NOAA AWARD NUMBER: NA13OAR4590191 (**FY 13 Joint Hurricane Testbed**)
Florida International University Project Number: 800002654

Mid-year Progress Report for Year-2 (Sep. 1, 2014 – Feb. 28, 2015)
& Work Plan for the rest of Year-2 (Mar. 1, 2015 –Aug. 31, 2016)

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

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1. Accomplishments during Year-1

Accomplishments during year-1 were summarized in our year-1 annual progress report in detail. Below is a simplified summary:

1) Real-time testing during 2013 hurricane season and evaluations of 2013 real-time testing results;
2) Real-time testing during 2014 hurricane season;
3) Changing the primary forecast frequency to 6-hourly (at each synoptic time);
4) Adapting the CIMSS ARCHER product for better TC center fixing;
5) Adding real-time AMSR2 data as an input
6) Implement and test the probability-based 37-GHz+85 GHz RI index

2. Accomplishments during the first half year of Year-2

2.1. Tasks finished during the real-time testing of the rest of 2014 hurricane season

During the first 1.5 months of year-2, we continued to work on the real-time testing till the end of the 2014 hurricane season. Two planned tasks have been finished during this period:

Task 1: Modify the code to read the new format of the CIMSS ARCHER product

Recently, the CIMSS ARCHER product has updated its output format. We have modified our code to read the new ARCHER output in order to continue to use the newest version of ARCHER product.

Task 2: Adding real-time GMI data as an input

The Global Precipitation Mission (GPM) satellite Microwave Imager (GMI) data has been available to us since July 2014. We have added this sensor into our algorithm.

2.2. Post-season evaluation

Due to so many tasks have been done during the 2014 hurricane season, our real-time testing output was kind of messy. For example, during the most part of the season, we were reading the old ARCHER output, which only had the 85 GHz center fixes, not the 37 GHz ones. A substantial difference exists between 85 GHz and 37 GHz center, which severely affects our ring detection algorithm. Another problem was that many microwave overpasses were missed during the software update after finishing each task. Therefore, after the 2014 season, an algorithm re-run was made right using the operational

A-deck, SHIPS RII, and most recent version of the real-time ARCHER output to resemble the real-time conditions. Below is the evaluation based on the re-run results.

The 37 Ghz Ring RI index:

The evaluation is done based on RI events and RI cases. Here 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 >=30 kts. Each RI case is a 24-h RI period starting at a synoptic time (00Z, 06Z, 12 Z or 18Z).

Each 6-hourly case has to meet the following Environment & Persistence Criteria in order to be forecast as a RI case:

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

During the 2014 season, there were 4 RI events and 9 RI casesin the Atlantic (AL) basin (table 1) and 10 RI events and 41 RI cases in the East Pacific (EP) basin (table 2). In the AL basin, only 3 (2) out of the 9 (4) RI cases (events) met the environment and persistence criteria above, while in the EP basin, there are 17 (6) out of 41 (10) RI cases (events) met the environment and persistence criteria. We call these as qualified RI cases or events. In the AL, 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. In the EP, 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.

Table 1: List of storm ID, name, RI start time and max. wind speed (Vmax) at RI start time, RI end time and Vmax at RI end time, # of 24-h RI cases, # of RI cases met environment and persistence criteria, Ring case based RI forecasts, Ring event-based RI forecasts, and the SHIPS RII in the Atlantic 2014 hurricane season. Qualified RI events are in red color. Note: 1) N/A means either no data or no cases met criteria; 2) SHIPS RII 30-kt >= 20% (AL) is used as threshold to forecast RI (*Kaplan et al. 2010*) .

#	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

Table 2: List of storm ID, name, RI start time and max. wind speed (Vmax) at RI start time, RI end time and Vmax at RI end time, # of 24-h RI cases, # of RI cases met environment and persistence criteria, Ring case based RI forecasts, Ring event-based RI forecasts, and the SHIPS RII in the East Pacific 2014 hurricane season. Qualified RI events are in red color. Note: 1) N/A means either no data or no cases met criteria; 2) SHIPS RII 30-kt >= 30% (EP) is used as threshold to forecast RI (*Kaplan et al. 2010*) .

#	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

Figs. 1-2 show the 37 GHz color image and the ring detected by our automatic ring detection algorithm for the AL & EP 2014 RI events. All the rings are correctly detected by the automatic algorithm for these RI events, with great assistance from the accurate ARCHER 37 GHz center fixes.

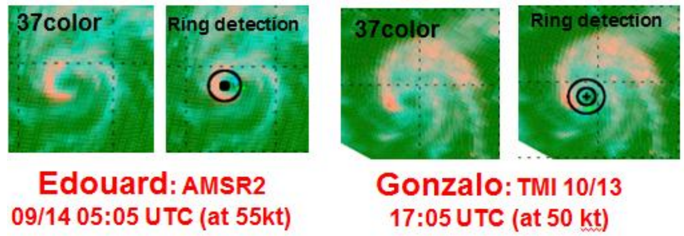

Fig. 1: The 37 GHz color image and objective ring detection for the two AL 2014 RI events correctly forecast by the 37 GHz ring RI index. The A-deck interpolated storm center is shown as a green cross, while the ARCHER center as a black cross.

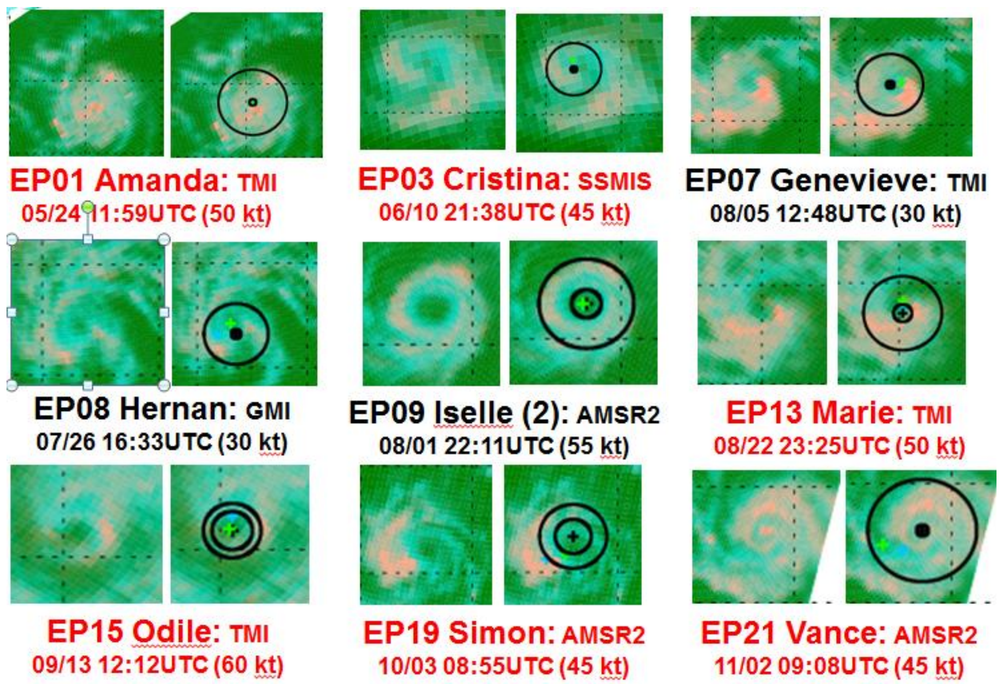

Fig. 2: The 37 GHz color image and objective ring detection for 9 EP 2014 RI events. Qualified RI events are labeled with red text, while unqualified RI events are labeled with black text. The A-deck interpolated storm center is shown as a green cross, while the ARCHER center as a black cross.

<u>The 85 GHz RI Index</u>

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%).

Fig. 3 shows Probability of Detection (POD), False Alarm Ratio (FAR), and Peirce Skill Score (PSS) for the SHIPS, 85 GHz and 37 GHz Ring RI indices for the 2014 hurricane season in AL & EP basins. PSS equal to 100% means perfect skill, 0 means random, and negative means for forecasts worse than random (Kaplan et al. 2010). From Fig. 3, we can see that for POD, Ring_event >

Ring_case > 85 GHz > SHIPS RII for both basins. For FAR, Ring_event is the best, followed by SHIPS RII. As for PSS, Ring_event > Ring_case > 85 GHz > SHIPS RII for AL, Ring_case>Ring_event > 85GHz = SHIPS RII for EP.

In summary, the TC center fixing problem found in previous seasons is solved by the ARCHER real-time product. 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.

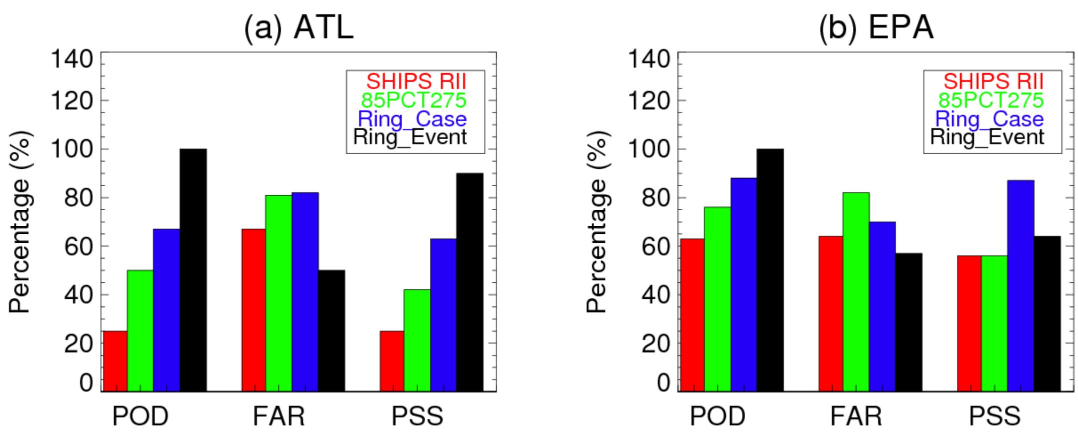

Figure 3. POD, FAR, and PSS of SHIPS, 85GHz, and Ring (case-based & event-based) RI Indices in the (a) AL and (b) EP 2014 hurricane season.

3. Work plan for the rest of year 1 and year-2

There are four tasks to be completed for this project:

Task 1: 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).

Task 2: 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.

Task 3: 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.Note that this problem will be automatically solved if ARCHER becomes operational at NHC (like SHIPS).

Task 4: Modify the existing IDL code to make it compatible with NHC environment.

4. Journal Papers (wholly or partially supported by this grant)

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 C. Tao, 2014: Contribution of tropical cyclones to global very deep convection. *J. Climate*, **27**, 4313-4336.

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.

Tao, C., and H. Jiang, 2012: Global distribution of hot towers in tropical cyclones based on 11-year TRMM data. *J. Climate*, **26**, 1371–1386.

Jiang, H., E. M. Ramirez, and D. J. Cecil, 2012: Convective and rainfall properties of tropical cyclone inner cores and rainbands from 11 years of TRMM data. *Mon. Wea. Rew.*, **141**, 431-450.

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.

4. Conference Presentations (wholly or partially supported by this grant)

Jiang, H., Y. Pei, C. Tao, M. Kieper, and, J. Zagrodnik 2015: Improvement to the Satellite-based 37 GHz Ring Rapid Intensification Index—A Year-2 Update. 69th *Interdepartmental Hurricane Conference/Tropical Cyclone Research Forum*, Mar 2-5, 2015.

Jiang, H., M. Kieper, and Y. Pei, 2014: Improvement to the Satellite-based 37 GHz Ring Rapid Intensification Index. 68th *Interdepartmental Hurricane Conference/Tropical Cyclone Research Forum*, Mar 4-7, 2014.

Jiang, H., Y. Pei and J. Zagrodnik, 2014: Rainfall and Convection Asymmetries of Tropical Cyclones from TRMM Precipitation Radar Observations. *AMS 31st Conference on Hurricanes and Tropical Meteorology*, San Diego, California, March 30- April 4, 2014.

Jiang, H., M. Kieper, and Y. Pei, 2014: Improvement to the Satellite-based 37 GHz Ring Rapid Intensification Index. 67th *Interdepartmental Hurricane Conference/Tropical Cyclone Research Forum*, Mar 4-7, 2014.

Kieper, M., C. Landsea, and H. Jiang, 2014: The Internal Structure of 1969 Hurricane Camille for the Atlantic Hurricane Database Reanalysis Project. *AMS 31st Conference on Hurricanes and Tropical Meteorology Session 5C.7*, San Diego, California, March 30- April 4, 2014.

Tao, C. and H. Jiang, 2014: Distributions of convection in rapidly intensifying tropical cyclones. *AMS 31st Conference on Hurricanes and Tropical Meteorology Session 6D.1*, San Diego, California, March 30- April 4, 2014.

Pei, Y. and H. Jiang, 2014: Asymmetries of Tropical Cyclone Convection in Different Intensity Change Stages as Derived from Satellite 85 and 37 GHz observations. *AMS 31st Conference on Hurricanes and Tropical Meteorology Session 9C.6*, San Diego, California, March 30- April 4, 2014.

Fischer, M., J. Zagrodnik, H. Jiang, and M. E. Kieper, 2014: An Analysis of Rapidly Intensifying Tropical Cyclones Derived from 13 Years of TRMM Data. *AMS 31st Conference on Hurricanes and Tropical Meteorology*, San Diego, California, March 30- April 4, 2014.

Jiang, H., M. Kieper, and Y. Pei, 2014: Improvement to the Satellite-based 37 GHz Ring Rapid Intensification Index. 67th *Interdepartmental Hurricane Conference/Tropical Cyclone Research Forum*, Mar 4-7, 2014.

Jiang, H., M. Kieper, T. Yuan, E. Zipser, and J. Kaplan, 2013: Enhancement of SHIPS RI Index Using Satellite 37 GHz Microwave Ring Pattern: A Year-2 Update. 67th *Interdepartmental Hurricane Conference/Tropical Cyclone Research Forum*, Mar 5-7, 2013.

Jiang, H. and E. M. Ramirez 2012, Necessary Conditions for Tropical Cyclone Rapid Intensification as

Derived from 11 Years of TRMM Data. *AGU Fall Meeting Session A23K (oral),* San Francisco, CA, December 3-7.

Kieper, M. and H. Jiang, 2012: Quantifying Intensity Forecasts for Rapid Intensification of Tropical Cyclones. *AGU Fall Meeting Session A13L (poster),* San Francisco, CA, December 3-7, 2012.

Tao, C. and H. Jiang, 2012: Contribution of tropical cyclones to global deep convection with overshooting tops. *AGU Fall Meeting Session A13L (poster),* San Francisco, CA, December 3-7, 2012.

Zagrodnik, J. P., and H Jiang, 2012: Comparison of TRMM PR and TMI Version 6 and Version 7 rainfall algorithms in Tropical Cyclones relative to the NEXRAD Stage-IV Multi-sensor Precipitation Estimate dataset. *AGU Fall Meeting Session H33C (poster),* San Francisco, CA, December 3-7, 2012.

Jiang, H., M. Kieper, and E. Zipser, 2012: The "Warm Rain" Ring Pattern and Tropical Cyclone Rapid Intensification. *NASA GRIP Science Team Meeting*, Wallops Flight Facility, VA, May 9-10, 2012, 2012.

Jiang, H., and E. M. Ramirez, 2012: Necessary Conditions for Rapid Intensification as Derived from 11 Years of TRMM Tropical Cyclone Precipitation Feature Database (TCPF). *NASA GRIP Science Team Meeting*, Wallops Flight Facility, VA, May 9-10, 2012.

Jiang, H., E. M. Ramirez, and D. J. Cecil, 2012: Convective and Rainfall Properties in the Inner Core and Tropical Cyclone Intensity Change Using 11-yr TRMM Data. AMS 30th *Conference on Hurricane and Tropical Meteorology*, Ponte Vedra Beach, FL, April 15-20, 2012.

Kieper, M., and H. Jiang, 2012: The 37 GHz Cyan Ring and Tropical Cyclone Rapid Intensification: What Does the Cyan Color Truly Represent? AMS 30th *Conference on Hurricane and Tropical Meteorology*, Ponte Vedra Beach, FL, April 15-20, 2012.

Tao, C., and H. Jiang, 2012: Climatology of Hot Towers in Tropical Cyclones Based on 12-year TRMM Data. AMS 30th *Conference on Hurricane and Tropical Meteorology*, Ponte Vedra Beach, FL, April 15-20, 2012.

Yuan, T., and H. Jiang, 2012: Evaluation of 37 GHz Microwave Ring Pattern for Forecasting Rapid Intensification of Tropical Cyclones from SSM/I, SSMI/S and AMSR-E data. AMS 30th *Conference on Hurricane and Tropical Meteorology*, Ponte Vedra Beach, FL, April 15-20, 2012.

Zagrodnik, J. P., and H. Jiang, 2012: Quantitative Comparison of TRMM Precipitation Algorithms in Tropical Cyclones. AMS 30th *Conference on Hurricane and Tropical Meteorology*, Ponte Vedra Beach, FL, April 15-20, 2012.

Jiang, H., M. Kieper, T. Yuan, E. Zipser, and J. Kaplan, 2012: Enhancement of SHIPS Rapid Intensification Index Using The 37-GHz Ring Pattern. 66th *Interdepartmental Hurricane Conference*, Charleston, SC, Mar 5-8, 2012.

Jiang, H., M. Kieper, T. Yuan, E. Zipser, and J. Kaplan, 2011: The 37-GHz Ring Pattern as An Early Indicator of Tropical Cyclone Rapid Intensification. *NASA GRIP Science Team Meeting,* Los Angeles, CA, Jun 6-9.

Jiang, H., C. Liu, and E. J. Zipser, 2011: The 13-yr TRMM-based Tropical Cyclone Cloud and Precipitation Feature (TCPF) Database. *NASA GRIP Science Team Meeting,* Los Angeles, CA, Jun 6-9.

Jiang, H., M. Kieper, T. Yuan, E. Zipser, and J. Kaplan, 2011: Improving SHIPS rapid intensification (RI) index using 37 GHz microwave ring pattern around the center of tropical cyclones. 65th *Interdepartmental Hurricane Conference*, Miami, FL, Feb. 28-Mar. 3.

Yuan, T., Jiang, H., and M. Kieper, 2011: Forecasting rapid intensification of tropical cylones in the Western North Pacific using TRMM/TMI 37 GHz microwave signal. 65th *Interdepartmental Hurricane Conference*, Miami, FL, Feb. 28-Mar. 3.