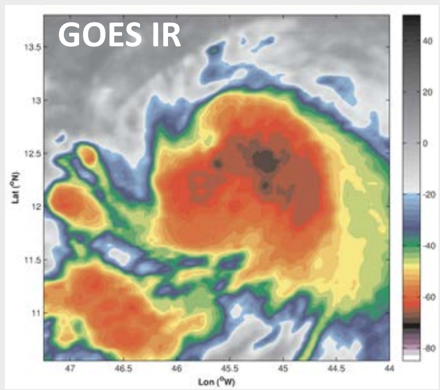
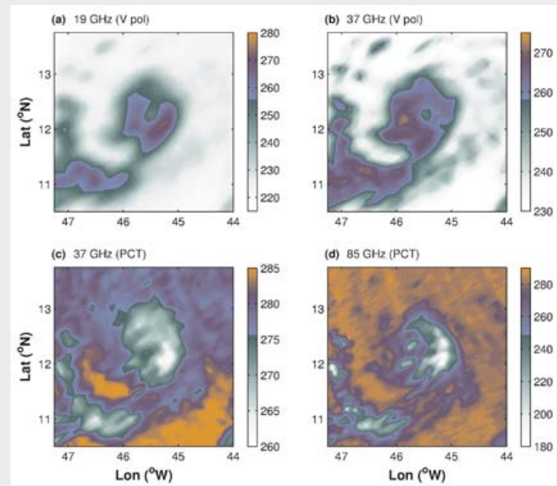
Probabilistic Prediction of Tropical Cyclone Rapid Intensification Using Satellite Passive Microwave Imagery





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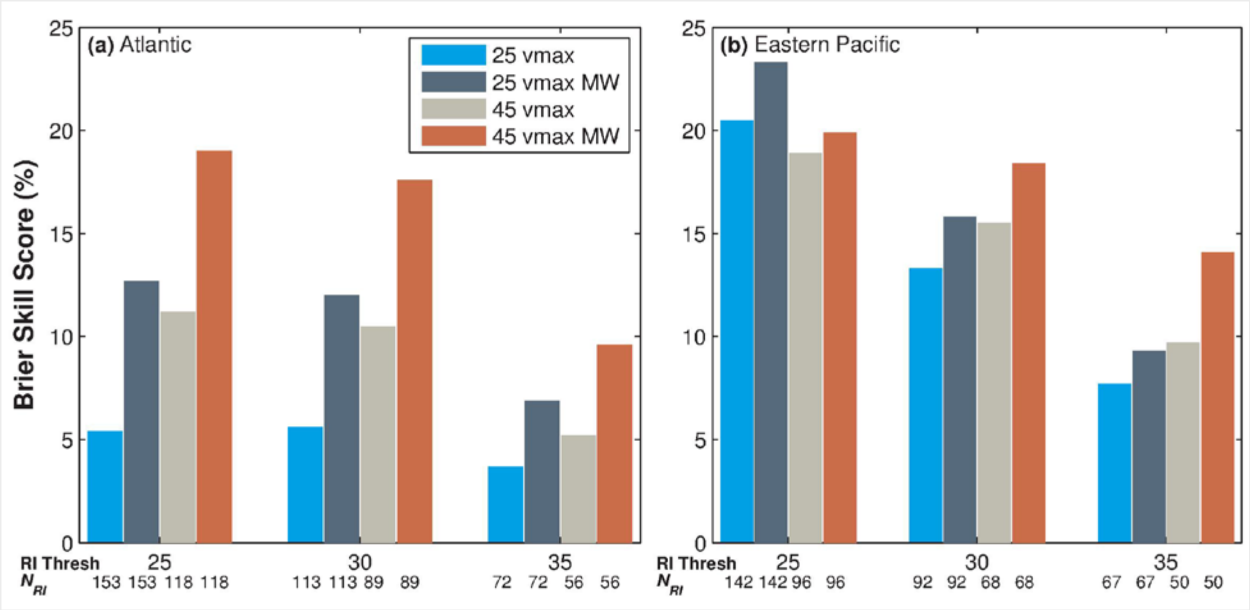
Goal of work

Improve probabilistic prediction of rapid intensification (RI)

- SHIPS-RII, consensus of multi-model products

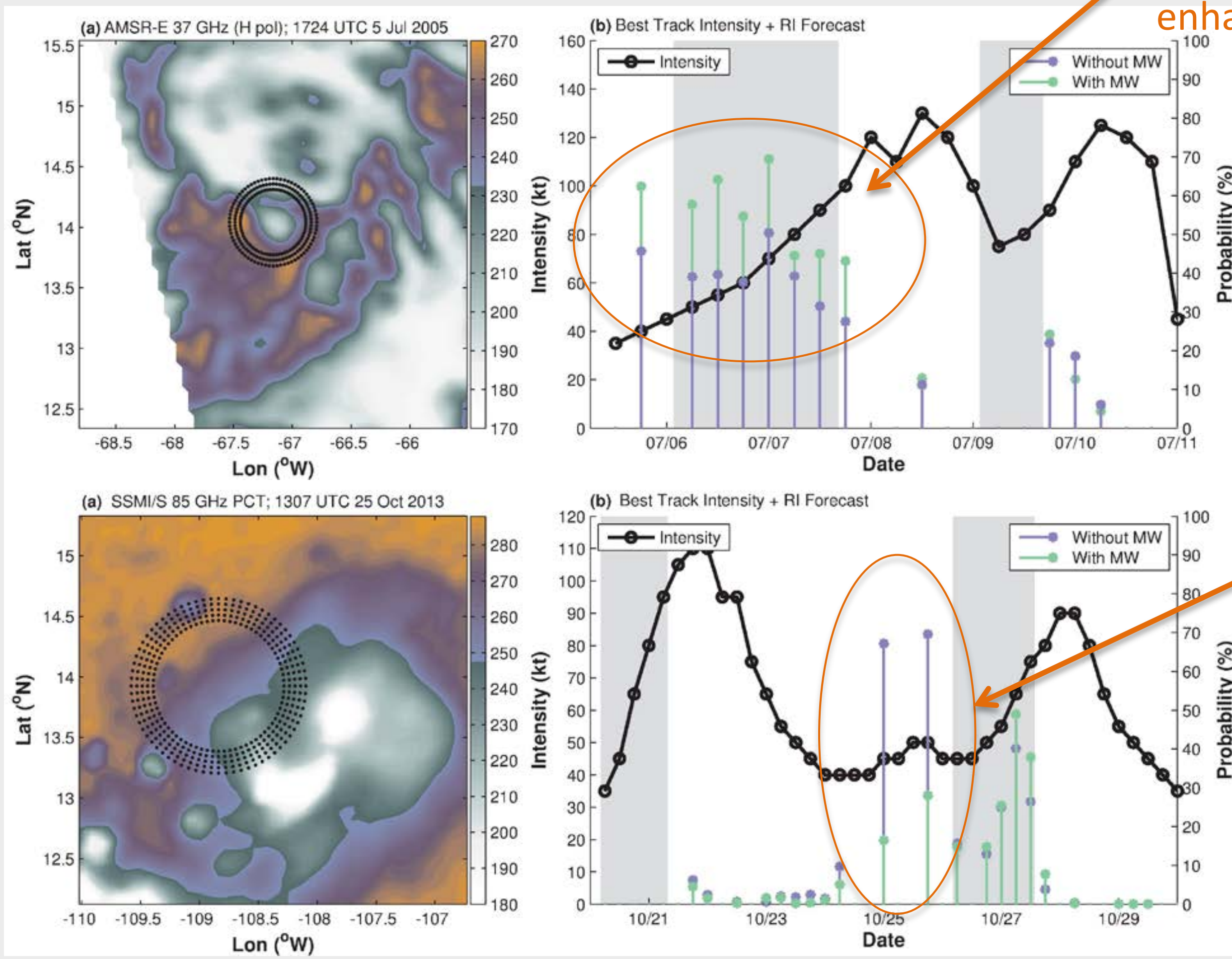
Approach: Exploit passive microwave imagery to evince aspects of storm structure in order to improve statistical models.

Proof of Concept



An example of how simple microwave imagery (MI)-based predictors enhanced the forecast skill of a logistic-regression (LR) based model for RI otherwise using SHIPS-based predictors [from Rozoff et al. 2015; *Wea. Forecasting*]

Proof of Concept



Symmetric, intense precipitation enhances RI probs

Dennis (2005)

Disorganized precipitation decreases RI probs

Raymond (2013)

Examples of how RI probabilities can be enhanced or diminished by MI [from Rozoff et al. 2015; *Wea. Forecasting*]

Tasks as proposed

Status	Task description
Ongoing ✓	Update developmental dataset to include MI of Atlantic and eastern Pacific TCs from all available sensors (1998 – 2016)
Jan 2016 ✓	Develop new MI-based predictors for statistical models.
Jan - May 2016	Enhance and test logistic regression model, SHIPS-RII, and Bayesian models with new MI-based predictors
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May-Nov. 2016/2017	Real-time testing
Jun 2017	NCEP ready code and documentation delivered.

Datasets

Low-earth orbiting satellites with MI, 1998 – 2016

	Low Frequency Channel		Medium Frequency Channel		High Frequency Channel	
Sensor	Fequency (GHz)	Footprint (km x km)	Fequency (GHz)	Footprint (km x km)	Fequency (GHz)	Footprint (km x km)
SSM/I	19.35	69 x 43	37.0	37 x 28	85.5	15 x 13
SSMI/S	19.35	73 x 47	37.0	41 x 31	91.655	14 x 13
TMI	19.35	30 x 18	37.0	16 x 9	85.5	7 x 5
AMSR-E	18.7	27 x 16	36.5	14 x 8	89.0	6 x 4
AMSR2	18.7	22 x 14	36.5	12 x 7	89.0	5 x 3
GMI	18.7	18 x 11	36.5	15 x 9	89.0	7 x 4

Data Preparation Steps

Data calibration

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- Match to GMI, AMSRE/2 18.7, 36.5, and 89.0 GHz

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    - Need matching overpasses

- AMSR-E - TMI 8 ATL matches within 5 min
- SSMIS - GMI 29 matches EP/ATL within 30 min
- SSM/I – GMI 8 EP matches within 30 min

Data Preparation Steps

Data calibration

Match to GMI, AMSRE/2 18.7, 36.5, and 89.0 GHz

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Interpolate to common grid where swaths overlap.

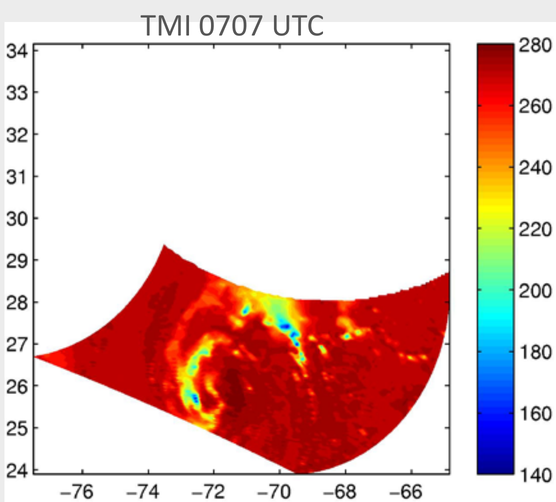
- Common grid is the grid of the lower spatial resolution sensor.

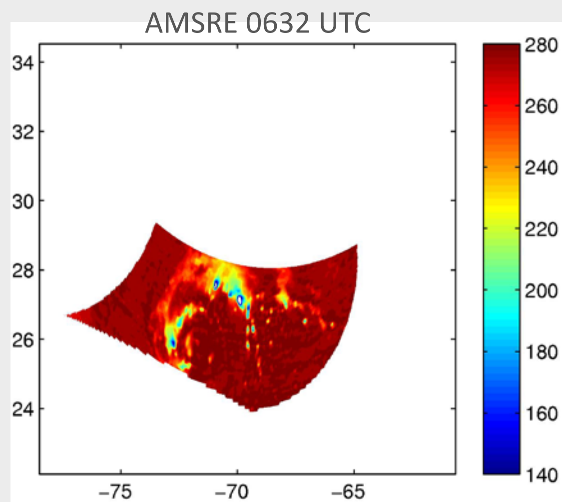
Data Preparation Steps

Matching storms example

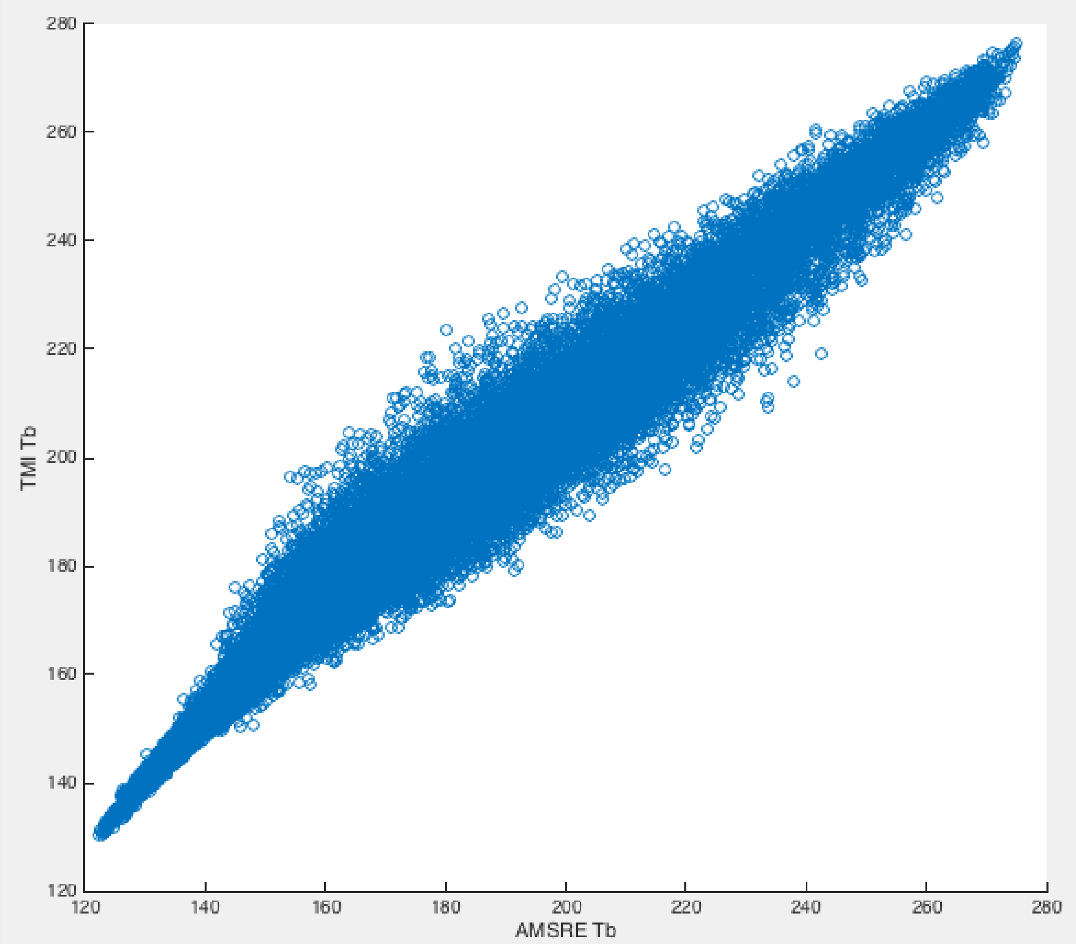
Only uses swath overlap region

e.g., Hurricane Jeanne (2004), 85.5-89.0 GHz (V pol)





Example: AMSR-E – TMI calibration, 19 GHz



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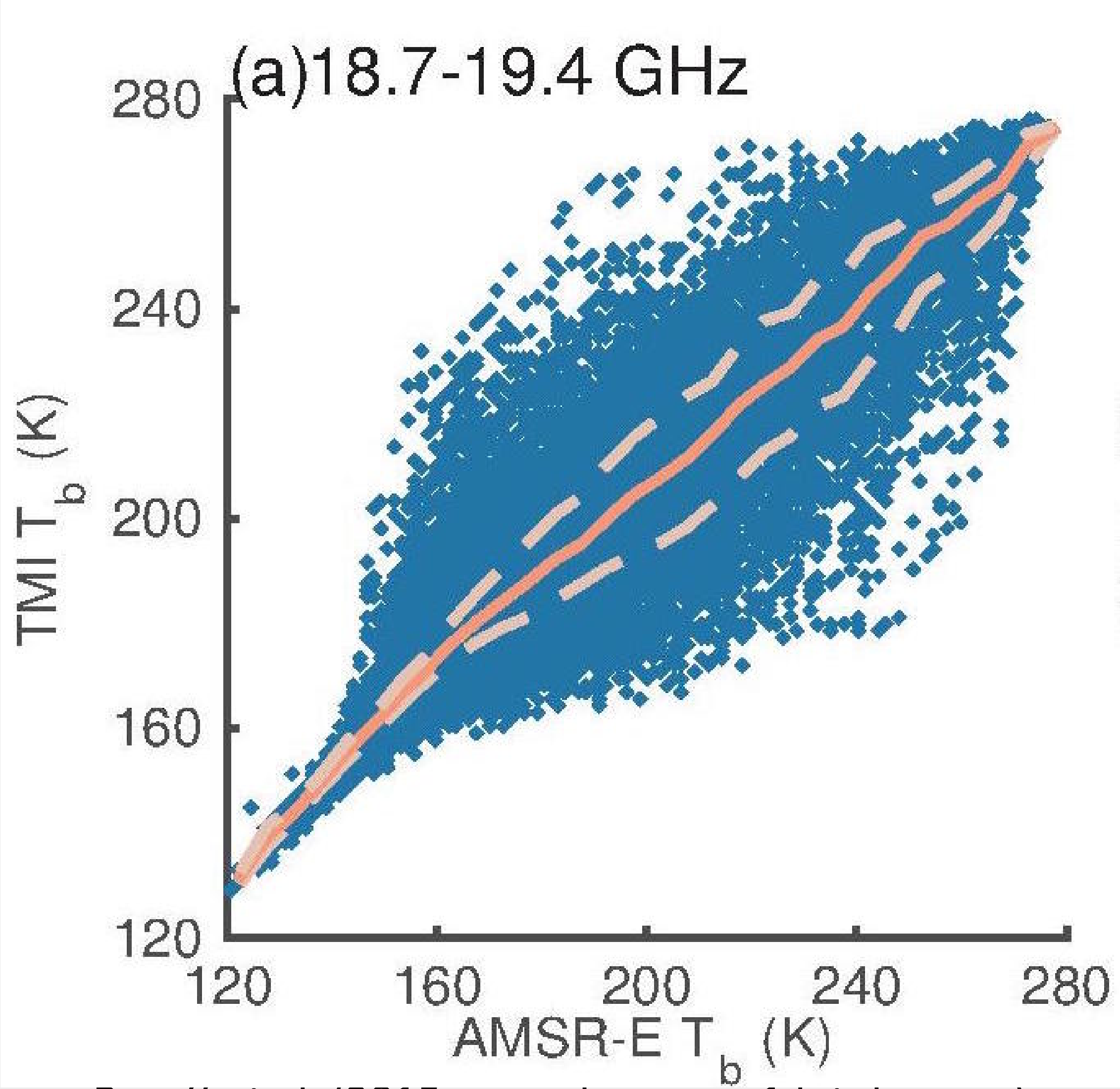
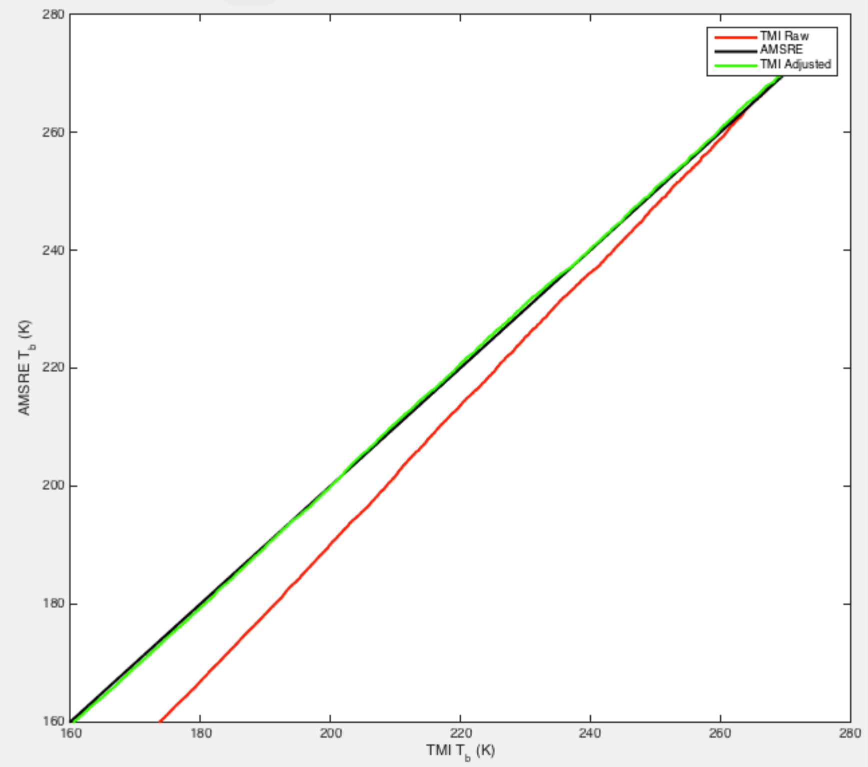
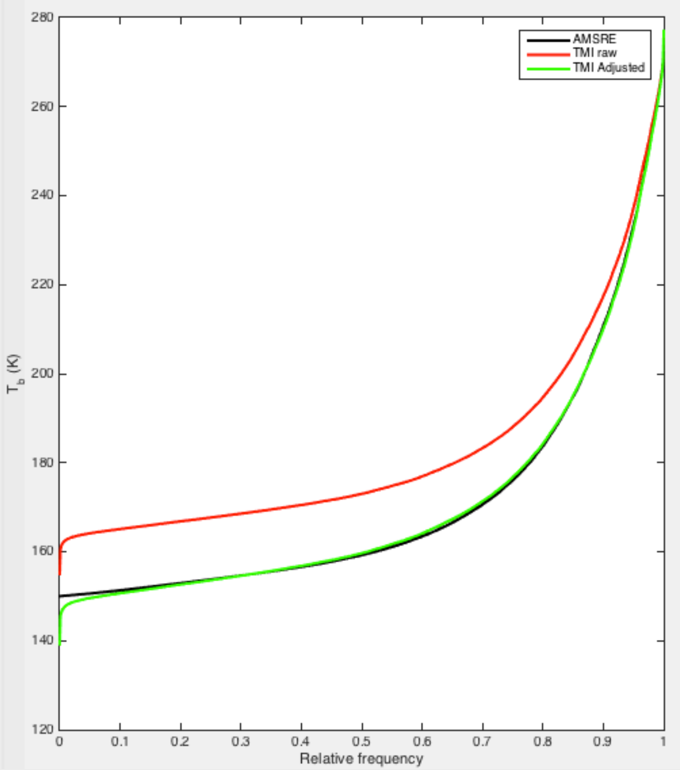


Rozoff et al. (2015; more leeway – 1 h tolerance)

Example: AMSR-E – TMI calibration, 19 GHz

$$T_{b,adj} = T_0 + \alpha\, T_b.$$





Models Used in this Study

Goal

Develop a consensus RI tool composed of multiple competitive probabilistic models.

Models Used

- SHIPS-RII (Kaplan et al. 2010)
- logistic regression model (Rozoff and Kossin 2011)
- Bayesian model (Rozoff and Kossin 2011)

Microwave-Based Predictors

Rozoff et al. (2015) study

Basic SHIPS-like predictors

Objective Maximum Inner-Core Precipitation Annulus (MIPA)

-> proxy for eyewall or developing eyewall

New Predictors

Precipitation asymmetries and rainband features

Juxtaposition of latent heating and inertial stability

Temporal based models (e.g., Zagrodnik and Jiang 2014)

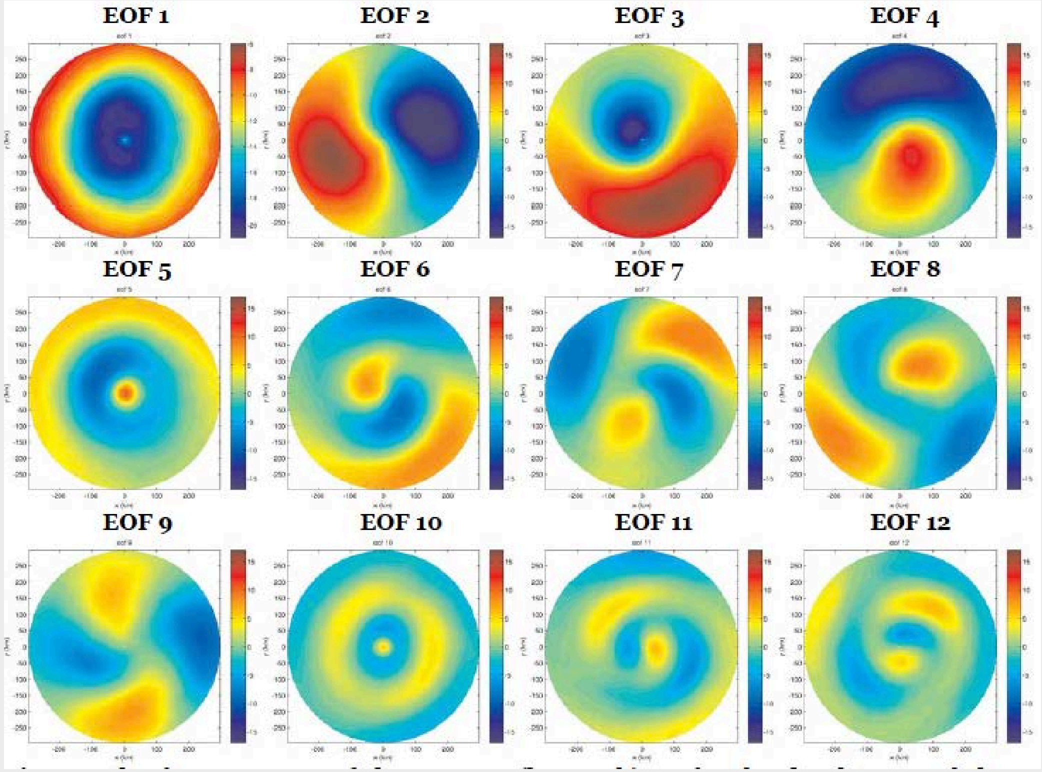
New Predictor Classes

Asymmetric structure

2D EOFs (Rozoff and Knaff 2016; Manuscript to be submitted)

Parameters from Automated Rotational Center Hurricane Eye Retrieval (ARCHER) (Wimmers and Velden 2010)

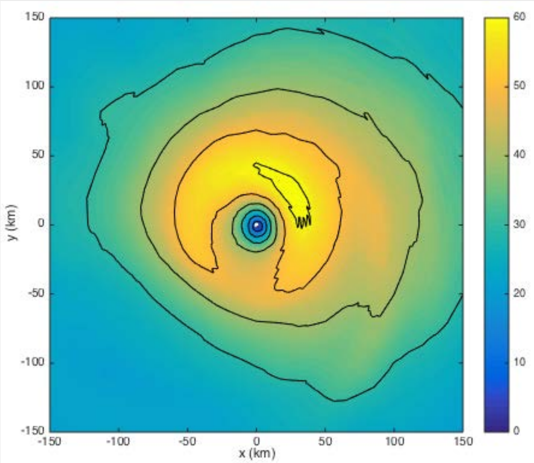
Example of 37-GHz (H pol) 2D EOFs from developmental RI data.

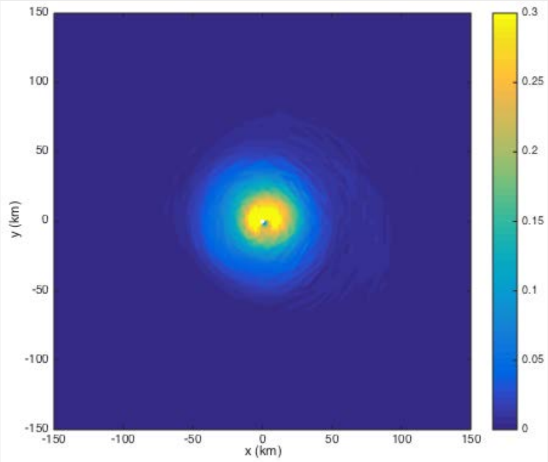


New Predictor Classes

Inertial Stability – Latent Heating Coupling

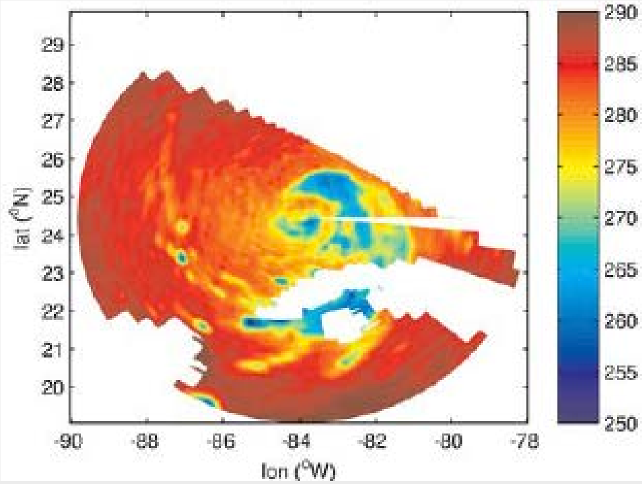
Approach 1: HWRF (vsn. 2015) reforecast/real-time data (2011 – 2015)

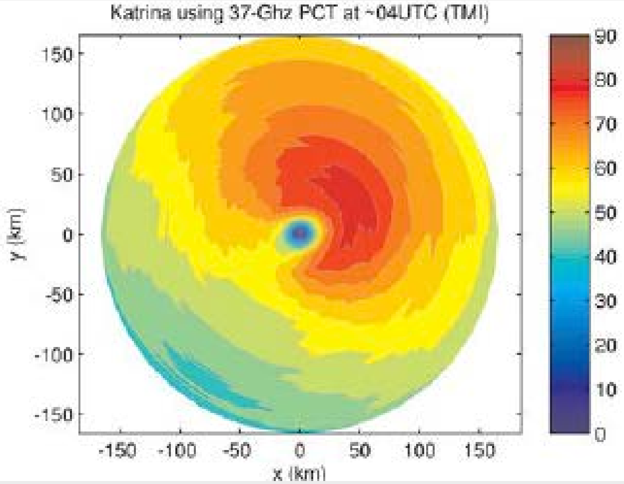




HWRF tang. wind + derived inertial stability parameter

Approach 2: Microwave-based wind structure estimates (Rozoff and Knaff 2016)





Katrina (2005) 37-GHz PCT + wind est.

Project Status

- All datasets collected and readily updated. We added GPM-GMI, AMSR2, and new DMSP data to our large retrospective microwave dataset for TCs.
- Data calibration completed.
- New predictors have now been created.
- The 3 RI models are currently being updated with new predictors.
  - Let us take a preliminary look at how we expect the final updates to produce a consensus product superior to the results in Rozoff et al. (2015)

Multi-Model Consensus - Atlantic

1998 – 2012 training period

Models

- logistic regression and Bayesian models (Rozoff and Kossin 2011)

Original Baseline Predictors (Does not include MW)

Feature Description	Model	RI ave
Previous 12-h intensity change	Logistic, Bayesian	higher
Reynolds sea surface temperature	Logistic	higher
Ocean heat content	Bayesian	higher
850-700-hPa Relative Humidity	Bayesian	higher
200-hPa divergence (r = 0 – 1000 km)	Logistic, Bayesian	higher
800-200-hPa vertical wind shear magnitude (r = 200 – 800 km)	Logistic	lower
Departure from the TC's maximum potential intensity	Logistic, Bayesian	higher
Standard deviation of IR cloud-top T_b (r = 50 – 200 km)	Bayesian	lower
Standard deviation of IR cloud-top T_b (r = 100 – 300 km)	Logistic	lower
Average IR cloud-top T_b (r = 0 – 30 km)	Logistic	lower
% of T_b < - 30C (r = 50 – 200 km)	Bayesian	higher

Multi-Model Consensus - Atlantic

1998 – 2012 training period

Additional Microwave Predictors

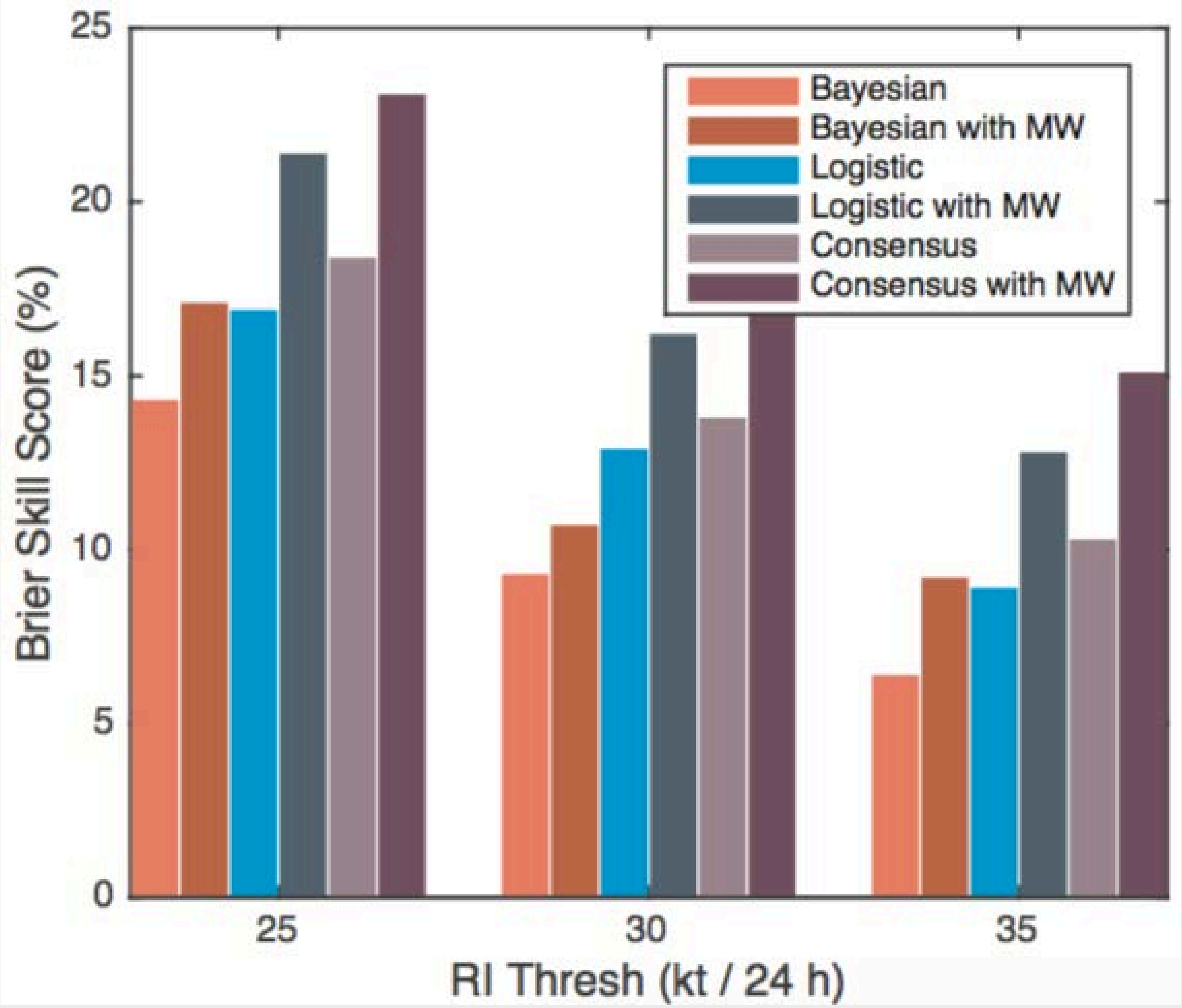
Feature Description	Model	RI ave
Mean 37-GHz T_b (h pol) in “eyewall”	Logistic	higher
Maximum 85.5-GHz PCT in the “eye”	Logistic	lower
Radius of maximum 37-GHz T_b (v pol) found within r = 30 – 130 km	Logistic,Bayesian	lower
Radius of minimum 85.5-GHz T_b (h pol) found within r = 30 – 130 km	Logistic	lower
Mean 85.5-GHz PCT in the ”eye”	Bayesian	lower
“Eyewall” completeness parameter	Bayesian	higher

Note: LDA-based SHIPS-RII product with MW in progress, will be complete by beginning of 2016 Hurricane Season (May – Nov).

Multi-Model Consensus - Atlantic

1998 – 2012 training period

Brier Skill Score with respect to climatology



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Extra Slides

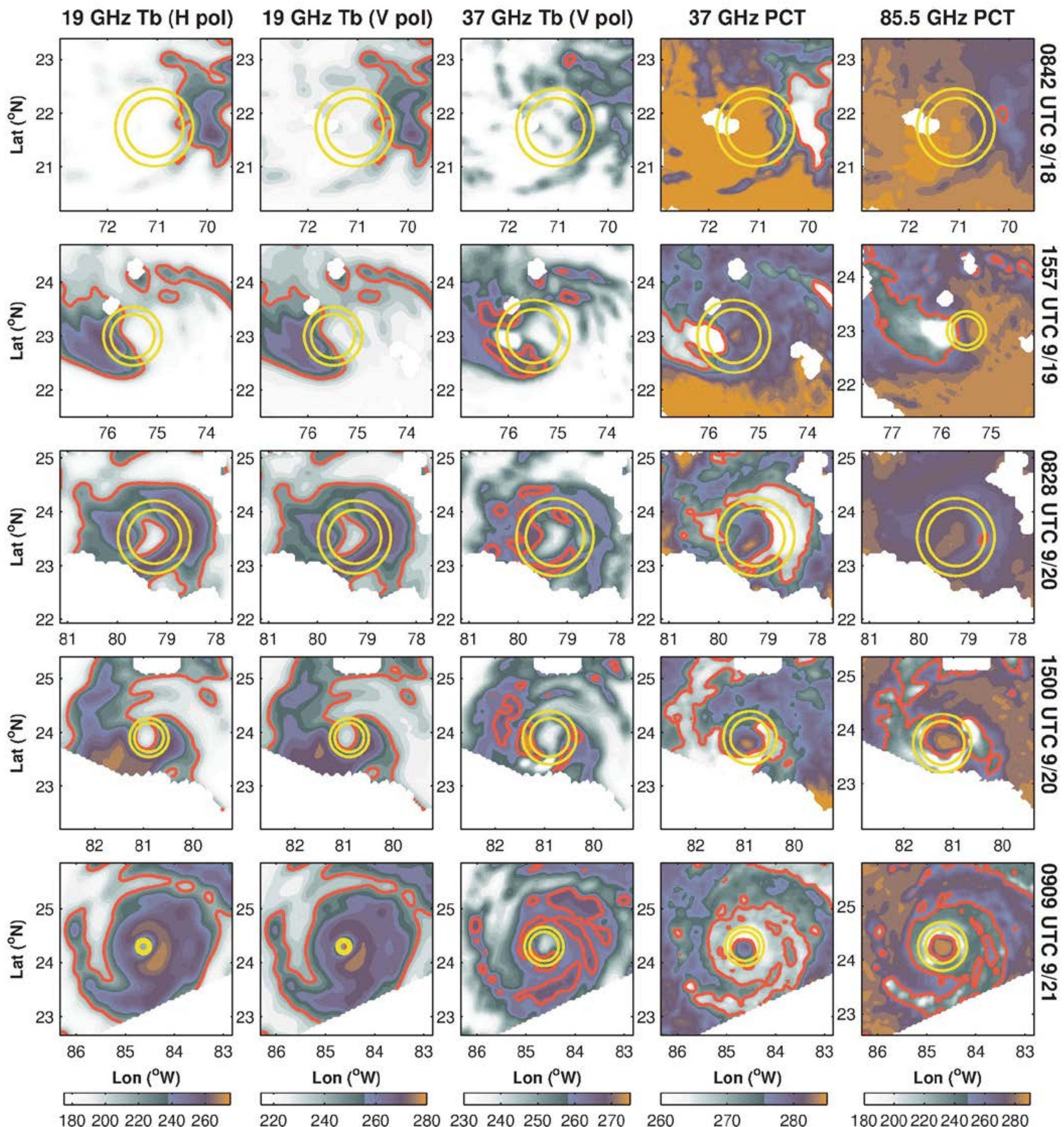

Illustration of MIPAs
- older class of predictors

Rozoff et al. (2015)