14. 1 Comparison of Storm Evolution Characteristics: The NWRT and WSR-88D

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1. INTRODUCTION

Early detection of rapidly developing hazardous storms requires a rapid-scan radar. The National Weather Radar Testbed (NWRT) collects data from a 10-cm, single-faced, phased array radar (PAR) that supports adaptable scanning strategies and volumetrically scans a storm in time scales of seconds instead of several minutes. Such high temporal sampling provides unprecedented opportunity to research small-scale phenomena and improve warning lead-time for severe weather. Another significant advantage of the PAR is the ability for making cross-beam wind, shear, and turbulence measurements (Zhang and Doviak 2006). Other meteorological benefits are considered in Doviak et al. (2001).

The NWRT and PAR became operational in September 2003 and data collected in 2004 and 2005 for engineering tests, weather observations, and system checks have resulted in hardware stability and estimates of reflectivity, velocity, and spectrum width comparable to the WSR-88D (Forsyth et al. 2006). Furthermore, Cheong et al. (2006) used some of these data to explore the implementation of refractivity measurements for estimating low-level moisture fields.

This paper is the first to analyze the meteorological advantages of the higher temporal sampling capability of the PAR as compared to the WSR-88D. In cases where WSR-88D data are unavailable, comparisons of storm structure and evolution are accomplished by comparing PAR images at ~4-min 13-s intervals (length of VCP-12 scan) to those collected with higher frequency. The comparison focuses on rapid evolution of three storms observed by the PAR in 2006, including a supercell (24 April), a multicell (30 May), and a hail storm (15 August) that produced a three-body scatter spike (e.g., Zrnić 1987; Lemon 1998).

2. SCANNING STRATEGIES

As mentioned in the Introduction, the PAR's electronically steered beam supports the requirement for the significantly faster, high quality volumetric update rates needed for early detection of hail, tornadoes, microbursts, and other weather hazards. Because the PAR is currently single-faced, it collects volumetric data within a 90° sector at a rate of less than one min. Such fast scanning is unachievable by conventional single-beam, mechanically scanned radars like the WSR-88D. The result is more temporally realistic depictions of meteorological phenomena.

The scanning strategies used for each of the three events described herein were chosen based on areal coverage of storms and storm proximity to the PAR. On 24 April and 30 May 2006, a flavor of the VCP 12 scanning strategy was chosen for comparison with the Twin Lakes (KTLX) radar, located ~20 km to the northeast of the PAR. To scan storms of interest on 24 April, a 90° sector was required, whereas a 20° sector was adequate for the 30 May storms. These scanning strategies resulted in volume scan times of ~58 s on 24 April and ~18s on 30 May. A different scanning strategy was used on 15 August that focused on scanning "close" storms by adding additional elevation angles. The temporal resolution was kept under 30 s by reducing the dwell pulse count and pulse repetition time (PRT). The meteorological advantages of these rapid scan events are shown in section 3.

3. ADVANTAGES OF HIGHER TEMPORAL SAMPLING

3.1 *24 April 2006*

On 24 April 2006 conditions were favorable for supercell development near central Oklahoma and well within range of the PAR.

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Severe storms were continuously sampled with the PAR between 2000 UTC on the 24th through 0300 UTC on the 25th. Fortunately several supercells were sampled, including a tornado-warned storm, but none produced a tornado. This event provides a unique comparison between KTLX and the PAR as both radars scanned the same storms in southwest OK using VCP-12 as described in section 2. Radar reflectivity characteristics are addressed in subsequent sections, hence this section focuses on assessing velocity features, namely low-level convergence (Fig. 1).

Figure 1 shows an area of developing low-level convergence and rotation located approximately 50 km southwest of the PAR (~ 70 km southwest of KTLX). Both KTLX and the PAR capture the strengthening thunderstorm gust front, depicted by increasing in-bound velocity to the southwest and south of an area of out-bound velocity. The PAR volume scan update time of 58 s provided an earlier signal of increasing velocity magnitude and spatial contraction of the inbound/outbound convergence signature and velocity couplet than KTLX with its 213 s volume scan update time. The rapid updating of volumetric Doppler radar data also allows the user to closely monitor the vertical structure of velocity within a storm, such as the intensification or decay of a mesocyclone or tornado vortex signature.

3.2 *30 May 2006*

During the early afternoon, a line of severe storms developed over south-central Kansas, along and just ahead of a quasi-stationary front. Outflow produced by these storms initiated new convection over northern Oklahoma. The strongest of these storms, eventually located just northwest of Enid, OK, caught the attention of the Norman WFO, who issued a severe thunderstorm warning at 2227 UTC. Near this time, data collection on this multicell storm began at the NWRT. Because the center of the storm was located 150 km from the PAR, data were collected with a 20° sector-version of VCP-12 that scanned a full volume every 18 s.

The high temporal scanning captured the subsequent evolution of this multicell storm in great detail. During the period of about one conventional VCP-12 scan (223346–223804 UTC), a new “cell” formed at the leading edge of the multicell (X = 30–35 km) and the middle cell (X = 35–47 km) deepened, intensified, and began to produce a strong downdraft (Fig. 2). Within a second conventional VCP-12 scan (223840 –224235 UTC), the cell at the leading edge of the multicell intensified and precipitation began to descend, while the middle cell began to merge with the multicell and further intensified as it developed a core of reflectivities exceeding 60 dB*Z.* Furthermore, within this period the right-most cell initiated, grew, and began to merge with the middle cell (X=47–50 km). The relative lack of vertical growth and intensification of the right-most cell, compared to the middle cell, indicated the beginning of the long dissipation process of the multicell storm. A conventional VCP-12 scan would have completely missed the rapid evolution of these cells.

3.3 *15 August 2006*

During the early afternoon as surface temperatures reached the mid 90's to low 100's south of a weak front located across central Oklahoma, numerous small convective cells developed. Data collection at the NWRT began shortly after the appearance of the first radar echoes, just to the south of Norman. Since many of the cells were developing within 100 km of the PAR, a 12 pulse, 31 level (up to 41° elevation) short PRT (831 ms) scan strategy was used that would sample the tops of “close” storms and be completed in ~26 s. Most of the initial cells were short-lived (30 min) and remained below a 7.5-km midlevel cap, which was evident in the 12-UTC OUN sounding. A slight northward drift of these cells corresponded with weak southerly winds below the cap.

In the late afternoon, near the frontal boundary, one cell broke through the cap and quickly grew to over 14 km in height (Fig. 3). This cell rapidly evolved into a severe storm with reflectivities exceeding 70 dB*Z*. The Norman WFO issued a warning for this storm at 2231 UTC with the main threats of hail and strong outflow winds.

The PAR captured the evolution of this storm very well. Fig. 3 illustrates the evolution of the main cell and the well-pronounced “Three-body Scatter Spike” (TBSS; Zrnić 1987; Lemon 1998), which developed around 2229 UTC. This feature continued to develop and eventually descended with the main reflectivity core until it dissipated around 2244 UTC. The rapid update capability of the PAR provided a clear picture of the storm during its evolution. Correspondingly, the TBSS would have been visible in only a few WSR-88D volumes (using VCP-11 or 12) and its descent through the storms life cycle would not have been as evident.

4. CONCLUSIONS

This study explored the meteorological advantages of unprecedented rapid-scan data collected by the PAR for three severe storms during the spring and summer of 2006. A comparative analysis of storm evolution depicted by the PAR and the WSR-88D illustrates that significant, rapid storm development occurs during the period of a conventional VCP-12 scan. Important features captured only by the PAR:

- Rapid deepening and intensification of a maturing storm cell
- Merging process for three cells
- Rapid development and descent of a hail core and attendant three-body scatter spike
- Tracking rapid evolution of low-level convergence

Although WSR-88D data are a proven tool for assessing storm severity, this study illustrates the ability of PARs to provide the high-temporal resolution data needed for early detection of significant storm development, hail signatures, convergence, and wind shear. These high-temporal resolution data should aid in short-term forecasting and warnings, though users may be challenged by the rapid influx of data.

5. REFERENCES

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6. ACKNOWLEDGEMENTS

We acknowledge the support of our various organizations in funding and helping to implement this national facility. This paper was funded by NOAA/Office of Oceanic and Atmospheric Research under NOAA-University of Oklahoma Cooperative Agreement #NA17RJ1227, U.S. Department of Commerce (DOC). The statements, findings, conclusions, and recommendations are those of the authors and do not necessarily reflect the views of NOAA or the U.S. DOC. For this paper, we especially thank the leadership of Doug Forsyth and the dedicated work of Mark Benner, Dan Suppes, Kurt Hondl, and John Thompson, who kept data collection, archiving, and data display going.

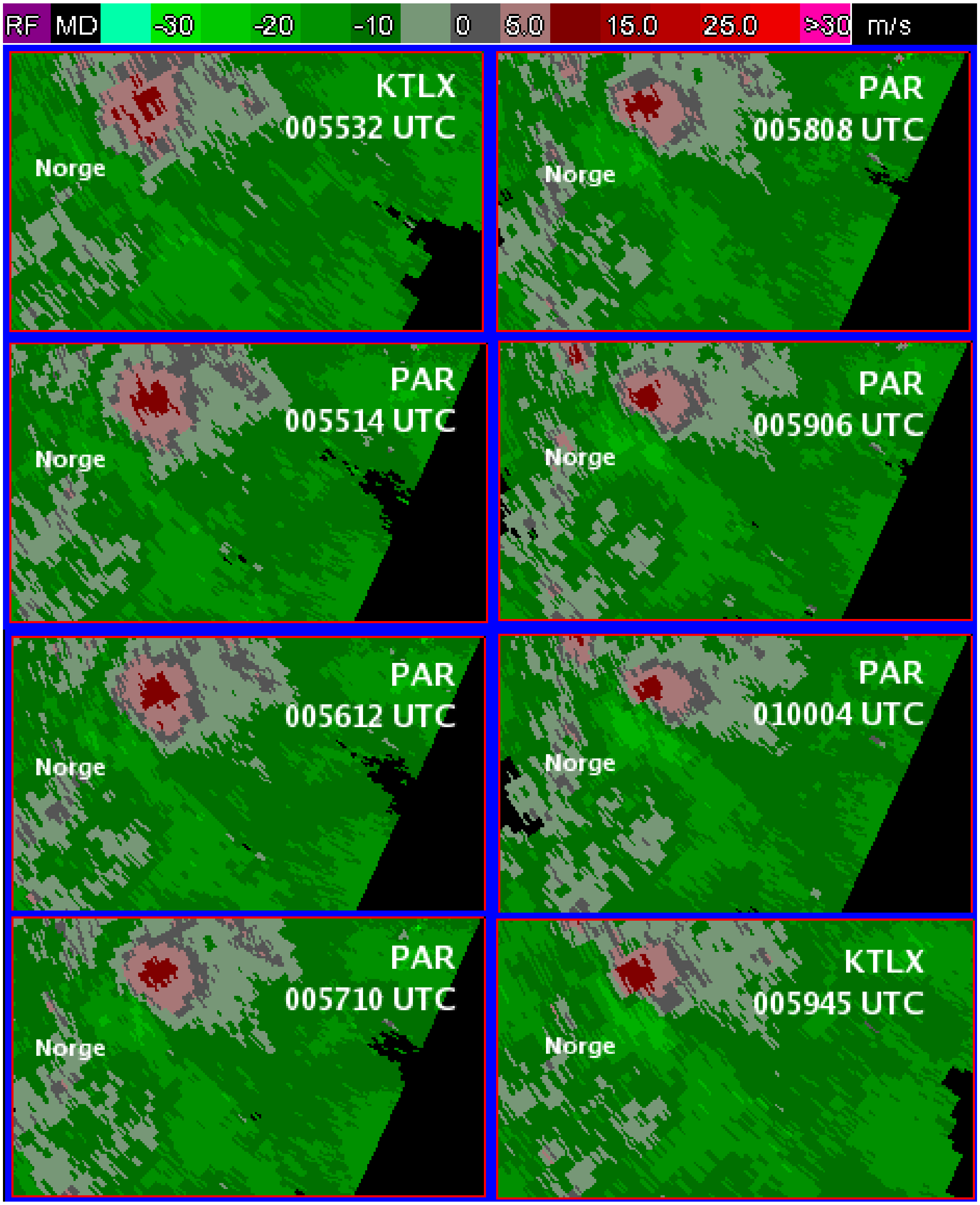

Figure 1. Development of low-level convergence and rotation within a severe thunderstorm near Norge, OK (approximately 50 km from the PAR) on 25 April 2006. The top left and bottom right panels are from consecutive 0.5° elevation scans from KTLX. The panels in between are consecutive 0.5° elevation scans from the PAR. There are 213 s between KTLX scans and 58 s between PAR scans. Note the detailed development of the gust front depicted by increasing in-bound (green) velocity to the southwest and south of the out-bound (red) velocity.

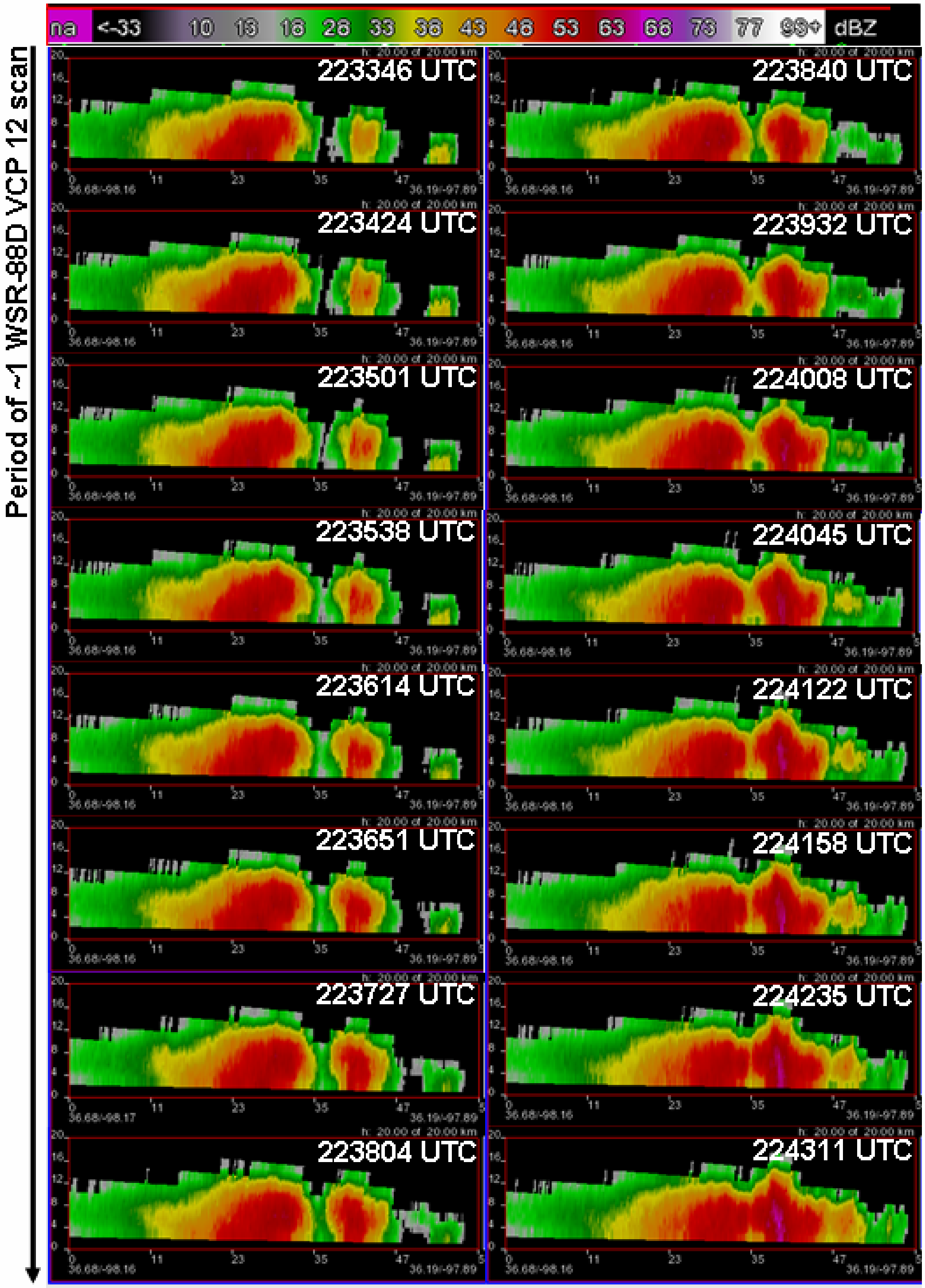

Figure 2. Time sequence of vertical cross-sections of reflectivity through a multicell (far left), a strong, growing cell (middle), and a few weaker cells (far right). The vertical and horizontal scales are in km. Initially the center of the multicell is located about 150 km to the northwest of the PAR and moves toward the south-southeast at ~13.4 m s^{-1}. Each column shows the evolution of each storm during the time needed to complete about one WSR-88D VCP-12 scan. The freezing level is at ~4.0 km and the -20°C level is at ~7.5 km (based on 12-UTC OUN sounding).

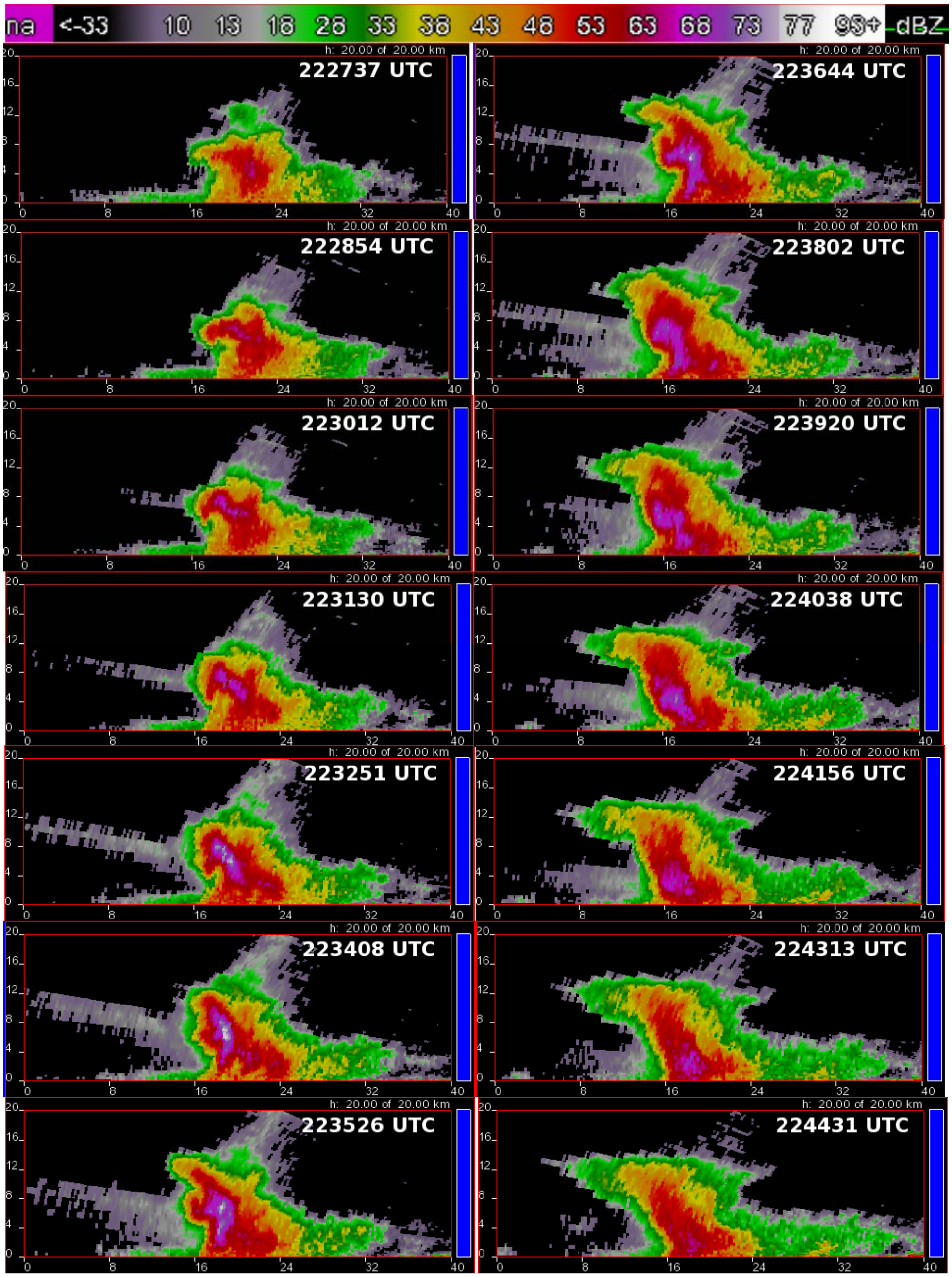

Figure 3. Time sequence of vertical cross-sections of reflectivity thorugh a severe storm on 15 August 2006 as seen by the PAR. The vertical and horizontal scales are in km. The center of the storm is approximately 40 km from the PAR. The freezing level is at ~4.5 km and the -20°C level is at ~8.1 km (based on 12-UTC OUN sounding).