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Improving Hurricane Intensity Forecasts by Combining Microwave Imagery with the SHIPS Model

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1. Introduction

Tropical cyclone intensity prediction has improved significantly in the past decade with the advent of the Statistical Hurricane Intensity Prediction Scheme (DeMaria and Kaplan 1999). SHIPS currently uses environmental parameters derived from the GFS model, cyclone climatology and persistence, and sea-surface temperature in a linear regression model to calculate intensity change out to 120 hours at 12 hour intervals. However, little information about the structure of the cyclone is taken into account. To overcome this shortcoming, the work presented here adds passive microwave measurements to further describe cyclones' cloud and precipitation structure.

2. Microwave Imagery

Microwave channels available from both SSM/I and TMI sensors include dual polarized 19 GHz, 37 GHz, and 85 GHz frequencies. From these channels, brightness temperature (BT or PCT) values are calculated. Previous literature including Cecil and Zipser (1999) and Rao and McCoy (1997) have shown that observations of tropical cyclones in these channels are correlated with the current and future intensity of tropical cyclones.

3. Methodology

Microwave imagery from SSM/I and TMI sensors was obtained for all tropical cyclones in the Atlantic basin (depressions and above) for the years 1996 to 2002. (For TMI, data are available only back to 1998). Microwave predictors include minimum (maximum for 19 GHz), mean, and standard deviation of brightness temperature values around a 100 km radius of a cyclone. Additional predictors such as percent of pixels below a certain threshold (e.g. PCT85 < 250 K) were considered, but found to not provide any additional predictive information.

All cyclones within 120 km of a significant landmass are removed from the data set due to the high emissivity of land. Also, forecasts are not considered valid if the future track crosses a significant landmass. Only forecasts errors to the point of landfall are calculated.

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SHIPS data are acquired from the 1989-2002 Atlantic diagnostic file though only post 1996 data are used. Storm and environmental data for each cyclone are given in 12 hour intervals at 0Z and 12Z. The 16 predictors present in the SHIPS model (listed in Table 1) are interpolated to match the microwave observations of a particular cyclone. New models are created incorporating the three new microwave predictors using the techniques discussed by DeMaria and Kaplan (1999). Separate models are created for each channel to determine their relative usefulness resulting in SHIPS-MI19, SHIPS-MI37, and SHIPS-MI85 models respectively. In addition, a model derived using only interpolated SHIPS predictors (SHIPS-I) is used as a baseline to assess the usefulness of the microwave data.

Table 1. Operational (2003) SHIPS predictor descriptions. Also includes microwave predictor descriptions. Regression coefficient values for the 24 hour SHIPS-MI19 model are also given.

SHIPS:	**Description:**	**Coeff:**
EDAY	Exp of (days from peak of season)	-0.007
MSW	Maximum sustained wind	-0.055
12WCG	12 hour wind change	0.361
CGMSW	12WCG times MSW	-0.191
USPD	Zonal cyclone motion	-0.012
PSLV	Pressure steering level	0.015
D200	200 mb divergence	0.093
POT	Max potential intensity – MSW	0.911
POT2	Square of POT	-0.644
VSHR	850 – 200 mb vertical wind shear	-0.683
T200	200 mb temperature	-0.204
RHHI	500 – 300 mb relative humidity	-0.002
Z850	850 mb relative vorticity	0.167
SRLAT	VSHR times sin(lat)	0.370
SRMSW	VSHR times MSW	-0.035
EPOS	Theta E of lifted surface parcel	0.132
19GHz:		
VBT19	0-100 km brightness temperature	0.493
STD19	0-100 km BT standard deviation	0.057
MIN19	0-100 km min (or max) BT	-0.053

4. Results and Conclusions

The interpolated SHIPS-MI data set consists of 1145 observations of 88 cyclones (out of a possible 102) valid for a 12 hr model which decreases to 654 observations of 47 cyclones at 72 hours (Table 2). All observations are at least two hours apart. Valid SSM/I or TMI observations of several short-lived tropical depressions and tropical storms did not exist.

Table 2. Number of cyclone observations for each microwave enhanced SHIPS model. Mean absolute errors in knots for the SHIPS-I, SHIPS-MI19 and SHIPS-MI85 models also given for each forecast time. Errors are computed using all available cyclone observations. Note that for all forecast times the microwave enhanced model performs better.

Forecast	TCs	Obs.	SHIPS-I	MI19	MI85
0 hr	102	NA	NA	NA	NA
12 hr	88	1145	5.78	5.60	5.65
24 hr	81	1033	9.44	9.03	8.12
36 hr	70	919	12.67	11.94	12.11
48 hr	62	828	14.98	14.26	14.48
60 hr	51	728	16.85	16.43	16.66
72 hr	47	654	18.66	18.34	18.68

For the SHIPS-MI19 model, the microwave predictors are very significant predictors when compared to the environmental predictors. The VBT19 predictor is the fourth most important predictor behind only POT, the square of POT (POT2), vertical wind shear (VSHR) for the 12 through 36 hour models. Since POT and POT2 are offsetting predictors, VBT19 is actually of greater importance than both at early forecast times. For forecast models beyond 48 hours, the importance of VBT19 decreases significantly. It appears that VBT19 takes the place of the current intensity predictor in the operational SHIPS model. Given that mean brightness temperature in the core of a cyclone is often highly correlated with its current intensity, this replacement is not unexpected. The other microwave predictors, STD19 and MAX19, are much less important than VBT19, but are still statistically significant. At the forecast intervals beyond 48 hours, MAX19 appears to overtake VBT19 in importance for reasons that are not entirely clear.

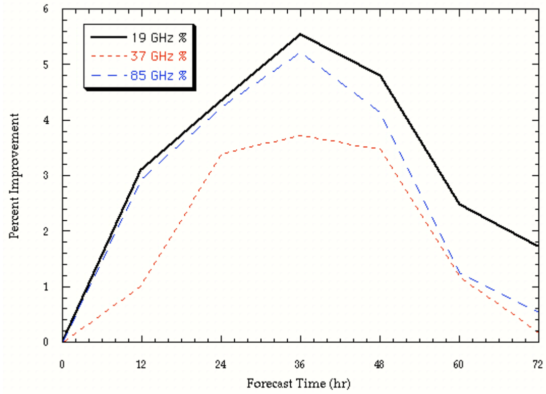
The SHIPS-MI37 and SHIPS-MI85 models exhibit similar behavior, but with somewhat more forecast error (Fig. 1).

The SHIPS-MI19 model provides measurable improvement in forecast error for all forecast periods. The improvement ranges from 0.2 to 0.7 knots of mean absolute error over the SHIPS-I model with the best improvement seen at the 36 hr forecast (Fig. 1). This corresponds to a 6% improvement over SHIPS-I forecasts.

5. Future Work

Several avenues of research are currently underway to further improve microwave enhanced cyclone intensity forecasts. One focus is to rederive the SHIPS environmental predictors with microwave data taken into account at the initial step.

Figure 1. Percent improvement of each microwave enhanced model over the SHIPS-I model.



Adding microwave data to the existing predictors changed the significance of several of them leading to the possibility that currently unused environmental parameters may need to be reconsidered. Since the microwave imagery has been shown to be better associated with current and future intensity (not intensity change), a model will be created that is regressed against future intensity at each time interval. This should allow the full weight of the microwave imagery to be incorporated into forecasts. Additional microwave derived products such as eye-wall brightness temperature are also being tested for use as predictors in certain situations. It is hoped that an improved formulation of the SHIPS-MI model will be ready for initial real-time testing for the 2004 Atlantic season. Finally, work is underway to extend the SHIPS-MI model to additional tropical cyclone basins. See Cecil et al. P1.23 in this text for further details.

Acknowledgements

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