WSR-88D-derived Diagnosis of Tropical Cyclone Intensity Changes Near Landfall

Year 1 report to the Joint Hurricane Testbed

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Project Abstract:

This project will provide TPC with a radar-based hurricane diagnostic software package, the Vortex Objective Radar Tracking and Circulation (VORTRAC), that tracks intensity (via central pressure) and radius of maximum wind (RMW) of landfalling tropical cyclones. The central pressure and RMW are retrieved from the ground-based velocity track display technique (GBVTD) and the hurricane volume velocity processing method (HVVP) anchored by the surface pressure observations from coastal weather stations, buoys, and dropwindsondes. VORTRAC will provide TPC/NHC with automatically-updated charts of radar-derived, TC central surface pressure and its tendency when a tropical cyclone is within the Doppler range of coastal WSR-88Ds. In addition, the radius of maximum wind and its tendencies will also be offered in chart form.

First Year Progress Report:

During the first year, project has been focused on (1) the design and implementation of a user interface using the Qt tool kit, (2) implementation of the radar data quality control algorithm on NEXRAD level-II data to be used in the overall VORTRAC package, and (3) converting GBVTD, HVVP, etc, algorithms from FORTRAN (research code) to C++ (object-oriented operational code) to be used in VORTRAC.

The following is an itemized list of tasks completed in the first year:

1. A review of existing graphical user interface libraries was undertaken to determine which would suit the needs of the VORTRAC package. The Qt package, a set of C++ libraries developed by Trolltech Inc., was found to have the best combination of graphics, ease of programming, and support.
2. An object oriented class diagram was designed for incorporating the existing single Doppler algorithms (GBVTD, GBVTD-simplex, HVVP, VAD, GVAD, Bargen-Brown dealiasing), input (NEXRAD Level II reader), quality control, and graphical user interface (Qt GUI) into a single C++ application. The principles of object-oriented design allow for maximum flexibility and code reuse as the algorithms and data formats evolve in the future.
3. The existing formatted text files used for controlling user parameters in FORTRAN were converted to extensible markup language (XML) for its simplicity, portability, and support in Qt.
4. An analytic hurricane consisting of a Rankine vortex with user-controlled attributes, and idealized Doppler radar with variable volume control patterns (VCPs) and Nyquist intervals were programmed to aid in testing and debugging of the code.
5. Writing a Level II decoder in C++, thresholding data with noisy Doppler velocities, removing data contaminated by the ground or radar side-lobes, removing the terminal fall speed of particles from their Doppler velocities, and unfolding of Doppler velocities beyond the Nyquist interval using the VAD and Bargen-Brown dealiasing algorithms.
6. Construction of constant altitude plan position indicators (CAPPIs) from the raw level II data in the VORTRAC package using Cressman objective analysis has been completed.
7. Convert GBVTD-simplex, GBVTD, and pressure retrieval code from FORTRAN to C++ and integrate into VORTRAC.

Accomplishments:

1. Graphical User Interface (GUI)

Much of the first year design and software development has been focused on the Qt graphical user interface, which allows the user to easily change the configurable parameters, run the program, and view the resulting intensity guidance. Ease of use and robust reporting capabilities formed the primary focus for the design, as these were deemed to be the most critical aspects of the interface for the time-limited hurricane specialist.

Example of the GUI for the VORTRAC program is shown in Fig. 1. This interface was designed for use in the operational environment, with a large display of the time series of central pressure (red line) and RMW (blue line) that continuously updates in real-time when the center of a TC is within the Doppler range of coastal WSR-88Ds. Uncertainty estimates, given by the hash marks about each line, and potential dropwindsonde measurements (black dots) are also shown, providing the forecaster with confidence estimates for the radar retrievals. Additional features of the GUI include: (1) a status log indicating success or errors in the program operation, (2) a progress bar showing a graphical indication of the analysis stage, and (3) a configuration tree, allowing the user to adjust the default operational parameters of the program.

The configuration of the program relies on an extensible markup language (XML) text file that can be manually modified via a text editor, the configuration tree shown in the left panel, or more intuitively through a point and click interface shown in Fig 2. While standard configurations of most parameters will be valid for many storms, specific information such as the hurricane name and available radar coverage can be modified quickly and easily with this GUI. All of the available configuration information will be described in the user's manual to be presented in year two.

Feedback from our NHC contact at the 2006 Interdepartmental Hurricane Conference led to some modifications of the GUI design, including the addition of a 'warning' system, similar to a traffic light, in which unusual central pressure and/or RMW tendencies, critical errors by the automated algorithm, or potential extreme meteorological conditions (i.e., rapid intensification) can be communicated quickly and effectively to the operator (Fig. 3).

2. Software and algorithm development

On the algorithm development side, the radar data quality control software have been rewritten from FORTRAN to C++ and integrated with the Qt tool kit. The radar data control software includes 1) simple ground clutter removal by setting thresholds on the Doppler velocity and spectrum width data, 2) Doppler velocity correction for hydrometeor terminal fall speed using a standard technique that draws from the work of Nunez and Gray (1977) and Beard (1985), and 3) Doppler velocity unfolding that uses a reliable reference wind estimated from the gradient VAD (GVAD) technique of Gao et al. (2004), which is then used to initialize the standard Bargen and Brown (1980) unfolding algorithm.

Conversion of the GBVTD-simplex, GBVTD, and pressure retrieval algorithms into C++ and assimilation into VORTRAC package has been completed.

3. Testing of the VORTRAC and case studies

Tests with analytic data and realistic amounts of noise, as well as sample volumes from Hurricane Charley (2004) are performing well. Further testing and validation of the HVVP technique on the Hurricane Charley (2004) NEXRAD data set has also been conducted. This testing has led to an improvement in the way HVVP handles environmental wind estimates in the presence of radial outflow within the tropical cyclone's circulation, in addition to improved quality control of the HVVP wind estimates. The revised HVVP profiles of the environmental wind components around Hurricane Charley are consistent with NOAA/NCDC/SRRS 850 and 700 mb analysis charts and the veering of Charley's track with time (Fig. 4).

Doppler radar data from Hurricane Katrina (2005) was processed in a 'quasi-operational' setting using the existing software tools. Results from this test indicate good agreement between dropsonde central pressure estimates and VORTRAC using the existing algorithms in a nearly automated way. This test also indicated some potential pitfalls that need to be addressed in the fully-operational version, such as sudden changes in the radar VCP and the ability to handle very large and asymmetric storms like Katrina before landfall. Including the HVVP-derived across-beam component of the environmental winds in the pressure retrieval showed good agreement with several available dropwindsonde measured central pressure in Katrina. The HVVP estimates of the environmental wind components around Hurricane Katrina at 0933 and 1044 UTC are shown in Fig. 5.

4. Porting prototype VORTRAC to TPC

A prototype VORTRAC will be ported to TPC workstation during PIs visit to TPC on 7-9 June 2006. This prototype VORTRAC includes the capability of Doppler radar QC, compute and displaying RMW and retrieve center pressure deficit (without HVVP mean wind correction) from historical landfalling tropical cyclones. This is a major milestone of the first year project as the basic framework of VORTRAC will be established at TPC, allowing future updates and upgrades to be easily implemented remotely.

Summary and Plans for year 2:

The project is progressing well and on schedule based on the revised time line (attached at the end of this document). Mid-term report for the first year was submitted on 28 February 2006 and progress of the project was reported at the 2006 Interdepartmental Hurricane Conference in Mobile Alabama. We have designed and completed the user interface of the VORTRAC package and tested the prototype VORTRAC package using analytical data and using historical NEXRAD data at UCAR. This prototype VORTRAC will be ported to TPC in June during PIs visit to TPC. The capability to ingest WSR-88D data in real time will be implemented in July so the prototype VORTRAC can be tested in the 2006 hurricane season.

Year 2 of the project includes (1) convert HVVP from Fortran to C++ and link HVVP with Qt GUI, (2) implement the pressure corrections from HVVP-derived mean wind and derive the absolute center pressure by anchoring the GBVTD-HVVP-derived pressure deficit with surface pressure measurement, (3) implement changes based on the feedback from TPC staff on the performance of the prototype VORTRAC during the 2006 hurricane season, (4) update VORTRAC at TPC for field test in the 2007 hurricane season, and (5) complete the scientific documentation, algorithm user's guide, and the final project report, and provide case studies for training by August 2007.

A revised year 2 budget is attached reflecting the 9.4% reduction of the original year 2 budget. The budget reduction is primarily on PI's travel to NHC to interact with NHC staff on testing of VORTRAC before 2007 hurricane season.

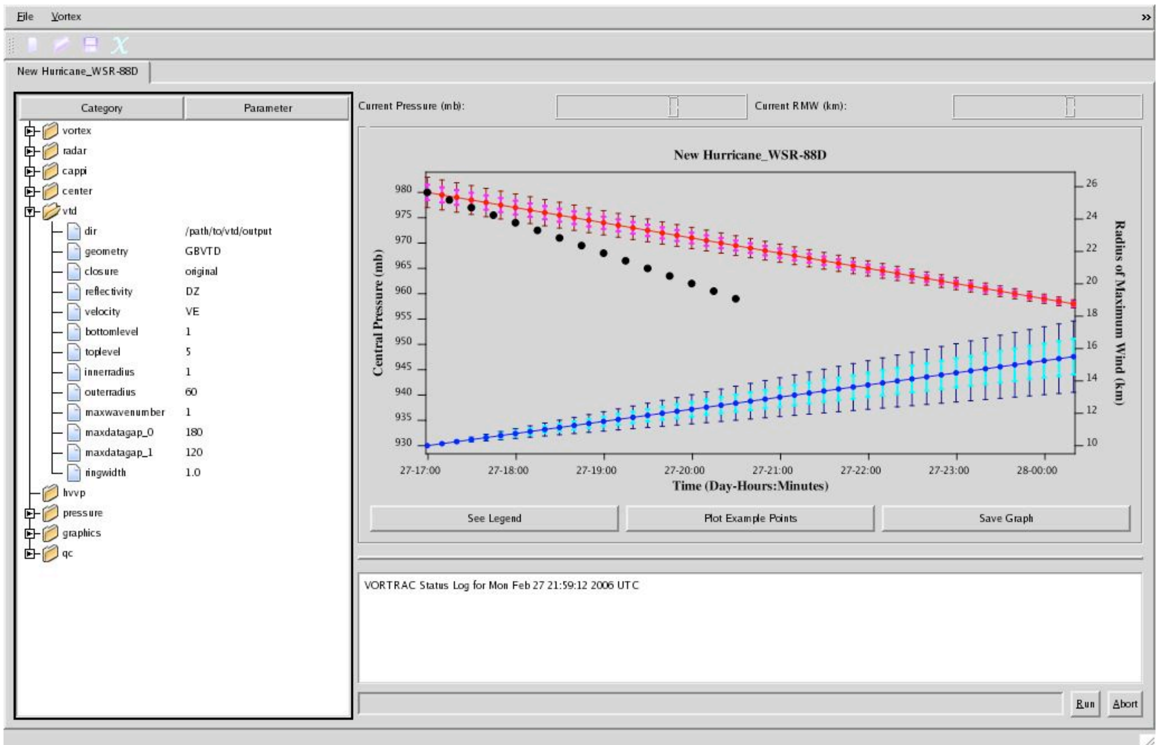

Figure 1. Time series display (screen shot) of central pressure (in red) and radius of maximum wind (in blue) in VORTRAC. Central pressure observed by dropsonde or other sources is displayed in black dots when available. Hash marks represent the uncertainty estimate associated with each computation. See text for details.

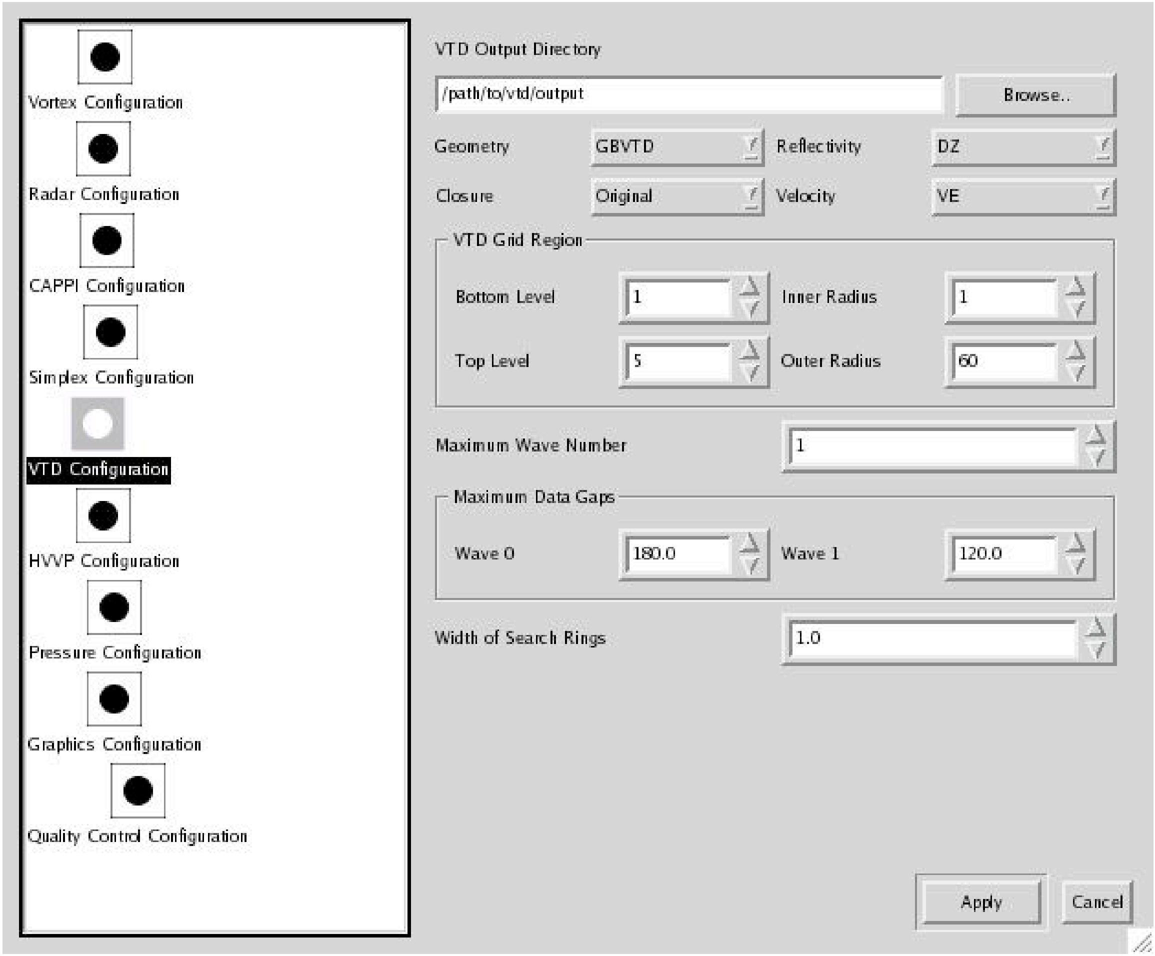

Figure 2. Example of the point and click user interface to change VORTRAC parameters. See text for details.

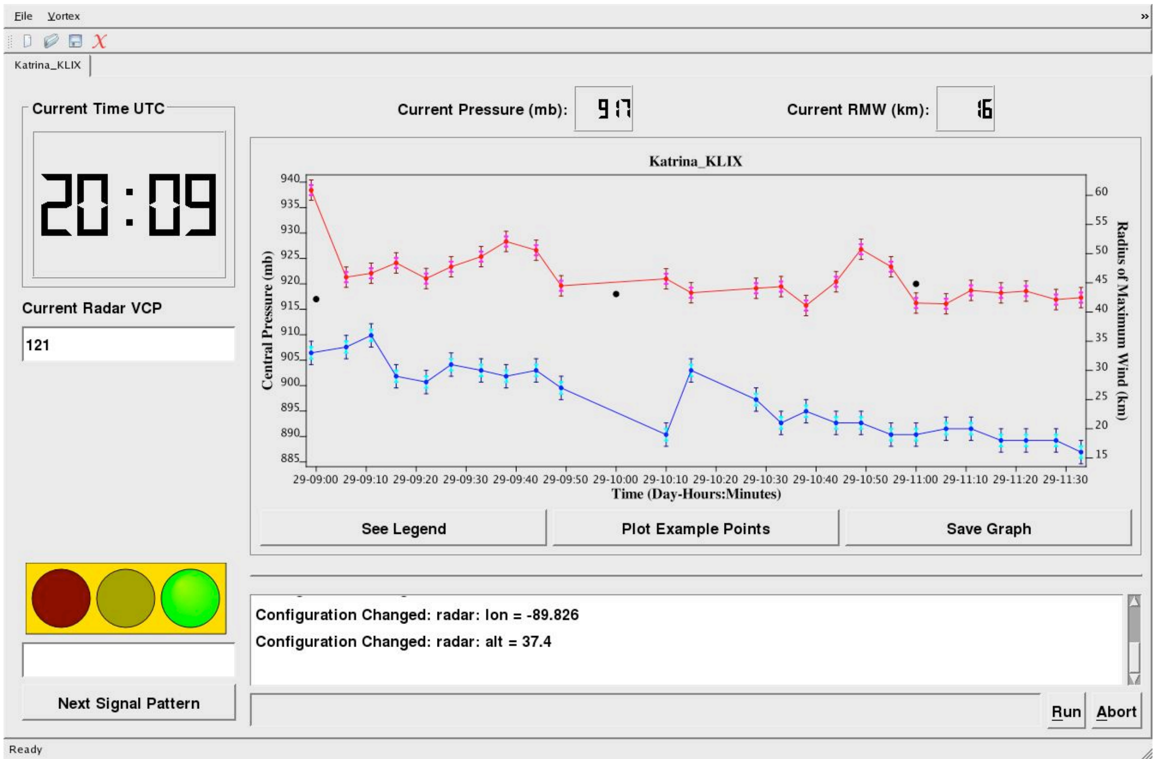

Figure 3: An updated GUI page evolved from Fig. 1 and 2 based on feedback from NHC contact during the 2006 Interdepartmental Hurricane Conference. Option trees in Fig. 1 have been placed in the pull-down menu. New features include a clock showing the elapse time of the current VORTRAC run, digital displays of current central pressure and RMW estimate, and a warning light system to indicate whether the software is running normally (green), may need attention (yellow), and something is definitely unusual (red). Displayed lines are the central pressure (red) and RMW (blue) of Katrina data (computed off-line).

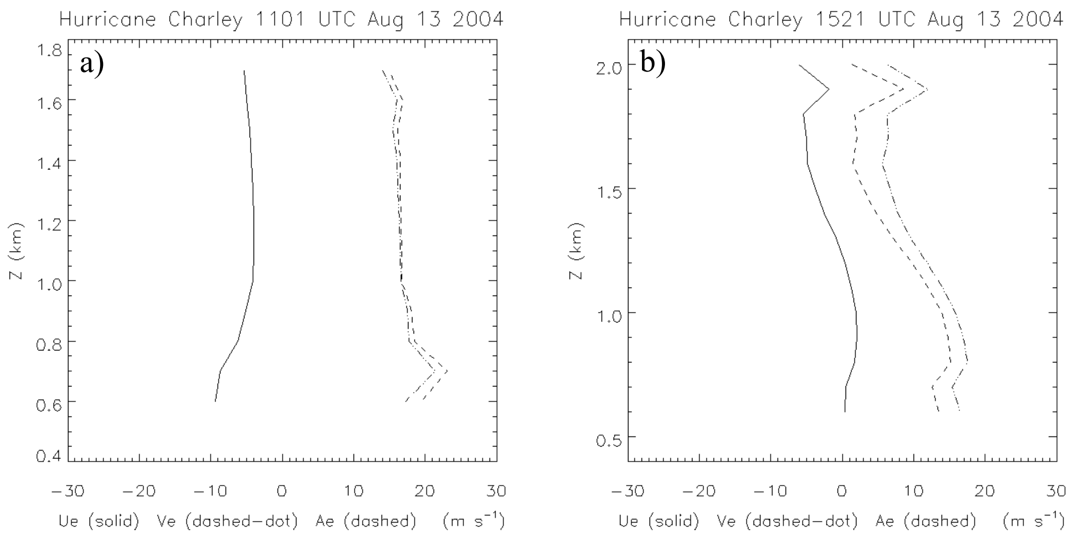

Figure 4. Vertical profiles of the Cartesian wind components of the environmental wind (Ue, Ve), and the across-beam component of the environmental wind (Ae), around Hurricane Charley on August 13 2004 at a) 1101 UTC and b) 1521 UTC. Note the decreasing easterlies shown in Ue and decreasing southerlies in Ve with time and altitude are consistent with more steering toward the north-east (veering) as Charley's track demonstrated during the 4 hours and 20 minutes between HVVP analyses. This postulated effect assumes all other winds aloft, not estimated by HVVP, also contribute to this possibility of veering of the track with time, in the vertically integrated sense of steering.

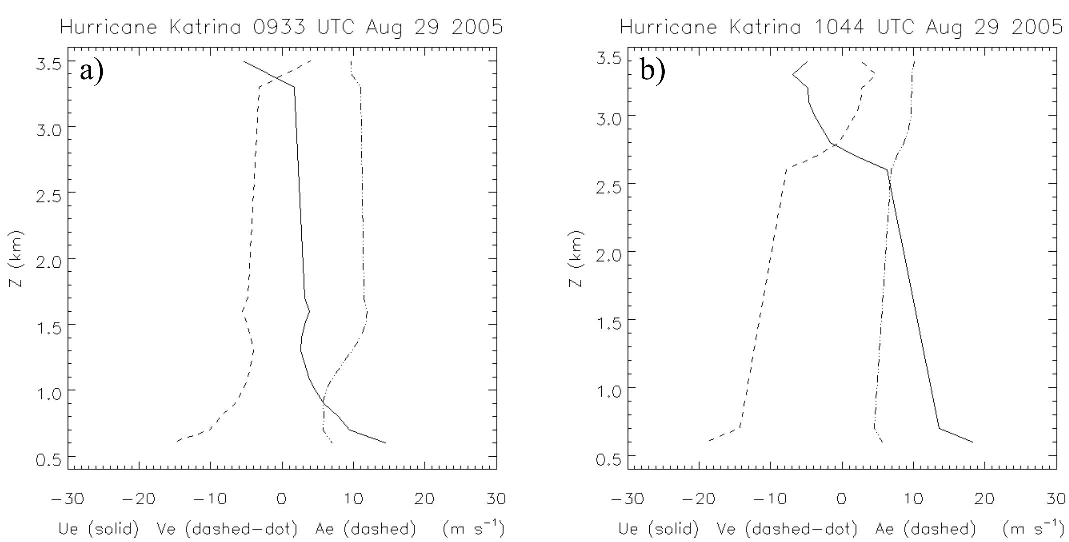

Figure 5. Vertical profiles of the Cartesian wind components of the environmental wind (Ue, Ve), and the across-beam component of the environmental wind (Ae), around Hurricane Katrina on August 29 2005 at a) 0933 UTC and b) 1044 UTC. Note the increasing westerlies in Ue and decreasing southerlies in Ve with time below 2.7 km are consistent with more steering toward the north-east (veering) as demonstrated by

Katina's track just after 1044 UTC. This postulated effect assumes all other winds aloft, not estimated by HVVP, also contribute to this possibility of veering of the track with time, in the vertically integrated sense of steering.

Revised timeline for JHT (submitted to JHT September 2005)

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(iii) Key Milestones (assuming a start date of August 1, 2005)

(a) August 2005-February 2006: Integrate the core algorithms and test at UCAR.

(b) Present a prototype at IHC, March 2006, complete first semi-annual report

(c) May 2006: Port and install integrated algorithm at TPC/NHC. Install a rudimentary graphical display capability.

(d) August 2006: Complete first annual report.

(e) August-October 2006: PIs will be present to monitor functional tests during one pre-selected time period (7 days) of the 2006 hurricane season and obtain feedback from TPC staff on the performance of the products.

(f) November 2006-April 2007: Incorporate TPC feedback and develop a NHC-appropriate graphical user interface at UCAR. Complete the semi-annual report.

(g) May 2007: Update algorithm and install graphical user interface at NHC.

(h) June-July 2007: PIs will be present to monitor pre-implementation operational tests during pre-selected time periods of the 2007 hurricane season and obtain feedback from TPC staff on the performance of the products. Assist in the operational implementation as required

(i) August 2007: Complete the scientific documentation, algorithm user's guide, and the final project report, and provide case studies for training.