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

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This Progress Report Period: 9/1/2015 – 3/30/2016
Entire Project Period: 9/1/2015 – 8/31/2017

1. General Description of Progress

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.

2. Transition to Operations

a. Summary of testbed-related activities and outcomes

TCGI was originally funded as a 2-year NOAA JHT project that began in September 2011. An Atlantic version of TCGI was successfully transitioned to operations at NHC in October 2014 and the current project objectives include improving TCGI and expanding it to the Pacific.

b. What was transitioned?

The operational code to run the Atlantic TCGI was transitioned to operations at NHC in October 2014 and is currently running on the NOAA NCEP Weather & Climate Operational Supercomputing System (WCOSS).

c. TRL current vs. start of project*

TCGI is currently at TRL 8 (actual system completed and "mission qualified" through test and demonstration in an operational environment). The current project efforts to improve and expand TCGI began at TRL 3 (analytical and experimental critical function and/or characteristic proof-of-concept) are currently at TRL 4 (component/subsystem validation in laboratory environment). We anticipated this project to be at TRL 7 (system prototyping demonstration in an operational environment) by August 2017.

d. Lessons learned

If this project is accepted we will apply the lessons learned from the previous TCGI JHT project regarding the challenge of converting the new TCGI code to an operational environment (i.e. the NCEP WCOSS).

e. Next steps – future plans (has it been approved for transition yet? Plans for future transition?

Although TCGI has been successfully transitioned to operations at NHC, the current TCGI project efforts are in their early stages and have not been approved for transition yet. We will complete the following deliverables outlined in the timeline below to help ensure that this project can be completed and considered for transition to operations at NHC:

April 2016	Begin development of an ECMWF-based Atlantic TCGI using predictors and predictor weights that were developed for the GFS version of TCGI
June-Nov 2016	Begin sensitivity testing for optimal combinations of Atlantic and eastern/central Pacific TCGI predictors (GFS version)
Aug-Oct 2016	Develop and test graphical TCGI products with real-time cases
Dec 2016	Develop code for running a real-time version of the Atlantic and eastern/central Pacific TCGI (GFS version)
March 2017	Present year-2 results at IHC
April 2017	Based on POC and IHC feedback, refine TCGI graphical products.
June-Aug 2017	Perform real-time tests of TCGI graphical products in-house at NHC or online at: http://rammb.cira.colostate.edu/realtime_data/nhc/tcgi/
May-Aug 2017	Perform real-time tests of 0-48 and 0-120 h Atlantic and eastern/central Pacific TCGI (GFS version) on NESDIS computers at CIRA with output being made available online at: http://rammb.cira.colostate.edu/realtime_data/nhc/tcgi/
	Perform real-time tests of 0-48 and 0-120 h Atlantic and eastern/central Pacific TCGI (ECMWF version) at NHC (requires computing and IT support from NHC)
May-Aug 2017	Finish development/evaluation of prototype ECMWF-based TCGI for Atlantic
Aug 2017	Final code for running both the Atlantic and eastern/central Pacific TCGI on operational NCEP computers will be provided to NHC/NCEP IT personnel if the project is accepted for operational transition.

3. Milestones

a. Completed

i. Collect, quality control, and format 2011-2014 Atlantic Dvorak information

This element of the proposal effort (led by Co-PI Cossuth) involved expanding the current TCGI NHC invest database by an additional 4 years (2011-2014). The new 2001-2014 database includes 6-hourly information including Dvorak T-number, CI number, and invest position for all Atlantic disturbances that were tracked by NHC over the 14-year period. This now-

completed 2001-2014 Atlantic invest database will provide two vital components to TCGI project: 1) a climatology of developing and non-developing tropical disturbances that were tracked by NHC in the Atlantic (including 6-hourly positions). This information will be used as a training set for the improved TCGI; and 2) Dvorak T-numbers (i.e. satellite-derived intensity estimates) for these developing and non-developing tropical disturbances. *"T-Num"* is one of the predictors currently used in the operational version of TCGI and one of the top predictors for determining TC genesis in the 2-day timeframe.

ii. Collect, quality control, and format 2011-2014 EPAC/CPAC Dvorak information

This element of the proposal effort involved developing a 2001-2014 TCGI NHC invest database for the Pacific basin. The new 2001-2014 database includes 6-hourly information including Dvorak T-number, CI number, and invest position for all Pacific (EPAC and CPAC) disturbances that were tracked by NHC over the aforementioned 14-year period. This 2001-2014 Pacific invest database will provide two vital components to TCGI project:

1) A climatology of developing and non-developing tropical disturbances that were tracked by NHC in the Pacific (including 6-hourly positions). This information will be used as a training set for the new Pacific TCGI;
2) Dvorak T-numbers (i.e. satellite-derived intensity estimates) for these developing and non-developing tropical disturbances. Dvorak *T-Num* is one of the predictors currently used in the operational version of the Atlantic TCGI and one of the top predictors for determining TC genesis in the 2-day timeframe. Preliminary tests of the Pacific version of TCGI suggest that Dvorak *T-Num* is an important predictor in this basin as well.

b. Not Completed:

i. Complete identification/development of new Atlantic and eastern/central Pacific TCGI predictors (this effort is nearing completion (anticipated to be complete in May 2016) and will not impact the timeline of year-1 deliverables)

The TCGI project requires a complete set of forecast positions out to five days for every Dvorak database disturbance at each 6-hourly synoptic time. Unfortunately, the dataset described above contains discontinuities and missing values, especially for entries in which the disturbance does not eventually form into a TC. To fill these missing forecast positions, a combination of Best Track and Dvorak positions and positions obtained from a BAMM type model (BAMG) were used to construct complete versions of the Atlantic and eastern/central Pacific TCGI NHC invest databases. The six predictors that are currently used in the operational version of the TCGI were tested with the newly expanded 2001-2014 Atlantic and eastern/central Pacific TCGI invest databases (Fig. 1.) This figure suggests that the relative weights of the current Atlantic TCGI predictors are markedly different when analyzed with the 2001-2014 Atlantic versus Pacific TCGI databases and may not be entirely surprising given the kinematic, thermodynamic, and sea surface temperature differences between these two basins. However, these tests do provide potential insight as to which predictor combinations may be more effective in each basin and whether or not some predictors should be targeted for possible replacement with new predictors.

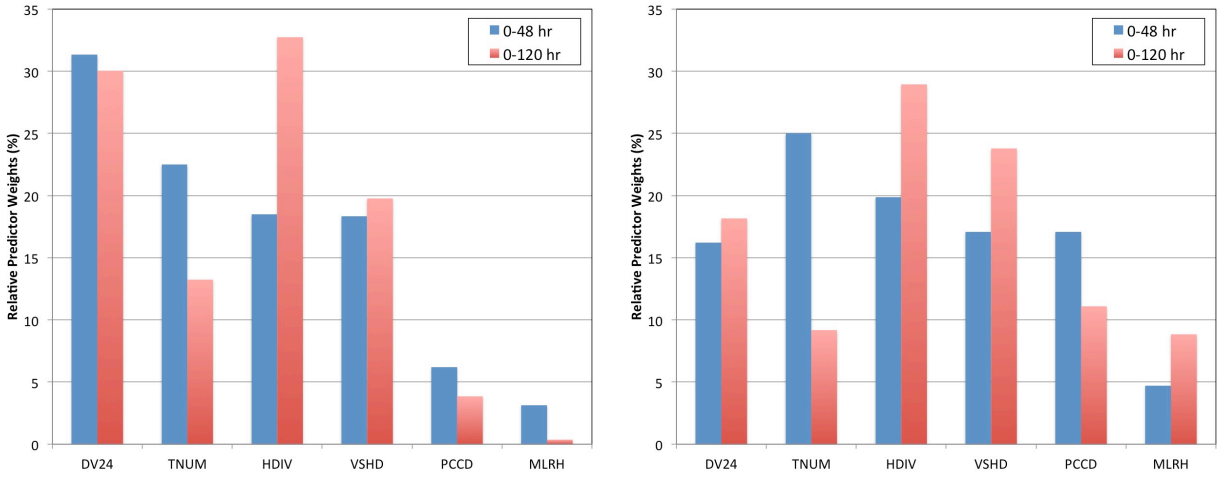

Figure 1: Relative predictor weights derived from the (left) newly expanded 2001-2014 Atlantic and (right) newly developed 2001-2014 Pacific TCGI invest databases. Blue and red bars indicate predictor weights for the 0-48 and 0-120 hr genesis forecasts respectively. The tested predictors include DV24 (24-hr change in GFS 850 hPa vorticity, TNUM (NOAA TAFB Dvorak T-number), HDIV (GFS 850 hPa horizontal divergence, VSHD (GFS 200-850 hPa vertical shear), PCCD (percent GOES water vapor pixels <-40 C), and MLRH (GFS 600 hPa RH).

Although the final list of optimal predictors for the new Atlantic and eastern/central Pacific versions of TCGI may change after further testing, the preliminary tests that were conducted to provide a means of testing the TCGI code on data from a new basin and of assessing the relative baseline skill level for both of the aforementioned basins. Figure 2 shows the cross-validated Brier Skill Score for the Atlantic and eastern/central Pacific TCGI. It can be seen that although the TCGI has slightly more skill in the Pacific, the performance in each basin is quite similar at both lead times.

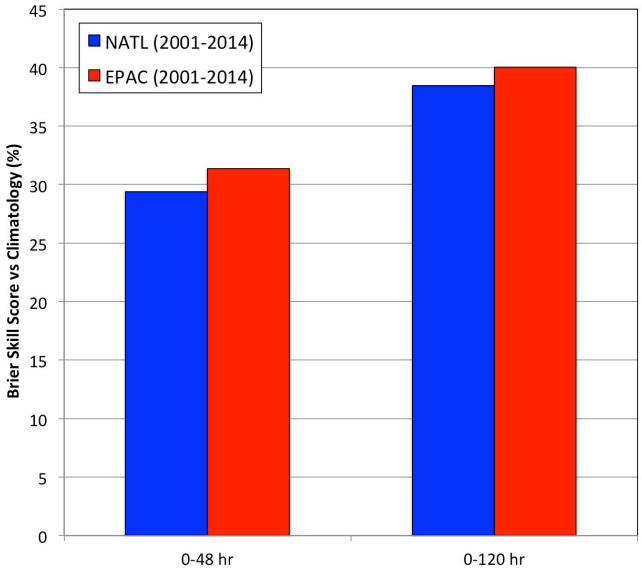

Figure 2: Cross-validated Brier Skill Score (relatively to climatology) for the newly expanded 2001-2014 Atlantic (blue shading) and the newly developed 2001-2014 eastern/central Pacific (red shading) TCGI invest databases. The skill for (left) 0-48 hr and (right) 0-120 hr was determined using the six predictors that are currently used in the operational TCGI.

With the completion of the TCGI Atlantic and eastern/central Pacific invest database and preliminary testing of the current operational predictors in each version, efforts have recently focused on examining the predictors that will be tested and eventually implemented in the new Atlantic and eastern/central Pacific versions of TCGI. We have begun examining the original 60 predictors that were tested in the original TCGI, several new predictors (Table 1), and a variable predictor search area that is smaller for the 0-48 hr forecast period (e.g. R=0-200 km or 0-300 km) and larger for the 0-120 hr forecast period (e.g. R=0-500 km).

New TCGI Predictor	Data Source
600-800 hPa RH	GFS/ECMWF model
925-1000 hPa RH	GFS/ECMWF model
Theta-E excess	GFS/ECMWF model
850 hPa vorticity	GFS/ECMWF model
850 hPa vorticity x divergence	GFS/ECMWF model
850 hPa moisture convergence	GFS/ECMWF model
Tropical Overshooting Tops (TOTs)	GOES/Meteosat (UW-CIMSS)
Lighting Strike Density	World Wide Lightning Location Network (WWLLN)

Table 1. New predictors being tested in the Atlantic and Pacific versions of TCGI.

4. Publications

a. Journal articles published
n/a

b. Journal articles in process (what stage?)
n/a

c. Other publications/presentations

Dunion, J.P., J. Kaplan, A.B. Schumacher, J. Cossuth, K.D. Musgrave, and P. Leighton, 2016: Improvements to the Tropical Cyclone Genesis Index (TCGI). *70th Interdepartmental Hurricane Conference - Tropical Cyclone Operations and Research Forum*, Miami, FL, Office of Fed. Coord. For Meteor. Services and Supporting Research, NOAA.

Dunion, J.P., J. Kaplan, A. B. Schumacher, J. Cossuth, K.D. Musgrave, and P. Leighton, 2016: The Tropical Cyclone Genesis Index (TCGI), *32nd Amer. Meteor. Soc. Conf. on Hurricanes and Tropical Meteor.,* San Juan, Puerto Rico.