Joint Hurricane Testbed Semi-Annual Report for Year 2
September 1, 2006-February 28, 2007

Project title: *Improved Statistical Intensity Forecast Models*
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Project dates: September 2005-May 2007
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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. The timeline and deliverables for year 2 of this project are listed below in the Appendix.

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. 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 is 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 that 1% at all forecast intervals and were not statistically significant.

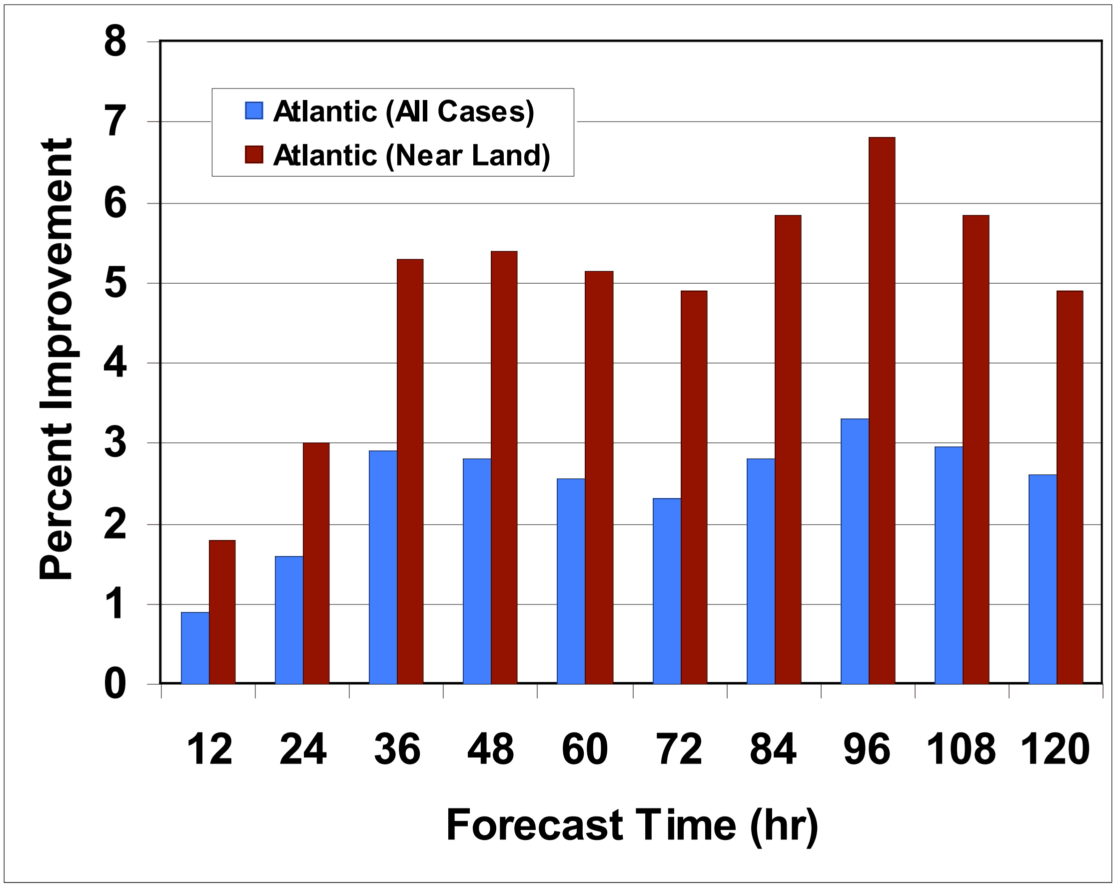

Figure 1. The improvements in the 2001-2006 Atlantic SHIPS forecasts due to the inclusion of the new decay model for the total sample and the sample where the best track position was within 500 km of land.

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 wind as a function of radius is calculated at each vertical level in the model. The radius where the circulation first becomes cyclonic is determined (to a maximum of 1000 km). The symmetric circulation from this radius inward is 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. It was also found that the 850 hPa environmental vorticity predictor (Z850), which uses a 0 to 1000 km averaging area has become problematic in the newest version of the GFS with higher resolution. Because the tropical cyclones are better represented, Z850 sometime represents the environment, and sometimes the storm itself. Because of this inconsistency, Z850 was eliminated in the test version of the model in favor of the new GFS vortex predictor, which always measures the storm circulation.

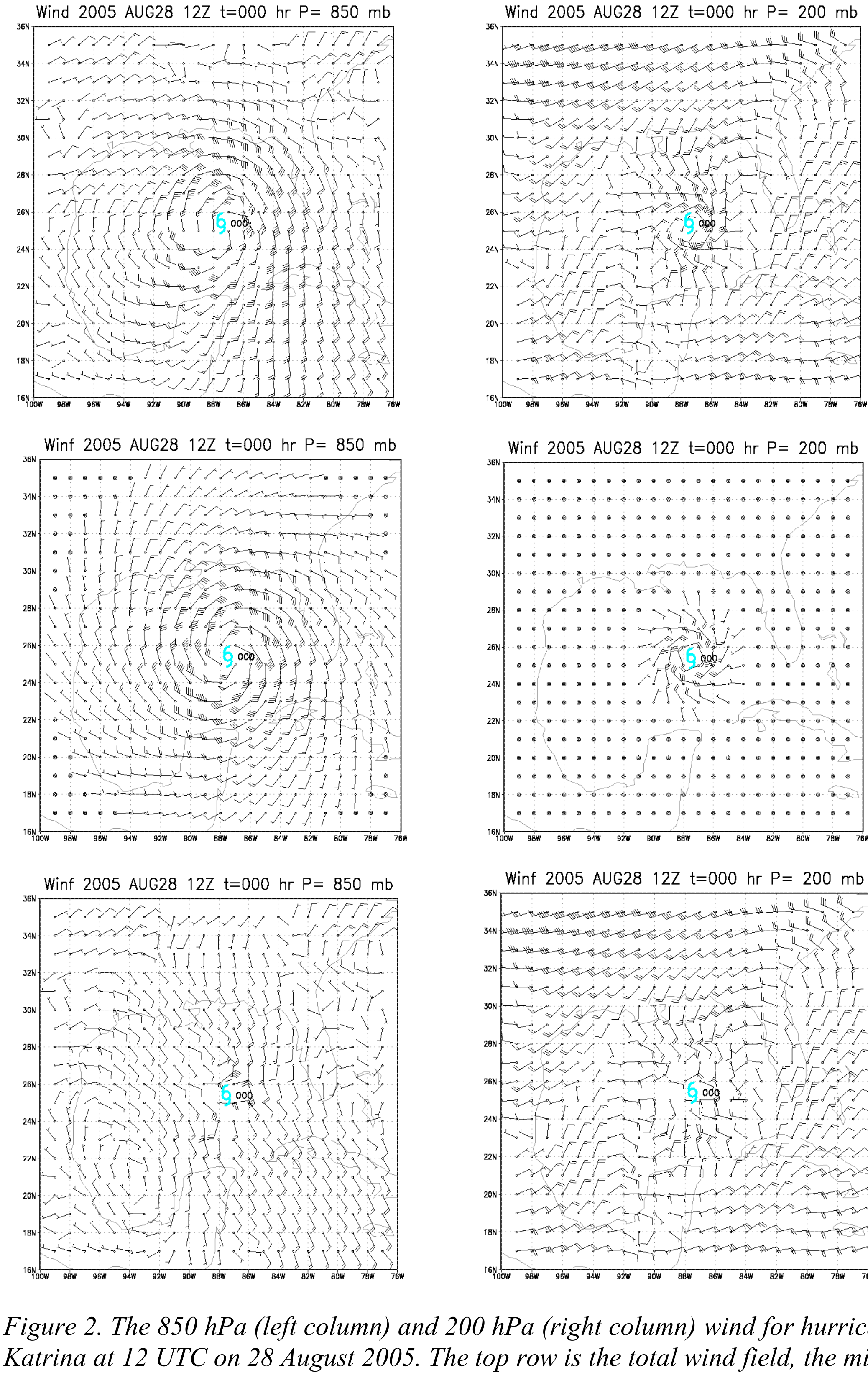

Figure 2. The 850 hPa (left column) and 200 hPa (right column) wind for hurricane Katrina at 12 UTC on 28 August 2005. The top row is the total wind field, the middle row is the symmetric circulation that is removed and the bottom row is field after the vortex is removed.

A parallel version of SHIPS with the new shear predictor (in place of the operational one) and GFS vortex predictor (in place of Z850) was implemented in real time beginning in September of 2006. However, the Atlantic season ended very early, so very few forecast cases were obtained. For this reason, all of the 2006 cases (Atlantic and east Pacific) were re-run after the season, with fully operational input. In doing the re-runs, a minor problem with the GOES data was identified and corrected. A more stringent GOES quality control procedure was implemented, which will be included in the operational version of SHIPS for 2007.

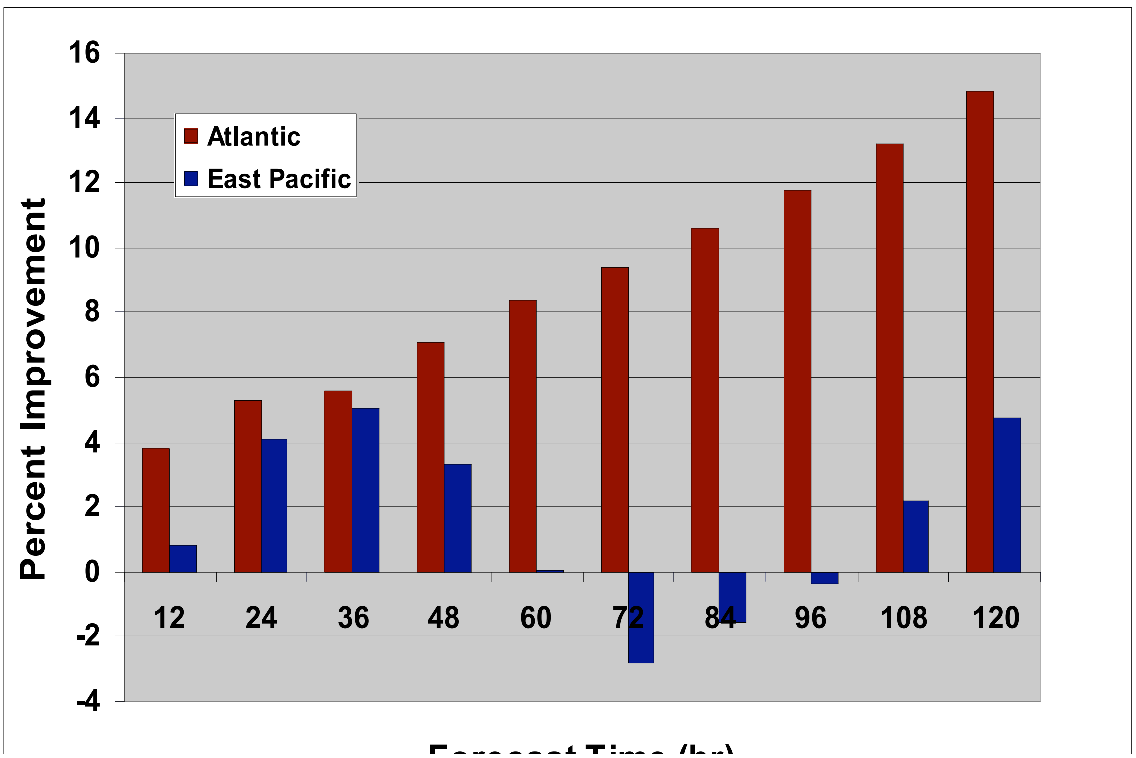

Figure 3. The percent improvement of the experimental SHIPS forecasts with the modified shear and GFS vortex variable in place of Z850 relative to the operational version of SHIPS. All cases from the 2006 season were included.

Figure 3 shows the percent improvement of the test version of SHIPS relative to the operational version. The results in the Atlantic are very positive, with improvements of up to 15% at the longer forecast times. The improvements at 24-120 hours were statistically significant at the 90% level. The results in the east Pacific were more mixed, although the improvements at 24 and 36 hours were also statistically significant at the 90% level. The differences between the experimental and operational SHIPS model for the east Pacific were not statistically significant at the longer times, so the results are considered neutral there.

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 (relative to a climatological rapid intensity probability) for the operational and DA RII were calculated for the dependent sample, as shown in Fig. 4. Results show that the DA version for the east Pacific had a higher Brier skill score 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 this year.

To get a feel for the comparison of the two methods with a larger sample, all of the cases from 2003-2005 seasons were re-run in dependent mode. This sample included 115 RI cases in the Atlantic and 59 in the east Pacific. The Brier skill scores for the DA and operational versions for this larger sample are shown in Fig. 5. The DA version was superior in both basins for this more representative sample. The 2006 cases will be added to the sample and the weights will be re-derived. The methods can again be compared for independent cases in 2007.

3. Things not Completed/Pending Items:

This project is nearly complete. The remaining task is to present the results at the 2007 IHC and finalize SHIPS and the RII for the 2007 hurricane season, and for TPC to make a final decision on operational transition.

4. Things that did not succeed.

The new decay model and shear results are very positive and will likely be included in the 2007 version of SHIPS, pending approval from TPC. One more year of evaluation of the discriminant analysis version of the rapid intensity index is needed in 2007 to confirm the positive results for the east Pacific dependent and independent samples, and the Atlantic for the dependent sample.

5. Plans for the remainder of Year 2

The project will continue according to the schedule listed in the Appendix with the final report completed in August of 2007.

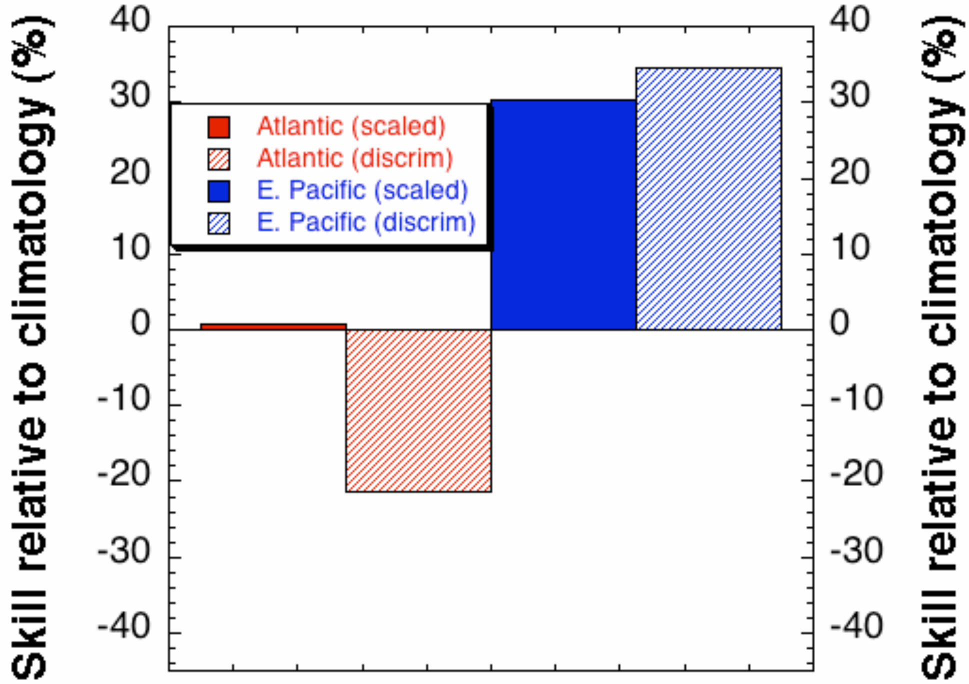

Figure 4. The Brier skill score for the independent RII forecasts from 2006 with the operational (solid) and DA (hatched) weights for the Atlantic and east Pacific.

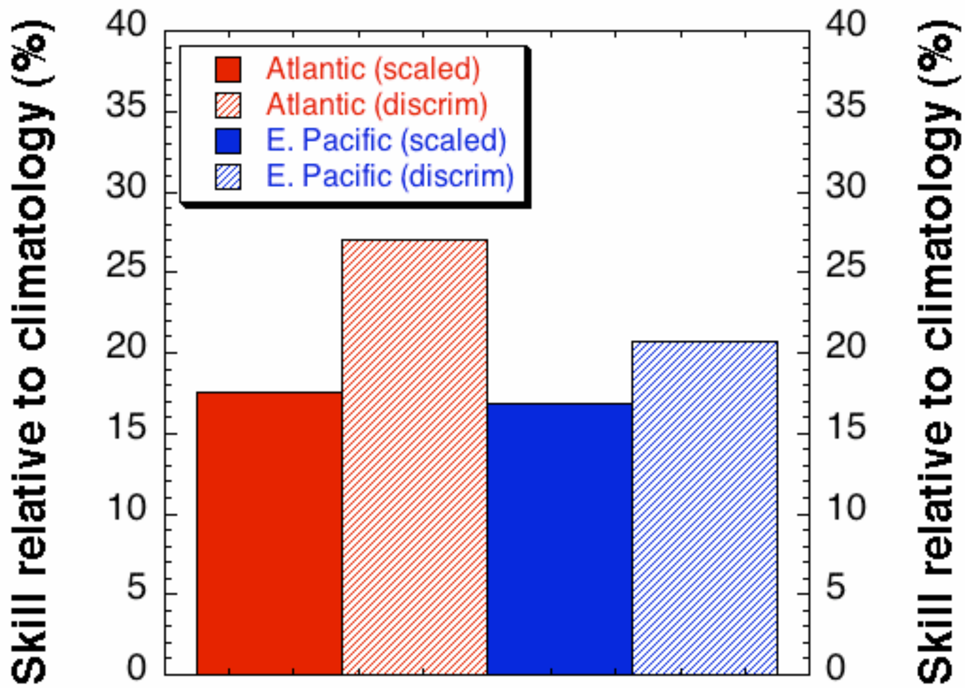

Figure 5. The Brier skill score for the dependent RII forecasts from the 2003-1005 seasons with the operational (solid) and DA (hatched) weights for the Atlantic and east Pacific.

Appendix

Year-two project timeline and deliverables:

Jun 2006 - Begin real-time testing of discriminant analysis version of RII
Sep 2006 - Begin real-time testing of parallel version of SHIPS with optimized shear
Jan 2007 – Perform verification and analysis of parallel SHIPS and RII and adjust code accordingly
Feb 2007 – Mid-year report due
Mar 2007 – Report progress at the IHC
May 2007 – Finalize SHIPS and RII for 2007 season pending JHT/TPC feedback
Aug 2007 Provide year 2 final report