

NOAA Joint Hurricane Testbed Project Final progress report

A New Secondary Eyewall Formation Index: Transition to Operations and Quantification of Associated Intensity Changes

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Summary

A new empirical/statistical model that provides a probability of onset of an eyewall replacement cycle (ERC) was successfully transitioned to an experimental operational product. The model provides probabilities at lead times of 12h, 24h, 36h, and 48h based on environmental and satellite-derived features. The model executes under the operational SHIPS, and derives its required input from the data streams that go into SHIPS.

The second phase of this project led to the recent completion of an objective climatology of intensity and structure changes associated with ERC. This required the construction of an expanded database, comprised mostly of low-level aircraft reconnaissance data. The resulting climatologies have provided new quantitative insights into ERC behavior, particularly related to associated intensity and structure changes. Work is now underway to complete the development of operational forecast tools based on the climatologies.

Synopsis of Project Milestones:

1. Conversion of model code to FORTRAN and transition to SHIPS prior to the onset of the 2010 hurricane season.
2. Successful implementation during the 2010 season and (ongoing) 2011 season (Fig. 1).
3. Verification of the 2010 operational skill of the model. Model showed skill out to 24h lead-time. A posteriori, but true operational verification of 2008–2010 seasons also showed skill out to 24h lead-time (Figs. 2 and 3).
4. Completion of new database of low-level aircraft reconnaissance measurements of intensity and wind structure.
5. Quantification of intensity (and structure) changes associated with eyewall replacement cycles (Fig. 4 and Table 1), and dissemination in peer-reviewed literature (Sitkowski, M., J. P. Kossin, and C. M. Rozoff, 2011: Intensity and structure changes during hurricane eyewall replacement cycles. *Mon. Wea. Rev.*, to appear. Early online release available at AMS.)

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* ATLANTIC SHIPS INTENSITY FORECAST *
* GOES DATA AVAILABLE *
* OHC DATA AVAILABLE *
* EARL AL072010 09/02/10 00 UTC *

TIME (HR) 0 6 12 18 24 36 48 60 72 84 96 108 120
V (KT) NO LAND 120 120 119 117 114 102 88 73 58 40 31 20 DIS
V (KT) LAND 120 120 119 117 114 102 88 64 45 33 24 DIS DIS
V (KT) LGE mod 120 122 120 117 112 98 81 55 46 36 37 39 41

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Portion of SHIPS output file removed

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** PROBLTY OF AT LEAST 1 SCNDRY EYEWL FORMTN EVENT AL072010 EARL 09/02/2010 00 UTC **
TIME (HR) 0-12 12-24 (0-24) 24-36 (0-36) 36-48 (0-48)
CLIMO (%) 33 33 ( 55) 30 ( 69) 24 ( 76) <-- PROB BASED ON INTENSITY ONLY
PROB (%) 36 14 ( 45) 0 ( 45) 0 ( 45) <-- FULL MODEL PROB (RAN NORMALLY)

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Figure 1: Operational SHIPS output file for Hurricane Earl (2010). The bottom 4 lines show the output of the new model. Probabilities are provided in four 12h periods, 0-12h, 12-24h, 24-36h, and 36-48h. The climatological probability based solely on intensity is provided for comparison above the probabilities provided by the full model. Values in parentheses are cumulative probabilities for 0-24h, 0-36h, and 0-48h.

Operational Model Verification

The cross-validated Brier Skill Score (BSS) based on the SHIPS developmental dataset, which is based on posterior reanalysis and best track, was found to be 21% for the combined years 1997–2006 with a range of –23% to +33% for the 10 individual years (Kossin and Sitkowski 2009). The *operational* BSS in 2010 verified at 27% at 00–12h lead-time (Fig. 2). The operational BSS for the combined years 2008–2010 was +17%. The relatively small degradation in skill from cross-validated (1997-2006) posterior reanalysis (+21%) to operational analysis (+17%) suggests that the model is not overly sensitive to operational input errors, and performs skillfully and predictably in an operational setting. To complement the operational skill assessment based on BSS, attributes diagrams are shown in Fig. 3.

As expected, skill degrades at longer lead-times. For 2008–2010, the model shows little to no skill past 24h. We suspect that our use of the satellite-based features may be one of the culprits here; we followed the SHIPS protocol of simply keeping these features fixed for all lead-times. But the SHIPS model does not strongly weight these features, and is less sensitive than the new model to large variations that can occur on time-scales relevant to forecasting. This issue will be addressed as part of our 2012 JHT project.

Operational Brier Skill Scores

Year	N (ERC)	00–12 hr	12–24 hr	24–36 hr	36–48 hr
2010	9	+27%	+20%	+0%	–3%
2009	3	–6%	–9%	–2%	+3%
2008	4	+14%	+11%	–9%	+1%
2008–2010	16	+17%	+12%	–3%	–1%

Figure 2: Assessment of model performance based on Brier Skill Score.

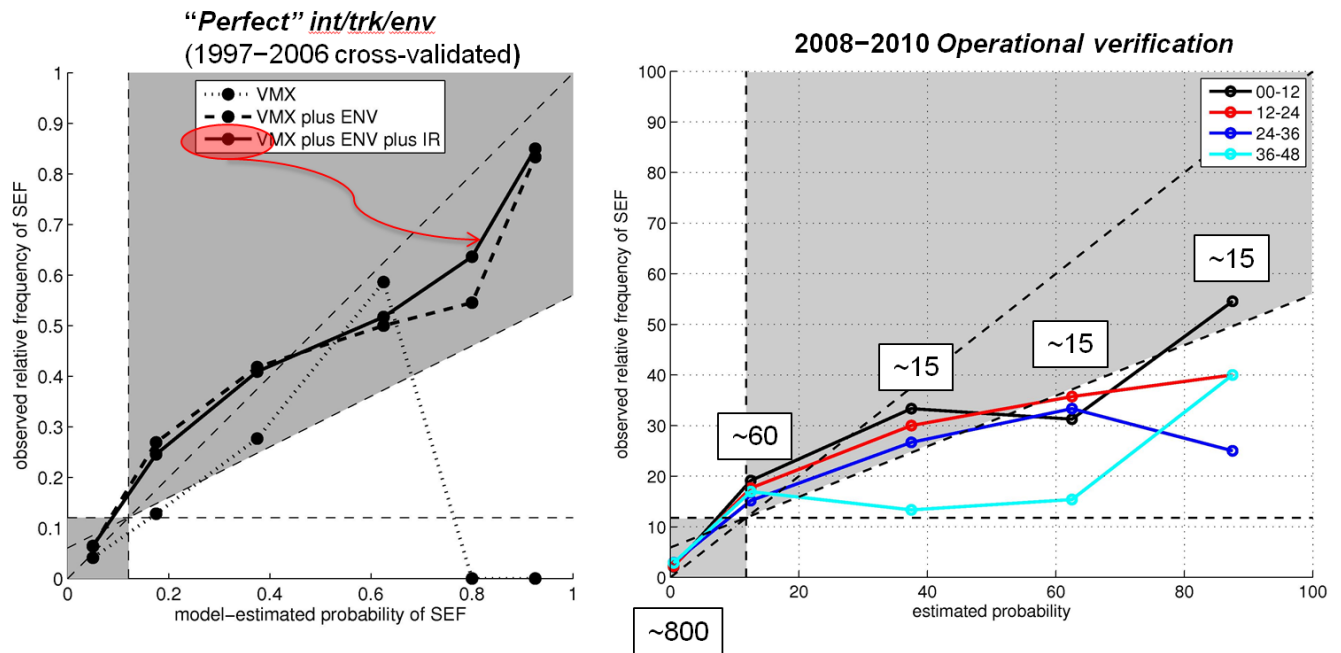


Figure 3: Comparison of cross-validated posterior reanalysis-based reliability (solid line in left panel) and operational reliability at all lead-times (right panel). Numbers in boxes are sample sizes.

Quantification of Intensity (and Structure) Changes Associated with ERCs

A new climatology of intensity and structure changes associated with ERCs was constructed by examining 24 complete ERCs (Sitkowski et al. 2011). We found that these changes naturally separate into 3 distinct phases: intensification, weakening, and re-intensification (Fig. 4). For intensity forecasting purposes then, there are potentially 6 targets that describe the intensity change and the duration of each phase. The average values of these targets and their standard deviations are shown in Table 1. The mean intensity change during phase I is +14kt over a 9h period. During the weakening phase, intensity decreases an average of 21kt over 17h, and re-intensification of 6kt over 11h occurs, on average, after that. The total cycle lasts 37h on average, and intensity ends, somewhat remarkably, about where it started.

The values shown in Table 1 represent the first step toward constructing forecast tools to provide objective guidance for modifying intensity forecasts during ERCs. The large associated standard deviations, however, demonstrate that the utility of the raw climatologies is limited. Identification of environmental features that can explain some of this large variance is underway and will be completed during the FY2012 JHT project.

The 3 Phases of an Eyewall Replacement Cycle

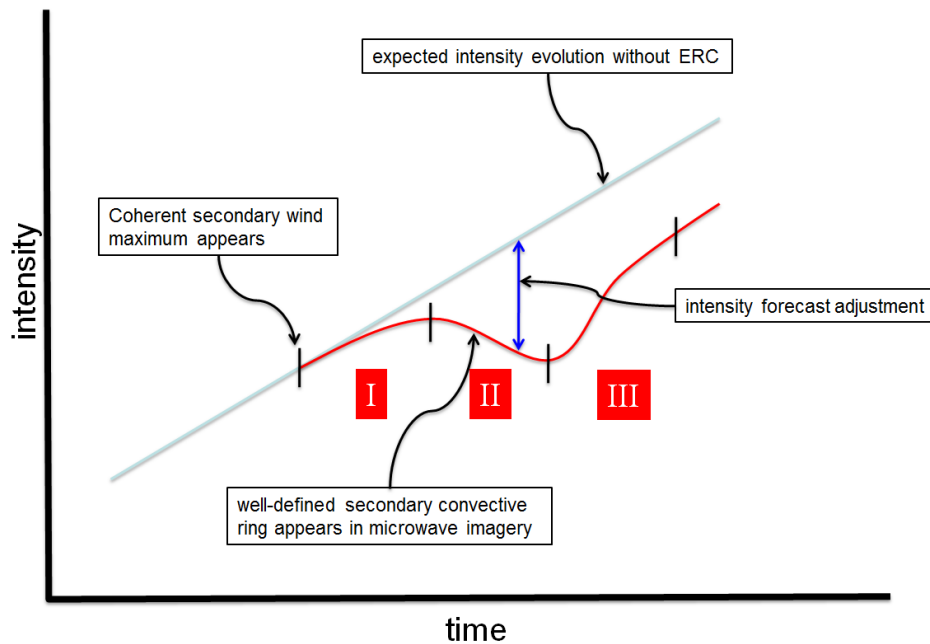


Figure 4: Schematic of the 3 phases of eyewall replacement. Each phase has an associated characteristic intensity (and structure) change and duration.

	Phase I (intensification)	Phase II (weakening)	Phase III (re-intensification)	Mean Total
ΔV (kt) (intensity change)	$\mu = +14$ $\sigma = 17$	$\mu = -21$ $\sigma = 12$	$\mu = +6$ $\sigma = 8$	-1
Δt (hr) (duration)	$\mu = 9$ $\sigma = 9$	$\mu = 17$ $\sigma = 9$	$\mu = 11$ $\sigma = 13$	37

Table 1: Mean values of the 6 forecast targets and their standard deviations. The rightmost column shows the total mean intensity change and duration for the entire eyewall replacement cycle.

Presentations

Results were presented at the 2010 and 2011 Interdepartmental Hurricane Conferences. Results were also presented at the AMS Hurricanes and Tropical Meteorology conference and at National Hurricane Center Colloquia.

Bibliography

- Kossin, J. P., and M. Sitkowski, 2009: An objective model for identifying secondary eyewall formation in hurricanes. *Mon. Wea. Rev.*, **137**, 876-892.
- Sitkowski, M., J. P. Kossin, and C. M. Rozoff, 2011: Intensity and structure changes during hurricane eyewall replacement cycles. *Mon. Wea. Rev.*, to appear.