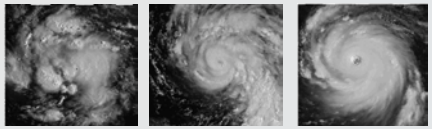

Examining Trends in Satellite-Detected Overshooting Tops as a Potential Predictor of Tropical Cyclone Rapid Intensification

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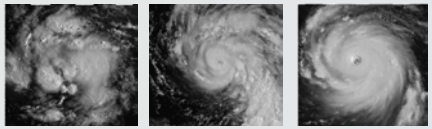
Topics: Tropical Storms/Hurricanes

Program: GOES-R Proving Ground



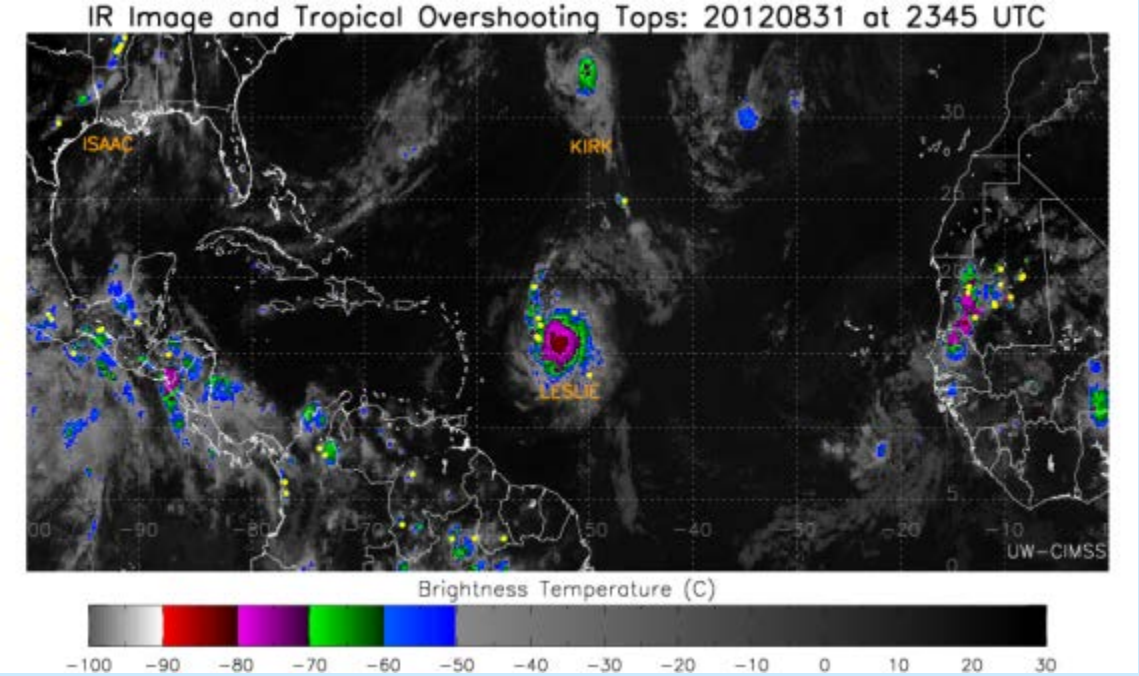
Introduction/Motivation

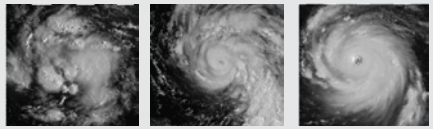
There remains a good deal of difficulty in predicting tropical cyclone (TC) rapid intensification (RI) in the Atlantic Basin. Current statistical models only demonstrate modest skill (Kaplan et al. 2010).

An essential ingredient to the intensification of TCs is active vigorous convection. Identifying and quantifying active convection in the tropics has been attempted in a variety of ways.

Here, we examine satellite IR imagery to identify Tropical Overshooting Tops (TOTs) in an attempt to isolate and quantify trends in vigorous tropical convection associated with TCs, relate that to episodes of RI, and look for potential statistically-significant predictability.

This study is part of the GOES-R Proving Ground for the National Hurricane Center, designed to demonstrate expected products that will be available to forecasters immediately after the launch and activation of GOES-R.





Tropical Overshooting Top Detection Algorithm

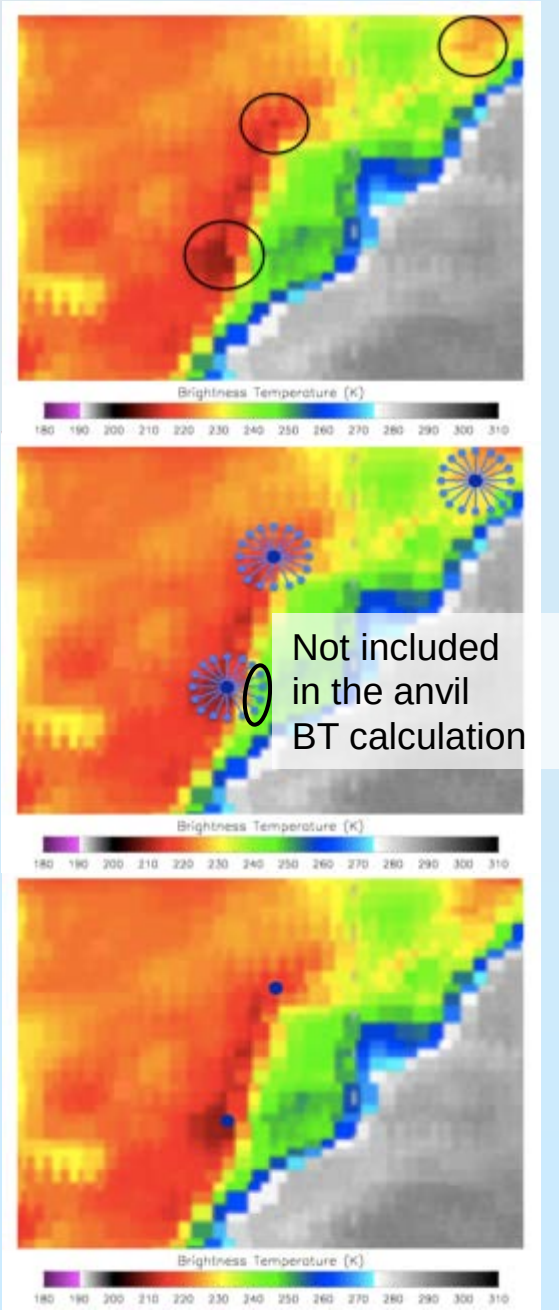
Employing geostationary satellite imagery, find relative minima in the 11 µm (IR) brightness temperature (BT) field colder than 215 K.

↓

Sample the surrounding anvil at an ~8 km radius in 16 radial directions. At least 9-of-16 anvil cloud pixels must be colder than 225 K. Compute the mean BT of these pixels.

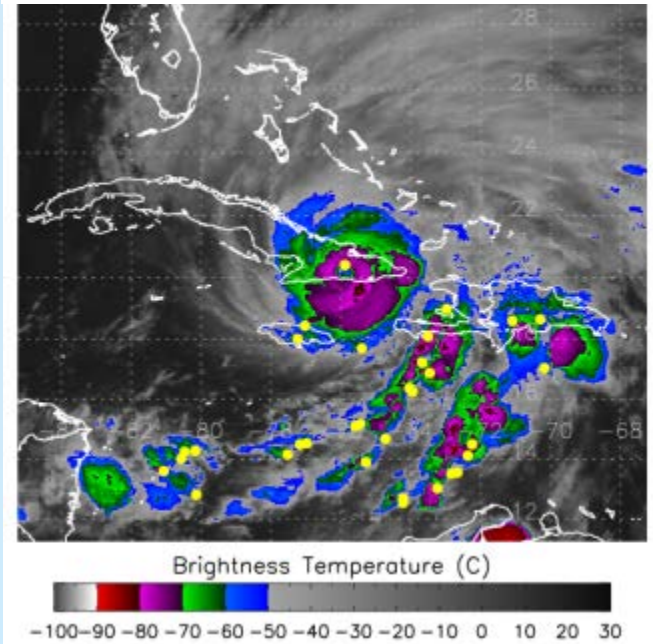
↓

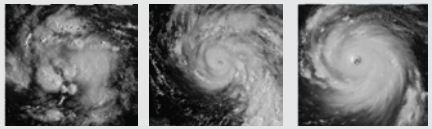
Cloud pixel minima at least 9 K colder than the surrounding anvil BT mean (BTD ≥ 9) are flagged as TOTs.



Example from 2012 NHC Proving Ground – Hurricane Sandy

GOES-E color-enhanced IR image and identified TOTs (yellow dots) at 0615 UTC on 25 October, 2012





Determine Optimal TOT Predictors for Probabilistic RI

Based on a number of TOT parameters, trends, and combinations, we run forecasts using TC cases from 1995-2005 & 2008 (dependent sample) of potential RI for 3 RI thresholds (after Kaplan et al. 2010):

25 kt increase, 30 kt increase, 35 kt increase in max wind speed in 24 h

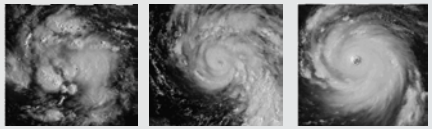
Optimal TOT parameter combinations are determined by the forecasts with best (highest) Peirce Skill Score (after Kaplan et al. 2010):

		Observed	
		Yes	No
Forecast	Yes	h	f
	No	m	z

Forecast Metric	Equation
Peirce Skill Score (PSS)	$\frac{h}{h+m} - \frac{f}{f+z}$
Probability of Detection (POD)	$\frac{h}{h+m}$
Probability of False Detection (POFD)	$\frac{f}{f+z}$
False Alarm Ratio (FAR)	$\frac{f}{h+f}$

<u>Summary of Results:</u>

- TOT trends show some skill at predicting RI to occur
- As expected, less skillful at predicting RI compared to operational RII multi-predictor model that includes other important environmental factors not captured through TOTs alone

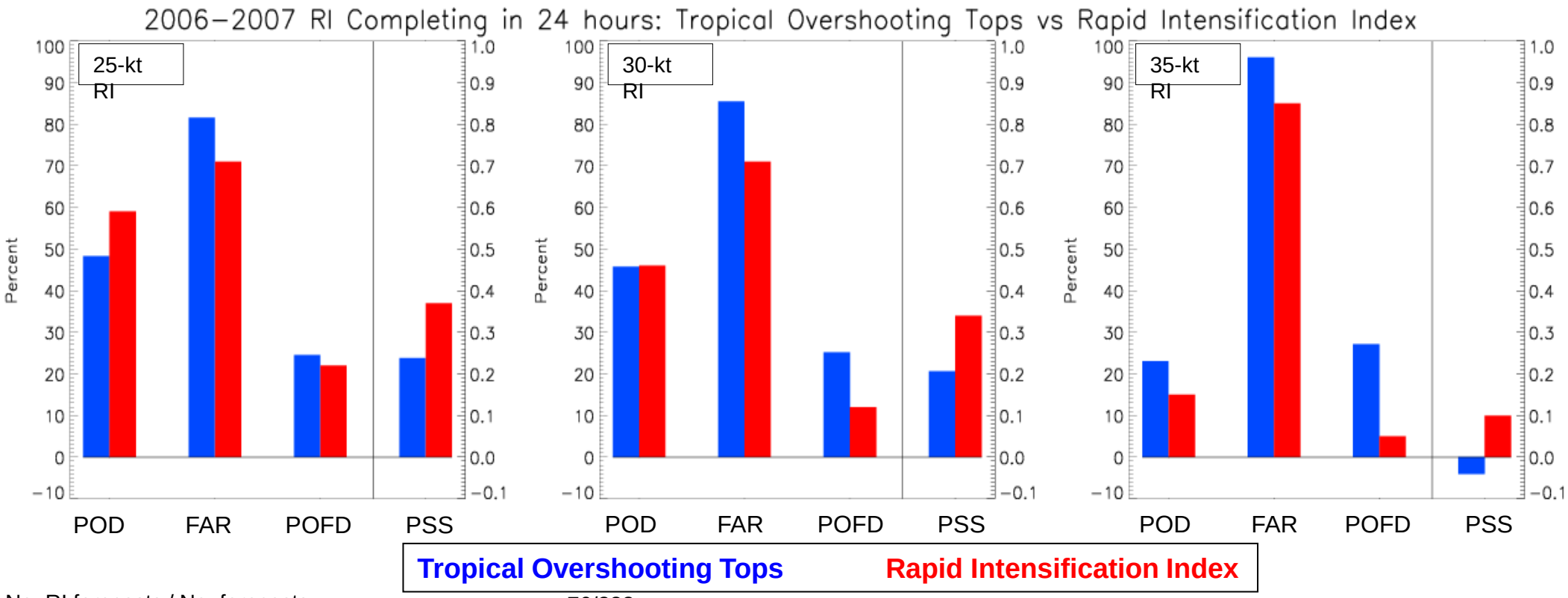


Forecasting RI in the subsequent 24 hours: Overall Results

TOT parameters for all RI thresholds:

3-hour average of at least 2.0 TOTs scan^{-1}, with a BT of 215 K or colder, and a BTD greater than or equal to 9 K within 300 km of the TC center.

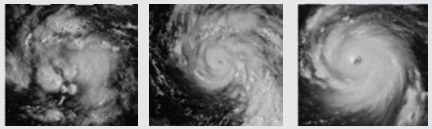
Forecasts run on independent sample of 2006-2007 Atlantic TCs to benchmark results against operational *Rapid Intensification Index (RII)* (Kaplan et al. 2010).



No. RI forecasts / No. forecasts 76/282

Based on Peirce Skill Scores, the TOT-based RI forecasts are skillful (exception 35-kt)

TOT-based forecast is less skillful than the Rapid Intensification Index (expected result).



Potential Addition of the TOT Information into a Probabilistic, Multi-Predictor RI Forecast Model

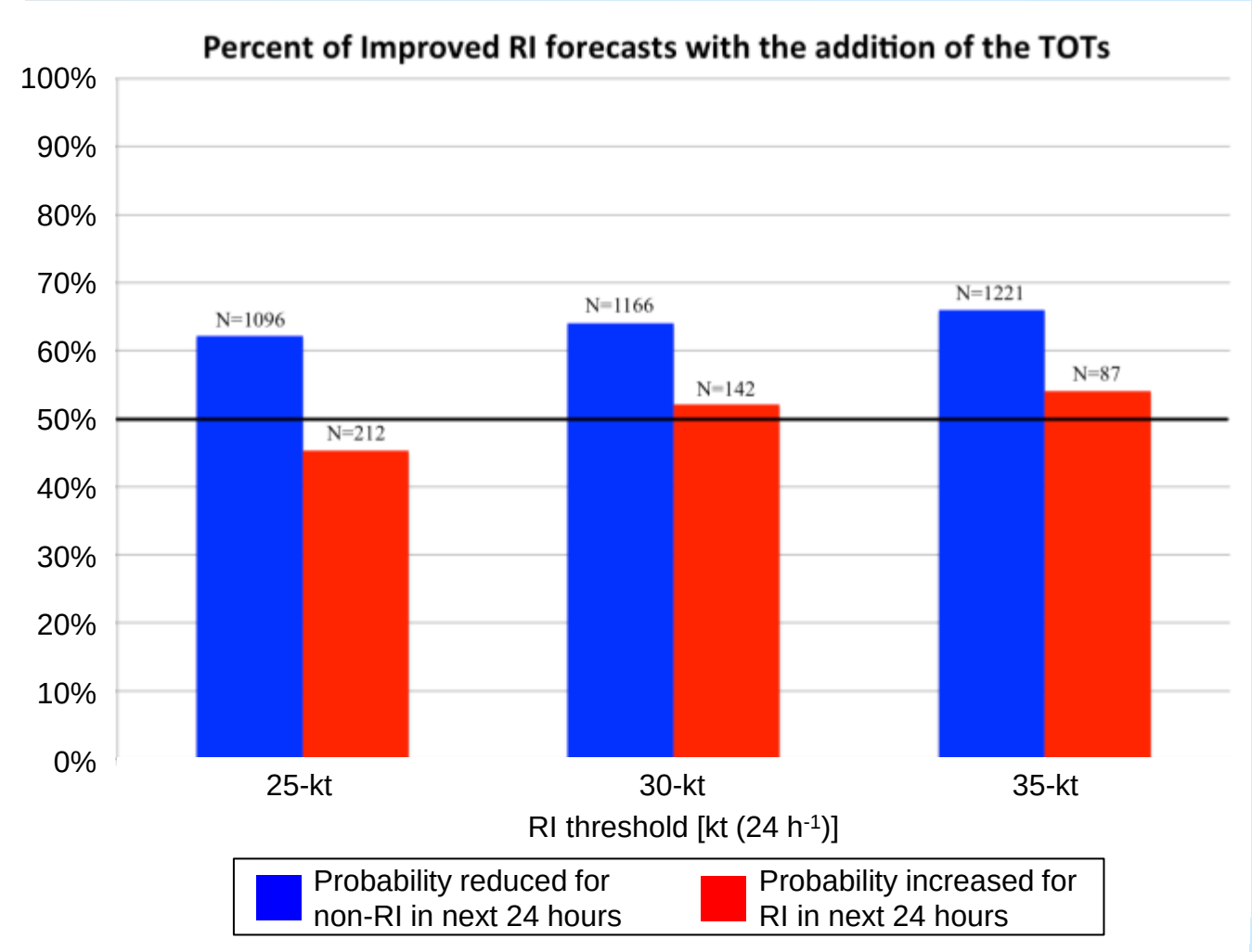
Logistic Regression (LR): Discriminative model where fitted coefficients for predictors are obtained through an iterative least squares approach

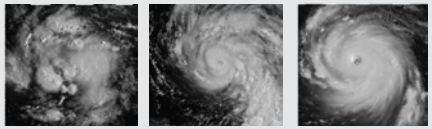
First attempt: TOT predictors added to 7 existing RI predictors in LR model (Rozoff and Kossin 2011):

- 3-h average TOTs within 50 km of TC center
- 6-h average TOTs within 200 km of TC center

Findings (graph at right):

- **TOTs reduce RI forecast probabilities for non-RI events in 60-65% of cases, for all thresholds**
- **Mixed results for improving the probability of forecasting RI events**





Potential Addition of the TOT Information into a Probabilistic, Multi-Predictor RI Forecast Model Where do the TOTs help?

Forecasts vs. Verification

RIGHT: Dotted-dashed lines represent perfect reliability
→ e.g. forecast probability of 10% has 10% of cases verifying.

- **Blue dots**: TOT forecast probabilities
- **Red dots**: non-TOT forecast probabilities

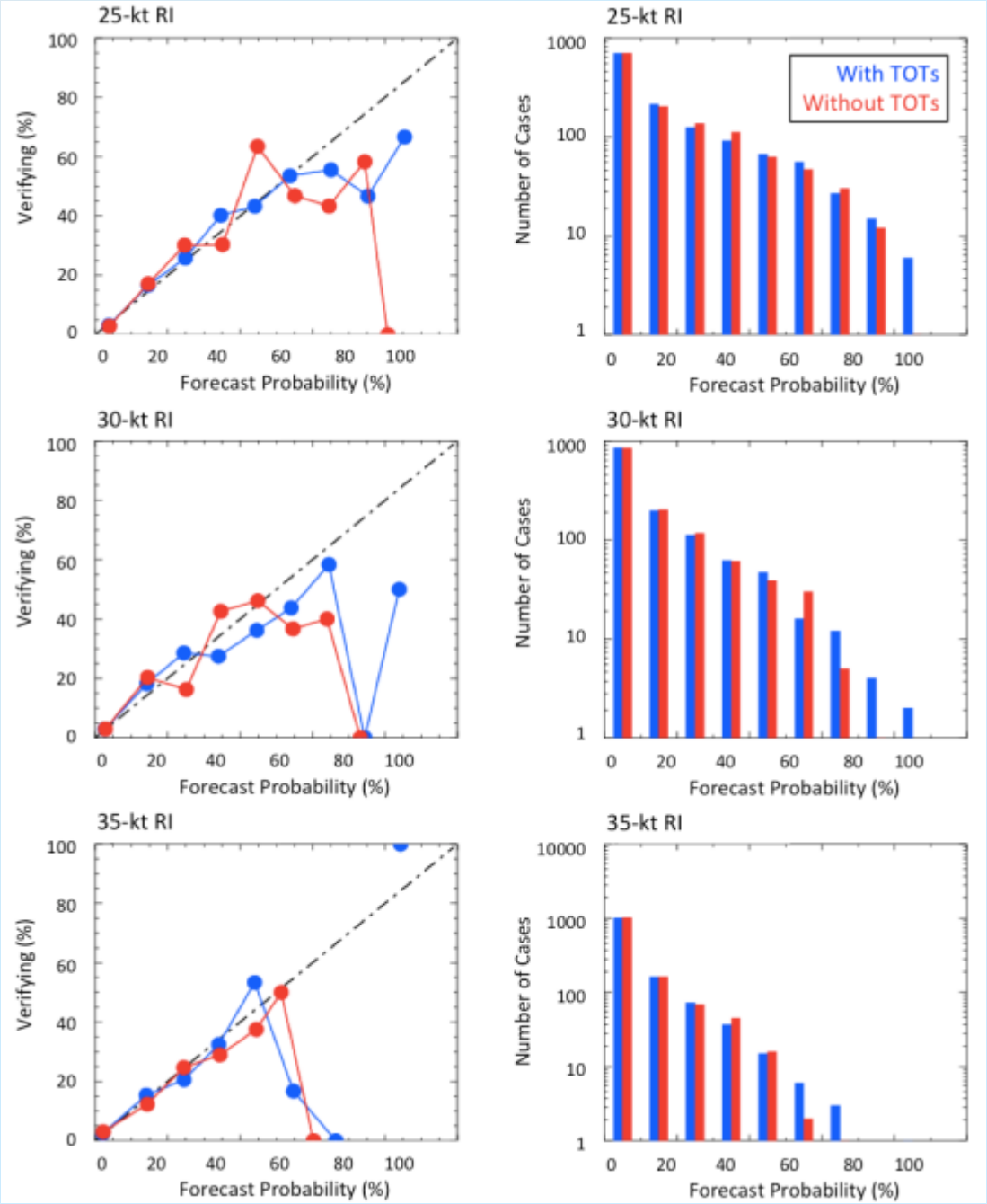
FAR RIGHT: Number of forecasts per 10% probability bin

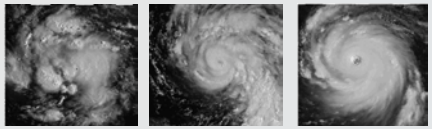
<u>For 25-kt and 30-kt RI:</u>

- TOTs produce a more reliable forecast at higher probabilities (≥ 40%)
  -- Exception: 70%-80% bin

<u>For 35-kt RI</u>:

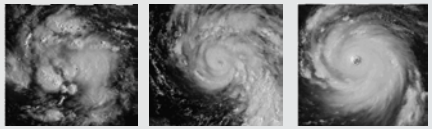
- Mixed results, no clear trend





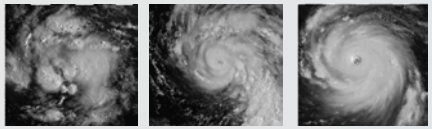
Path to Operations

1. Continue to investigate and refine the predictability potential of TOTs with respect to rapid intensification and other TC processes (such as genesis). (GOES-R Risk Reduction Program)
2. Demonstrate the TOT products and provide training on their potential usefulness in tropical analysis and forecasting in readiness for GOES-R applications. Receive user (NHC, TAFB) feedback. (GOES-R Proving Ground for the National Hurricane Center)
3. Upon user request, elevate the TOT products to operational status through Joint Hurricane Testbed program or NESDIS Product System Development and Implementation (PSDI) program.



Future Work

- Continue to demonstrate TOT products to NHC for the 2013 Atlantic and East Pacific hurricane seasons and provide training as part of the GOES-R Proving Ground. Refine the products based on feedback.
- Compare TOT location and frequency in TCs to observed lightning using the World Wide Lightning Location Network.
    - Lightning data is a part of an experimental RII.
- Examine TOT trends in E. Pacific TCs a potential predictor of rapid intensification and/or genesis.
- Test TOTs as a potential predictor in the Tropical Cyclone Formation Probability product (Schumacher et al. 2009).
- Examine methodology to assign heights to TOTs to enhance the utility of the product for aviation hazard avoidance over oceans.



Publications List

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Schumacher, A. B., M. DeMaria, and J. A. Knaff, 2009: Objective Estimation of the 24-h Probability of Tropical Cyclone Formation. *Wea. Forecasting*, **24**, 456–471.

- Project Publications

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