Probabilistic Prediction of Hurricane Intensity with an Analog Ensemble
NOAA Hurricane Forecast Improvement Project
Quarterly Status Report
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Project Personnel

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Introduction

This project seeks to apply an Analog Ensemble (AnEn) technique (Delle Monache et al. 2011, 2013) to the problem of tropical cyclone (TC) intensity prediction. The AnEn technique is used here to create a naturally calibrated ensemble prediction of TC intensity from a training dataset composed of the deterministic Hurricane Weather Research and Forecasting (HWRF) model. In the AnEn, a set of analog forecasts is created by searching archived HWRF forecasts that share key features in common with the ones associated with a current forecast from the same configuration of HWRF. The actual intensity observations associated with each forecast are used to produce an ensemble forecast.

The general AnEn technique applied to HWRF appears ideally suited for TC intensity forecasting for the following reasons:

- One can use a higher resolution model for an ensemble prediction (since only one real-time forecast is needed for the AnEn),
- There is no need for initial conditions and model perturbation strategies to generate an ensemble,
- The forecasts are intrinsically reliable and no post-processing is needed,
- The flow-dependent error characteristics can be determined, and
- The AnEn is ideal for TC forecasting given its ability to improve the prediction of rare events, which may enhance the skill of HWRF's rapid intensification (RI) forecasts.

Milestones Achieved This Quarter

The following milestones illustrate the type of work that has been carried in the second quarter of this project.

1. We developed a preliminary logistic regression model with the developmental predictor dataset derived from the 2014 version of HWRF. This model will be refined and completed in the upcoming quarter.

2. The HWRF Analog Ensemble (AnEn) was refined slightly for the Atlantic.
   - The AnEn forecast has been performed on 1/3 of the Atlantic dataset, which is used as the verification period. The new AnEn no longer separates the training and testing periods by a single date in time. Dates for the training and testing periods are more randomized to provide more robust measure of performance as more recent hurricane seasons produced weaker storms that were more challenging to forecast.
   - The mean absolute error (MAE) resulting from each couple of predictors was compared against the MAE of an AnEn developed only using the maximum wind speed as the sole predictor.
   - Nine predictors added greater than 1% MAE improvement relative to the AnEn forecast using only maximum wind speed as the only predictor. These predictors include: vertical wind shear, sea surface temperature, inner-core convective available potential energy (CAPE), outer rainband CAPE, the maximum potential intensity, the large-scale temperature gradient, the inner-core inertial stability (0-50 km and 0-100 km), and the symmetry of coupling between inertial stability and latent heating.
   - Maximum wind speed and the nine selected predictors (10 predictors in total) were used for preliminary tests of AnEn predictions of maximum wind speed. The set of optimal weights (w_i) of the 10 predictors is defined by choosing the combination that minimizes the MAE over 1/3 of the Atlantic dataset. All the possible combinations defined with the constraint $\sum_{i=1}^{10} w_i = 1$, where $w_i \in [0, 0.1, 0.2, \ldots, 1]$, are considered. Weight values greater than 0 result only for four predictors (maximum wind speed, outer rainband CAPE, large-scale temperature gradient, and inner-core inertial stability (0-100 km)) and they are respectively: 0.4 0.1, 0.1, 0.4. Those values are kept constant over the verification period defined by 1/3 of the Atlantic dataset not used for the optimization process.
   - The MAE index for maximum wind speed prediction is computed over the verification period for HWRF, AnEn using only the maximum wind speed as its only predictor (AnEn), and AnEn after the optimization (AnEn optim). AnEn and AnEn optimal improve the MAE of the HWRF by 6.2% and 7.7% respectively. MAE is plotted in Fig. 1 and bias is plotted in Fig. 2.
   - **Next steps:** We suspect we can improve the results by smoothing HWRF vmax in time, as the noisiness of the variable may be making finding analogs more difficult.

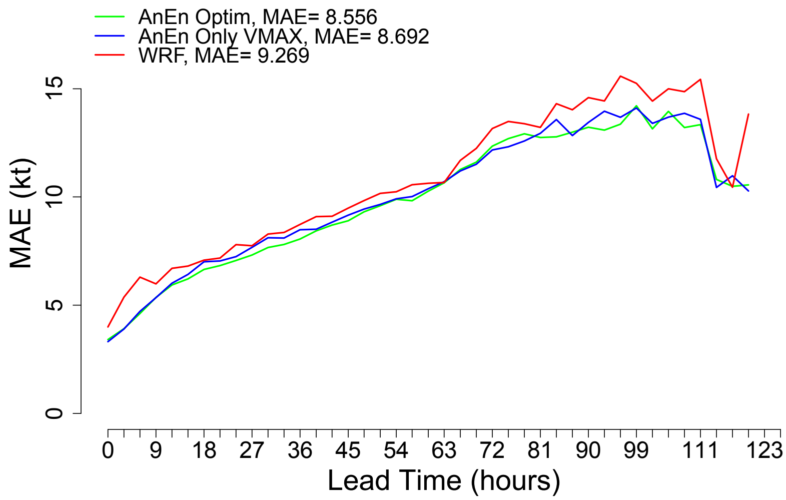

Fig. 1. Mean absolute error (MAE) for the WRF data used in the verification period, the MAE for an AnEn using only the predictor for VMAX, and an AnEn Optimal weighting with multiple predictors. In the first 48 h, the MAE differences are statistically significant.

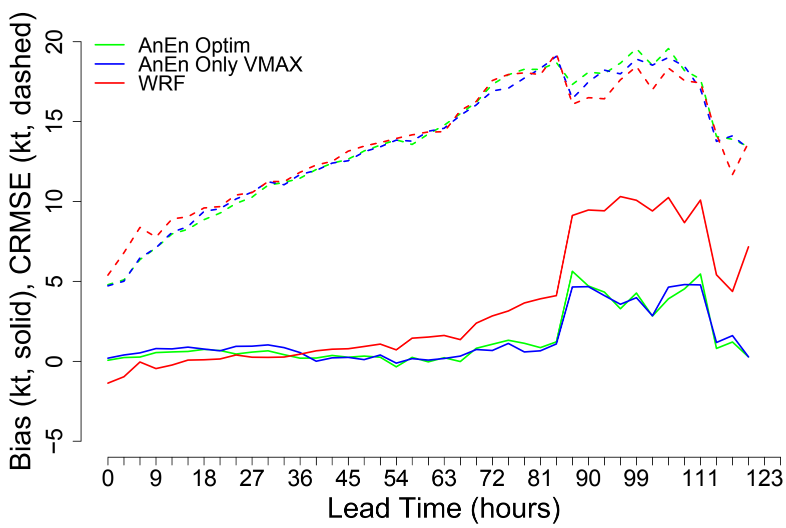

Fig. 2. Bias and combined root mean squared error for the WRF data used in the verification period, the MAE for an AnEn using only the predictor for VMAX, and an AnEn Optimal weighting with multiple predictors.

Project timeline

This project is slated to take place over a two-year period. The project timeline was modified from the original proposal to conform to the new starting date of August 2014 and is detailed below.

Task	Activity
1	Develop predictors from the HWRF data 2008-2013 training dataset for all forecasts and lead times (definitely ATL, perhaps WPAC) (led by UW personnel) [Aug 2014 – Feb. 2016]
2	Construct the AnEn for TC intensity prediction using a manually determined set of optimal predictors to get algorithm working / Also, start objective feature selection over large number of HWRF-based predictors [Nov. 2014 – July 2015]
3	Build extended logistic regression (LR) model with the HWRF training dataset (UW/NCAR) [Nov. 2014 – March 2016]
4	Process HWRF data from 2014 season (form predictors, make forecasts) (UW/NCAR personnel) [Sep. 2014 – Dec. 2014]
5	Verification/Evaluation of the AnEn and LR model (NCAR/UW personnel) [Dec. 2014 – July 2016]
6	Real-time testing of models on 2015 hurricane season and update AnEn (UW/NCAR). [May 2015 – November 2015]