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Incorporation of Ocean Heat Content and Storm-Scale Predictors in the
Statistical Hurricane Intensity Prediction Scheme (SHIPS)

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Background:

This project is to test an experimental version of the Statistical Hurricane Intensity Prediction Scheme (SHIPS) to determine if predictors from ocean heat content (OHC) analyses and GOES IR (10.7 m) imagery can improve the intensity forecasts.

1. Accomplishments:

The emphasis of the first year of the project was on the development of the databases of GOES imagery and OHC analyses from satellite altimetry data to test as predictors in SHIPS. In cooperation with Michelle Mainelli of TPC and Nick Shay of UM/RSMAS, the OHC analyses were obtained for a sample of Atlantic cases back to 1995, for storms that were west of 50^{o}W. The database of GOES IR imagery for Atlantic and east Pacific cases back to 1995 was extracted from the CIRA archives. Because the number of cases with this new data was less than half the size of the full SHIPS sample, a perturbation version of the model was developed. The prediction is first developed with the full sample, but without the OHC and GOES predictors. Then, a second regression is performed to try to predict the residuals from the first regression using the new input.

A statistical analysis of the Atlantic sample from 1995-2001 showed that the following three parameters were statistically significant predictors of the residuals from the full SHIPS model.

1. Standard deviation of GOES IR brightness temperature relative to the azimuthal mean, averaged from r=100 to 300 km. The actual predictor is the standard deviation times the initial intensity. Except for very weak systems, lower standard deviation is correlated with intensification.

2. The percent of GOES IR pixels colder than -20^{o}C, within an annulus from r=50 to 200 km. Out to 84 h, a higher percentage of cold pixels is correlated with intensification.

3. The ocean heat content (OHC) in KJ/cm2, averaged along the storm track. The actual predictor is a "threshold" version of OHC. The threshold predictor is (OHC-50), where the value is set to zero if it is negative. The threshold predictor explained much more variance in the SHIPS corrections than the OHC by itself. The net result is that the OHC does not change the SHIPS forecast very much until it exceeds 50. When it reaches 50, it can significantly modify the forecast. OHC above 50 is correlated with intensification.

For the east Pacific version of SHIPS, the first two parameters above were significant predictors of the residuals. OHC analyses were not available in the east Pacific.

The next step was to make the OHC and GOES predictors available in real-time on the NCEP IBM. NESDIS maintains a real-time database of GOES imagery on the IBM, which was utilized for the real-time prediction. M. Mainelli and Nick Shay implemented a real-time version of the OHC analysis at TPC, which covers the entire Atlantic basin. Nick Shay's contributions were supported by USWRP funding under a separate project. These analyses are updated daily and then sent to the IBM for inclusion in SHIPS.

The development of the parallel version of SHIPS for the Atlantic basin with the OHC and GOES data was completed and installed on the NCEP IBM beginning in August 20, 2002. Three short-lived Atlantic storms occurred before this date, but most of the cases occurred afterwards. The parallel and operational versions were run for the rest of the Atlantic season. All of the input for the model was saved, so that re-runs could be performed after the season to help separate the relative contributions from the GOES and OHC predictors.

After the season was over, the operational and parallel versions of SHIPS were compared as shown in Figure 1. The sample includes all real-time forecasts beginning with tropical storm Dolly, and contains 238 cases at 12 h, decreasing to 118 cases at 120. The forecasts from both versions of SHIPS were compared to the NHC best track intensities, and the sample was determined using NHC's new verification runs (all tropical cyclones, including depressions, as well as subtropical storms are included). The version of SHIPS with the correction for decay over land was used in this evaluation, since many of storms in 2002 were affected by land.

Figure 1 shows that the parallel version of SHIPS improved the real-time forecasts (reduced the mean errors) by a maximum of about 5% at 48 h. This result is consistent from what was expected from the dependent sample. The improvements at 12-36 h are statistically significant at the 90% level. Thus, the new predictors improve the forecasts out to 72 h. The parallel versions of SHIPS had larger errors at 96-120 hr, although the differences were not statistically significant due to the fairly small sample sizes.

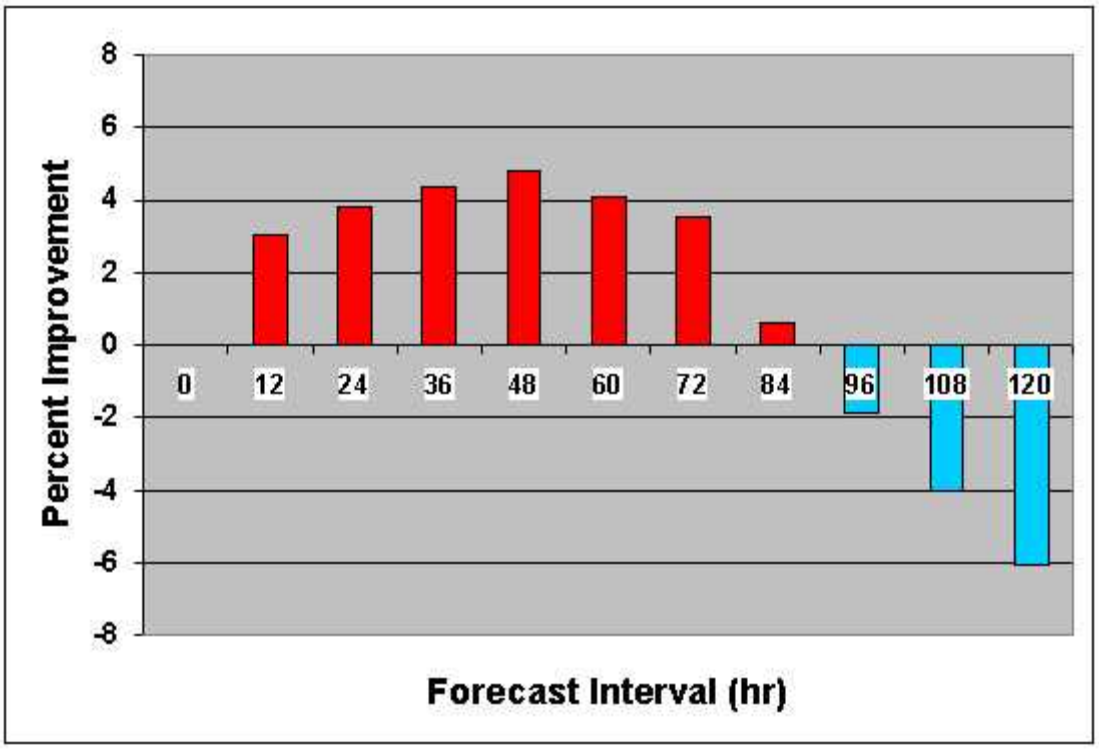

Figure 1. The percent improvement (reduction in mean intensity error) of the parallel version of SHIPS with the GOES and OHC predictors, relative to the operational version for real-time Atlantic forecasts from the 2002 hurricane season.

A parallel version of SHIPS for the eastern Pacific was also developed, but was not run in real time. The OHC analyses are only available in the Atlantic basin, so the east Pacific parallel version of SHIPS only includes additional predictors from the GOES data. All of the input for SHIPS was saved, and the forecasts for all east Pacific cases were re-run. The input for the re-runs is identical to what was available in real time (operational tracks, positions, and forecast fields were used).

Figure 2 shows the improvement of the parallel version of SHIPS relative to the operational version for the east Pacific 2002 re-runs. The sample includes 268 cases at 12 h, decreasing to 58 cases at 120 h. The verification rules were the same as described above for the Atlantic. Figure 2 shows that the parallel version of SHIPS improved the forecasts by up to 8% at 12-72 hr. These improvements were statistically significant at the 90% level at 12-72 hr. Similar to the Atlantic, the parallel SHIPS tended to degrade the forecasts at 96-120 h, although, again, the differences were not statistically significant due to the small sample sizes.

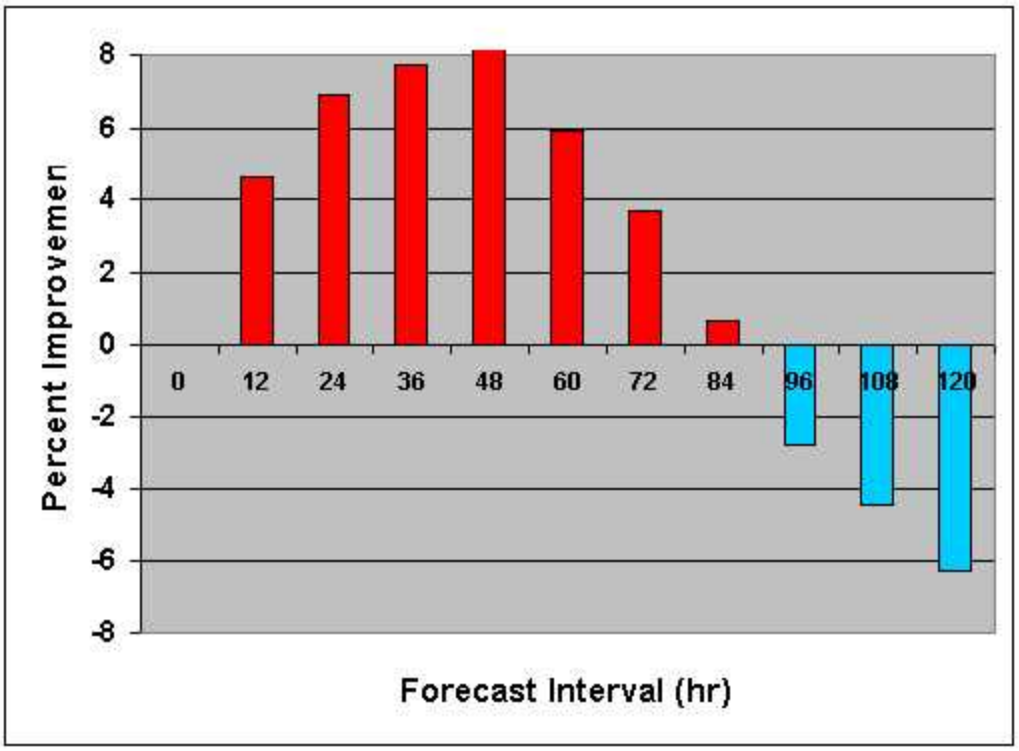

Figure 2. The percent improvement (reduction in mean intensity error) of the parallel version of SHIPS with the GOES predictors, relative to the operational version for post-season forecasts (with operational input) from the 2002 east Pacific hurricane season.

These results indicate that the predictors from the satellite data improve the SHIPS forecasts out to 72 in the Atlantic and east Pacific basins. The improvements are larger in the east Pacific, despite the fact that only GOES data was available for that basin.

Following the 2002 season, two additional versions of SHIPS were developed that included only the OHC input and only the GOES input. Figure 3 shows the percent improvement of the forecasts with these two versions of SHIPS and the version with both effects included, for the re-runs of the 2002 Atlantic forecasts. The sample sizes for these re-runs were slightly larger than for the operational runs since the first three storms of the 2002 were also included. Figure 3 shows that the percent improvement with the GOES and OHC both included was larger than the sum of the improvement with each effect by itself. This result suggests that there may be some interaction between the effects being measured by these input parameters. Figure 3 also shows that the degradation at day 4 and day 5 is due to the inclusion of the GOES data. This is not surprising because the GOES predictors are available only at the beginning of the forecast period, and should be less useful for the prediction at the longer time periods.

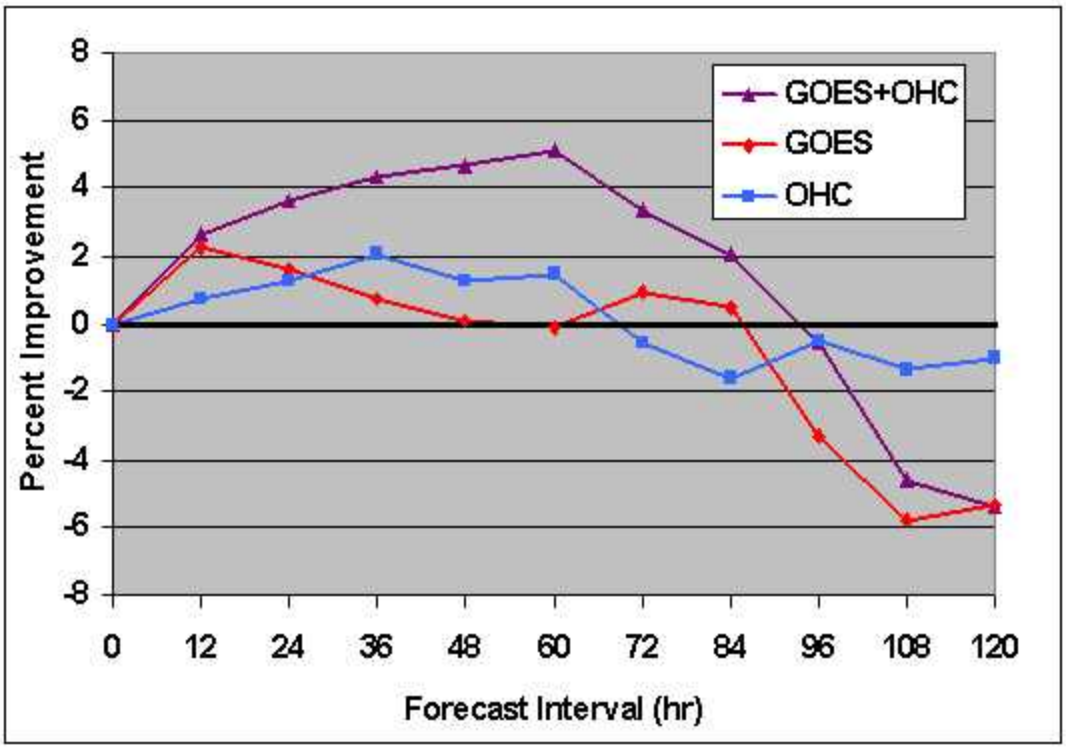

Figure 3. The percent improvement (reduction in mean intensity error) of the parallel version of SHIPS with the GOES predictors, OHC predictors and both GOES and OHC predictors, relative to the operational version for post-season forecasts (with operational input) from the 2002 Atlantic hurricane season. The sample size at each forecast period is shown along the bottom of the diagram.

The above results were presented at the Interdepartmental Hurricane Conference in the Spring of 2003, and were discussed with the TPC project representatives. Although the results are generally encouraging, there was some degradation in the forecasts at the longer time periods in both basins. Thus, it was decided not to make the SHIPS model with the GOES and OHC data operational for the 2003 season. Instead, the parallel version of SHIPS with the OHC and GOES data is again being run during 2003, and the results will be compared to the operational version of SHIPS following the 2002 season. A final decision on whether to implement the version with the GOES and OHC data will be made following the 2003 season.

In preparation for the 2003 season, both versions of the SHIPS model were re-derived with the 2002 cases included. In addition, a number of changes were made to the operational version of SHIPS to better include atmospheric thermodynamic effects. Because of these changes to the operational version of SHIPS, the effects of the OHC and GOES data on the forecasts may be different than shown for 2002. A careful evaluation will be performed following the 2003 season.

Also for the 2003 season, some re-coding of the model was necessary due to the upgrade of the NCEP computing system. These modifications were completed in time for the

second storms in both the Atlantic and east Pacific seasons, when the new IBM finally became available. The code is currently configured with a simple switch so that it will be a trivial task to make either version of SHIPS operational, when TPC makes its final determination.

2. Things not Completed/Pending Items

As described above, all of the technical aspects of the project were completed. The remaining task is to make a decision on the operational implementation. If the results of the 2003 season are ambiguous, another option would be to continue the parallel runs for 2004. Even though the project is completed, project personnel will continue to work with TPC on future improvements to the SHIPS model.

3. Things that did not succeed

None.