Probabilistic Prediction of Tropical Cyclone Rapid Intensification Using Satellite Passive Microwave Imagery

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Entire Project Period – 09/01/2015 – 08/31/2017

1. General Description of Progress

The primary goal of this project is to improve the probabilistic prediction of rapid intensification (RI) in tropical cyclones (TCs). The framework in which we work is probabilistic models. We specifically are innovating upon existing statistical models that use environmental and TC-centric predictors. The statistical models used in this work include the Statistical Hurricane Intensity Prediction System (SHIPS) RI Index (RII) (Kaplan et al. 2010; *Wea. Forecasting*) and the logistic regression and Bayesian models of Rozoff and Kossin (2011; *Wea. Forecasting*) and Rozoff et al. (2015; *Wea. Forecasting*). The updated models will include a new class of predictors derived from passive microwave imagery (MI) evincing aspects of storm structure relevant to RI. We now briefly describe the progress made so far.

Before model development, we updated our MI developmental dataset. We already possessed a dataset of SSM/I, SSMIS, TRMM-TMI, and AMSR-E (Rozoff et al. 2015) for 1998-2013. We updated this data to include the 2014-2015 time period as well, at least for those sensors that were still operational. In addition, we have added AMSR2 and GMI data to this dataset. We are interested in focusing on predictors derived from three different channels, including the 18.7, 36.5, and 89.0-GHz channels of AMSR-E/2 and GMI. To use predictors from all satellite platforms in a consistent way, we calibrated the 19.35, 37.0, and 85.5/91.7-GHz channels of the other sensors to the AMSR-E/2 and GMI channels. The simple histogram matching technique described in Rozoff et al. (2015) was used for calibration.

With the updated developmental dataset, we will continue to consider the simple inner-core MI-based predictors of Rozoff et al. (2015) in our model development, but have also developed new predictors describing aspects of storm structure. The new predictors can be summarized as follows:

a. Asymmetric structure predictors (including predictors describing rainband structure), derived from two-dimensional empirical orthogonal functions (Rozoff and Knaff 2016; *J. Appl. Meteor. Clim.*, to be submitted) and parameters from the Automated Rotational Center Hurricane Eye Retrieval (ARCHER) algorithm (Wimmers and Velden 2010; *J. Appl. Meteor. Clim.*),
b. Inertial stability and latent heating coupling predictors, derived from two different approaches: (1) HWRF (H215 version) initial wind analyses, and (2) the MI-based wind structure estimates developed from a developmental dataset of aircraft reconnaissance wind data, attendant HURDAT data, and MI. (Rozoff and Knaff 2016),
c. Models derived with respect to the stage of RI.

Currently, we are updating the logistic regression, Bayesian, and SHIPS-RII models to incorporate the new predictors and will test them as reforecasts on archived real-time data, as in Rozoff et al. (2015).

As a proof of concept of how we believe the updated models will benefit the skill of RI predictions, we developed a preliminary consensus using only the logistic regression and Bayesian model (Fig. 1) with the older predictors for the years 1998-2012. As can be seen, the consensus model is more skillful than its constituent models. Also, there are clear indications that the MW-based predictors add significant skill in all cases.

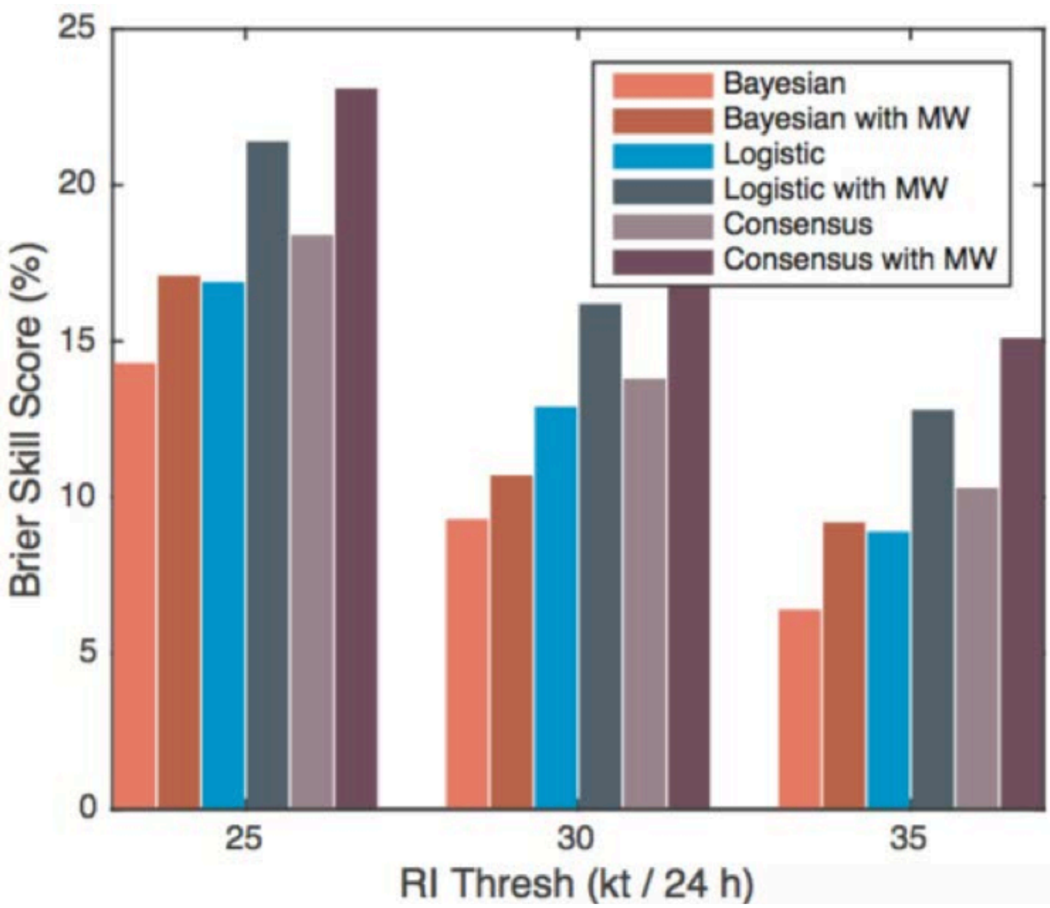

Figure 1. Brier skill scores for the Bayesian model, the logistic regression model, and their consensus at 25, 30, and 35 kt $(24\ h)^{-1}$ RI thresholds without MI-based predictors (light colors) and with MI-based predictors (darker colors) for the Atlantic Ocean. These results are validated using leave-one-year-out cross validation over the years 1998-2012.

2. Transition to Operations
    a. Summary of testbed-related activities and outcomes

       Currently, we are still in the development phase of this project. We plan on completing the evaluation of all probabilistic models for real-time testing by May 2016, as specified in our proposal. We also need to convert our code from Matlab to Fortran/C for operational implementation, and this work will commence soon in April 2016. Simultaneously, the experimental products will be tested at CIMSS in real-time for the May to November 2016 hurricane seasons in the Atlantic and Eastern Pacific Ocean basins.

b. What was transitioned?

Nothing has been transitioned to operations at this stage of the project.

c. TRL* current vs. start of project

TRL currently: 3 (soon to be 4)
TRL at start of project: 2

d. Lessons learned

While no roadblocks for transitional development have been experienced at this stage of the project, we have learned from past experience that the development of operational deliverables should be completed in the Fortran/C environment, and therefore, converting our code from Matlab format is an important priority in our work.

e. Next steps – future plans

In terms of operational transitions, we will soon (April 2016) begin substantial steps toward operational transitions by converting our code to Fortran/C which will mesh well with operational computing systems. Real-time testing on the upcoming hurricane season will help provide experience with the experimental system before porting to operational systems. We plan on preparing final NCEP-ready code and documentation for running and maintaining the models in early 2017 and hope for experimental testing of the models in an operational environment in the 2017 hurricane season.

i. Has it been approved for transition yet? Plans for future transition?

This project is at too early of a stage for transition approval, but that is our primary goal of this work. We will work with our points-of-contact to coordinate operational testing and eventual operational transitions.

3. Milestones

All milestones below are described in accordance to the timeline provided in our proposal.

a. Completed

(1) Update developmental dataset to include microwave imagery of Atlantic and eastern Pacific TCs from all available sensors (1998-2016).
(2) The new MI-based predictors have been created.

b. Not completed (in progress)

(3-5) Enhancement and evaluation of the updated logistic regression, Bayesian, and SHIPS-RII models (and thereby their consensus prediction) with the up-to-date MI dataset and new predictors.

i. Reasons

The data calibration in the updates of the new developmental dataset took longer than expected.

ii. Mitigation plan

Now that datasets are calibrated and fully collected, and predictors are created, model development and testing will follow rapidly and significant progress is being made at the time of this report.

(6-10) The remaining milestones in our proposal were not scheduled for completion in this period of performance, but we anticipate that we will meet these milestone goal times as they approach since the difficult work of data collection and calibration has been completed.

4. Publications

a. Journal articles published

None in this reporting period.

b. Journal articles in process

We plan on submitting at least one manuscript for peer-review publication, but it is too early to state the title and desired journal for submission.

c. Other publications/presentations

Rozoff, C. M., C. S. Velden, and J. Kaplan, 2016: JHT Project 7: Probabilistic prediction of tropical cyclone rapid intensification using satellite passive microwave imagery. *Presentation at the 2016 Tropical Cyclone Operations and Research Forum, Miami, FL, 16 March 2016.*

Rozoff, C. M., C. S. Velden, and J. Kaplan, 2016: Probabilistic prediction of tropical cyclone rapid intensification using passive microwave imagery. *Poster Presentation at the 32nd AMS Conference on Hurricanes and Tropical Meteorology, San Juan, Puerto Rico, 19 April 2016.*