Improvement and Implementation of the Probability-based Microwave Ring Rapid Intensification Index for NHC/JTWC Forecast Basins

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2) JTWC Point of Contact: ***Brian deCicco***
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2015 AL & EP Hurricane Season Real-time Testing Result (under JHT FY13 project)

- **37 GHz Ring RI Index (yes/no type):** if a 37 GHz ring is detected and if all of the following environment & persistence criteria are met:
  1. Current SHIPS probability for 25 kt RI >= 10% (AL), 20% (EP)
  2. Current TC intensity is between ~45 - 100 kt.
  3. The core of the TC is currently over water and is anticipated to remain over water for 24 hours.
  4. The past 6 h intensity change >0 (not in neutral or weakening stage).
  5. Latitude <=30 deg N

- 2015 Software/Algorithm Updates:
  - Added 85 GHz RI predictors (for testing the probability-based RI index) and run in a parallel mode with the 37 GHz-only ring RII
  - Added real-time ARCHER center as input for ring detection
  - Changed the output from satellite overpass centered to 6 hourly synoptic time centered *as requested by NHC*
  - Added AMSR-2 & GMI real-time data

All real-time forecasts during 2015 Hurricane Season were posted on http://tcpf.fiu.edu/JHT/

Positive RI forecasts were sent to NHC through emails

```
         ATLANTIC 37 GHz RING + 85 GHz RI INDEX
     JOAQUIN AL11 2015  09/30/15  00 UTC
    TMI,SSMI,SSMIS,AMSR2 and WINDSAT   Total Overpass Orbits:  2
===========RI FORECASTS BY 37GHz only and 37+85 GHz RI INDICES DURING PAST 6 HOURS==========
===37 GHz Only Forecast:===
     FUTURE 24-HOUR INTENSITY INCREASE >= 30 KT (RI):                YES
===37 GHz Ring+85 GHz Forecast:===
PROB OF RI FOR 25 KT RI THRESHOLD=    64%
PROB OF RI FOR 30 KT RI THRESHOLD=    35%
PROB OF RI FOR 35 KT RI THRESHOLD=    17%
================================================================================
--------------Current SHIPS---------------
PROB OF RI FOR 25 KT RI THRESHOLD=    20%
PROB OF RI FOR 30 KT RI THRESHOLD=    12%
PROB OF RI FOR 35 KT RI THRESHOLD=     7%
PROB OF RI FOR 40 KT RI THRESHOLD=     6%
================================================================

DETAILED RI FORECAST FROM OVERPASS #1:
         ATLANTIC 37 GHz RING + 85 GHz RI INDEX
            GMI   JOAQUIN  AL112015  09/29/15  2139 UTC

===========RI FORECAST BY THE 37 GHz only and 37+85 GHz RI INDICES==
37 GHz Only Forecast:
     FUTURE 24-HOUR INTENSITY INCREASE >= 30 KT (RI)? :       YES
37 GHz Ring+85 GHz Forecast:
37GHz RING+85GHz RI PROBABLITIES AT SATELLITE OVERPASS TIME
PROB OF RI FOR 25 KT RI THRESHOLD=    64%
PROB OF RI FOR 30 KT RI THRESHOLD=    35%
PROB OF RI FOR 35 KT RI THRESHOLD=    17%
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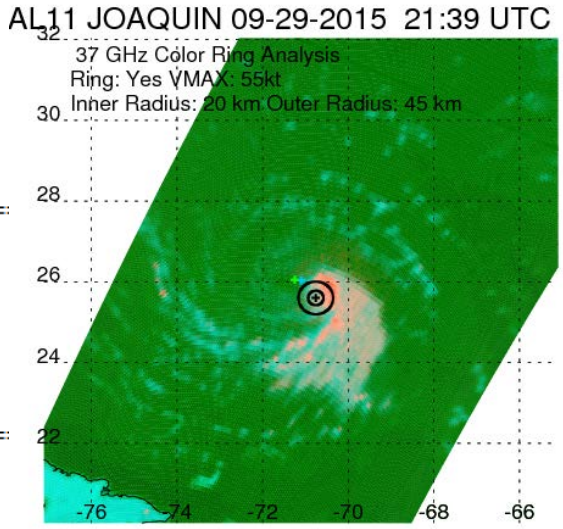


Example RI forecast: Joaquin 2015093000

37 GHz Ring RI Index 2015 Season Performance

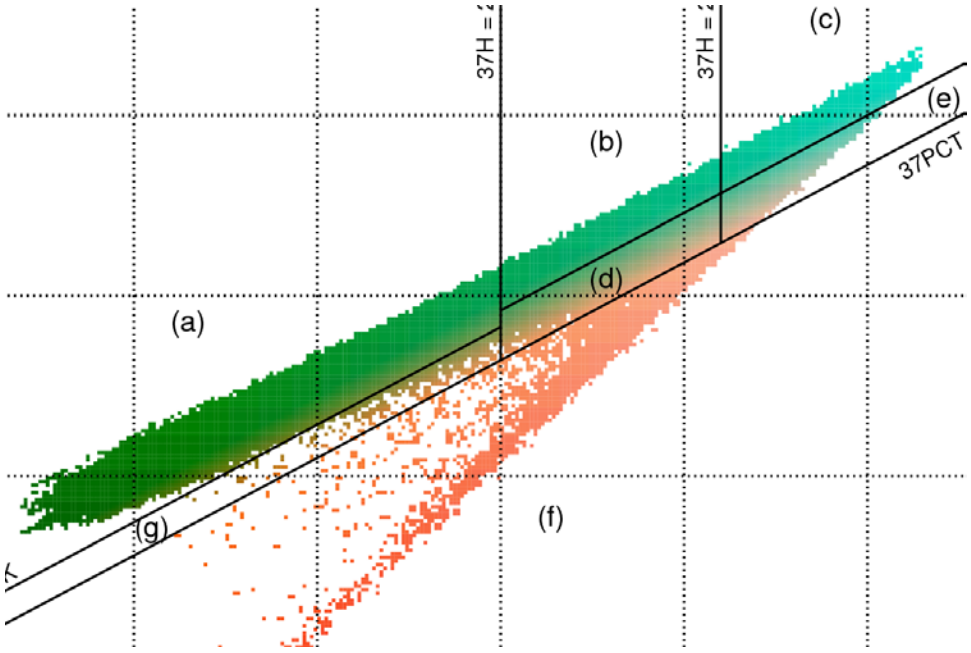
37 GHz Ring RII	AL case	EP case	AL event	EP event
# of qualified RI cases/events	4	12	2	6
# of correct RI forecasts (hits)	3	15	1	6
Probability of detection (POD)	75%	75%	50%	100%
# of false alarms	0	19	0	5
# of total RI forecasts	3	31	1	11
False Alarm Ratio (FAR)	0%	61%	0%	45%

19 RI-case false alarms (out of 854 best track 6-hrly TC cases):

- 16 of them were slowly intensifying cases;
- 10 of them had future intensity increase >= 20 kt/24 hour;
- only 3 of them were future 24-h steady state or weakening cases

Development of Probability-based Microwave Ring RI Index (PMWRing RII) for NHC/JTWC Forecast Basins (JHT FY15 Project Yr-1)

- **Predictors:**
  - **Ring_TD80, TD90, TD100:** 37 GHz cyan+pink ring (regions b, c, d, e, f, g)
  - **FracDark:** Fractional inner core area with 37 GHz color of cyan or pink (regions b, c, d, e, f, g)
  - **FracBright:** Fractional inner core area with 37 GHz color of bright cyan or pink (regions c, d, e, f, g)
  - **Frac275:** Fractional inner core area with 85 GHz PCT<275K
  - **Frac250:** Fractional inner core area with 85 GHz PCT<250K
  - **Frac225:** Fractional inner core area with 85 GHz PCT<225K



Scatter plot of real colors in the NRL 37color product as a function of 37H and 37V derived from the inner core region of TCs directly observed by the TRMM PR and TMI during 1998-2011.

Developmental sample sizes of AMSRE, SSMIS, and TMI overpasses that meet environment & persistence criteria #2-5 (not including SHIPS yet)

	ATL	EPA	NWP+NIO	SH
Number of TMI overpasses	139	85	249	269
Number of TMI overpasses with 30 kt/day RI	34	9	27	22
Number of AMSRE overpasses	146	136	339	248
Number of AMSRE overpasses with 30 kt/day RI	34	41	117	89
Number of SSMIS overpasses	190	222	390	324
Number of SSMIS overpasses with 30 kt/day RI	45	59	153	89

- Our algorithm development for each microwave sensor is done separately to avoid dealing with inter-calibration and different frequency issues

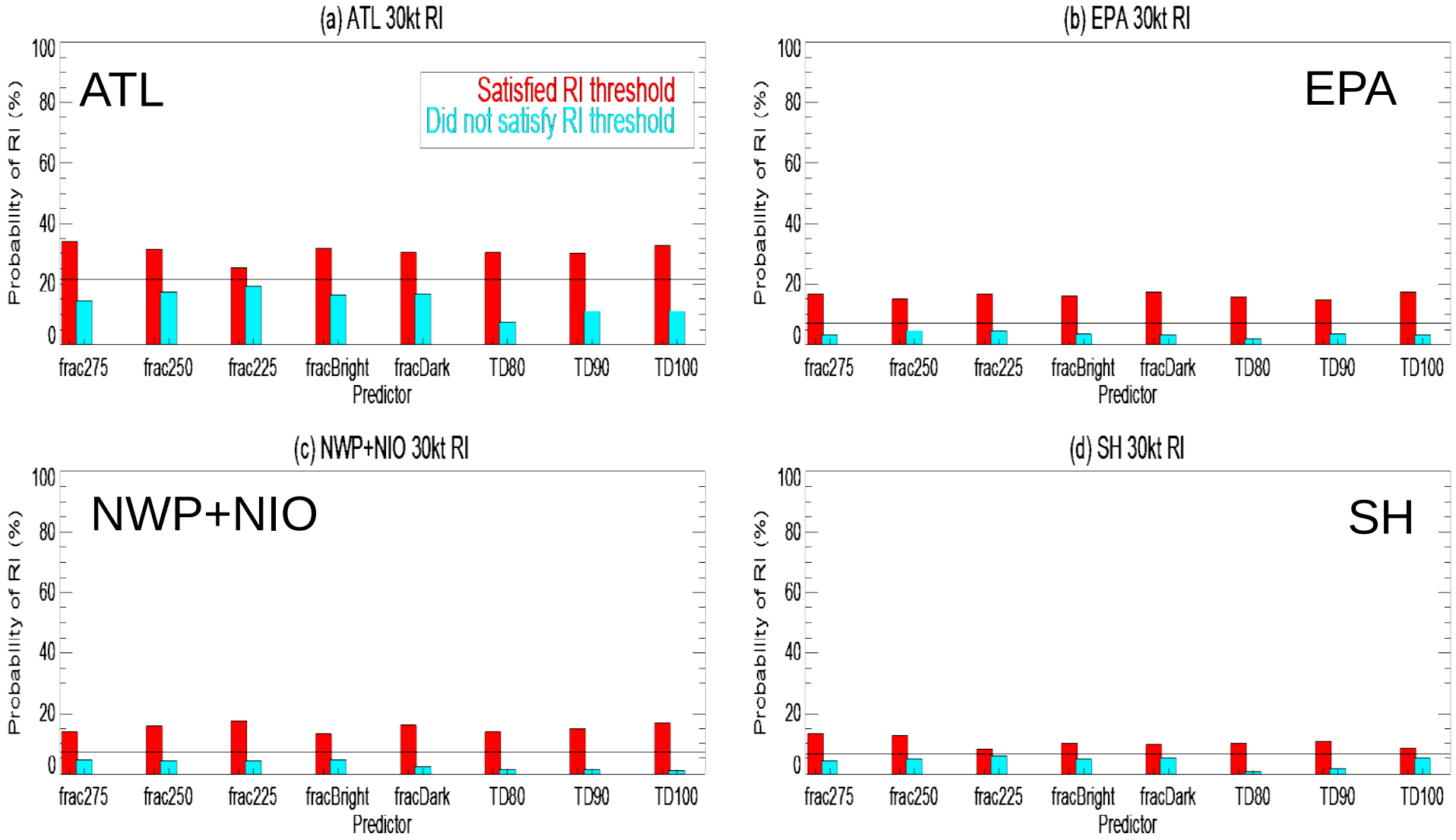
Results for TMI as an example

RI Thresholds for TMI overpasses

Threshold of 30 kt Intensity Change	ATL	EPA	NWP + NIO	SH
frac275	0.71	0.60	0.71	0.69
frac250	0.33	0.25	0.34	0.29
frac225	0.10	0.08	0.10	0.08
fracBright	0.61	0.46	0.62	0.62
fracDark	0.77	0.68	0.80	0.80
ring_TD80	y/n	y/n	y/n	y/n
ring_TD90	y/n	y/n	y/n	y/n
ring_TD100	y/n	y/n	y/n	y/n

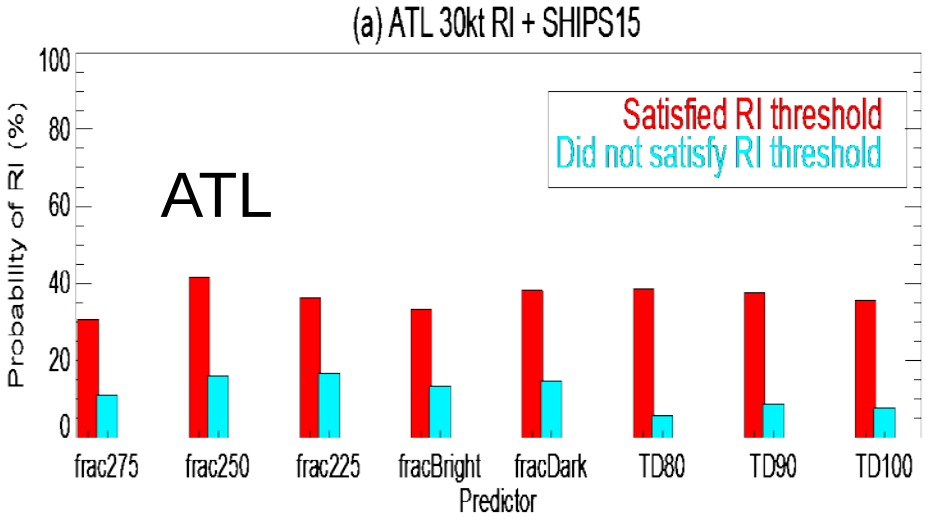
- For the fractional predictors, RI thresholds are computed as the mean values for all overpasses meeting a certain RI intensity change rate (i.e. 25, 30, 35, 40 kt/day)
- For the ring predictor, it's "yes" or "no".
- Same type of tables are generated for 25, 35, 40 kt/day RI categories as well.

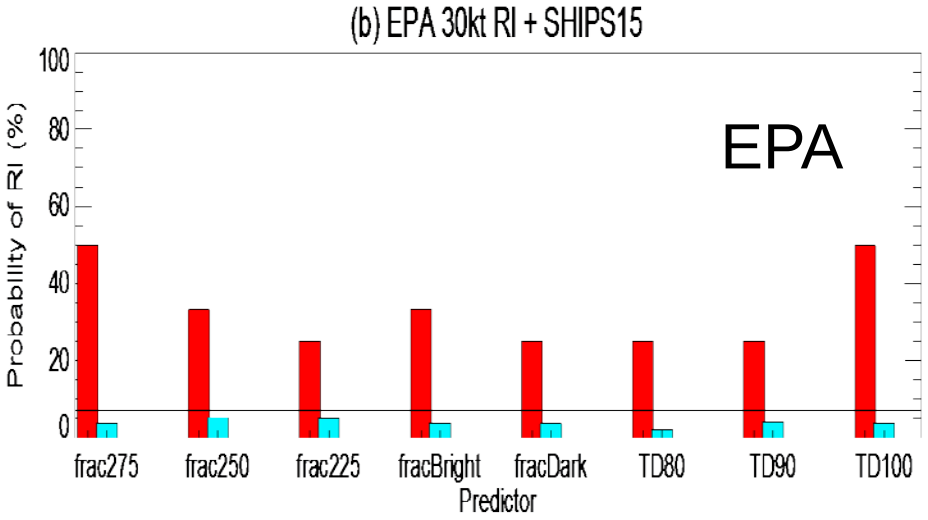
Probability of RI for predictors satisfying and not satisfying RI threshold (TMI, 30kt RI)

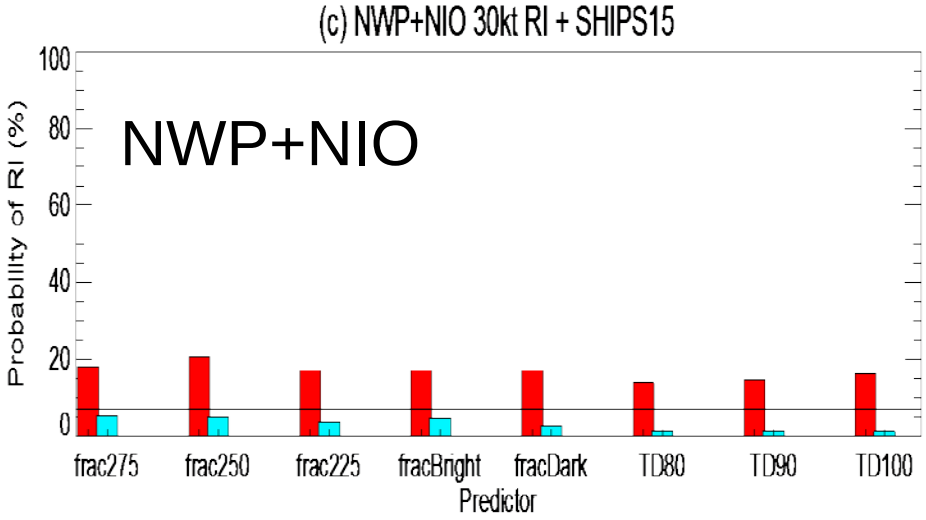


Solid line shows the climatology mean. All predictors are skillful in each basin. Similar results for AMSRE and SSMIS and for 25, 35, 40 kt/day RI categories.

Adding SHIPS RII Criterion (SHIPS RII >=15%)

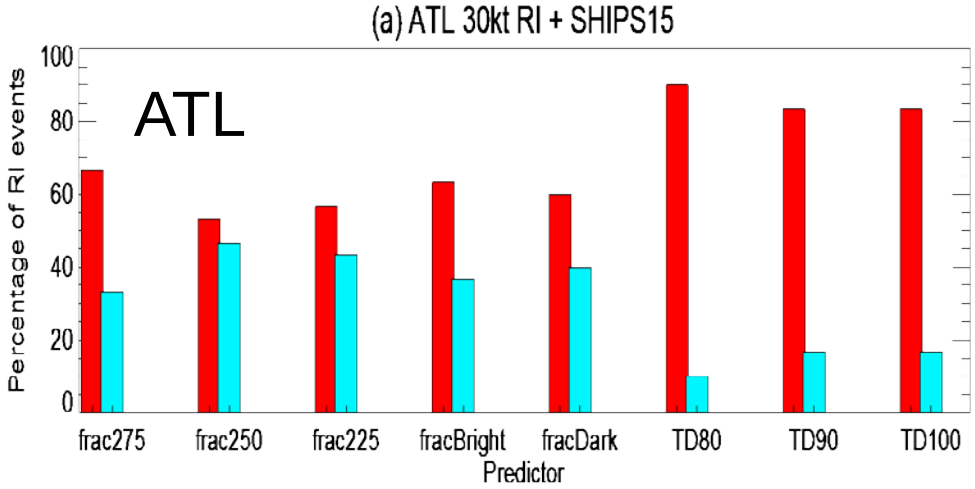


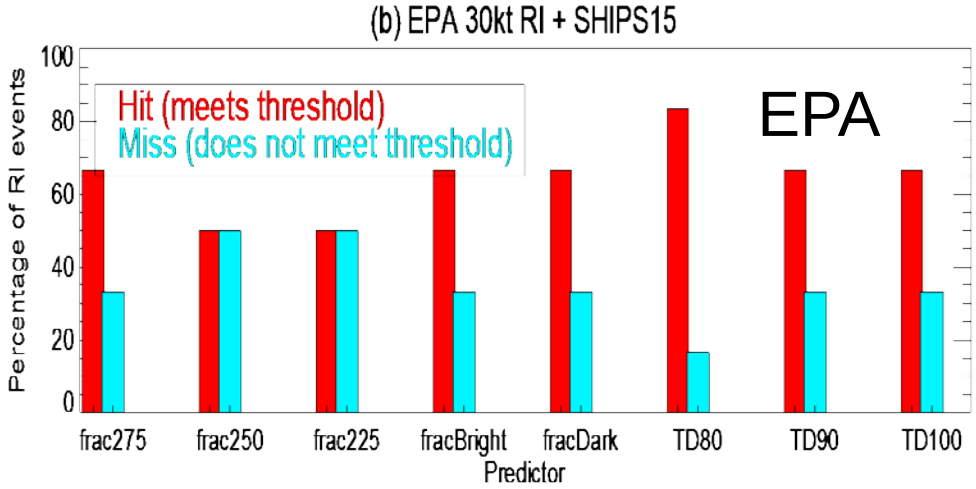


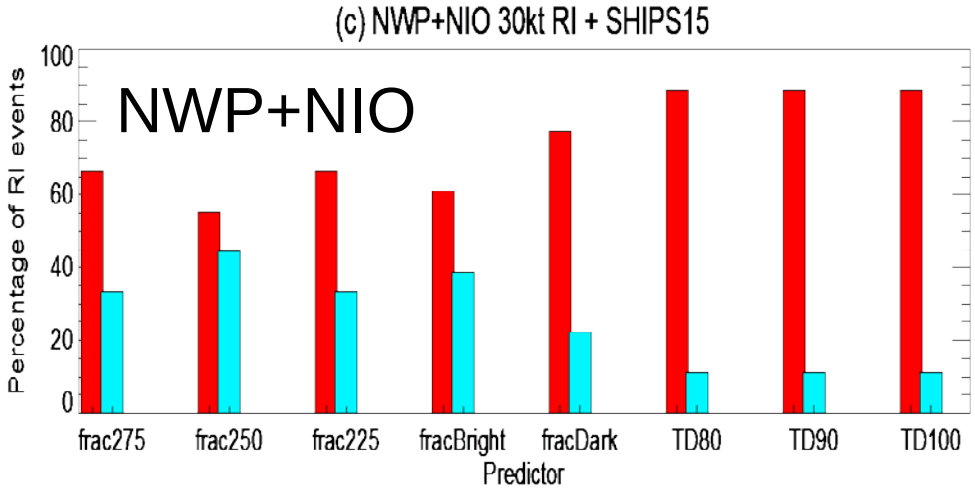


- **No SHIPS RII data for SH yet.**
- **We have tested the thresholds of 5, 10, 15, and 25% SHIPS RI probabilities for 25, 35, 40 kt/day RI categories.**
- **Probabilities of RI increased after adding the SHIPS criterion for both ATL & EPA basins, but not much in the NWP+NIO basins.**

% of Hit & Miss: TMI; 30 kt/day RI; & SHIPS RII >=15%







- **Much higher hit rate (POD) is seen for all predictors.**
- **The ring predictor still produces the highest POD & lowest rate of misses in all basins.**

Summary of Progress and Next-Step Plan

- **We are following the JHT FY-15 project timeline pretty well:**
  - **(Complete) Sep 2015 FIU**: Generate the developmental microwave data including TMI, AMSR-E, SSM/I, and SSMIS data for ATL, EPA, NWP and NIO basins; **CIRA:** Generate the developmental SHIPS RII dataset for NWP and NIO basins
  - **(Complete) Nov 2015 FIU:** develop RI thresholds for SHIPS RII and microwave predictors for ATL, EPA, NWP and NIO basins
  - **(Almost done) Jan 2016 FIU:** Begin development of the PMWRing RII for ATL, EPA, and NWP/NIO basins
- **(In preparation) May 2016: Complete the algorithm development and implement the real-time testing code for 2016 Hurricane/Typhoon season in ATL, EPA, NWP, and NIO basins :**
  - **ARCHER-2 code adaption (Matlab to IDL connection has been done by Cheng Tao) in progress (*Thanks Wimmer and Velden [2016 JAMC] for releasing the ARCHER-2 code!*)**
  - **Need real-time A-deck and SHIPS RII access from JTWC**

Thanks for your attention!

Related Publications

- Tao, C., and H. Jiang, 2016: The Evolution of Rainfall and Vortex Alignment in Rapidly Intensifying Tropical Cyclones based on 16 years of TRMM Data. Mon. Wea. Rev., submitted.
- Rogers, R. F., J. Zhang, Zawislak, J., G. R. Alvey III, E. J. Zipser, H. Jiang, 2016: Observations of the structure and evolution of Hurricane Edouard (2014) during intensity change. Part II: Kinematic structure and the distribution of deep convection. Mon. Wea. Rev., in revision.
- Zawislak, J., G. R. Alvey III, R. F. Rogers, J. Zhang, E. J. Zipser, H. Jiang, 2016: Observations of the structure and evolution of Hurricane Edouard (2014) during intensity change. Part I: Relationship between the thermodynamic structure and precipitation. Mon. Wea. Rev., in revison.
- Tao, C., and H. Jiang, 2015: Distributions of shallow to very deep precipitation-convection in rapidly intensifying tropical cyclones. *J. Climate*, 28, 8791-8824..
- Zagrodnik, J., and H. Jiang, 2014: Rainfall, Convection, and Latent Heating Distributions in Rapidly Intensifying Tropical Cyclones. *J. Atmos. Sci.,* **71**, 2789-2809.
- Jiang, H., and E. M. Ramirez, 2013: Necessary conditions for tropical cyclone rapid intensification as derived from 11 years of TRMM data. J. Climate., **26**, 6459-6470.
- Kieper, M., and H. Jiang, 2012: Predicting tropical cyclone rapid intensification using the 37 GHz ring pattern identified from passive microwave measurements. *Geophys. Res. Lett.*, **39**, L13804,doi:10.1029/2012GL052115.
- Jiang, H., 2012: The relationship between tropical cyclone intensity change and the strength of inner core convection. *Mon. Wea. Rev*., **140**, 1164-1176.
- Jiang, H., C. Liu, and E. J. Zipser, 2011: A TRMM-based Tropical Cyclone Cloud and Precipitation Feature Database. *J. Appl. Meteor. Climatol.*, **50**,1255-1274.

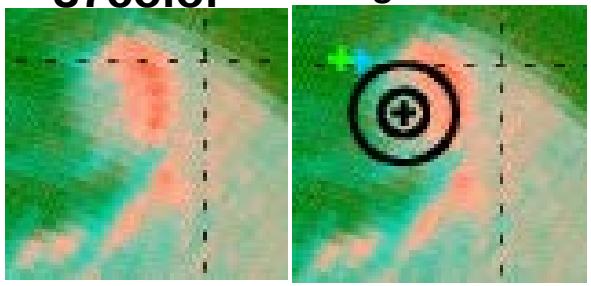
Atlantic Basin 2015 RI Events and Forecasts

#	storm	RI starts (best track Vmax in kt)	RI ends (best track Vmax in kt)	# of 24-h periods (cases)	# of periods met 5 criteria	Ring (case-based)	SHIPS 30-kt RII
1	AL04 Danny	0820 18Z (75)	0821 18Z (105)	1	1	No	No (11%)
~~2~~	~~AL06 Fred~~	~~0829 18Z (25)~~	~~0831 12Z (75)~~	~~4~~	~~0~~	~~N/A~~	~~N/A~~
3	AL08 Joaquin	0930 00Z (60)	1001 18Z (115)	4	3	3	3

Note: 1) N/A means either no data or no cases met criteria; 2) SHIPS RII 30-kt >= 20% (AL), 30% (EP) is used as threshold to forecast RI (*Kaplan et al. 2010*) ; 3) ARCHER center is used in the ring detection below.

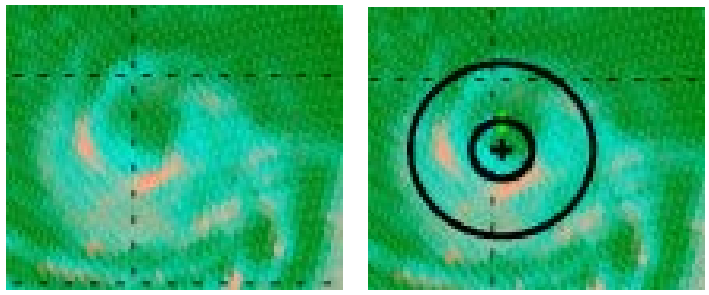
Joaquin Hits:

37color Ring detection



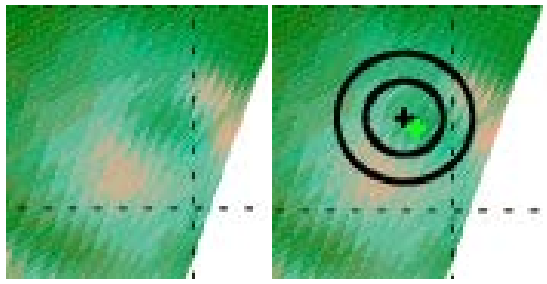
GMI 09/29 21:39 UTC

37color Ring detection



AMSR2 09/30 06:13 UTC

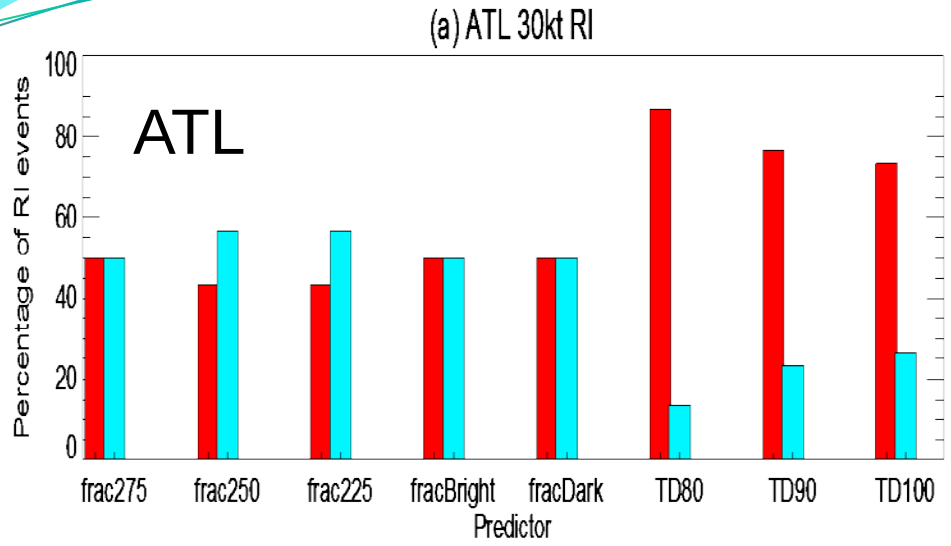
37color Ring detection

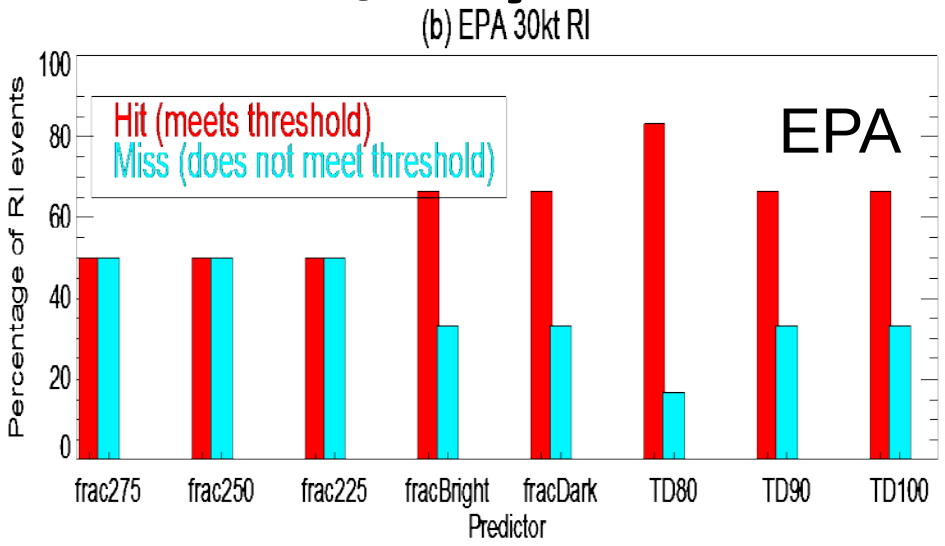


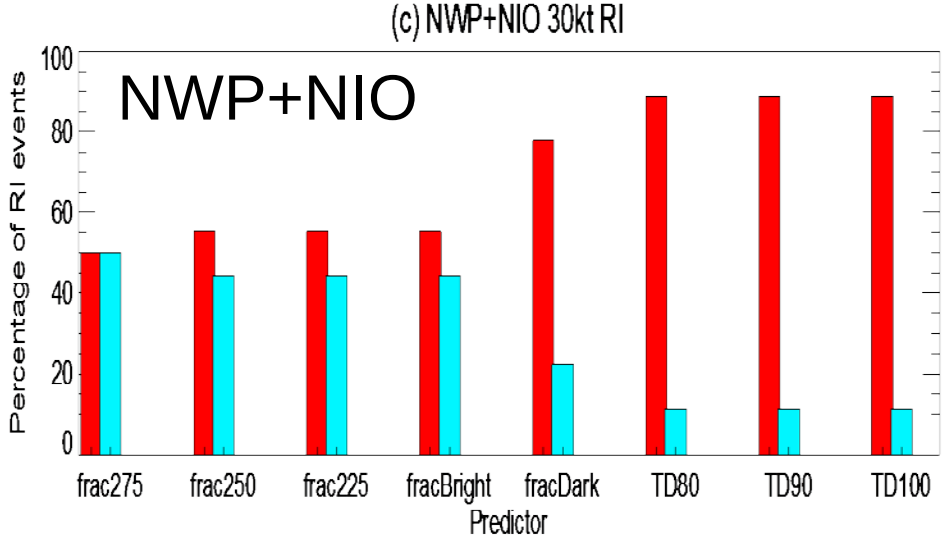
SSMIS 09/30 12:58 UTC

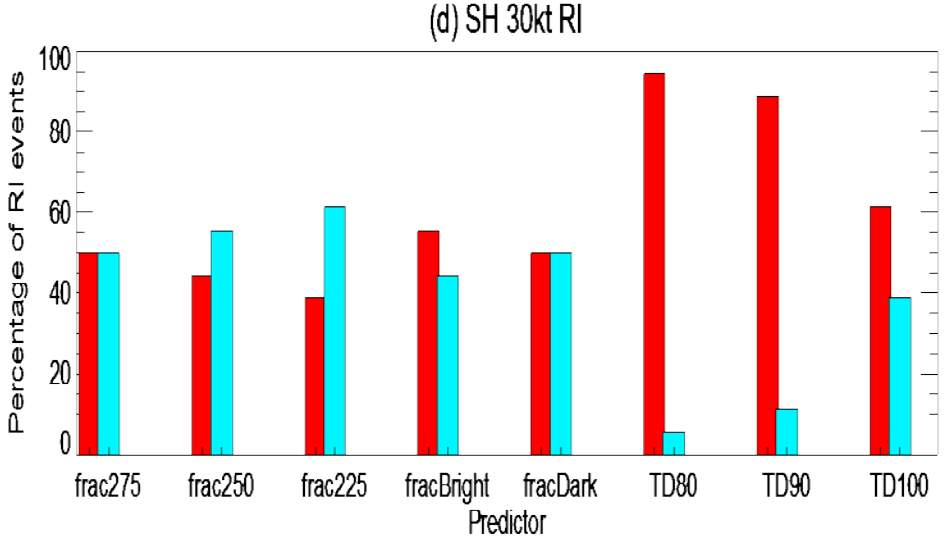
- Qualified RI cases: 4; Hits: 3 (POD=75%); False alarm: 0
- Qualified RI events: 2; Hits: 1 (POD=50%); False alarm: 0

% of Hit & Miss: TMI; 30 kt/day RI









- **Without adding SHIPS RII, the ring predictor produces much higher hit rate than miss rate in all basins.**
- **But the fractional predictors have about equal rates of hits & misses.**