12A.8 OPERATIONAL IMPLEMENTATION OF SINGLE-DOPPLER RADAR ALGORITHMS FOR TROPICAL CYCLONES

Paul R. Harasti*, Wen-Chau Lee, John Tuttle
National Center for Atmospheric Research, Boulder, Colorado

Colin J. McAdie
NOAA/NWS/Tropical Prediction Center, Miami, Florida

Peter Dodge, Shirley T. Murillo, Frank D. Marks, Jr.
NOAA/AOML/Hurricane Research Division, Miami, Florida

1. INTRODUCTION

In order to better depict the tropical cyclone wind field using single-Doppler radar data, several algorithms have been investigated. These include the Ground-based Velocity Track Display (GBVTD - Lee, et al., 1999), and The Tracking Radar Echoes by Correlation (TREC – Tuttle and Gall, 1999) methods. A continuing cooperative effort amongst the National Center for Atmospheric Research, the NOAA/AOML/ Hurricane Research Division (HRD) and NOAA/NWS/Tropical Prediction Center (TPC) has led to the improvement and operational implementation of these and other methods. The data source is the 10-cm Weather Surveillance Radar-1988 Doppler (WSR-88D) which provides the operational radar data stream to National Weather Service field offices. However, this data stream has its limitations.

Owing to the technological limitations of the early 1980's, the design emphasis of the WSR-88D was on remote display, not remote processing. As a consequence, TPC - and other national centers - have not had real-time access to full-resolution digital data (usually referred to as "level II" in the lexicon of the WSR-88D). Rather, data access has been limited to the "level IV" or imagery files. However, future builds of the Open Radar Product Generator (ORPG) will make level II data available in real-time to the national centers.

This paper presents an interim solution to the problem of data availability. Improvements to the GBVTD and TREC techniques are also described along with results of their application to the WSR-88D data of Hurricane Bret (1999). Results from Tropical Storm Barry (2001) will also be shown at the conference.

2. USE OF LEVEL IV AS A DATA PROXY

The Advanced Weather Interactive Processing System (AWIPS) at TPC receives radar products routinely through the Satellite Broadcast Network. Although the automatic receipt of radar products into AWIPS allows for file access, the files themselves are level IV and therefore must be used as a proxy for level II data.

The data resolution of level IV data is defined by a number of data levels, usually 8 or 16, corresponding to the familiar color-coded legend in a radar data map; e.g., the typical 16 levels of Doppler velocity in knots are ±64, ±50, ±36, ±26, ±20, ±10, 0, -1, including two levels for range ambiguous and weak signals. Thus the data resolution is very coarse in comparison to level II data.

Constant Altitude Plan Position Indicator (CAPPI) maps of reflectivity and Doppler velocity are constructed from all of the level IV data using the method first proposed by Marshall (1957). The GBVTD and TREC methods are then applied to the data that make up the CAPPI maps as follows.

Accurate Doppler velocity values are a requirement for the GBVTD method. The contour crossings on the CAPPI maps (whose values equal the data levels) are the only areas where the level II and IV data are equal and accurate. Thus, the radar (polar) coordinates of the Doppler velocity contours and their values are the only parts of the CAPPI maps used in the operational GBVTD algorithm. This approach was first proposed by Houston et al. (1999).

All of the level IV data constituting the CAPPI maps of reflectivity and Doppler velocity are used in the operational TREC algorithm. Exact reflectivity values are not required in this case because the TREC correlations can still be computed from the echo patterns labeled with inexact reflectivity values. However, the average values of adjacent Doppler velocity data levels are inserted in place of the same levels in order to improve the accuracy of the Doppler velocity estimates within the regions of echo that are between the contour crossings.

3. IMPROVEMENTS TO GBVTD AND TREC

The GBVTD method provides an estimate of the horizontal winds relative to the mean wind (V_M). In order to increase its operational utility, the GBVTD winds are adjusted to an earth-relative frame of reference. This is accomplished by using the storm motion as a proxy for the mean wind. This proxy is also used to make another correction for the mean wind found in the expression for the GBVTD wavenumber 0 component of the tangential wind:

$$V_T C_0 = -B_1 - B_3 - V_M \sin(\theta_T - \theta_M) \sin(\alpha_{\max}) \quad (1)$$

*Corresponding author address: Dr. Paul R. Harasti, NCAR, ATD–Advanced Study Program, Box 3000, Boulder, Colorado, 80307-3000. E-mail: harasti@ucar.edu. NCAR is sponsored by the National Science Foundation.

See equation 20 in Lee et al. (1999) for details, and note the correction to the sign of "B_3" in (1).

Tuttle and Gall (1999) proposed doing the TREC analysis on a polar grid centered on the hurricane eye in order to alleviate the poor results often shown in the eyewall of the more intense tropical cyclones. This recommendation has been implemented in the operational TREC algorithm. Preliminary tests show the new geometry to give significantly better results in regions of uniform reflectivity.

4. RESULTS AND DISCUSSION

Hurricane Bret was a category 4 hurricane that made landfall along the Texas coast on August 22, 1999 as a category 3. It was observed simultaneously by two WSR-88D coastal radars (KCRP and KBRO) and a Doppler radar aboard a NOAA P-3 aircraft. The operational GBVTD and TREC algorithms were applied in a post storm analysis to the level IV data of KCRP and KBRO. Fig. 1 shows the results obtained from the 3 km CAPPI maps constructed from the level IV data: 1a shows the GBVTD results and 1b shows the TREC results derived from the KCRP and KBRO data, respectively. Bret's center was ~100 km south (north) of KCRP (KBRO) at this time. The calm winds at the top of the TREC results are an artifact of the abrupt end to the CAPPI data there. Overall, the results agree reasonably well; both confirm Bret's category 3 status aloft. Both results also agree well with the results of a triple-Doppler radar wind synthesis obtained from HRD that used the KCRP, KBRO and the airborne Doppler radar (not shown).

Both the GBVTD and TREC (polar formulation only) algorithms require an estimate of the storm center. Specifically, an estimate of the position of the *vorticity* center is required for GBVTD and is often estimated operationally (as in this example) by the method of Lee and Marks (2000). The method of Harasti and List (2001) has also been used in conjunction with GBVTD as an alternative in certain situations. TREC on the other hand requires an estimate of the position of the *wind* center, usually obtained by Air Force aircraft reconnaissance aircraft (as in this example), although it has been demonstrated that the results are not that sensitive to the accuracy of this estimate.

The GBVTD and TREC algorithms have also been applied with great success to the level IV data sets of Hurricane Debby (2000) and Tropical Storm Barry (2001). The fact that these algorithms work so well with the coarse level IV data bodes well for the future when full resolution level II data become available in real-time.

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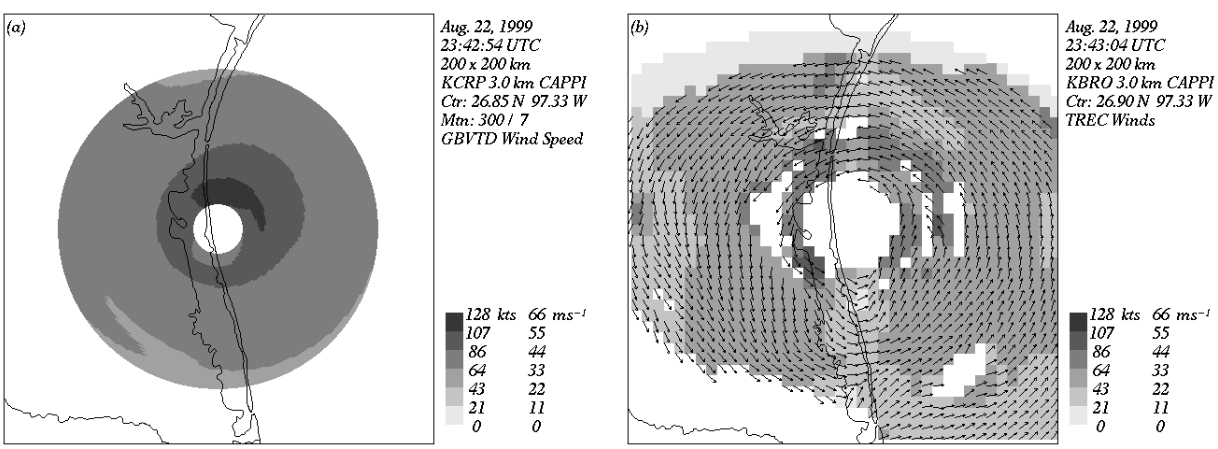

Figure 1. (a) GBVTD and (b) TREC results derived from the level IV data of Hurricane Bret (1999). A 3 km CAPPI map of Doppler velocity was constructed from the KCRP data and used as input for the GBVTD analysis. In contrast, both a 3 km reflectivity CAPPI map and a 3 km Doppler velocity CAPPI map were constructed from the KBRO data and used as input for the TREC analysis.