Joint Hurricane Testbed Final Report
September 1, 2005-August 31, 2007

Project title: *Improved Statistical Intensity Forecast Models*
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1. Background Information

This project is to improve statistical intensity forecast models by (1) incorporation of a new formulation of the inland decay component in the SHIPS model, (2) implementation of a new method for the evaluation of the vertical wind shear in SHIPS, and (3) improvements to the rapid intensity index (RII) by utilization of a discriminate analysis method that weights the input parameters to provide the optimal separation of the rapid and non-rapidly intensifying tropical cyclones.

2. Accomplishments

(1) New decay model

The new model reduces the decay rate over islands and other narrow landmasses to eliminate a bias that was prevalent in the original version. Details can be found in DeMaria et al (2006). The new decay model was included in the operational SHIPS beginning in 2005, based upon re-runs of the 2001-2004 seasons, all of which showed neutral or positive impact.

The decay component is a post-processing step, which is applied after the SHIPS forecast that neglects land effects is completed. Because the SHIPS forecasts without the land effects are saved in the ATCF, it was straightforward to re-run either version of the decay model on the operational forecasts. As a final test of the new decay model, all Atlantic and east Pacific forecasts from 2001-2006 were re-run with the new and old decay model. This period was chosen because 2001 was the first year the 5-day SHIPS forecasts were available.

Figure 1 shows the improvements with the new decay model for all 2001-2006 Atlantic forecasts and for those where the best track was within 500 km of land. All of the Atlantic improvements are statistically significant at the 95% level. The forecasts for the near-land sample improved by up to 6.8% confirming that the new decay formulation is more accurate on average.

The same analysis was applied to the 2001-2006 east Pacific sample. Because the east Pacific storms are rarely impacted by land, the forecasts differences were less than 1% at all forecast intervals and were not statistically significant.

Because the new decay model had a significant positive impact on the Atlantic forecasts and no significant change to the east Pacific forecasts, the PIs opinion is that the new decay module in SHIPS is ready for final operational approval.

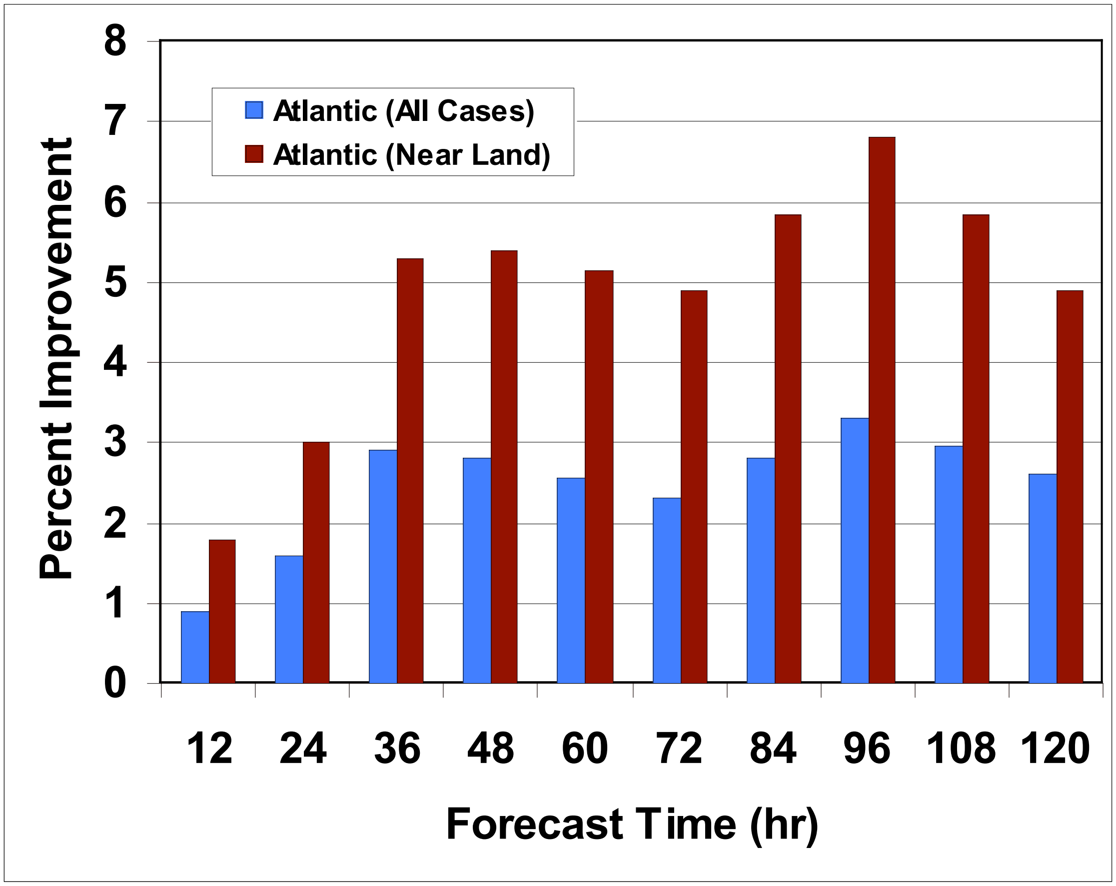

Figure 1. The improvements in the 2001-2006 Atlantic SHIPS forecasts due to the inclusion of the new decay model for the total sample and the sample where the best track position was within 500 km of land.

(2) New method for evaluating vertical shear in SHIPS

The operational SHIPS model averages the winds over an annulus from 200 to 800 km from the storm center for the shear calculation. This large area is used to account for potential differences between the official forecast track (used in SHIPS) and the track of the storm in the NCEP GFS model. In order to test smaller areas, the storm circulation must first be removed.

Two methods for removing the storm circulation were tested. The first involves removing the symmetric storm circulation, and the second involves a “Laplacian filter” where the wind fields inside a specified radius centered on the model storm location are replaced by solutions of $(u_{xx}+u_{yy}) = (v_{xx}+v_{yy}) = 0$. Results showed that the Laplacian filter method was inferior because the procedure does not remove the linear horizontal shear component of the vortex circulation, and it is not easy to distinguish between areas of cyclonic and anticyclonic rotation for the filtering. However, it was found that the Laplacian filter works well for scalar fields such as temperature and moisture, although that capability is not currently needed by SHIPS. Both options were implemented in the SHIPS code, but only the version that removes the symmetric circulation is utilized.

The most difficult aspect of the circulation removal method was determining the storm center in the GFS analysis. After considerable experimentation, a method was developed that starts with the initial location from the NHC t=0 forecast position. This position is adjusted within a specified search radius to find the location that maximizes the symmetric 850 hPa tangential wind averaged from 0 to 600 km. This position is then used for the t=0 shear calculation and as a first guess for the vortex position in the 6 hour forecast field from the GFS, and so on. Quality control checks were implemented to make sure that the vortex moves at a speed that is smaller than the maximum observed in the best track, where the upper limit is a function of storm latitude. The quality control also requires a minimum value of the cyclonic tangential wind. If either of the quality controls fail, the vortex is not removed for that forecast time onward. This method was found to be robust and often tracked the vortex longer than the operational vortex tracker implemented by NCEP.

Once the vortex center is determined, the mean symmetric tangential and radial winds as a function of radius are calculated at each vertical level in the model. The radius where the circulation first becomes cyclonic is determined (moving inward from a 1000 km radius). The symmetric radial and tangential winds from this radius inward are then subtracted from the GFS fields. The outer radius for the subtraction nearly always decreases with height, so that there is greater modification at 850 hPa than 200 hPa. Figure shows an example of the vortex removal at both levels. After the symmetric vortex removal at the GFS storm position, the vertical shear is calculated at the NHC official forecast position. Because the GFS vortex is removed, smaller averaging radii can be used. For the SHIPS tests, the shear was calculated from 0 to 500 km from the storm center, rather than the 200 to 800 km annulus used in the operational version of SHIPS. The dependent results showed that the new shear was better correlated with the intensity change than the old version.

Because the 0 to 600 km GFS vortex circulation is calculated as part of the vortex removal process, it was also tested as a predictor. It was found that the time tendency of the GFS vortex circulation was a significant predictor of intensity changes. Thus, the GFS vortex circulation parameter was added as a new predictor.

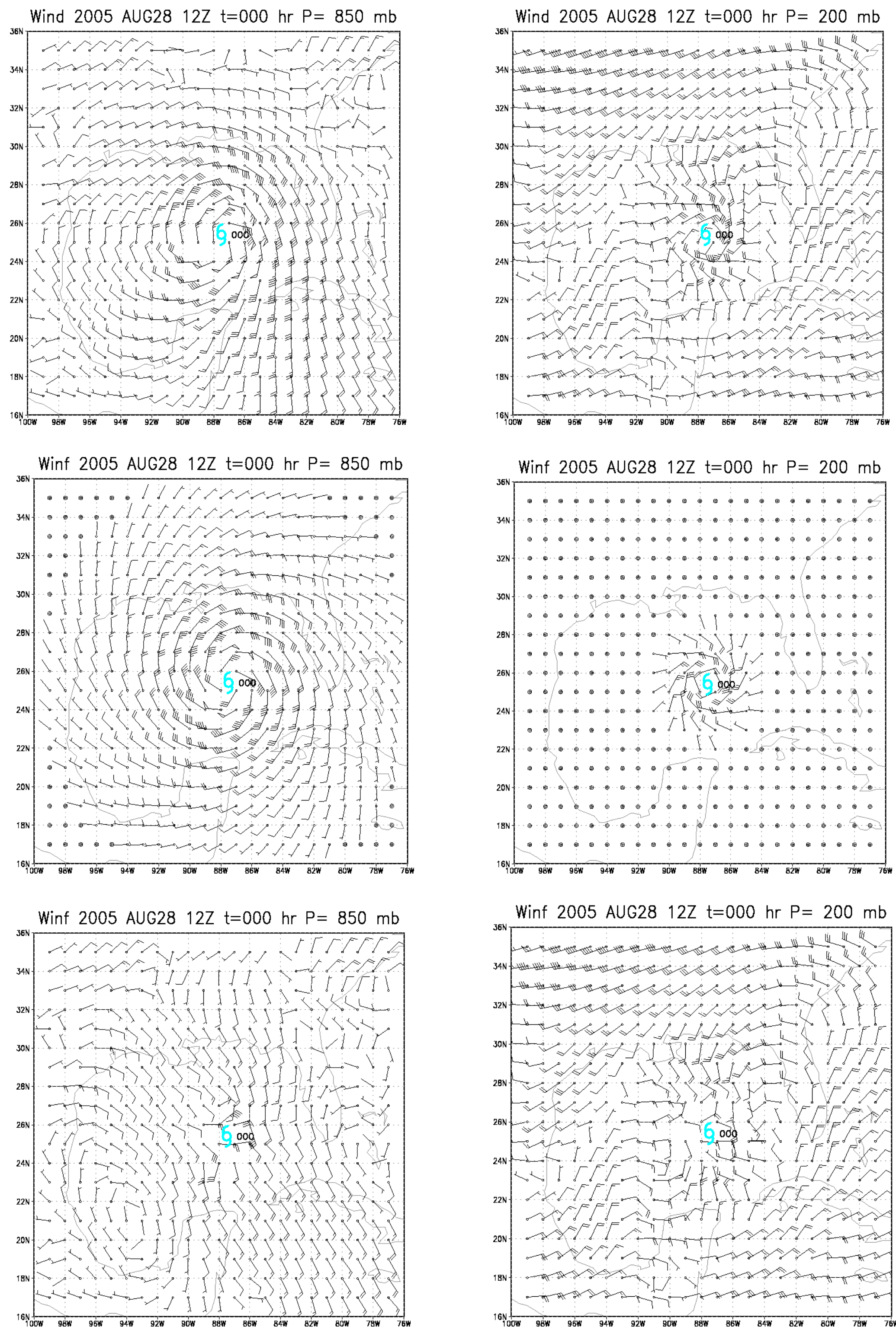

Figure 2. The 850 hPa (left column) and 200 hPa (right column) wind for hurricane Katrina at 12 UTC on 28 August 2005. The top row is the total wind field, the middle row is the symmetric circulation that is removed and the bottom row is field after the vortex is removed.

A parallel version of SHIPS with the new shear predictor with the GFS vortex removed and the smaller averaging area and the GFS vortex predictor was implemented in real time beginning in September of 2006. However, the Atlantic season ended very early, so very few forecast cases were obtained. To better test the new method, all the forecasts from the 2004-2006 seasons were rerun with the modified model and compared with the reruns of the operational version of SHIPS. The same information was input to both versions to allow for a fair comparison. Figure 3 shows the percent improvement with the new shear and GFS vortex predictor for this sample. The new version provided modest improvements in both basins at all forecast intervals. Because of this improvement in a test with a very large sample size, the PIs opinion is that the new version of SHIPS is ready for final operational approval.

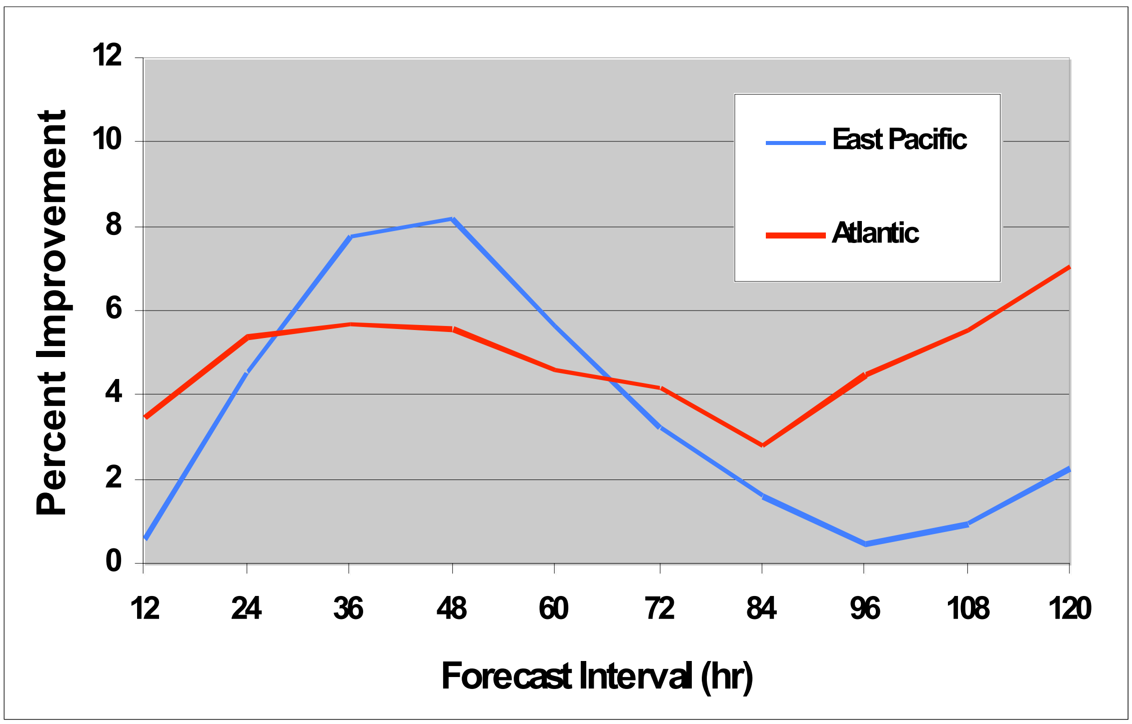

Figure 3. The percent improvement of the experimental SHIPS forecasts with the modified shear and the new GFS vortex variable compared to the operational version of SHIPS for all cases from reruns of both versions of the model for the entire 2004-2006 sample. The reruns of both versions used the same input.

(3) Improved Rapid Intensity Index

J. Kaplan visited CIRA in April of 2006 to finalize the discriminant analysis (DA) version of the RII. The DA software available from the IMSL library was adapted to the RII development code and the performance relative to the operational RII was evaluated for the dependent sample. In the operational RII, the seven scaled inputs are equally weighted, while the DA chooses optimal weights that best separate the rapid intensifying cases from the non-rapid intensifiers.

The DA version of the RII was run in real-time in parallel with the operational version during the 2006 season. The Brier Skill Score (BSS) relative to a climatological rapid intensity probability for the operational and DA RII were calculated for the independent samples, as shown in Fig. 4. Results show that the DA version for the east Pacific had a higher BSS than the operational version, but in the Atlantic, the DA version had a lower skill score. The east Pacific had 45 synoptic times when rapid intensity occurred. However, in the Atlantic, there were only 11 cases, which is much lower than average. When the sample is this small, the BSS calculation is very unstable and can be strongly influenced by just a few cases. Thus, there were not enough cases to properly evaluate the DA version of the RII in the Atlantic in 2006.

In preparation for use during the 2007 Hurricane Season, the RII was re-derived using data from the updated 1995-2006 SHIPS developmental database. The predictors used to re-derive the 2007 version of the RI index were the same as those used in the 2006 version except that the new modified version of the shear that is computed over a smaller area after removing the GFS vortex was used in place of the old shear. Figure 5 shows the Atlantic and E. Pacific dependent results for the aforementioned time period. The figure indicates that the DA version of the RII index was superior to the operational version for both the Atlantic and E. Pacific basins for this time period. The updated 2007 operational and DA versions of the RII were tested and then installed on the IBM in early May 2007 and the RII output from both versions of the index are currently being provided on the SHIPS text files during the 2007 season.

Additional research was conducted to develop RII indices that could be used to estimate the probability of RI for higher intensity thresholds in both the Atlantic and E. Pacific basins. Sensitivity tests conducted while developing these experimental RI indices showed that superior skill could be obtained by first eliminating cases from the developmental sample that either had potential intensities that were below the specified RI threshold or predictor magnitudes that were outside the observed range of values of the RI cases. These tests also indicated that utilizing slightly different GOES predictors yielded improved RII results. Figure 6 shows the skill of both the current and experimental DA versions of the RII for both the Atlantic and E. Pacific basins. The figure indicates that the experimental version of the RII outperforms the current version in both basins. It also suggests that it might be possible to provide skillful RII forecasts for RI thresholds that are higher than the presently used value of 25 kt in future seasons. However, additional tests with independent data will be required to determine if this is indeed feasible. This study of the RII extensions was not part of the original proposal, but was performed at no cost to the JHT, and may lead to further improvements to the RII.

In summary, the DA version of the RII was superior to the current operational version in the 2006 independent tests for the east Pacific, and in the much larger dependent sample (1995-2006). The DA version was also superior in the Atlantic dependent sample (1995-

2006), but not in the independent tests in 2006. However, the 2006 Atlantic sample had a very small number of RII cases, which made the evaluation of a probabilistic forecast difficult. The code is set up to run both versions in 2007. Thus, the PIs opinion is to postpone an operational decision on the new RII until one more year of confirmation with independent forecasts is available following the 2007 season.

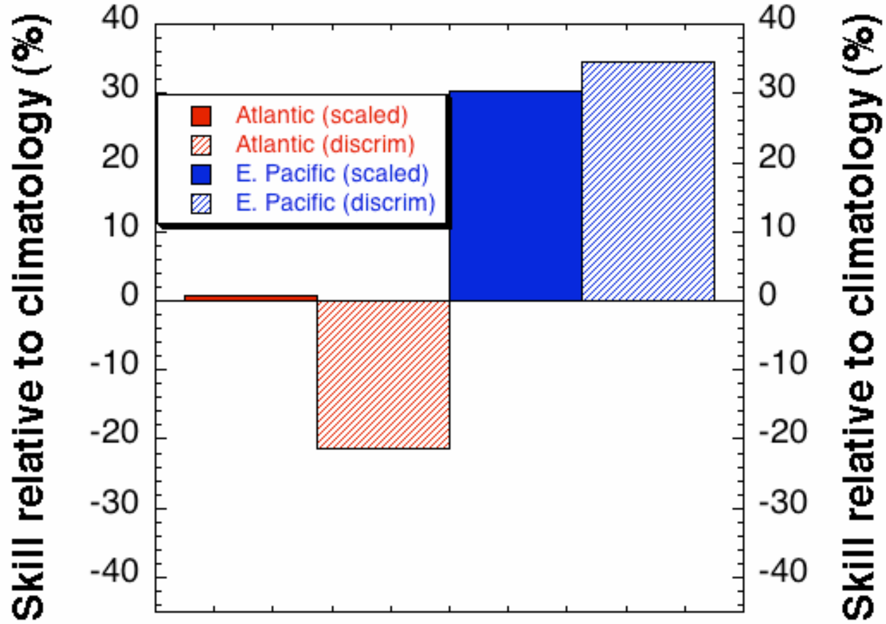

Figure 4. The Brier skill score for the independent RII forecasts from 2006 with the operational (solid) and DA (hatched) versions of the RII for the Atlantic and East Pacific basins.

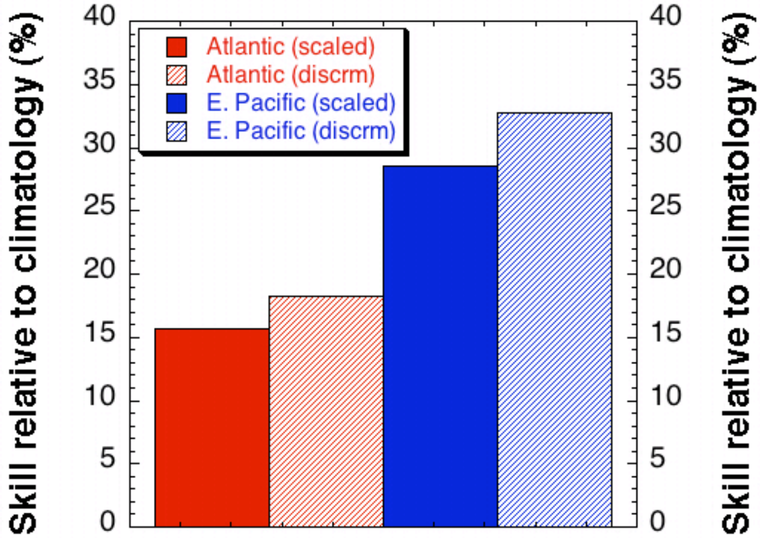

Figure 5. *The Brier skill of the operational (solid) and DA (hatched) RII forecasts for the dependent 1995-2006 Atlantic and East Pacific samples.*

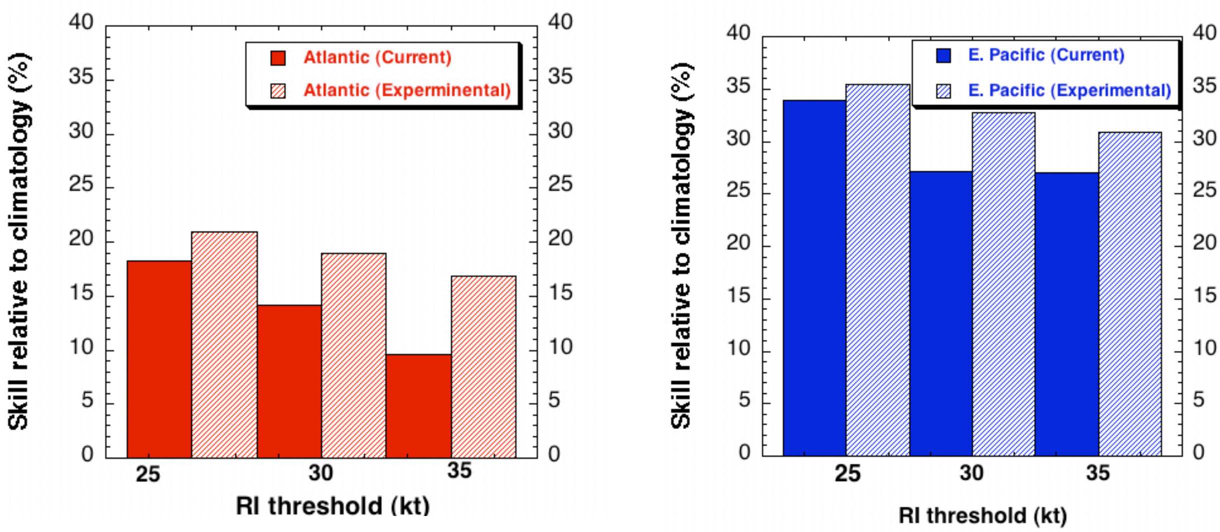

Figure 6. Brier skill of the DA version of the index obtained using the current (solid) and experimental (hatched) versions of the RII for the Atlantic and E. Pacific basins. Results are shown for the 25, 30, and 35 kt RI thresholds.

3. Things not Completed/Pending Items:

This project is complete. The new decay model and new shear calculate are implemented in the SHIPS model on the NCEP IBM and have been running during the 2007 season. Both versions of the Rapid Intensity Index (the previous operational version and the discriminant analysis version) are running during the 2007 season to provide one additional year of data for confirmation of the improvements.

4. Things that did not succeed.

All three parts of this project were successful.

References

DeMaria, M., J.A. Knaff, and J. Kaplan, 2006: On the decay of tropical cyclone winds crossing narrow landmasses, *J. Appl. Meteor.*, **45**, 491-499.