NOAA/OAR Joint Hurricane Testbed

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Improved Eyewall Replacement Cycle Forecasting Using a Modified Microwave-Based Algorithm (ARCHER)

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1. ACCOMPLISHMENTS DURING THIS PERIOD

The milestones for this project, first described in the project proposal, are summarized in the following table. The major goals for this reporting period (Feb 2017-Aug 2017) are highlighted in yellow and described in turn directly below.

Milestones/Deliverables

Milestone	Start Date	Forecasted Completion	Actual Completion	% Complete
1. Create a double eyewall module for ARCHER	July 2015	Dec 2015	Dec 2015	100%
2. Create real-time online display of ARCHER-ERC output	Jan 2016	June 2016	June 2016	100%
3. Evaluate performance of online ARCHER module display	Jan 2016	June 2016	June 2016	100%
4. Produce initial online technical documentation	Jan 2016	June 2016	June 2016	100%
5. Calibrate/validate the ERC probability product	Jan 2016	June 2016	Feb 2017	100%
6. Finalize double eyewall ARCHER module to optimize performance	July 2016	Dec 2016	Dec 2016	100%
7. Finalize online display of algorithm	July 2016	Dec 2016	(May 2017)	100%
8. Complete online technical documentation	Jan 2017	June 2017	June 2017	90%
9. Deliver ERC module for SHIPS	Jan 2017	Feb 2018		
10. Create real-time online text file output of ERC module for SHIPS	Jan 2017	Feb 2018		

Here we report on the progress on **Milestones 7-8** in the previous six-month period, and update on the evaluation of the real-time performance of the algorithm in this particularly active hurricane season:

Milestone 7. Finalize online display of algorithm

The online display has now reached its intended form, with three columns of plots for forecaster guidance. This is shown below for a six-day period of Hurricane Irma (Figure 1). On the left is the Hovmoller diagram of ARCHER ring score, which clarifies the progression of eyewall and proto-eyewall inner edges with time. In the center is the M-PERC "probability of an imminent ERC" using a probabilistic model of ARCHER scores and Vmax history ("Full model": *), and also using Vmax history only (o). On the right is the operational Vmax, which helps to contextualize the M-PERC scores in the progress of a TC's intensification or de-intensification. This is situated within a directory of microwave images through the TC's history, as shown in earlier reports.

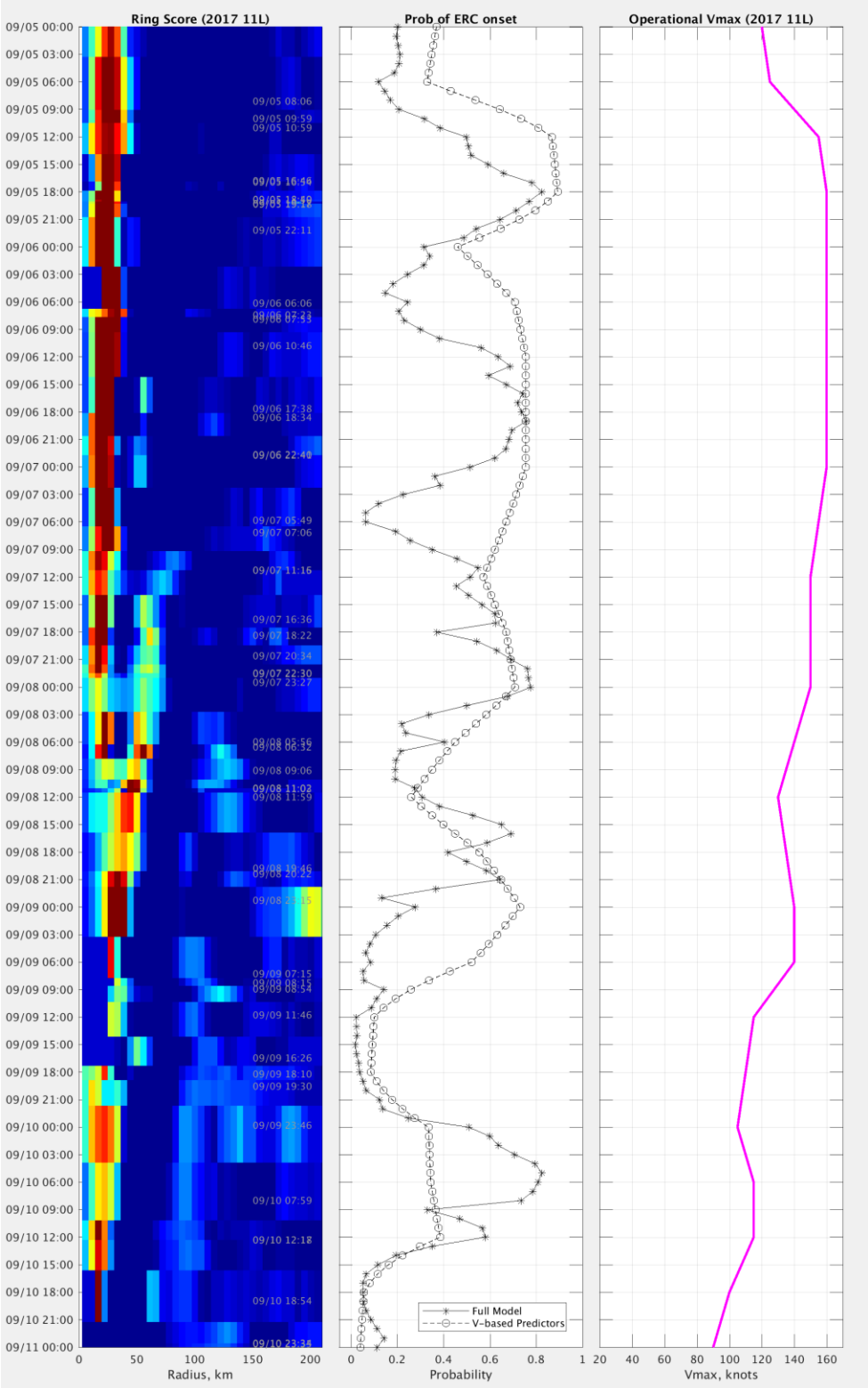

Figure 1: Example of real-time display of ERC guidance for six days of Hurricane Irma (2017). Details explained in text.

We have been following the performance of this product in real time during each of the North Atlantic tropical storms to evaluate the effectiveness of these probabilistic predictions. The example from above is a reasonably good case of typical performance. Below we discuss the details of this performance, with annotations shown in Figure 2.

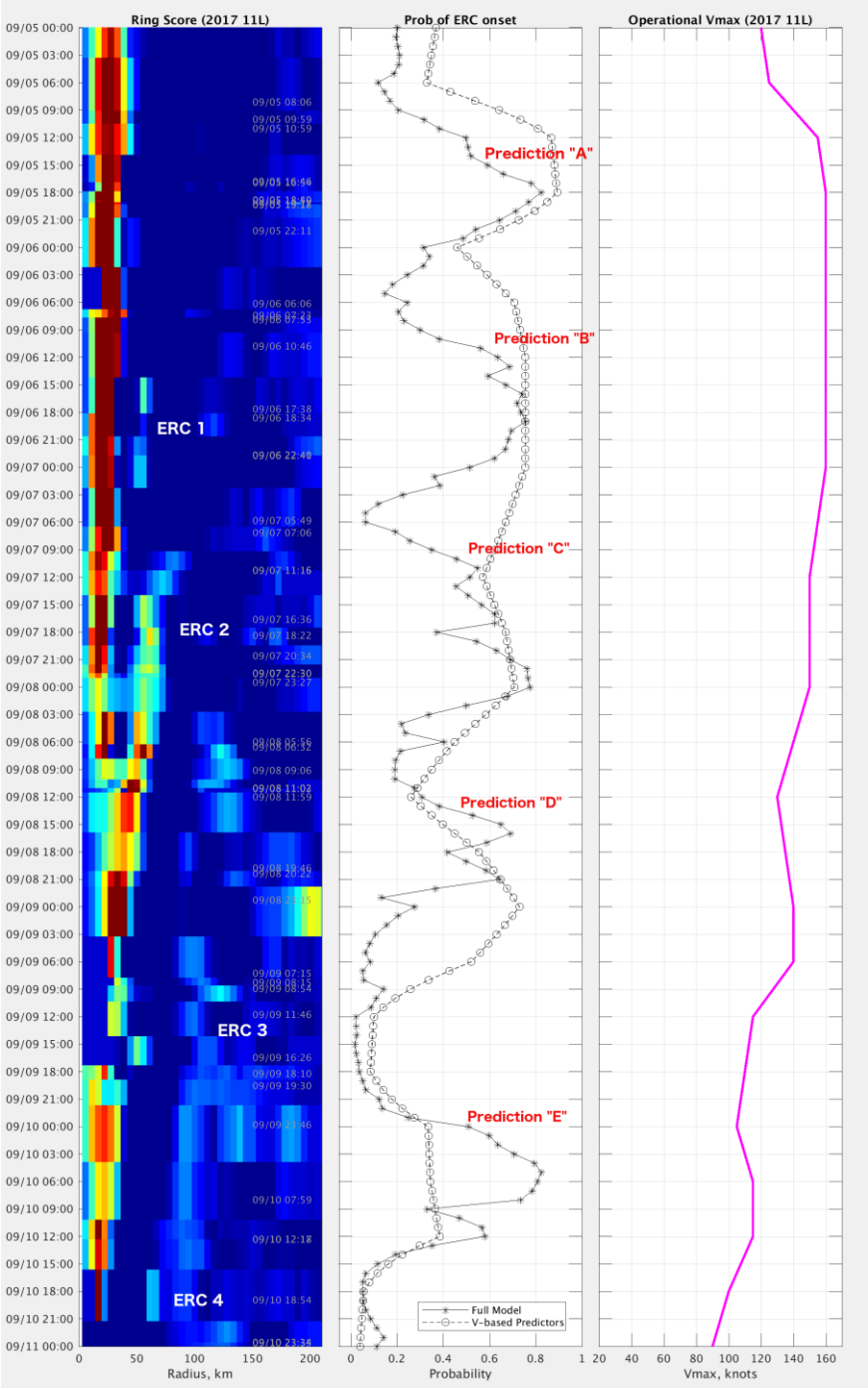

Figure 2: Annotation of the real-time display of ERC guidance for six days of Hurricane Irma (2017). Details explained in text.

During this particularly intense period in the evolution of Hurricane Irma (2017), four ERCs took place in the span of these six days. The ERCs are labeled and numbered in the ARCHER ring score Hovmoller plot in the left of Figure 2. Although each ERC is unique, they can be identified by their common characteristic of an outer branch of relative maximum scores merging with the more intense inner branch and increasing the radius of the new eye.

Here we classify a "Prediction" of an imminent ERC from the M-PERC model as a moment in which the M-PERC Full Model reaches above a 50% probability. In four out of five cases, the prediction is verified with an ERC completing approximately 18-24 hours later. The one exception is "Prediction A" at about 9/15 15Z. Here we can see that the less accurate "V-based" model is much more aggressively predicting an ERC, and it is clear that the influence of the sudden increase in Vmax in the intense hurricane was responsible for directing the Full Model toward a positive prediction. However, this can be easily discounted by a user because of the complete absence of a secondary eye feature in the microwave imagery. (This can be seen in the Hovmoller plot at that time, in the dark blue area throughout the outside of the eyewall.)

In summary, the performance of this predictive model is good, but we are still developing optimal methods of interpreting the probabilistic results and employing these results in an intensity prediction scheme. This is expanded upon in Section 5.

Milestone 8. Complete online technical documentation

The online technical documentation was produced as a wiki collaborative document hosted at SSEC (https://groups.ssec.wisc.edu/groups/archer/archer-erc-introduction), and linked from the ARCHER-ERC page. The documentation is complete, but we are keeping the progress on this milestone at "90%" because we intend to add further guidelines for interpreting the probabilistic model when the 2017 hurricane season has provided us with a larger sample size of cases.

2. PRODUCTS

As described in Section 1, we have developed the following deliverables/products during this reporting period:

a. The real-time ERC guidance website at CIMSS, showing Hovmoller plots of ARCHER ring score, the M-PERC model output, and a directory of TC microwave imagery that the model is built from.
b. A website of online technical documentation.

3. PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS

As this is a fairly small project, we have kept the activity limited to the three original participants – Anthony Wimmers, Derrick Herndon and Jim Kossin. We have provided regular updates to our colleagues at the NHC.

4. IMPACT

The expected impact of this project is to improve the forecasting accuracy for intense hurricanes in one of the current areas of need for the NHC: understanding and predicting eyewall replacement cycles. We attempt to do this using an automated analysis of eyewall (and developing eyewall) sizes and trends from 85-92 GHz microwave imagery. The information is organized into real-time online graphics and an associated probabilistic model. These new tools under development will offer a more rigorous analysis of a phenomenon that requires greater understanding and analysis to provide adequate warning during weather-related emergencies.

5. CHANGES/PROBLEMS

We have requested and received a one year no-cost extension to this project in order to further evaluate the real-time performance of the probabilistic model, and develop optimal methods for interpreting the output. This hurricane season has been a rich source of data for evaluation. At the conclusion of this season, we will finalize our evaluation of how the model performs at various intensities, shear environments, data availability, and so on. This will allow us to provide the right level of guidance to help forecasters apply the appropriate amount of confidence to the model output.

6. SPECIAL REPORTING REQUIREMENTS

Test Plans for the ARCHER-ERC / M-PERC Project

As stated in Sections 1 and 5, we will continue to run the automated ARCHER-ERC and MPERC for the real-time website at CIMSS through the next year and beyond. At the end of the 2017 hurricane season, we will evaluate and report the model performance in order to develop the appropriate guidelines for users.

The primary criterion for success is a positive review from NHC participants within the JHT. Their decision will be based on quantitative performance metrics compiled by the CIMSS team (accuracy, Brier Skill Score), case histories, as well as the NHC's professional judgment of the skill of the algorithm in real-time.

Project Readiness Level

The online tools (Milestones 2 and 3) and the M-PERC probability model can be considered "RL 7: Prototype system." (This is 7 of 9). These tools are currently working in an operational environment in a demonstration phase and user documentation is online and ready for further feedback. The remaining criterion for reaching the next level is receiving the operator approval.

Transition to Operations Activities

In preparation for transition to operations, we are testing the final products in real time and continue to explore options for recoding the full ARCHER system into a format that is compatible with the NHC system.

Testbed Approval

The decision to transition to operations will occur after the close of the project, in late 2017.

7. BUDGETARY INFORMATION

We are currently on budget and our planned expenditures are as expected. Our proposal stated that the product development should proceed quickly by following the development pathways of the original ARCHER project and the pERC model. This has gone as expected. The approved budget is $80,299 and spending to date through the reporting period of August 2017 is $56,355.95, which is 70% spent two years into this three-year project. Note that from an accounting perspective, there is a one month posting lag time (ie. charges from February post in March), which often gives the appearance of being underspent.

8. PROJECT OUTCOMES

The anticipated outcome of this project is a new system to automatically analyze near real-time microwave imagery of hurricanes and provide comprehensive forecaster guidance on the potential for an upcoming eyewall replacement cycle. This guidance will take the form of an online graphical depiction of the relevant image characteristics, and a probabilistic model using microwave image information in the same fashion as the pERC model.

REFERENCES

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