NOAA Joint Hurricane Testbed (JHT)
Mid-Year Progress Report, Year 2

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Reporting Period:	September 1, 2014 – February 28, 2015
Project Title:	Guidance on Intensity Guidance
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1. Long-term Objectives and Specific Plans to Achieve Them:

The goal of this project is to develop a system for real-time prediction of the expected errors of individual hurricane intensity forecast models and to use this information to improve operational forecasts. In the first year of the project, we built on the recent results of Bhatia and Nolan (2013) to construct a model that predicts the expected error of each intensity forecast model at each forecast interval based on real-time synoptic and climatological information, such as wind shear, current intensity, and latitude. Error prediction models have been developed for each of the "early" intensity forecast models that are available to forecasters: DSHP, LGEM, GHMI, and HWFI. Our goal by the end of year 1 was to have a prototype of this prediction system running in real-time during the 2014 hurricane season. Unfortunately, this goal was not quite met by the end of year 1. However, the prediction system is now fully developed and will be ready for real-time operations for the Atlantic hurricane season of 2015. Our goals in year 2 are to a) support the real-time operation of the PRIME (Prediction of Intensity Model Error) system, b) to develop a corrected-consensus model where the predicted errors of each model are used to make a weighted consensus intensity forecast that performs better than simply averaging the four models, and c) work with forecasters to develop the best way to communicate the PRIME model output to them in real time.

2. Mid-Year Accomplishments:

a. Further improvement of PRIME

As noted above, we were not able to put the PRIME system into real-time operation during any part of the hurricane season of 2014. The primary reason was that in the time period leading up to and during the season, we continued to find ways to substantially improve the system, many of which required significant modifications to how both the input variables (shear, RH, deviation from ensemble mean) and the output variables (expected absolute error, expected bias) were processed and generated by the model. More careful treatments of how to handle storms that were forecast to go over or near land also led to significant improvements. Data from retrospective forecasts, using forecasts from older seasons generated by updated versions of the GFDL and HWRF models, did not in fact lead to improvements as was expected. Nonetheless, the version(s) of PRIME developed in the first half of Year 2 are considerably improved from earlier versions, showing positive skill over climatology (the average forecast error) at all times. As noted in previous reports, there is more skill for longer forecasts and there is more skill for prediction of model bias as compared to absolute error.

Percent Improvement over AE Climatology

Hours	DSHP	LGEM	HWFI	GHMI
12	7.7	6.1	7.7	8.9
24	9.2	7.9	8.1	8.6
36	8.3	6.3	9.5	9.7
48	6.8	6.9	11.0	10.0
60	8.5	10.0	10.0	10.8
72	10.0	10.1	11.5	9.9
84	15.0	12.5	11.5	10.4
96	17.8	11.2	10.6	12.5
108	11.9	8.1	11.0	16.0
120	10.5	9.5	12.0	18.2

Percent Improvement over Bias Climatology

Hours	DSHP	LGEM	HWFI	GHMI
12	8.0	8.6	9.7	11.4
24	14.9	13.0	11.3	13.9
36	14.2	15.8	14.2	19.4
48	13.9	14.8	15.0	20.4
60	17.9	15.1	16.1	20.9
72	22.1	16.3	20.9	21.1
84	23.8	15.4	23.1	18.6
96	25.7	12.3	25.1	16.6
108	25.2	9.8	26.8	15.5
120	23.2	11.0	30.2	22.8

Fig. 1: Relative skills of absolute error (top) and bias (bottom) forecasts from PRIME based on validation from independent (left out) seasons from 2007-2013.

b. Corrected-consensus models

As noted above, another goal of the project is to produce unequally-weighted ensemble forecasts based on the expected error of each model, i.e., the models with larger predicted absolute error are given less weight, and vice-versa. We are also now considering a bias-corrected ensemble, where the predicted bias is removed from each forecast before they are then averaged (equally). In fact, as shown in the figures below, the bias-correction makes a considerable improvement for individual models and the best improvement for the weighted consensus.

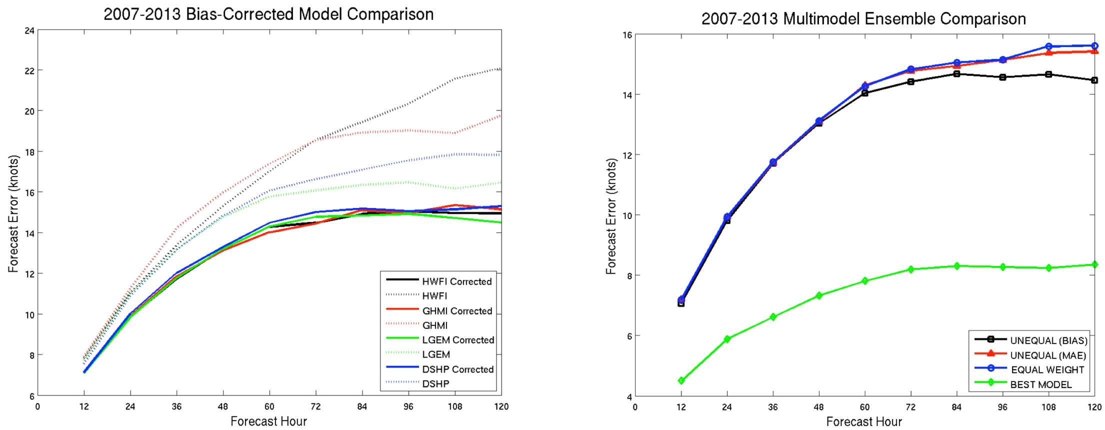

Fig. 2: Improvement in absolute error for individual models after bias-correction by PRIME from 2007-2013 (left), and the performance of bias-corrected, unequally weighted, and the standard consensus model from the same period (right). Also shown on the right is the average abolute error of each model that happened to be closest to the real-time analysis at each forecast time.

While the bias-corrected consensus forecast shows only a small improvement over the other consensus forecasts, the differences are statistically significant at the longer forecast times. The green line on the right panel above, labeled "best model," shows the average error of each model that happened to be closest to the analyzed intensity. This is a useful reference point but probably an unrealistic goal.

c. Preparation for real-time operation in 2015

The PIs (Nolan and Schumacher) and the graduate student (Kieran Bhatia) have been working together to make PRIME and the corrected consensus models work in parallel with other real-time systems, such as SHIPS. While the model has been developed entirely using Matlab software at the University of Miami, calculation of the real-time error forecasts is straightforward and Fortran code that works on systems at NOAA has been developed to reproduce the results from UM. Future corrections and improvements should only require updates to the constants and coefficients in the predictor manipulations and the generation of the predictands by the linear model.

On February 24th, a first meeting was held with several forecasters (Avila, Blake, Landsea) to explain the system and to ask for input on how they would like to see the results in real time.

3. Further Year 2 Efforts:

April - May 2015: Implementation of a real-time PRIME system that predicts absolute error (AE) and error (bias) for each of the 4 intensity forecast models, and the corrected consensus outputs. We will also further develop the method for delivering the results to forecasters and obtain further feedback in meetings with them.

June - October 2015: Monitoring of the system in real-time use and occasional improvements, as needed. The methodology will be documented in a paper prepared for publication.

November - December 2015: Evaluation of the performance of PRIME and the corrected consensus forecasts and production of the final report.

4. References

Bhatia, K. T., and D. S. Nolan, 2013: Relating the Skill of Tropical Cyclone Intensity Forecasts to the Synoptic Environment. *Wea. Forecasting*, **28**, 961–980.

Bhatia, K. T., and D. S. Nolan, 2014: Prediction of tropical cyclone intensity forecast error. 31st Conference on Hurricanes and Tropical Meteorology, American Meteorological Society, San Diego, California. Available for download from: https://ams.confex.com/ams/31Hurr/webprogram/Paper244417.html

DeMaria, M., and J. Kaplan, 1994: A statistical hurricane intensity prediction scheme (SHIPS) for the Atlantic basin. *Wea. Forecasting*, **9**, 209-220.