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REAL-TIME IMPLEMENTATION OF TROPICAL CYCLONE-SPECIFIC RADAR DATA PROCESSING ALGORITHMS

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1.0 INTRODUCTION

In order to better depict the tropical cyclone wind field using single-Doppler radar velocity data, several algorithms have been investigated. A continuing cooperative effort with the Atlantic Oceanographic and Meteorological Laboratory/Hurricane Research Division (HRD) has allowed us to make significant progress in this area, including the implementation of the Ground-based Velocity Track Display (GBVTD) algorithm (Lee, et al., 1999), which gives an estimate of the total horizontal wind from the single-Doppler velocities. The data source is the 10-cm Weather Surveillance Radar-88 Doppler (WSR-88D) which provides the operational radar data stream to National Weather Service field offices.

A significant obstacle in this work has been the lack of real-time access to the digital data (usually referred to as "archive II" in the lexicon of the WSR-88D). Rather, at the NOAA/Tropical Prediction Center (TPC) - and other national centers - access is limited to the "archive IV" or imagery files. This is because the technology of the early 1980's did not appear to provide any cost-effective way to move large amounts of data in real-time to remote users, such as TPC. The design emphasis was on remote display, not remote processing.

We note in passing that the next generation of this radar system (Saffle and Johnson, 2001) will address this problem through a base data distribution system. Pending the deployment of this new system, an alternative (described below) has been put in place at TPC utilizing the imagery files as a proxy for the full-resolution digital data.

2.0 OBTAINING THE ARCHIVE IV FILES

The Principal User Processor (PUP) which receives the archive IV image files (Fig. 1) was designed as a display platform. Requests are sent via a dial-up line to a Radar Product Generator (RPG) located (in this case) in a remote forecast office. Once the files have been received by the PUP, there is no convenient method of transferring them to another processor. To overcome this problem, it is necessary to intercept the files upon arrival. This is made possible by technology developed by the Federal Aviation Administration Technical Center in conjunction with NWS/Eastern Region.

This PC-based system, known as the Weather Information Disseminator (WID) employs a modem splitter, and monitors file headers as they are transmitted over the dial-up line. A GUI allows selection of desired products, which are stored on the WID hard drive. As the WID is network mounted, the files are then available for off-line processing (HP in Fig.1). Demonstration or test products thus generated are viewable on a remote terminal placed adjacent to the PUP.

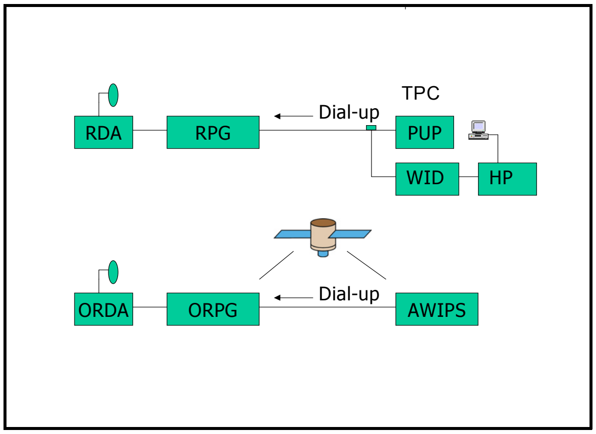

Figure 1. Schematic of existing radar data delivery system (top) with PC-based WID attached for file capture, and open system replacement (bottom).

The bottom portion of Fig. 1 shows the transition to open systems, in which the Advanced Weather Interactive Processing System (AWIPS) becomes the display platform, replacing the PUP. AWIPS is a UNIX-based networked platform, making the interception of files by the WID unnecessary. Note that AWIPS receives radar products routinely through the Satellite Broadcast Network (SBN), with the dial-up retained as a backup. Although the automatic receipt of radar products into AWIPS will simplify file access, the files themselves are still archive IV, and still must be utilized in post-processing as described below. Future builds of the open RPG (ORPG) should make the digital data available.

3.0 USE OF ARCHIVE IV AS A DATA PROXY

Software has been developed by AOML/HRD (Dodge, personal communication) which allows the use

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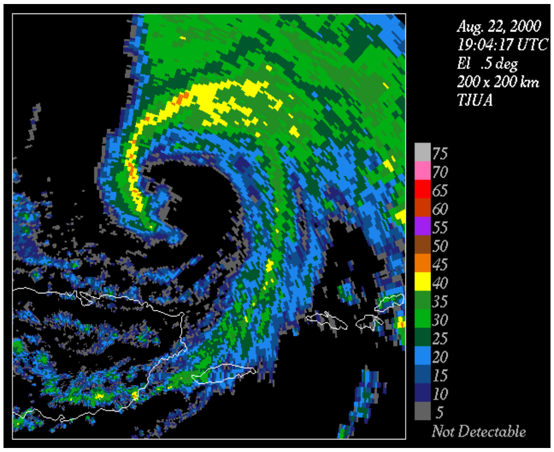

Figure 2. Reflectivity image of H. Debby at 22 Aug 2000, 1904 UTC, from the San Juan WSR-88D.

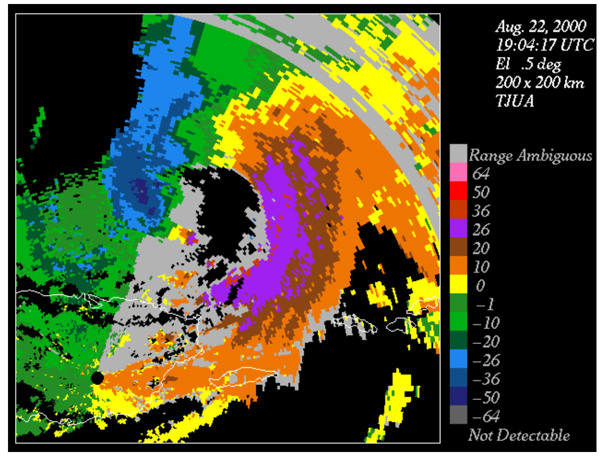

Figure 3. As in Fig. 2, except for velocity image.

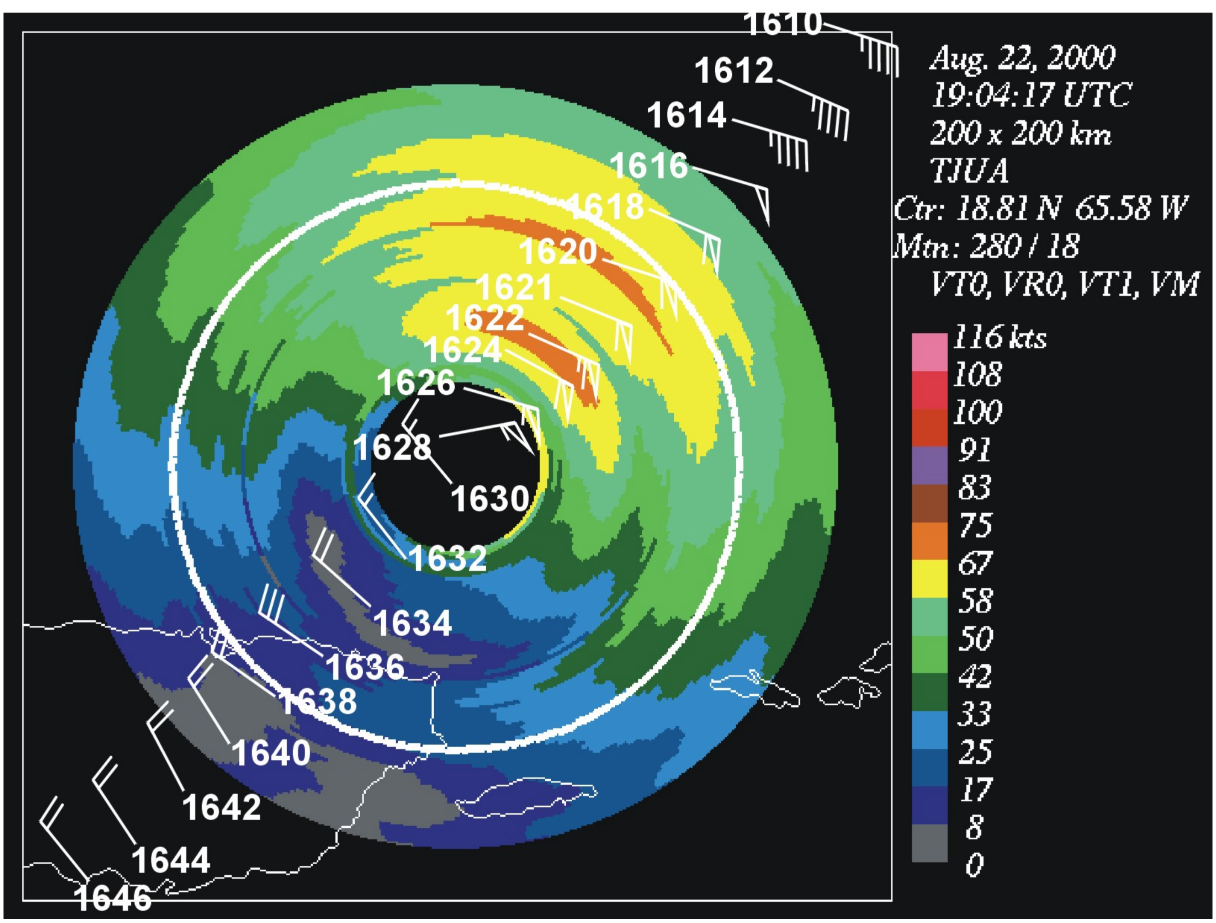

Figure 4. Ground-based Velocity Track Display (GBVTD) analysis for the time shown in Fig. 3.
Air Force aircraft reconnaissance winds shown have been translated to match the 1904 UTC center position for comparison.

of the velocity image files as a proxy for the digital data. Briefly, the radar images are received by TPC (as in Fig 1.) in r-Θ format. The data "resolution" is defined by a number of data levels, usually 8 or 16. These levels correspond to the familiar color-coded legend along the border of a radar image. In the image file itself, each data element along a radial is an integer ranging from 0 to 15 (in the case of the 16-level product) representing a pre-defined data level. The gist of the technique is that as integer values are read in along the radial, changes in value are noted. A change in integer value represents a contour (or isodop) crossing. The value deduced at this point is thus representative of that contained in the full-resolution digital data. As these points are accumulated, the isodops become defined in an x-y coordinate system. The net result of this procedure is a data array which is available for further processing.

4.0 APPLICATIONS

As an example of the use of the proxy data, results from H. Debby are shown in Figs 2-4. Debby was a category 1 hurricane at this time, traveling WNW at about 19 kt. Figs 2 and 3 show the reflectivity and velocity images, respectively, for Debby at 22 Aug 2000, 1904 UTC as Debby moved within radar range of the San Juan WSR-88D. The island of Puerto Rico is outlined in the bottom left of the figures.

A set of data points (contour crossings) was obtained from the velocity image in Fig. 3, in real-time, and was provided as input to the GBVTD algorithm. Figure 4 shows the results of the GBVTD analysis. Briefly, the algorithm has derived an estimate of the total tropical cyclone horizontal wind field through harmonic analysis on concentric rings surrounding the circulation center. A full description of the logic appears in Lee, et al. (1999). The harmonic analysis provides storm-relative winds which are adjusted to ground-relative (shown in Fig. 4) in a local implementation by utilizing the TPC operational estimate of the storm motion.

Note the good agreement with Air Force aircraft reconnaissance winds. The height of the radar beam in the vicinity of the wind maximum is about 10000 ft, equal to the aircraft flight-level, forming an excellent basis for comparison. (Note that the San Juan WSR-88D is at an elevation of almost 3000 ft). Also note that the wind maximum has been correctly identified along the zero isodop, on the side of the hurricane "away" from the radar. This maximum would be extremely difficult or impossible to deduce based only upon visual inspection of the single-Doppler velocities shown in Fig 3.

The algorithm does require a center position in order to run. It may be supplied manually, or objectively. In this example, created in real-time during the event, an objective center-finding technique (Harasti and List, 2001) was used. The technique employs a principal component analysis of the velocity data to estimate the center position, and is sufficiently robust to obtain a center using the archive IV proxy data. The PCA center was near the operator fix, and in fact resulted in a better final wind analysis. The advantage of a reliable objective technique, especially if anchored by an initial operator fix, is that it allows an algorithm to run in background mode, creating a history of frames available for looping on demand.

We are working towards complementing this algorithm with additional techniques, including Tracking Reflectivity Echos by Correlation (TREC) (Tuttle and Gall, 1999), and Hurricane-Customized Extension of the VAD method (HEVAD) (Harasti and List, 2001). Both algorithms will significantly extend the wind analysis beyond the range of the Doppler velocities, and could be integrated into a combined product with GBVTD, or other techniques.

5.0 CONCLUSIONS

The WSR-88D archive IV files have been used to provide a proxy for the full-resolution digital data for tropical cyclone applications. This utilization has allowed us to proceed with coding and testing of tropical-cyclone specific algorithms prior to the availability (in real-time) of the full-resolution digital data. Significant benefit is derived from running (or attempting to run) algorithms in real-time under operational conditions. The fielding of open systems platforms should greatly facilitate this effort.

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