IHC 2014 – Session 5-02 :
Real-Time Verification of a Passive Microwave Imagery-Based Statistical Model of Tropical Cyclone Rapid Intensification

Contributors:

- Christopher Rozoff : CIMSS / UW-Madison

- Christopher Velden : CIMSS / UW-Madison

- John Kaplan : NOAA / HRD

- Anthony Wimmers: CIMSS / UW-Madison

- James Kossin : NOAA / NCDC

Introduction :
Passive Microwave Imagery in Tropical Cyclone Rapid Intensification (RI) Forecasting

Recent studies illustrate benefits of using passive microwave imagery (MI) in statistical forecasts of RI
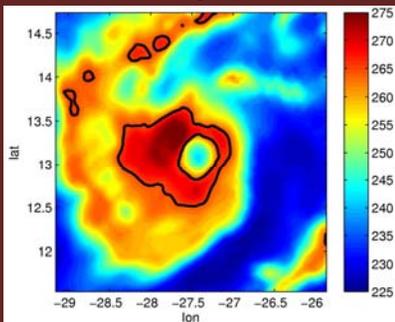
- Kieper and Jiang (2012, *Geophys. Res. Lett.*)
- Rozoff et al. (2012, *30th Conf. Hurr./Trop. Met.*; 2014, *WAF*)

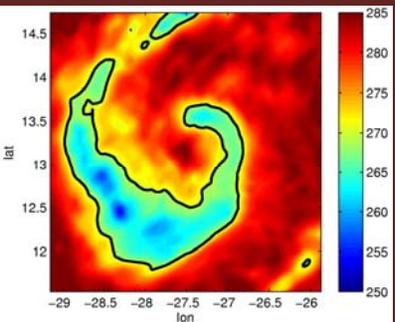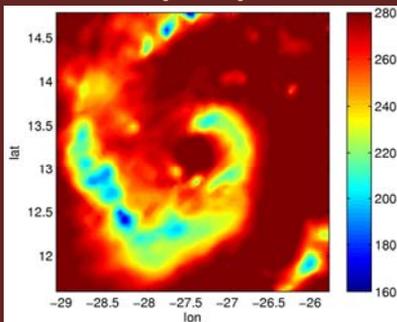Passive MI depict precipitation structure of TC inner core
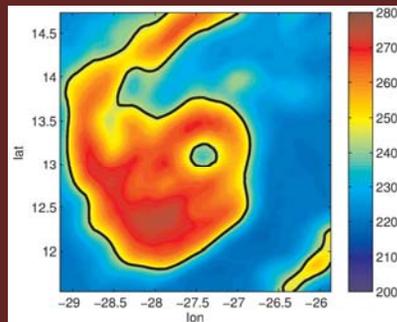
19 GHz (V pol.)   **37 GHz (V pol.)**   **37 GHz (PCT)**   **85 GHz (PCT)**

TMI : Atlantic Hurricane Danielle at 1527 UTC 14 Aug 2004

Methodology :
Logistic Regression Model

Logistic regression-based RI model (Rozoff and Kossin 2011) :

$$p_L\left(\Delta v_{\max} / \Delta t \geq a\right) = \frac{1}{1 + \exp\left(\beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_{N_L} x_{N_L}\right)}$$

here, the $\mathbf{x}_L = (x_1, x_2, \ldots, x_N)$ represent certain environmental and GOES-IR features, β_i are fitted coefficients, and a represents the RI thresholds of 25, 30, 35-kt intensity change per 24 h

Baseline models for Atlantic and Eastern Pacific use SHIPS-developmental dataset predictors used in Rozoff and Kossin (2011)

Methodology :
Atlantic Baseline SHIPS-based Predictors

Feature Description - *Atlantic*	RI ave
Previous 12-h intensity change	higher
Reynolds sea surface temperature	higher
200-hPa divergence ($r = 0 - 1000$ km)	higher
800-200-hPa vertical wind shear magnitude ($r = 200 - 800$ km)	lower
Departure from the TC's maximum potential intensity	higher
Standard deviation of IR cloud-top T_b ($r = 100 - 300$ km)	lower
Average IR cloud-top T_b ($r = 0 - 30$ km)	lower

Methodology :
Eastern Pacific Baseline SHIPS-based Predictors

Feature Description - *East Pacific*	RI ave
Previous 12-h intensity change	higher
Ver. Ave. of neg. diff. between θ_e of parcel lifted from sfc and θ_e^* (r = 200-800 km)	higher
800-200-hPa vertical wind shear magnitude (r = 200 – 800 km)	lower
Departure from the TC's maximum potential intensity	higher
IR cloud-top T_b (r = 100 – 300 km)	lower
Standard deviation of IR cloud-top T_b (r = 50 – 200 km)	lower
Maximum IR cloud-top T_b (r = 0 – 30 km)	lower

Methodology :
Microwave Data

Datasets

- Special Sensor Microwave Imager (SSM/I)

- Special Sensor Microwave Imager / Sounder (SSMI/S)

- Tropical Rainfall Measuring Mission (TRMM) Microwave Imager (TMI)

- Advanced Microwave Scanning Radiometer-EOS (AMSR-E)

  * Data encompass 1998 – 2012 and cover the Atlantic and Eastern Pacific Ocean basins

Methodology :
Microwave-Based Predictors

Calibration

- AMSR-E 18.7, 36.5, and 89.0-GHz channels calibrated to match 19.4, 37.0, and 85.5-GHz TMI/SSMI channels via histogram matching (e.g., Jones and Cecil 2006)

- SSMI/S 91.7-GHz channels were not calibrated to 85.5-GHz channels since the results were insensitive to such a correction.

Predictor Creation

- Various fixed-geometry and objective eye/eyewall-detection based predictors tested on all channels

- Optimal storm-centered predictors chosen such that they are statistically independent from other model predictors and so that they maximize Brier Skill Score in independent testing.

Methodology :
# Optimal MI-based Predictors Added to Baseline Models

Feature Description - *Atlantic*	RI ave
Minimum 37-GHz (horiz. pol.) T_b in eyewall (within t = -6 h)	higher
Maximum 37-GHz (horiz. pol.) T_b in eyewall (within t = -6 h)	higher
Maximum 85-GHz polarization corrected temperature (PCT) of eye (within t = -6 h)	lower
Radius of maximum 37-GHz (vert. pol.) T_b (r = 30 − 130 km) (within t = -6 h)	lower
Radius of minimum 85-GHz (horiz. pol.) T_b (r = 30 − 130 km) (within t = -6 h)	lower

| Feature Description − *Eastern Pacific*	RI ave
Mean 37-GHz (vert. pol.) T_b in eyewall (within t = -6 h)	higher
Radius of min. 85-GHz PCT (r = 30 − 130 km) (within t = -6 h)	lower
Mean 37-GHz (horiz. pol.) T_b (r = 100 − 300 km) (within t = -6 h)	higher

Model Evaluation :
Independent Testing

Brier Skill Score from leave-one-year-out cross evaluation 2008 – 2012 for 00, 06, 12, 18 UTC forecasts / Atlantic & East Pacific

Atlantic   Eastern Pacific
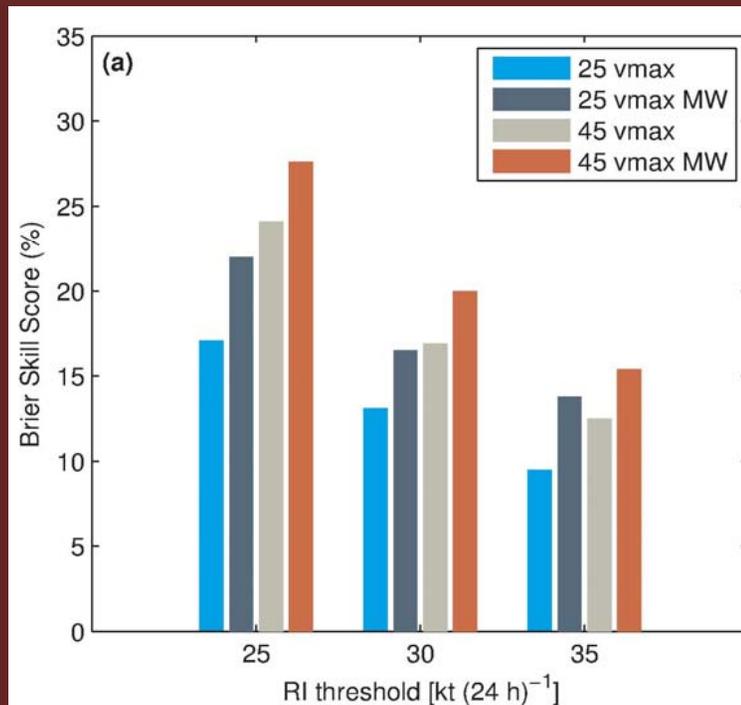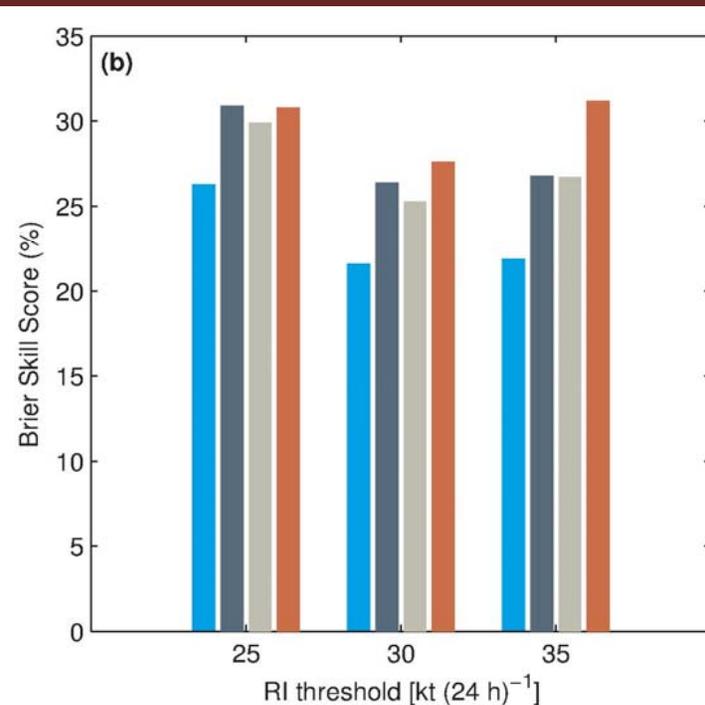
Model Evaluation :
Simulated Real-time Testing

Reforecasts

- MI-based models re-run over 2004 – 2013 using real-time GFS forecast fields and archived initial storm data.

- Cross-validation done by deriving individual year coefficients for 2004-2012 by excluding data from a given year that is being evaluated in reforecast mode.

- Only forecast times in which all of the non-MI and MI-based predictors are available are included in the analysis to allow for a fair comparison of performance.

  - Satellite data (< 6-h old prior to each forecast time) were available ~40% and ~45% of the time for storms of at least 25-kt intensity in the Atlantic and eastern Pacific, and ~47% and ~60% of the time for storms having an intensity of at least 45 kt in the Atlantic and eastern Pacific, respectively.

Model Evaluation :
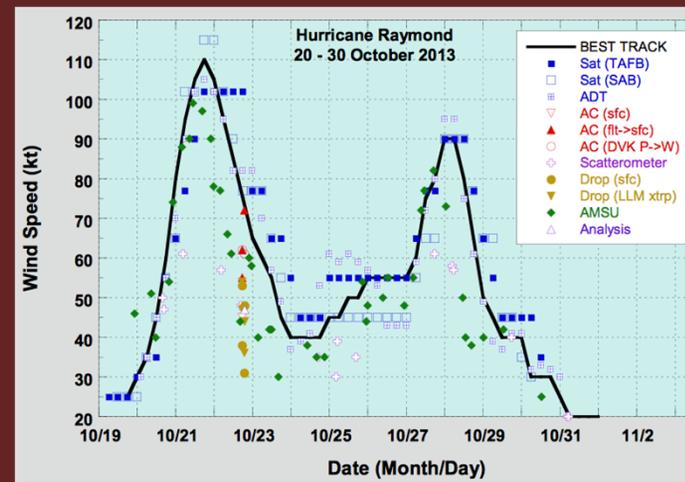# Real-time Model Example

Example Forecast – Eastern Pacific Raymond (2013)
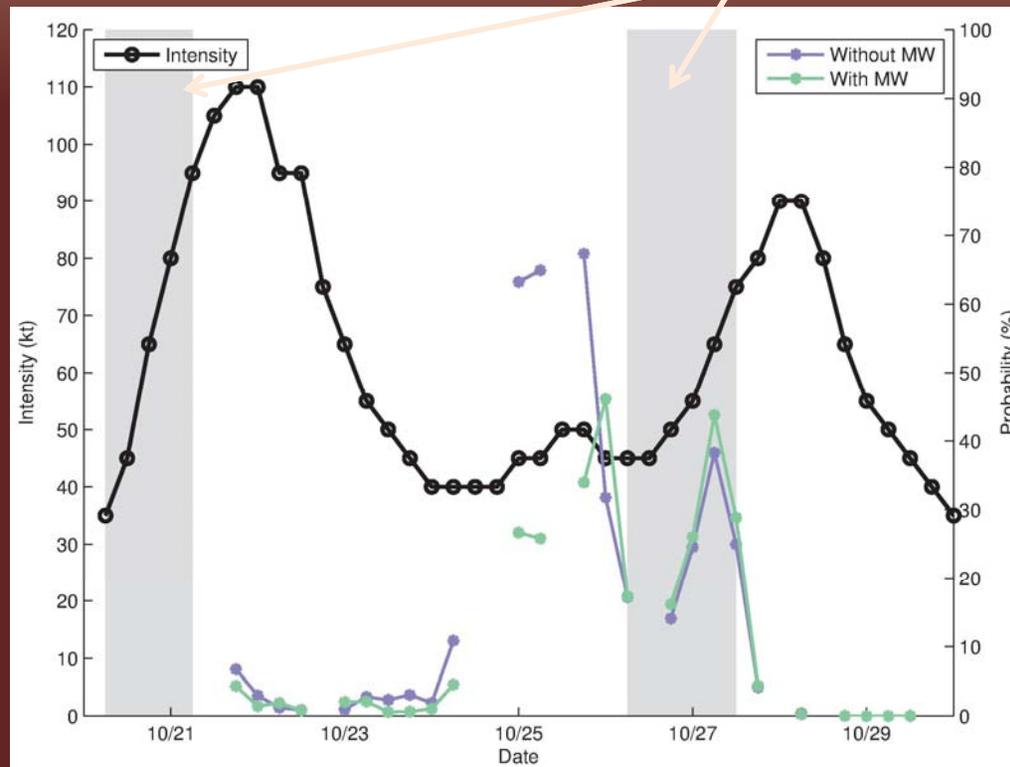

MODIS (Oct. 21, 2013)

From Wikipedia

From NHC

Model Evaluation :
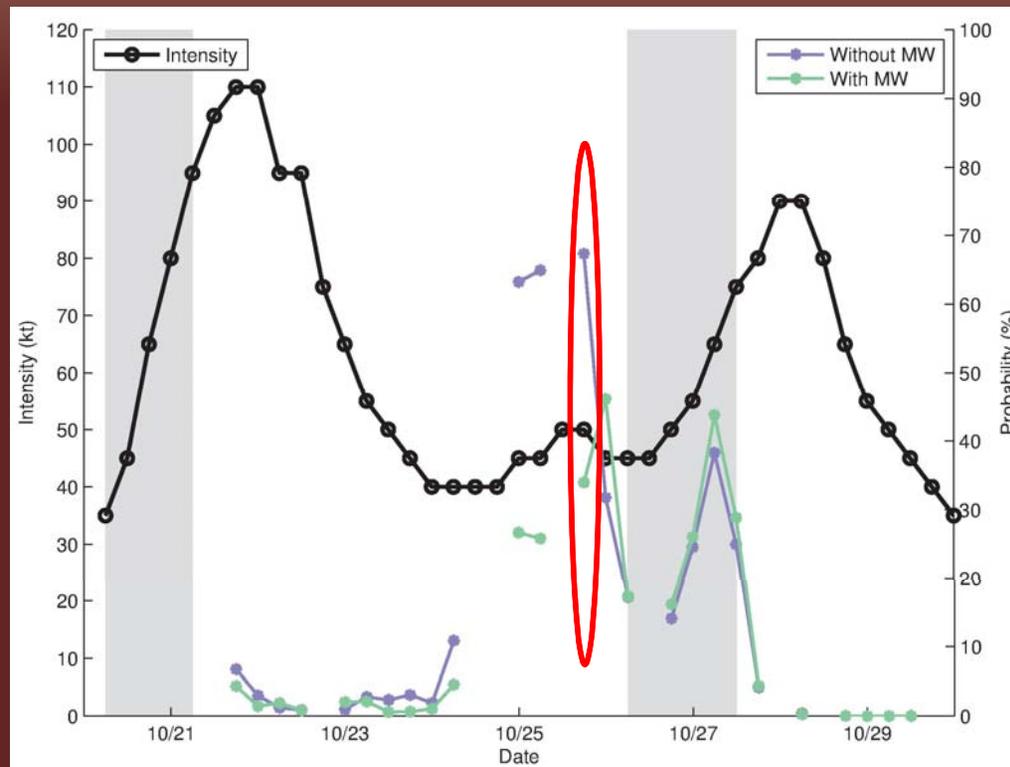# Eastern Pacific Raymond (2013)

Model performance

Gray regions denote times in which RI ($\Delta v_{max} \geq 25$ kt per 24 h) occurred over the following 24 h.

Model Evaluation :
Eastern Pacific Raymond (2013)

Focus on 18 UTC 25 Oct.

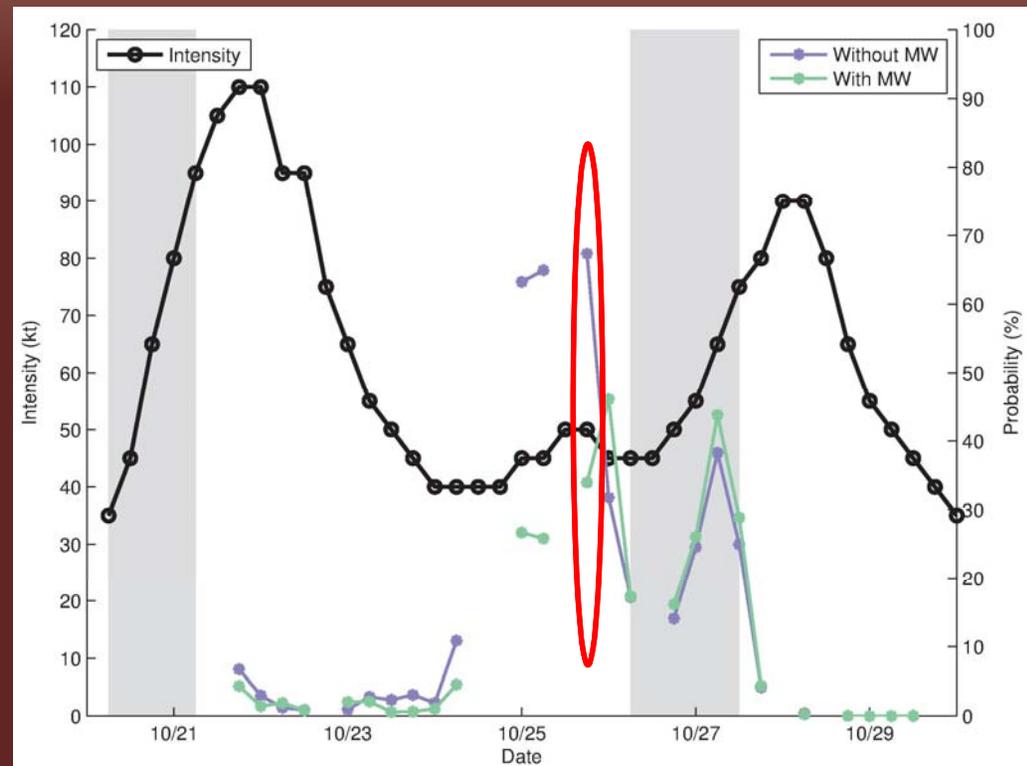# Model Evaluation :
Eastern Pacific Raymond (2013)

Focus on 18 UTC 25 Oct.

Baseline Predictors:

Predictor Name	Value	RI Ave	Non-RI Ave
PER (kt) :	5.0	11.6	1.1
ENSS (K) :	2.5	2.5	4.0
Shear (kt) :	3.2	8.3	12.2
IR cloud-top T_b (^{o}C) : (r =100-300 km):	-51.9	-43.2	-28.2
Std Dev IR T_b (K) : (r = 50–200 km)	7.7	11.4	14.9
Max. IR T_b (^{o}C) : (r = 0-30 km)	-73.8	-63.0	-41.7
POT (kt) :	98.5	94.7	74.7

MW Predictors:

Predictor Name	Value	RI Ave	Non-RI Ave
Ave 37G (V) ring T_b (K) :	247.4	258.4	253.6
StD 19G (H) eye T_b (K) :	14.0	14.2	12.3
Rad min 85G PCT (K) : (r = 30-130 km)	112.7	67.4	76.9
Ave 37G (H) T_b (K) : (r = 100-300 km)	206.7	212.9	205.2
StD 37G PCT (K) : (r = 100-300 km)	6.5	5.2	4.6

Model Evaluation :
Eastern Pacific Raymond (2013)
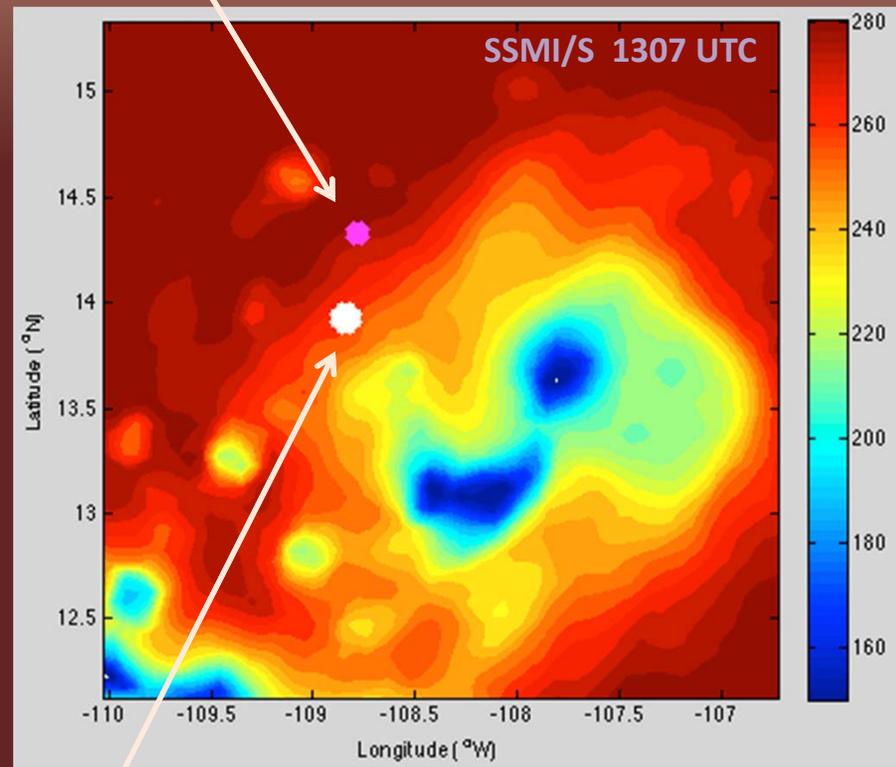## Displaced Convection from Center Degrades RI Probs

Focus on 18 UTC 25 Oct.

Baseline Predictors:

Predictor Name	Value	RI Ave	Non-RI Ave
PER (kt) :	5.0	11.6	1.1
ENSS (K) :	2.5	2.5	4.0
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MW Predictors:

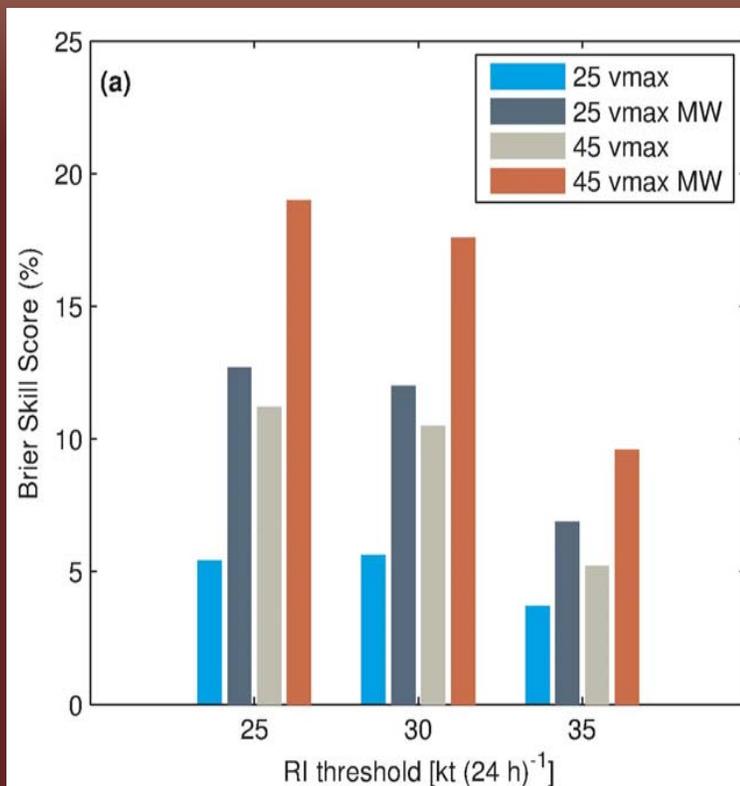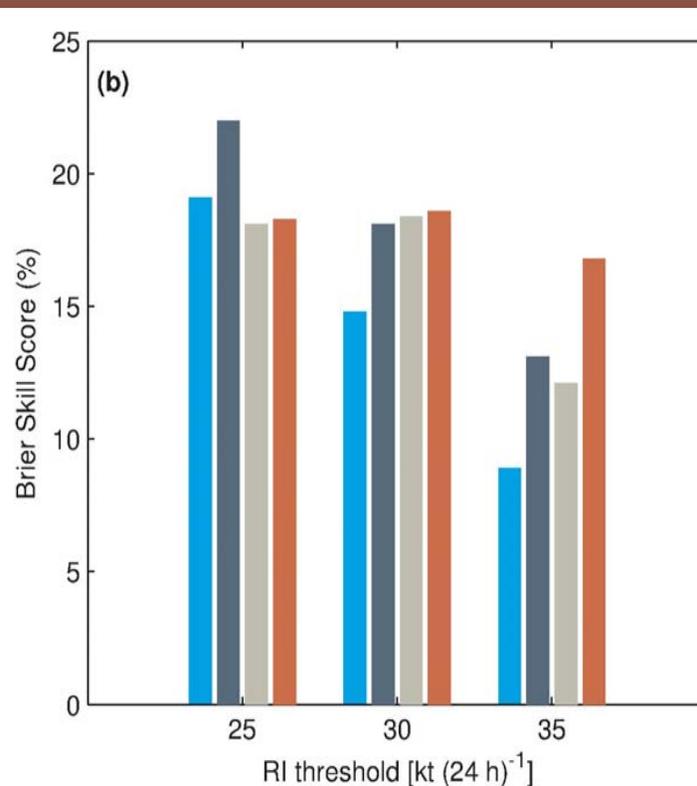| Predictor Name	Value	RI Ave	Non-RI Ave
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ARCHER Center (Rejected)

SSMI/S 1307 UTC

Forecast Center (NHC) (Accepted)

Model Evaluation :
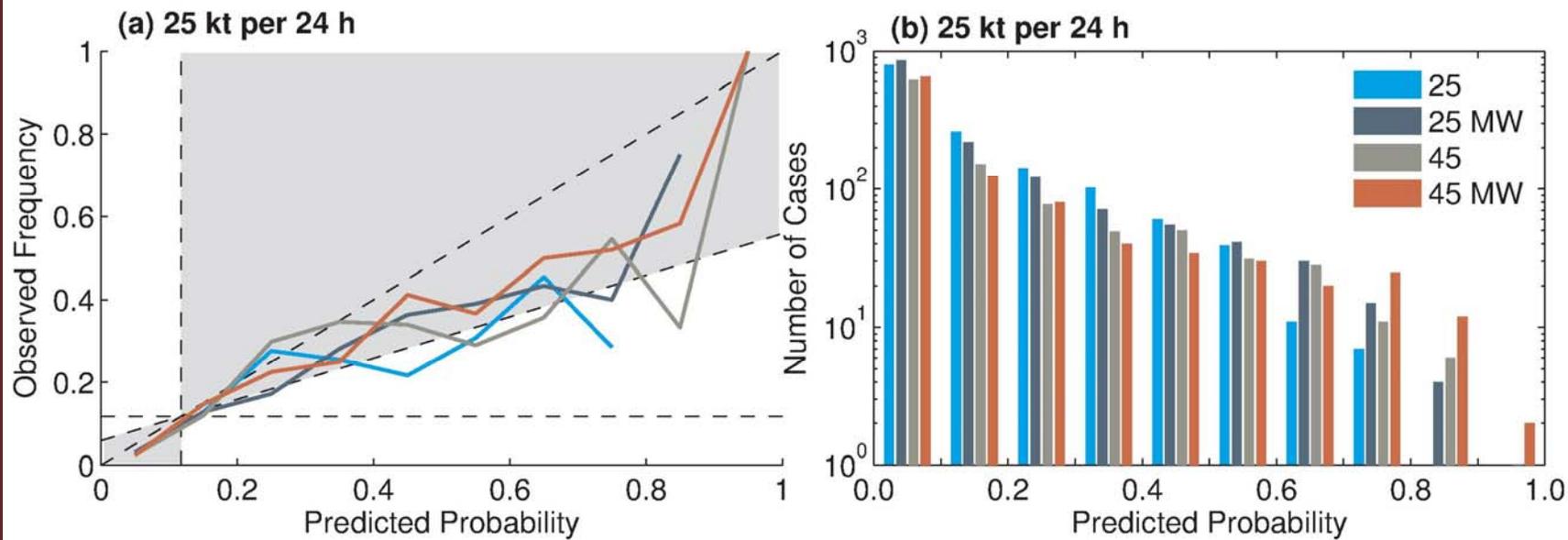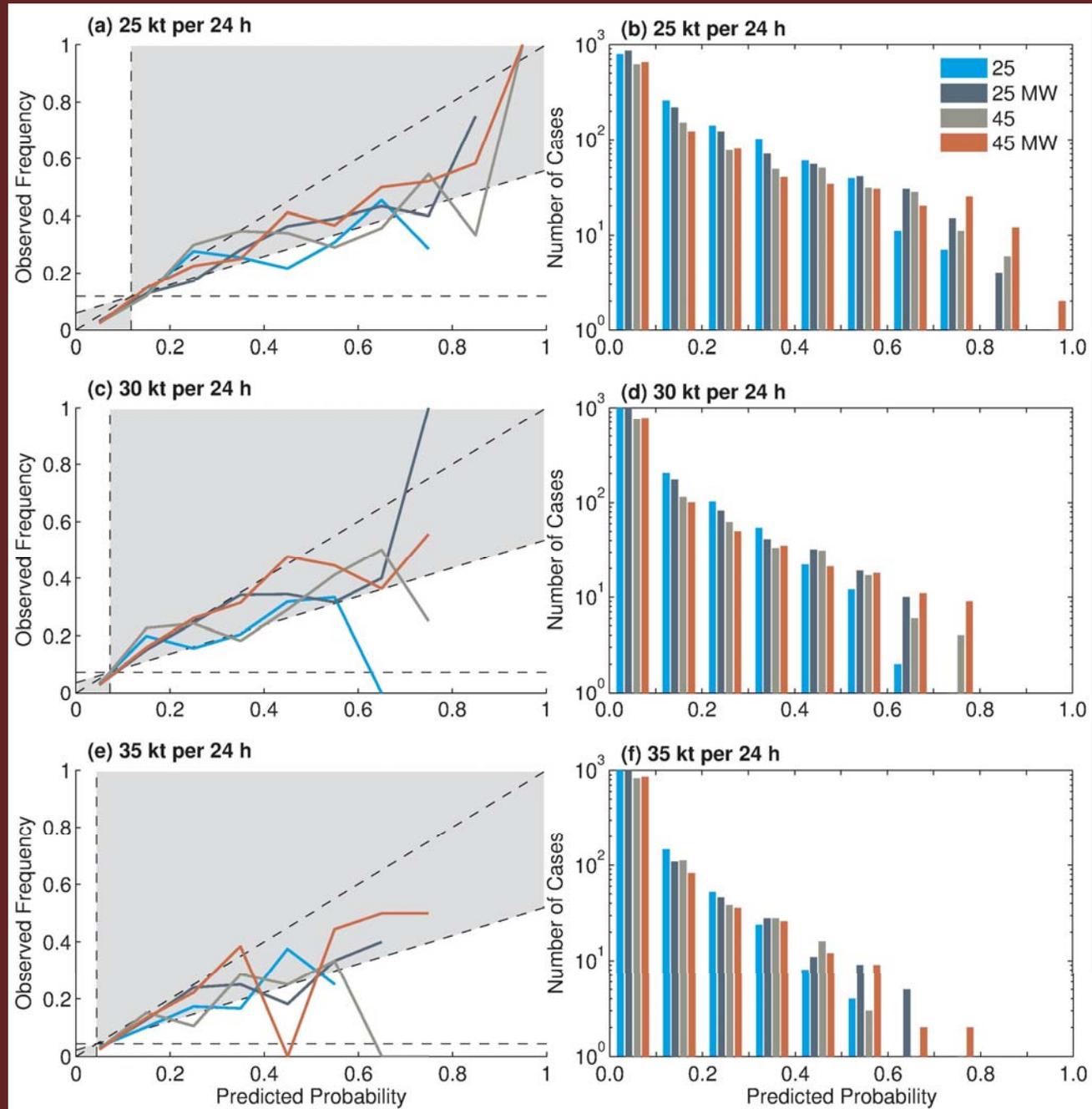# Simulated Real-time Forecast Skill (2004 – 2013)
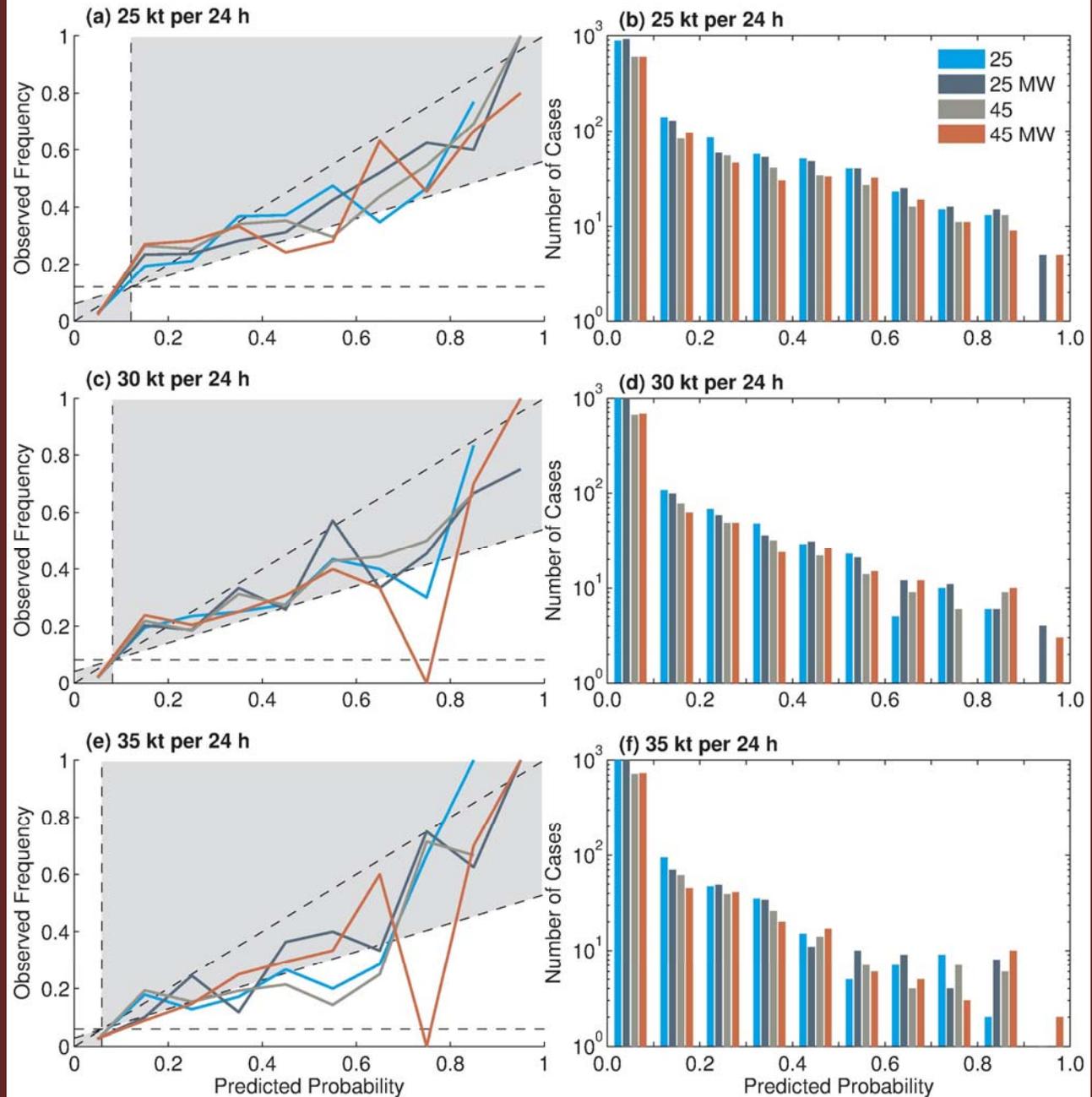
Atlantic

Eastern Pacific

Model Evaluation :
Atlantic Simulated Real-Time Model Reliability Diagrams

Model Evaluation : East Pac. Simulated Real-Time Model Reliability Diagrams

(a) 25 kt per 24 h

(b) 25 kt per 24 h

25
25 MW
45
45 MW

(c) 30 kt per 24 h

(d) 30 kt per 24 h

(e) 35 kt per 24 h

(f) 35 kt per 24 h

Observed Frequency

Number of Cases

Predicted Probability

Conclusions & Future Prospects

Real-time version of MI-based RI model tested

- Automated code at CIMSS uses real-time GFS-based SHIPS predictors and real-time NESDIS feeds of passive microwave imagery.

- Infrastructure in place for implementation at operational centers.

- Reforecasts using real-time data from 2004-2012 + 2013 evaluation show MI-based predictors improve the already competitive logistic regression-based RI model, especially in the Atlantic.

Future considerations

- Loss of AMSR-E and eventual loss of TMI, SSM/I, and SSMI/S satellites mitigated by AMSR2, MADRAS, and GMI.

- Improvements to MI-based predictors and statistical models

- Methods mixing NWP models / post-processing / analogs