Joint Hurricane Testbed Final Report for Year 1
October 1, 2007-March 31, 2007

Project title: *An Improved Wind Probability Estimation Program*
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1. Background Information

Under Previous JHT support a new program for estimating the probability of occurrence of 34, 50 and 64 kt winds was developed. A Monte Carlo (MC) method was utilized to combine the uncertainty in the track, intensity and wind structure forecasts.

In the current proposal, three improvements are proposed to the MC model, as follows:

Topic1: The MC wind probability estimates will be refined by making the underlying track error distributions a function of the forecast uncertainty. The current MC model uses basin-wide error statistics but recent research has shown that the spread of track forecasts from various models can provide information about the expected track error. J. Goerss from NRL developed a real-time tool to quantitatively estimate the track forecast uncertainty (the Goerss Predicted Consensus Error, GPCE), which will be incorporated into the MC model.

Topic 2: The timeliness of the MC model will be improved by optimizing and modifying the code.

Topic 3: The code that calculates the track and intensity error distributions for the MC model will be generalized to also update the "stand-alone" intensity probability product utilized by NHC. This product is provided in real time as the "wind speed probability table" on the NHC web site, and was developed from data from 1988-1997. The current version of this product only extends to 72 h even though the NHC official forecasts were extended to 120 h in 2003.

The timeline and deliverables for Year 1 of this project are listed below in the Appendix.

2. Accomplishments

Topic 1: A database of GPCE values from 2002-2006 was obtained from P. Harr and B. Sampson to determine their utility for improving the MC model. The GPCE values are designed to estimate the error in the CONU track forecast, which is an ensemble average of several of the most commonly used track forecast models. However, the MC model samples the error distributions from the NHC official forecasts. For the GPCE values to be useful in the MC model, they would also have to be predictors of the NHC track errors.

As a first test of the utility of GPCE, the NHC along and cross track errors were stratified into three equally sized groups based on the terciles of the corresponding GPCE values. As an example, Fig. 1 shows the 72 h along track error distributions for the upper and lower terciles of the GPCE values. The error distribution is considerably wider for the upper GPCE tercile, indicating that the NHC track forecasts are sensitive to the GPCE values.

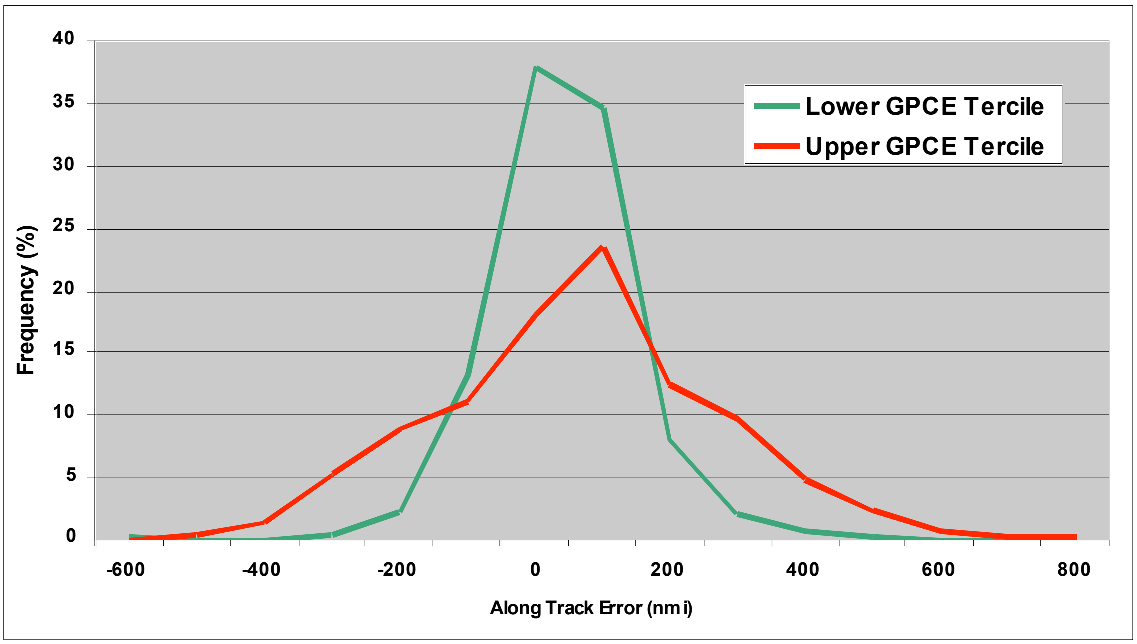
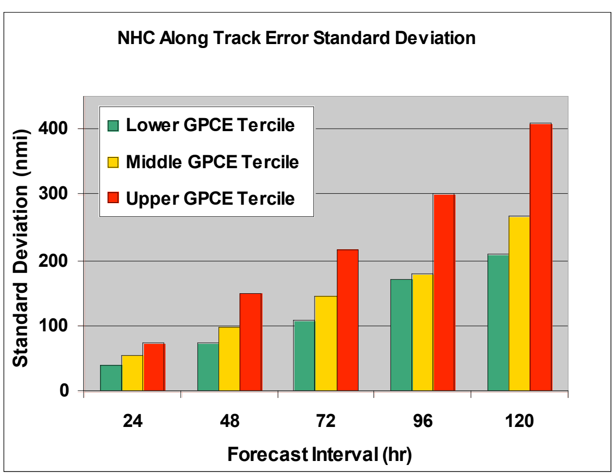


Figure 1. The 72 h NHC along track error distributions from the 2002-2006 sample for the lower and upper GPCE terciles.



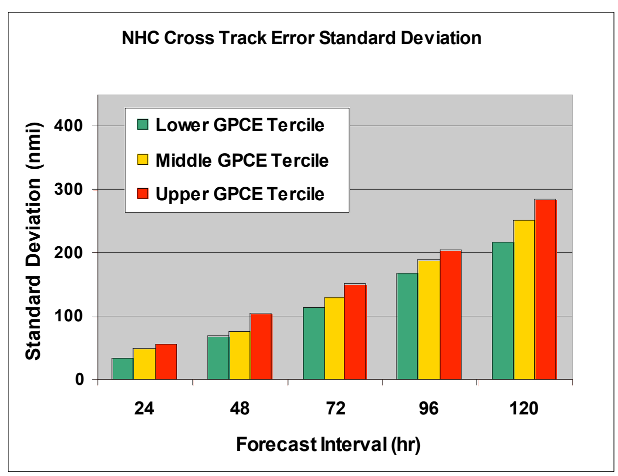


Figure 2. The standard deviations of the along (left) and cross (right) track NHC error distributions for the lower, middle and upper terciles of the GPCE values.

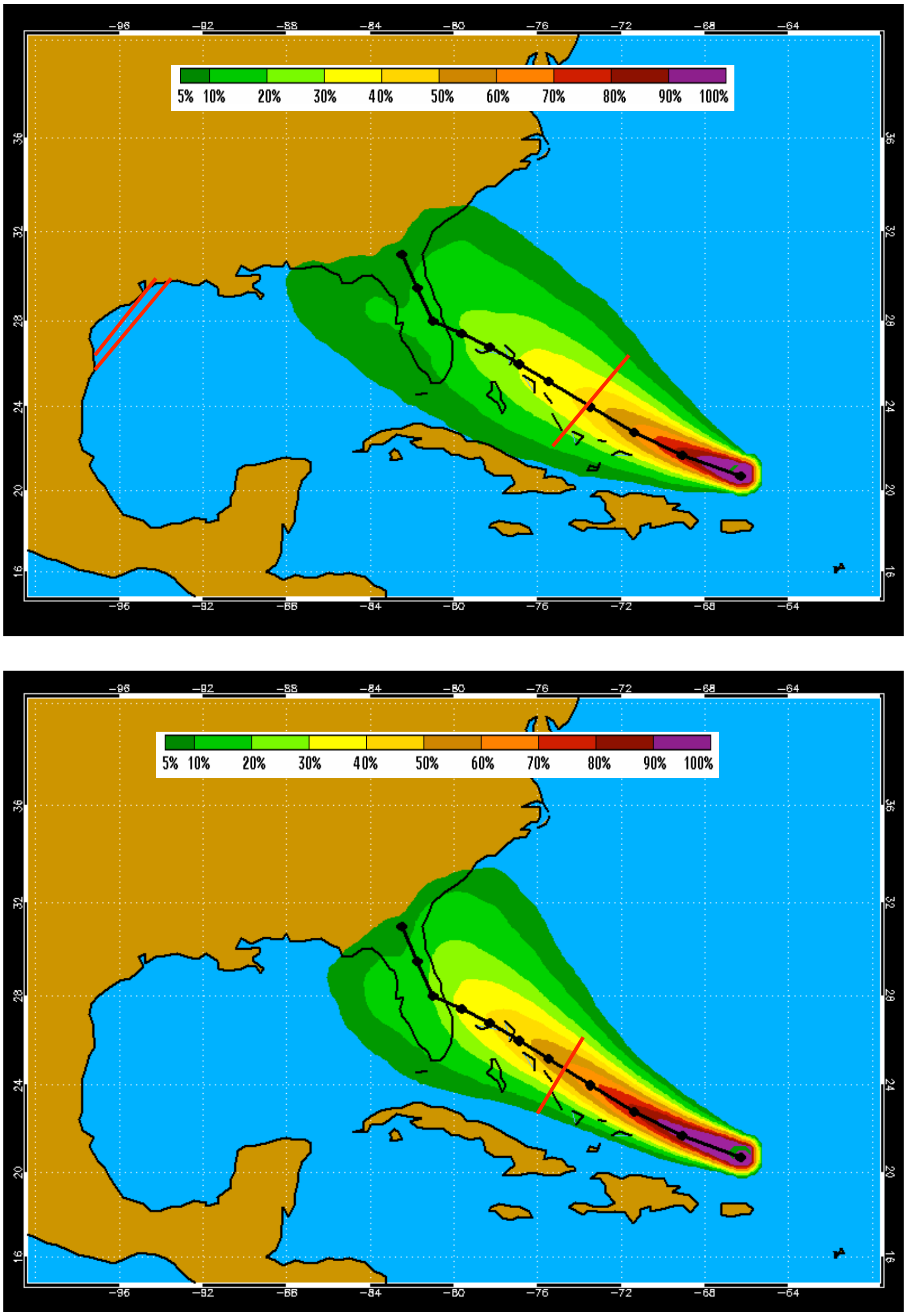


Figure 3. The 0-120 hr cumulative probability of 64 kt winds for Hurricane Frances beginning on 00 UTC on 1 Sept 2004. The probabilities using the upper (upper panel) and lower (lower panel) terciles of the GPCE values are shown.

The along and cross track error distributions, such as those shown in Fig. 1, are approximately normally distributed. Thus, the standard deviation can be used to characterize the width of the distributions. Figure 3 shows the standard deviations of the NHC track error distributions at 24, 48, …, 120 h for the lower, middle and upper terciles of the GPCE values. At every forecast time the standard deviations monotonically increase from the lower to upper GPCE terciles. These results confirm that there is a strong and consistent relationship between GPCE and the NHC track errors, so that the GPCE input can be used in the MC model.

To determine the impact of the GPCE input on the MC model, three separate track error distributions were determined for the lower, middle and upper terciles of the GPCE values. As a test case, the MC model was run for the Hurricane Frances forecast initiated on 00 UTC on 01 Sept 2004. The MC model was run three times, using the error distributions from the lower, middle and upper GPCE terciles. Figure 3 compares the 64 wind probabilities for the cases with the upper and lower GPCE terciles. Away from the storm track, the 64 kt probabilities increase for the upper tercile case. However, near, and especially along the forecast track, the probability values increase for the lower tercile case. This result confirms that the use of the GPCE input will refine the MC model probabilities.

The MC model code is being modified so that it can use the actual GPCE values for a given case. Real time tests of this new capability are anticipated in the main part of the 2008 hurricane season.

<u>Topic 2</u>: A CIRA programmer (R. DeMaria) was supported to work on optimization of the MC code. A profiler was run on the code and it was found that about 80% of the CPU was utilized on just two routines that are involved in distance calculations. These routines determine whether a point is inside or outside the radii of the various wind speed thresholds (34, 50 or 64 kt) at each time step of each MC realization. Based on this result, the programmer suggested a modification to the code that takes advantage of the two dimensional aspects of the large grid used for most of the probability products. A new routine was written to automatically determine whether the input grid points are in a two-dimensional form. If so, a masking algorithm is applied before any of the distance calculations occur so that only those points that have a finite chance of being inside the wind radii are checked. This procedure resulted in a factor of 11 speed up of the code in the test cases with moderate sized grids, with no change to the output. The operational code already included a much simpler screening algorithm, so the new optimization resulted in a factor of 6 speed up when applied to the IBM code. Because these results were so encouraging, we worked with Chris Lauer to install the new optimized code on the IBM before the start of the 2007 season, and it ran for the entire season with no problems. In the proposal we anticipated a speed of about 50%, but ended up with a 600% improvement. This part of the project is complete.

<u>Topic 3:</u> Rick Knabb and Dan Brown of TPC, who routinely provide training on the various TPC probability products, pointed out that the Wind Speed Probability Table (WSPT) product uses a different technique than the new MC wind probability product. They also pointed out that all of the information needed for the WSPT product is calculated as part of the MC wind probability routine. They suggested that the MC model code be modified to calculate the input for the WSPT so that it would be consistent with all the operational products that are derived from the MC model code. If this method were successful, the WSPT could be generalized to include 96 and 120 h with no further work, and it would not be necessary for the TPC Technical Support Branch (TSB) to support a separate routine for updating the WSPT.

As a first test of this idea, we coordinated with Rick and Dan to come up with a set of test cases to compare the wind speed probabilities from the two methods, which are listed in Table 1. Each forecast case includes 5 times (12, 24, 36, 48 and 72 h) and 9 probability categories (Dissipated, TD, TS, Hurr, Cat1, Cat2, Cat2, Cat3, Cat4/5), so the 8 cases in Table 1 provided a sample of 360 pairs of probabilities for comparison (5*9*8).

Table 1. The test cases for comparison of the WSPT values and the analogous values derived from the MC model.

Storm Name	Date	Time
Frances	29 Aug 2004	12 UTC
Katrina	24 Aug 2005	18 UTC
Katrina	27 Aug 2005	18 UTC
Ernesto	29 Aug 2006	06 UTC
Ernesto	29 Aug 2006	18 UTC
Humberto	12 Sep 2007	12 UTC
Humberto	12 Sep 2007	18 UTC
Ingrid	13 Sep 2007	00 UTC

Figure 4 shows the distribution of the probability differences from the operational WSPT product and those estimated form the MC model output. Almost ¾ of the differences were within 5%. This agreement was a little surprising because the values are calculated by different methods and use different historical periods (the WSPT product is based on 1988-1997 and the MC model used 2002-2006). The differences for a few of the cases were as large as 25%. All of these cases were for storms near land. In these cases, the MC model takes into account the relationship between track and intensity error, and corrects for the fact that the observed track might be over land even when the forecast track is over water. This is a real effect, so the MC model values were considered more reliable for those cases.

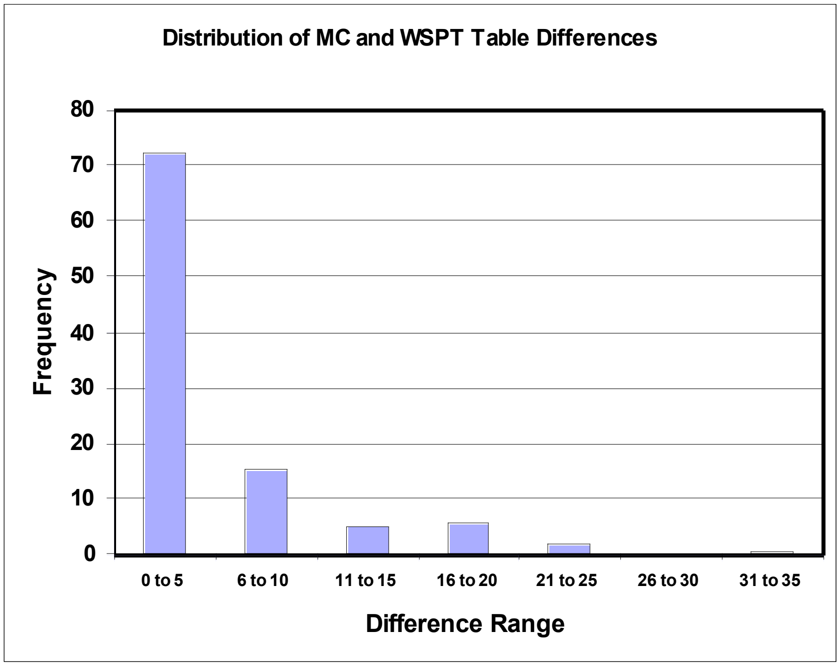


Figure 4. Frequency distribution of the probabilities differences from the WSPT and the MC model. The sample includes 360 probability pairs from 8 forecast cases.

Based on the above comparison, a decision was made to use the MC model output for the WSPT product starting with the 2008 season. The main MC model subroutine was modified to calculate the table input and return an array of values as a calling argument. The new routine was delivered to C. Lauer in March of 2008. At the request of TPC, additional convergence tests were performed to determine if there were enough realizations in the MC model to warrant listing the probabilities to 1%, rather than to the nearest 5% as in the current version of the WSPT product. These tests showed that information would be lost if the values were rounded to 5%, so the new product will list the probabilities to the nearest percent. With the delivery of the modified MC routine, the work for this topic is complete.

3. Things not completed

The funds for this project arrived at CIRA in Oct of 2007, which was about 6 months after the start of the year 1 timeline. However, two of the three topics were still completed on time, and the majority of the planned work on topic 1 was finished. The only aspect not completed as planned is the verification of the probabilities with the GPCE input. This task will be completed in year 2 using the real time parallel runs that are planned to begin by the main part of the 2008 hurricane season (August of 2008).

4. Things that did not succeed.

So far, no serious problems have been encountered.

5. Plans for Year 2

The GPCE version of the MC model will be developed and tested on cases from the 2008 season. The probabilities will be verified using the MC model verification code developed under previous JHT support to provide a quantitative measure of the improvement with the GPCE input.

Appendix

Year-1 Project timeline and Deliverables:

Apr 2007 - Project begins
Apr 2007 - Begin Optimization of MC code
Jul 2007 - Compare optimized code with real-time runs, implement on IBM in coordination with TPC
Aug 2007 - Finalize creation of GPCE database for the Atlantic
Sep 2007 - Adjust probability generation code for wind probability table
Oct 2007 - Complete GPCE database for other basins
October 16, 2007 - Mid-year report due
Jan 2008 - Complete first version of MC code with track-dependent probabilities
Jan 2008 - Select case studies from 2007 season and run parallel MC code
Feb 2008 - Complete verification of case studies and compare with operational MC model
Mar 2008 - Report results at the IHC
April 16, 2008 - Year one progress report/renewal proposal due