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

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This Progress Report Period (Mid-yr Report for Yr1) - (09/01/2015 – 02/29/2016)
Entire Project Period – 09/01/2015 – 08/31/2016

1. General Description of Progress

During the report period, there are 3 milestones proposed in the original proposal:

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
Nov 2015	FIU: develop RI thresholds for SHIPS RII and microwave predictors for ATL, EPA, NWP and NIO basins
Jan 2016	Begin development of the PMWRing RII for ATL, EPA, and NWP/NIO basins

We have finished the first two milestones, and the third one is almost done. Please see Section 3 for details.

2. Transition to Operations

a. Summary of testbed-related activities and outcomes:

The PMWRing RII for ATL, EPA, and NWP/NIO basins is being developed.

b. What was transitioned?

It has not been tested, therefore is not ready for transition yet.

c. TRL* current vs. start of project

TRL 4 VS. TRL 3

d. Lessons learned

Need to develop the algorithm for each microwave sensor separately.

e. Next steps – future plans

We will start the real-time testing in Jun. 2016.

i. Has it been approved for transition yet? Plans for future transition?

No, not yet.

3. Milestones

a. Completed

(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

The developmental microwave datasets have been created for TMI, AMSR-E, and SSMIS for all basins for which the PMWRing RII will be run: ATL (Atlantic), EPA (East Pacific), NWP (Northwest Pacific), NIO (Northern Indian) and SH (Southern Hemisphere) [preparation of the developmental dataset for the SH also accomplishes the first milestone in Year 2, September 2016]. The TMI developmental dataset, which will be used to assess probabilities for GMI overpasses, consists of cases between 1997 and 2013. The AMSR-E dataset, which will be used to assess probabilities for AMSR2 overpasses, consists of the complete sensor data record between 2002 and 2011, while SSMIS includes all available sensors (F-16, F-17, F-18) available between 2007 (first availability of SSMIS-16) and 2013. Considering that DMSP-13 is the only remaining platform that supports SSMI, that sensor will not be included in the real-time algorithm.

Although the proposal indicated that an intercalibration between the sensors would be applied for the developmental dataset, we have subsequently decided that this is not necessary for the real-time algorithm. Instead, each sensor will be treated independently in the algorithm (e.g., when an SSMIS overpass is detected, probabilities will be specifically drawn from the SSMIS portion of the developmental dataset only).

Similar to the previous versions, overpasses that contribute to the developmental dataset must be over water (includes the location 24 h later), have an increase in intensity during the previous 6 hours, have an intensity between 45 and 100 kt, have a center location below latitude 30 ºN, and contain complete data with 100 km. However, in contrast to past versions of the developmental dataset that used interpolated centers from the best track, which caused a high number of false alarms, center locations were determined using the CIMSS Automated Rotational Center Hurricane Eye Retrieval (ARCHER) algorithm for 37 GHz. This should reduce the high number of false alarms that was a consequence of using the less accurate, interpolated best-track centers. Statistics for each predictor are only quantified for locations in which ARCHER is able to determine a center location.

SHIPS developmental datasets (for 2004–2014) were provided by CIRA for not only the NWP and NIO, but also (updated) for the ATL and EPA. For basins under NHC responsibility (ATL, EPA) probabilities for all SHIPS intensity change rates (25, 30, 35, and 40 kt day^{-1}) were provided. For basins under JTWC responsibility, SHIPS developmental data was only provided for 30 kt day^{-1}. The SHIPS probability, if available, for each intensity change rate was interpolated to the microwave overpass time.

(COMPLETE) *Nov 2015* *FIU: develop RI thresholds for SHIPS RII and microwave predictors for ATL, EPA, NWP and NIO basins*

As in previous versions of the TMI developmental dataset, the thresholds for each high frequency (i.e., 85–91-GHz) and ring-related (fraction of the "Dark" and "Bright" cyan definitions in the 37-GHz color composite) predictor are computed as the mean value for all overpasses meeting a certain RI intensity change rate (i.e., 25, 30, 35, and 40 kt day^{-1}). Note that the "Dark" and "Bright" cyan definitions have been modified from those shown in the proposal.

Figure 1 is an update of Figure 3 from the proposal and shows how the individual "37color" regions are separated by horizontal and vertical-polarized brightness temperature (T_B), as well as 37-GHz polarization corrected temperature (PCT). The new thresholds (compared to the old in Table 1) are shown in Table 2.

Table 1: Previous definitions for the six color categories and their corresponding brightness temperature ranges.

Region	Definition (T_B's are in K)
(a) Green	37PCT > 260 & 37H <= 225
(b) Weak Cyan	37PCT > 275 & 225<37H<=255
(c) Bright Cyan	37PCT > 275 & 37H > 255
(d) Weak Cyan/Pink	260<37PCT<=275 & 225<37H<=255
(e) Bright Cyan/Pink	260<37PCT<=275 & 37H >255
(f) Pink	37PCT <= 260

Table 2: Current definitions for the seven color categories and their corresponding brightness temperature ranges as defined in Fig. 1.

Region	Definition (T_B's are in K)
1 (green)	PCT37 > 270 & H37 < 225
2 (weak cyan)	PCT37 > 275 & 225 ≤ H37 < 255
3 (bright cyan)	PCT37 > 275 & H37 ≥ 255
4 (green/pink)	260 < PCT37 ≤ 270 & H37 < 225
5 (weak cyan/pink)	260 < PCT37 ≤ 275 & 225 ≤ H37 < 255
6 (bright cyan/pink)	260 < PCT37 ≤ 275 & H37 ≥ 255
7 (pink)	PCT37 ≤ 260

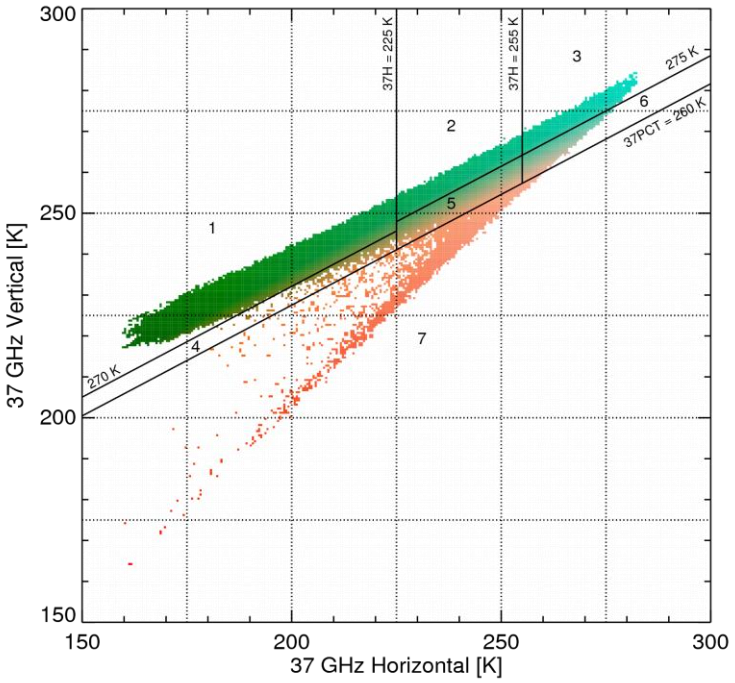

Figure 1: Scatter plot of real colors in the NRL 37color product as a function of 37H and 37V derived from the inner core region of TCs directly observed by the TRMM PR and TMI during 1998-2011. Seven color categories are defined as 1-7 regions with the corresponding colors and brightness temperature ranges shown in Table 2. Constant 37PCT=270 K is shown as the tilted solid black line.

The RI thresholds quantified for each predictor and intensity change rate, individualized by sensor, are provided in tables in the Appendix. The "Probability of RI" is computed as the fraction of cases that satisfy the RI threshold divided by the total number in the available dataset that satisfy the RI threshold. Tables 3–5 below show the sample size of overpasses available in the developmental dataset that meet our requirements (< 30 ° latitude, over ocean, intensification in previous 6 h, and initial intensity between 45 and 100 kt), as well as the number of overpasses from that sample that meet each intensity change rate. The individualized-sensor RI probabilities, which will be used in the real-time PMWRing RII algorithm, are provided in tables that follow those that list the accompanying RI thresholds.

Table 3: Sample size of AMSRE overpasses that meet the requirements

	ATL	EPA	NWP+NIO	SH
Number of overpasses that meet the requirements	146	136	339	248
Number of overpasses with 25 kt intensity change	34	41	117	89
Number of overpasses with 30 kt intensity change	25	26	81	71
Number of overpasses with 35 kt intensity change	18	22	62	49
Number of overpasses with 40 kt intensity change	14	16	44	31

Table 4: Sample size of SSMIS overpasses that meet the requirements

	ATL	EPA	NWP+NIO	SH
Number of overpasses that meet the requirements	190	222	390	324
Number of overpasses with 25 kt intensity change	45	59	153	89
Number of overpasses with 30 kt intensity change	34	41	126	72
Number of overpasses with 35 kt intensity change	20	27	103	47
Number of overpasses with 40 kt intensity change	13	22	76	31

Table 5: Sample size of TMI overpasses that meet the requirements

	ATL	EPA	NWP+NIO	SH
Number of overpasses that meet the requirements	139	85	249	269
Number of overpasses with 25 kt intensity change	34	9	27	22
Number of overpasses with 30 kt intensity change	30	6	18	18
Number of overpasses with 35 kt intensity change	17	4	11	5
Number of overpasses with 40 kt intensity change	13	2	7	2

Figures showing the RI probabilities ("Satisfied RI Threshold") of 30-kt for each sensor are also provided below. A figure showing the "Hits", which is defined as the percentage of cases that underwent 30-kt intensity change that satisfied the threshold, as well as "Misses," which is defined as the fraction of cases that underwent 30-kt RI that did not meet the threshold, are shown following the figures for the RI probabilities. The accompanying RI probabilities for each predictor+SHIPS are also provided (note that for the ATL and EPA, 25, 35, and 40 kt are also available, while in the NIO and NWP only 30 kt are available. SHIPS developmental data for the SH have not yet been provided, but will be, as proposed, in Year 2).

Based on these figures and tables, a few observations and conclusions can be made, particularly about the sensitivity to the choice of predictors and their thresholds:

- Although the probabilities for meeting the RI threshold for the fraction of the "Bright" ring definition are slightly greater in each basin (and for each sensor, as well) than for the "Dark" definition of a ring, there does not appear to be an appreciable benefit for using one over the other.

- Compared to the climatological RI probability, the probabilities quantified from the 85–91-GHz predictors (areal fractions of PCT $\leq$ 275, 250, 225 K) could provide some added value over the contributions from just the ring predictors, but this is not universal

between each sensor and basin. In another metric — the "hit" and "miss" percentages — the ring-based predictors are demonstrably more useful than the 85–91-GHz predictors. Note that for the 85–91-GHz predictors the percentage of "hits" (percent of RI cases that meet the RI threshold) is nearly similar to the "miss" percentage (percent of RI cases that do not meet the threshold) for 85–91-GHz predictors. This suggests that using the RI threshold (defined as the average value) for those predictors is being skewed towards a higher fraction that many of the RI cases do not meet. The "hits" percentages, in contrast, for the ring-based predictors are significantly greater than the "miss" percentage, which reinforces their critical importance as a symptom that RI is occurring.

- There is little sensitivity to the choice of requiring an 80, 90, or 100% "Dark" cyan ring, given that the RI probabilities for each (regardless of choice of sensor or basin) vary little from one another.

- For each sensor, small sample sizes are generally a problem for cases of 35- and 40-kt RI, particularly when the additional requirement for exceeding a SHIPS probability threshold of 15% is added (i.e., for the "predictor+SHIPS"). An issue with sample sizes is even apparent when requiring a SHIPS probability of at least 5% for 35- and 40-kt RI for TMI overpasses.

- As a result of small sample sizes, many of the RI probabilities (tables given in the Appendix) are 100%. This means that of the few cases in the dataset that meet the thresholds for both the microwave and SHIPS probability, every one also undergoes RI.

b. Not completed

ii. Reasons: Generation of SHIPS RII dataset for NWP & NIO was delayed. It wasn't released until in early Feb. 2016.

iii. Mitigation plan: We have been working hard to catch up. See below. It's almost done.

(IN PROGRESS) Jan 2016 Begin development of the PMWRing RII for ATL, EPA, and NWP/NIO basins

Given the completion of both the microwave and SHIPS developmental datasets, as well as the calculation of all of the RI probabilities, work is in progress on preparing the PMWRing RII for the upcoming season.

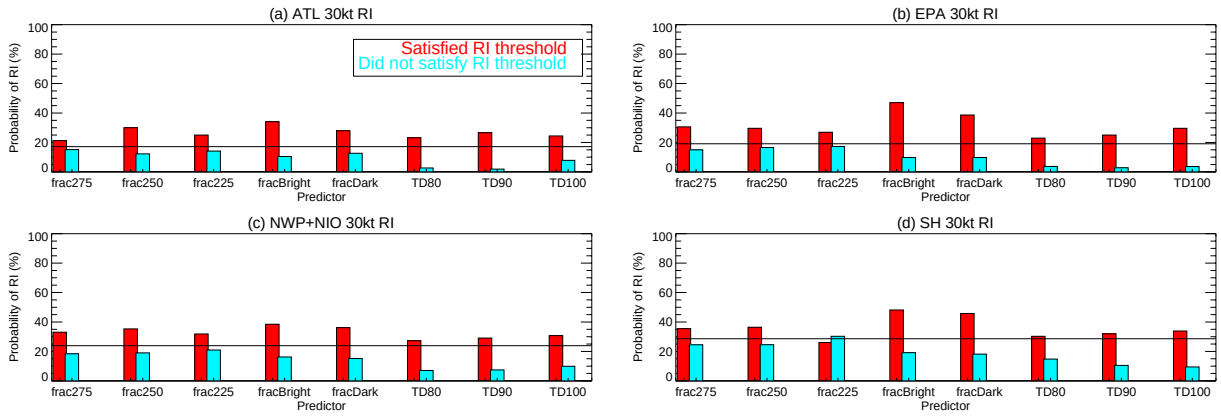

Figure 2a: For the AMSRE developmental dataset, the probability of RI (for 30-kt RI category only) for predictors satisfying and not satisfying RI thresholds for (a) ATL, (b) EPA, (c) NWP+NIO, and (d) SH basin. The climatological probability of RI is indicated by the solid horizontal line. "TD" represents the percentage coverage for the "Dark" definition of the cyan ring.

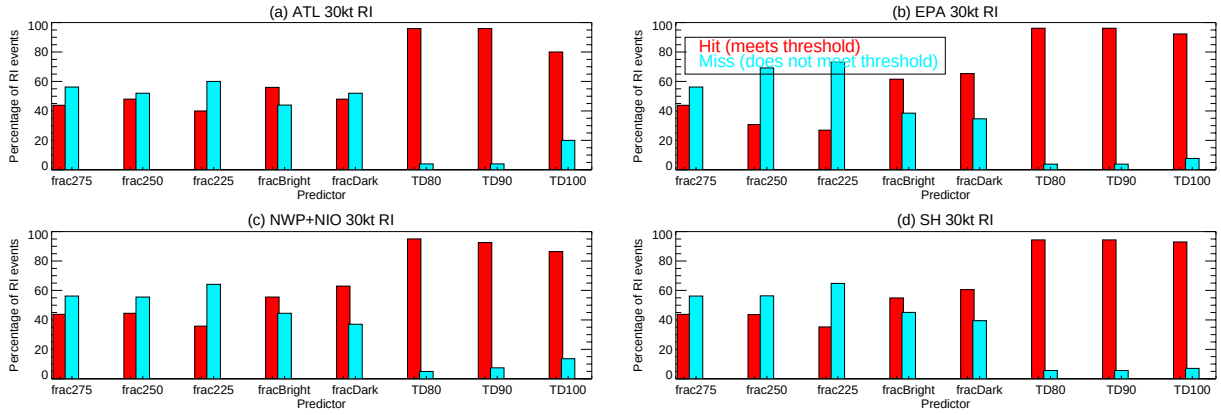

Figure 2b: For the AMSRE developmental dataset, the percentage of "hits" (for 30-kt RI category only) and "misses" for predictors satisfying RI thresholds for (a) ATL, (b) EPA, (c) NWP+NIO, and (d) SH basin.

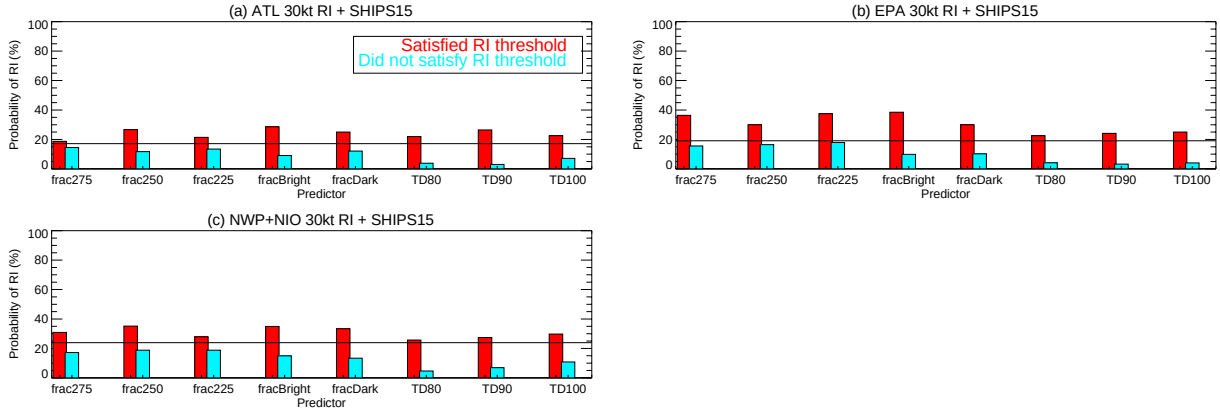

Figure 2c: For the AMSRE developmental dataset, the probability of RI (for 30-kt RI category only) for predictors satisfying and not satisfying RI thresholds for (a) ATL, (b) EPA, and (c) NWP+NIO, including the requirement for the SHIPS 30 kt RI probability to be at least 15%. The climatological probability of RI is indicated by the solid horizontal line.

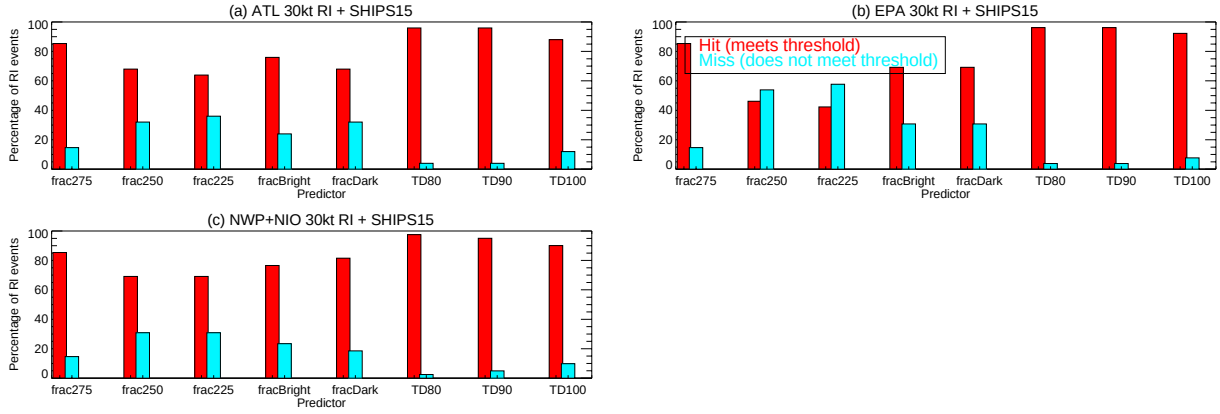

Figure 2d: For the AMSRE developmental dataset, the percentage of "hits" (for 30-kt RI category only) and "misses" for predictors satisfying RI thresholds for (a) ATL, (b) EPA, (c) NWP+NIO, and (d) SH basin, including the requirement for the SHIPS 30 kt RI probability to be at least 15%.

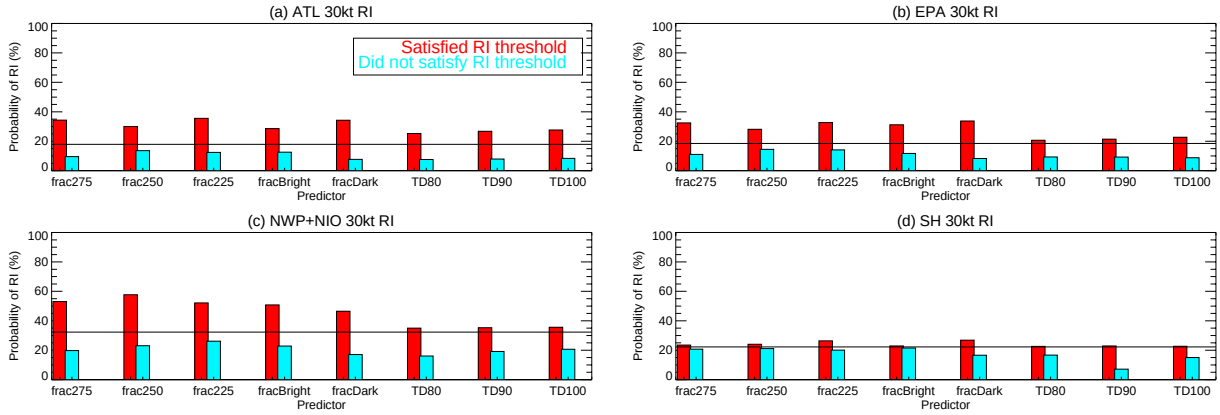

Figure 3a: Same as Figure 2a, except for the SSMIS developmental dataset

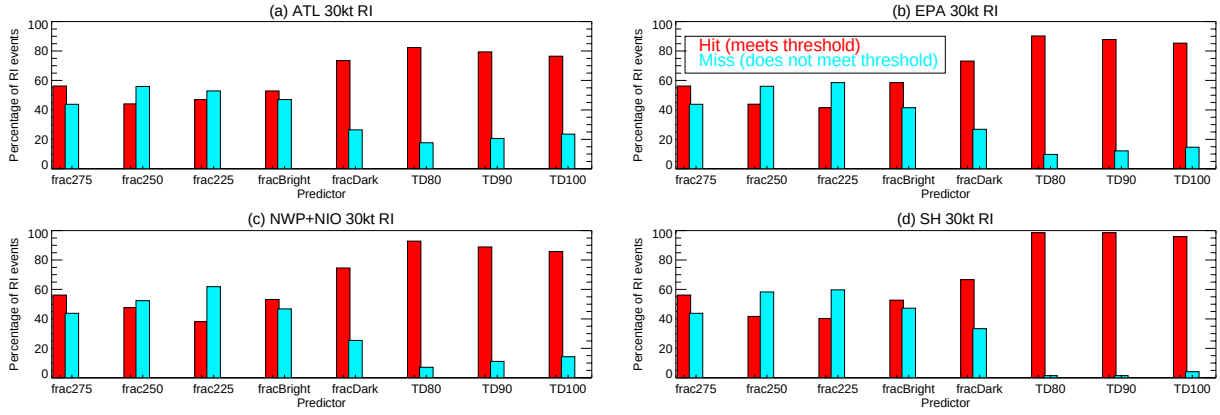

Figure 3b: Same as Figure 2b, except for the SSMIS developmental dataset

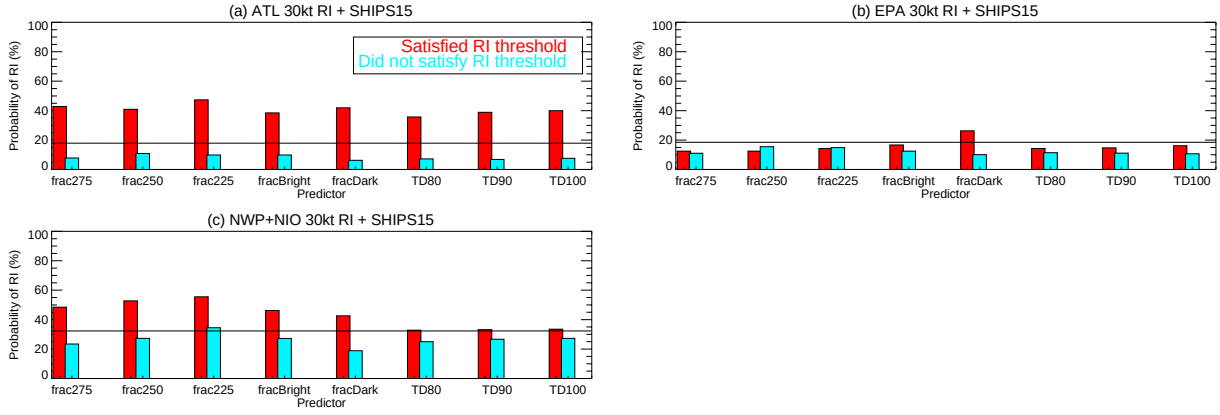

Figure 3c: Same as Figure 2c, except for the SSMIS developmental dataset

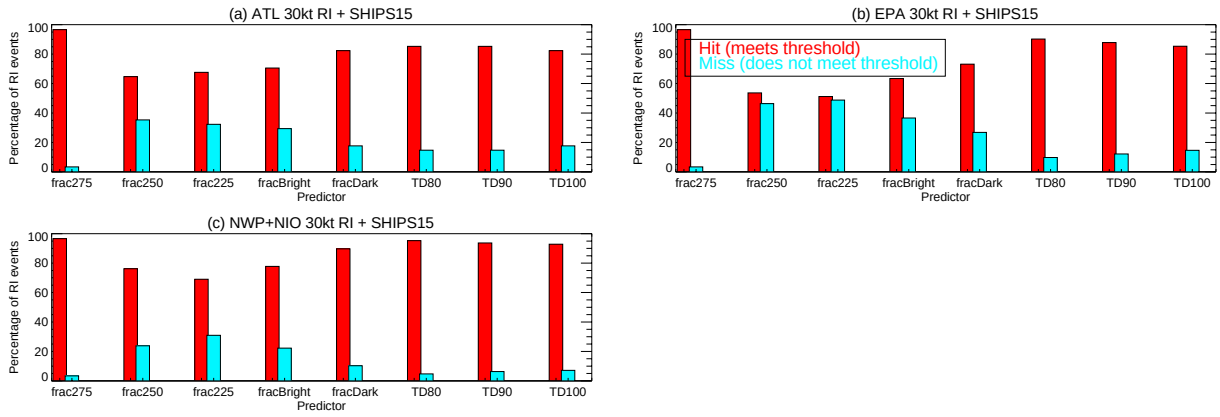

Figure 3d: Same as Figure 2d, except for the SSMIS developmental dataset

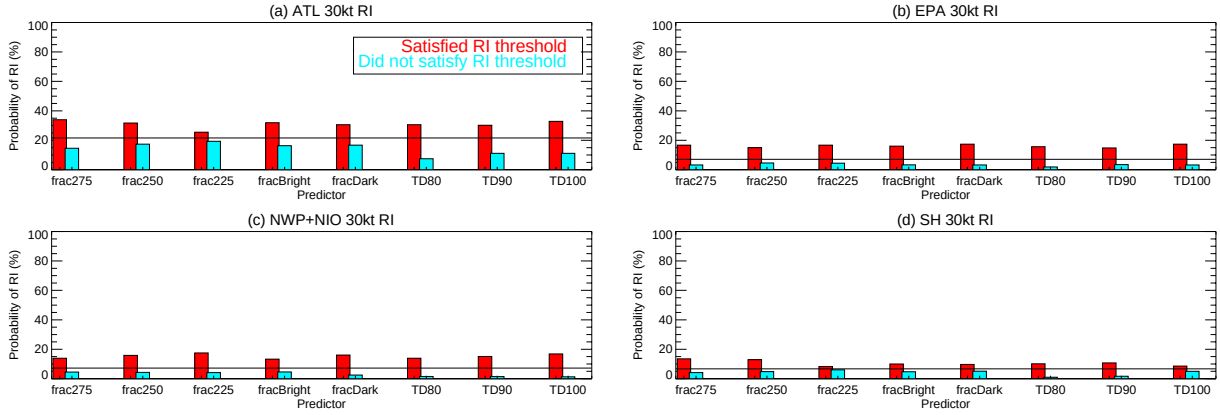

Figure 4a: Same as Figure 2a, except for the TMI developmental dataset

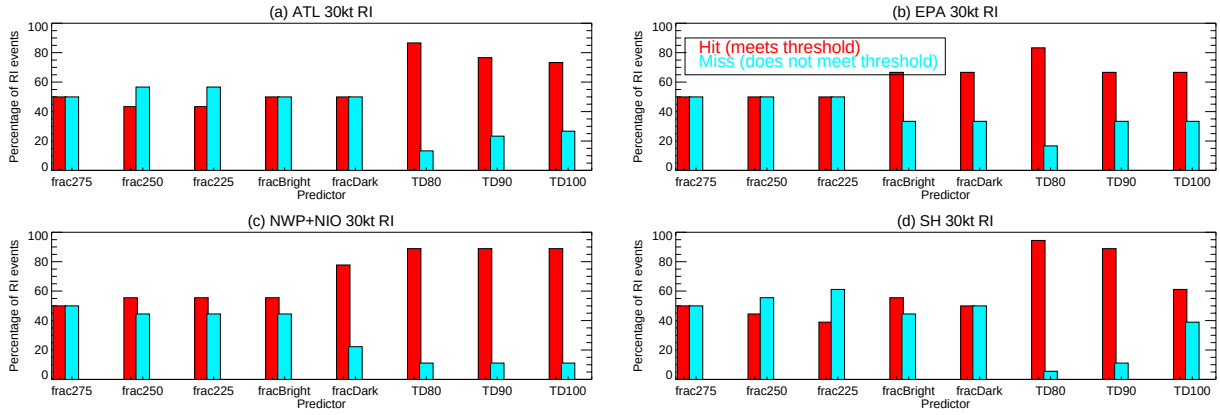

Figure 4b: Same as Figure 2b, except for the TMI developmental dataset

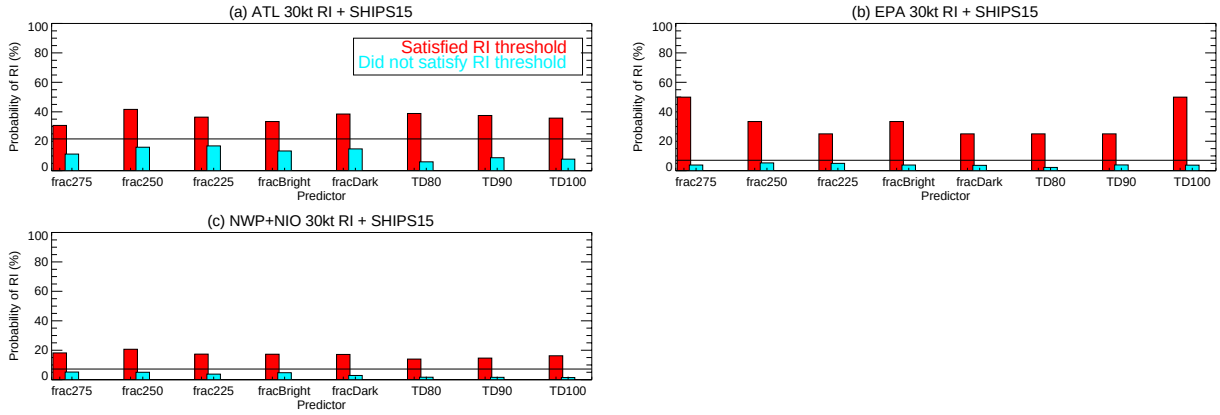

Figure 4c: Same as Figure 2c, except for the TMI developmental dataset

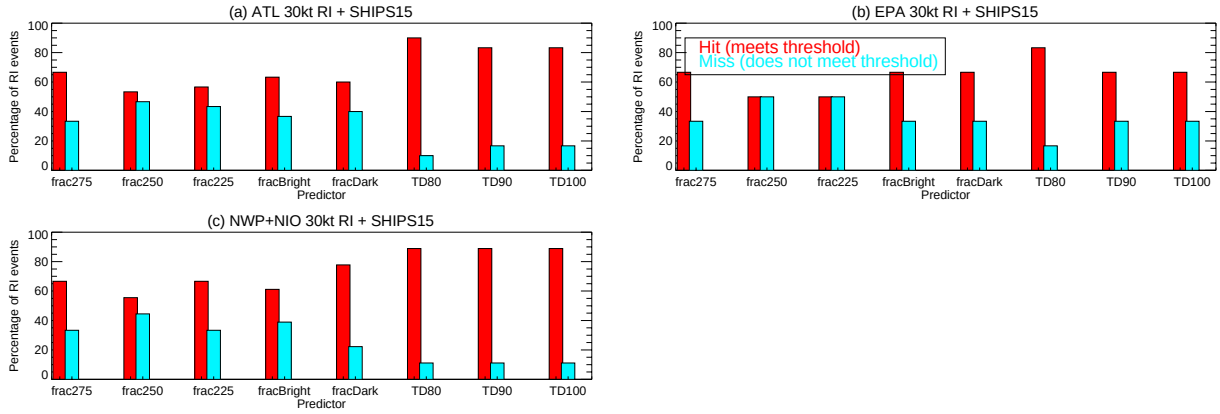

Figure 4d: Same as Figure 2d, except for the TMI developmental dataset

4. Publications

a. Journal articles published** :

Tao, C. and H. Jiang, 2015: Distributions of shallow to very deep Precipitation–Convection in rapidly intensifying tropical cyclones. *J. Climate*, 28, 8791-8824. doi: http://dx.doi.org/10.1175/JCLI-D-14-00448.1

b. Journal articles in process (what stage?)

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 revision.
Tao, C. and H. Jiang, 2016: The Evolution of Rainfall and Convection in Rapidly Intensifying Tropical Cyclones based on 16 years of TRMM Data. *J. Climate*, in review.

Jiang, H., J. Zagrodnik, C. Tao, M. Kieper, and E. Zipser 2015: What Is In the 37 GHz Cyan Color Ring of Rapidly Intensifying Tropical Cyclones? *Mon. Wea. Rev*., in preparation.

c. Other publications/presentations

Jiang, H., J. Zawislak, Y. Pei, C. Tao, M. Kieper, K. Musgrave, and Galina Chirokova 2016: Improvement and Implementation of the Probability-based Microwave Ring Rapid Intensification Index for NHC/JTWC Forecast Basins. 70th *Interdepartmental Hurricane Conference/Tropical Cyclone Research Forum*, Mar 15-17, 2016.

APPENDIX

AMSRE RI Thresholds

RI Thresholds for an intensity change of 25 kt for AMSRE overpasses

Threshold of 25 kt Intensity Change	ATL	EPA	NWP + NIO	SH
frac275	0.76	0.70	0.74	0.80
frac250	0.37	0.31	0.37	0.38
frac225	0.13	0.11	0.14	0.12
fracBright	0.63	0.60	0.64	0.70
fracDark	0.82	0.79	0.82	0.88
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

RI Thresholds for an intensity change of 30 kt for AMSRE overpasses

Threshold of 30 kt Intensity Change	ATL	EPA	NWP + NIO	SH
frac275	0.73	0.74	0.75	0.81
frac250	0.36	0.33	0.38	0.39
frac225	0.13	0.12	0.15	0.12
fracBright	0.63	0.64	0.66	0.71
fracDark	0.82	0.83	0.84	0.88
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

RI Thresholds for an intensity change of 35 kt for AMSRE overpasses

Threshold of 35 kt Intensity Change	ATL	EPA	NWP + NIO	SH
frac275	0.75	0.74	0.77	0.81
frac250	0.37	0.35	0.39	0.40
frac225	0.13	0.13	0.15	0.12
fracBright	0.64	0.64	0.68	0.70
fracDark	0.84	0.83	0.85	0.89

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

RI Thresholds for an intensity change of 40 kt for AMSRE overpasses

Threshold of 40 kt Intensity Change	ATL	EPA	NWP + NIO	SH
frac275	0.77	0.77	0.77	0.84
frac250	0.39	0.35	0.39	0.43
frac225	0.14	0.13	0.15	0.13
fracBright	0.65	0.70	0.68	0.73
fracDark	0.85	0.87	0.85	0.91
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

AMSRE RI Probabilities

RI Probability [%] of an intensity change of 25 kt for AMSRE overpass

Probability of 25 kt Intensity Change	ATL	EPA	NWP + NIO	SH
frac275	43	42	48	42
frac250	41	42	47	43
frac225	35	45	45	32

fracBright	44	49	48	53
fracDark	42	47	48	54
ring_TD80	31	36	39	38
ring_TD90	34	38	41	40
ring_TD100	33	42	43	42

RI Probability [%], which includes also meeting the thresholds of 5, 10, 15, 20, 25% (each comma delimited number) SHIPS 25-kt RI probability, for an intensity change of 25 kt for AMSRE overpasses

Probability of 25 kt Intensity Change	ATL	EPA	NWP + NIO	SH
frac275+SHIPS	43, 44, 46, 40, 42	42, 42, 44, 42, 33	-	-
frac250+SHIPS	39, 37, 38, 36, 36	37, 37, 40, 35, 27	-	-
frac225+SHIPS	32, 28, 29, 33, 36	40, 40, 40, 47, 40	-	-
fracBright+SHIPS	45, 44, 44, 41, 36	46, 46, 47, 44, 33	-	-
fracDark+SHIPS	43, 42, 41, 36, 31	48, 48, 48, 45, 36	-	-
ring_TD80+SHIPS	31, 30, 29, 27, 26	34, 34, 35, 33, 31	-	-
ring_TD90+SHIPS	34, 34, 33, 30, 28	36, 36, 37, 36, 34	-	-
ring_TD100+SHIPS	33, 33, 33, 28, 24	40, 40, 42, 41, 37	-	-

RI Probability [%] of an intensity change of 30 kt for AMSRE overpass

Probability of 30 kt Intensity Change	ATL	EPA	NWP + NIO	SH
frac275	21	31	33	35
frac250	30	30	35	36
frac225	25	27	32	26
fracBright	34	47	38	48
fracDark	28	39	36	46

ring_TD80	23	23	27	30
ring_TD90	27	25	29	32
ring_TD100	24	30	31	34

RI Probability [%], which includes also meeting the thresholds of 5, 10, 15, 20, 25% (each comma delimited number) SHIPS 30-kt RI probability, for an intensity change of 30 kt for AMSRE overpasses

Probability of 30 kt Intensity Change	ATL	EPA	NWP + NIO	SH
frac275+SHIPS	21, 22, 19, 17, 50	28, 32, 36, 100, 100	34, 32, 31, 30, 28	-
frac250+SHIPS	28, 30, 27, 40, 50	23, 26, 30, 100, 100	36, 36, 36, 37, 32	-
frac225+SHIPS	19, 19, 21, 20, 100	17, 19, 38, 100, 100	32, 30, 29, 33, 26	-
fracBright+SHIPS	36, 36, 29, 40, 33	43, 43, 38, 100, 100	38, 38, 35, 35, 31	-
fracDark+SHIPS	28, 28, 25, 25, 50	36, 36, 30, 100, 100	37, 35, 33, 32, 27	-
ring_TD80+SHIPS	23, 22, 22, 21, 14	20, 21, 23, 33, 100	30, 28, 27, 26, 25	-
ring_TD90+SHIPS	27, 26, 26, 27, 20	21, 23, 24, 50, 100	31, 29, 28, 26, 25	-
ring_TD100+SHIPS	25, 24, 23, 23, 25	27, 29, 25, 50, 100	33, 31, 30, 29, 26	-

RI Probability [%] of an intensity change of 35 kt for AMSRE overpass

Probability of 35 kt Intensity Change	ATL	EPA	NWP + NIO	SH
frac275	20	29	28	28
frac250	22	32	29	30
frac225	18	26	25	20
fracBright	24	41	30	34
fracDark	23	33	30	33

ring_TD80	17	19	21	22
ring_TD90	19	21	22	23
ring_TD100	20	25	25	24

RI Probability [%], which includes also meeting the thresholds of 5, 10, 15, 20, 25% (each comma delimited number) SHIPS 35-kt RI probability, for an intensity change of 35 kt for AMSRE overpasses

Probability of 35 kt Intensity Change	ATL	EPA	NWP + NIO	SH
frac275+SHIPS	19, 50 100, 100, 100	29, 67, 100, 100, 100	-	-
frac250+SHIPS	21, 25, 100, 100, 100	29, 60, 100, 100, 100	-	-
frac225+SHIPS	12, 33, 100, 100, 100	21, 100, 100, 100, 100	-	-
fracBright+SHIPS	28, 33, 100, 100, 100	37, 57, 100, 100, 100	-	-
fracDark+SHIPS	27, 33, 100, 100, 100	29, 40, 100, 100, 100	-	-
ring_TD80+SHIPS	17, 26, 100, 100, 100	16, 31, 100, 100, 100	-	-
ring_TD90+SHIPS	20, 31, 100, 100, 100	17, 36, 100, 100, 100	-	-
ring_TD100+SHIPS	21, 29, 100, 100, 100	22, 36, 100, 100, 100	-	-

RI Probability [%] of an intensity change of 40 kt for AMSRE overpass

Probability of 40 kt Intensity Change	ATL	EPA	NWP + NIO	SH
frac275	15	24	22	22
frac250	19	22	20	21
frac225	17	17	19	13
fracBright	21	43	23	22
fracDark	19	33	20	23

ring_TD80	13	15	15	14
ring_TD90	15	16	16	15
ring_TD100	15	20	18	16

RI Probability [%], which includes also meeting the thresholds of 5, 10, 15, 20, 25% (each comma delimited number) SHIPS 40-kt RI probability, for an intensity change of 40 kt for AMSRE overpasses

Probability of 40 kt Intensity Change	ATL	EPA	NWP + NIO	SH
frac275+SHIPS	18, 100, 100, 100, 100	23, 100, 100, 100, 100	-	-
frac250+SHIPS	18, 100, 100, 100, 100	17, 100, 100, 100, 100	-	-
frac225+SHIPS	11, 100, 100, 100, 100	25, 100, 100, 100, 100	-	-
fracBright+SHIPS	25, 100, 100, 100, 100	42, 100, 100, 100, 100	-	-
fracDark+SHIPS	26, 100, 100, 100, 100	28, 100, 100, 100, 100	-	-
ring_TD80+SHIPS	15, 25, 100, 100, 100	13, 50, 100, 100, 100	-	-
ring_TD90+SHIPS	18, 25, 100, 100, 100	15, 100, 100, 100, 100	-	-
ring_TD100+SHIPS	18, 33, 100, 100, 100	17, 100, 100, 100, 100	-	-

SSMIS RI Thresholds

RI Thresholds for an intensity change of 25 kt for SSMIS overpasses

Threshold of 25 kt Intensity Change	ATL	EPA	NWP + NIO	SH
frac275	0.76	0.78	0.79	0.86
frac250	0.36	0.41	0.41	0.46
frac225	0.11	0.14	0.13	0.16

fracBright	0.54	0.59	0.60	0.68
fracDark	0.80	0.85	0.87	0.95
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

RI Thresholds for an intensity change of 30 kt for SSMIS overpasses

Threshold of 30 kt Intensity Change	ATL	EPA	NWP + NIO	SH
frac275	0.77	0.81	0.82	0.86
frac250	0.36	0.41	0.43	0.47
frac225	0.11	0.15	0.14	0.16
fracBright	0.54	0.58	0.63	0.68
fracDark	0.81	0.87	0.89	0.95
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

RI Thresholds for an intensity change of 35 kt for SSMIS overpasses

Threshold of 35 kt Intensity Change	ATL	EPA	NWP + NIO	SH
frac275	0.85	0.81	0.85	0.89
frac250	0.43	0.40	0.45	0.48
frac225	0.13	0.14	0.15	0.16
fracBright	0.60	0.54	0.64	0.70
fracDark	0.89	0.86	0.90	0.96

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

RI Thresholds for an intensity change of 40 kt for SSMIS overpasses

Threshold of 40 kt Intensity Change	ATL	EPA	NWP + NIO	SH
frac275	0.86	0.83	0.86	0.88
frac250	0.43	0.43	0.46	0.46
frac225	0.14	0.16	0.15	0.14
fracBright	0.56	0.59	0.65	0.70
fracDark	0.89	0.87	0.91	0.97
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

SSMIS RI Probabilities

RI Probability [%] for an intensity change of 25 kt for SSMIS overpasses

Probability of 25 kt Intensity Change	ATL	EPA	NWP + NIO	SH
frac275	43	42	59	29
frac250	38	42	61	32
frac225	44	44	60	32

fracBright	38	45	53	28
fracDark	45	45	52	32
ring_TD80	34	29	42	28
ring_TD90	36	30	42	28
ring_TD100	36	32	43	28

RI Probability [%], which includes also meeting the thresholds of 5, 10, 15, 20, 25% (each comma delimited number) SHIPS 25-kt RI probability, for an intensity change of 25 kt for SSMIS overpasses

Probability of 25 kt Intensity Change	ATL	EPA	NWP + NIO	SH
frac275+SHIPS	43, 43, 43, 42, 48	41, 39, 40, 40, 30	-	-
frac250+SHIPS	38, 39, 39, 40, 43	42, 40, 42, 42, 31	-	-
frac225+SHIPS	44, 44, 44, 47, 50	45, 43, 45, 45, 36	-	-
fracBright+SHIPS	38, 39, 40, 42, 48	42, 41, 42, 39, 26	-	-
fracDark+SHIPS	45, 45, 47, 45, 50	44, 43, 43, 42, 35	-	-
ring_TD80+SHIPS	36, 36, 37, 38, 42	29, 28, 30, 27, 26	-	-
ring_TD90+SHIPS	37, 37, 38, 39, 46	30, 29, 30, 28, 24	-	-
ring_TD100+SHIPS	37, 37, 38, 39, 47	32, 31, 33, 30, 27	-	-

RI Probability [%] for an intensity change of 30 kt for SSMIS overpasses

Probability of 30 kt Intensity Change	ATL	EPA	NWP + NIO	SH
frac275	34	32	53	24
frac250	30	28	58	24
frac225	36	33	52	26
fracBright	29	31	51	23
fracDark	34	34	47	27

ring_TD80	25	21	35	23
ring_TD90	27	21	35	23
ring_TD100	28	23	36	23

RI Probability [%], which includes also meeting the thresholds of 5, 10, 15, 20, 25% (each comma delimited number) SHIPS 30-kt RI probability, for an intensity change of 30 kt for SSMIS overpasses

Probability of 30 kt Intensity Change	ATL	EPA	NWP + NIO	SH
frac275+SHIPS	33, 32, 43, 60, 100	32, 32, 13, 33, 100	53, 50, 48, 46, 42	-
frac250+SHIPS	30, 30, 41, 67, 100	29, 29, 13, 50, 100	58, 55, 53, 48, 46	-
frac225+SHIPS	34, 34, 47, 75, 100	34, 35, 14, 50, 100	53, 55, 56, 51, 47	-
fracBright+SHIPS	30, 29, 38, 60, 100	31, 31, 17, 29, 100	51, 50, 46, 43, 34	-
fracDark+SHIPS	35, 35, 42, 55, 100	35, 34, 26, 38, 100	47, 47, 43, 40, 39	-
ring_TD80+SHIPS	27, 27, 36, 43, 100	21, 22, 14, 23, 100	35, 35, 33, 32, 27	-
ring_TD90+SHIPS	28, 28, 39, 43, 100	22, 22, 15, 25, 100	36, 35, 33, 31, 27	-
ring_TD100+SHIPS	29, 29, 40, 46, 100	23, 23, 16, 27, 100	36, 36, 34, 31, 27	-

RI Probability [%] for an intensity change of 35 kt for SSMIS overpasses

Probability of 35 kt Intensity Change	ATL	EPA	NWP + NIO	SH
frac275	20	19	49	17
frac250	24	16	49	17
frac225	24	21	46	18
fracBright	26	16	43	15
fracDark	20	21	41	19

ring_TD80	17	13	29	15
ring_TD90	19	14	30	15
ring_TD100	19	15	30	15

RI Probability [%], which includes also meeting the thresholds of 5, 10, 15, 20, 25% (each comma delimited number) SHIPS 35-kt RI probability, for an intensity change of 35 kt for SSMIS overpasses

Probability of 35 kt Intensity Change	ATL	EPA	NWP + NIO	SH
frac275+SHIPS	18, 23, 100, 100, 100	23, 25, 100, 100, 100	-	-
frac250+SHIPS	20, 30, 100, 100, 100	20, 25, 100, 100, 100	-	-
frac225+SHIPS	22, 22, 100, 100, 100	28, 33, 100, 100, 100	-	-
fracBright+SHIPS	23, 22, 100, 100, 100	20, 27, 100, 100, 100	-	-
fracDark+SHIPS	20, 15, 100, 100, 100	24, 33, 100, 100, 100	-	-
ring_TD80+SHIPS	18, 15, 100, 100, 100	15, 20, 100, 100, 100	-	-
ring_TD90+SHIPS	19, 15, 100, 100, 100	16, 21, 100, 100, 100	-	-
ring_TD100+SHIPS	19, 16, 100, 100, 100	17, 22, 100, 100, 100	-	-

RI Probability [%] for an intensity change of 40 kt for SSMIS overpasses

Probability of 40 kt Intensity Change	ATL	EPA	NWP + NIO	SH
frac275	17	18	41	10
frac250	19	16	39	10
frac225	15	19	35	9
fracBright	13	17	33	10
fracDark	15	19	32	13

ring_TD80	11	11	22	10
ring_TD90	12	11	22	10
ring_TD100	12	12	23	10

RI Probability [%], which includes also meeting the thresholds of 5, 10, 15, 20, 25% (each comma delimited number) SHIPS 40-kt RI probability, for an intensity change of 40 kt for SSMIS overpasses

Probability of 40 kt Intensity Change	ATL	EPA	NWP + NIO	SH
frac275+SHIPS	18, 50, 100, 100, 100	23, 100, 100, 100, 100	-	-
frac250+SHIPS	21, 100, 100, 100, 100	25, 100, 100, 100, 100	-	-
frac225+SHIPS	15, 40, 100, 100, 100	32, 100, 100, 100, 100	-	-
fracBright+SHIPS	12, 40, 100, 100, 100	23, 33, 100, 100, 100	-	-
fracDark+SHIPS	18, 25, 100, 100, 100	27, 33, 100, 100, 100	-	-
ring_TD80+SHIPS	12, 29, 100, 100, 100	14, 25, 100, 100, 100	-	-
ring_TD90+SHIPS	14, 29, 100, 100, 100	14, 25, 100, 100, 100	-	-
ring_TD100+SHIPS	14, 29, 100, 100, 100	16, 25, 100, 100, 100	-	-

TMI RI Thresholds

RI Thresholds for an intensity change of 25 kt for TMI overpasses

Threshold of 25 kt Intensity Change	ATL	EPA	NWP + NIO	SH
frac275	0.69	0.64	0.69	0.66
frac250	0.32	0.26	0.32	0.29
frac225	0.10	0.06	0.10	0.09

fracBright	0.58	0.49	0.57	0.61
fracDark	0.74	0.68	0.75	0.79
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

RI Thresholds for an intensity change of 30 kt 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

RI Thresholds for an intensity change of 35 kt for TMI overpasses

Threshold of 35 kt Intensity Change	ATL	EPA	NWP + NIO	SH
frac275	0.73	0.56	0.76	0.75
frac250	0.35	0.23	0.38	0.30
frac225	0.13	0.07	0.11	0.05
fracBright	0.64	0.40	0.70	0.70
fracDark	0.79	0.60	0.88	0.86

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

RI Thresholds for an intensity change of 40 kt for TMI overpasses

Threshold of 40 kt Intensity Change	ATL	EPA	NWP + NIO	SH
frac275	0.74	0.69	0.73	0.72
frac250	0.34	0.31	0.37	0.19
frac225	0.12	0.10	0.12	0.02
fracBright	0.65	0.61	0.68	0.67
fracDark	0.82	0.82	0.85	0.82
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

TMI RI Probabilities

RI Probability [%] for an intensity change of 25 kt for TMI overpasses

Probability of 25 kt Intensity Change	ATL	EPA	NWP + NIO	SH
frac275	35	29	22	14
frac250	32	26	22	15
frac225	27	15	23	11

fracBright	34	25	20	11
fracDark	37	26	18	12
ring_TD80	33	25	18	13
ring_TD90	33	26	19	13
ring_TD100	36	26	21	12

RI Probability [%], which includes also meeting the thresholds of 5, 10, 15, 20, 25% (each comma delimited number) SHIPS 25-kt RI probability, for an intensity change of 25 kt for TMI overpasses

Probability of 25 kt Intensity Change	ATL	EPA	NWP + NIO	SH
frac275+SHIPS	36, 37, 37, 35, 32	13, 13, 14, 25, 50	-	-
frac250+SHIPS	32, 32, 33, 32, 33	17, 17, 17, 25, 33	-	-
frac225+SHIPS	28, 28, 29, 35, 33	10, 10, 11, 17, 20	-	-
fracBright+SHIPS	34, 35, 35, 36, 29	11, 11, 11, 17, 33	-	-
fracDark+SHIPS	37, 38, 38, 39, 33	10, 10, 11, 17, 25	-	-
ring_TD80+SHIPS	33, 34, 34, 34, 32	9, 9, 10, 14, 25	-	-
ring_TD90+SHIPS	33, 33, 33, 33, 30	10, 10, 10, 14, 54	-	-
ring_TD100+SHIPS	35, 35, 35, 33, 30	17, 17, 17, 25, 50	-	-

RI Probability [%] for an intensity change of 30 kt for TMI overpasses

Probability of 30 kt Intensity Change	ATL	EPA	NWP + NIO	SH
frac275	34	17	14	14
frac250	32	15	16	13
frac225	25	17	18	8
fracBright	32	16	13	10
fracDark	31	17	16	10

ring_TD80	31	16	14	10
ring_TD90	30	15	15	11
ring_TD100	33	17	17	9

RI Probability [%], which includes also meeting the thresholds of 5, 10, 15, 20, 25% (each comma delimited number) SHIPS 30-kt RI probability, for an intensity change of 30 kt for TMI overpasses

Probability of 30 kt Intensity Change	ATL	EPA	NWP + NIO	SH
frac275+SHIPS	35, 35, 31, 43, 100	13, 14, 50, 100, 100	19, 17, 18, 17, 12	-
frac250+SHIPS	32, 30, 42, 75, 100	14, 14, 33, 100, 100	20, 20, 21, 19, 13	-
frac225+SHIPS	26, 24, 36, 40, 100	13, 14, 25, 50, 100	20, 16, 17, 20, 17	-
fracBright+SHIPS	30, 32, 33, 43, 100	11, 11, 33, 100, 100	17, 19, 17, 15, 11	-
fracDark+SHIPS	30, 32, 38, 43, 100	10, 11, 25, 100, 100	16, 18, 17, 16, 11	-
ring_TD80+SHIPS	30, 31, 39, 43, 100	9, 10, 25, 100, 100	14, 15, 14, 13, 10	-
ring_TD90+SHIPS	29, 31, 38, 43, 100	10, 10, 25, 100, 100	15, 16, 15, 13, 10	-
ring_TD100+SHIPS	31, 32, 36, 43, 100	17, 17, 50, 100, 100	16, 17, 16, 15, 10	-

RI Probability [%] for an intensity change of 35 kt for TMI overpasses

Probability of 35 kt Intensity Change	ATL	EPA	NWP + NIO	SH
frac275	20	7	6	5
frac250	23	8	10	3
frac225	18	13	9	2
fracBright	20	7	8	4
fracDark	23	7	9	4

ring_TD80	18	9	10	3
ring_TD90	18	7	10	3
ring_TD100	19	9	12	2

RI Probability [%], which includes also meeting the thresholds of 5, 10, 15, 20, 25% (each comma delimited number) SHIPS 35-kt RI probability, for an intensity change of 35 kt for TMI overpasses

Probability of 35 kt Intensity Change	ATL	EPA	NWP + NIO	SH
frac275+SHIPS	15, 40, 100, 100, 100	13, 100, 100, 100, 100	-	-
frac250+SHIPS	13, 67, 100, 100, 100	13, 100, 100, 100, 100	-	-
frac225+SHIPS	11, 100, 100, 100, 100	13, 33, 100, 100, 100	-	-
fracBright+SHIPS	20, 50, 100, 100, 100	11, 100, 100, 100, 100	-	-
fracDark+SHIPS	25, 57, 100, 100, 100	11, 100, 100, 100, 100	-	-
ring_TD80+SHIPS	19, 67, 100, 100, 100	11, 100, 100, 100, 100	-	-
ring_TD90+SHIPS	18, 63, 100, 100, 100	11, 100, 100, 100, 100	-	-
ring_TD100+SHIPS	18, 57, 100, 100, 100	20, 100, 100, 100, 100	-	-

RI Probability [%] for an intensity change of 40 kt for TMI overpasses

Probability of 40 kt Intensity Change	ATL	EPA	NWP + NIO	SH
frac275	16	6	6	2
frac250	14	7	7	1
frac225	15	8	8	1
fracBright	17	8	5	1
fracDark	20	9	6	1

ring_TD80	14	6	6	1
ring_TD90	16	7	7	1
ring_TD100	16	9	7	1

RI Probability [%], which includes also meeting the thresholds of 5, 10, 15, 20, 25% (each comma delimited number) SHIPS 40-kt RI probability, for an intensity change of 40 kt for TMI overpasses

Probability of 40 kt Intensity Change	ATL	EPA	NWP + NIO	SH
frac275+SHIPS	20, 100, 100, 100, 100	50, 100, 100, 100, 100	-	-
frac250+SHIPS	15, 100, 100, 100, 100	33, 100, 100, 100, 100	-	-
frac225+SHIPS	18, 100, 100, 100, 100	50, 100, 100, 100, 100	-	-
fracBright+SHIPS	27, 100, 100, 100, 100	50, 100, 100, 100, 100	-	-
fracDark+SHIPS	33, 100, 100, 100, 100	100, 100, 100, 100, 100	-	-
ring_TD80+SHIPS	21, 100, 100, 100, 100	17, 100, 100, 100, 100	-	-
ring_TD90+SHIPS	23, 100, 100, 100, 100	17, 100, 100, 100, 100	-	-
ring_TD100+SHIPS	23, 100, 100, 100, 100	33, 100, 100, 100, 100	-	-