Eyewall Replacement Cycles: Forecasting Onset and Associated Intensity and Structure Changes

A Joint Hurricane Testbed Project

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RAMMB/CIRA team
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JHT project goals:

1. Transition a new model to operations that provides probabilistic forecasts of eyewall replacement cycle (ERC) events in hurricanes.

2. Utilize low-level aircraft reconnaissance data to expand the general climatology of intensity and structure changes associated with ERCs.

3. Use the new climatology to construct new operational tools that can provide some objective guidance for forecasting intensity and wind structure changes associated with ERCs.

4. Continue model development toward increasing skill.

Models: probability of ERC onset

3 statistical/empirical models have been developed and tested:

1. Bayesian probability
2. Bayesian probability with optimized feature selection
3. Logistic regression

The models provide probability of the onset of an ERC within lead-time periods: 0−12h, 12−24h, 24−36h, 36−48h.

All models execute within SHIPS using environmental and satellite-based features as input.

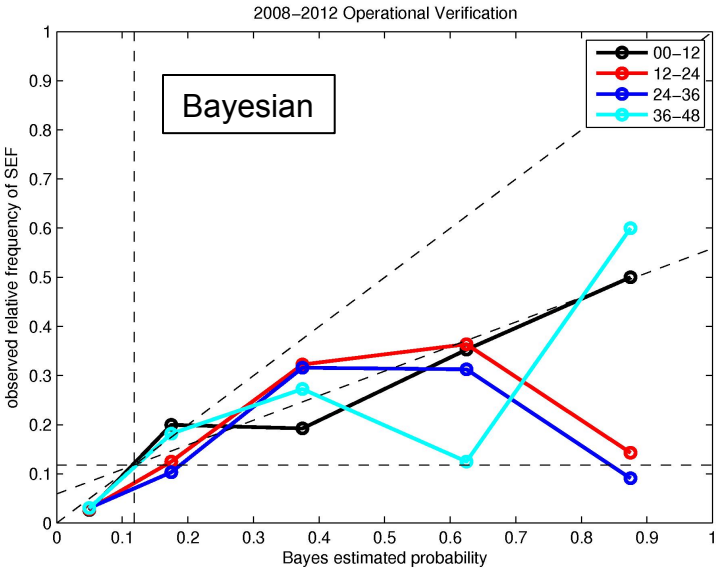
Operational Model Verification 2008-2012 (Brier Skill Scores)

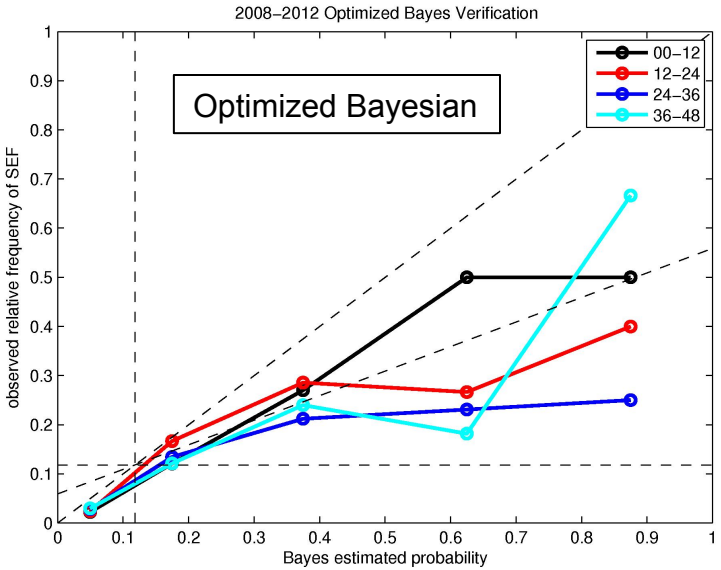
Year	N (TS)	N (HUR)	N (ERC)	00-12 hr	12-24 hr	24-36 hr	36-48 hr
2012	19	10	1	+57 +54 +54 +56	+58 +53 +51 +54	+58 +54 +42 +52	+57 +54 +35 +49
2011	18	6	5	+21 +22 +10 +20	+18 +16 +11 +17	+14 +13 +6 +14	+19 +16 +11 +18
2010	19	11	9	+27 +41 +25 +38	+23 +20 +25 +28	+11 +17 +15 +20	+10 +17 +8 +17
2009	9	3	3	−6 −6 +11 +7	−2 −8 +6 +3	−1 −6 +28 +17	+5 +6 +36 +27
2008	16	8	4	+14 +11 +2 +10	+12 +4 −7 +4	−5 −7 +0 +0	+2 −6 −4 +0
2008-2012	81	38	22	+20 +26 +22 +27	+17 +16 +18 +21	+9 +13 +15 +17	+11 +15 +12 +17

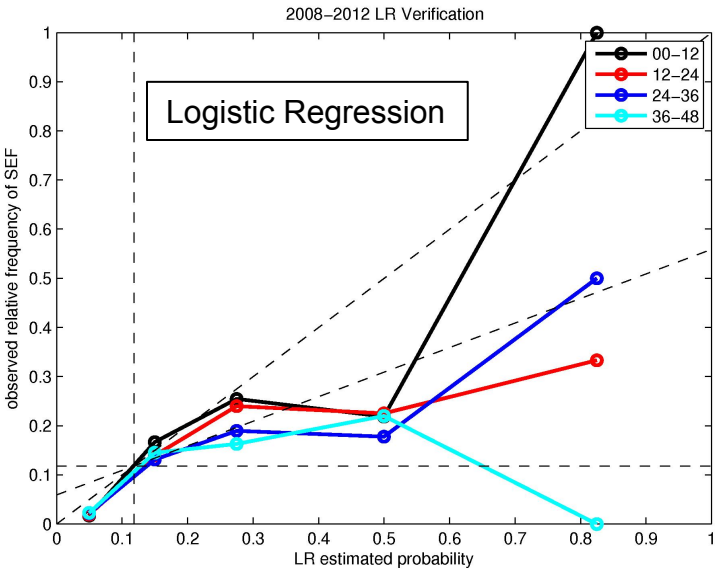
Bayesian | Optimized Bayesian | Logistic Regression | Ensemble

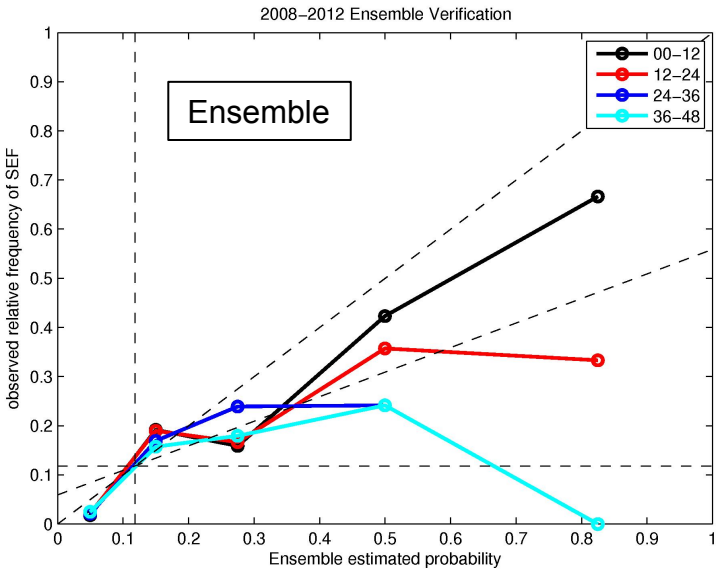
J. Kossin, 67th IHC, Mar 2013

Operational model verification 2008-2012 (attributes diagrams)









An ERC is forecast to begin or there is evidence that one is starting...

What are the forecast questions?

How much does the usual intensity guidance need to be tweaked?

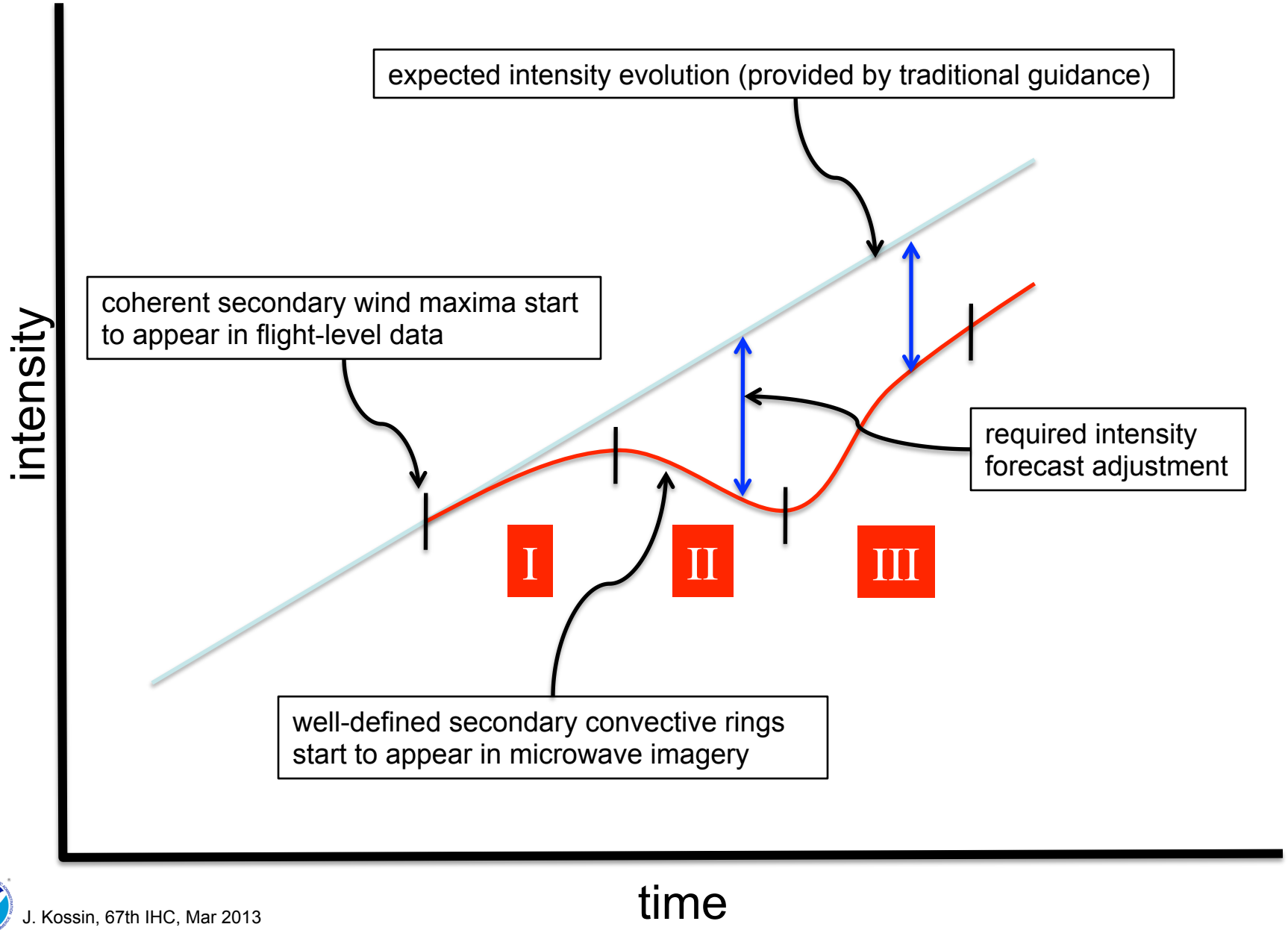
How much will the current intensification rate change?
How much weakening, if any, will occur? Over what period of time?
When will re-intensification begin? At what new rate?

Subjective expectation during ERC:

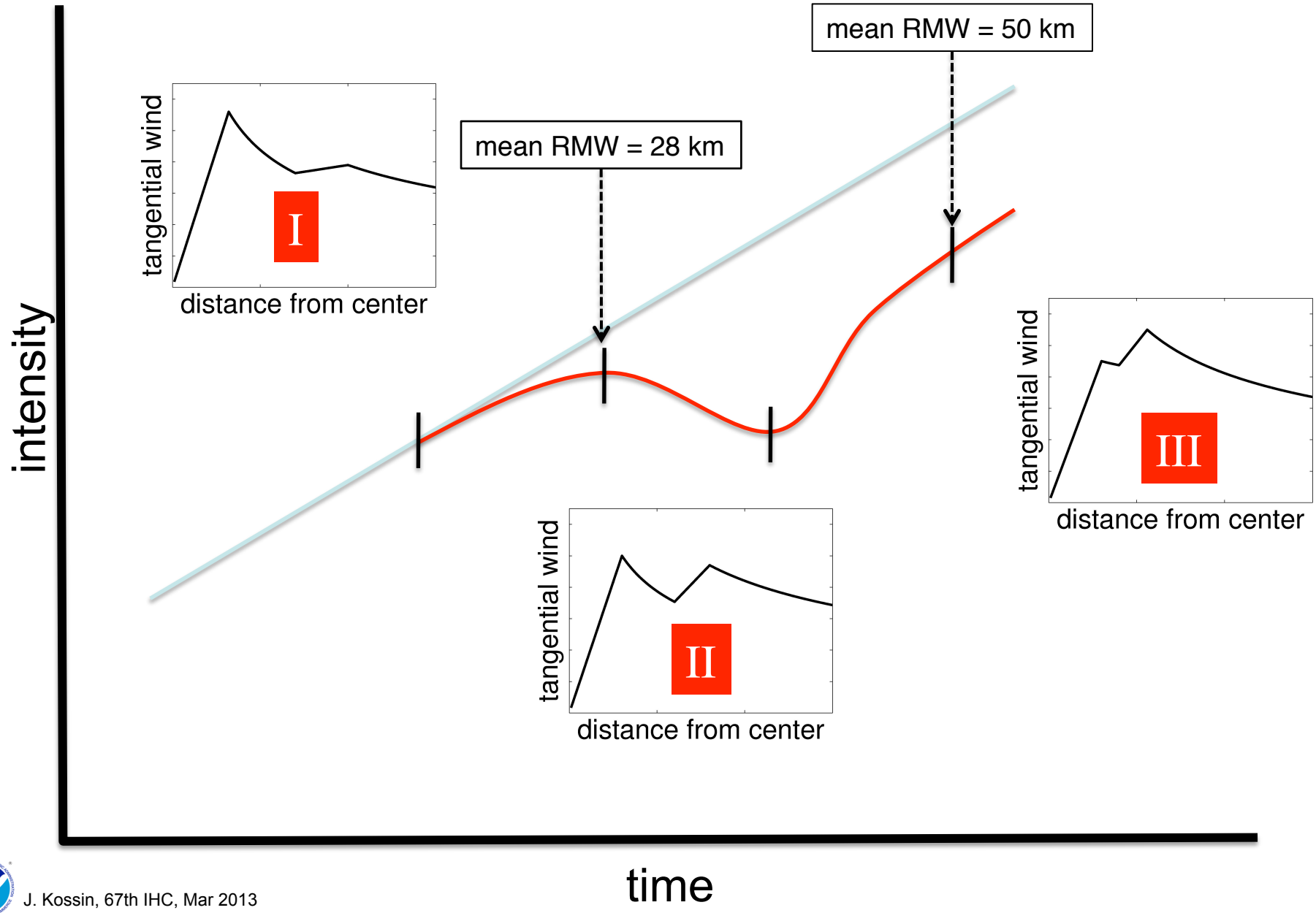
Intensification rate decreases or **weakening** occurs
re-intensification } ⟶ *transient effect*

Wind field **expansion** ⟶ *~permanent effect*

The Three Phases of an Eyewall Replacement Cycle

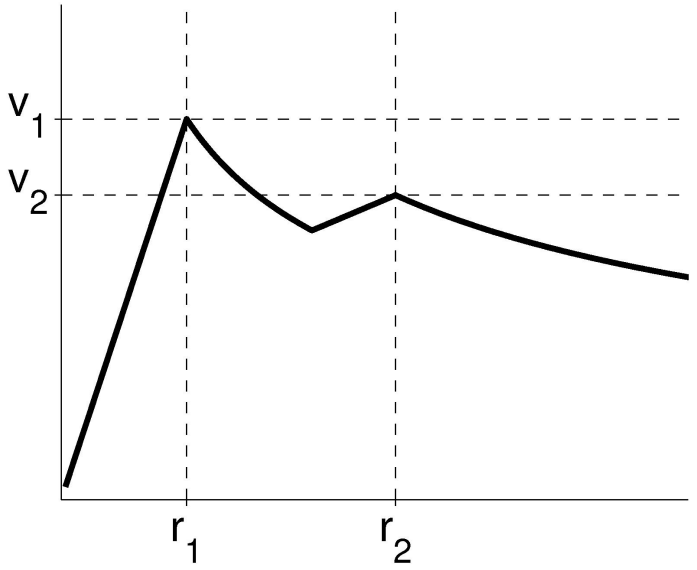


The Three Phases of an Eyewall Replacement Cycle



Climatology of intensity and structure changes

(based on limited events that were well-observed throughout the process)



	Intensification		Weakening		Reintensification	
	Mean	SD	Mean	SD	Mean	SD
Δv_1 (kt)	+14	18	−20	11	−15	14
Δv_2 (kt)	+9	11	+18	14	+8	8
$\Delta v_{\text{best-track}}$ (kt)	+7	11	−9	12	−2	5
Δr_1 (km)	−7.0	11.5	−1.4	6.9	−2.2	8.0
Δr_2 (km)	−14.8	18.8	−28.8	15.9	−12.7	12.0
Δt (h)	9.4	9.1	16.6	8.6	10.7	12.6

Can we use this climatology and the SHIPS features ($\mathbf{F}$) to create useful predictive models?

Phase II ΔV: mean = –20 kt, STDev = 18 kt

$\Delta V = f(\mathbf{F})$ $R^2 = 68\%$, RMSE = 3.6 kt

Phase II ΔT: mean = –17 hr, STDev = 9 hr

$\Delta T = f(\mathbf{F})$ $R^2 = 49\%$, RMSE = 6.2 hr

Phase III $\Delta V / \Delta T$: mean = +0.8 kt hr^{-1}, STDev = 2.3 kt hr^{-1}

$\Delta V / \Delta T = f(\mathbf{F})$ $R^2 = 47\%$, RMSE = 1.3 kt hr^{-1}

Total expansion of RMW: mean = 22 km, STDev = 13 km

$\Delta RMW = f(\mathbf{F})$ $R^2 = 51\%$, RMSE = 9.9 km

Summary

The *P*(ERC)-model has performed skillfully in the NHC operational environment for the past 3 seasons (2010, 2011, 2012). Overall operational skill for the extended period 2008-2012 is also good and has been consistent and stable. Improvements to the original *P*(ERC)-model and use of a simple ensemble have improved the skill further.

The climatology of flight-level intensity and wind structure changes associated with ERCs has been used to construct new intensity forecasting tools. The utility of these tools and whether they should be transitioned into the NHC operational test-bed needs to be discussed further with NHC personnel.