4.4 VISUALIZATION OF RADAR DATA IN THREE-DIMENSIONS

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1. INTRODUCTION

To more fully explore storm scale features associated with sever thunderstorms, it has become necessary to incorporate radar data from all elevation angles of the volume scan and evaluate those data from a volumetric standpoint. This would allow better study of features such as the rear-flank downdraft, updraft core, mesocyclone, and downburst regions (see [3], [4], [5],[1]). In addition, such efforts might shed light in trying to identify sub-scale phenomena such as tornadoes (see [2]).

Most radar software packages do not provide for such volumetric representation of the data. The user is left to mentally align data from various scans and qualitatively construct three-dimensional storm structure. At best, cross sections and proxy variables such as VIL and composite reflectivity provide some depth to the data sets. However, technology from fields such as medial imaging is available that can be used to provide more compressive depictions of the radar volumes scans.

In an attempt to develop better three-dimensional rendering, the NASA Radar Software Library (RSL) is being used to access unprocessed Level-II NEXRAD radar data. RSL is a library of object-oriented routines written in support of NASA's Tropical Rainfall Measuring Mission's (TRMM) Global Validation Program that allow raw radar data of different formats to be read, processed, and displayed. More information on the software library can be found on-line at http://trmm-fc.gsfc.nasa.gov/trmm_gv.

Three-dimensional volumetric representations are then constructed of the storm structure from the raw radar data using MATLAB software tools. Additionally, it is hoped that the raw radar volume scans can be put into a data format that can be used by other image processing algorithms and software. This would allow more sophisticated representations to be developed and expand the utility of the technique.

Such representation of the data can provide a richer interpretation of storm evolution, structure, and dynamics. While the visualization is still rather crude, it does open the door to a wide variety of applications. In this paper, we present such a case study using three-dimensional volume radar data collected during a tornado/thunderstorm event. The data was collected near Louisville Kentucky in 1996. Sequences of volume radar images will be presented and analyzed.

2. RADAR DATA PROCESSING

Raw Level-II WSR88D radar data collected for a tornadic thunderstorm on 28 May 1996 will be used to demonstrate the data processing technique. A tornado was reported at approximately 22:30 UTC 28 May 1996. Since this tornado was within 25 km of the Louisville radar (KLVX), the radar was in a good position to be able to sample much of the storm scale structure. While the tornado itself was below the bin size of the radar data and not definable, features such as the rear flank downdraft, the mesocyclone, and weak echo regions should be able to be identified. Examination of the base reflectivity data from the closest time to the report shows a well-defined supercell with a hook echo is easily identifiable (Figure 1).

The RSL routines were used to gain access to raw reflectivity, radial velocity, and spectrum width data for an entire WSR88D volume scan. Data are save in data structures that sort the information into volumes, sweeps, and individual rays. Data within individual rays can be accessed on a bin-bin-bin basis. While RSL has a built in utility to create a three-

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dimensional Cartesianized cube of data from the raw input, this utility creates some processing artifacts that leave some problems in the cube. Specifically, rings of missing data appear at certain ranges from the radar.

To overcome this problem, two solutions were examined. The first was to apply a low-level smoothing to the resulting cube. This creates an atheistically acceptable end product, but leaves questions about the quantitative accuracy of the data. The second solution was to write a new algorithm to transform the data from the raw three-dimensional polar coordinate format into a three-dimensional Cartesian format. This solution provides results that look much like the smoothed data case, without the quantitative uncertainties.

Ultimately the Cartesianized data were written to a new data file in a format that can be accessed by MATLAB software. MATLAB, which stands for Matrix Laboratory, is a software package that allows for the processing, visualization, and manipulation of data saved in matrix format. MATLAB includes built in functionality for using these types of data sets.

3. VISUALIZATION OF RADAR DATA

Using the "sliceomatic" program from the MATLAB package, several new visualization options are made available. First, pseudo cross-sections are possible in either the north-south or east-west direction. This is accomplished interactively by defining an anchor point, which can be moved to look at different regions of the data set.

A second visualization option is to reorient the cube to look down from above. Horizontal planes can then be created to allow for a top-down or a bottom-up display. This provides a display that is similar to looking at a sequence of constant altitude PPI's (CAPPI). The difference is that the display is in a Cartesian form instead of the raw polar coordinate form.

Finally, a three-dimensional volume can be displayed by setting a threshold data value. For example, for a reflectivity volume, choosing a threshold value of 20 dbZ provides a good overall view of the storm. For focusing in on the precipitation core, a higher reflectivity value can be chosen to limit the data domain.

To illustrate the MATLAB-based visualization technique, six sequential radar images are provided in Figure 2 - Figure 7. The data displayed in these figures is a subset of the northeast quadrant of the display shown in Figure 1, so the lower left corner of the cube is anchored at the center of the original domain.

In Figure 2, the main thunderstorm structure is visible. The main updraft region is to the left side of the image, the heavy precipitation area is in the center, and the anvil blows off to the right. As the figures progress, the main updraft area becomes more easily defined. This is part due to the choice of viewing angles for this case. In Figures 4 through 7, you can see the development of the hook near the lower center of the display. This feature wraps around into the core of the storm over time. The three-dimensional nature of the feature is apparent in this representation. The time closest to the reported tornado is represented in Figure 5.

4. CONCLUSIONS

The goal of this project is to develop visualization tools that aid in on-going radar research. While this effort is the first step in developing such visualization techniques, it demonstrates the capabilities and potential of even simple representations. It is hoped that these tools can be couple with quantitative algorithms, so that new statistical analyses can be developed. In addition, the processing time for a full volume of data is relatively brief. On a SGI O2 workstation, a full volume of WSR88-D data can be processed in under 30 seconds. Since the porting to MATLAB is also quick, there may be some operational tools and applications that could eventually arise.

ACKNOWLEDGMENTS

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References

[1] Federal Meteorological Handbook No. 11, 1991: Doppler radar meteorological observations, Part B, WSR-88D products and algorithms. FCM-H11C-1991, Interim Version One. Office of the Federal Coordinator for Meteorological Services and Supporting Research, Rockville, Maryland, 210 pp.

[2] Mitchell, E. D., S. Vasilof, G. J. Stumpf, A. Witt, M. Eilts, J. T. Johnson, and K. Thomas, 1998: The National Severe Storms Laboratory Tornado Detection Algorithm. *Wea. Forecasting*, **13**, 352-366.

[3] Moller, A. R., C. A. Doswell III, M. P. Foster, and G. R. Woodall, 1994: The operational recognition of supercell thunderstorm environments and storm structures. *Wea. Forecasting*, **9**, 327-347.

[4] Stumpf, G. J., Witt, A., E. D. Mitchell, P. L. Spencer, E. D. Mitchell, J. T. Johnson, M. Eilts, K. Thomas, and D. Burgess, 1998: The National Severe Storms Laboratory Mesocyclone Detection Algorithm for the WR-88D. *Wea. Forecasting*, **13**, 304-326.

[5] Witt, A., M. Eilts, G. J. Stumpf, E. D. Mitchell, J. T. Johnson, and K. Thomas, 1998: Evaluating the performance of the WSR-88D severe storm detection algorithm. *Wea. Forecasting*, **13**, 513-518.

Figure 1. Radar Image Sweep 4 Data from Fig. 5

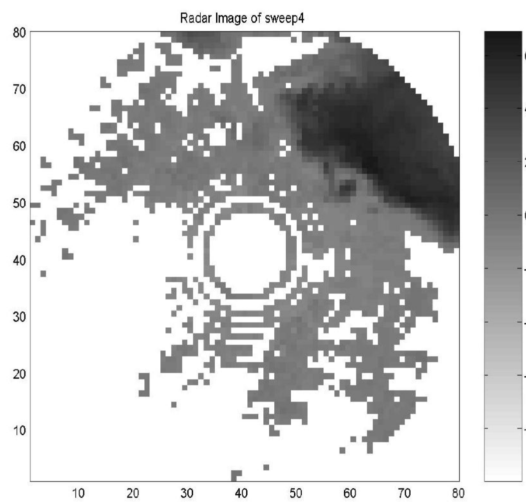

Figure 2. 3-D Radar Image $t = 0$ min

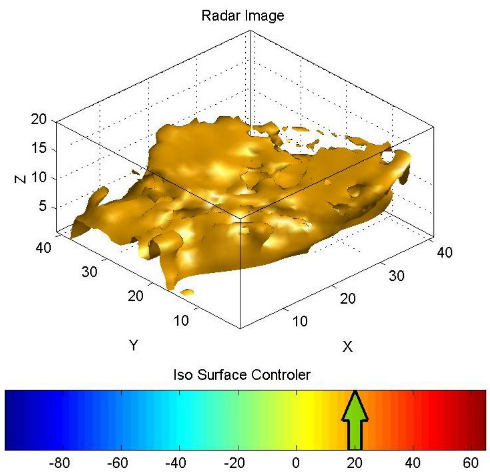

Figure 3. 3-D Radar Image $t = 5$ min

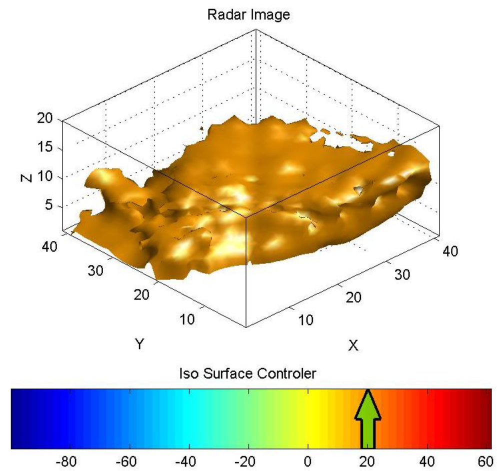

Figure 4. 3-D Radar Image $t = 10$ min

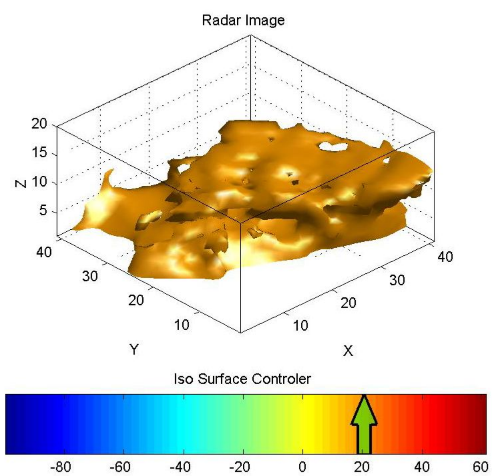

Figure 5. 3-D Radar Image $t = 15$ min

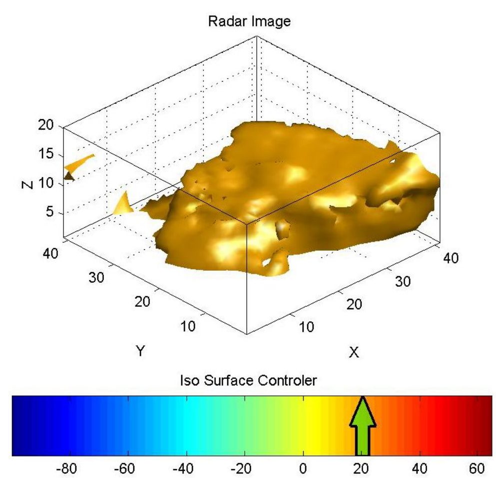

Figure 6. 3-D Radar Image $t = 20$ min

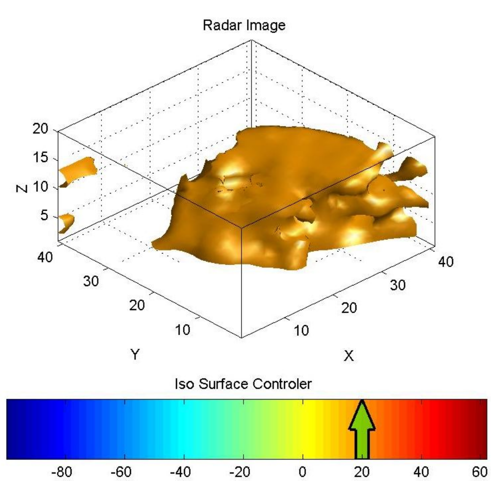

Figure 7. 3-D Radar Image $t = 25$ min