Sharp from the Melbourne, FL WFO, an extensive verification of the 12 h incremental probabilities was performed for coastal and inland points to help them refine their WFO applications. 400 forecast cases from 20 landfalling storms from the 2004-2008 hurricane seasons were run with the most current version of the MC model (the 2009 version). Results from this study were presented by Pablo Santos at the AMS 20th Conference on Probability and Statistics in the Atmospheric Sciences in January 2010.

Application 3. Integrated probabilities

The HuLPA application described above is being adapted to include the ability to calculate probabilities integrated along the points selected by the user. A conference call was held on March 8 with the NHC focal points Dan Brown, Mike Brennan and Chris Lauer and one former focal point (Rick Knabb, now with the Weather Channel). A demonstration of the prototype HuLPA program was provided and several suggestions were given. These included also adding an option to display the probability distributions of the time of arrival and departure of 34, 50 and 64 kt winds. This capability was add to HuLPA. An example of this application is shown in Figure 2. It was also suggested that additional selection points in Mexico and the Western Caribbean be added. These new points can also be seen in Fig. 2.

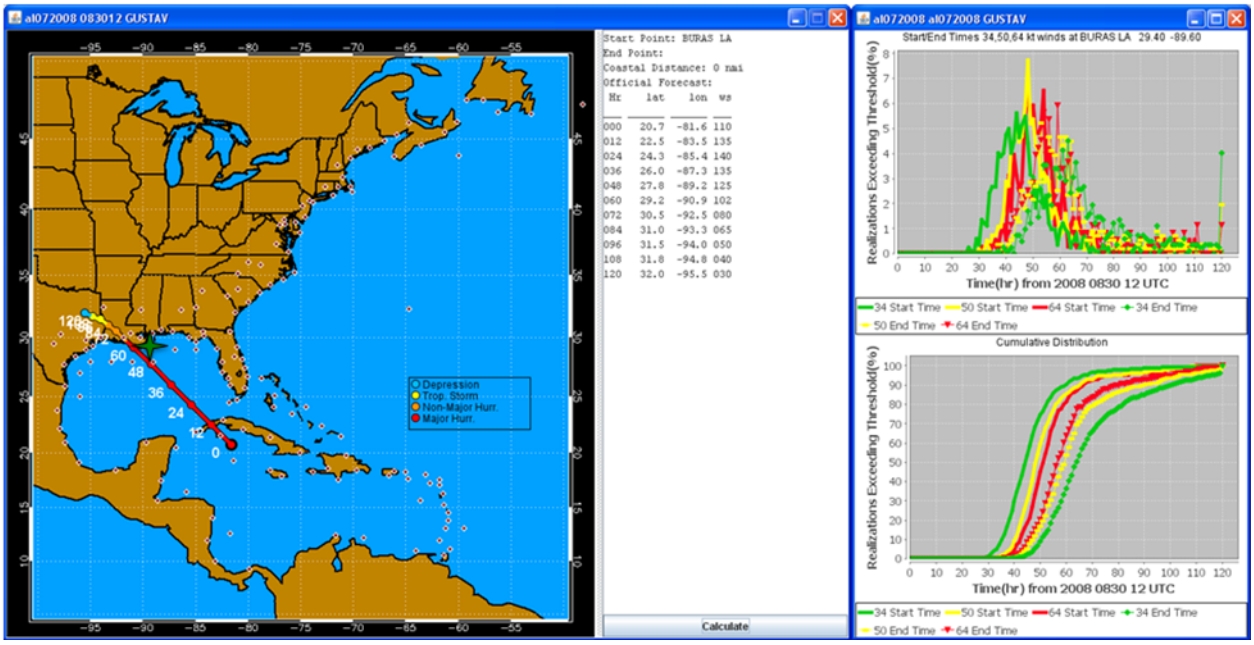

Figure 2. A screen capture of HuLPA illustrating the new capability to show the probability (upper right) and cumulative probability distributions of the time of arrival and departure of 34, 50 and 64 kt. This example is for the distributions at Buras, LA for the 30 Aug 2008 12 UTC forecast of Hurricane Gustav.

In coordination with NHC, the new code to write the output file for HuLPA was installed on their ATCF systems in May of 2010. It is anticipated that the prototype HuLPA system will be available for testing at NHC by mid-August of 2010.

Application 4. Automated watch/warning guidance

The algorithm for providing automated coastal hurricane and tropical storm watch/warning guidance was tested to take into account the change in the time interval in the official watches and warnings. Results showed that no modification was needed because the new timing definitions are actually more consistent with what was done in operations the past few seasons than the previous definitions. In coordination with JTWC

and NHC, a similar application for providing objective guidance for Tropical Cyclone Conditions Of Readiness (TC-COR) at DoD sites was developed. These applications will be ready for testing by the 2011 hurricane and typhoon seasons. Details of this work were presented by A. Schumacher at the AMS 29th Conference on Hurricanes and Tropical Meteorology in Tucson, AZ in May of 2010.

Code refinement 1. Time step adjustment.

The MC model code was modified to allow the underlying time step to be changed. The original version interpolated the tracks, intensities and wind radii to a 2 hr interval. A guideline for the time step value (in hr) is that it should be smaller than the wind radius (in nmi) divided by the translational speed (in kt). The current time step of two hours is valid for the average radius of hurricane winds (40 nmi) for storms moving at up to 20 kt, which is adequate in most cases. However, for very small or very fast moving storms, this time step is too large, and results in probability fields with a "centipede" appearance, especially for the early part of the forecast before the realizations spread out. An extreme example of this problem occurred for latter stages of Hurricane Gordon in 2006. For the 18 UTC model run on 19 September, Gordon was a smaller than average hurricane (average wind radii of 30 nmi) moving eastward at about 28 kt. The left side of Fig. 3 shows the 0-120 cumulative probabilities of 64 kt winds for this forecast using the 2 hr time step. With the revised code, the time step was reduced to 1 hr and the "centipede" appearance was greatly reduced (right side of Fig. 2). This example was run with much higher spatial resolution (0.1° lat/lon) than the current operational model (0.5° lat/lon grid) so the differences could be more readily seen.

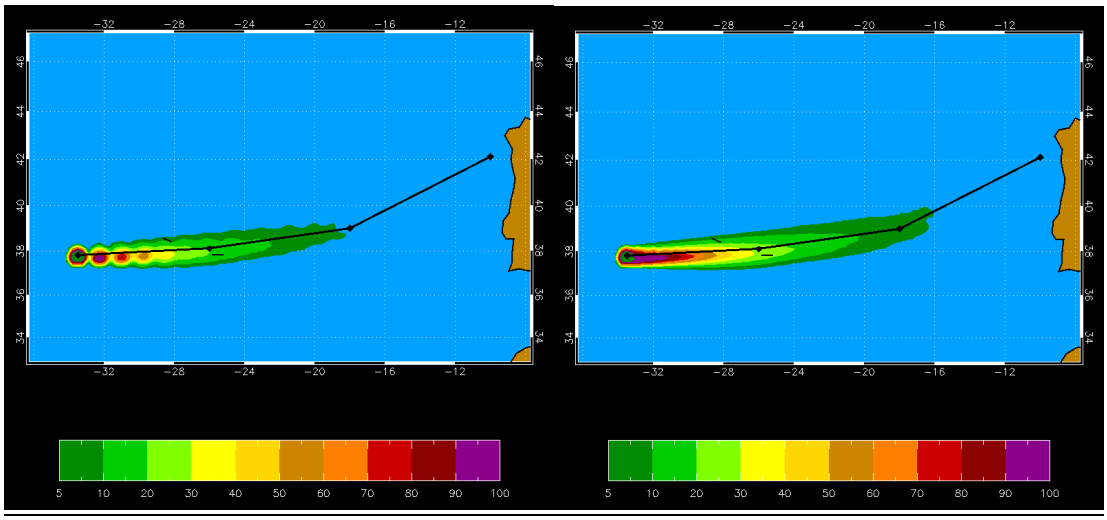

Figure 3. 0-120 hr cumulative 64 kt wind probabilities for Hurricane Gordon (2006) initialized on 19 Sept 2006 at 18 UTC. The left panel used the 2 hr time step of the current operational MC model and the right panel used a 1 hr time step.

Because of the MC model code optimization, doubling the number of time steps only increased the run time by about 10%. For this reason, the change to the 1 hr time step was included in the operational MC model code on the NCEP IBM and ATCF systems for the

2010 hurricane season. The 1 hr time step is also need for the real time evaluation of the HuLPA algorithms. Because this was implemented at NHC before the start of the 2010 season, the HuLPA application can be tested on all storms, including Hurricane Alex.

Code refinement 2. Azimuthal interpolation of wind radii

The wind radii in the MC model are determined from a simple climatology and persistence model. If used in its continuous form, the radii of each wind threshold (34, 50 and 64 kt) would be consistent. However, because the model includes a persistence component based on the 4 quadrant values from the NHC official forecast, the wind radii are azimuthally interpolated from the underlying vortex model evaluated in 4 quadrants. This interpolation works very well in most cases. However, in a few cases where the radii are zero in some quadrants for some wind thresholds but not for others, the interpolation can introduce inconsistency between the radii values. For example, the 34 kt radii can be smaller than the 50 kt radii for a small range of azimuth. It was found that a straightforward solution is to use azimuthal extrapolation rather than interpolation when a wind radii value is non-zero in one quadrant, but zero in the next quadrant. Unfortunately, this modification was not ready in time to be included in the 2010 operational code. However, this is inconsistency is a very rare event (it requires a nearly stationary, large tropical storm near the coast at an initial intensity of 50 kt), and will be ready for the 2011 operational model.

Code refinement 3. Spatial interpolation of probabilities

The MC model is run on a large domain on a 0.5^{o} lat/lon grid and on a set of coastal points for text products. The large domain product is interpolated to a much finer grid for use in AWIPS and the National Digital Forecast Database (NDFD). In regions of large probability gradients, the interpolated gridded values do not agree perfectly with the corresponding coastal values calculated directly. Two approaches to solving this problem are being considered. First, it may be feasible to increase the resolution of the large domain run to 0.25^{o}. Tests will be run to determine if this change reduces the inconsistency of the interpolated and coastal probabilities to an acceptable level. If not, a more complex interpolation method will be investigated that includes the gridded and coastal values simultaneously. This task will be the main focus of Year 2.

Code refinement 4. Radii model evaluation

Because NHC does not forecast wind radii out to 120 h, the radii in the MC model are determined from a simple climatology and persistence wind radii model and its error distributions. This simple wind radii model is used because the radii must be constructed from a very small set of parameters (the storm position and maximum wind at each forecast time) for each realization. The wind radii model assumes a modified Rankine vortex structure. Although very simple by necessity, this wind model should reproduce the observed distribution of wind radii.

A large sample of modeled 34 kt radii for Atlantic storms were compared to those estimated from observations. As described in the Year 1 mid-year report, the statistical distributions of radii produced by the MC model compared very well with those estimated from observations. Thus, it appears that, given the rather severe constraint of having to estimate wind radii out to 5 days from just the storm track and maximum wind, the method is doing as well as can be expected. A follow up study for the eastern and western North Pacific will be performed in Year 2.

3. Plans for Year 2

In Year 2, the HuLPA application will be modified based on experience gained at NHC during the 2010 Hurricane Season. The automated watch/warning guidance application will be available for testing during the 2011 Hurricane Season. Pending final testing, the azimuthal interpolation correction will be added to the operational code in 2011. The successful evaluation of the statistical distribution of the wind radii for the Atlantic will be repeated for the eastern and western North Pacific.

An additional capability for the HuLPA application was suggested by Robbie Berg from NHC following Hurricane Alex in June of 2010. A new capability to estimate the probability of a storm becoming a major hurricane at any time during the forecast period will be developed. The goal is to make this new capability available in time for the mid-August of 2010 delivery of the prototype HuLPA code. The probabilities for all of the intensity thresholds in the wind speed probability table will actually be provided, since this requires little extra work compared to providing just the estimate for major hurricanes.

The largest remaining project task for 2011 is the development of the methods to improve the consistency between the text and gridded products. A preliminary version should be ready by the 2011 season.

References

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Schumacher, A.B., M. DeMaria, J. Knaff, C.R. Sampson, and D. P. Brown, 2010: Objective tropical cyclone warning guidance using Monte Carlo wind speed probabilities. Extended Abstract, 29th Conference on Hurricanes and Tropical Meteorology, (10-14 May 2010) (Tucson, AZ). Available from http://ams.confex.com/ams/29Hurricanes/techprogram/paper_168839.htm

Appendix
Year 1 Project Timeline

Aug 3, 2009 - Project Begins
Oct 2009 - Completion of the incremental probability verification (application II) for the Miami WFO

Nov 2009 - Completion of the time step adjustment (code modification I)

Jan 2010 - Completion of the wind radii consistency (code modification II)

Mar 2010 - Addition of the landfall timing and intensity distribution calculation to the main MC model code (application I)

February 1, 2010 - Mid-year report due

Mar 2010 - Progress report at the Interdepartmental Hurricane Conference

April 1, 2010 – Year two renewal proposal due

May 2010 - Modification of the MC model code on the IBM and ATCF for include code upgrades I and II, and the output for application I (landfall probabilities)

Jun 2010 - Completion of the wind radii evaluation study (code modification IV)

Jul 2010 - Completion of the first version of application the watch/warning guidance (application IV)

Aug 3, 2010 –Year one ends/ year one progress report due