

**Submitted to: OAR Office of Weather and Air Quality (OWAQ)**

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**Project Title:** Improvement to the Tropical Cyclone Genesis Index (TCGI)

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**Recipient Organization:** Cooperative Institute for Research in the Atmosphere, Colorado State University, 1375 Campus Delivery, Fort Collins, CO 80523-1375

**Project/Grant Period:** 09/01/2015 - 08/31/2017

This project was granted a no-cost extension with an end date of 8/31/2018

**Reporting Period Start/End Date:** 03/01/2017 - 08/31/2017

**Report Term or Frequency:** Quarterly

**Reporting Timeline:** Year-2 final report

## **1. ACCOMPLISHMENTS**

The main goal of this project is to implement improvements to the Tropical Cyclone (TC) Genesis Index (TCGI) that was transitioned to operations at the NOAA National Hurricane Center (NHC) in October 2014. TCGI is a disturbance-following scheme designed to provide forecasters with an objective tool for identifying the 0-48hr and 0-120hr probability of TC genesis in the North Atlantic basin. Progress made under this current funded project includes expanding the TCGI North Atlantic database to include the years 2001-2014, developing a new 2001-2014 Pacific (eastern north Pacific (EPAC) and central North Pacific (CPAC)) TCGI database, identifying new predictors to test in both the Atlantic and Pacific versions of TCGI, deriving an eastern/central Pacific basin TCGI utilizing predictors that were employed in the previously developed Atlantic basin version and developing an ECMWF-based Atlantic TCGI using predictors and predictor weights that were developed for the GFS version of TCGI. The following tasks were conducted and/or completed during this reporting period:

- i. Begin development of an ECMWF-based Atlantic TCGI using predictors and predictor weights that were developed for the GFS version of TCGI (April 2016)*
  - Development of the ECMWF TCGI is complete and real-time code has been implemented and tested on WCOSS (Sept 2017). We are still working with the Technology & Science Branch (TSB) at NHC to obtain real-time ECMWF tracks and forecast fields at CIRA so that parallel runs can be performed.

ii. *Begin sensitivity testing for optimal combinations of Atlantic and Pacific TCGI predictors- GFS version (June-November 2016)*

- New TCGI predictors using the 2001-2014 Atlantic and Pacific datasets were tested alongside ~60 other previously tested predictors. Sensitivity tests included WWLLN lightning data, Tropical Overshooting Tops (only available in the Atlantic), and several GFS-based predictors: (1) relative humidity (850-600 hPa and 1000-925 hPa), (2) moisture convergence at 850 hPa, (3) vertical wind shear magnitude and direction for the 850-500 hPa layer, (4) generalized vertical wind shear from 1000-100 hPa, and (5) vorticity x divergence at 850 hPa.
- All area-averaged predictors were calculated using the original TCGI 0-500 km predictor search radius, as well as several smaller search radii: 0-200, 0-300, and 0-400 km. Although dependent dataset tests indicated that smaller search radii were increasingly skillful, simulated real-time tests for 2011-2016 showed that smaller search radii, in fact, produce increasingly less skillful TCGI forecasts. This discrepancy likely relates to the fact that the dependent test benefitted “perfect prog” forecasts (i.e. tropical disturbance positions were known throughout the storm lifecycle), which is not representative of real-time operations. The 2011-2016 simulated real-time tests suggest that track forecast uncertainty inherent in weak tropical disturbances is significant and requires the use of 0-500 km search radii for both 0-48 and 0-120 hr TCGI forecasts.
- Sensitivity tests were conducted to identify the optimal combination of predictors for the expanded version of the Atlantic TCGI and new Pacific TCGI. These 6 optimal predictors calculated using the 0-500 km search radius are highlighted in Fig. 1 and will be used for both the Atlantic and Pacific versions of TCGI. Figure 2 shows the cross-validated Brier Skill Score for the new Atlantic and Pacific versions of TCGI derived from the 2001-2014 TCGI invest database.

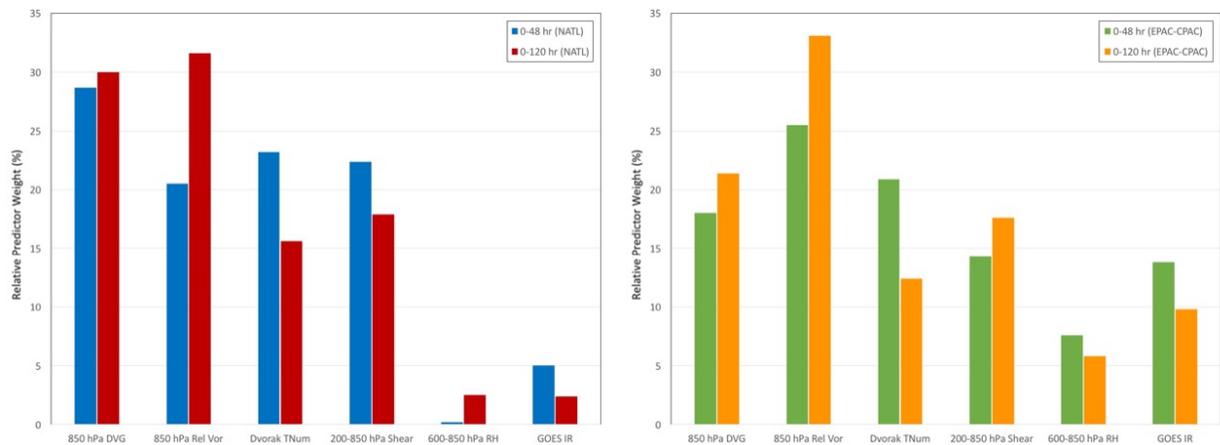


Fig. 1: Relative predictor weights for the new 2001-2014 Atlantic (left) and Pacific (right) versions of TCGI. The 0-48 hr predictor weights are shown in blue (Atlantic TCGI) and green (Pacific TCGI) and the 0-120 hr predictor weights are shown in red (Atlantic TCGI) and orange (Pacific TCGI). Predictors include: 850 hPa divergence (DVG), 850 hPa relative vorticity (Rel Vor), Dvorak T-number (TNum), 200-850 hPa vertical wind shear (Shear), 600-850 hPa relative humidity (RH), and GOES water vapor pixels <-40°C (GOES IR). Predictor weights were derived using 0-500 km search radii.

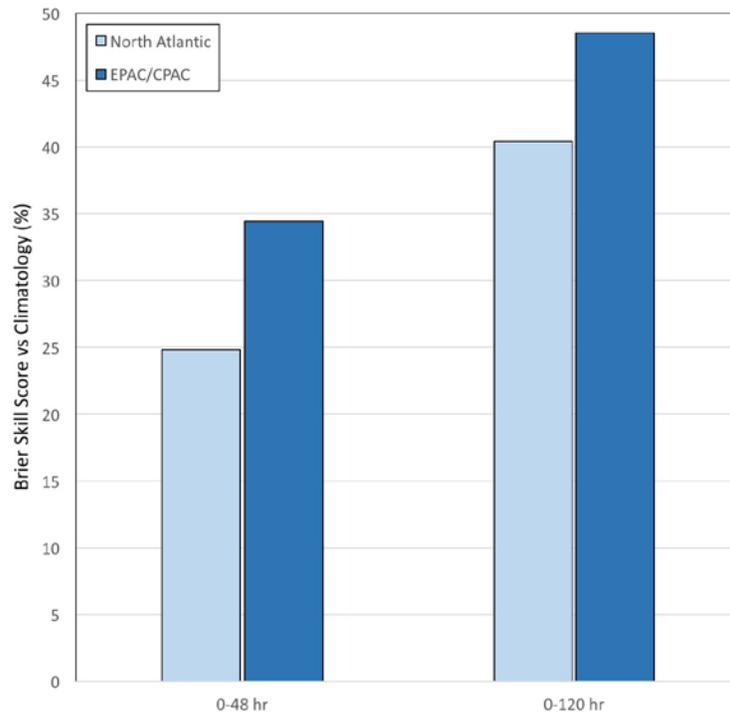


Fig. 2: Cross-validated Brier Skill Score (relatively to climatology) for the new Atlantic and Pacific versions of TCGI based on the 2001-2014 TCGI invest database.

- iii. *Perform real-time tests of 0-48 and 0-120 h Atlantic and Pacific TCGI (GFS version) on NESDIS computers at CIRA with output being made available online at (May-August 2017): [http://rammb.cira.colostate.edu/realtime\\_data/nhc/tcgi/](http://rammb.cira.colostate.edu/realtime_data/nhc/tcgi/)*
  - The new Atlantic and Pacific versions of TCGI have been running in real-time at CIRA through the 2017 season. Output has been available online at: [http://rammb.cira.colostate.edu/projects/tc\\_genesis/](http://rammb.cira.colostate.edu/projects/tc_genesis/)
- iv. *Perform real-time tests of 0-48 and 0-120 h Atlantic and Pacific TCGI (ECMWF version) at NHC (requires computing and IT support from NHC) (May-August 2017)*
  - Real-time tests of the ECMWF TCGI were conducted during Co-PI Schumacher's visit to NHC from 8/28-9/1 2017. The ECMWF TCGI was set up to run right after the GFS version finishes, with output files named: YYMMDDHH{bas}YY\_tcgie.txt. After this visit, a small script error was found by Co-PI Schumacher that is preventing the ECMWF files from being created since 9/1/17. Co-PI Schumacher will fix this bug during her next scheduled visit to NHC in November 2017.
- v. *Finish development/evaluation of prototype ECMWF-based Atlantic TCGI (May-August 2017)*
  - See item iv above.

- vi. *Work with IT personnel at NOAA NHC to establish a means to more efficiently access real-time NOAA TAFB Dvorak fix information. This will help ensure increased reliability of real-time TCGI forecasts for use by NHC forecasters (May-August 2017).*
  - The new Atlantic and Pacific versions of TCGI now use NOAA TAFB Dvorak fix files instead of fixes from the f-decks. Since this change was put into place, TCGI runs have been much more timely and consistent. This improvement was implemented for TCGI on WCOSS and the parallel TCGI being run at CIRA.
- vii. *Final code for running both the Atlantic and Pacific versions of TCGI on operational NCEP computers will be provided to NHC/NCEP IT personnel if the project is accepted for operational transition (August 2017).*
  - Atlantic and N.E. Pacific versions of the updated GFS-based TCGI and the new ECMWF-based TCGI are running in a quasi-production environment on WCOSS. A few minor bug fixes need to be implemented during A. Schumacher's next visit to NHC (November 2017) based on product feedback gathered since the last updates made in September 2017.

Deliverables *ii*, *iii*, and *vi* have been completed. Deliverables *i*, *iv*, *v*, and *vii* are nearing completion and will be carried out during the approved no-cost extension period of this project. We anticipate that all deliverables will be completed by the end of the calendar year 2017.

## 2. PRODUCTS

Efforts related to this project's current reporting period have produced the following:

- a. Conference Papers & Presentations
  - Dunion, J.P., J. Kaplan, A.B. Schumacher, J. Cossuth, K.D. Musgrave, and P. Leighton, 2017: Improvements to the Tropical Cyclone Genesis Index (TCGI). *71<sup>st</sup> Tropical Cyclone Operations and Research Forum*, Miami, FL, Office of Fed. Coord. For Meteor. Services and Supporting Research, NOAA. <http://www.ofcm.gov/meetings/TCORF/tcorf.htm>
  - Dunion, J.P., J. Kaplan, A. B. Schumacher, J. Cossuth, K.D. Musgrave, and P. Leighton, 2016: The Tropical Cyclone Genesis Index (TCGI), *32<sup>nd</sup> Amer. Meteor. Soc. Conf. on Hurricanes and Tropical Meteor.*, San Juan, Puerto Rico. <https://ams.confex.com/ams/32Hurr/webprogram/start.html>
- b. Real-Time TCGI Website (hosted by the Colorado State University-CIRA):
  - [http://rammb.cira.colostate.edu/projects/tc\\_genesis/](http://rammb.cira.colostate.edu/projects/tc_genesis/)
- c. 2001-2014 Tropical Disturbance Database for the Atlantic and Pacific
  - An updated tropical disturbance database for the North Atlantic spanning the years 2001-2014 has been developed under this project.
  - A new tropical disturbance database for the central and eastern North Pacific spanning the years 2001-2014 has been developed under this project.
- d. Software for Analyzing Tropical Cyclone Genesis in Atlantic and Pacific

- New software has been developed to analyze important tropical cyclone inner core and environmental predictors for forecasting tropical cyclone genesis.
- Algorithms have been developed to analyze the 2001-2014 Atlantic and Pacific databases and have been incorporated into the upgraded (new) TCGI for the Atlantic (Pacific).

### **3. PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS**

The following team members have contributed to this project (no changes to senior/key project personnel has occurred since the last reporting period and only the personnel and institutions listed below have been involved in the project during this reporting period):

**PI:**

Jason Dunion, University of Miami/CIMAS – NOAA/AOML/HRD, [jason.dunion@noaa.gov](mailto:jason.dunion@noaa.gov)

**Co-PIs:**

John Kaplan, NOAA/AOML/Hurricane Research Division, [john.kaplan@noaa.gov](mailto:john.kaplan@noaa.gov)

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**Co-Is:**

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Kate Musgrave, Colorado State University/CIRA, [Kate.Musgrave@colostate.edu](mailto:Kate.Musgrave@colostate.edu)

The following lists the tasks outlined in Sec. 1 and the project team members who contributed to those efforts:

- Task i: Co-PI Schumacher and Co-I Musgrave
- Task ii: PI Dunion and Co-PI Kaplan
- Task iii: Co-PI Schumacher and Co-I Musgrave
- Task iv: Co-PI Schumacher
- Task vi: Co-PI Schumacher and Co-I Musgrave
- Task vii: Co-PI Schumacher

### **4. IMPACT**

This project is in the developmental year-2 phase the important NOAA-identified impacts for this reporting period do not apply. None of this project's awarded budget has been spent in a foreign country.

### **5. CHANGES/PROBLEMS**

No changes to the methodology and approach for this project have been made for this reporting period. The project budget is on track and future changes are not anticipated. A few of the project timelines require assistance from TSB IT personnel at NHC and were delayed. A no-cost extension was requested and approved to allow extra time for these final deliverables to be completed.

## 6. SPECIAL REPORTING REQUIREMENTS

The readiness level for this reporting period is estimated to be RL5 to RL6. Upcoming efforts in fall 2017 will elevate the project to RL7 to RL8. The following outlines test plans for this USWRP-supported testbed project:

- I. *What concepts/techniques will be tested? What is the scope of testing (what will be tested, what won't be tested)?*
  - TC genesis forecasts from the new GFS model-based Atlantic and Pacific versions of TCGI are being tested in real-time on the NOAA/NCEP WCOSS computer.
  - TC genesis forecasts from the new ECMWF model-based Atlantic and Pacific versions of TCGI will be tested in real-time on the NOAA/NCEP WCOSS computer.
- 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?*
  - The new Atlantic and Pacific versions of TCGI are being run in a parallel real-time mode to the current operational version of TCGI. The computer code for the new TCGI has also been installed on WCOSS and is running in real-time.
- 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?*
  - Testing and evaluation of the new TCGI code has been conducted since the beginning of the 2017 Atlantic hurricane season.
- IV. *Where will it be tested? Will it be done at the PI location or a NOAA location?*
  - The new TCGI is being run in parallel on both the NOAA/NCEP WCOSS computer and on servers at the Cooperative Institute for Research in the Atmosphere. Project personnel are testing and evaluating TCGI on both computing systems.
- V. *Who are the key stakeholders involved in testing (PIs, testbed support staff, testbed manager, forecasters, etc.)? Briefly what are their roles and responsibilities?*
  - The entire project team is involved in testing and evaluating the new TCGI. Feedback from this project's NHC points of contact have also been vital and they have been included during the ongoing testing and evaluation process. Some support/input from IT personnel at NOAA NHC has been and still is required to ensure that the ECMWF model data is available in real-time for use in the ECMWF-based Atlantic TCGI.
- 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?*
  - Continued access to the NOAA/NCEP WCOSS system will be required.

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?*

- Real-time availability of TCGI, as well as statistical assessments of TCGI's performance during the 2017 Atlantic and eastern/central North Pacific hurricane seasons will be assessed to demonstrate success and advance the readiness levels.

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

- Statistics of TCGI's performance during the 2017 Atlantic and eastern/central North Pacific hurricane seasons will be made and will include reliability diagrams and Brier Skill Scores. These results will be included in a final JHT report to NOAA.

## **7. BUDGETARY INFORMATION**

This project's budget is on track and no budget changes are anticipated.

## **8. PROJECT OUTCOMES**

The main deliverable of this project is to implement improvements to the Tropical Cyclone Genesis Index (TCGI) that was transitioned to operations at NOAA NHC in October 2014. The outcome of this effort will be to turn over the operational code for running the upgraded TCGI to NOAA by the end of the 2017 calendar year. Performance measures that are defined in this project are being achieved and although a few of the deliverables have been delayed, a recently approved no-cost extension will help ensure that these deliverables will be completed.