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: NA15OAR4590204

Title: Improvements to Operational Statistical Tropical Cyclone Intensity Forecast Models

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Report Term or Frequency: semi-annual

Final Annual Report? No

1. ACCOMPLISHMENTS

Summary of the project accomplishments for the 3 main project tasks:

1) **Replace in SHIPS and LGEM weekly 1° resolution SSTs with daily 0.25° resolution SSTs.** These changes were designed to improve forecast performance and set the stage for including upper-ocean data to explicitly account for SST cooling. The software for pre-processing daily Reynolds SST (DSST) data was developed and modifications to the model to add the option to use either weekly SST (RSST) or DSST were completed. A new module was added to SHIPS/LGEM to handle the selection of SST and ocean heat content (OHC) data and that module was implemented in the 2016 version of SHIPS on WCOSS. Changes for this task were incorporated into the 2016 version of SHIPS and retrospective and parallel runs with daily SST and verification have been completed. The code to generate global and regional DSST, the modified SHIPS/LGEM, and verification results have been provided to NHC for evaluation. Statistical tests were performed and demonstrated that DSST is very noisy compared to RSST. It was also found that using temporally or spatially averaged DSST produces better improvement to SHIPS and LGEM forecasts, as compared to DSST. The updated real-time processing for DSST data and the updated database of 1982 - 2017 DSST data were provided to NHC, and will be used for operational runs and to include DSST in the SHIPS predictors' database. The spatially-averaged DSST (DSTA) will be implemented in the operational versions of SHIPS and LGEM on WCOSS for 2018.

2) **Add to SHIPS/LGEM a physical mechanism to account for storm-induced SST cooling.** Lin et al. (2013) and Price (2009) have demonstrated that the use of tropical cyclone- (TC) cooled SST instead of SST to calculate the storm maximum potential intensity (MPI) produces a more realistic upper intensity bound estimate and that the ocean temperature vertically-averaged from the surface to the depth of TC-induced mixing is a more robust metric of the SST cooling effect than the OHC. The algorithm for estimating the depth-averaged temperature (DAVT) assuming constant and variable mixing depth from the OHC data available in real-time has been developed and incorporated into the SHIPS and LGEM processing scripts. The option to use either SST or DAVT has been added to both SHIPS and LGEM. It was found that the results of using DAVT in SHIPS and LGEM are not as good as expected to the large extend due to poor quality of input data. The available ocean data that include SST, mixed-layer depth (DML), and depths of 26° and 20° isotherms (D26 and D20), do not provide enough information to accurately estimate DAVT. The OHC, the subsurface ocean data, and the corresponding climatologies were completely re-derived from full ocean profiles to obtain an input dataset (the Extended OHC, EOHC) that allows for the accurate calculation of DAVT. The dependent tests demonstrated improved SHIPS and LGEM forecasts with using re-derived data. The OHC data from EOHC dataset were also found beneficial for SHIPS, LGEM, and RII, and will be used with the operational 2018 version of SHIPS on WCOSS. The final version of the algorithm to use DAVT with variable mixing depth and final regression coefficients will be derived using the 2018 version of SHIPS/LGEM to allow direct comparison of the experimental version with the operational version during 2018 Atlantic and East Pacific hurricane seasons. It is planned to run SHIPS with DAVT in quasi-production on WCOSS for 2018.

3) **Add forecasts of TC structure (wind radii and MSLP) to SHIPS/LGEM.** A statistical-dynamical method to predict TC wind structure (Decay SHIPS Wind Radii, DSWR) in terms of wind radii has been developed and has been running in real-time at CIRA since August 2016. The basis for TC size variations is developed from an infrared satellite-based record of TC size (Knaff et al. 2014), which is homogenously calculated from a 1996-2012 sample. The change in TC size is predicted using a statistical-dynamical approach where predictors are based on environmental diagnostics derived from global model forecasts and observed storm conditions. Once the TC size has been predicted, the forecast intensity and track are used along with a parametric wind model to estimate the resulting wind radii following Knaff et al. (2017). The DSWR code and verification for 2017 was completed and results were provided to NHC and JTWC. DSWR was transitioned to operations at the Joint Typhoon Warning Center (JTWC) in September, 2017. It is planned to run DSWR in quasi-production at WCOSS for the 2018 Atlantic Hurricane season.

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)

Goals, Objectives, Tasks	Planned: Sep 2017 – Feb 2018	Actual: Sep 2017 – Feb 2018
Modify SHIPS and LGEM to use 0.25° daily Reynolds SST	Update DSST database and software and provide final software and data to NHC.	The DSST database was updated to account for the new data format and provided to NHC together with the updated SHIPS and software for processing DSST in real-time.
Modify SHIPS and LGEM models to use DAVT	Derive new ocean data including OHC and subsurface data to obtain a dataset that allows deriving accurate DAVT, and complete depended sample tests with the updated data.	A comprehensive dataset of OHC, DML, and subsurface ocean data was derived from the full ocean profiles. The dependent sample testing demonstrated that the new data provide better improvement to SHIPS and LGEM forecasts. In addition updated OHC proved to be beneficial for SHIPS, LGEM, and RII and will be used in the 2018 operational version of SHIPS.
Add forecasts of TC structure (wind radii and MSLP) to SHIPS/LGEM	Complete verification for 2017 and provided updated software to NHC and JTWC.	Verification for 2017 was completed and the results were provided to NHC and JTWC. DSWR was transitioned to operations at JTWC in September 2017. It is planned to run DSWR in quasi-production on WCOSS from 2018 Atlantic Hurricane 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)
Modify SHIPS and LGEM models to use 0.25° daily Reynolds SST	100%	Feb 2017	Yes
Modify SHIPS and LGEM models to use DAVT	90%	Aug 2018	Yes
Add forecasts of TC structure (wind radii and MSLP) to SHIPS/LGEM	100%	Feb 2017	Yes

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
Updated DSST database and software to account for the changed format of the input data	DSST software and database were updated as planned and provided to NHC
Re- derive ocean dataset required for producing accurate estimates of DAVT	That was additional task requested by NHC based on the results of previous testing. The task was completed as planned and the updated software and databases were provided to NHC
Complete SHIPS verification by comparing the intensity forecasts against the final NHC best track, and size parameters against the final wind radii in the best track	Verification of 2017 DSWR was completed as planned and the results were provided to NHC and JTWC. Verification of SHIPS with DAVT will be completed by August 2018, using 2018 version of SHIPS, as planned.

Detailed description of the work completed for each milestone since the last report is presented below. Some milestones were updated to include additional testing for DAVT and changed datasets. The original milestones are expected to be completed by the end of NCE as planned.

Milestone: updated DSST database and software to account for the changed format of the input data. The format of the DSST data was changed in April 2017 from NetCDF3 to compressed NetCDF4. The software for processing DSST was updated to account for that change. The full 1982 - 2017 database of DSST was updated to ensure that it contains exactly the same data that are available in the updated DSST archive on https://www.ncei.noaa.gov/data/sea-surface-temperature-optimum-interpolation/access/. The updated database and software were provided to NHC. The data will be included in SHIPS developmental database and the software will be used to generate at NHC DSST in SHIPS format that will be used for the 2018 operational versions of SHIPS and LGEM.

Milestone: Re-derive ocean dataset required for producing accurate estimates of DAVT. Testing of SHIPS and LGEM with DAVT completed at the earlier stages of this project demonstrated that DAVT does not provide the expected forecast improvement. It was found that the available ocean data that include SST, mixed-layer depth (DML), and depths of 26° and 20° isotherms (D26 and D20), do not provide enough information to accurately estimate DAVT. NHC requested that ocean data be completely re-derived from the full NCODA ocean profiles available at ftp://usgodae.org/pub/outgoing/fnmoc/models/glb_ocn/. The OHC, the subsurface ocean data, and the corresponding climatologies were completely re-derived from full ocean profiles to obtain an input dataset that allows for the accurate calculation of DAVT. The new dataset includes, DML, OHC, OHC relative to 20° isotherm, depth of all isotherms from 16° to 32°, as well as the maximum temperature (Tmax) at each point to capture temperature inversions, and the depth of the ocean and the temperature of the lowest available level in each profile. These additional points allow for a very accurate estimation of DAVT. Figure 1 shows the R^2 (upper) and Yerr (lower) percent improvement for the dependent tests for the Atlantic (left) and east Pacific (right), showing that use of DAVT results in SHIPS forecast improvement at all forecast times. The global re-derived ocean data together with the software for generating these data in real-time were provided to NHC. The dependent sample tests of SHIPS and LGEM with DAVT estimated from re-derived data demonstrated much better forecast improvement compared to earlier results which used DAVT estimated from just 4 points, SST, DML, D26, and D20. The best results are obtained when using DAVT assuming constant mixing depth of 80 m or variables DAVT, which is consistent with the previous results (i.e. Lin et al. (2013) and Price (2009))

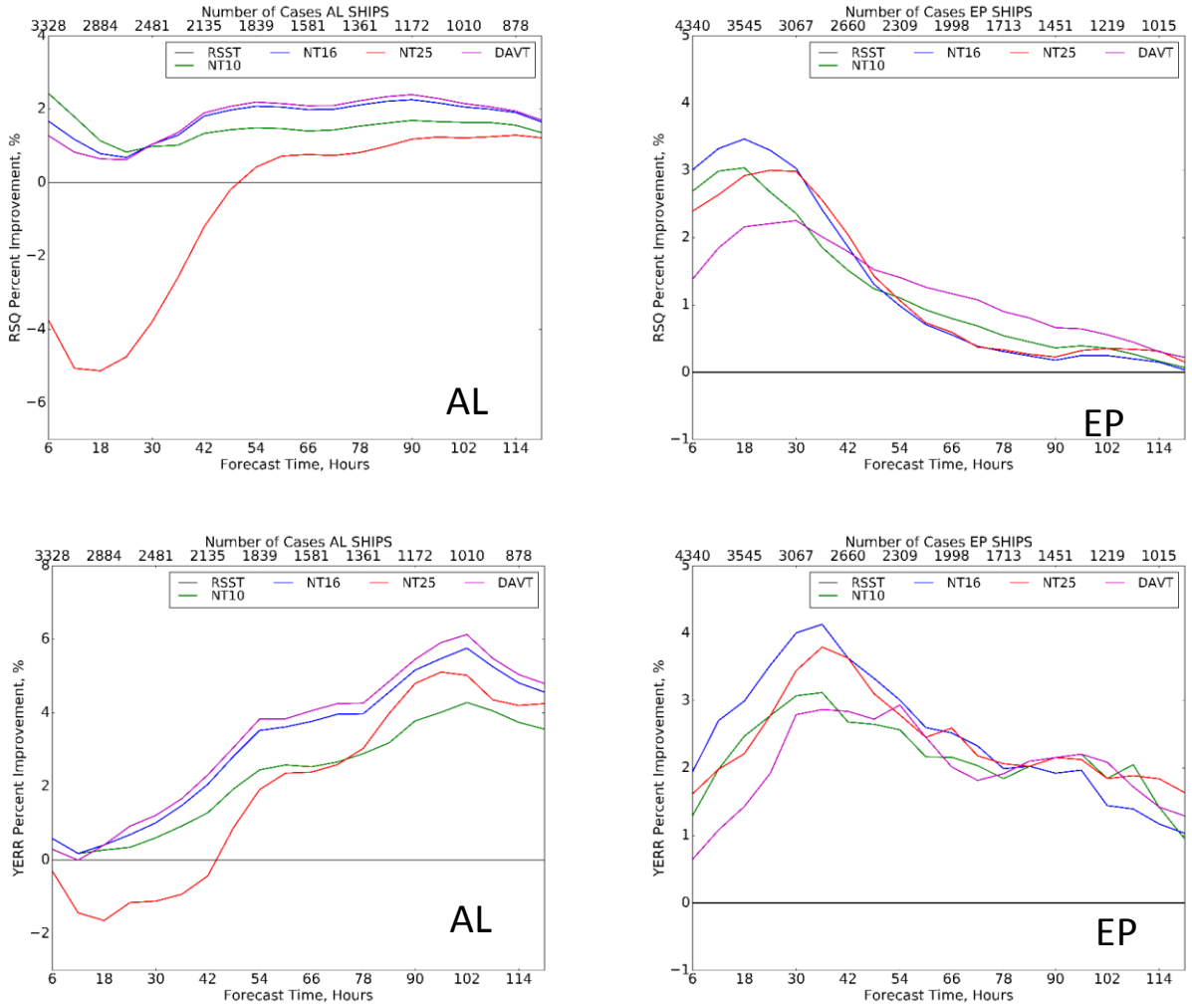

Figure 1. Upper left: R^2 percent improvement for SHIPS/LGEM dependent tests for the Atlantic with weekly SST replaced by DAVT. Black horizontal line is the baseline daily SST (RSST), green line - DAVT assuming constant mixing depth of 50 m (NT10), blue line - same for constant mixing depth of 80 m, red line - 125 m, and purple line - assuming variable mixing depth based on the "ocean age". Lower left: same for east Pacific. Upper right: same for Yerr for the Atlantic, and lower right: same for Yerr for the east Pacific.

Milestone: Complete SHIPS verification by comparing the intensity forecasts against the final NHC best track, and size parameters against the final wind radii in the best track. Verification of DSWR for 2017 was completed and provided to NHC and JTWC. It was found that in the Atlantic DSWP performs similar to other methods and is high-biased. In the east Pacific DSWR is skillful relative to DRCL for 2017. The biases in both east and west Pacific are very low. In addition, it was found that DSWR improves the multi-model wind radii consensus, RVCN that includes GFS (AHNI), HWRF (HHFI), and ECMWF (EMXI). DSWR provided either improvements or no degradation to RVCN when added as a member for all basins and all wind radii thresholds. Figure 2 shows MAE for 2017 RVCN consensus wind radii forecasts with and without using DSWR. The DSWR was transitioned to operations at JTWC in September 2017. It is planned to run DSWR in quasi-production at NHC on WCOSS for the 2018 Atlantic Hurricane season. SHIPS and LGEM verification with final modifications will be completed in the next reporting period using 2018 versions of SHIPS and LGEM to allow for direct comparison with the operational versions of the models.

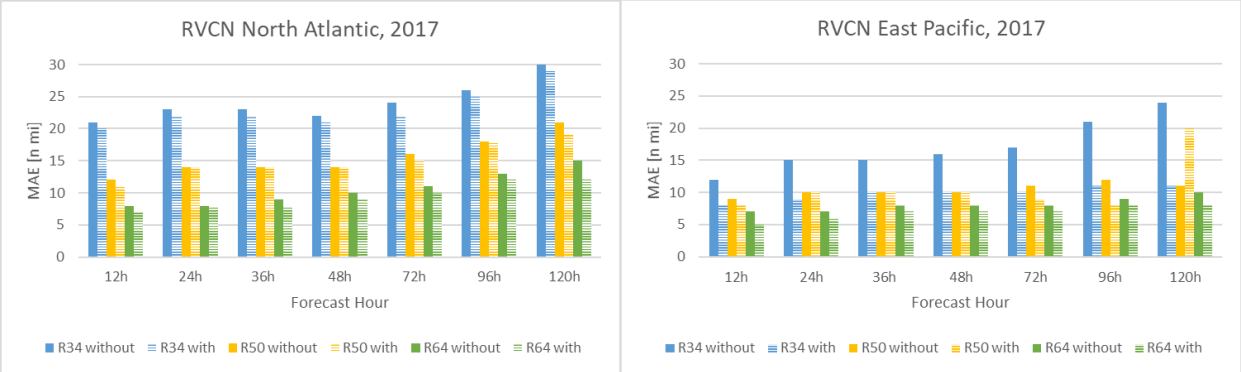

Figure 2: RVCN MAE (Left) for the Atlantic and (Right) East Pacific basin. RVCN included HWRF, GFS, and ECMWF. Solid bars show runs without DSWR and dashed bars show runs with DSWR.

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. Project PIs, Galina Chirokova (in 2016, 2017, and 2018), Andrea Schumacher (in 2017) and Collaborator, John Knaff (in 2016) participated in the TCORF/IHC conferences. There were no training activities during the reporting period.

How were the results disseminated to communities of interest?

1) The project results were presented at the IHC in 2016, 2017, and 2018) The IHC presentations and previous project reports are available online at http://www.nhc.noaa.gov/jht/15-17_proj.php?large. Additional details about the project were communicated to NHC points of contact, Dan Brown, Lixion Avila, and Chris Landsea.

2) Real-time DSWR (2016 and 2017) and SHIPS/LGEM with DSST (2016) forecasts were also provided to NHC POCs via an ftp server per NHC's request.

3) Verification of 2016 retrospective runs with DSST and dependent test with DAVT were provided to NHC.

3) The DSWR code has been provided to NHC and Naval Research Laboratory (NRL), Monterey for implementation at JTWC. The DSWR was transitioned to operations at JTWC in September, 2017.

4) The 2017 SHIPS/LGEM code updated to use RSST, DSST, or DAVT was provided to NHC. The changes will be implemented in the 2018 operational version of SHIPS.

5) The global and regional DSST and the new EOHC ocean data together with the software for creating and reading historical and real-time DSST and EOHC data were provided to NHC. The updated database of DSST, OHC, and ocean data will be included in the SHIPS developmental database, and should eventually replace the RSST and the old OHC data. The software for generating real-time DSST and OHC data will be used to generate data for the operational 2018 SHIPS and LGEM.

6) The updated climatology of DSST, OHC, D20, D26, DML, and all other variables included in the EOHC dataset, as well as the software for updating, reading, and including that climatology into SHIPS developmental database was provided to NHC.

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 conduct retrospective runs and verification of the experimental version of the 2018 SHIPS/LGEM with DAVT assuming either constant or variable mixing depth. In addition, final adjustments and modifications to the code will be implemented based on the results of the retrospective runs. We will further work with JHT and NHC TSB staff to implement experimental versions of SHIPS/LGEM and DSWR on quasi-production on WCOSS for the 2018 season and/or will implement parallel runs at CIRA.

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
2017 SHIPS/LGEM code modified to work with RSST, DSST, and DAVT	Provided to NHC as planned
Updated DSST database in SHIPS format for global and regional files for 1982 - 2017	Provided to NHC as planned
Verification of SHIPS/LGEM dependent tests with the re-derived DAVT	Provided to NHC as planned
New dataset of the OHC and subsurface ocean data for 2006 - 2017	Provided to NHC as planned
Updated climatology for DSST, OHC, MLD, and depths of 16° (D16) - d32° (D20) isotherms	Provided to NHC as planned
Updated software for processing DSST and EOHC climatology	Provided to NHC as planned
Software for real-time processing of DSST and EOHC data	Provided to NHC as planned
Verification of DSWR runs	Provided to NHC as planned

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

Presentations:

Chirokova G., J. Kaplan, and J. Knaff, 2018: Improvements to Operational Statistical Tropical Cyclone Intensity Forecast Models Using Wind Structure and Eye Predictors. *2018 Tropical Cyclone Operations and Research Forum (TCORF)/71th Interdepartmental Hurricane Conference (IHC), 13-15 March, 2018, Miami, Florida*. The presentation will be available online at http://www.nhc.noaa.gov/jht/15-17_proj.php?large.

Schumacher A., G. Chirokova, J. Knaff, and M. DeMaria, 2018: Improvements to Operational Statistical Tropical Cyclone Intensity Forecast Models. 98th AMS Annual Meeting / 22nd Conference on Satellite Meteorology and Oceanography, 7 - 11 January 2018, Austin Texas

Publication: A manuscript detailing the statistical-dynamical method to predict tropical cyclone wind structure in terms of wind radii method, its independent performance in 2014 and 2015, and how it may contribute to the wind radii consensus has been published in Weather and Forecasting.

Knaff, J., C. Sampson, and G. Chirokova, 2017: A global statistical–dynamical tropical cyclone wind radii forecast scheme. *Wea. Forecasting*, **32**, 629–644, doi: 10.1175/WAF-D-16-0168.1.

Highlights of that paper suggest:

1. This method (DSWR) is a competitive method for predicting the wind radii, even if the SHIPS forecasts of intensity and track are used for wind radii estimates.
2. That its inclusion in a simple wind radii consensus (RVCN), results in no degradation, and, in most cases, improves the consensus forecasts.
3. That the predictors related to mid-level moisture (+), initial size (-), storm latitude (+), 200 hPa divergence (+) are best related to changes in TC size, the sign of the relationships is shown in parentheses.

-website(s) or other Internet site(s);

- The real-time DSRW forecasts are available at ftp://rammftp.cira.colostate.edu/knaff/DSWR/

-technologies or techniques;

- Improved (lower biased) TC vortex model for wind radii.
- Method to estimate DAVT from limited, yet routinely measured ocean parameters.

-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.

- New improved EOHC dataset that includes OHC and other subsurface ocean data. EOHC dataset includes both global and regional files.
- Database of DSST data converted to SHIPS input format. The database includes both global and regional files.
- Updated climatology of DSST, OHC, MDL, D16 - D32, based on the EOHC data for 2005 - 2017
- Database of NCODA OHC, D16 - D32, OHC20, and MLD converted to SHIPS input format. The database includes both global and regional 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, Andrea Schumacher, Robert DeMaria, Jack Dostalek

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 addresses program priorities NHC-1/JTWC- 1, NHC-13/JTWC- 10, and NHC-17/JTWC-13. The results of this project will first provide improved statistical-dynamical guidance for TC intensity. These intensity guidance techniques are routinely used operationally at NHC and JTWC to forecast TC intensity. Secondly this project developed a new statistical-dynamical forecast guidance for TC structure (i.e., wind radii) that appears somewhat independent to NWP guidance, making it a nice addition to wind radii consensus methods.

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 operations. Examples include DAVT calculations assuming constant or variable storm-induced mixing depth and a simple vortex model.

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.

It was found that the available ocean data that include SST, mixed-layer depth (DML), and depths of 26° and 20° isotherms (D26 and D20), do not provide enough information to accurately estimate DAVT. NHC requested that ocean data be completely re-derived from the full NCODA ocean profiles available at ftp://usgodae.org/pub/outgoing/fnmoc/models/glb_ocn/. The ocean data were re-derived, and the new EOHC dataset was developed using subsurface ocean data from full ocean profiles. The DAVT estimated from re-derived data provides improvement to the SHIPS/LGEM forecasts. In addition, OHC data from the EOHC dataset will be implemented in the 2018 operational version of SHIPS, LGEM, and RII.

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

A one-year NCE for the project was requested and approved by NOAA. The extension is used to complete additional testing and provide to NHC the final updated version of the developed software and databases, as well as final verification results. Additional milestones required to produce new datasets and conduct additional testing were completed in this reporting period. The remaining project milestones are expected to be completed by August 2018.

-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: RL6-7

-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 NCE, in the spring of 2019, if accepted by NHC. The timing of the final transition will depend on the availability of NHC Technology and Science Branch (TSB) resources.

However, several items developed as part of this project were already transitioned to operations, including:

- Fixes to some minor computer bugs in the SHIPS/LGEM/RII processing that were identified in the course of this work were implemented in the 2016 operational version of the NHC guidance suite on WCOSS.
- The spatially-averaged DSST data and OHC data from the new EOHC dataset produced by this project will be implemented in the operational 2018 version of SHIPS and LGEM in the NHC guidance suite on WCOSS.
- The DSWR was transitioned to operations at JTWC in September, 2017.

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

1) Real-time forecasts of the TC-size estimates were made available via the CIRA ftp server, server at ftp://rammftp.cira.colostate.edu/knaff/DSWR/ starting on the 18th of August. Past forecasts made in 2016 were also provided at this time.

2) Real-time SHIPS forecasts with DSST were made available via CIRA ftp server at
ftp://rammftp.cira.colostate.edu/chirokova/JHT_2015_2017/rt_demo/
during 2016 Atlantic and East Pacific Hurricane seasons.

3) Verification of the retrospective SHIPS runs with DSST and parallel runs from 2016 season were provided to NHC

4) 2017 version of SHIPS modified to use DSST and DAVT was provided to NHC.

5) DSWR model was provided and tested on WCOSS for potential 2017 or 2018 quasi-prod production.

6) Updated database of DSST global and regional data from 1982 – 2017 in SHIPS format was provided to NHC

7) Re-derived EOHC global and regional datasets for 2005 - 2017 were provided to NHC

8) Updated NCODA-based climatology of DSST, OHC, MLD, D26, and D20 and all ocean variables included in the EOHC dataset was provided to NHC together with the software for creating and reading that climatology and adding climatological data to the SHIPS diagnostic files

9) Software for generating DSST and EOHC data in SHIPS format in real-time was provided to NHC and will be used to generate data for the operational 2018 versions of SHIPS and LGEM.

9) The possibility of including Decay SHIPS Wind Radii (DSWR) and MSLP estimates in operational Automated Tropical Cyclone Forecast System (ATCF) A-decks has been discussed with NHC points of contact (POCs). The implementation of DSWR in the operational A-decks for 2018 season will depend on the availability of NHC resources.

9) The possibility of implementing SHIPS with DAVT in the quasi-production version of SHIPS on WCOSS for 2018 seasons has been discussed with NHC POCs and NHC TSB staff. The implementation

of SHIPS with DAVT in the quasi-production for 2018 season will depend on the availability of NHC TSB resources.

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

Testing of SHIPS with DAVT and DSWR for this project is planned for the experimental quasi-production version of the NHC Guidance Suite on WCOSS during 2018 season. The implementation of the new products in the quasi-production for 2018 season will depend on the availability of NHC TSB resources.

-- What was transitioned to NOAA?

The following software was transitioned to NOAA:

1) Some minor computer bugs in the SHIPS/LGEM/RII processing were identified in the course of this work, and were corrected in the 2016 operational version of the NHC guidance suite on WCOSS.

2) Software necessary for DSWR forecasts with updated coefficients were provided to NHC. The implementation of DSWR is planned (personal communication, Mark DeMaria) on quasi production for forecasting during the 2018 season, depending on the availability of NHC TSB resources

3) 2017 version of SHIPS model with the option to use both DSST and DAVT was provided to NHC. The new modifications will be implemented in the 2018 operational version of SHIPS and LGEM.

4) Updated database of DSST data (1982 - 2017) and newly derived EOHC data (2005 - 2017) were provided to NHC and will be included in the SHIPS developmental database

5) Updated climatology of DSST and ocean data, including IHC, D26, D20, and MLD climatology, as well as climatology of other variables included in the EOHC dataset and related software.

6) Software for generating real-time DSST and EOHC data that will be used to run 2018 operational versions of SHIPS, LGEM, and RII

7) DSWR model was transitioned to operations at JTWC in September, 2017

Test Plans for USWRP-supported Testbed Projects

*I. What **concepts/techniques** will be tested? What is the scope of testing (what will be tested, what won't be tested)?*

The following models will be tested:

- SHIPS/LGEM with DAVT assuming constant mixing depth
- SHIPS/LGEM with DAVT assuming variable mixing depth
- DSWR

*II. **How** will they be tested? What **tasks** (processes and procedures) and activities will be performed, what preparatory work has to happen to make it ready for testing, and what will occur during the experimental testing?*

1) Tasks that will be performed during testing at CIRA:
- run scripts to receive operational SHIPS diagnostic files in real-time

- run scripts to add DAVT to the operational diagnostic files
- run the models
- save the model output and make it available to NHC and JTWC via ftp

2) Preparatory work:
- complete retrospective runs using 2018 version of SHIPS/LGEM
- derive updated coefficients for different version of SHIPS

3) During the testing:
- monitor model performance
- conduct post-season verification

III. ***When*** *will it be tested? What are* ***schedules and milestones*** *for all tasks described in section II that need to occur leading up to testing, during testing, and after testing?*

1) When it will be tested:
- During the 2018 Atlantic and East Pacific Hurricane seasons

2) Schedules and Milestones:
- Complete retrospective runs of modified SHIPS/LGEM (Oct 2017 - June 2018)
- Coordinate with TSB staff to implement parallel runs on quasi-production on WCOSS or implement them at CIRA (Jun 2018 - Aug 2018)
- Complete post-season verification (Dec 2018 - Jan 2019)

IV. ***Where*** *will it be tested? Will it be done at the PI location or a NOAA location?*

1) If possible, the updated models will tested on quasi-production on WCOSS, depending on the availability of TSB resources.

2) If parallel runs of experimental SHIPS/LGEM and DSWR cannot be implemented on quasi-production, they will be implemented at CIRA.

V. *Who are the key* ***stakeholders*** *involved in testing (PIs, testbed support staff, testbed manager, forecasters, etc.)? Briefly what are their* ***roles and responsibilities****?*

Stakeholders and Roles:
- PIs: prepare model: provide code and data to NHC, conduct parallel runs at CIRA if needed
- TSB staff and JHT support staff: if possible, implement updated models on quasi-production on WCOSS. Evaluate the new products and provide feedback.
- JHT POCs: monitor the model performance and provide feedback to PIs

VI. *What* ***testing resources*** *will be needed from each participant (hardware, software, data flow, internet connectivity, office space, video teleconferencing, etc.), and who will provide them?*

- The updates models require resources similar to the operational versions. Existing hardware and software will be used for testing on quasi-production on WCOSS and/or at CIRA.

VII. *What are the* ***test goals, performance measures, and success criteria*** *that will need to be achieved at the end of testing to measure and demonstrate success and to advance Readiness Levels?*

1) Test goals:
- Evaluate the performance of the updated and new models
- Compare experimental parallel runs with operational runs
- Provide testing results to NHC and JTWC and respond to feedback

2) Performance measures:
- Model verification with the algorithms that are used to evaluate the performance of the operational models

3) Success criteria:
- Performance of the experimental models compared to the performance of the operational models

VIII. *How will testing **results** be documented? Describe what information will be included in the **test results final report**.*

Test results will be provided to NHC and JHT in the final project report and test results final report.
1) The documentation of the test results will include:
- the results of retrospective model verification
- the results of the post season verification of real-time runs.
2) The test results final report will include the result of the retrospective model verification. The post season verification cannot be completed until the end of the hurricane season, therefore these results might not be available in time to be included in the test results final report.

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 version of the operational statistical-dynamical models for forecasting TC intensity is being developed. The new statistical dynamical model for forecasting TC wind radii has been 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

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I.-I. Lin, P. Black, J. F. Price, C.-Y. Yang, S. S. Chen, C.-C. Lien, P. Harr, N.-H. Chi, C.-C. Wu and E. A. D'Asaro, 2013: An ocean coupling potential intensity index for tropical cyclones. *Geophysical Res. Letters*, **40**, 1878–1882. DOI: 10.1002/grl.50091

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Appendix B

NOAA READINESS LEVELS (RLs)

There are nine readiness levels defined in NOAA Administrative Order 216-105A as follows:

A. Research

RL 1: Basic research: experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundations of phenomena and observable facts, without any particular application or use in view. Basic research can be oriented or directed towards some broad fields of general interest, with the explicit goal of a range of future applications;

RL 2: Applied research: original investigation undertaken in order to acquire new knowledge. It is, however, directed primarily towards a specific, practical aim or objective. Applied research is undertaken either to determine possible uses for the findings of basic research or to determine new methods or ways of achieving specific and predetermined objectives.

B. Development

RL 3: Proof-of-concept for system, process, product, service or tool; this can be considered an early phase of experimental development; feasibility studies may be included;

RL 4: Successful evaluation of system, subsystem, process, product, service or tool in laboratory or other experimental environment; this can be considered an intermediate phase of development;

RL 5: Successful evaluation of system, subsystem process, product, service or tool in relevant environment through testing and prototyping; this can be considered the final stage of development before demonstration begins;

C. Demonstration

RL 6: Demonstration of prototype system, subsystem, process, product, service or tool in relevant or test environment (potential demonstrated);

RL 7: Prototype system, process, product, service or tool demonstrated in an operational or other relevant environment (functionality demonstrated in near-real world environment; subsystem components fully integrated into system);

RL 8: Finalized system, process, product, service or tool tested, and shown to operate or function as expected within user's environment; user training and documentation completed; operator or user approval given;

D. Deployment

RL 9: System, process, product, service or tool deployed and used routinely.