FLORIDA INTERNATIONAL UNIVERSITY

Improvement to the Satellite-based 37 GHz Ring Rapid Intensification Index

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Outline

- **Project overview: a continuous JHT project-- 37 GHz Ring RI Index**

- **Real-time testing results during 2013 hurricane season**

- **Plans for the coming 2014 season**

Project Overview: Motivation

- SHIPS Rapid Intensification (RI) index (Kaplan and DeMaria 2003) is an operationally used RI index which uses the environmental parameters to predict the probability of RI.

- Although the probability of detection (POD) is as high as 15-59% when using the SHIPS RI to forecast Atlantic storms, the false alarm ratio (FAR) is also as high as 71-85% (Kaplan et al. 2010).

- Favorable environmental conditions are necessary for RI, but not all favorable environmental conditions will lead to RI. To reduce the high FAR of SHIPS RI index, it's necessary to look at storm internal (precipitation and convective) parameters.

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** to forecast RI.

- Using all microwave sensors for Atlantic storms during 2003-2007, the method produced a POD of 75% with a low FAR of only 9%.

- 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).
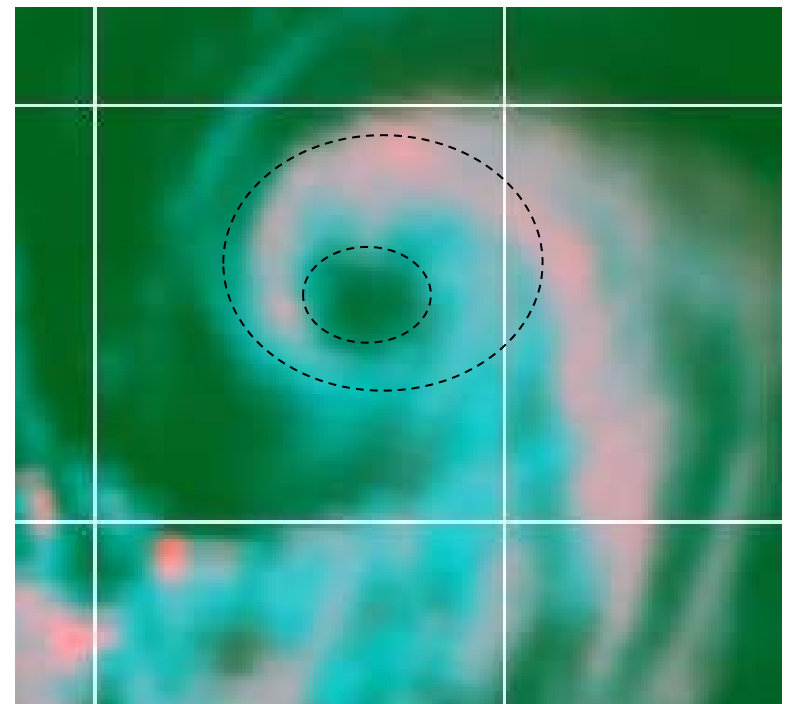
NRL 37 GHz Color Product for Hurricane Ivan (2004), WindSat overpass at 09/04/2004 2043Z. 55 kt intensity increasing during the next 24 hours.

Forecast method

The Objective 37 GHz Ring RI Index

- A ring pattern is detected by the automatic 37 GHz ring pattern identification algorithm.

- Initial TC intensity is between ~45 - 100 kt.

- The core of the TC is currently over water and is anticipated to remain over water for 24 hours.

- The past 6 h intensity change >=0 (not in weakening stage).

The Combined Ring+SHIPS RI Index

- Satisfy the Ring index definition
- The SHIPS RI probability >= 10%

Real Time Tests During 2013 Hurricane Season:

All real-time forecasts were posted on http://tcpf.fiu.edu/JHT/Txt/.
An email was sent to NHC when a positive RI forecast was made.

Atlantic Basin 2013 RI Events and Forecasts

- Each RI event is defined as the whole RI period which usually includes several 24-h overlapping RI periods with each of them having 24-h intensity increase >= 25 kts. Note that more than one RI events for each storm is possible.

- Inactive season: no RI case with 24-h intensity increase >= 30 kts

Storm ID/Name	RI start time & Vmax	RI end time & Vmax	Ring (Objective Method)	SHIPS 25 kt RI Prob.
AL09/ Humberto	09/10 18:00 55 kt	09/12 00:00 80 kt	Yes (SSMIS 09/10 19:19UTC)	26%
AL10/ Ingrid	09/14 00:00 50 kt	09/15 00:00 75 kt	Yes (SSMIS 09/14 01:45UTC)	41%

Humberto

Ingrid
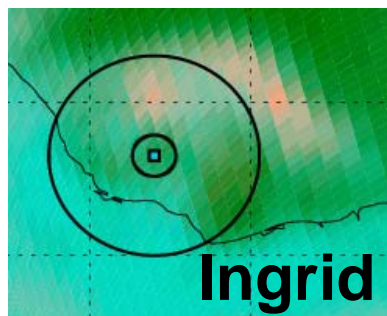
- **Two RI events were all correctly forecasted, no miss: POD= 100%!**

East Pacific Basin 2013 RI Events

| Storm ID/Name	RI start time & Vmax	RI end time & Vmax	RI period	Max. Intensity Change per 24 hr
EP05/ Erick	07/05 06:00 40 kt	07/06 06:00 65 kt	24 h	25 kt
EP07/Gil	07/31 00:00 40 kt	08/01 06:00 70 kt	30 h	30 kt
EP08/Henriette	08/05 06:00 45 kt	08/06 18:00 80 kt	36 h	25 kt
EP11/Kiko	08/31 00:00 30 kt	09/01 12:00 65 kt	36 h	30 kt
EP13/ Manuel	09/18 00:00 30 kt	09/19 06:00 65 kt	30 h	55 kt
EP17/Raymond (1)	10/20 00:00 30 kt	10/22 00:00 105 kt	48 h	60 kt
EP17/Raymond (2)	10/27 00:00 55 kt	10/28 06:00 90 kt	30 h	35 kt

- **Total 7 RI Events based on best track data, but 3 of them started as early as 30 kt.**
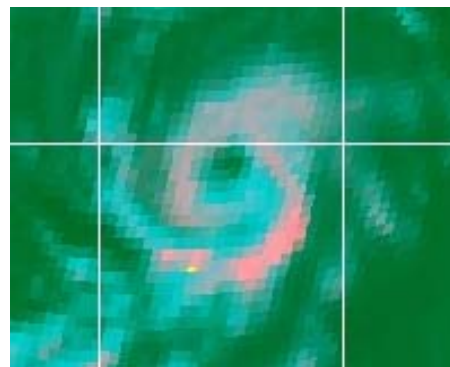
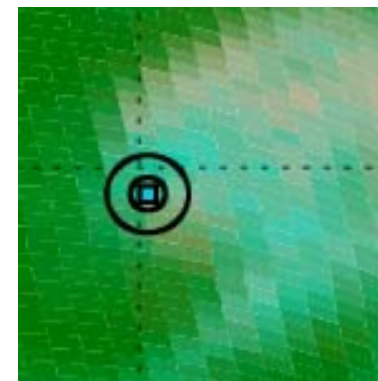# 37 GHz Rings for East Pacific 2013 RI Events
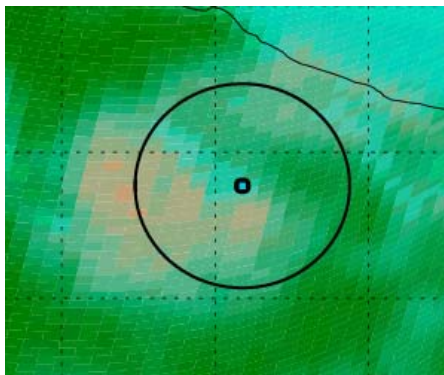
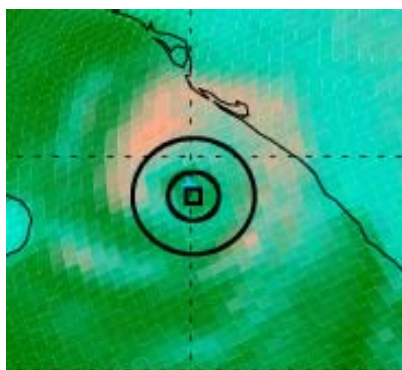**Erick:** SSMIS 07/05 12:25UTC (18 h before RI ends)
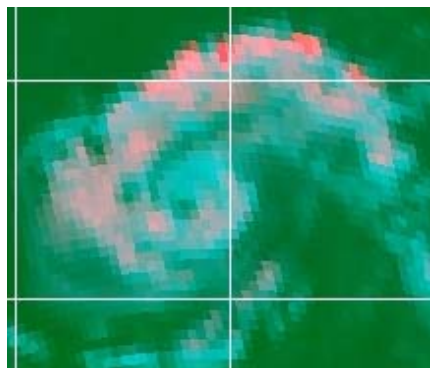
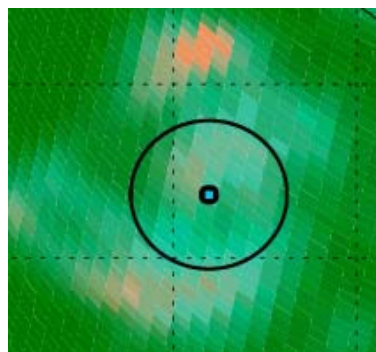**Gil:** AMSR2 07/30 20:45 UTC (33 h before RI ends)

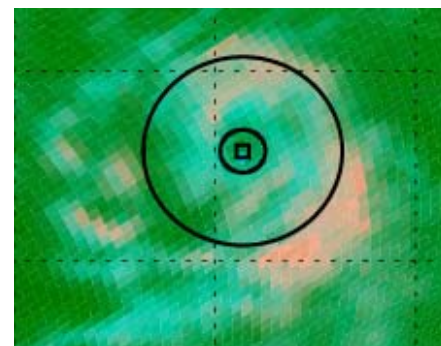**Henriette:** AMSR2 08/06 10:08 UTC (only 8 h before RI ends)

Kiko: SSMIS 09/01 00:54UTC (only 12 h before RI ends)

Manuel: TMI 09/18 18:44UTC (12 h before RI ends)

Raymond: SSMIS 10/20 12:30UTC (29 h before RI ends)

Raymond: TMI 10/26 22:49UTC (31 h before RI ends)

Performance for East Pacific 2013 Season

Storm ID/Name	Ring (Objective method)	SHIPS 25 kt RI Prob.	RI forecasted (emailed to NHC)?
EP05/ Erick	yes	46%	Yes
EP07/Gil	No (no AMSR2 data)	37%	No
EP08/Henriette	No (no AMSR2 data)	29%	No
EP11/Kiko	Yes	31%	Yes
EP13/ Manuel	Yes	40%	Yes
EP17/Raymond (1)	Yes	missing	No
EP17/Raymond (2)	Yes	28%	yes

- Hit 4 out 7! POD=57%

False Alarms for Atlantic & East Pacific

	ATL	EPA
# of qualified forecasting periods	9	14
# of RI events	2	7
# of correct RI forecasts	2	4
Probability of detection (POD)	100%	57%
# of false alarms	1	3
False Alarm Ratio (FAR)	11%	21%

- A qualified forecasting period is defined as a non-weakening period with storm initial intensity between 45-100 kt and current and future 24-h storm center over water.
- A total of about 250 microwave overpasses (including TMI, SSMIS, SSM/I, WindSat) were processed in real-time during 2013 season.
- There are some false alarm cases due to bad TC center fixing.

Summary of Yr-1 Real-time Tests

➢ Although high PODs and low FARs are achieved in both Atlantic and East Pacific basins, our algorithm usually can't capture the early onset of RI. The alert time ranges between 8-31 hours before RI ends(the preferred alert time is 24-h before RI ends).

➢ Bad TC center fixing is still a problem to be fixed, as found in 2012 season.

➢ The method works better than last year (2012). Possible reasons:

 ➢ 2013 is a very inactive season, especially in the Atlantic.
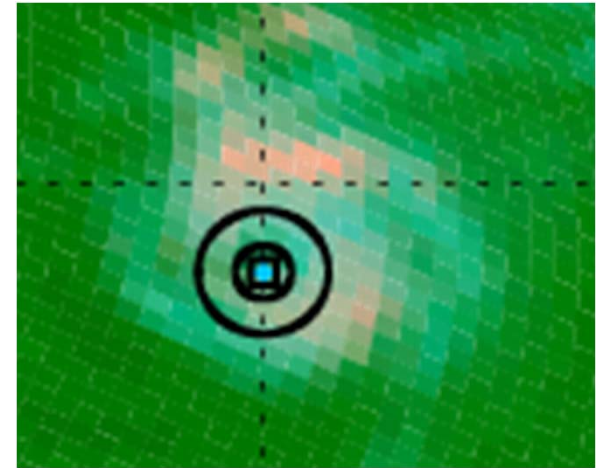
 ➢ SHIPS works better in 2013 for both basins.

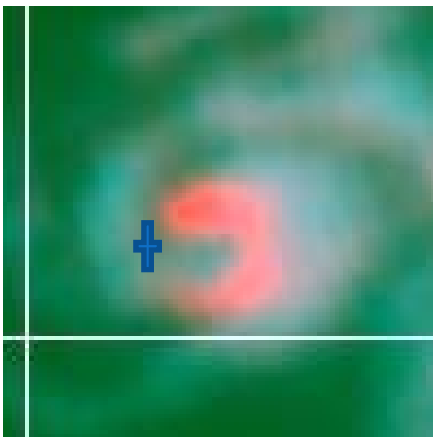# TC Center Fixing Problem for Atlantic 2012 Season
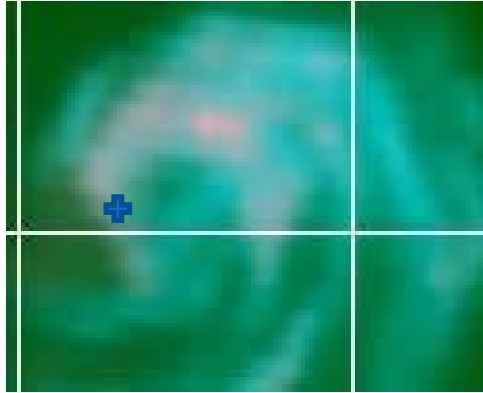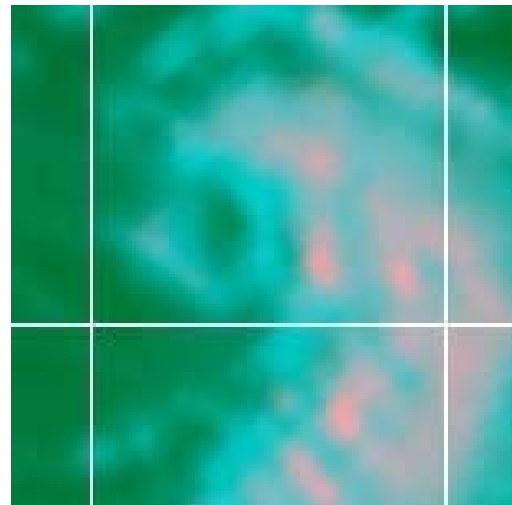

Chris: WindSat 06/20 10:03UTC (26 h before RI ends)
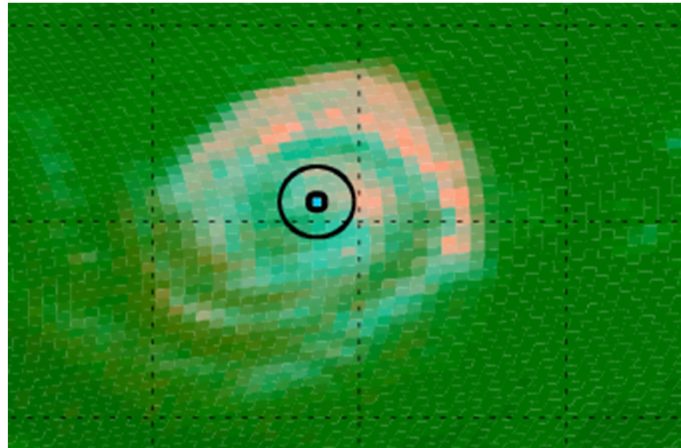
Gordon: TMI 08/18 02:04 UTC (28 h before RI ends)

Kirk: TMI 08/30 00:41 UTC (35 h before RI ends)

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

**Sandy**: WindSat 10/23 22:43UTC (37 h before RI ends)

Working Plans for 2014 Season

- **Obtaining real-time AMSR2 data:**
  - Request has been filed to NOAA NESDIS. Data should be accessible when the season starts.
- **Adpating ARCHER product for better TC center fixing**
  - The center-fixing problem was a main factor for poor ring detections during 2012 season, mainly for Atlantic storms.
  - The problem wasn't as bad as in 2012, probably because the 2013 season was inactive.
  - So for future more active seasons, we still need to adapt the CIMSS ARCHER algorithm (Wimmers and Velden 2010, FY13 JHT funded). Will collaborate with CIMSS PIs and implement it for the 2014 season.

Working Plans for 2014 Season (Cont.)

➢ **Implementing the probability-based 37 GHz Ring index by adding 85-89 GHz predictors:**

   ➢ The current 37 GHz ring RI index is a "yes" and "no" type of forecast. A probability-based forecast is preferable to NHC.

   ➢ Using a 11-yr TRMM database, we have identified three additional RI predictors: the area of 85 GHz PCT < 275 K, 250 K, and 225K within the inner core. A combination of 37 GHz ring, SHIPS, and 85 GHz PCT predictors will be used to generate a probability-based RI forecast.

   ➢ During 2014 season, we plan to test both the current "yes" and "no" forecast and probability-based forecast in a parallel mode.
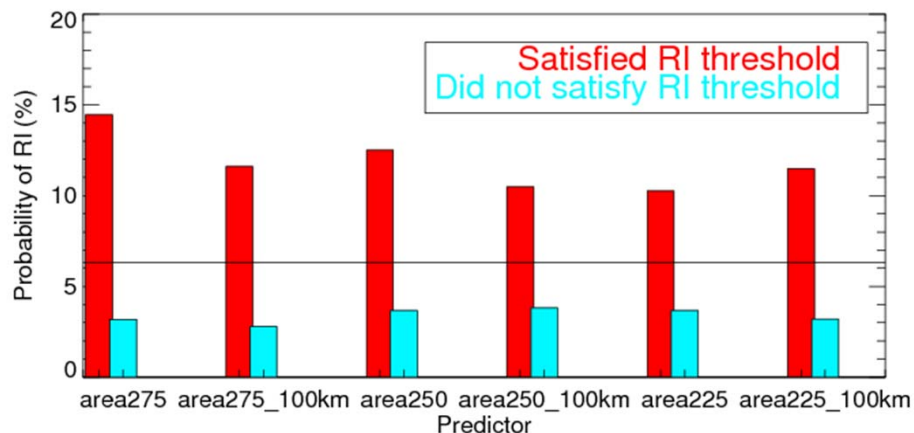
Figure on the left: Probability of RI for predictors satisfying and not satisfying RI thresholds. The climatology mean RI probability is 6.67% (solid horizontal line).

Thanks for your attention!

Related Publications

➢Zagrodnik, J., and H. Jiang, 2014: Rainfall, Convection, and Latent Heating Distributions in Rapidly Intensifying Tropical Cyclones. *J. Atmos. Sci.,* first revision submitted.

➢ 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.

Back-up Slides

The 37 GHz Ring RI Index

- The NRL 37 GHz color product: 1) combines 37 GHz Polarization Corrected brightness Temperature (PCT), 37 GHz vertically and horizontally polarized TB's; 2) no quantitative information; 3) pink→ cloud & precipitation with ice, cyan→low level clouds/shallow or light rain, green→ sea surface (Lee et al. 2002).

- To automate Kieper's subjective method into an objective method, we have determined quantitative values of the 37 GHz TB's in different color regions using the TRMM Tropical Cyclone Precipitation Feature (TCPF) database (http://tcpf.fiu.edu; Jiang et al. 2011, JAMC).
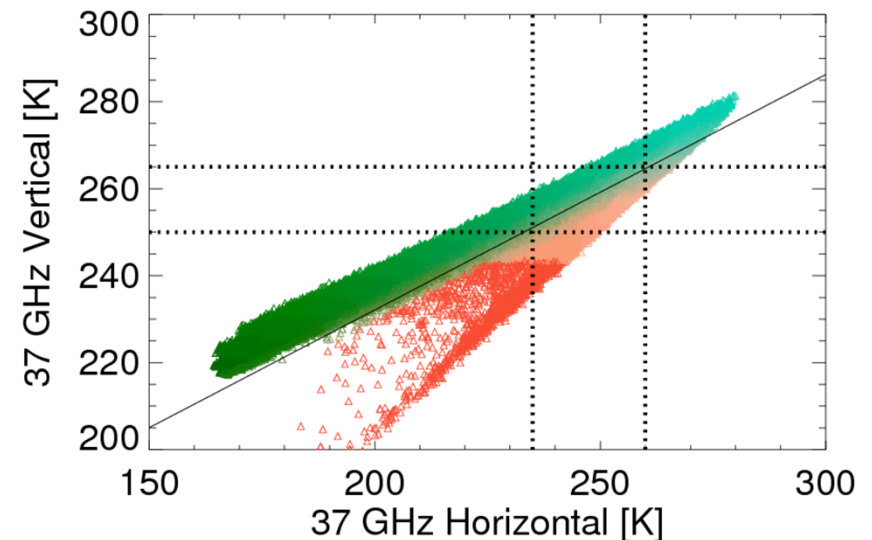
The scatter plot of all the TRMM TMI 37 GHz pixels within 200 km radius of the storm center for all the TCs that were well observed by TMI during 1998-2011. The thin tilted line is the PCT37=270 K line. Those dotted lines indicate V37=250 and 265 K, and H37 = 235 and 260 K.

FY 11 Yr-1 Evaluation

- Evaluation of the subjective method using all microwave sensors for Atlantic storms during 2003-2007 (Kieper and Jiang 2012, GRL)

  - RI event based verification results:

| # of total RI events	28
# of total forecasts	23
# of correct forecasts	21
# of false alarms	2
Probability of detection (POD)	75%
False Alarm Ratio (FAR)	9%
Probability of RI	91%

➢ *The method may miss the first 6-12 h of the onset of RI, but for most cases, the 37 GHz ring is associated with the highest intensity increase.*

The Atlantic Basin 2012 RI events

- Each RI event is defined as the whole RI period which usually includes several 24-h overlapping RI periods with each of them having 24-h intensity increase >=30kts. Note that more than one RI events for each storm is possible.

| Storm ID/Name	RI start time & Vmax	RI end time & Vmax	RI period	Max Intensity Change
AL03/Chris	06/20 06:00 40 kt	06/21 12:00 75 kt	30 h	35 kt
AL08/Gordon	08/17 18:00 55 kt	08/19 06:00 90 kt	36 h	35 kt
AL11/Kirk	08/29 18:00 45 kt	08/31 12:00 90 kt	42 h	45 kt
AL13/Michael	09/05 00:00 45 kt	09/06 18:00 95 kt	42 h	50 kt
AL18/Sandy	10/23 18:00 45 kt	10/25 12:00 95 kt (landfall)	42 h	55 kt

Performance for Atlantic Basin 2012 Season
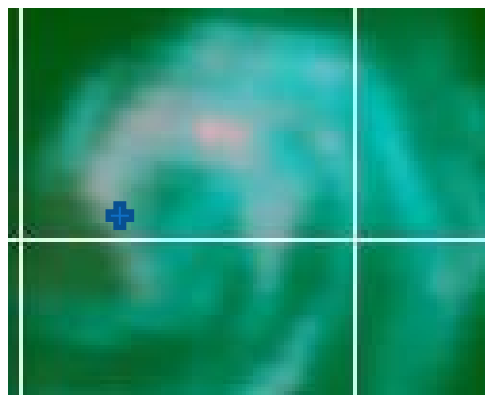
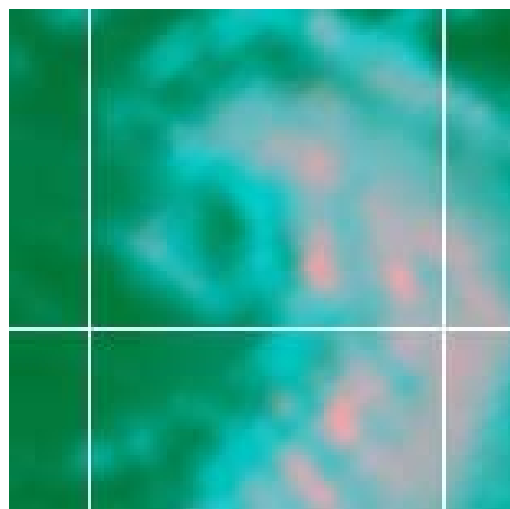**Chris**: WindSat
06/20 10:03UTC
(26 h before RI ends)
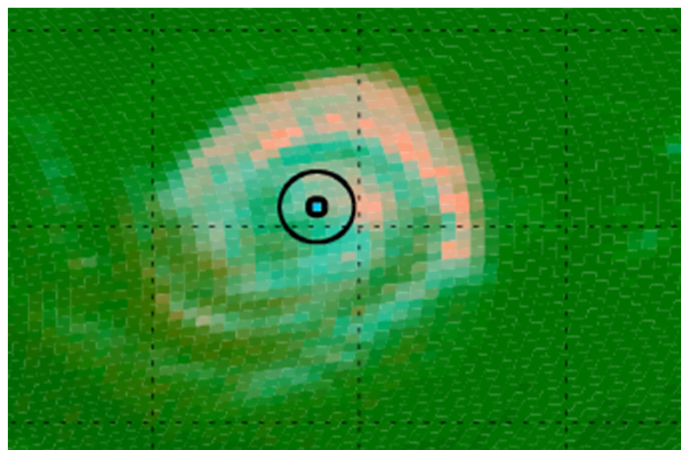
Gordon: TMI 08/18
02:04 UTC (28 h before
RI ends)
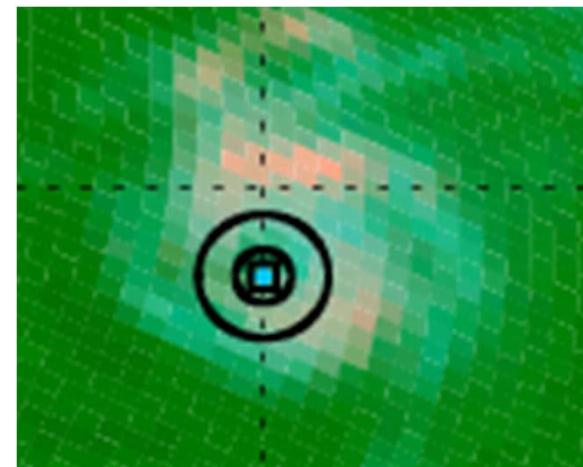
Kirk: TMI 08/30
00:41 UTC (35 h before
RI ends)
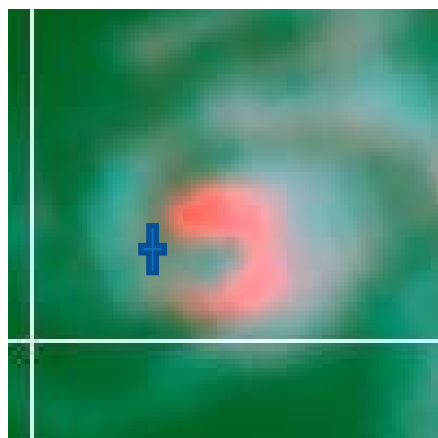
Michael: TMI 09/05 15:00UTC
(27 h before RI ends)

Sandy: WindSat
10/23 22:43UTC
(37 h before RI ends)

Performance for Atlantic Basin 2012 Season

Storm ID/Name	Ring (subjective)	Ring (Objective)	SHIPS 25 kt RI Prob.	New SHIPS RII
AL03/Chris	Yes	No (center fix problem)	12%	11%
AL08/Gordon	Yes	Yes	15%	17%
AL11/Kirk	Yes	Yes	4%	16%
AL13/Michael	Yes	No (center fix problem)	12%	12%
AL18/Sandy	Yes	Server Down (will improve reliability next season)	??	63%

- Subjective method: Miss: 4 out of 5!
- Objective methos: Miss: 5 out 5%

- SHIPS RII values were <20% for these 4 misses.

The East Pacific Basin 2012 RI events

| Storm ID/Name	RI start time & Vmax	RI end time & Vmax	RI period	Max Intensity Change
EP02/Bud	05/23 06:00 50 kt	05/25 00:00 100 kt	42 h	50 kt
EP03/Carlotta	06/14 18:00 45 kt	06/16 00:00 90 kt (landfall)	36 h	45 kt
EP04/Daniel	07/07 06:00 70 kt	07/08 06:00 100 kt	24 h	30 kt
EP05/Emilia	07/08 12:00 45 kt	07/10 12:00 115 kt	48 h	75 kt
EP13/Miriam	09/23 06:00 45 kt	09/25 00:00 100 kt	42 h	55 kt
EP16/Paul	10/14 12:00 50 kt	10/16 06:00 100 kt	42 h	50 kt

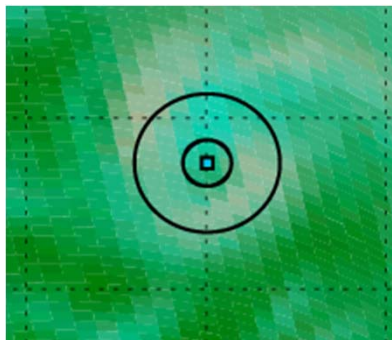# Performance for East Pacific 2012 Season
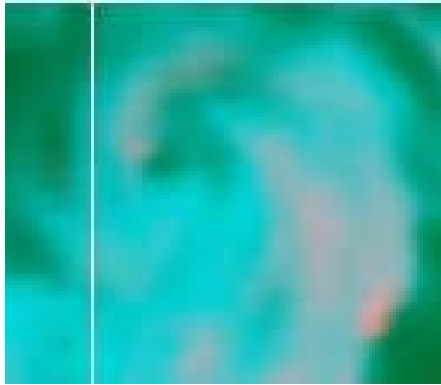
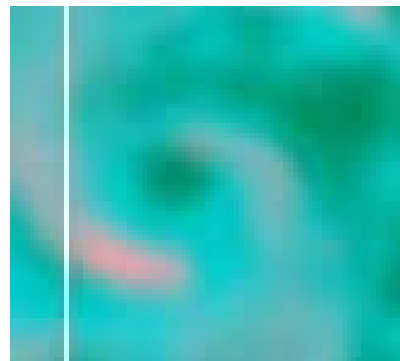**Bud**: WindSat 05/23 13:29UTC (34 h before RI ends)
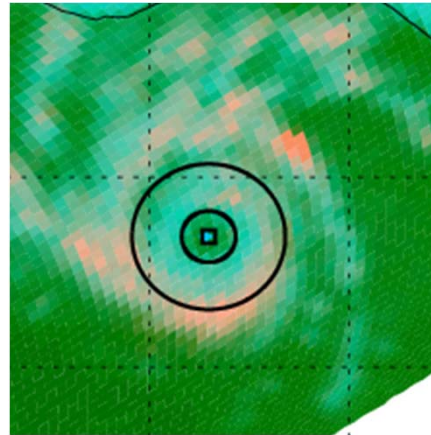
Carlotta: TMI 06/15 10:08 UTC (14 h before RI ends/landfall)
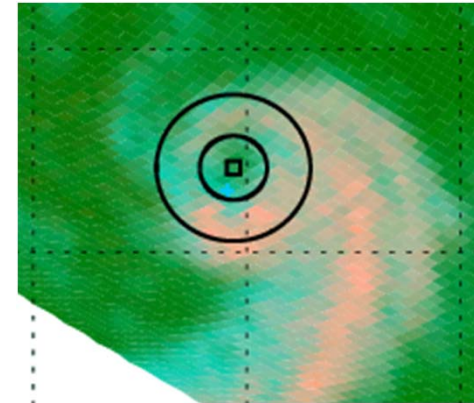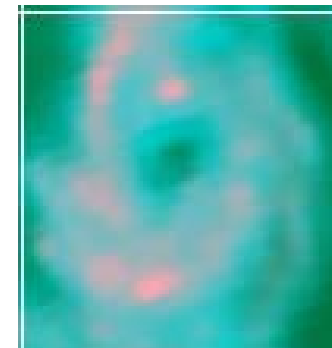

Daniel: TMI 07/07 09:27 UTC (21 h before RI ends)

Emilia: SSMIS 07/09 01:07UTC (34 h before RI ends)

Miriam: WindSat 09/23 13:48UTC (34 h before RI ends)

Paul: WindSat 10/15 01:25UTC (29 h before RI ends)

Performance for East Pacific 2012 Season

Storm ID/Name	Ring (subjective)	Ring (Objective)	SHIPS 25 kt RI Prob.	New SHIPS RII
EP02/Bud	Yes	No (early season, coding error)	29%	67%
EP03/Carlotta	Yes	Yes	33%	59%
EP04/Daniel	Yes	Yes	24%	25%
EP05/Emilia	Yes	Yes	59%	74%
EP13/Miriam	Yes	No (didn't receive WindSat data)	>20%	No data
EP16/Paul	Yes	Server Down	??	51%

- Subjective method: Hit: 6 out of 6!
- Objective method: Hit: 3 out 6!

- SHIPS RII was correct.

Summary of 2012 Real-time Tests

- **Atlantic RI events are harder to predict:**

  - **Hard to get environmental conditions correct; low SHIPS RII values**

  - **TC center fix problem: a linear interpolation was used to determine TC center between NHC track points**

- **East Pacific RI events seem easier to predict:**

  - **Correct SHIPS RII**

  - **The storm track is more linear so that a linear interpolation between track points works OK**

  - **EPAC TCs seem intensify more quickly once ring feature is seen (need one more season to verify)**

Works in Progress (early 2013)

- **For Atlantic storms:**

  - Recalibrate SHIPS RII threshold to increase hits and minimize false alarms

  - **For Atlantic & East Pacific storms:**

  - Using additional methods to determine an accurate center fix

    - We are adapting CIMSS ARCHER algorithm (Wimmers and Velden 2010) to determine TC center using 37 GHz data

    - We are also testing a pattern recognition algorithm

- **Working on West Pacific basin storms:**

  - Margie has been working with JTWC actively. Tie Yuan has developed an algorithm for WPAC.