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Midyear Progress Report for Year-2 (September 1, 2012 – February 28, 2012)

Project Title: Enhancement of SHIPS Rapid Intensification (RI) Index Using Satellite 37 GHz Microwave Ring Pattern

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1. Accomplishments during Year-1

Accomplishments during year-1 were summarized in our year-1 progress report in detail. Below is a simplified summary: *1) Real-time testing of the 37 GHz Ring RI Index at NHC:* After several months of preparation, the real-time testing of the automatic 37 GHz ring pattern tropical cyclone (TC) rapid intensification (RI) index started to run on May 15, 2012 and the real-time forecasts started to be sent to the National Hurricane Center (NHC) during the 2012 Atlantic and East Pacific Hurricane season. The testing started on May 15, 2012 and will continue throughout the season. Prior to the start of the hurricane season, we made contact with various NOAA and NASA agencies about requesting an active account for real-time microwave data access. We have successfully obtained the access for the real-time Tropical Rainfall Measuring Mission (TRMM) Microwave Imager (TMI) data from NASA Goddard, and real-time Special Sensor Microwave Imager (SSM/I), Special Sensor Microwave Imager/Sounder (SSMIS), and WindSat data from NOAA NESDIS. We have also put a lot of efforts on making the real-time testing code and designing the output format based on discussions with NHC points of contact. All the output and a readme file can be found online at an ftp site (http://tcpf.fiu.edu/JHT/). *2) Evaluation and Refinement of the 37 GHz ring+SHIPS RI index:* There are two aspects in term of evaluating and refining the ring+SHIPS RI index. i) Evaluating the performance of the index based on a subjective determination of the ring pattern, ii) Evaluating the performance of the index based on the automatic ring identification algorithm, which will be eventually used for the project. The first aspect has been done in a published journal paper (Kieper and Jiang 2012, GLR) using a dataset including 84 TCs in the Atlantic basin during 2003-2007. Statistics based on RI events showed that the subjective 37 GHz ring+SHIPS RI index produced a probability of detection of 75%, and a false alarm ratio of 9%. Based on the results, some refinement has been made for the 37 GHz ring RI index. The objective version of the refined subjective RI index using the automatic ring identification algorithm was evaluated using all the TRMM TMI observations of tropical cyclones in the Atlantic (ATL) and eastern North Pacific (EPA) basins that developed from 1998 to 2010. It is found that both ATL and EPA the probability of RI for cases that satisfied the SHIPS criterion is higher than for cases that satisfied the 37 GHz ring criterion. However, when both criteria were satisfied, the probability of RI is about equal to the sum of the two probabilities with only one criterion satisfied. For example, for the ATL basin, the probability of RI for 30-kt intensity change in 24-h is 10% when a 37 GHz ring pattern is detected, and is 22% when the environmental condition is favorable as indicated by SHIPS RII_25kt greater than 20%. The probability increases to 34% when both a ring pattern is seen in the inner core and the SHIPS criterion is satisfied. This indicates that the 37 GHz ring pattern index and the SHIPS index are independent predictors. *3) Application of the ring pattern RI index into the*

Northwest Pacific Basin: Although it is beyond the general tasks for this JHT project, a similar ring pattern RI index is developed and applied to TCs in the Northwest Pacific basin. The work for the Northwest Pacific basin has been led by Dr. Tie Yuan (postdoc). He presented his preliminary results in 2011 IHC meeting at Miami. Currently a journal manuscript based on the results is in preparation.

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

During the first 1.5 months of year-2, we continued to work on the real-time testing till the end of the 2012 hurricane season. After that, we have been working on analyzing the real-time outputs and evaluating the performance of real-time forecasts.

The evaluation is done based on RI events. 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 >=30kts. Note that more than one RI events for each storm is possible. During the 2012 hurricane season, there were five RI events in the Atlantic (AL) basin (table 1) and six RI events in the East Pacific (EP) basin (table 2).

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, the total RI period, and the maximum intensity change of the five RI events in the Atlantic 2012 hurricane season.

Storm ID/Name	RI start time (UTC), Vmax	RI end time (UTC), 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

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, the total RI period, and the maximum intensity change of the five RI events in the East Pacific 2012 hurricane season.

Storm ID/Name	RI start time (UTC), Vmax	RI end time (UTC), 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 (landfall)	42 h	55 kt
EP16/Paul	10/14 12:00, 50 kt	10/16 06:00, 100 kt	42 h	50 kt

The table 3 shows the performance of the real-time subjective and objective 37 GHz ring RI index for these two basins, respectively. From this table, for the Atlantic basin, we can see the subjective ring method would generate hits for all 5 RI events if we had used a SHIPS 25-kt RI probability>=5% as the criterion. This 5% criterion was found in Kieper and Jiang (2012, GRL) by using a historical microwave dataset and the 2011 version of SHIPS RI index developmental dataset. Unfortunately, since Margie Kieper has been using "SHIPS 25-kt RI probability>=20%" as the criterion as suggested by NHC forecasters, we didn't adapted this new criterion because we were lack of confidence and felt

that we need at least one year of real-time test. On the other hand, even if we used the "SHIPS 25-kt RI probability>=5%" criterion, our automatic/objective ring+SHIPS RI index would still miss 3 out of 5 RI cases with 2 misses due to the bad center fixes and one due to FIU server problem.

For the East Pacific basin, the subjective ring+SHIPS method did a great job with 5 hits out of 6 RI events (we consider the Miriam RI event as a miss due to no SHIPS RI data, although we did email NHC for an RI alert in real-time). For the automatic algorithm, there is no bad center fix problem probably because that East Pacific storms have more linear tracks. Three misses by the automatic algorithm were caused by coding error (has been fixed after that) and server problems.

Table 3: The real-time performance of the subjective and objective 37 GHz ring RI index for the 5 (6) RI events in the Atlantic (East Pacific) 2012 hurricane season.

Storm ID/name	37 GHz Ring (subjective)	37 GHz Ring (objective/automatic ring detection algorithm)	SHIPS 25-kt RI Probability (>= 20% or not)
AL03/Chris	Yes	No (due to bad center fix)	11% (No)
AL08/Gordon	Yes	Yes	17% (No)
AL11/Kirk	Yes	Yes	16% (No)
AL13/Michael	Yes	No (due to bad center fix)	12% (No)
AL18/Sandy	Yes	FIU server down	63% (Yes)
EP02/Bud	Yes	No (early season, real-time algorithm coding error)	67% (Yes)
EP03/Carlotta	Yes	Yes	59% (Yes)
EP04/Daniel	Yes	Yes	25% (Yes)
EP05/Emilia	Yes	Yes	74% (Yes)
EP13/Miriam	Yes	No (NESDIS sever problem, no WindSat data received)	No Data
EP16/Paul	Yes	FIU server down	51% (Yes)

In summary for the 2012 real-time testing, the Atlantic RI events were harder to predict. The SHIPS RI index values were too low. A lower threshold would be better. Also in this basin, the main reason for misses (except for cases with data/server/coding problems) is due to bad tropical cyclone center fixes. A linear interpolation was used to determine the storm center at the satellite observation between two NHC-forecasted storm track points. However, the storm track between these two points might quite far from linear. Interestingly the problem of misses due to bad center fixes did not happen to East Pacific storms. Instead, East Pacific RI events seemed easier to predict during 2012. All the SHIPS RI index values were greater than the threshold we chose. The storm track seemed more linear so that a linear interpolation worked OK.

3. Works in progress

Based on a preliminary check, most of the false alarms were due to bad storm center fixes. For the rest of year 2, an important work to do is to collect all the false alarm cases and generate a careful statistic.

From the evaluation results above, there are two more items that we are currently working on in order to improve the performance of our automatic ring+SHIPS RI index, especially in the Atlantic basin: 1) using a better center fixing technique; 2) updating/recalibrating the SHIPS RI criterion. The second item (updating/recalibrating the SHIPS RI criterion) is kind of straightforward. We'll follow the approach demonstrated in Kieper and Jiang (2012, GRL) to do this using the new SHIPS RI index values provided by John Kaplan. The first issue will need a longer time to solve. The best approach to solve the center fixing problem would be to incorporate the CIMSS ARCHER center fix technique. However, since ARCHER is not an operational technique yet, a close collaboration with Chris Velden and Tony Wimmers at CIMSS is necessary. We are currently working on this.

During year 2, we will continue to synthesize our findings into manuscripts and presentations at conferences and workshops.

4. Contribution by collaborators and others

J. Kaplan: We have had several meetings with John exclusively for this JHT project. He has been extremely helpful on the algorithm design and how to cooperate with the SHIPS RI index. He has provided the SHIPS RII developmental dataset between 1995-2010, which is crucial for our algorithm development, verification, and refinement. Currently we are using his most recently updated SHIPS RI real-time forecasts as the input of our real-time testing algorithm.

E. Zipser: As an unfunded collaborator, Dr. Zipser has been very helpful on providing insights on the fundamental aspect of the problem, and providing the TRMM database as well.

M. Kieper: Ms. Kieper was listed a private consultant at the proposal writing stage. However, she became a research assistant of the PI in Aug. 2011, and is a PhD student of the PI since Aug. 2012. She has been supported by the JHT grant. She is continuing to make great contributions to the project in assisting with the automatic algorithm evaluation and further refinement and providing the subjective 37 GHz ring RI index forecasts in real-time .

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

Zagrodnik, J., and H. Jiang, 2013: Validation of PR and TMI Version 6 and Version 7 Rainfall Algorithms in Landfalling Tropical Cyclones Relative to the NEXRAD Stage-IV Multi-sensor Precipitation Estimate Dataset. *J. Appl. Meteor. Climatol.*, in revision.

Jiang, H., and E. M. Ramirez, 2013: Necessary conditions for tropical cyclone rapid intensification as derived from 11 years of TRMM data. *J. Climate*., in press.

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

Zagrodnik, J., and H. Jiang, 2012: Properties of Tropical Rainfall Measuring Mission (TRMM) Precipitation Radar (PR) and Microwave Imager (TMI) Rainfall Retrievals in Tropical Cyclone Inner Cores and Rainbands. *J. Geophys. Res.*, in press.

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.

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

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.