P9.13 SUPER-RESOLUTION POLARIMETRIC OBSERVATIONS OF A CYCLIC TORNADIC SUPERCELL

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1. INTRODUCTION

Recent developments have shown that WSR-88D radars are capable of collecting data with higher resolution than is currently employed by the National Weather Service. Conventional data are sampled every one degree in azimuth with 250-meter gate spacing. In contrast, the so-called "super-resolution" data are sampled every half degree in azimuth. For the first time, super-resolution dual-polarization radar data have been collected for a cyclic tornadic supercell storm in north-central Oklahoma. The data were obtained by the NSSL research prototype dual-polarization WSR-88D in Norman (KOUN).

The next section provides an overview of the storm and its environment. The data are presented in section 3, which discusses the various polarimetric signatures observed in the storm, their evolution, and their relation to the storm behavior and morphology. We conclude with a discussion of the implications of the availability of super-resolution polarimetric data following the forthcoming nationwide polarimetric upgrade of the WSR-88D network, focusing on the benefits and operational applications of super-resolution data.

2. EVENT OVERVIEW

At 1200 UTC on 24 May, a positively-tilted upper level trough approaching the southern plains was evident on the synoptic charts. The OUN sounding reveals a veering wind profile, but wind speed shear is only modest. Thermodynamically, conditions were very unstable (> 3000 J kg^{-1} of CAPE) above a stout inversion. Data from the Oklahoma Mesonet (Fig. 1) show two areas of lower θ_e air. The region in the north and northeast portion of the state is due to outflow from an MCS the previous night, maintained by remnant low-level clouds (differential diabatic heating). To the west, a very dry air mass made it into Oklahoma, its leading edge marked by a well-defined moisture gradient, though there was no significant temperature gradient. The storm initiated about 1830 (herein all times UTC) in the vicinity the intersection of the dryline and outflow boundary, after which it progressed slowly to the east along the outflow boundary.

The supercell produced at least 10 tornadoes, one of which was nearly a mile wide and caused high-end EF-2 damage. The last tornado occurred at about 2330, after which the storm quickly lost supercell characteristics as multicellular convection in the vicinity began to develop.

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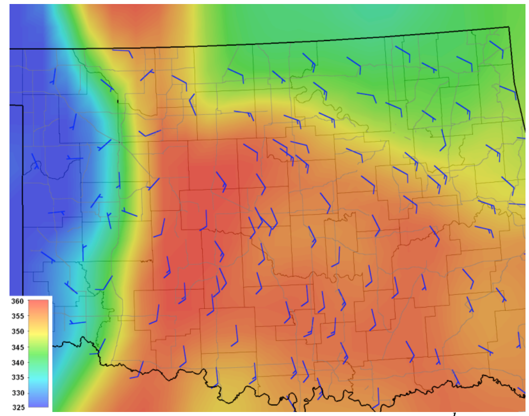


Fig. 1: Surface θ_e (K) and wind barbs (m s^{-1}) from the Oklahoma Mesonet at 1915 UTC on 24 May 2008.

3. POLARIMETRIC DATA

The super-resolution polarimetric data were collected nearly continuously over the duration of this storm. Despite its large distance from the radar (> 115 km), the resolution of the data is such that many features are still readily apparent. Polarimetric signatures characteristic of supercell storms (Kumjian and Ryzhkov 2008) are found in the data from this case throughout its lifetime. The signatures include the Z_{DR} arc, Z_{DR} and K_{DP} columns, the low-level hail signature, midlevel rings of enhanced Z_{DR} and decreased ρ_{HV}, the updraft signature, and the tornadic debris signature (Ryzhkov et al. 2005).

Beginning at 2109 UTC, a well-defined Z_{DR} arc is present along the edge of the FFD, extending back into the updraft region (not shown). The Z_{DR} arc is evidence of raindrop size sorting by the strong inflow and veering wind shear and is proportional to the low-level storm-relative helicity. Kumjian and Ryzhkov (2009) suggest that the arc extends back into the updraft at times preceding the occlusion of the low-level mesocyclone. Doppler velocity data indicate a strong cyclonic shear couplet in the hook echo, which is characterized by relatively high ρ_{HV} at this time. At midlevels, a well-defined BWER is present, collocated with a Z_{DR} column and an updraft signature in ρ_{HV}.

Figures 2 – 4 present the vertical structure of the storm from the VCP beginning at 2216. A well-defined hook echo and "flying eagle" pattern (see Kumjian and Schenkman 2008) in Z_H indicate that the storm is mature and well-organized. In the polarimetric variables, a tornadic debris signature is present at low levels (Figs. 3a, 4a), centered at about x = - 5 km, y = 115 km. A nice Z_{DR} arc still remains (Fig. 3a), though is decreased in areal extent from the previous scan. A Z_{DR} ring is evident in Figs. 3b-c, and a half-ring of ρ_{HV} is present (Fig. 4c). Columns of positive Z_{DR} (Fig. 3d) and K_{DP} (not shown) extend well above the updraft perturbed melting layer (> 5 km). Farther aloft, an updraft signature is present in ρ_{HV} despite the lack of a BWER in Z_H

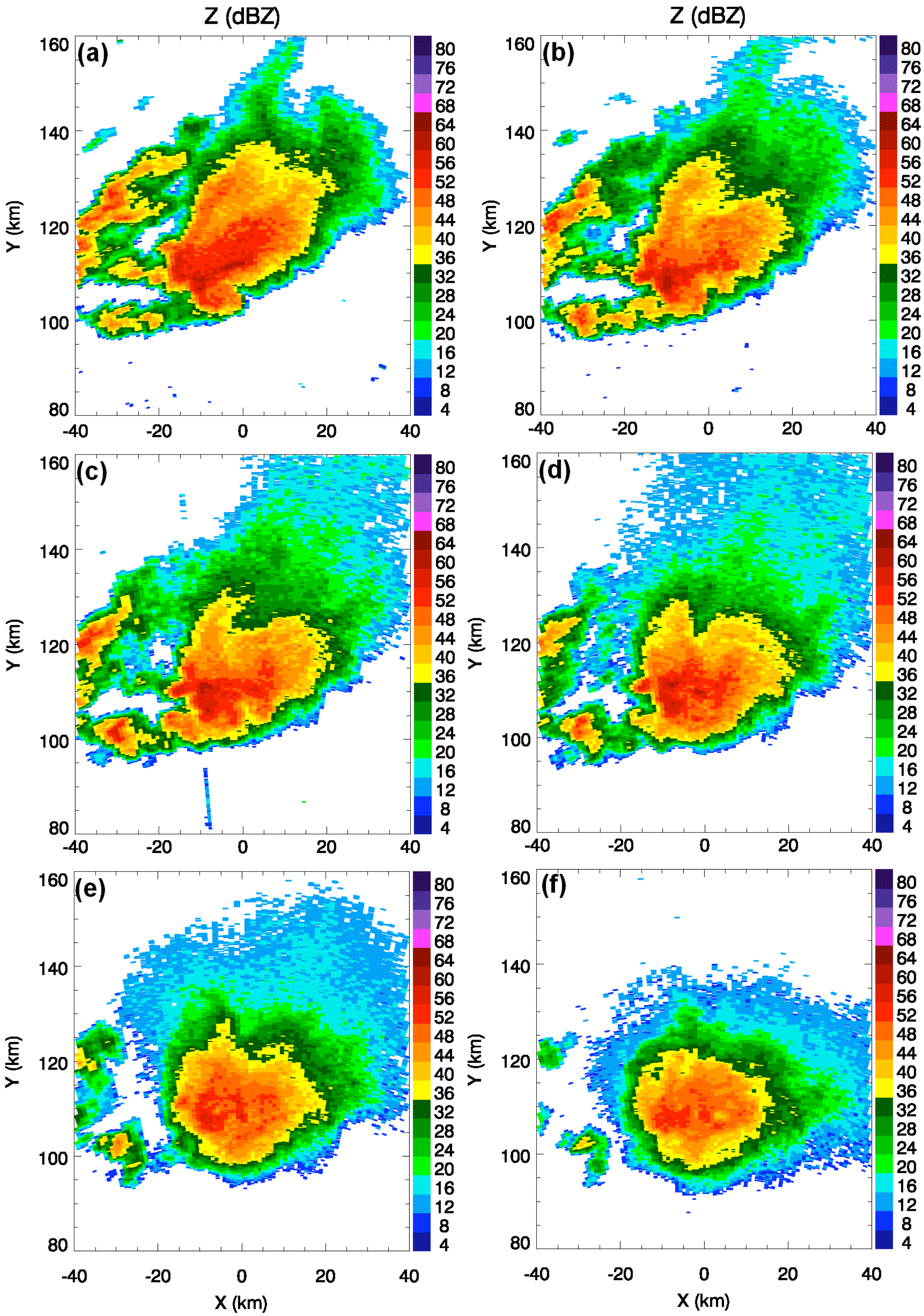


Fig. 2: Observed Z_H from the VCP starting at 2216:42 UTC on 24 May 2008. Elevation angles of the PPIs are: (a) 0.5°, (b) 1.5°, (c) 2.5°, (d) 3.5°, (e) 4.3°, and (f) 5.3°.

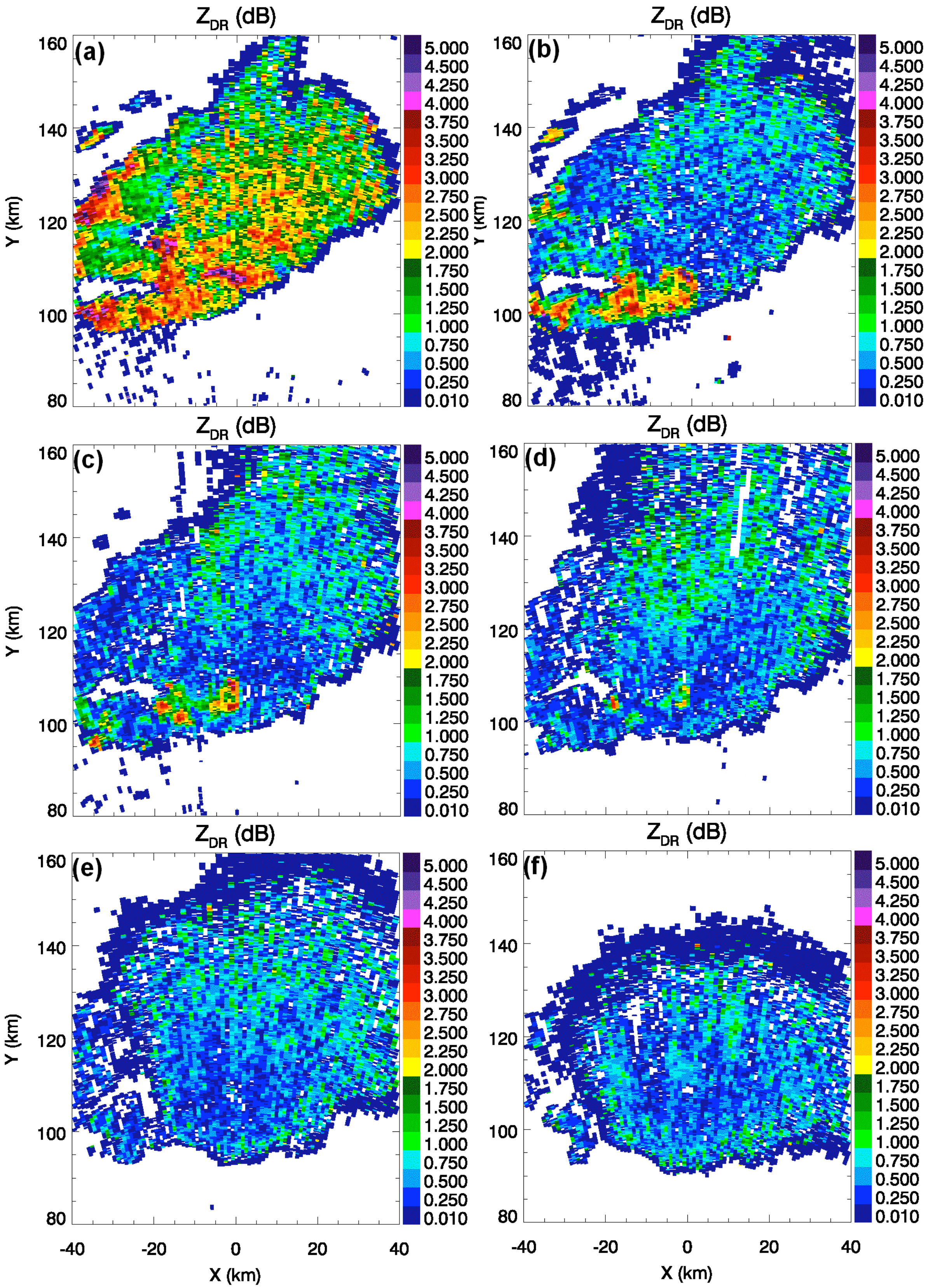


Fig. 3: As in Fig. 2, but Z_{DR} is shown.

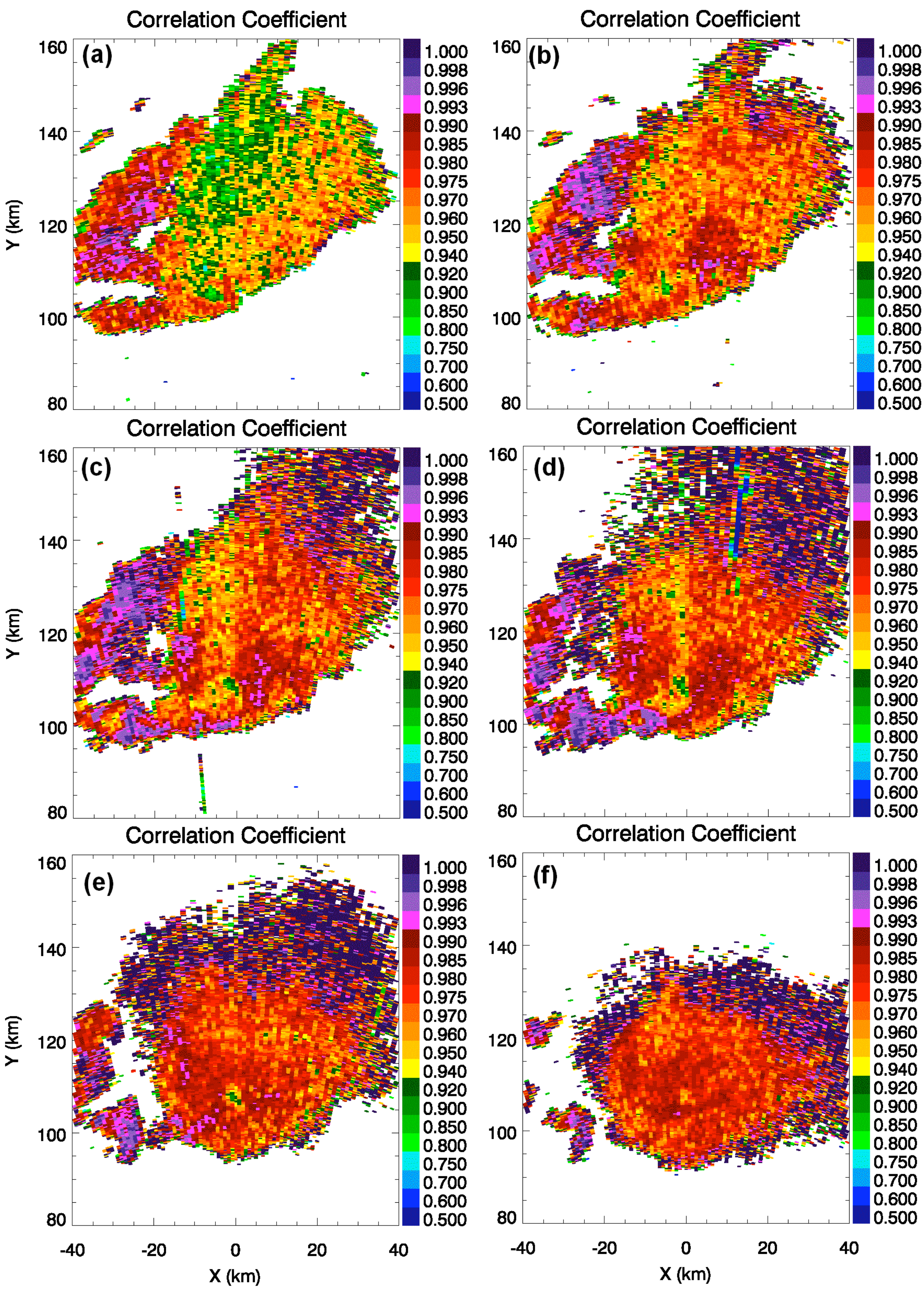


Fig. 4: As in Fig. 2, but ρ_{HV} is shown.

(Fig. 4d-e). All of these signatures are consistent with those of a mature supercell storm.

Because the storm was moving slowly, we can analyze its vertical structure better than in most cases, where faster storm motion results in larger errors due to advection. For each elevation angle PPI, the 35-dBZ Z_H outline is drawn and then overlaid (Fig. 5). Perhaps the most striking feature of this analysis is the sloping Z_H overhang on the right flank of the storm. The edge of the echo becomes displaced northwestward with decreasing height, similar to observations by Browning (1964). Notice that the left flank of the storm does not have such a slope with height. This is evidence of size sorting on the right flank of the storm: as precipitation falls from the anvil, it is advected northwestward by the environmental wind shear as well as the strong inflow. Some of the particles may be "recycled" by the updraft, becoming hail embryos (e.g., Conway and Zrnić 1993). This also explains why large drops (high Z_{DR}) are found on the edge of the FFD echo, as smaller particles are advected farther into the forward flank precipitation, leaving the largest drops at the edge.

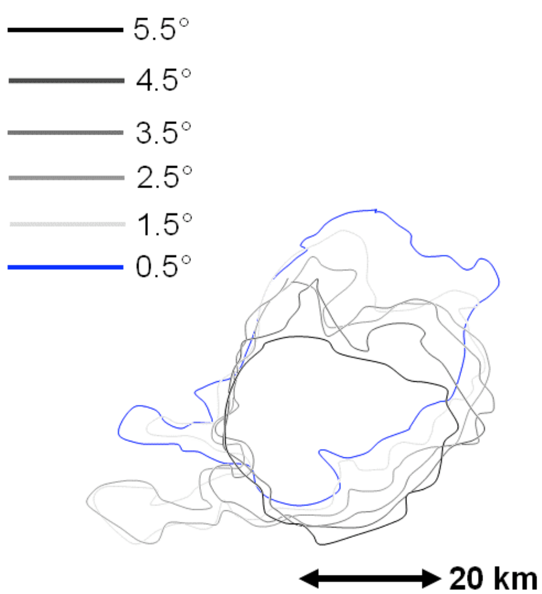


Fig. 5: Outlines of the 35-dBZ Z_H echo at five elevation angles (shown in the legend) overlaid. A scale is provided for reference.

At approximately 2250, television news storm spotters reported seeing a "clear slot" forming, followed by tornado development within 10 minutes (Table 1). The polarimetric data reveal an interesting evolution of the hook echo during the scans leading up to this apparent clear slot. At 2227, the supercell has the appearance of a "kidney bean," common to high-precipitation storms (Fig. 6a). At 2237, however, an erosion of Z_H in the hook echo begins (Fig. 6b). This continues through 2248 (Fig. 6c-d), whereupon a large region of Z_H has now vanished from the hook echo. Throughout this period, Z_{DR} remains quite low in the hook, while ρ_{HV} increases substantially (from about 0.96 – 0.99). This is indicative of very small drops with a relative lack of larger drops in the hook echo. It is possible that the erosion of the

Time of Observation (UTC)	Observation
2250	"Clear slot" – presumed RFD
2259	Tornado on the ground
2301	Rapid rotation visible; RFD
2304	2 Tornadoes on the ground
2309	Tornadoes have lifted up
2313	Strong rotation visible
2330	Tornado on the ground; damage evident

Table 1: Visual observations of local television spotter crews with the time of observation (UTC). These observations were recorded on the radio and thus no verification can be made.

Z_H echo (and the concurrent clear slot observation) is a manifestation of the occlusion downdraft (e.g., Klemp and Rotunno 1983), or localized enhancement of the RFD that often precedes the occlusion of the low-level mesocyclone. The increase of Z_H in the core, appearance of the hail signature in Z_{DR}, and filling in of the BWER aloft (not shown) suggest that the updraft has weakened, also a sign that the occlusion process is taking place (e.g., Lemon and Doswell 1979).

4. CONCLUSIONS AND DISCUSSION

The super-resolution data presented in this study represents a sample of the type of data available to operational meteorologists in the forthcoming nationwide polarimetric upgrade of the WSR-88D network. First, it is demonstrated that the WSR-88D radar is capable collecting data with increased resolution. These higher resolution data are of adequate quality for operational use. The half-degree azimuthal resolution becomes important at long ranges for identifying potentially useful features in severe storms, such as the supercell signatures documented above which may otherwise not be resolved. Additionally, mesocyclone detection algorithms and tornado detection algorithms based on azimuthal shear of the Doppler velocities will better resolve such velocity gradients. Quantitative studies may be improved by the increased sampling in azimuth, especially for better resolving gradients of polarimetric variables.

Such increased resolution does not come without its drawbacks, however. For the same conventional volume coverage patterns, fewer pulses are used to estimate the radar moments. Thus, the data will be noisier than if one-degree sampling is used. This should be taken into consideration when using the data for rainfall estimation or hydrometeor classification algorithms.

The storm presented in this case study is typical of supercell storms in its polarimetric characteristics. Its motion was slow, allowing for an analysis of its vertical structure. Evidence of size sorting is found on the inflow side of the storm, further confirming the observations by Browning (1964). By incorporating visual observations with the polarimetric data, this case allows for a better understanding of how the structure and microphysics of the storm evolves and how this evolution is manifest in polarimetric radar observations.

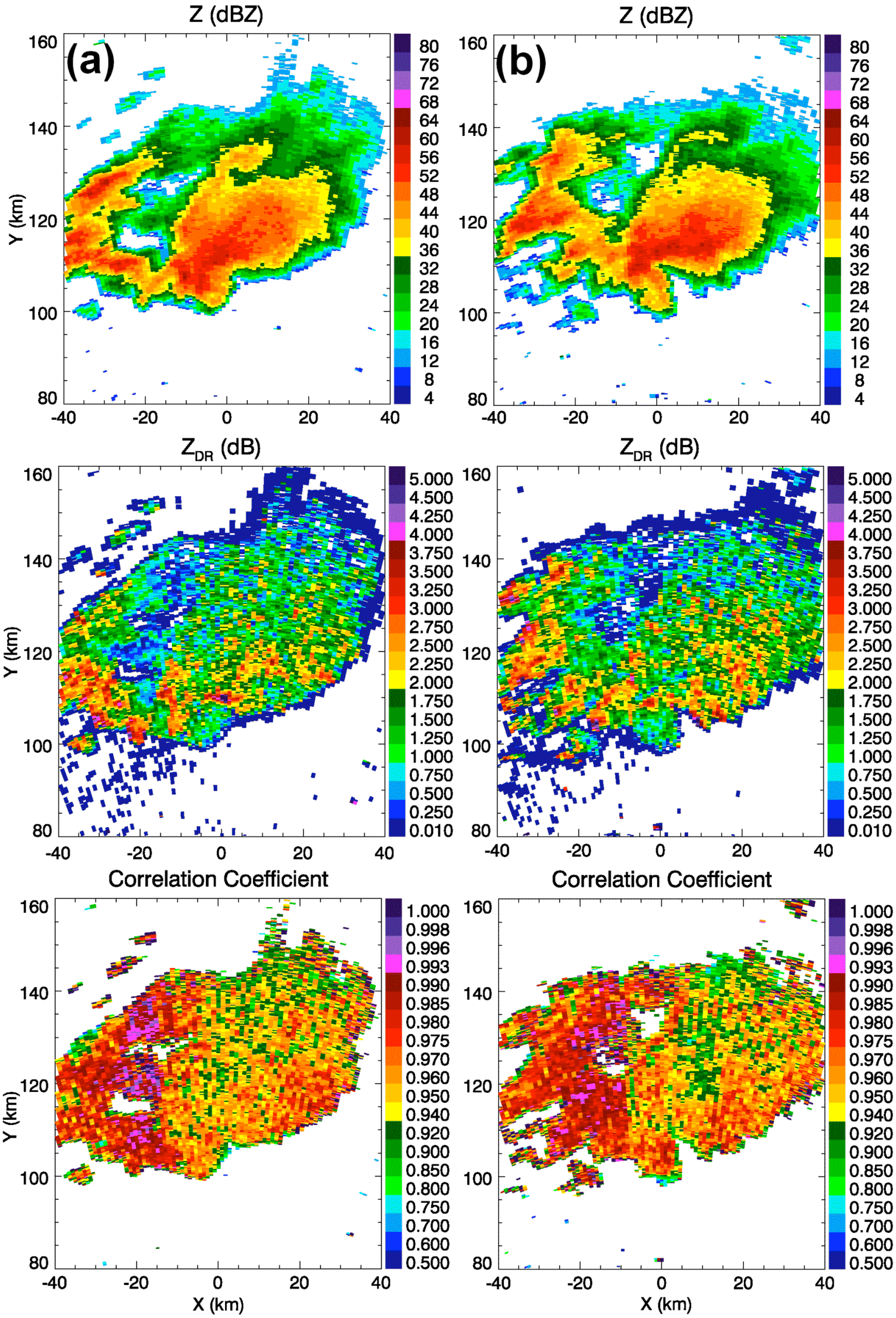
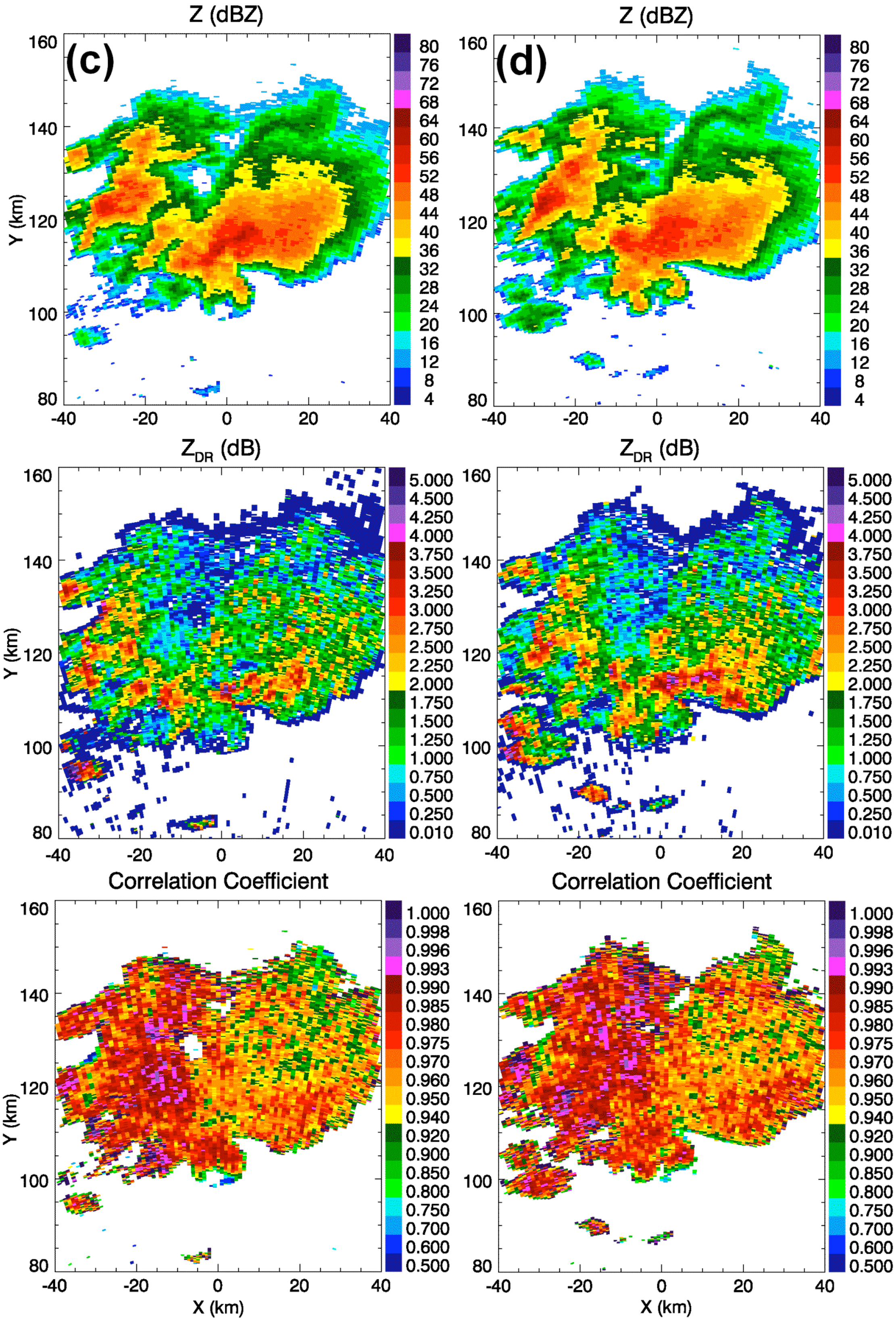


Fig. 6: Series of 0.5° elevation PPI scans of Z_H, Z_{DR}, and ρ_{HV} from: (a) 2227 UTC, (b) 2237 UTC, (c) 2242 UTC, (d) 2248 UTC. These scans correspond to the time twenty minutes before and leading up to the visual observation of a "clear slot" (Table 1).



(Fig. 6 continued).

5. ACKNOWLEDGEMENTS

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