Enhancement of SHIPS Using Passive Microwave Imager Data

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Activities during August 2005 – February 2006

During the first six months of this Joint Hurricane Testbed project, documentation and source code for SHIPS-MI were provided to NHC and test forecasts for the 2005 Atlantic hurricane season were generated. Development has begun on an interactive web page that allows users to explore the results of changing model input variables. A brief summary follows, along with some initial results from the tests on 2005 storms.

Upon initiation of the project in August, documentation was available on the webpage: http://nsstc.uah.edu/~tjones
This included past conference presentations, a manuscript that had been submitted to *Weather and Forecasting*, and descriptions of the SHIPS-MI input and output. Forecasts for active tropical cyclones were also posted to that page. Since then, the *Weather and Forecasting* manuscript has been accepted for publication and the readme documentation on the web page has been streamlined.

Source code (in the IDL language) and shell scripts for generating SHIPS-MI forecasts were sent to NHC in November. There were a few iterations of corrections / simplifications made to the source code, followed by a visit to NHC in early January. During this visit, Alison Krautkramer was able to successfully generate test SHIPS-MI forecasts at NHC. Discussions with Krautkramer, Chris Sisko, and Chris Landsea, in particular, led to a simplified format for additional SHIPS-MI output files. After a few more iterations of fixing problems, the code seems to be working well on an NHC computer. We expect to have SHIPS-MI forecasts generated there in real-time during the 2006 season, beginning with the acquisition of satellite data by NHC and ending with text output files going to the printers for consideration by NHC forecasters.

SHIPS-MI was also discussed with Stacy Stewart during the NHC visit. Stewart and Landsea both suggested making changes to SHIPS-MI in order to improve the long range forecasts, even though the benefit from adding microwave data is realistically confined to the first ~48 hours of the forecast. In response to this feedback, some of the SHIPS predictors that are useful at 48-120 hours were added to SHIPS-MI. The SHIPS-MI regression coefficients were re-derived including these predictors, and also using an expanded training sample (after adding microwave data for 1988-1994 to the sample that already included 1995-2004). For this new version of SHIPS-MI, errors based on the training sample tend to be ~5% smaller than those

from SHIPS for the first 36 hours of the forecast, and roughly comparable to those from SHIPS for the remaining forecast out to 120 hours.

Based on suggestions from Landsea, Sisko, and Stewart, the new version of SHIPS-MI has been used to regenerate forecasts for the 2005 cases in which we initially collected forecast information. Some initial results are presented below and will also be presented at the 2006 Interdepartmental Hurricane Conference. *These results are based on verification using NHC's operational intensity estimates, since the 2005 best tracks are not yet complete.*

Finally, one of the suggestions from Stewart was to refine the vertical wind shear predictor that is used in the forecasts. For many cases, particularly late this season, the shear averaged over a large radius around the tropical cyclone does not accurately represent the shear that is being experienced by the tropical cyclone. Toward this end, a SHIPS-MI web page is under development that allows users to adjust the input value for vertical wind shear or any other predictor. This functionality can be used to fine tune a particular forecast, or simply to explore the behavior of the statistical model in response to varying input conditions. Currently this web page is offline and still under development using archived forecasts, not current forecasts.

Initial Results for the 2005 Atlantic Season

SHIPS-MI forecasts are only generated when the satellite data is available during an appropriate time window. The forecasts here use only satellite data that was collected between T-4 and T-1 hours (e.g., 0200 – 0500 UTC for a 0600 UTC forecast). Using this criterion, we were able to generate SHIPS-MI forecasts for about 25% of all synoptic times. This fraction should have been higher (30-40%), but some forecasts were missing due to network, power, or scripting issues at UAH. In operations, some forecasts may be available slightly later than T-1 hours, but the analysis here assumes a worst-case-scenario.

For the homogeneous sample of forecasts where SHIPS-MI can be compared against SHIPS, SHIFOR, and OFCL, we get the RMS errors in Table 1 and bias in Table 2. These exclude any forecasts in which landfall occurred before the forecast verified.

Table 1. RMS Errors for 2005 forecasts, excluding landfalls.

	12-h	**24-h**	**36-h**	**48-h**	**72-h**	**96-h**	**120-h**
# fcsts	*115*	*103*	*94*	*85*	*71*	*58*	*45*
SHIPS-MI	8.5	12.4	16.0	19.3	21.9	22.5	27.7
SHIPS	8.7	12.6	16.4	18.7	21.3	21.7	26.3
OFCL	7.4	11.1	14.6	17.7	20.9	22.9	28.4
SHIFOR	9.2	14.0	18.8	21.0	24.8	25.4	25.5

Table 2. Bias for 2005 forecasts, excluding landfalls.

	12-h	**24-h**	**36-h**	**48-h**	**72-h**	**96-h**	**120-h**
SHIPS-MI	-0.1	0.1	1.0	0.2	-0.2	0.8	3.5
SHIPS	-0.9	-1.1	-0.6	-2.1	-3.7	-3.2	-3.4
OFCL	0.2	-0.5	0.0	-2.7	-4.9	-5.1	-4.9
SHIFOR	-0.8	-1.6	-2.1	-5.0	-6.6	-6.3	-6.7

Generally, SHIPS-MI forecasts are within a few knots of the SHIPS forecasts. For short range forecasts (< 48 h), SHIPS-MI is usually nudging the SHIPS forecast in the correct direction, although the opposite is sometimes the case. For the 24 h forecasts, SHIPS-MI is more accurate than SHIPS 60% of the time. These differences for 2005 are smaller than expected; errors in the training sample are generally around 5% smaller for SHIPS-MI than for SHIPS.

Individual 2005 Storms

For most storms, only a few forecasts are available for analysis and it is difficult to make meaningful statements about forecast quality in those storms. Those with at least ten 36-hour forecasts are listed in Table 3. In some cases, the scripts at UAH did not keep up with the record-setting pace of storm development in 2005 (i.e., a storm name was not added to the script until after forecasts had been missed). In other cases, the sun-synchronous DMSP satellites visit parts of the Western Caribbean and Gulf of Mexico at a bad time of day for the data to be included in the normal forecast cycle. Dealing with this latter issue will be a point to address with NHC – for example, can a SHIPS-MI forecast be at all useful if it arrives late? Is it preferable to have a forecast that uses data several (>4) hours old?

Table 3. 36-h RMS errors for those storms that had at least ten SHIPS-MI forecasts.

Storm	# fcsts	SHIPS-MI	SHIPS	OFCL	SHIFOR
Emily	13	24.9	27.3	18.5	33.5
Irene	15	12.3	8.6	8.8	8.2
Maria	12	8.7	9.9	12.3	10.5
Epsilon	13	15.2	17.6	17.1	15.1

Pre-2005 Training Sample

Beginning with 1995, infrared (IR) and oceanic heat content (OHC) data is available for use in SHIPS. That data is *not* used in SHIPS-MI, because an insufficient number of forecasts have the full combination of microwave, infrared, and oceanic heat content data. SHIPS is developed from a 1982-2004 training sample, with the IR and OHC correction in the 1995-2004 sample. SHIPS-MI is now developed from a 1988-2004 training sample (1991-2004 for the Eastern North Pacific). A homogeneous sample of 1995-2004 forecasts is used to compare SHIPS-MI and SHIPS forecast errors. Note that this is a dependent subset of the training samples for both SHIPS and SHIPS-MI.

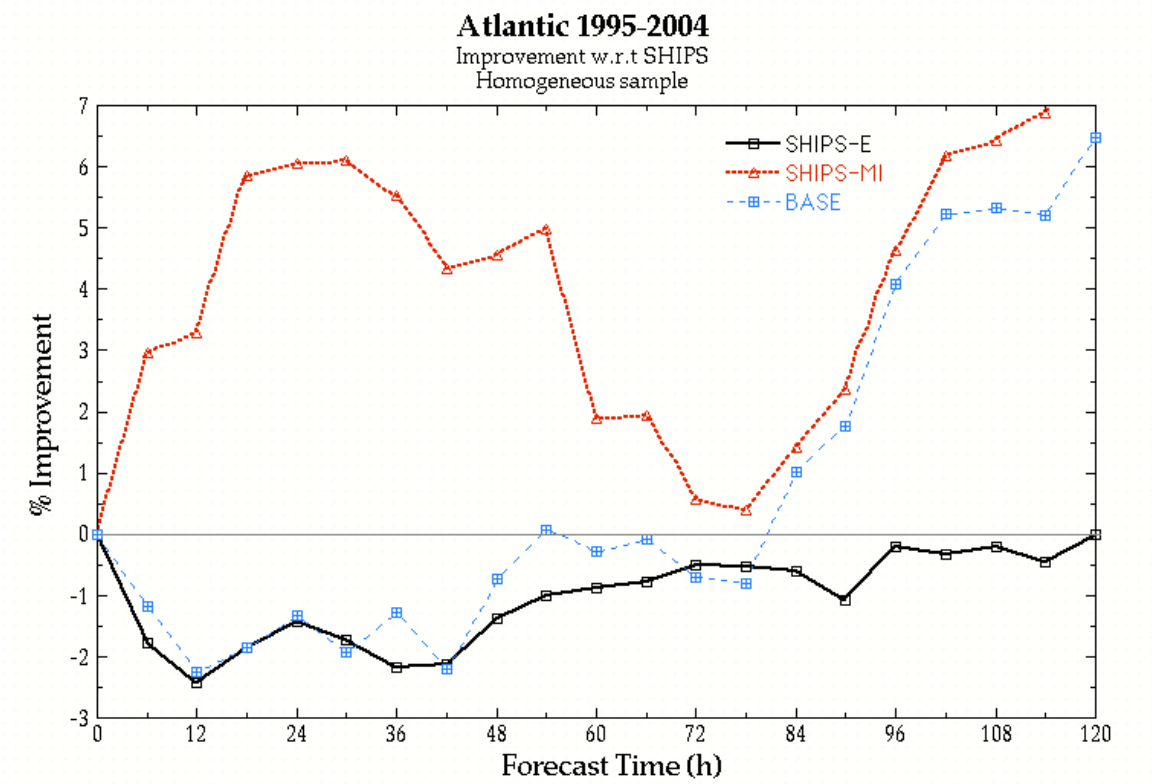

Figure 1. Percentage improvement of Atlantic SHIPS-MI mean absolute errors, compared to SHIPS using the 2005 version of the model. A homogeneous 1995-2004 sample is used for verification, allowing inclusion of the IR and OHC corrections in SHIPS. This is a subset of the dependent training sample for both SHIPS-MI and SHIPS. "SHIPS-E" is SHIPS without the IR and OHC corrections. "Base" uses the same predictors as SHIPS-MI, except microwave predictors are excluded.

Mean absolute errors are normalized against those from SHIPS in Fig. 1 for the Atlantic and Fig. 2 for the Eastern North Pacific. That is, the zero line represents forecasts generated using the 2005 operational coefficients for the SHIPS model. Atlantic SHIPS-MI mean absolute errors are up to 6% smaller than those from SHIPS at 18-30 hours (Fig. 1). The apparent improvements beyond 60 hours should be disregarded, as the small sample size for long-term forecasts makes these insignificant. The additional lines in Fig. 1 show the detrimental effect of removing IR and OHC inputs from SHIPS ("SHIPS-E") or removing microwave data from SHIPS-MI ("base"). In both cases, the forecasts are up to about 2% worse than SHIPS if no satellite data is included.

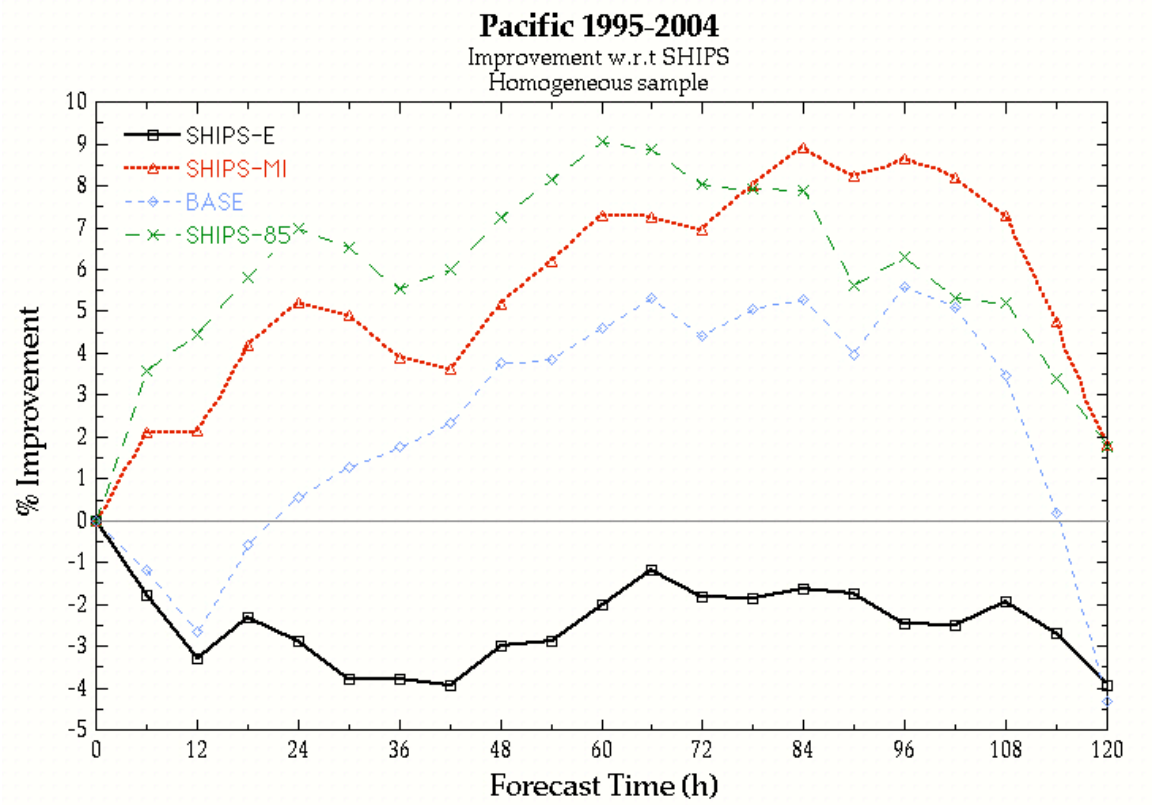

Figure 2. As in Figure 1, but for the Eastern North Pacific. "SHIPS-85" uses only the 85 GHz channel for microwave terms, whereas SHIPS-MI also uses 19 GHz.

For the Eastern North Pacific (Fig. 2), SHIPS-MI mean absolute errors are 5% smaller than SHIPS at 24 hours. Another line is added in this figure ("SHIPS-85") showing a model in which only the 85 GHz channel is used to produce microwave-based forecasts. Normally these errors are slightly worse than those from SHIPS-MI, but they happen to be smaller than SHIPS-MI errors for the 1995-2004 sample.

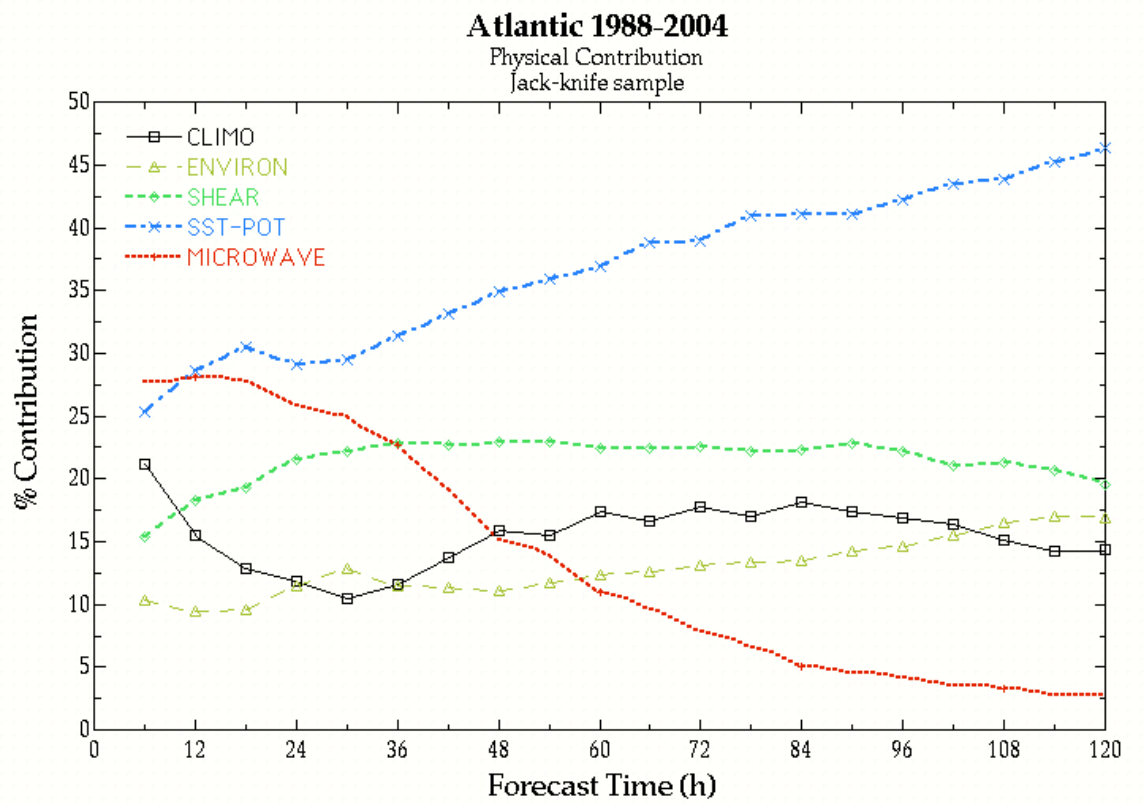

Figure 3. Mean relative contribution to Atlantic SHIPS-MI forecasts from predictors grouped together as microwave; potential for intensification based on sea surface temperature (SST); vertical wind shear; other environmental variables; and climatology and persistence. This accounts for related predictors that sometimes have offsetting effects. At any given forecast period, the lines sum together to 100%.

Fig. 3 shows the relative contribution to the Atlantic SHIPS-MI forecasts from predictors grouped together as microwave; potential for intensification based on sea surface temperature (SST); vertical wind shear; other environmental variables; and climatology and persistence. While SST is generally the most important type of input, the microwave predictors are more important than vertical wind shear in the first 36 hours. There is very little contribution from the microwave predictors at 72 hours and beyond – it would be alarming if this were not the case.

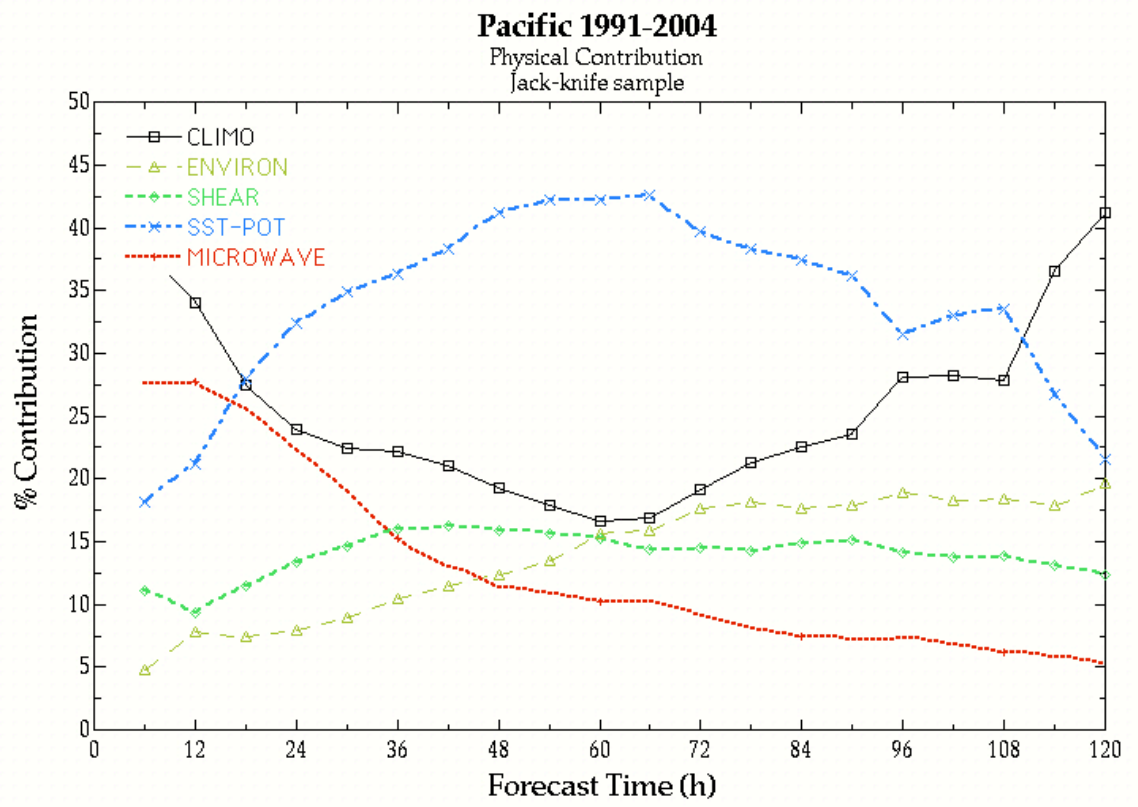

Figure 4. As in Figure 3, but for the Eastern North Pacific.

Similarly, Fig. 4 shows the contributions to the Eastern North Pacific SHIPS-MI. Climatology and persistence has the greatest impact in the first 12 hours, followed by the microwave predictors. SST-based predictors dominate after 12 hours. The relative importance of microwave predictors decreases more rapidly with increasing forecast time in the Eastern North Pacific than in the Atlantic.

Plans for 2006 Hurricane Season

After the hurrdat and SHIPS training files are updated through the 2005 season, SHIPS-MI will be updated to include 2005 in the training sample. New coefficients for the predictors will be provided to NHC. As noted before, the source code for generating SHIPS-MI forecasts has already been tested at NHC. While TMI and SSM/I satellite data has been acquired by NHC, access to AMSR-E data still needs to be established.

SHIPS-MI forecasts will be generated at both NHC and UAH in real time during 2006. UAH will monitor the forecasts, looking for either deficiencies or for instances where consideration of SHIPS-MI could substantially alter an operational forecast.

Contingencies will hopefully be developed (coordinating with the NHC forecasters for an acceptable solution) to make use of satellite data that arrives at inopportune times, particularly in the Western Caribbean and Gulf of Mexico where landmasses are threatened and SSM/I data is often late.