Appendix A

FORMAT FOR USE IN SUBMISSION OF INTERIM AND FINAL RESEARCH PERFORMANCE PROGRESS REPORTS

COVER PAGE

NOAA/JHT

Federal Grant Number Assigned by Agency: NA17OAR4590138

Title: Improvements to Operational Statistical Tropical Cyclone Intensity Forecast Models Using Wind Structure and Eye Predictors

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Submission Date: 08/30/2018

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Award Period: 8/1/17-7/31/19

Reporting Period End Date: 7/31/18

Report Term or Frequency: semi-annual

Final Annual Report? No

1. ACCOMPLISHMENTS

Summary of the project accomplishments for the 4 main project tasks:

Tasks 1 and 2: Add a tropical cyclone (TC) wind structure based predictor or combination of predictors to Statistical Hurricane Intensity Prediction Scheme (SHIPS), the Logistic Growth Equation Model (LGEM), the multi-lead time probabilistic Rapid Intensification Index (MLTRII), and the global Rapid Intensification Index (GRII). These changes are designed to improve SHIPS, LGEM, and RIIs forecast performance based on the recent research that demonstrated that both TC intensification rate and the likelihood of undergoing Rapid Intensification (RI) are related to storm size, with smaller storms found to be more likely to intensify, and that the wind structure parameters, such as the radius of maximum winds (RMW), the average radius of gale-force winds (R34), and the objective size parameter (R5, Knaff et al, 2014) are strongly negatively correlated with the rate of change of intensity. The software for creating databases of RMW, R34, and corresponding climatological parameters for the developmental database, reruns, and real-time runs was developed. The full developmental database of R34 and RMW was created for the years 1982-2017, which is the full length of the developmental database sample used for SHIPS, LGEM, and RIIs. The 2018 versions of SHIPS, LGEM, GRII, and MLTRII were modified to use new size-based predictors, including RMW, R34, R5, FR5, and time-averaged storm latitude (TLAT). Depended sample testing for 2017 and 2018 versions of the models was completed, and demonstrated that the addition of three new predictors, including two TC-size parameters and time-averaged latitude results in most forecast improvements for all models for both Atlantic and east/central Pacific basins. New predictors, including R34, R5, and TLAT were added to the 2018 versions of SHIPS, LGEM, and GRII; and RMW, FR5, and TLAT to MLTRII, and retrospective model runs with the new predictors were completed for the years 2007 - 2017. Verification of reruns is in progress.

Tasks 3 and 4: Add a predictor or a group of predictors based on the probability of the eye existence and the code to calculate that probability to SHIPS/LGEM, MLTRII, and GRII. These changes are designed to use the automated objective eye-detection algorithm (EDA) recently developed at CIRA (Knaff and DeMaria, 2017) to improve SHIPS, LGEM, and RIIs forecast performance based on multiple studies that demonstrated that the appearance of the eye is strongly related to storm intensity and often indicates the beginning of RI (Weatherford and Gray 1988, Willoughby 1990, Vigh 2012). The current intensity combined with the intensification trend over the last 12 hours was shown to be one of the most important predictors for TC intensity (Fitzpatrick, 1997). In operations, eye-detection is currently performed manually by forecasters. The EDA allows to automate that procedure making it possible to use eye-existence based predictors for statistical intensity forecast models. Development has begun on a Fortran90 version of the eye detection algorithm that generates the eye detection probabilities and adds them to the diagnostic file used by the SHIPS, LGEM, and RII models.

What were the major proposed **goals, objectives, and tasks** of this project, and what was accomplished this period under each task? (a table of planned vs. actuals is recommended as a function of each task identified in the funded proposal)

Note: Funding for this project arrived 1 month later than expected. All the millstones were shifted accordingly, which was approved by JHT. All milestone dates below are adjusted dates.

Goals, Objectives, Tasks	Planned: Aug 2017 – July 2018	Actual: Aug 2017 – July 2018
Create updated database of wind structure predictors	Create SHIPS developmental database of R34, RMW, and R5 predictors and corresponding climatology	The databases of R34, RMW, and R5 and corresponding climatologies were created for the years 1982 - 2017, and added to the SHIPS developmental database.
Complete SHIPS dependent sample testing and RII statistical testing to determine the best combination of wind structure parameters to use as new predictors	Perform dependent sample testing of SHIPS/LGEM, and RIIs to determine the best combination of wind structure predictors.	The dependent sample testing with 2017 and 2018 versions of the models was completed. The combination of new predictors, R34, R5, and TLAT (RMW, FR5 and TLAT for MLTRII) was selected based on the overall best performance.
Modify SHIPS and both RIIs to use wind structure predictors	Modify SHIPS and both RIIs to use wind structure predictors	2018 versions of SHIPS, LGEM, and RIIs were updated to use additional wind structure predictors.
Derive updated regression coefficients and complete retrospective SHIPS and RII runs with new structure predictors	Derive updated regression coefficients and complete retrospective SHIPS and RII runs with new structure predictors	The updated regression coefficients were derived for 2018 versions of all models for several combinations of new predictors. Reruns were completed with the best combination of predictors.
Present project's progress at the Interdepartmental Hurricane Forum and meet with NHC points of contact (POC).	Present project's progress at the IHC and meet with NHC POCs.	Project progress was presented at the IHC and discussed with NHC and JTWC POCs
Conduct algorithm changes based on feedback and validation results	Conduct algorithm changes based on feedback and validation results	The choice of the best combination of predictors use was adjusted based on testing 2018 versions of the models.
Develop operational version of the CIRA's EDA and incorporate it into SHIPS processing	Develop operational version of the CIRA's EDA and incorporate it into SHIPS processing	Development has begun on a Fortran90 version of the EDA that generates the eye detection probabilities and adds them to the diagnostic file used by the SHIPS, LGEM, and RIIs.
Prepare final updated version of the modified SHIPS and RII code for parallel runs during the 2018 season (to include use of new structure predictors) for Atlantic and east Pacific basins.	Prepare final updated version of the modified SHIPS and RII code for parallel runs during the 2018 season for Atlantic and east Pacific basins	Task is late due to the late delivery of the 2018 version of NHC guidance by TSB, which is the starting point for the modified version. The models will be tested on independent 2018 data after season.

Are the proposed project tasks **on schedule**? What is the cumulative percent toward completion of each task and the due dates? (table recommended)

Task	Cumulative percent towards completion and due dates	Due Date	On schedule (yes/no)
Create updated database of wind structure predictors	100%	Nov 2017	Yes
Complete SHIPS dependent sample testing and RII statistical testing to determine the best combination of wind structure parameters to use as new predictors	100%	Jan 2018	Yes
Modify SHIPS and both RIIs to use wind structure predictors	100%	Feb 2017	Yes
Derive updated regression coefficients and complete retrospective SHIPS and RII runs with new structure predictors	90%	Jul 2018 for the 2018 versions of the model	The regression coefficients were derived and reruns were completed for 2018 models. Verification is in progress.
Present project's progress at the Interdepartmental Hurricane Forum and meet with NHC points of contact.	100%	Mar 2018	Yes
Conduct algorithm changes based on feedback and validation results	100%	May 2018	Yes
Develop operational version of the CIRA's EDA and incorporate it into SHIPS processing	70%	June 2018	The tasks is slightly delayed which will not affect overall project schedule.
Prepare final updated version of the modified SHIPS and RII code for parallel runs during the 2018 season (to include use of new structure predictors) for for the Atlantic and east Pacific basins.	70%	July 2018	Task is late due to the late delivery of the 2018 version of NHC guidance by TSB, which is the starting point for the modified version. The models will be tested on independent 2018 data after season.

What were the major completed **milestones** this period, and how do they compare to your proposed milestones? (planned vs. actuals table recommended)

Milestone	Completed vs proposed
Create updated database of wind structure predictors	Completed as proposed
Complete SHIPS dependent sample testing and RII statistical testing to determine the best combination of wind structure parameters to use as new predictors	Completed as proposed. In additions, dependent sample testing was completed for 2018 versions of SHIPS, LGEM, and RIIs.

Modify SHIPS and both RIIs to use wind structure predictors	Completed as proposed. In additions, changes were incorporated into 2018 versions of SHIPS, LGEM, and RIIs.
Derive updated regression coefficients and complete retrospective SHIPS and RII runs with new structure predictors	Task is 90% complete. Updated coefficients were derived for 2018 version and reruns of 2018 models were completed. Verification is in progress.
Present project's progress at the Interdepartmental Hurricane Forum and meet with NHC points of contact.	Completed as proposed
Conduct algorithm changes based on feedback and validation results	Completed as proposed
Develop operational version of the CIRA's EDA and incorporate it into SHIPS processing	Task is 70% complete. The task is on schedule for testing EDA predictors with SHIPS that is planned for November 2018.
Prepare final updated version of the modified SHIPS and RII code for parallel runs during the 2018 season (to include use of new structure predictors) for the Atlantic and east Pacific basins	Task is late due to the late delivery of the 2018 version of NHC guidance by TSB, which is the starting point for the modified version. The reruns for 2018 season will be used as independent verification.

Detailed description of the work completed for each milestone for the Year 1 of the project is presented below.

Milestone: Create updated database of wind structure predictors. The updated databases of RMW, R34A, and R5 were created and added to a full SHIPS developmental database for the years 1982 - 2017. The operational SHIPS developmental database is available at http://rammb.cira.colostate.edu/research/tropical_cyclones/ships/developmental_data.asp. The R34 and RMW wind data were obtained from the extended best track (http://rammb.cira.colostate.edu/research/tropical_cyclones/tc_extended_best_track_dataset/, Demuth et al, 2006) and from the ATCF a- and b-decks for data after 1990 for RMW (after 2002 for R34). Updated readers for the ATCF data were developed to complete these tasks. The statistical models require input at all synoptic times, however, data are not available at all times. For example, RMW is not available prior to 1987 for the Atlantic (prior to 2000 for east Pacific), and R34 data are not available prior to 1988 for the Atlantic (prior to 2001 for eat Pacific). Thus, a climatology is required for running the models. The climatology of RMW as a function of maximum wind speed and latitude was created following Willougby and Rahn (2004), who found that RMW can be approximated as

$$RMW = 51.6 \exp(-0.0223Vmax + 0.0.281\ \varphi),$$

where Vmax is the maximum intensity and φ is the latitude. The climatology for the R34 was derived based on Knaff et all (2007) using the modified Rankine vortex, assuming there are no asymmetries:

$$V(r) = Vmax\left(\frac{r^m}{r}\right)^x,$$

where Vmax is the maximum wind speed and m and x can be determined as function of Vmax and latitude as described in Knaff et al (2007). The R5, the normalized R5 (FR5), and the corresponding climatological values were determined as described in Knaff et al. (2015).

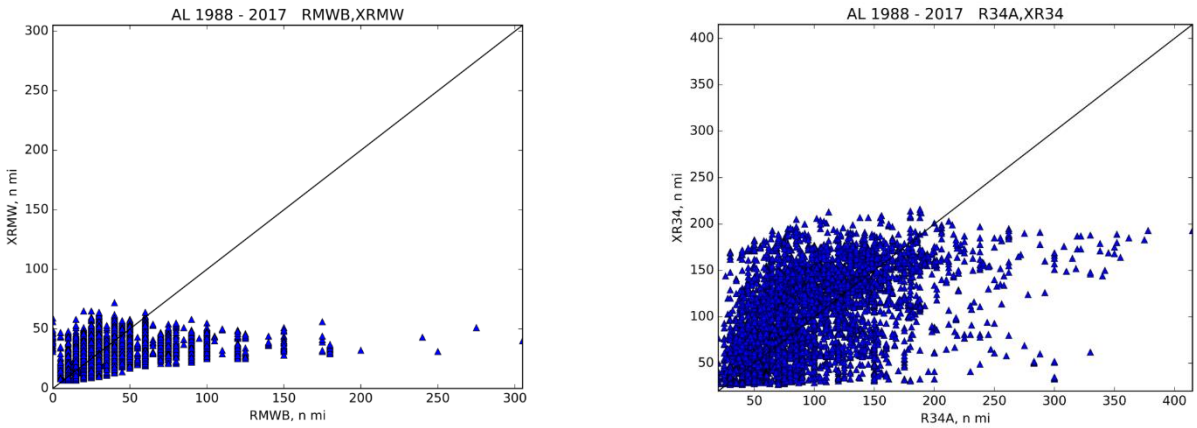

Figure 1. Left: scatter plot of climatological RMW (XRMW) vs RMW from ATCF and extended best track. Right: the same for R34.

Complete SHIPS dependent sample testing and RII statistical testing to determine the best combination of wind structure parameters to use as new predictors.

Dependent sample testing was completed for 2017 and 2018 versions of SHIPS, LGEM, GRII, and MLTRII. Various combinations of new predictors were tested. Depended sample testing demonstrated that using the combination of data and climatology for size predictors produces results similar or better than using data only for the cases when data are available. The tested predictors included non-zero-averaged R34 (R34A), RMW from best track (RMWB), IR-based size parameters (R5, FR5, and azimuthally averaged tangential wind at 500 km, V500), and time-averaged latitude, TLAT.

Figure 2 shows dependent sample tests for the MLTRII. It was found that smaller RMW and R34 are more favorable for RI, which is consistent with other studies. Additional tests were completed using 2018 version of MLTRII (not shown). It was determined that the overall best results are obtained with using RMW, FR5, and TLAT as new predictors. The new MLTRII provided mean absolute (relative) improvements of 1.0 % (5.2%) over the baseline 2018 operational SHIPS-RII model for the Atlantic basin and mean absolute (relative) improvements of 0.9% (3%) for the eastern North Pacific basin when tested on the 1995-2017 developmental samples for all seven of the RI thresholds.

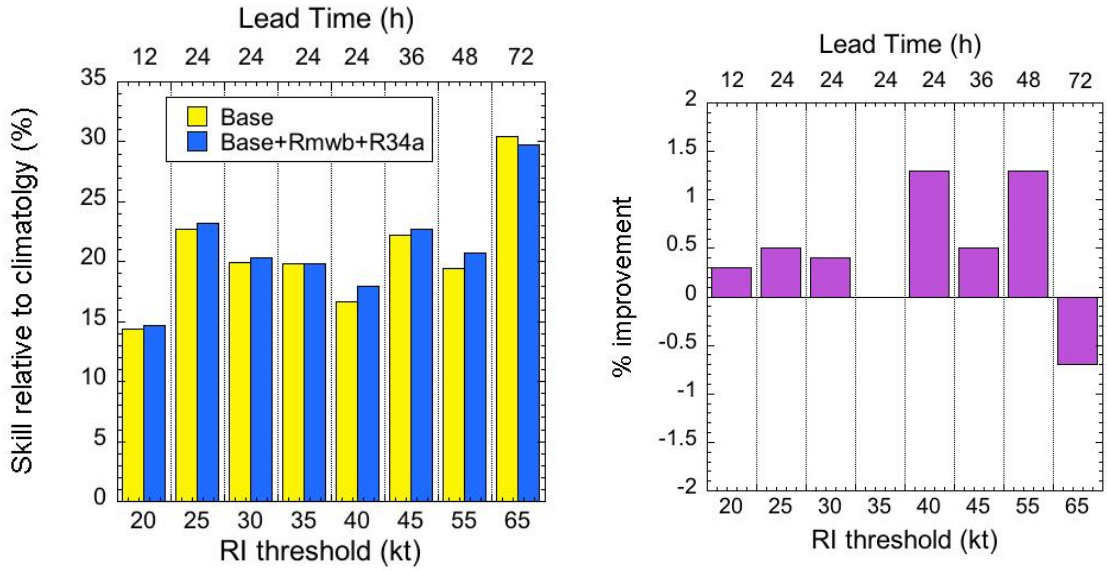

Figure 2. Results of MLTRII dependent sample testing with RMW and R34. Left: Skill of the RII relative to climatology with base model and with added RMW and R34. Left: Forecast percent improvement at different forecast lead times.

Figures 3 and 4 show the dependent sample testing results for 2018 versions of SHIPS and LGEM for the Atlantic and east Pacific for SHIPS and LGEM. For these tests a full data sample for the years 1982 - 2017 was used, and climatological values were used for the cases when data are not available. The test results are similar to the results of testing 2017 versions of the models. For the Atlantic basin there is about 0.8% improvement in forecast for SHIPS forecast lead time of 18 hours. That is a significant improvement compared to preliminary tests that were performed using a limited subset of cases.

The dependent sample testing results were consistent between 2017 and 2018 versions of the models and between models. In all cases it was found that adding a combination of three new predictors, including two structure predictors and TLAT, produces the best results. The best three predictors are slightly different between Atlantic and east/central Pacific and different models. It is easier to interpret the model results when the same predictors are used. Thus, based on the overall performance it was decided to add R34A, R5, and TLAT to SHIPS, LGEM, and GRII for both Atlantic and east/central Pacific. TLAT, RMWB, and FR5 were added to MLTRII. The selection of best structure-based predictors may be further adjusted when EDA-based predictors will be added to the models.

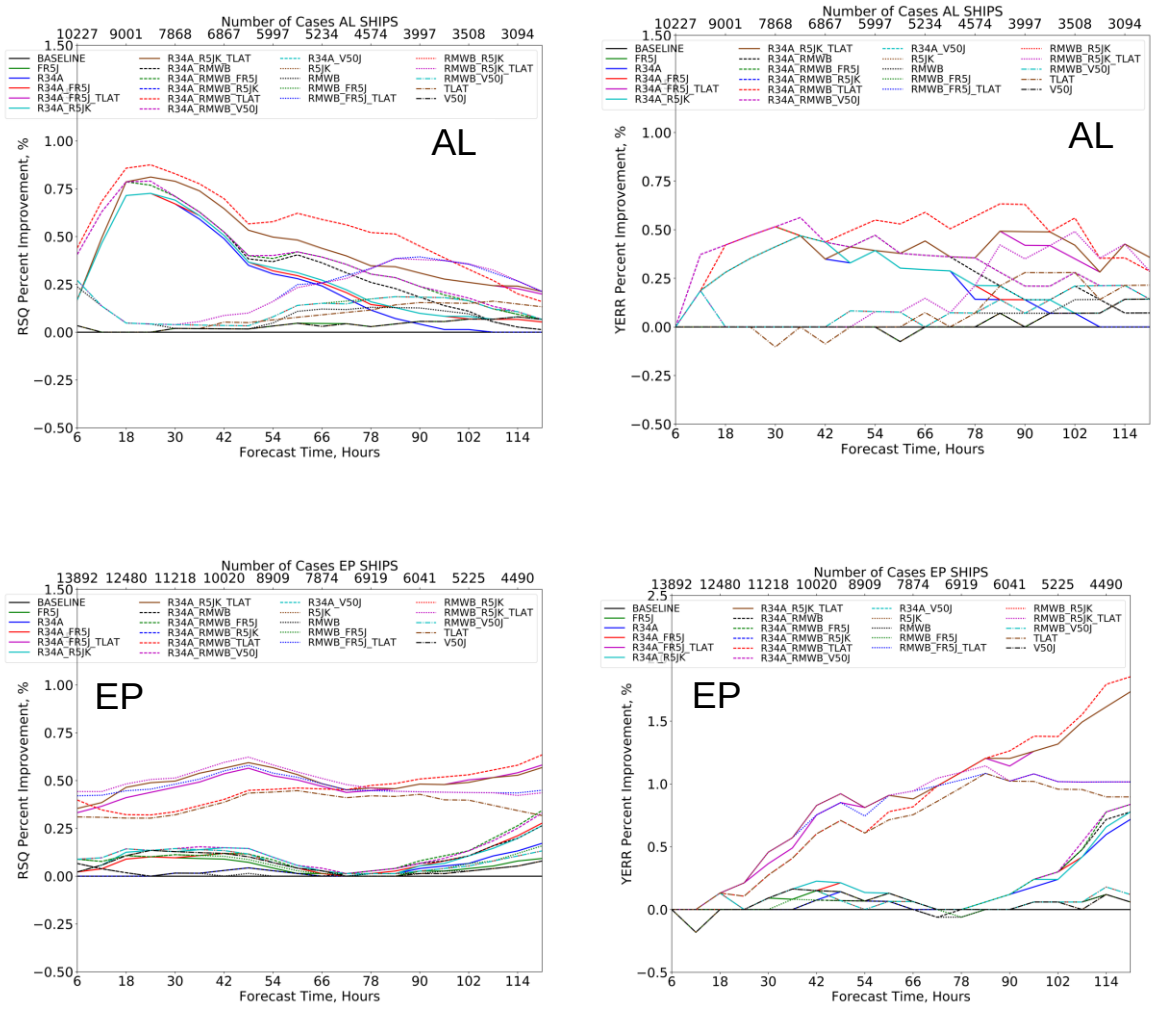

Figure 3. Results of 2018 version of SHIPS dependent sample testing with added structure predictors. Upper left: percent improvement (PI) in R^2 for the Atlantic basin. Upper right: PI in Yerr for the Atlantic basin. Lower left: PI in R^2 for the east Pacific basin. Lower right: PI in Yerr for the east Pacific basin Predictors shown: RSST - baseline using operation model; R34A - non-zero averaged R34; RMWB - RMW from ATCF best track; R5JK - objective TC size parameter R5; FR5J - normalized objective TC size parameter FR5; V50J - azimuthally averaged tangential wind at 500 km; and TLAT - time-averaged storm latitude. All predictors use climatological values when data are not available.

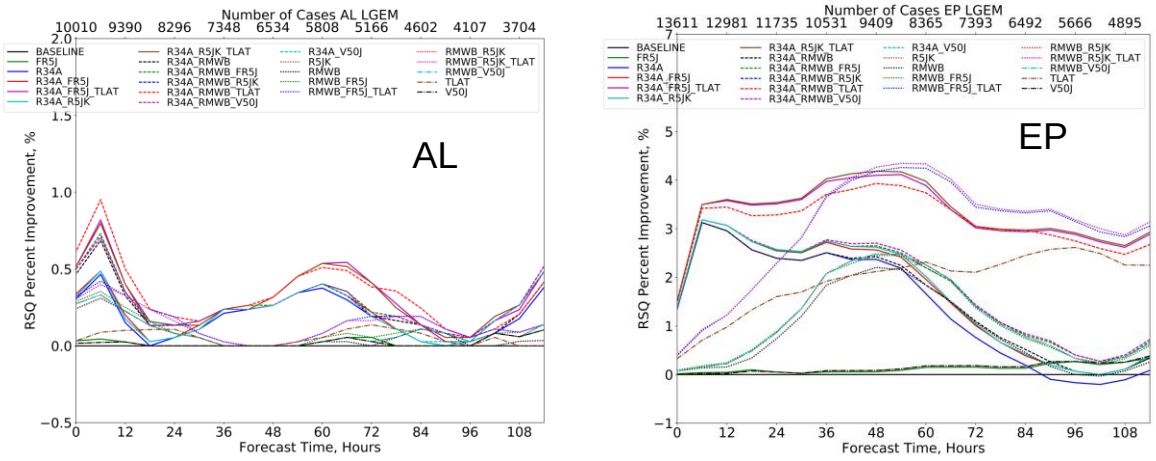

Figure 4. Results of 2018 version of LGEM dependent sample testing with added structure predictors. Left: PI in R^2 for the Atlantic basin. Right: PI in Yerr for the east Pacific basin. New predictors are the same as for SHIPS on Figure 4.

Milestone: Modify SHIPS and both RIIs to use wind structure predictors.

2018 versions of SHIPS, LGEM, GRII, and MLTRII were modified to include new predictors. R34A, R5, and TLAT were added to SHIPS, LGEM, and GRII. TLAT, RMWB, and FR5 were added to MLTRII.

The Fortran90 software was developed for adding to SHIPS diagnostic files R34 and RMW from ATCF a-decks. The same software also produces and adds to the diagnostic files estimates of the climatological R34 and RMW. The new software uses NRL ATCF reader, and can be used for adding new parameters to diagnostic files for reruns, as well as for real-time runs.

Milestone: Derive updated regression coefficients and complete retrospective SHIPS and RII runs with new structure predictors.
Updated regression coefficients for the selected best combination of TC-structure-based predictors were derived for 2018 versions of SHIPS, LGEM, GRII, and MLTRII. The retrospective runs of 2018 versions of the models were completed for the years 2007 - 2017. Reruns were completed using the 2018 operational version of SHIPS, LGEM, and RIIs as well as modified versions. Modified versions of SHIPS, LGEM, and GRII included three new predictors: R34A, R5, and TLAT. The modified version of MLTRII included RMW, FR5, and TLAT. The reruns were completed later than expected due to the very late delivery of the final version of the NHC guidance suite by TS, which is the starting point for the modified version. Verification of reruns is in progress.

Milestone: Present project's progress at the Interdepartmental Hurricane Forum and meet with NHC points of contact.
The project's progress was presented at the IHC in March, 2018, and the project was discussed with NHC and JTWC POCs. The IHC presentation is available online, at https://www.nhc.noaa.gov/jht/17-19_proj.php

Milestone: Conduct algorithm changes based on feedback and validation results.
The combination of best structure-based predictors was adjusted based on the dependent sample testing with 2018 versions of the models.

Milestone: Develop operational version of the CIRA's EDA and incorporate it into SHIPS processing.

Development has begun on a Fortran90 version of the EDA that generates the eye existence probabilities and adds them to the diagnostic file used by the SHIPS model. Code has been written to read the SHIPS diagnostic file and IR satellite data file, loop through all cases in the file, and extract the input needed for the EDA. The input includes the storm center position (latitude and longitude), 12 h old position for motion vector calculation, maximum wind estimate and IR Window channel brightness temperatures on an 80 by 80-pixel grid centered on the TC center location. Code has also been written and tested to project the IR data onto empirical orthogonal functions (EOF) to provide the EOF amplitudes, also known as principal components (PCs). The PCs are also used as input to the eye detection probability routine. To ensure that the EOF projection routine is working property, test code was written to reconstruct the original images with an increasing number of EOFs times the PCs and the resulting fields converge to the original images. Subroutines were also written to read the mean and standard deviation of the composite IR image, which are used to normalize each image. The final steps are to write subroutines to read the parameters of the Gaussian functions and to evaluate those to determine the eye detection probabilities. Then a comparison will be made with the probably estimates from the Fortran90 code to those from the original Python code for a set of cases with low and high probabilities of having an eye.

Milestone: Prepare final updated version of the modified SHIPS and RII code for parallel runs during the 2018 season (to include use of new structure predictors) for the Atlantic and east Pacific basins.

The setup of the parallel runs of the modified versions of SHIPS, LGEM, and RIIs at CIRA has been delayed relative to the original schedule. This delay was due to the very late delivery of the final version of the NHC guidance suite by TSB, which is the starting point for the modified version. Retrospective reruns for the 2018 season will be completed at the end of the season to evaluate the performance of the experimental models on independent data, and the results of the retrospective 2018 runs will be provided to JHT POCs for evaluation.

What opportunities for training and professional development has the project provided?

People working on the project obtained increased knowledge and skills in the development of statistical models. Also, collaboration between CIRA and AOML on this project provides opportunities for professional development for people working on the project

How were the results disseminated to communities of interest?

1) The project results were presented at the IHC in March 2018. The presentation is available online at https://www.nhc.noaa.gov/jht/17-19_proj.php . Also, John Kaplan visited CIRA in September, 2017, and presented a talk "Statistical rapid intensity prediction: Implications of recent Model Results 2016 and 2017" at a CIRA seminar. The talk included some of preliminary results and future plans for this project. Additional details about the project were communicated to JHT points of contact, Dan Brown (NHC), Mark DeMaria (NHC), Robert Ballard (CPHC), Brian Strahl (JTWC) and Chris Landsea (NHC).

2) The project was discussed with JTWC POC, Brian Strahl by Kate Musgrave (CIRA) during her visit to JTWC in October, 2017.

3) The project work is coordinated with NHC POC Mark DeMaria. The project was also discussed with JTWC POC, Brian Strahl, and NHC POC, Dan Brown, at IHC.

4) At later stages of the project updated software and databases will be provided to NHC, and test results will be provided to NHC, CPHC, and JTWC POCs.

What do you plan to do during the next reporting period to accomplish the goals and objectives?

During the next reporting period we plan to complete verification of the retrospective runs of the SHIPS/LGEM and RIIs with size predictors, to test modified models on independent 2018 data sample, and to make adjustments to the experimental versions of the models with added structure predictors, if needed. In addition, the Fortran90 version of EDA will be completed and incorporated into SHIPS processing. We also plan to begin work on adding EDA-based predictors to SHIPS, LGEM, and RIIs.

2. PRODUCTS

What were the major completed **products or deliverables** this period, and how do they compare to your proposed deliverables? (planned vs. actuals table recommended)

Product/Deliverable	Actual
Updated database of size predictors and corresponding climatological values for the years 1982 - 2017.	Developed as planned. The updated 2018 version will be provided to NHC.
Fortran90 software for adding R34, RMW, and corresponding climatologies to SHIPS diagnostic files	Developed as planned. Software will be provided to NHC at the end of the project.
Experimental versions of SHIPS, LGEM, GRII, and MLTRII with added structure predictors	Developed as planned. Software will be provided to NHC at the end of the project.

What has the project produced?
-publications, conference papers, and presentations*;

Knaff, J. A., and R. T. DeMaria, 2017: Forecasting tropical cyclone eye formation and dissipation in infrared imagery. *Wea. Forecasting*, **32**(6), 2103-2116, doi: 10.1175/WAF-D-17-0037.1.

-technologies or techniques;

None

-inventions, patent applications, and/or licenses; and

None

-other products, such as data or databases, physical collections, audio or video products, software, models, educational aids or curricula, instruments or equipment, research material, interventions (e.g., clinical or educational), or new business creation.

- Database of TC-size predictors converted to SHIPS input format. The database includes both available data and climatology.
- Updated climatology of RMW, R34, and R5
- Fortran90 software for adding R34, RMW, and corresponding climatologies to SHIPS diagnostic files

*For **publications**, please include a full reference and digital object identifier (DOI; http://www.apastyle.org/learn/faqs/what-is-doi.aspx) and attach all publications and presentations on this project from this reporting period to the progress report, or include web links to on-line versions. Within your publications and presentations, please include language crediting the appropriate NOAA/OAR organization and program (e.g., NOAA/OAR/OWAQ and the U.S. Weather Research Program; or NOAA/OAR/NSSL and the VORTEX-SE program) for financially supporting your project. Suggested language is as follows:
"This material is based upon work supported by the U.S. Weather Research Program within NOAA/OAR Office of Weather and Air Quality under Grant No. XXXXXXX."

3. PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS

What individuals have worked on this project?

Galina Chirokova, John Knaff, John Kaplan

Has there been a change in the PD/PI(s) or senior/key personnel since the last reporting period?

No

What other organizations have been involved as partners? Have other collaborators or contacts been involved?

NHC points of contact have been involved. Also work for this project has been coordinated with NHC TSB branch.

4. IMPACT

What was the impact on the development of the principal discipline(s) of the project?

The project directly addresses the program priorities JHT-3 and JHT-1. Specifically, improved SHIPS and RIIs will provide a better guidance for TC intensity change including the onset, duration, and magnitude of RI events, and over-water weakening events (JHT-3). These intensity guidance techniques are routinely used operationally at NHC, CPHC, and JTWC to forecast TC intensity. In addition, the use of the EDA output as predictor in SHIPS and RIIs will provide improved capability to observe the TC and its environment to support forecaster analysis and model initialization (JHT-1). This work also addresses the NOAA goal for a Weather-Ready Nation. NOAA's Weather-Ready Nation is about *"building community resilience in the face of increasing vulnerability to extreme weather and water events. Record-breaking snowfall, cold temperatures, extended drought, high heat, severe flooding, violent tornadoes, and massive hurricanes have all combined to reach the greatest number of multi-billion-dollar weather disasters in the nation's history. The devastating impacts of extreme events can be reduced through improved readiness."*

What was the impact on other disciplines?
The results of this project should allow for improved operational TC intensity and structure forecasts that are important for other agencies and general public. Improvements in these capabilities may also lead to other high priority forecasts (e.g., storm surge watch/warnings, wave forecasts) and decisions (e.g., evacuations, ship routing).

What was the impact on the development of human resources?
Nothing to report

What was the impact on teaching and educational experiences?
Nothing to report

What was the impact on physical, institutional, and information resources that form infrastructure?
Nothing to report

What was the impact on technology transfer?
Methods developed at CIRA, if approved by the JHT, will transition to NHC, CPHC, and JTWC operations. Examples include the automated objective EDA.

What was the impact on society beyond science and technology?
The results of this project should allow for improved operational TC intensity forecasts that are important for other governmental agencies, industry, and general public. These efforts significantly contribute to NOAA's goal of a *Weather-Ready Nation*.

What percentage of the award's budget was spent in a foreign country(ies)?
None

5. CHANGES/PROBLEMS

Describe the following:

-Changes in approach and reasons for the change.
None

-Actual or anticipated problems or delays and actions or plans to resolve them.

The verification of retrospective runs of the 2018 models and the setup of the parallel runs of the modified versions of SHIPS, LGEM, and RIIs at CIRA were delayed relative to the original schedule. This delay was due to the very late delivery of the final version of the NHC guidance suite by TSB, which is the starting point for the modified version. Retrospective reruns for 2007 - 2017 were completed and verification is in progress. Retrospective reruns for the 2018 season will be completed at the end of the season to evaluate the performance of the experimental models on independent data. This delay will not impact the overall project schedule.

The development of the Fortran90 of the EDA is slightly behind the schedule. This development is 70% complete, and will be completed by November 2018 when testing of EDA predictors in SHIPS should begin. This will not impact the overall project schedule or other tasks.

-Changes that had a significant impact on expenditures.
None

-Change of primary performance site location from that originally proposed.
None

6. SPECIAL REPORTING REQUIREMENTS

Report on any special reporting requirements here (see previous instruction #3). If there are none, state so.

- Your assessment of the project's Readiness Level (current and at the start of project; see definitions in Appendix B)

Start of the project: RL3
Current: RL4

-If not already reported on in Section 1, please discuss:
-- Transition to operations activities

The transition to operations for this project is scheduled after the end of Year 2, in 2019, if accepted by NHC. The timing of the final transition will depend on the availability of NHC Technology and Science Branch (TSB) resources.

-- Summary of testbed-related collaborations, activities, and outcomes (if it's a testbed project)

1) Result and verification of the retrospective and real-time runs will be made available to JHT POCs when these are produced.

2) Updated software and databases will be provided to NHC toward the end of the Year 2 of the project.

3) The possibility of implementing real-time EDA processing and experimental versions of SHIPS, LGEM and RIIs with added structure predictors in quasi-production on WCOSS for 2019 season has been discussed with NHC POCs and NHC TSB staff and will depend on the availability of NHC TSB resources. As an alternative, parallel runs for the 2019 season could be setup at CIRA.

-- Has the project been approved for testbed testing yet (if it's a testbed project)?

The Testing Plan for this project was submitted in March, 2018. The revised version of the Testing Plan was submitted in May, 2018.

-- What was transitioned to NOAA?

The transition activities for this project are planned at the end of the Year 2 of the project, as described in Research to Operations Transition Plan.

Test Plans for USWRP-supported Testbed Projects. Test plan for this project is submitted as a separate document.

7. BUDGETARY INFORMATION

Is the project on budget? Much of the quantitative budget information is submitted separately in the Federal Financial Report. However, describe here any major budget anomalies or deviations from the original planned budget expenditure plan and why.

The project is on budget

8. PROJECT OUTCOMES

What are the outcomes of the award?

The improved versions of the operational statistical-dynamical models for forecasting TC intensity are being developed.

Are performance measures defined in the proposal being achieved and to what extent?

The performance measures defined in the proposal (the milestones) are being achieved as planned.

9. REFERENCES

Demuth, J., M. DeMaria, and J. A. Knaff, 2006: Improvement of Advanced Microwave Sounding Unit tropical cyclone intensity and size estimation algorithms. *Journal of Applied Meteorology and Climatology*, **45**, 1573–1581.

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