JHT Year One Report

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Improved Automation and Performance of VORTRAC Intensity Guidance

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Introduction:

This document gives the year one progress report on the "improved automation and performance of Vortex Objective Radar Tracking and Circulation (VORTRAC) intensity guidance" for the JHT. VORTRAC uses a series of algorithms to deduce the central pressure and radius of maximum wind (RMW) of a landfalling TC in near real time from WSR-88D Level II radar data and environmental reference pressure data from nearby coastal weather stations. The purpose of this project is to improve the capability to automatically diagnose central surface pressure and its tendency from radar-derived wind fields at TPC/NHC as additional guidance for TC intensity change near landfall when a TC center is within the Doppler range of a coastal WSR-88D. VORTRAC was officially accepted for operation at the National Hurricane Center (NHC) in 2008. In its current operational form, VORTRAC requires external scripts to fetch this data and user input of an initial TC position, RMW estimate, and radar selection. This procedure was not streamlined and encountered difficulties during several landfalling hurricanes. The PIs have improved several aspects of VORTRAC in year one. A new version of VORTRAC was installed and tested at NHC for Hurricane Isaac's (2012) landfall. Details are summarized below.

Accomplishments:

The progress in year one can be broadly divided into two categories: 1) Reestablish communications with NHC to facilitate code improvements that benefit operational guidance through improved automation, robustness, and display capabilities, and 2) identify and correct points of failure through analysis of historical landfalling datasets. Communications were established with Wallace Hogsett, who replaced the retired Colin McCadie in 2010, as well as Stacy Stewart and Chris Landsea. The PIs had a conference call with NHC POCs, meetings at the IHC, and several emails to discuss the project and obtain updates on the computer infrastructure at NHC for accessing vital datasets in real time during operations.

Based on POC feedback, several upgrades to the software were made in year one. The most notable change was the removal of all external scripts to handle necessary data feeds and transition to automatic operation. In the past, environmental pressure observations and Level II radar data were downloaded and pre-processed on Colin McAdie's workstation prior to VORTRAC ingest. The previous data feeds operated on a 'push' basis through LDM, such that the data flow had to be manually turned on or off by the user. The new data feeds are built into VORTRAC itself and operate on a 'pull' basis from the web. NEXRAD Level II data, environmental pressure observations from NOAA's MADIS service, and real-time storm information from ATCF are now obtained automatically, and only in the region of interest to reduce bandwidth. Only the storm ID and radar name are now required to start VORTRAC, and no further manual updates are required by the user.

Two new display features were added in year one based on POC feedback. A radar reflectivity display is now included to see how well the VORTRAC derived center matches with the convective pattern. This display is especially useful in disorganized systems. A second addition is an enhanced display for the maximum inbound and outbound Doppler velocities, including height, range, and direction from the radar and an overlay on the velocity and reflectivity display. Improved, more readable numeric displays were also added for clarity.

Another main focus of the first year project was to identify possible points of failure by running historical landfalling datasets through VORTRAC package. This information is critical to form the basis to improve the automation and performance of VORTRAC. A total of 12 US landfalling hurricanes between 2005 and 2011 were selected as the test cases (See Table 1) and their tracks are illustrated in Fig. 1. The level II data of the 12 hurricanes were downloaded from NCDC and the VORTRAC package was updated to handle the new Level II Message 31 format. Then the PIs ran these 12 storms through VORTRAC and have been analyzing the results. Additional tests were performed on Hurricane Charley (2004) to compare with previous VORTRAC results, and Hurricane Isaac (2012) for real-time testing this season.

The examination of these VORTRAC test cases provided useful insights on several areas that could be improved in the VORTRAC logic. Key improvements to the software are listed below.

1) **Improved "robustness" to unhandled exceptions.** Given the wide variety of storm shapes and sizes, VORTRAC must be able to run and handle many different types of tropical cyclones, even if an analysis is not possible. Considerable testing has led to many "under the hood" improvements that will allow VORTRAC to operate under a wider variety of conditions and radar data quality. Continued testing to identify more exceptions, such as missing or incorrect data feeds, missing or bad radar data, and different storm types will be conducted in year two.

2) **Improved use of operational products.** The addition of operational products into VORTRAC not only reduces the amount of user input required for initialization, but also provides useful information and checks on the quality of the VORTRAC results. For example, if the RMW or center identified by VORTRAC are drastically different than the operational estimates then the analysis results may be suspect. Tests with historical cases indicated the most challenging cases were large storms where VORTRAC could not identify the correct RMW, leading to incorrect center estimates. Successive incorrect analyses would lead to a situation where it was very difficult for VORTRAC to recover (see case study for Hurricane Ike in the mid-term report for an example). Nearby operational environmental pressures are also important in large storms, where the

environmental pressure obtained from ATCF is found at a very large radius beyond radar range. Improvements to the program logic that take advantage of automatic inclusion of real-time operational data have been incorporated, and will be further evaluated in year two.

3) **Improved radar algorithms.** VORTRAC is based on a combination of several radar algorithms, including quality control, center finding, and intensity estimation. Improvements to each of these algorithms have begun, and will continue in year two. One example is in radar data dealiasing. The previous algorithm was based on the Bargen and Brown (1980, hereafter BB80) dealiasing procedure. The new algorithm combines an improved BB80 algorithm with an azimuthal second derivative minimization and multi-PRF dealiasing algorithm. In the first step, the BB80 algorithm dealiases each radar beam in the radial direction using a running median instead of the traditional running mean. The use of the median reduces dealiasing failures due to outlier velocities that can skew the mean calculation. In step two, the second derivative of the azimuthal velocity gradient is minimized along each radar ring. This step fixes dealiasing failures along isolated beams. In the third step, a multi-PRF technique is used to further correct and verify that the dealiased velocities are consistent when multiple Nyquist velocities are used at the lower elevations. An example of the previous and current radar quality control algorithm is shown in Figure 2. The multi-step dealiasing algorithm has helped improve the quality of the VORTRAC results.

4) **Testing in Hurricane Isaac (2012).** An improved version of VORTRAC was installed on the NHC server before Hurricane Isaac (2012) passed by Key West on 8/24/2012. This version of VORRTRAC was run parallel at both NHC and University of Hawaii in real time. The PI (Bell) was able to run VORTRAC continuously at his home site (U. of Hawaii) during Isaac's landfall. Initial report from our NHC contact, Jose Salazar, indicated that VORTRAC ran continuously at NHC and provided RMW estimates. The PIs will evaluate the VORTRAC results of Isaac's landfall in year 2.

Summary and Future Work:

The project is progressing well and on schedule. We completed the VORTRAC runs for 12 historical hurricanes, and an examination of the 12 cases revealed several challenging characteristics and exceptions that caused previous VORTRAC failures. Several improvements were made in year one, and a new version of VORTRAC was installed at NHC. A test of the upgraded software during Hurricane Isaac's landfalls at Key West and New Orleans showed significant improvement over the previous version of the software. Some screenshots of the VORTRAC runs by the PIs for Hurricane Isaac are shown in Figure 3. VORTRAC did run continuously at NHC during Isaac's landfall. Further improvements to the software in year two will focus on software robustness, analysis diagnostics, and improvements to the center tracking that take advantage of multiple radar algorithms. Modifications based on feedback from the NHC POCs will also be incorporated, and updated documentation will be completed.

Table 1. The list of 12 hurricanes used in the VORTRAC test set.

Year	Max. Intensity (Kts)	Hurricane
2005	110	Katrina
2005	105	Dennis
2005	105	Wilma
2005	100	Rita
2005	65	Cindy
2005	65	Ophelia
2007	80	Humberto
2008	75	Dolly
2008	90	Gustav
2008	95	Ike
2009	60	Ida
2011	75	Irene

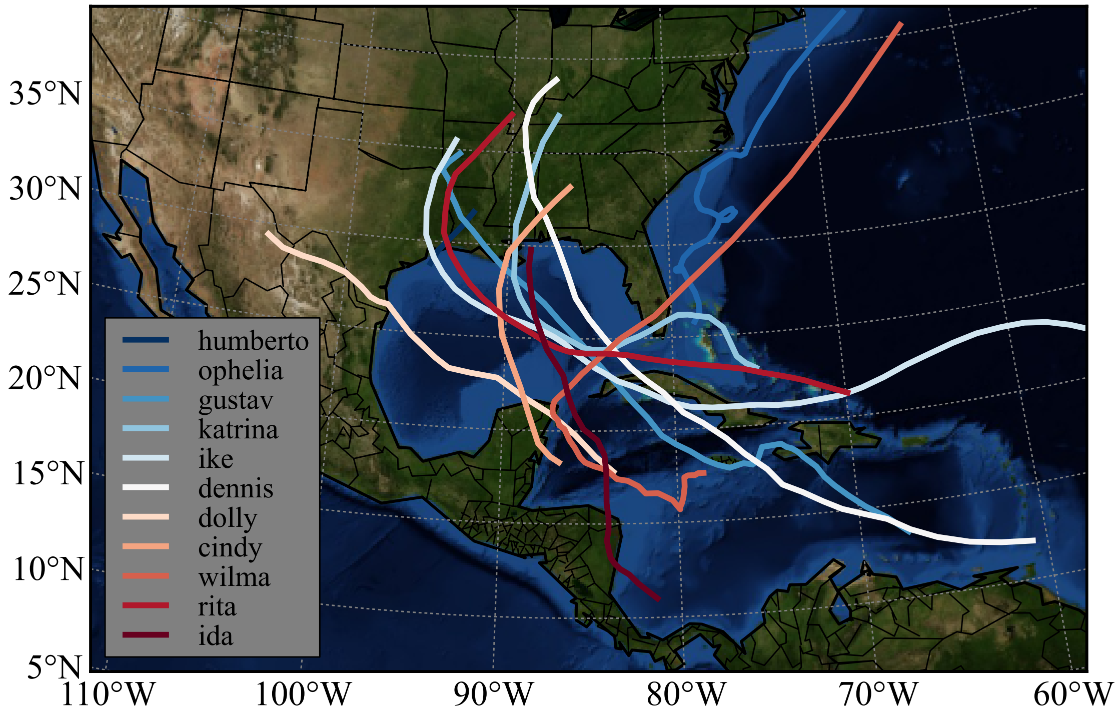

Figure 1. The best tracks of 12 hurricanes selected for the VORTRAC test set.

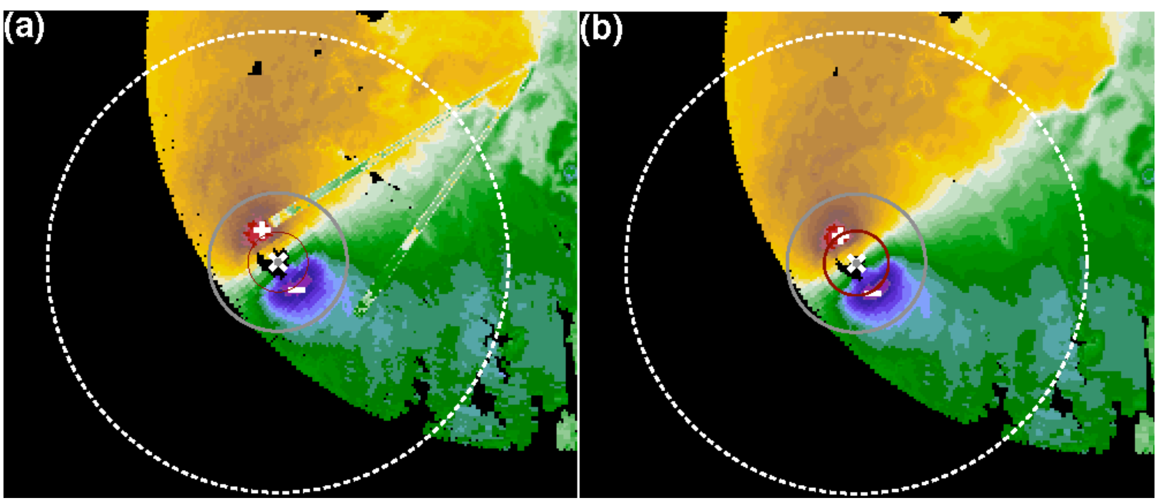

Figure 2. Example of improved radar quality control for Hurricane Charley (2004).

(a)

(b)

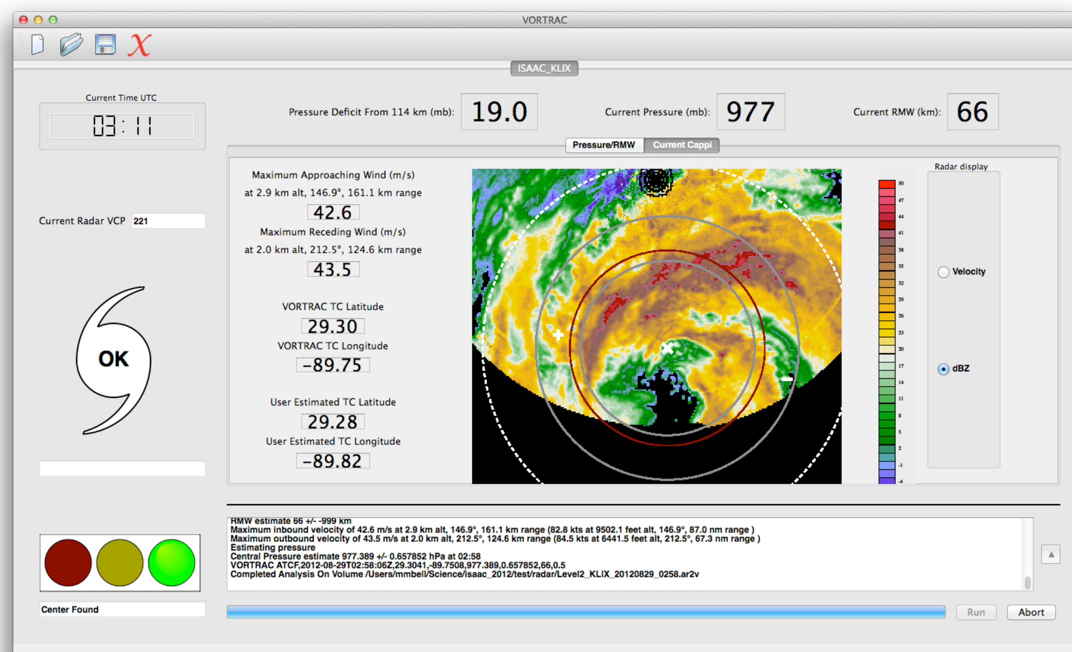

Figure 3. VORTRAC screenshots from Hurricane Isaac (2012) landfall at New Orleans. Panel (a) shows pressure and RMW trace on Linux version. Panel (b) shows new reflectivity display on Mac version. Both screenshots are from real-time operation.