Joint Hurricane Testbed

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Improvements and extensions to an existing probabilistic TC genesis forecast tool using an ensemble of global models

Principal Investigators:
Robert Hart, Professor of Meteorology, Florida State University (rhart@fsu.edu; 850-645-1552)
Daniel Halperin, Assistant Professor of Meteorology, Embry-Riddle Aeronautical University (halpea17@erau.edu; 386-226-7069)

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Florida State University
874 Traditions Way
Tallahassee, FL 32306-4166

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Semi-Annual Progress Report

1. Accomplishments

a. Maintained moe website to disseminate current guidance

The web site to disseminate the guidance products (http://moe.met.fsu.edu/modelgen) was maintained throughout the 2017 hurricane season. Guidance products were updated four times daily, with the arrival of each model cycle.

b. Model status web site addition

It was noticed during the 2017 TC season (as with the 2016 season) that occasionally the genesis guidance wasn't available on time for the NHC forecasters, or arrived late. Often these gaps or delays were a result of conditions beyond the PIs' control, such as delayed or incomplete gridded model guidance from one of the forecast centers. To communicate such events such that forecasters can anticipate delays, the PIs created a new web site (http://moe.met.fsu.edu/modelstatus) that graphically displays the status of all the model feeds received by the PIs, colorized by their timeliness. This website also makes it easier for the PIs to retroactively get missing model data, if needed.

c. Rewriting of UKMET ingesting/processing scripts for their new model format and resolution

On approximately 1200 UTC 11 July 2017, the UKMET model dramatically increased in resolution and also changed its output file type (gzip of otherwise uncompressed GRIB2). This led to an increase in volume of about a factor of 10 for each run, which required a revision of the ingest/processing scripts to handle the files quickly enough such that the genesis guidance could process the fields in time for NHC's use. Additionally, archiving in the GRIB2 format sent by UKMET was inappropriate for development (26GB per 0/12Z run, or about 10TB per six-month season). Accordingly, we reprocessed the UKMET output to use the same GRIB2 packing/compression as the GFS, such that each of those runs uses about 6GB on disk instead (2TB/season). Note that the reprocessing of the GRIB2 packing/compression is not done for the real-time files given the time it takes to reprocess would be prohibitive, and there is no space constraint for the real-time runs.

d. Addition of NAVGEM to the growing archive

When the PIs' first JHT project was proposed, the switch to NAVGEM from NOGAPS had just occurred, and the archive of NAVGEM forecasts was not sufficiently long to include as part of the genesis guidance. By the start of the current JHT project, however, the NAVGEM forecast archive has now reached 4.5 years (5 years as of the writing of this report), and thus the NAVGEM can now feasibly be tested for inclusion in the genesis guidance (using perhaps a 3 or 4-year development dataset and 1-2 year testing dataset). After a conference call between the PIs and the NHC points-of-contact (POCs) in mid-January, it was determined that adding the NAVGEM to the ensemble was likely to be a more fruitful addition than the potential for adding the GEFS. Accordingly, the NAVGEM forecast archive was extracted from tape at FSU. During late summer 2016, the NAVGEM switched from GRIB1 to GRIB2 and also from 1 to 0.5 degree resolution. During this switch, the archive at FSU is incomplete, with only 56% of the

NAVGEM model cycles during the 2016 hurricane season included. The PIs have been in touch with contacts at NRL to attempt to fill in the gaps in FSU's archive of NAVGEM forecast output.

e. Converted all forecast graphics to Python

Many of the early tasks for this project involve converting existing code to languages that are compatible with the NHC's IT infrastructure. The first completed task was converting and streamlining the graphics scripts from GrADS to Python. Examples of the old and new graphics are provided in Fig. 1. The change is purely cosmetic to the end user, but now ensures that the graphics can be generated on NHC's JHT workstation.

f. Prepared developmental dataset archive for transfer to NHC

In order for NHC to be able to calculate future regression equations independently of the PIs, they will need a local copy of the model output data archive that serves as the developmental set. We first identified any data gaps in the archive at FSU. Data gaps were filled via download from NCEI, file transfer from Andy Penny at NHC, tape archive at FSU, and file transfer from the U.K. Met Office. A spreadsheet with the data inventory was sent to NHC and is attached here as well. Data are ready for transfer, but are currently awaiting the necessary storage capacity at NHC. NHC also suggested on a conference call and in a follow-up email from Andy Penny that they may seek to interpolate all model data to 0.5 degree resolution for homogeneity. We note that this may not be possible since we are unaware of a multi-year archive of the CMC Global model output that is 0.5 degree or finer resolution.

g. Consensus tracker algorithm updated

The consensus tracker was updated in accordance with the proposed work. It was converted from R to Python to ensure NHC IT infrastructure compatibility. In addition, the algorithm was enhanced to improve detection of matching TC genesis events. The old version of the tracker only accounted for the distance between TC genesis events. The new version of the tracker considers the distance between TC genesis events at the same time. Preliminary tests indicate that the new tracker is working as intended. Further testing will occur during the 2018 hurricane season. An example of the old algorithm vs new algorithm is provided in Fig. 2. Note in Fig. 2 how the new version correctly matches the forecasts as the same genesis event and yields an appropriately greater genesis probability.

h. Began code conversion for other aspects of the guidance tool

In addition to the graphics and consensus tracker, other scripts must be converted to Python for the same NHC IT infrastructure compatibility. This code conversion began early in 2017 (months before the start of this project) and is still in progress/testing. It is on track to be completed and tested well in advance of the 2018 hurricane season.

i. Began genesis criteria sensitivity studies

As outlined in the proposal, one weakness of the current version of the guidance is low probability of detection for TCs with baroclinic genesis pathways. Therefore, we are currently conducting sensitivity studies of the genesis criteria. We will present the results to our NHC POCs before implementing new genesis criteria. It is likely that we will run two parallel versions of the tool during 2018 – one with the current genesis criteria, and one with the new genesis criteria. The performance will be compared after the season ends.

2. Products

All of the guidance products from the current version of the tool have been maintained and were available during the 2017 hurricane season at http://moe.met.fsu.edu/modelgen. The graphics products have been updated aesthetically with the code conversion to Python. A new version of the consensus tracker has been implemented and will be tested quasi-operationally during 2018. An abstract for a presentation detailing the progress of the project was accepted to the 33rd American Meteorological Society Conference on Hurricanes and Tropical Meteorology. These updates will also be presented at the upcoming TCORF/IHC Conference in March.

3. Participants and other collaborating organizations

The PI and Co-PI are the primary participants on this project. They continue to collaborate with their NHC/JHT points-of-contact: Chris Landsea, Richard Pasch, and Matt Onderlinde. Other NHC personnel, including Mark DeMaria, Andy Penny, and Mike Brennan have participated in planning meetings as well.

There were no other organizations formally involved in the project during the reporting period. Nonetheless, we greatly appreciate the feedback and aid provided by contacts at NRL and the UKMO regarding the data availability and archive issues discussed earlier.

4. Impact

Given how early it is in the project, it is difficult to quantify the impact of the ongoing work. However, we can report that we had extensive communication with several NHC forecasters during the 2017 TC season regarding product availability and updates, suggesting that the products continue to be used at a high volume as previously. Web access logs at FSU reveal that the products are also being heavily used by the general public and/or forecasters outside of the NHC environment as well.

5. Changes/Problems

The scripts that were converted to Python have not yet been transferred to NHC. More testing is needed to ensure the Python code is accurate and reliable. We will test the code rigorously during the 2018 hurricane season, fix any potential issues, and transfer it to NHC after the hurricane season.

The operational model output archive is ready to transfer to NHC. However, we are awaiting the necessary data storage capabilities at NHC. In addition, a final decision has not yet been made regarding the subset of the data they wish to store (whether through interpolation, variable subsetting, or geographic subsetting).

Separately, note that some of the changes/problems were noted in the "Accomplishments" section above, as they represented challenges to overcome as well.

6. Special Reporting Requirements

After consultation with our POCs during a conference call in mid-January, we assess the Readiness Level of the project at the beginning of the project period and currently as a 5.

The Test Plan is attached as a separate document.

The R2O Transition Plan is attached as a separate document.

As noted previously, the PIs have conducted a series phone calls with the JHT POCs: one during Fall 2017 with Mark DeMaria, Matthew Onderlinde, and Andrew Penny, and one in mid January 2018 with a larger POC team. These have generally been planning calls so far regarding testing plans for 2018 and IT requirements to which the project will need to adhere.

7. Budgetary Information

The project is on budget. No deviations from the proposed budget are anticipated.

8. Project Outcomes

It is difficult to quantify the project outcomes at this time, given how early it is in the project cycle.

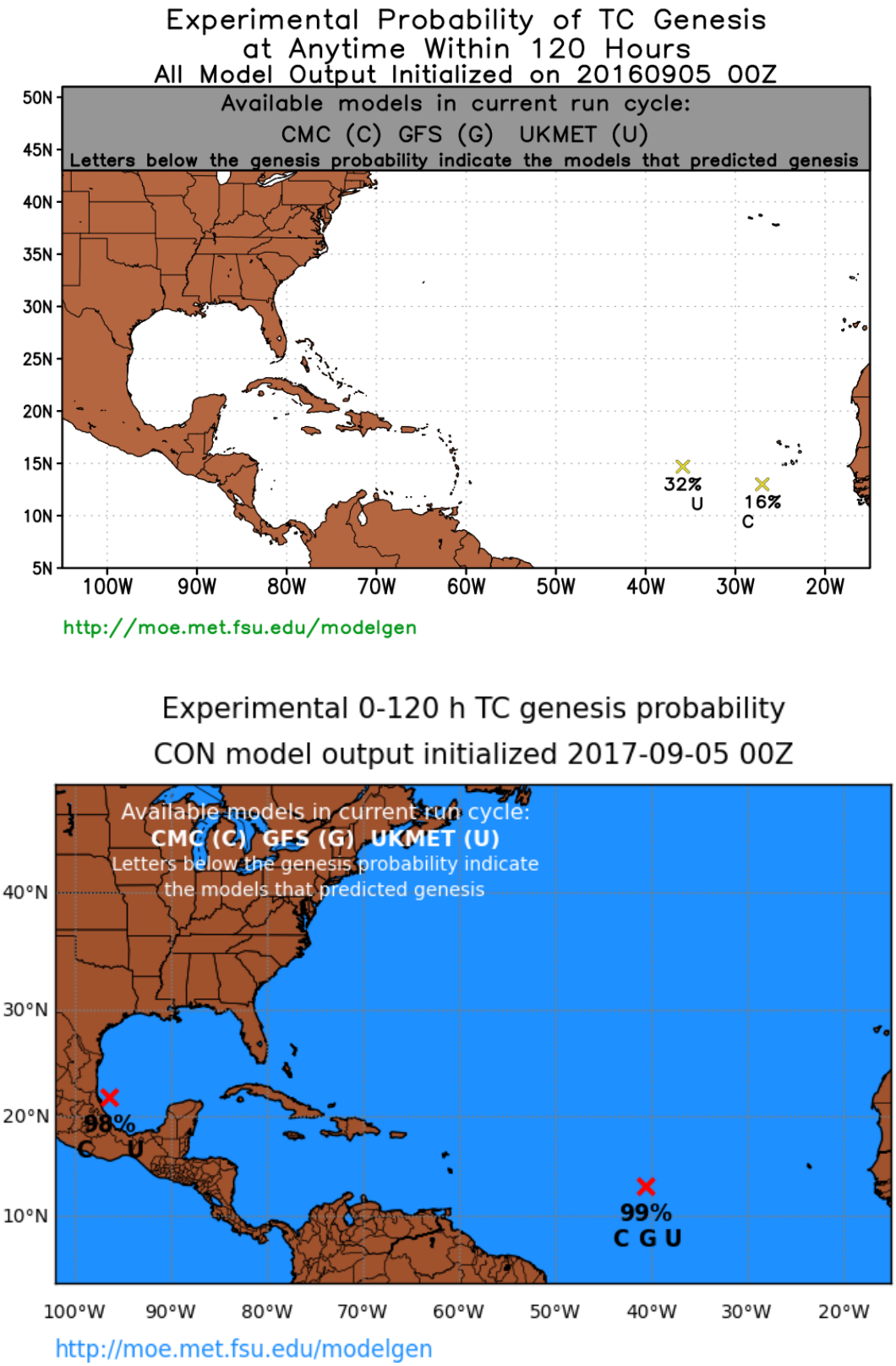
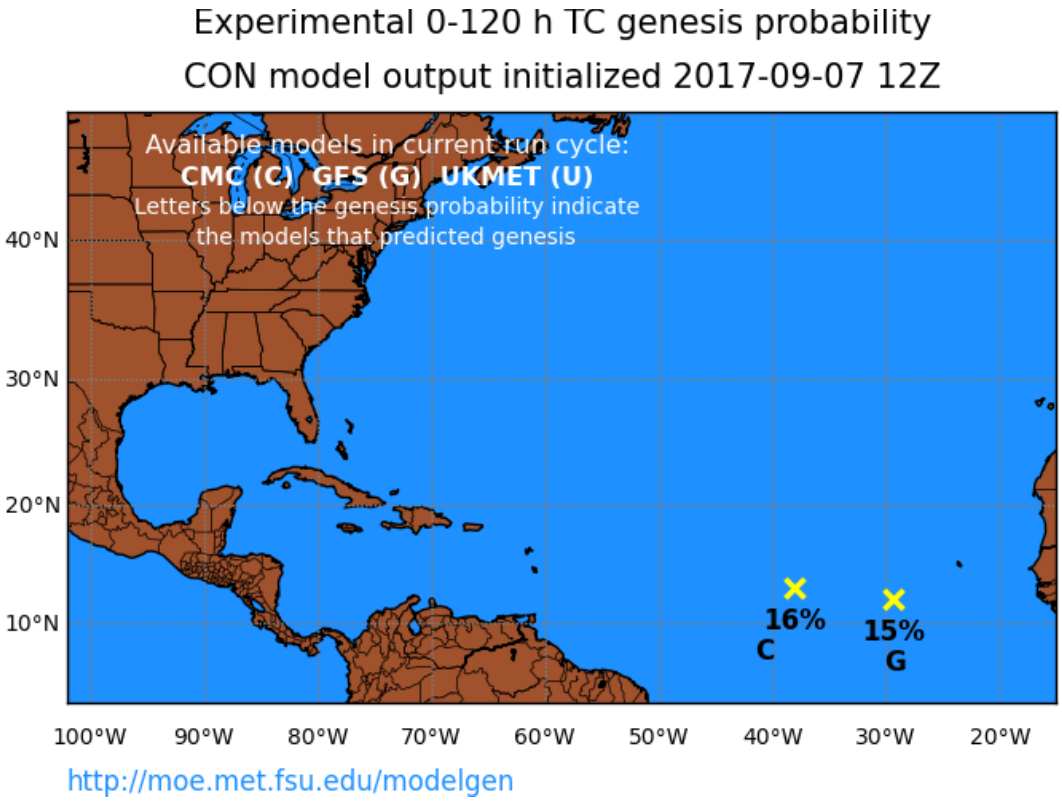


Fig. 1: Examples of the graphics products using GrADS (top) and using Python (bottom).



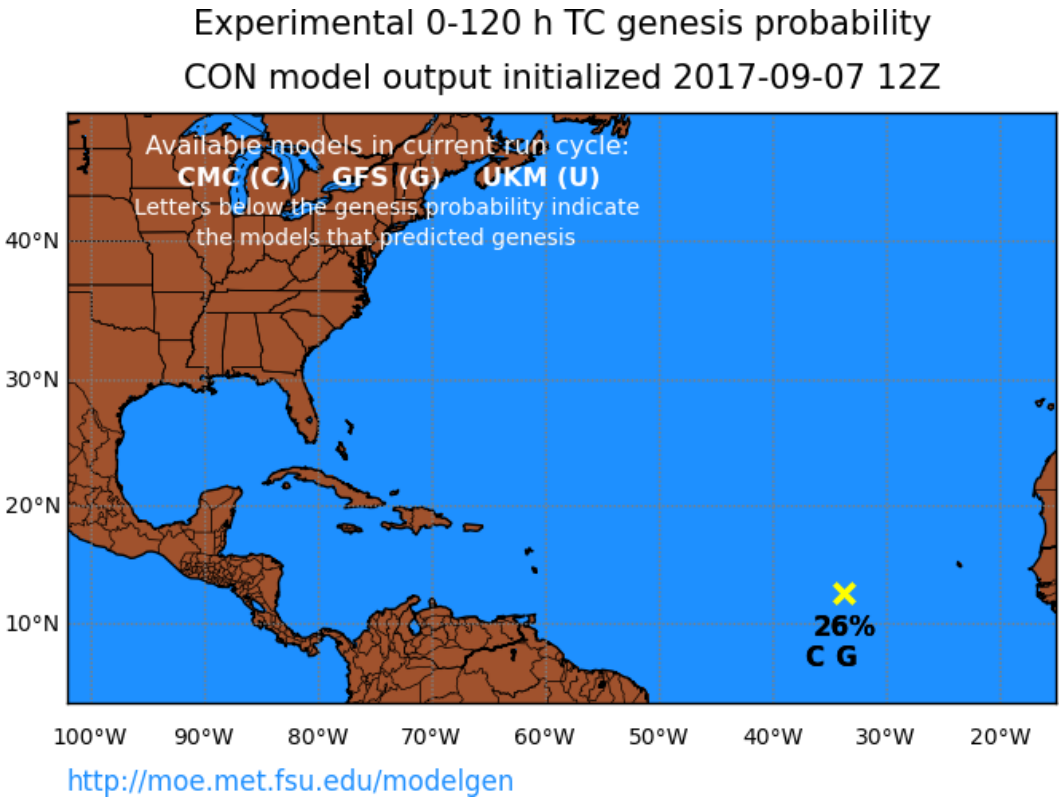


Fig. 2: The old consensus tracker algorithm did not match the two genesis events (top). The new consensus tracker algorithm correctly matches the genesis events from the two different global models as the same forecast TC (bottom).

Test Plan for NOAA/OAR/OWAQ Testbed Projects

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

The proposed TC genesis guidance tool will be tested. All components of the tool (e.g., tracker, verification script, graphics, etc.) will be tested by NHC during the project cycle. After a conference call, it was decided that for the 2019 TC season, having the probabilities in e-deck format will be tested – although there were several questions outstanding on that target, such as system numbering since not all potential genesis systems in the models with guidance from this project will necessarily be an official Invest by NHC.

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 NOAA testing, and what will occur during the experimental testing in the testbed?

The code for the TC genesis guidance tool will continue to be provided to the JHT IT specialist, Jose Salazar, and the NHC POCs. To test the development of the regression equations, NHC will need to acquire the developmental set of archived model output. The PIs and POCs have agreed upon a method of data transfer, and have provided to NHC extensive statistics on the data volume, format (GRIB1 vs. GRIB2), and grid spacing by year and model to Andrew Penny. Currently, we are awaiting the necessary storage space capabilities at NHC. Conversely, NHC (through Andrew Penny) has been providing archived model runs of the GFS since 2015 to fill in the few gaps that the PIs have at the FSU archive. We are grateful for this exchange.

III. **When** will it be tested in coordination with the NOAA testbed? 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?

Date	**Task**
Jul 2017	Project start -- maintain moe website to disseminate current guidance.

Aug 2017	Transfer 2007-2016 thinned operational model output archive to NHC.
Current-Sep 2017	Convert real-time guidance code to Python.
Sep-Nov 2017	Test/evaluate Python code for accuracy and operational reliability. Display guidance products from Python code on a parallel website (http://moe.met.fsu.edu/modelgenp).
Dec 2017-Jan 2018	Send Python real-time code to NHC. Assist with implementation.
Jan 2018	Improve consensus tracker to include spatial and temporal metrics.
Jan-Mar 2018	Conduct genesis criteria sensitivity studies.
Mar 2018	Present mid-year 1 results at Interdepartmental Hurricane Conference.
Apr-May 2018	Update regression equations after adding 2017 forecasts to the developmental dataset.
Apr 2018	Present mid-year 1 results at AMS Conf. on Hurricanes and Trop. Met.
Jun-Aug 2018	Develop regression equations for NAVGEM data.
Sep-Nov 2018	Test NAVGEM probabilities and probabilities with different genesis criteria on parallel development website.
Fall 2018	Multi-day NHC trip for meetings, including providing research update, address implementation questions/issues, and solicit overall feedback.
Dec 2018-Jan 2019	Evaluate GFSX TC genesis reforecasts compared to operational GFS.
Feb-Mar 2019	Provide GFSX evaluation code to NHC. Assist with implementation.
Mar 2019	Present mid-year 2 results at the IHC Conference.
Apr-May 2019	Update regression equations after adding 2018 forecasts to the developmental dataset.
May-Jun 2019	Convert post-season statistical analysis code to Python. Transfer to NHC.
Jun 2019	Test guidance products with output in ATCF e-deck format.

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

Testing will take place at both PIs locations (FSU, Embry Riddle) using the computing hardware at FSU, and also at NHC. Both institutions will run parallel versions of the guidance tool, although one difference at FSU is that the ECMWF probabilities cannot be calculated due to inaccessibility of real-time ECMWF data.

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

The NHC IT specialist and the POCs are the key stakeholders in testing the compatibility of the guidance tool on the NHC IT platform. They will implement the code on the JHT workstation for testing. The NHC hurricane specialists are the key stakeholders for testing the usefulness and reliability of the forecast guidance. The PIs are responsible for running a parallel version of the guidance tool, and assisting with code implementation at NHC for testing – whether remotely or if requested, in person.

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

No office space or video teleconferencing will be necessary. The PIs have all of the necessary hardware, software, data flow, and internet connectivity to run a version of the guidance tool at the PI institution – as has been done since 2014. The POCs will be responsible for ensuring the necessary hardware, software, data flow, and internet connectivity is available for testing at NHC. A Linux desktop is the required hardware. Python, c-shell, and FORTRAN are the required software. Real-time output from the GFS, UKMET, ECMWF, and CMC are the required data flow. Internet connectivity is 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 to advance to higher Readiness Levels and to proceed to full transition to NOAA operations (Readiness Level 8)?

Test goals: (1) Run a parallel version of the guidance tool at NHC quasi-operationally during the 2018 hurricane season. (2) Re-calibrate the regression equations at the end of the 2018 hurricane season at NHC.

Performance measures: (1) Does the guidance tool run reliably during the hurricane season? (2) Are the genesis probabilities reasonable and providing adequate guidance to forecasters? (3) Can NHC POCs successfully re-calibrate the regression equations at the end of the 2018 hurricane season?

Success criteria: (1) For times when the real-time datafeed is completely available, the guidance tool will run without errors for 95% of the forecast cycles during the 2018 hurricane season. (2) The genesis probabilities will be well-calibrated, as measured by reliability diagrams and Brier scores. (3) The NHC POCs will re-calculate the regression equations after the 2018 hurricane season.

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

(1) The hurricane specialists will note any time when the guidance products are unavailable. (2) The POCs will report which components of the guidance tool have been implemented on the JHT workstation. (3) The PIs will verify the probabilistic genesis forecasts. All of this information will be included in the test results final report.