Improvement to the Satellite-based 37 GHz Ring Rapid Intensification Index – A Year-2 Update

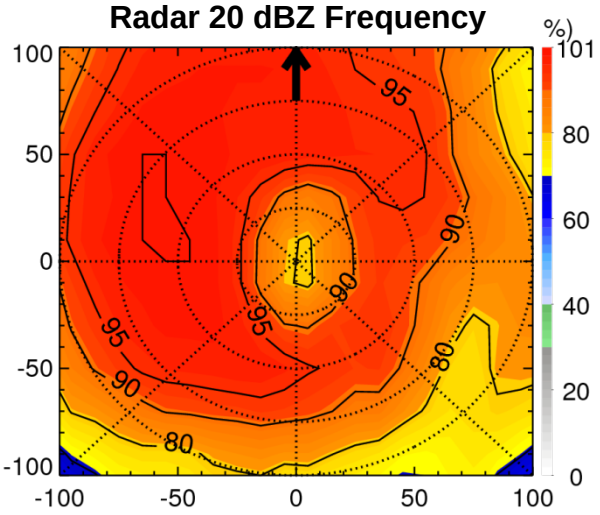
PI: Haiyan Jiang
Graduate Students: Yongxian Pei, Margaret Kieper, Cheng Tao, and Joseph Zagrodnik

Florida International University

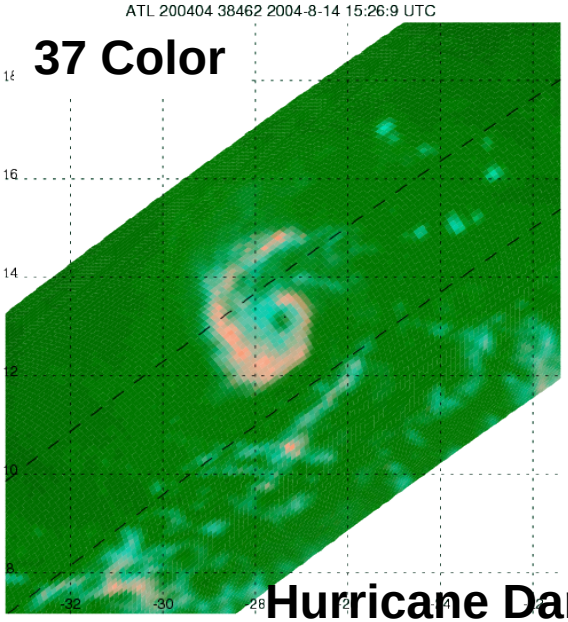
Acknowledgements:
1) NHC Points of Contact: ***Chris Landsea, John Cangialosi, and Stacy Stewart***
2) This NOAA Joint Hurricane Testbed project was funded by the US Weather Research Program in NOAA/OAR's Office of Weather and Air Quality.

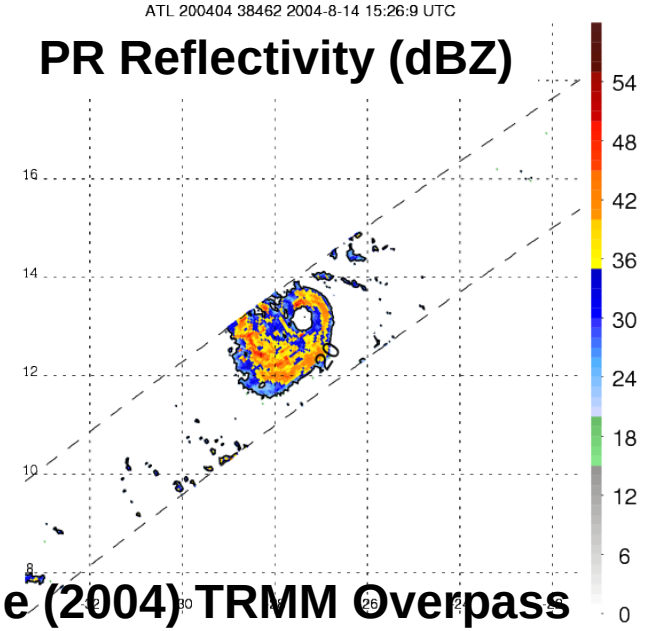
The 37 GHz Cyan+Pink Ring

- ***Kieper and Jiang (2012, GRL):*** **the 37 GHz ring is a good predictor of rapid intensification (RI) when the environment is favorable.**
  - **The ring must be solid cyan+pink & at least 90% closed**
  - **About 82% of RI cases had a 37 GHz ring appeared before or at the beginning of the 24-h RI period (>=30 kt/24 h, *Kaplan and DeMaria, 2013*)**
- **What's in the ring?**
  - **It's *precipitative, mainly shallow & moderate convection with 20 dBZ echo height <10 km (Tao and Jiang 2015, JCLI, under review)***
  - **If there is a simultaneous overpass by radar, the 37 GHz ring also shows as a 20-dBZ ring.**



Composite of Many PR Passes Associated with RI and Having a 37 GHz Ring

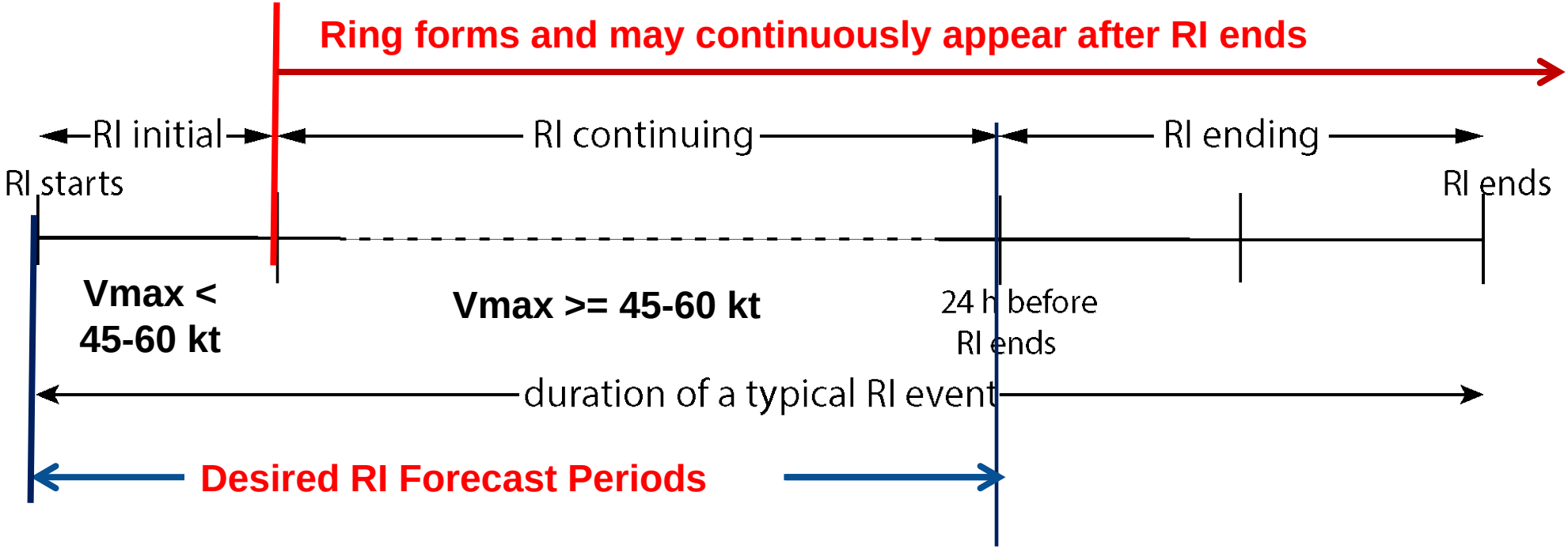




Hurricane Danielle (2004) TRMM Overpass

37 GHz Ring Formation and RI Events

- **General RI definition:** 24 hour Intensity Increase >= 30 kt **(Kaplan and DeMaria 2003).** This only defines the intensification rate, not the duration, although forecasters usually consider each 24-h period.
- **The concept of RI event:** A RI event can continue for 48-60 hours and contain multiple, continuous, and overlapping 24-h periods in which the intensity increased in each period by 30 kt or more **(Kieper and Jiang 2012).**
- RI could start as early as Vmax=25-30kt, while the 37 GHz ring usually forms when Vmax>=45-60kt.
- A typical RI event includes **the onset of RI (Vmax < 45-60 kt), in the middle of RI (Vmax >= 45-60 kt), and the ending period of RI (< 24 h before RI ends)**.
- The ring RI index is usually unable to forecast the onset of RI, and would make false alarms during RI ending period if no other criteria were used. **But it can catch the highest intensity increase!**

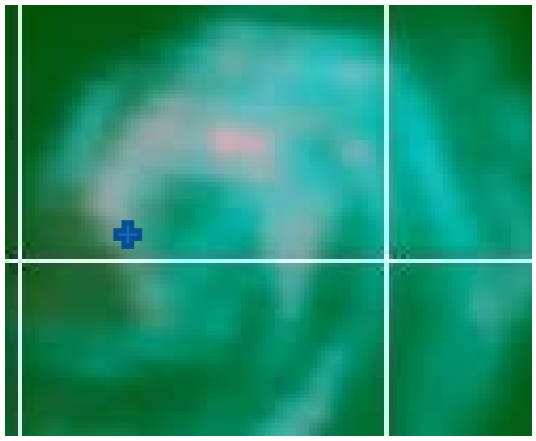


The 37 GHz Ring RI Index

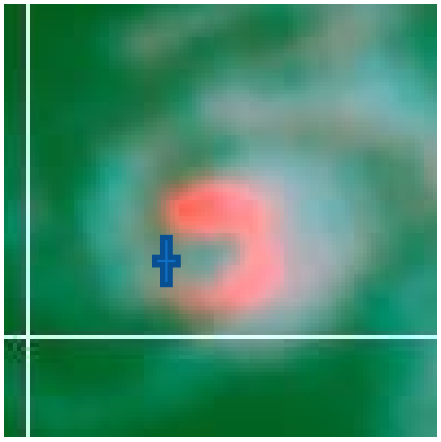
- ***Kieper and Jiang (2012, GRL)*** proposed a subjective method, which uses the precipitative ring pattern showing in NRL 37 GHz color product (***Lee et al. 2002***) of satellite microwave imagery ***on top of the SHIPS RI index (RII)*** to forecast RI.

- Based on the subjective method, an objective 37 GHz ring RI index was developed and tested during the PI's FY-11 funding period (2012-2013 hurricane seasons).
- During the FY-11 period, we found that the **center-fixing problem** was a main factor for poor ring detections of Atlantic storms.
- **Solution: to adapt the CIMSS ARCHER center-fixing** (***Wimmers and Velden 2010***, FY13 JHT funded)

2012 Season Storm Center Fixing Problem



Chris: WindSat 06/20 10:03UTC (26 h before RI ends)



Michael: TMI 09/05 15:00UTC (27 h before RI ends)

Major Updates in 2014 (FY-13 Yr-1)

Environment & Persistence Criteria Updates:

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

Software/Algorithm Updates:

- Add real-time ARCHER center as input for ring detection
- Add 85 GHz RI predictors and run in a parallel mode
- Change the output from satellite overpass centered to 6 hourly synoptic time centered *as requested by NHC*
- Add AMSR-2 & GMI real-time data

The real-time test output during 2014 Hurricane Season was messy because of so many changes were made throughout the season (many satellite overpasses were missed).

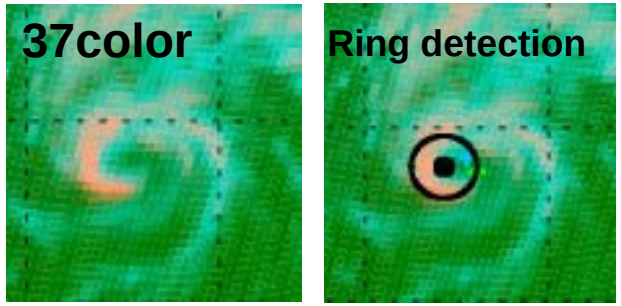
An algorithm re-run was made right after the season using the operational A-deck, SHIPS RII, and most recent version of the real-time ARCHER output to resemble the real-time conditions.

The evaluations to be presented next are based on the re-run results.

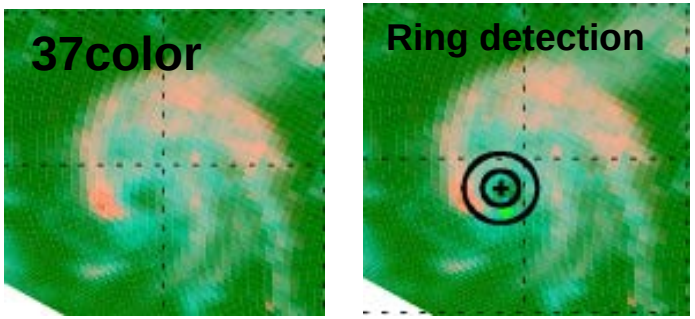
Atlantic Basin 2014 RI Events and Forecasts

#	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)	Ring (event based)	SHIPS 30-kt RII
1	AL03 Bertha	0803 12Z (40)	0804 12Z (70)	1	0	N/A	N/A	0
2	AL06 Edouard	0914 06Z (60)	0915 06Z (90)	1	1	1	Yes	0
3	AL07 Fay	1010 12Z (30)	1011 12Z (60)	1	0	N/A	N/A	N/A
4	AL08 Gonzalo	1012 18Z (35)	1015 00Z (110)	6	2	1	Yes	2

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.



Edouard: AMSR2
09/14 05:05 UTC (at 55kt)



Gonzalo: TMI 10/13
17:05 UTC (at 50 kt)

Gonzalo: SSMIS 10/14
00:15 UTC (at 60 kt, *Land*)

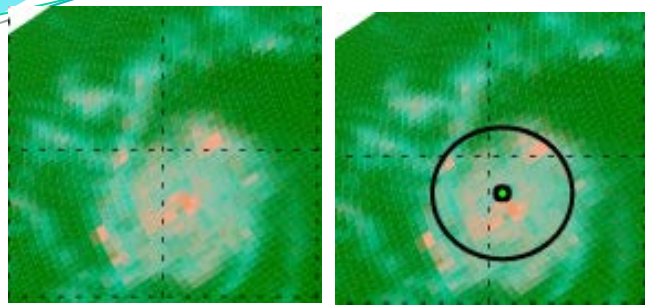
- **Two qualified RI events** were all correctly forecasted by the 37 GHz Ring RII (event-based), no misses. **One out of 3 qualified RI cases** was missed.

East Pacific Basin 2014 RI Events and Forecasts

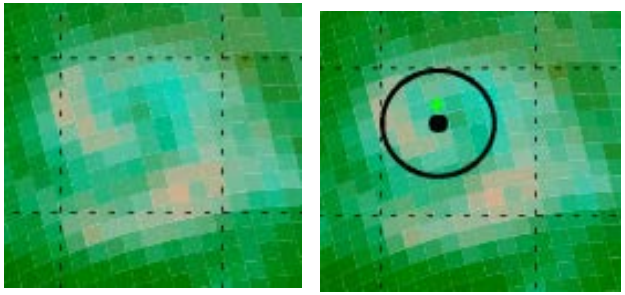
#	storm	RI starts (best track Vmax in kt)	RI ends (best track Vmax in kt)	# of 24-h periods (cases)	# of periods met 5 criteria	Ring (case-based)	Ring (event based)	SHIPS 30-kt RII
1	EP01 Amanda	0523 06Z (25)	0526 00Z (125)	8	4	3	Yes	7
2	EP03 Cristina	0610 18Z (45)	0612 18Z (125)	5	4	4	Yes	3
3	EP07 Geneviene	0805 12Z (30)	0807 00Z (100)	3	0	N/A	N/A	2
4	EP08 Hernan	0726 12Z (30)	0727 18Z (65)	2	0	N/A	N/A	1
5	EP09 Iselle (1)	0731 12Z (25)	0801 12Z (55)	1	0	N/A	N/A	N/A
6	EP09 Iselle (2)	0802 00Z (65)	0803 00Z (95)	1	0	N/A	N/A	0
7	EP13 Marie	0822 00Z (30)	0825 00Z (130)	9	5	4	Yes	6
8	EP15 Odile	0913 00Z (55)	0914 18Z (110)	4	2	2	Yes	3
9	EP19 Simon	1003 12Z (45)	1005 06Z (100)	4	1	1	Yes	1
10	EP21 Vance	1101 12Z (40)	1103 06Z (90)	4	1	1	Yes	2
	Total			41	17	15		25

- **Six qualified RI events** were all correctly forecasted by the 37 GHz Ring RII (event-based), no misses. Two out of **17 qualified RI cases** was missed.

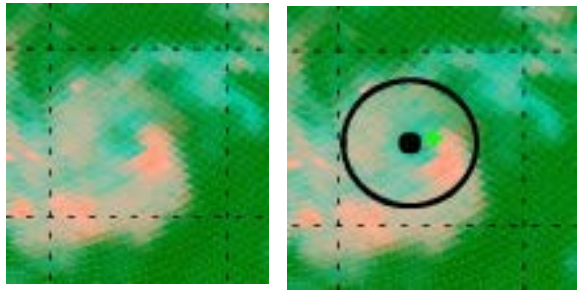
The First 37 GHz Rings for East Pacific 2014 RI Events



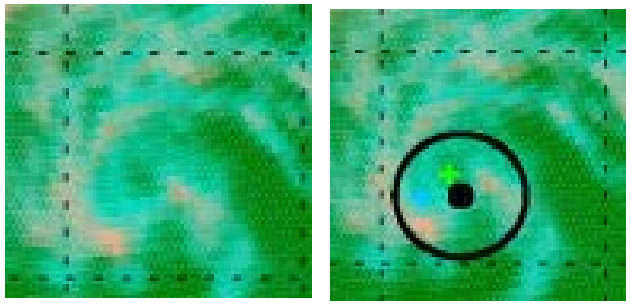
EP01 Amanda: TMI
05/24 11:59UTC (50 kt)



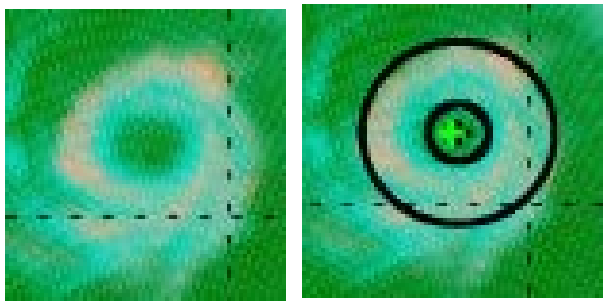
EP03 Cristina: SSMIS
06/10 21:38UTC (45 kt)



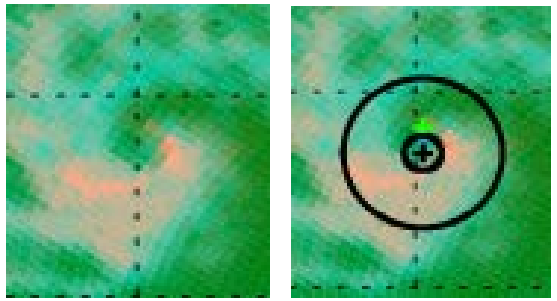
EP07 Genevieve: TMI
08/05 12:48UTC (30 kt)



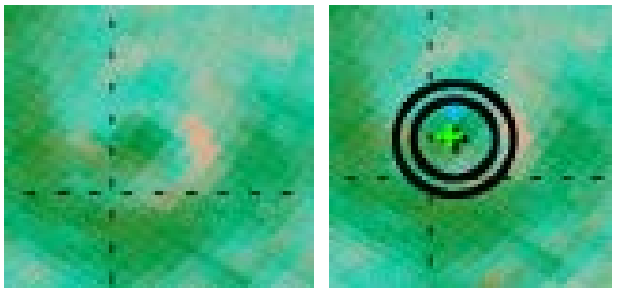
EP08 Hernan: GMI
07/26 16:33UTC (30 kt)



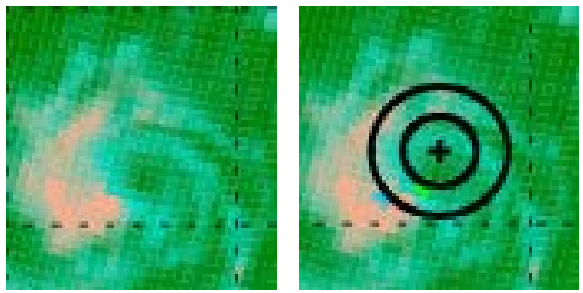
EP09 Iselle (2): AMSR2
08/01 22:11UTC (55 kt)



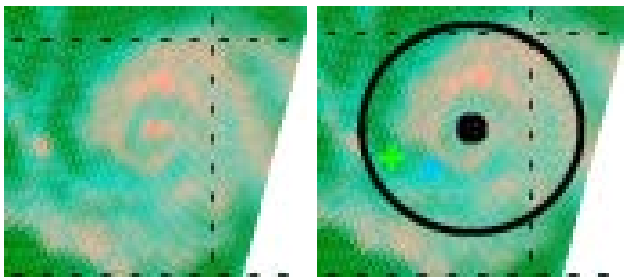
EP13 Marie: TMI
08/22 23:25UTC (50 kt)



EP15 Odile: TMI
09/13 12:12UTC (60 kt)



EP19 Simon: AMSR2
10/03 08:55UTC (45 kt)



EP21 Vance: AMSR2
11/02 09:08UTC (45 kt)

The 85 GHz RI Index

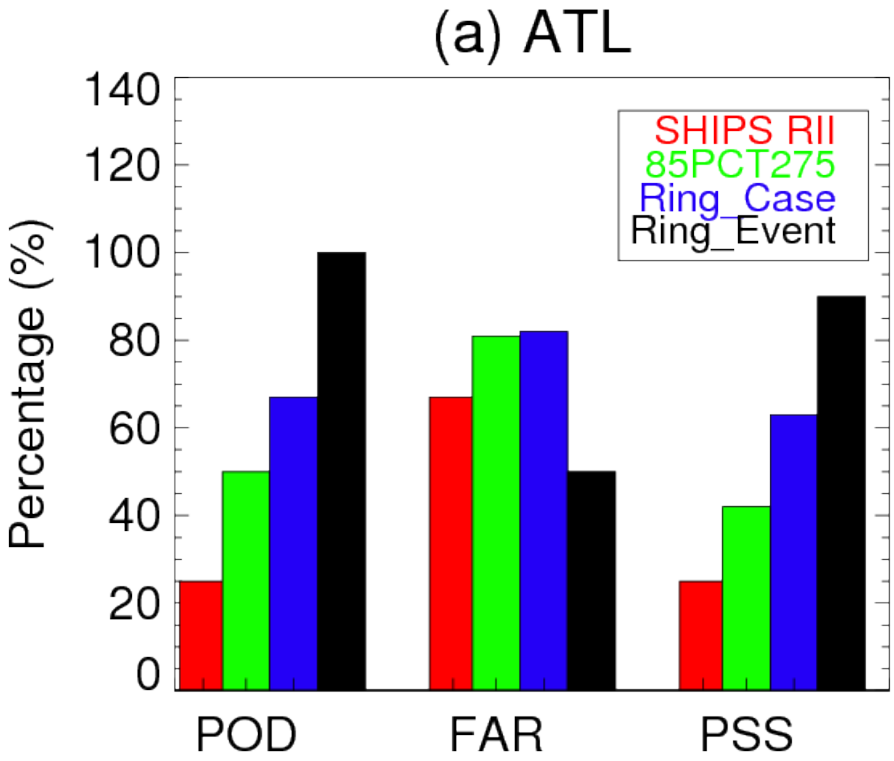
Criteria used to forecast 30-kt RI:

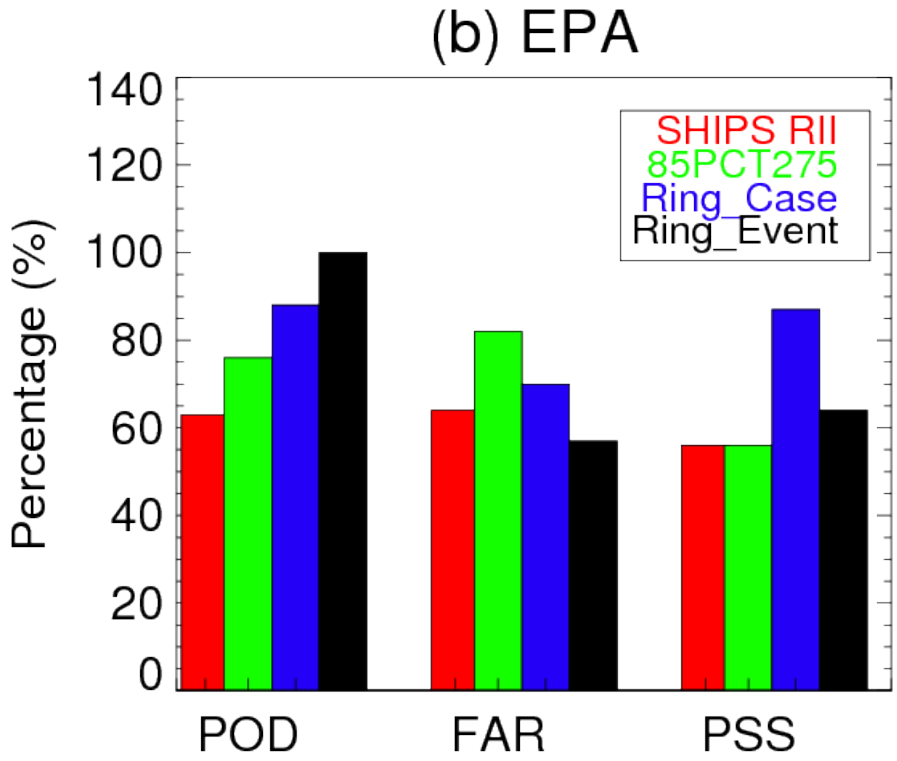
1. Current SHIPS probability for 25 kt RI >= 10% (AL), 20% (EP)
2. The areal fraction of 85 GHz Polarization Corrected Brightness Temperature (PCT) <275 K within 100 km radius >= a threshold (69%).

85 GHz RII (2014)	ATL	EPA
# of qualified RI Periods (cases)	8	34
# of correct RI forecasts	4	26
Probability of detection (POD)	50%	76%

POD, FAR, and PSS of SHIPS, 85GHz, and Ring RII

POD = Probability of Detection ; FAR=False Alarm Ratio
PSS= Peirce Skill Score (100% is perfect skill, 0 is random, negative is for forecasts worse than random, ***Kaplan et al. 2010***)





- POD: Ring_event > Ring_case > 85 GHz > SHIPS RII for both basins
- FAR: Ring_event is the best, followed by SHIPS RII
- PSS: Ring_event > Ring_case > 85 GHz > SHIPS RII for AL,
  Ring_case>Ring_event > 85GHz = SHIPS RII for EP

Summary of 2014 Real-time Tests

- The TC center fixing problem found in previous seasons is solved by the ARCHER real-time product **(A Big Applause for CIMSS ARCHER team)!**
- The 37 GHz ring RII usually can't capture the early onset (Vmax <=45kt) of a RI event. After removing those unqualified RI periods, the ring event-based forecasts during 2014 obtained a 100% POD in both AL & EP basins.
- The statistical evaluation results show that both the event-based and 6-hourly case-based ring RII can improve the SHIPS RII by increasing POD & skill core.
- The 85 GHz predictors are promising too, but need more testing to convert to probability-based forecasts.

Working Plans for 2015 Season

- **More testing and refinement:** is needed to change the yes & no type of forecast to a probability-based RI Index. Both 37 & 85 GHz properties will be used & two more 37 GHz predictors will be added(not shown here, but in our FY-15 proposal).
- **Re-structure the software code:**
  - Originally the software runs in time order as each satellite overpass file coming in. However, now there are 6 microwave sensors (SSM/I, SSMIS, WindSat, TMI, GMI, AMSR2) available, and it's necessary to run each sensor separately to avoid data missing.
- **Better cooperate with the ARCHER team**
  - Need to know the approximate running time of ARCHER so that our algorithm can wait for the proper time period before running.
  - This problem will be automatically solved if ARCHER becomes operational at NHC (like SHIPS).
- **If funded by JHT FY-15, we plan to transfer the ring RII to JTWC forecast basins (NWP, NIO, SIO, & SPA)**

Thanks for your attention!

Related Publications

- Tao, C., and H. Jiang, 2015: Distributions of shallow to very deep convection in rapidly intensifying tropical cyclones. *J. Climate*, in second review after first major revision.
- 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.