Enhancement of SHIPS Using Passive Microwave Imager Data

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February 2007 Year 2 Semi-Annual Report

1. Summary

Most of the Year 2 activities so far have focused on generating, monitoring, and evaluating the real-time Statistical Hurricane Intensity Prediction Scheme with Microwave Imagery (SHIPS-MI) forecasts. SHIPS-MI forecasts for the Atlantic, Eastern North Pacific, and Central North Pacific were successfully generated at both UAH and NHC (separately) during the 2006 hurricane season. STIPS-MI forecasts for the Western North Pacific were generated at UAH. They were briefly being transmitted to JTWC (via CSU/CIRA), but major changes became necessary in how this was done. These changes and the current status will be described below.

This report will mainly describe verification of the 2006 SHIPS-MI forecasts, in Section 2. SHIPS-MI errors were slightly smaller than those from SHIPS for the Atlantic, and much smaller than those from SHIPS for the Eastern North Pacific. In fact, Eastern North Pacific SHIPS-MI errors were smaller than most guidance and official forecasts. Section 3 will note changes that were made in the implementation of SHIPS-MI and STIPS-MI. Section 4 will cover some miscellaneous items and Section 5 will mention outstanding items for the remainder of the project, and suggestions for the future.

2. 2006 Verification

Forecast evaluation here is based on the SHIPS-MI forecasts that were generated at NHC during 2006. Verification procedures follow the NHC guidelines, using the best track as "truth" and considering all forecast periods where the best track identifies a system as a tropical depression, tropical storm, or hurricane (i.e., including landfalls but excluding extratropical stages). SHIPS-MI forecasts were generated for 77 of 253 Atlantic advisories (30%) and 141 of 385 Eastern North Pacific advisories (37%). SHIPS-MI forecasts were also generated for the Central North Pacific, but the sample size was so small that these are not formally evaluated here. SHIPS-MI was unavailable for roughly two thirds of all advisories because it relies on microwave brightness temperatures from satellites in low earth orbit. If timely satellite data from a recent observation are not available, a SHIPS-MI forecast will not be generated.

By starting with SHIPS predictors and adding microwave data related to inner core latent heating, SHIPS-MI is expected to improve upon SHIPS forecasts at 12-72 hours. The microwave data has little impact beyond 72 hours, and the developmental sample size is small beyond 72 hours. The SHIPS-MI forecasts do not account for inland decay, but this can be handled by adding the difference {Decay SHIPS minus SHIPS}. This is done to produce Decay SHIPS-MI (DSHM) in the verification tables and figures that follow.

a. Atlantic

Mean absolute errors (kt) are shown for Decay SHIPS-MI (DSHM) and other guidance in Table 1. As expected, the errors are smaller for DSHM than for DSHP at 12-72 h. This improvement is maximized at 60 h, with the DSHM errors 1.7 kt (almost 8%) lower than DSHP. However, both DSHM and DSHP performed poorly in 2006 compared to most other Atlantic guidance in Table 1.

Duration	*0*	*12*	*24*	*36*	*48*	*60*	*72*	*84*	*96*	*108*	*120*
DSHM	**2.5**	**6.4**	**9.4**	**13.2**	**16.2**	**20.6**	**23.2**	**25.4**	**23.4**	**21.7**	**21.3**
DSHP	**2.4**	**6.5**	**9.6**	**13.7**	**17.2**	**22.3**	**24.1**	**24.6**	**22.2**	**19.0**	**16.2**
OFCL	***1.8***	6.4	10.4	13.7	15.3		20.7		21.8		17.3
SHF5	2.4	6.4	8.3	***10.2***	***11.2***	***12.8***	***12.9***	***13.7***	***11.3***	***13.0***	***12.4***
LGEM	2.4	***6.4***	***8.1***	11.2	14.2	17.7	19.0	20.1	19.4	17.6	16.4
GFDI	2.8	7.7	9.5	11.4	13.3	16.4	18.3	19.3	20.2	18.5	21.9
NGPI	6.4	11.5	14.5	17.3	18.9	22.4	24.7	27.9	30.1	33.6	34.5
# forecasts	*74*	*70*	*64*	*57*	*54*	*45*	*42*	*36*	*33*	*30*	*26*

Table 1. Atlantic basin 2006 mean absolute errors (kt) for Decay SHIPS-MI (DSHM); Decay SHIPS (DSHP); NHC official forecast (OFCL); SHIFOR 5-Day (SHF5); Logistic Growth Equation Model (LGEM); GFDL Interpolated (GFDI); and NOGAPS Interpolated (NGPI). Errors are taken from the homogeneous set of forecasts (number listed in bottom row) where guidance is available from all these sources. The lowest mean absolute errors at a given forecast duration are marked in bold italics.

Figure 1 shows the individual Decay SHIPS-MI forecasts (blue) and corresponding Decay SHIPS forecasts (red) for each storm. The two guidance products usually agree on the general shape of the intensification or weakening trend, although the magnitude of that trend often differs. It is noteworthy that SHIPS-MI particularly struggled with early season tropical storms such as Chris and Debby, but performed better with subsequent hurricanes such as Florence and Gordon. Errors were also often large for invests, although they have not been formally computed or compared to any other guidance, since SHIPS-MI is not designed to account for invests. The relatively poor performance on the invests and first few tropical storms *may* have contributed to a lack of confidence in SHIPS-MI, although SHIPS-MI did perform well (relative to SHIPS) later in the season. (I personally had the perception that SHIPS-MI had done poorly, until doing this analysis for the season.)

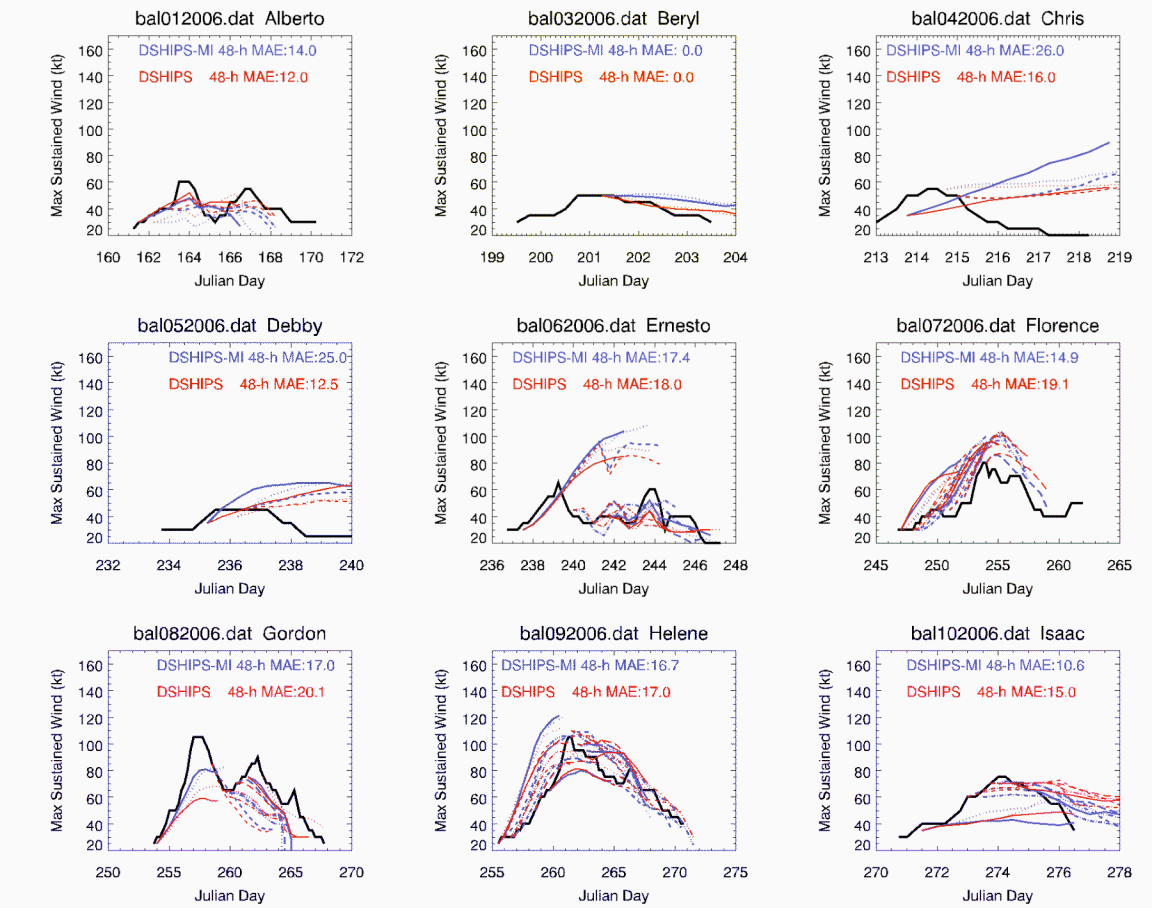


Figure 1. Individual Decay SHIPS-MI and Decay SHIPS forecasts for each 2006 Atlantic basin tropical cyclone. Alternating linestyles are used for forecasts originating at different times. For each DSHIPS-MI forecast (blue), there is a corresponding DSHIPS forecast (red) with the same linestyle. 48-h mean absolute errors are printed for each tropical cyclone, using those forecasts that meet the NHC verification criteria and have guidance available for all products listed in Table 1.

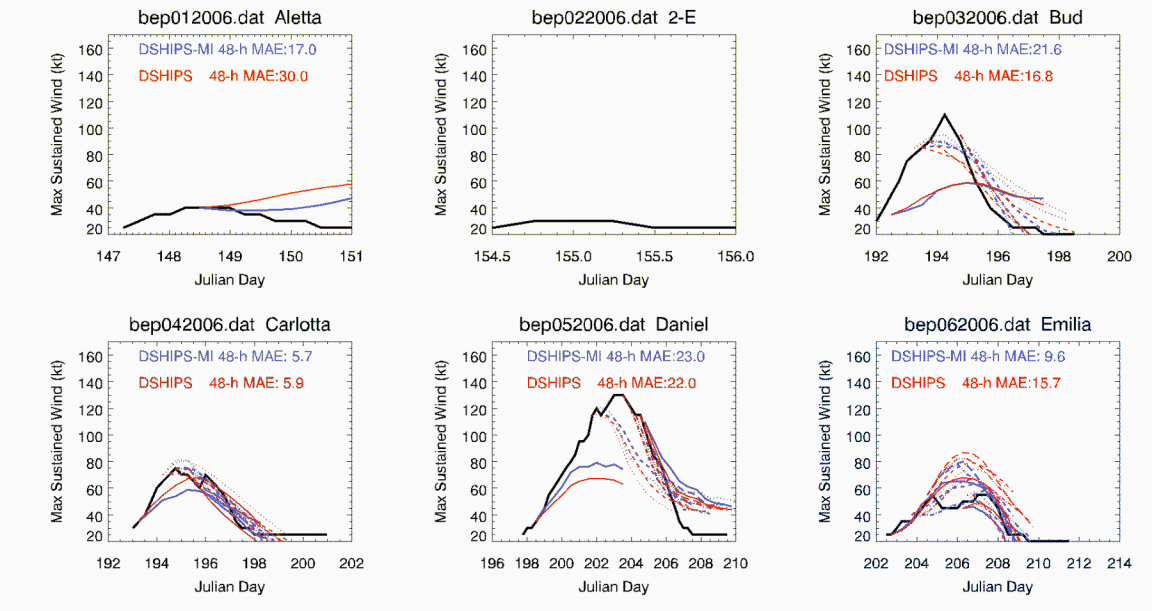
b. Eastern North Pacific

Mean absolute errors (kt) are shown for Decay SHIPS-MI (DSHM) and other guidance in Table 2. DSHM errors are at least 1.3 kt smaller than those from DSHP for all forecast durations from 24-120 h. Among the 0-72 h forecasts where confidence in DSHM is highest, the improvement is again greatest at 60-h (2.6 kt; 16%). The DSHM errors are smaller than those from NHC official forecasts or any of the other guidance in Table 2 at each forecast duration from 24-72 h.

duration	*0*	*12*	*24*	*36*	*48*	*60*	*72*	*84*	*96*	*108*	*120*
DSHM	**2.5**	**8.5**	***11.6***	***12.3***	***13.1***	***13.6***	***15.1***	***15.5***	**15.2**	**18.0**	**18.8**
DSHP	**2.5**	**8.5**	**12.9**	**14.1**	**15.3**	**16.2**	**17.2**	**17.6**	**18.4**	**20.5**	**20.6**
OFCL	***2.0***	***7.4***	11.8	13.0	14.0		17.3		15.6		17.2
SHF5	2.5	9.4	13.4	14.5	16.6	18.3	19.0	19.2	19.2	18.9	20.8
LGEM	2.5	8.9	12.9	13.2	14.8	15.8	16.6	***15.5***	***14.8***	***16.2***	16.6
GFDI	3.0	9.9	13.5	14.8	16.9	19.4	23.0	20.1	18.7	16.5	***15.8***
NGPI	5.7	13.4	19.0	23.1	26.8	30.8	33.3	30.4	27.3	25.4	26.4
# forecasts	*132*	*119*	*105*	*93*	*83*	*66*	*56*	*50*	*42*	*31*	*25*

Table 2. As in Table 1, but for Eastern North Pacific basin 2006 mean absolute errors (kt).

Figure 2 shows the individual Decay SHIPS-MI forecasts (blue) and corresponding Decay SHIPS forecasts (red) for each storm. As in the Atlantic, the general shape of the intensification or weakening trend is usually similar for both products. The difference in magnitude of the forecasts is greater in the Eastern North Pacific than the Atlantic. There are some examples of SHIPS-MI substantially improving the forecast for initial intensification (e.g., Daniel, Hector) and other examples where SHIPS-MI improves the forecast rate of weakening (e.g., Hector, John). Another interesting case is Tropical Storm Emilia, which both SHIPS-MI and SHIPS wanted to make a hurricane. Despite consistently over-forecasting Emilia's intensification, SHIPS-MI was more restrained (and more accurate) than SHIPS in this case.



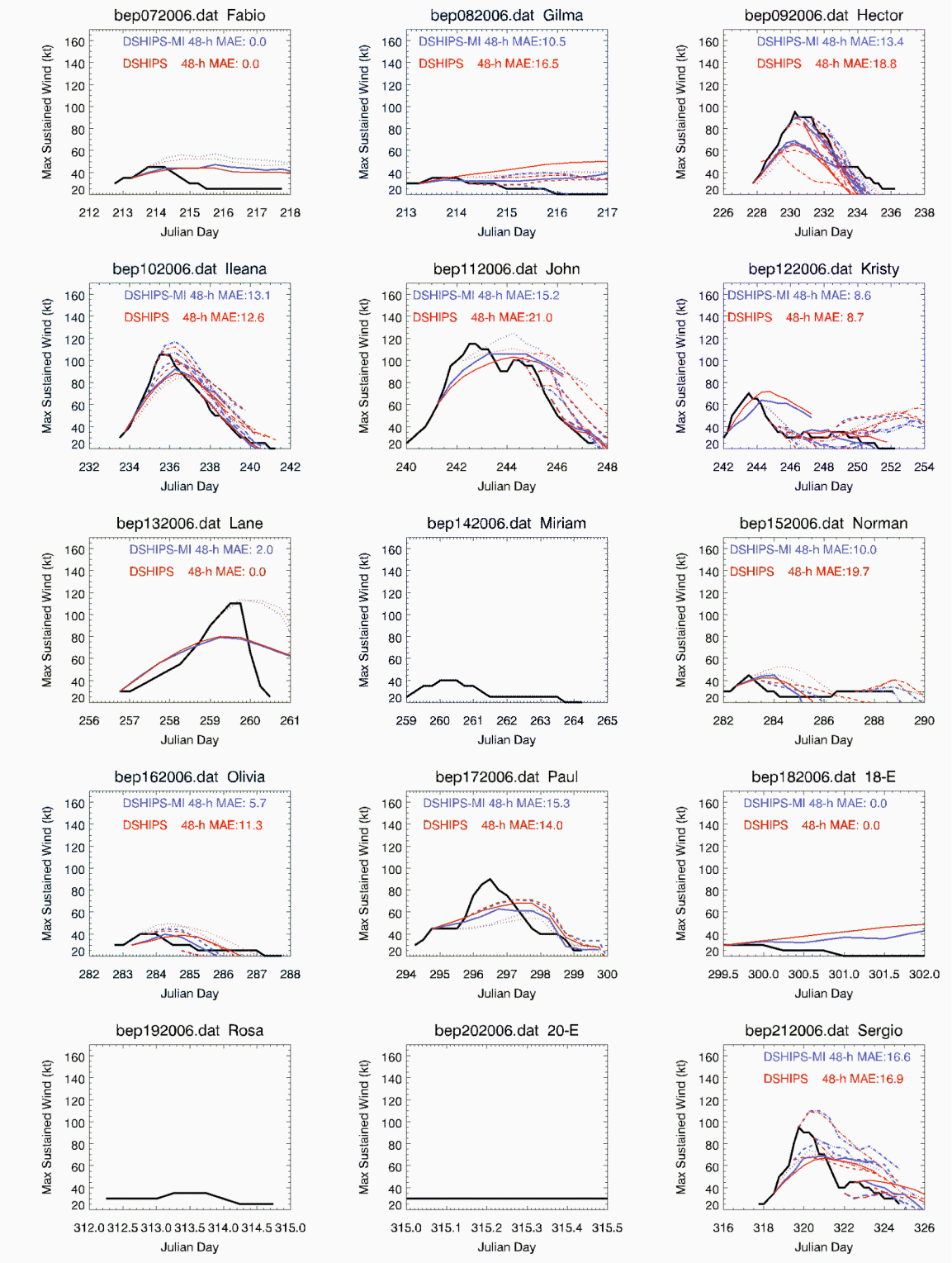


Figure 2. As in Figure 1, but for 2006 Eastern North Pacific basin tropical cyclones.

It should be noted that the Eastern North Pacific version of SHIPS-MI includes two non-microwave terms that are not included in SHIPS ({Latitude} and {200 hPa Divergence}) and excludes two that are included in SHIPS ({Pressure of the Steering Level} and {Initial Intensity

times Persistence}). These changes alone account for some of the improvements from SHIPS-MI compared to SHIPS. They could be incorporated into the Eastern North Pacific SHIPS, likely improving the forecasts even when microwave data are not available.

3. Procedural changes since July 2006

SHIPS-MI generally ran smoothly for the Atlantic, Eastern North Pacific, and Centtral North Pacific basins at NHC. There were some relatively minor software revisions, either aimed at preventing the occasional crash or making the source code more clean and robust. Some of these revisions were inititiated by NHC (Alison Krautkramer), some by UAH. The biggest glitch was the temporary loss of access to AMSR-E data in August and September, but this was later resolved.

STIPS-MI for the Western North Pacific was run only at UAH. Output in the ATCF format was ftp'd to CSU/CIRA, and beginning in July this output was forwarded to JTWC by CSU/CIRA. The STIPS-MI forecast generation process began with STIPS large-scale diagnostic files being ftp'd from JTWC to UAH. Unfortunately, JTWC stopped producing these files in late July. Coordination with Buck Sampson at NRL-Monterey eventually led to a solution where UAH ftp's an ensemble of large-scale diagnostic files from NRL, then computes STIPS-MI for each member of the ensemble, then ftp's the STIPS-MI outputs back to NRL. For this process to have any chance of yielding STIPS-MI forecasts that are available during the operational forecast cycle, it requires that six hour old forecast inputs are used. Together with the small impact of microwave data in STIPS-MI, it is unlikely that this will yield useful forecasts for the Western North Pacific.

After those issues with the Western North Pacific were mostly resolved, a new set of issues arose with Super Typhoon Ioke (01C). Many aspects of the SHIPS-MI and STIPS-MI scripts are governed by the basin identified in the tropical cyclone's name. Ioke retained the identifier 01C after crossing from the Central Pacific to Western Pacific, and this led to a long chain of debugging issues. All the issues were apparently resolved before Ioke's demise, and the software should now be robust for the next time this happens.

4. Miscellaneous

An interactive web page was completed, allowing users to manipulate the inputs to any SHIPS-MI forecast. Separate pages for each basin are located at
http://nsstc.uah.edu/shipsmi/Atlantic/shipsmi.cgi
http://nsstc.uah.edu/shipsmi/Pacific/EPACshipsmi.cgi
http://nsstc.uah.edu/shipsmi/CentralPacific/CPACshipsmi.cgi
The user has the ability to type in new values for any predictor, hit `submit`, then see the resulting new SHIPS-MI forecast and the original SHIPS-MI forecast. This is not limited to changing the microwave predictors, but can be used to change any of the inputs (e.g., shear, sea surface temperature, etc.). An example is shown in Figure 3.

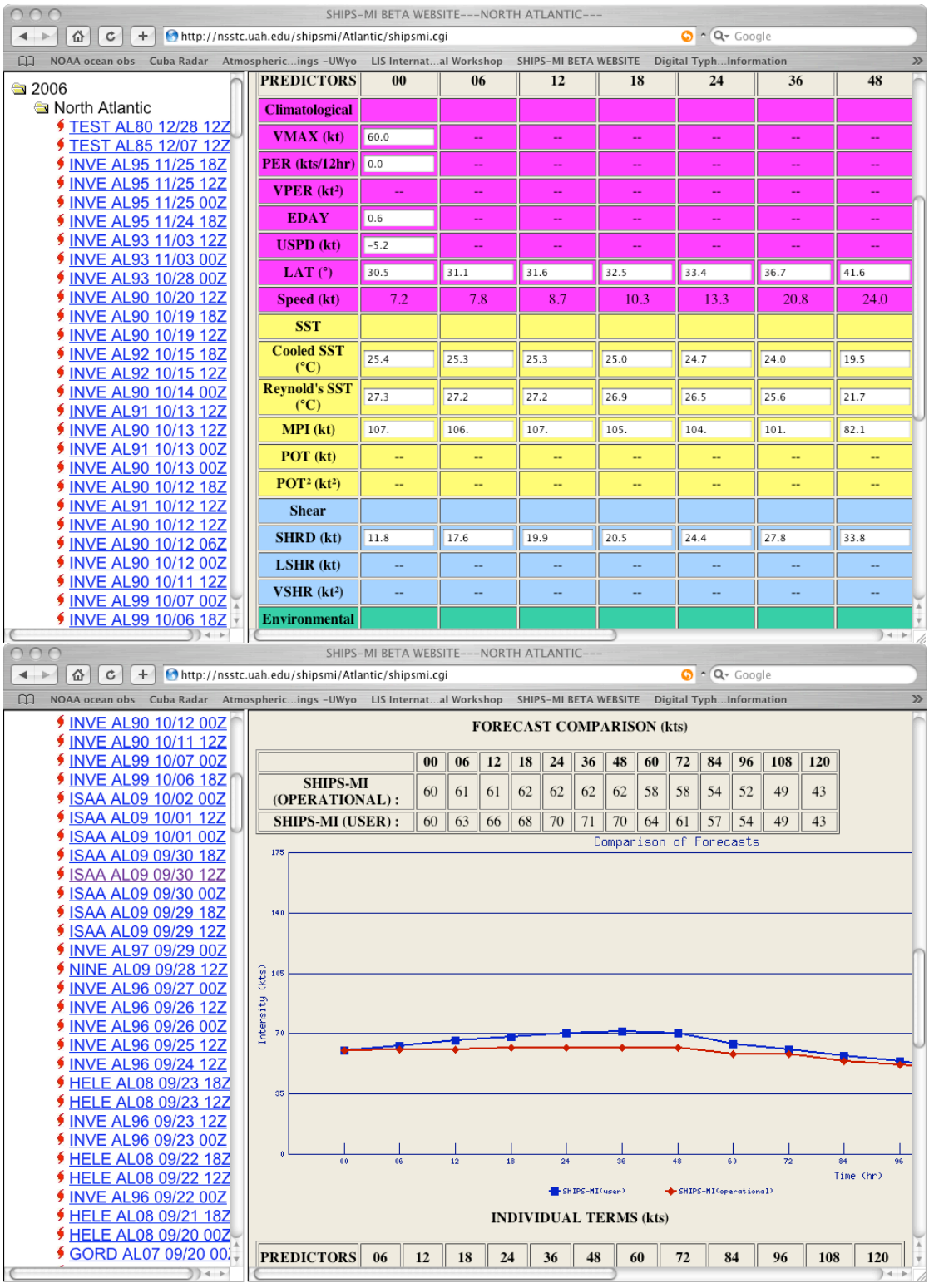


Figure 3. Screen captures from the interactive SHIPS-MI web page.

Several of the tasks in Year 2 of this project were intended (and budgeted) for a graduate research assistant. The graduate student from Year 1 graduated in May 2006, and the graduate student for Year 2 left school after August 2006. It would have been inefficient to spend time

spinning up a new student on this project. As a result, all tasks are shifted to the PI and the funds are charged to increasing support for the PI instead of a GRA.

5. The future of SHIPS-MI and STIPS-MI

The 2006 performance of SHIPS-MI in the Atlantic and especially the Eastern North Pacific was encouraging. Regression coefficients will be re-derived for the 2007 season, after adding 2006 to the training sample. This first requires the 2006 large-scale diagnostic training sample from Mark DeMaria, which is usually available in May.

In hopes that NHC will wish to maintain SHIPS-MI upon the completion of this JHT project, the software for updating the training sample and re-deriving the regression coefficients will be provided to NHC. The archive of microwave statistics for the pre-2006 training sample will also be provided to NHC.

The read software and a real time data source for SSMIS brightness temperatures are still outstanding items. Hopefully those can be resolved during spring 2007.

As discussed with Mark DeMaria, I intend to try producing a subroutine that can be added to his operational SHIPS code, computing the SHIPS-MI forecast and appending it as an additional line of output on the same page as SHIPS. This would make it more accessible to the forecasters, by having SHIPS-MI and SHIPS output together in the same place. This would probably require running part of the SHIPS-MI program at NHC (as is currently done), and having the computer that runs SHIPS acquire the output from that.

Given the troubles encountered with STIPS-MI for the Western North Pacific, I expect to discontinue its production. In the short term, it does not appear likely to produce useful forecasts. It may be worth re-visiting later, if forecasts can be generated in a more efficient, timely manner in a different computing environment.