Joint Hurricane Testbed Final Report
September 1, 2005-August 31, 2007
Continued Development of Tropical Cyclone Wind Probability Products

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1. Background

This project is continue the development of the Monte Carlo (MC) wind probability program and assist with the implementation of new products that are derived from the output. A verification system for the probabilities will also be developed. At the request of TPC, a new task involving the evaluation of the probabilities associated with hurricane watches and warnings from the 2004 and 2005 hurricane landfalls was added. Results from this new study were presented at the 2006 IHC. Michelle Mainelli from TPC is extending the work with the probabilities and the watches/warnings.

2. Accomplishments

a. Training assistance and product improvement.

M. DeMaria coordinated with Rick Knabb of TPC to provide feedback on a training session that was developed to help explain the new probabilities to NWS forecasters and other users of the new products. In addition, several cases from the 2004 and 2005 seasons were re-run using the most current version of the program for Pablo Santos from the Miami WFO, for the development of an experimental algorithm that utilizes the probability output. A web site was created at CIRA displaying the complete set of probabilities from all of the cases for Hurricanes Charley, Frances, Jeanne and Ivan from 2004 and Katrina and Rita from 2005 (see http://rammb.cira.colostate.edu/projects/tc_wind_prob). A short description of the MC program is also provided on the web site to assist with training.

A feature in the code that assigned the climatological wind radii calculation by basin of origin instead of current location was identified. This problem has been fixed in the current version of the code.

b. Examining wind probabilities at the watch/warning break points

Using the rerun cases, the probabilities associated with hurricane warnings from the 2004 and 2005 seasons were evaluated. Table 1 lists all the storms that had a warning issued for at least on time period. The probability program was adapted so that it provides probabilities directly at the same set of coastal breakpoints that are used to issue warnings. This set includes 195 points along the U.S. coastline from Brownsville, Texas to Eastport, Maine. The distance between these points is fairly irregular with spacing ranging from about 5 to 50 nmi. To provide more even coverage, the official breakpoints were supplemented by additional coastal points, so that the difference between points is no more than 15 nmi. The final set includes 342 coastal points. The MC model runs at the supplemented breakpoint set for all 14 storms in Table 1 were completed.

Table 1. Atlantic Storms with at Least One Hurricane Warning

Storm Name	Year
Alex	2004
Charley	2004
Frances	2004
Gaston	2004
Ivan	2004
Jeanne	2004
Arlene	2005
Cindy	2005
Dennis	2005
Emily	2005
Katrina	2005
Ophelia	2005
Rita	2005
Wilma	2005

A program to match the supplemental break points with a hurricane warning with the probability output has also been developed. The probabilities at the break points had slight negative biases, but nonetheless were 28% better than the deterministic forecast at determining whether hurricane conditions occurred (noting that 50% of the OFCL forecasts verified) and very skillful in discriminating between events and non-events. Results show that for all the coastal points for which a warning was issued for these 14 storms, the average 5-day cumulative probability was 28%, and the probabilities at the ending point of the warning were 9%. This is consistent with previous analysis of the warning regions which suggests that when a warning is issued there is actually only about a 1 in 4 chance of the point experiencing hurricane winds. Another interesting finding was that for this sample, warnings were left up long after the threat was over (i.e., P=0%) in some cases and the warning areas could be reduced if probabilities set to the 10th percent were use as guidance for when to drop warnings. The above results were presented at the 60th IHC.

In the spirit of continuing this work, Mark DeMaria visited TPC on Feb. 22, 2007 and again on Aug. 6, 2007 and met with Michelle Mainelli from TPC to discuss her plans to evaluate the utility of the MC probabilities to the problem of watches and warnings. She has agreed to continue this evaluation, and has already begun a preliminary analysis of the probabilities for the hurricane watches and warnings at the time when they were first issued.

c. Verification code

The primary goal of this project was the development of FORTRAN code to verify the Monte Carlo wind probabilities and compare those forecasts to information contained in the deterministic forecasts issued by TPC and JTWC. The verification code creates statistics that answer specific questions about the MC forecasts. Table 2 shows those statistics and the questions they answer.

Table 2. Statistics associated with the verification of probabilistic forecasts and the questions they are designed to answer.

Statistic	Question answered
Brier Score	*What is the magnitude of the probability forecast errors?*
Brier Skill Score a. climatology reference b. deterministic forecast reference	*What is the relative skill of the probabilistic forecast over that of climatology and the deterministic forecast, in terms of predicting whether or not an event occurred?*
Reliability Diagrams	*How well do the predicted probabilities of an event correspond to their observed frequencies?*
Relative Operating Characteristics	*What is the ability of the forecast to discriminate between events and non-events?*

Before one can calculate the statistics there were several steps that were necessary to create matching grids associated with the best track and the OFCL forecasts and the MC grids produced during the hurricane season. These include

1) Special code (FORTRAN 90 modules) was developed to read the A-decks, B-decks, and MC grids.
    a. grib1 and grib2 readers were developed for the MC grids (see "Things that did not succeed")
2) Since the deterministic forecast (i.e., OFCL) does not contain forecasts of the wind radii through 120-h, special procedures were developed to insert the

forecasts of the five-day wind radii CLIPER model (DRCL) forecasts where TPC made a forecast of location and maximum winds, but not of wind radii. This capability is only needed if comparisons between the NHC deterministic forecast and the probabilities are desired.

3) Since the wind probabilities are valid for a specific time interval, best track and deterministic forecasts were interpolated to the same time period that the MC program uses to integrate individual realizations. This is a variable that can be changed as the MC code itself evolves.
4) Since the best track can exist when the determinist forecast does not exist (e.g., following extratropical transitions), special procedures were developed to clip (set values to missing) the best track at times when the OFCL forecasts were unavailable.
5) Since several storms can be active at the same time and on the same grid, each MC grid, deterministic forecasts and best tracks are matched in a time-relative manner.
6) Subroutines to calculate the Brier Score, Brier Skill Score, reliability diagrams, and the relative operating characteristics were created. These are called for each grid time and the statistics are accumulated during the time stepping.

The verification consists of the comparison of the six MC grids (i.e., 34, 50, 64, cumulative and incremental) with similar grids populated by ones and zeros that were created from observed (i.e., best track) and deterministic (i.e., OFCL +DRCL wind radii when no OFCL wind radii exist) forecasts. The final output consist of an accumulation of statistics (in three files) shown in Table 2 at each 6-hourly time period. The year-to-year changes in the statistics can be used to gauge deterministic forecast improvements, and improvements/changes in the MC algorithms.

Examples of the reliability diagrams for the 72-hour cumulative probabilities in each of these basins are shown in Figure 1. There is evidence of a slight low bias in the Atlantic R34 and R50 wind probabilities, a rather pronounced positive bias in the R34 wind probabilities in the East Pacific and some evidence of under confidence in the R34 probabilities in the West Pacific. The central Pacific reliability diagram is solely based on Hurricane Ioke. The statistics (not shown) also indicate the wind probabilities are in the Atlantic, East Pacific and Central Pacific are performing well with acceptable initial biases, are able to outperform the deterministic forecasts in detecting winds exceeding the 34-, 50-, and 64-kt thresholds and are very skillful in discriminating events (in a basin wide sense).

The Western North Pacific probabilities on the other hand have larger initial biases and do not outperform the deterministic forecast until beyond 48 hours. We speculate that this problem as well as the under confidence of the R34 wind probabilities are likely due to the initial wind radii being misperceived (likely 0 values) at t=0 (i.e., no persistence) and the resulting sole reliance on the wind radii climatology. The JTWC decks are missing 34, 50 and 64-kt wind radii when the storm intensity is equal to 35, 50 and 65 kt, respectively.

Other issues involve the use of the East Pacific wind radii climatology and persistence model for Typhoon Ioke west of the dateline. The later problem has been fixed and revised code has been provided C. Lauer (TPC). Any of these results are far from conclusive and it will be interesting to compare the 2006 verification results with those of 2007 to see if some of these issues in the East (bias in R34) and West Pacific (under confidence in R34) still exist.

Finally, the verification code has been provided to TPC via C. Lauer.

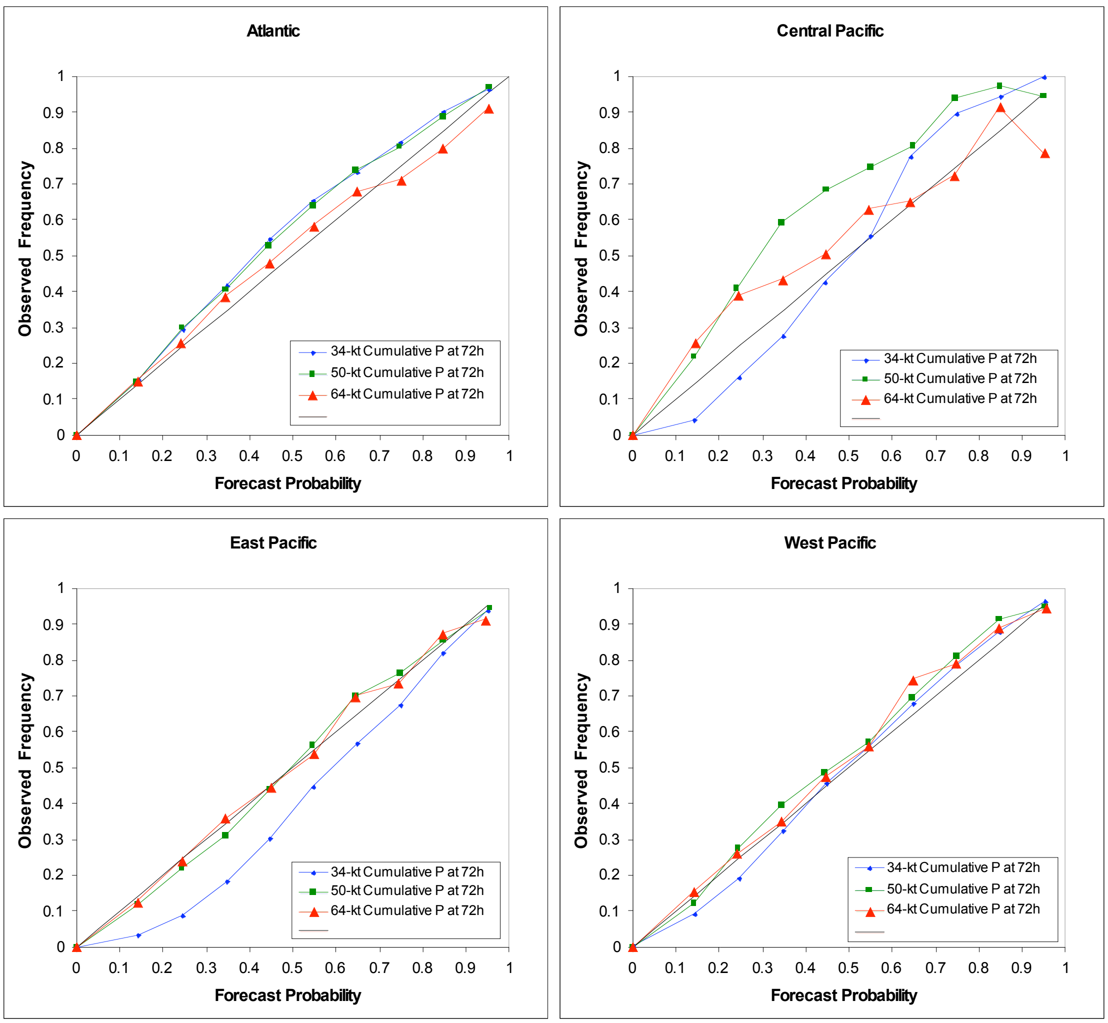

Figure 1. Reliability diagrams for cumulative 72-h tropical cyclone wind probabilities at 34-, 50-, and 64-kt wind thresholds in the Atlantic (110W-1W), Central Pacific (180W-140W), East Pacific (95W-140W), and the West Pacific (100E-180). The latitude domain is 1N to 60N.

3. Things not Completed/Pending Items:

The proposed work was completed, with the exception of the inclusion of grib2 file readers in the verification code, as described below.

4. Things that did not succeed.

Grib2 reader for the verification code: We were unable to get the NCO grib2 libraries to open and decode more than one grib2 file at a time. It appears that the de-assignment of pointers and de-allocation of memory is not working properly within the libraries. Because of this limitation the version of the verification code that was delivered to TPC uses the grib1 instead of grib2 input.

After corresponding with NCEP/NCO, the grib2 libraries, while released to the public, were not bug/feature free. When NCO provides working grib2 readers, they can be added to the verification code. This part of the code is a separate module so it should be straightforward to swap the grib1 reader to grib2 once they are available from NCO.