NOAA Joint Hurricane Testbed (JHT)
Mid-Year Project Progress Report, Year 1

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Project Title:	Guidance on Intensity Guidance
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1. Long-term Objectives and Specific Plans to Achieve Them:

This 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 part of the project, we will build 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 will be developed for each of the "interpolated" intensity forecast models that are available to forecasters: DSHP, LGEM, GHMI, and HWFI, for forecasts every 12h out to 120 h. Our goal by the end of year 1 is to have a prototype of this prediction system running in real-time during the 2014 hurricane season. In year 2, we plan to build a corrected consensus model which will weight each of the four intensity models based on their relative expected errors at each time.

2. Mid-year Accomplishments:

a. Development of model error and predictor data bases

In the first half-year of this project, we have developed a comprehensive data base of intensity forecasts, intensity forecast errors, and synoptic and environmental information from the 2007-2012 hurricane seasons. All information such as storm intensity, wind shear, maximum potential intensity, ocean heat content, etc., comes from the SHIPS data base (stext files) which is information that will be available in real-time during operational forecasts. Fig. 1 below summarizes the data used and the verification conditions used so far to date (in the next few months, we will extend the analyses to forecasts every 12 h).

From this data base, a large number of candidate predictors of error have been selected. These can be divided into synoptic predictors (which include information about the storm itself, such as its current intensity and location) and "proxy" predictors which are indicative of the stability of the atmospheric flow or the uncertainty of the initial condition. For each forecast, the synoptic predictors are computed at the analysis time (zero hour) and for the average of the forecast period (e.g., the 48 hour average wind shear magnitude during a 48 hour forecast). Table 1 lists the predictors evaluated to date.

Dataset Detail	Data Used
Hurricane Seasons	2007-2012 (Atlantic Basin)
Forecast Hours	24, 48, 72, 96, and 120
Models Evaluated	LGEM, DSHP, HWFI, and GHMI ("early" models)
Predictors	**Dynamical Predictors**: Initial and forecast intensity, forecast average and 0 hour: 700-500 hPa RH, 200 hPa divergence, 850 hPa vorticity, potential intensity, storm speed, latitude, shear direction, and shear magnitude (850-200 hPa) **Initial Condition Error and Atmospheric Stability**: Standard deviation of ensemble forecast intensity, deviation of forecast from ensemble mean, forecasted intensity change, and track forecast spread
Verification criteria	Excludes "LO", "EX", INVESTS, and forecasts including land. All models must have verification and all predictors for particular time to be included (homogeneous).

Fig. 1. Summary of intensity forecasts and predictors used for the initial development of the error prediction models.

Synoptic Predictors	Atmospheric Stability and Initial Condition Error Predictors
Initial Intensity	Forecasted intensity change
Forecasted Intensity	Early models intensity forecast spread
0-hour and Forecast Average Shear	Early models track forecast spread
0-hour and Forecast Average Storm Speed	Deviation from intensity forecast ensemble mean
0-hour and Forecast Average MPI	Previous 12 hour forecast error
0-hour and Forecast Average Latitude	Previous 12 hour intensity change
0-hour and Forecast Average Shear Direction	
0-hour and Forecast Average Latitude Squared	
0-hour and Forecast Average Relative Humidity	
0-hour and Forecast Average Vorticity	
0-hour and Forecast Average Divergence	

Table 1. Summary of synoptic predictors and proxy predictors for atmospheric flow stability and initial condition error.

b. Predictor selection, early results, and plans for improvement

The methodology for the development of the error prediction models is very similar to that used for SHIPS (DeMaria and Kaplan 1994). Multiple linear regression models have been created using the synoptic and proxy predictors to predict the absolute error (AE) of DSHP, LGEM, GHMI, and HWFI every 24 hours, out to 120 h. The 2007-2011 Atlantic hurricane seasons were used as the training period and the 2012 period is used for verification. As in SHIPS, each predictor that predicts the smallest amount of error is eliminated, for each forecast model and at each forecast time, until only those predictors remain with weighting coefficients statistically different from zero at the 95% confidence interval.

To date, results are mixed, with only very small correlations (R values ~ 0.1) for error prediction in some cases and a few cases of fairly high correlations (R values ~ 0.5). Examples of poor and very good correlations of predicted AE versus true AE are shown in Fig. 2. The general trend is for better predictions of forecast errors for the longer intervals (96h, 120h). This may be due to multiple factors, such as the accumulated effect of physical processes over time (e.g., large ocean heat content over several days), or the fact that errors are simply larger over longer forecast periods. A more complete summary of the methods and results is available in the AMS 2014 Conference on Hurricanes and Tropical Meteorology extended abstract of Bhatia and Nolan (2014).

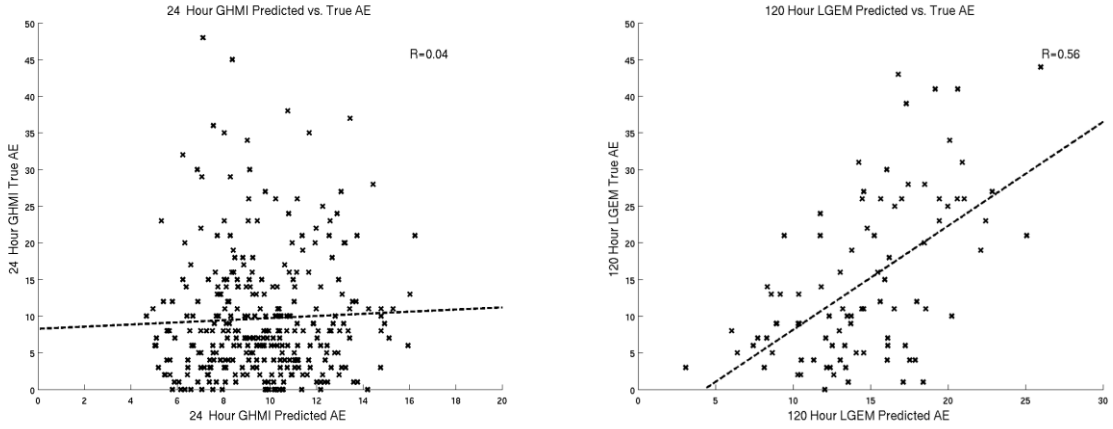

Fig 2. Predicted absolute (intensity) error (AE) versus true absolute error from the first results of the error prediction system for 24 hour GHMI forecasts (left) and 120 hour LGEM forecasts (right). The dashed line indicates the least squares regression line and the R values are shown in the upper-right of each plot.

Since the Intergovernmental Hurricane Conference, a number of directions for improvement have been identified. These include using individual model tracks for determining land interactions (rather than the OFCL track), and further manipulations of predictor inputs. For example, given that Bhatia and Nolan (2013) found that model error is sometimes largest

for intermediate values of wind shear, the shear magnitude input variable should be maximized for medium shear and trend toward zero for both low and high shear.

3. Current and Future Year 1 Efforts:

April 2014: Refinement of predictor data bases and input variables, individual-model-based evaluation of land interactions, and extension to error predictions every 12 hours.

May-June 2014: Conceptual development of a real-time prediction system that delivers error predictions in a useful way to forecasters and preliminary tests.

July-August 2014: Implementation of a prototype system to run real-time in parallel with other statistical models during the hurricane season.

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.