P4B.3 OPERATIONAL USES OF POLARIMETRIC RADAR DATA IN SEVERE LOCAL STORM PREDICTION

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1. INTRODUCTION

As part of the future enhancement of the WSR-88D, the National Severe Storms Laboratory (NSSL) recently upgraded the KOUN WSR-88D radar to include polarimetric capabilities. During the spring of 2003, polarimetric radar data were made available in real time at the National Weather Service Weather Forecast Office (WFO) in Norman, Oklahoma as part of the Joint Polarization Experiment (JPOLE, Schuur et al. 2003). For the first time, these data were used during operational severe thunderstorm and flash flood prediction. This manuscript provides a preliminary overview of the integration of polarimetric radar data into the warning decision-making process, including specific examples of such integration.

The JPOLE demonstration was conducted at the WFO from 15 April through 15 June 2003. During this period, NSSL meteorologists were “on call” to participate in any severe weather warning operations at the WFO. Base polarimetric data, as well as algorithms estimating precipitation accumulation and hydrometeor type, were tested operationally during convective events.

During severe weather operations at the WFO, NSSL meteorologists studied polarimetric data provided by KOUN, and assisted WFO staff in the warning decision-making and verification processes. The NSSL meteorologists noted radar data quality issues, documented how the data were used in operations, and monitored the performance of the hydrometeor classification algorithm (HCA) and quantitative precipitation estimation algorithms (QPEAs). Base polarimetric radar data and algorithm output were displayed at the WFO by the Warning Decision Support System - Integrated Information (WDSS-II) software package (Hondl 2002).

During severe weather demonstrations, KOUN could be operated in a low PRF (mode “A”) or high PRF (mode “B”) volume coverage pattern (VCP). The low PRF VCP was designed to provide routine coverage to 300 km at the lower elevation angles, while the high PRF VCP was designed to allow for a higher Nyquist velocity when supercell thunderstorms were present within 148 km of the radar. These VCPs (Table 1) were designed to be similar to the WSR-88D's VCP-11, with the addition of a 0.0 degree elevation angle. The “A” VCP took just over five minutes to be completed, while the “B” VCP took just over six minutes to be completed.

TABLE 1. Volume coverage patterns with low PRF at low levels (“A”) and high PRF at low levels (“B”) used by the KOUN Polarimetric WSR-88D during the Spring 2003 JPOLE operational demonstration.

Elevation angle, degrees	Pulse Repetition Freq., Hz	Maximum Distance, km	Nyquist Velocity, ms^{-1}	Number of samples
0.0 A:	446	300	12	48
B:	1013	148	27.8	48
0.5 A:	446	300	12	48
B:	1013	148	27.8	48
1.5 A:	446	300	12	48
B:	1013	148	27.8	48
2.5 A,B:	1013	148	27.8	48
3.5 A,B:	1013	148	27.8	48
4.5 A,B:	1013	148	27.8	48
5.5 A,B:	1013	148	27.8	48
6.5 A,B:	1013	148	27.8	48
7.5 A,B:	1013	148	27.8	48
8.7 A,B:	1013	148	27.8	48
10.0 A,B:	1013	148	27.8	48
12.0 A,B:	1013	148	27.8	48
14.0 A,B:	1013	148	27.8	48
16.7 A,B:	1013	148	27.8	48
19.5 A,B:	1013	148	27.8	48

2. OPERATIONAL IMPACTS

Using polarimetric radar data, forecasters are able to more directly observe thunderstorm updrafts than with a conventional radar. Liquid lofted above the

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freezing level in convective updrafts is often revealed by a column of high differential reflectivity (Z_{DR}) and low correlation coefficient coincident with relatively low reflectivity (Illingworth et al. 1987). The NSSL HCA (Zrnic et al. 2001) classifies and displays this signature to forecasters as “big drops”.

The presence of hail may also be directly observed and classified by the HCA. Local minima in Z_{DR} and correlation coefficient coincident with very high reflectivity has been found to be a reliable hail signature (Straka et al. 2000). Using this technique, hail contamination in QPEAs may be mitigated (Ryzhkov et al. 1997), improving local flash flood forecasts.

Finally, polarimetric radar has proved useful in the mitigation of non-precipitating echoes, such as echoes resulting from ground clutter, anomalous propagation, birds, and insects. Research data sets at the NSSL suggest this technique may also be used to identify concentrated regions of lofted tornado debris (Ryzhkov et al. 2002).

3. SPECIFIC CASE EXAMPLES

A number of severe thunderstorm events struck the WFO Norman area during the JPOLE intensive observation period. This provided WFO forecasters an opportunity to use KOUN polarimetric data on a number of occasions. This section provides a preliminary overview of a few of the more noteworthy cases.

3.1 Supercell initiation on 8 May 2003

On 8 May 2003, significant instability and wind shear were present over central Oklahoma, but a capping inversion had prevented thunderstorm development through mid afternoon. For a period of approximately one hour, towering cumulus clouds produced transient radar echoes, but none of the convection became strong enough to produce a sustained updraft through the capping inversion.

The first available data that suggested sufficiently strong updrafts had developed were the KOUN Z_{DR} product and HCA output. In two cells, columns of enhanced Z_{DR} extending above an altitude of 6 km (Figure 1a), and an associated HCA classification of “big drops” (Figure 1b), confirmed liquid drops were being lofted in updrafts well above the capping inversion and ambient melting level.

Upon this observation, WFO forecasters were able to notify spotters, media, and emergency managers that thunderstorms were developing and were expected to quickly intensify into supercells. As forecast, one of the nascent thunderstorms intensified into a supercell rapidly, and over the next hour produced a damaging tornado in the Oklahoma City metropolitan area.

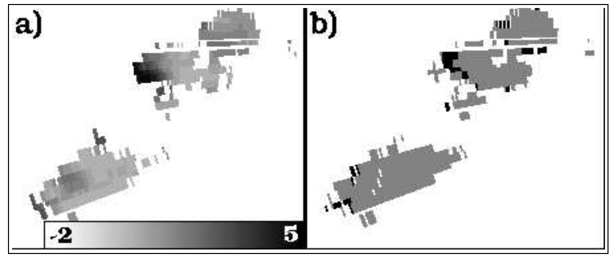

Figure 1. KOUN radar data at 4.5° elevation angle at 2057Z 8 May 2003, corresponding to an approximate altitude of 6 km. **a)** Differential reflectivity (Z_{DR}, dB); **b)** Hydrometeor classification algorithm (HCA), where black areas indicate classification of “big drops” and gray areas indicate other hydrometeors.

3.2 Tornado debris signature on 9 May 2003

The next evening, a supercell thunderstorm moved into the Oklahoma City area well after sunset. The storm had produced a few weak, brief tornadoes during its approach to the city, but produced its first and only significant tornado in the northeast part of the city. Storm spotters faced difficulty not only with spotting at night in a metropolitan area, but with the increasing density of trees as the storm moved across north Oklahoma City.

At the time of the significant tornado, KOUN radar detected a well-defined tornado debris signature in the polarimetric fields at the tip of the reflectivity hook echo (Figure 2a). Z_{DR} values fell to near zero dB in the debris signature (Figure 2b), with correlation coefficient values near 0.7 (Figure 2c). This detection increased confidence that a significant tornado was ongoing, and enhanced wording was used in the statements issued by WFO forecasters. A post-storm survey revealed the tornado had indeed lofted a large amount of debris and was at its strongest during this phase.

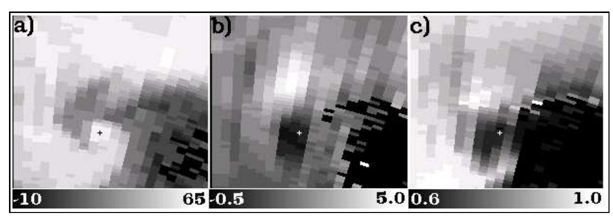

Figure 2. KOUN radar data at 0.5° elevation during Northeast Oklahoma City tornado, 0346Z 10 May 2003. Tornado debris signature location marked by cross on each panel. **a)** Reflectivity (dBZ); **b)** Differential reflectivity (Z_{DR}, dB); **c)** Correlation coefficient.

3.3 Giant hail event on 14 May 2003

A supercell thunderstorm in southern Oklahoma early in the morning on 14 May 2003 produced hailstones more than 13 cm in diameter. Although many other storms on radar at the time had reflectivity in excess of 70 dBZ (Figure 3a), this storm produced a well-defined hail signature in the Z_{DR} (values below zero dB, Figure 3b) and correlation coefficient (values as low as 0.6, Figure 3c) fields.

The HCA correctly identified hail in a number of thunderstorms on the morning of 14 May (Figure 3d). Future enhancements to radar hail size estimation will be possible after thorough examination of these and similar polarimetric signatures.

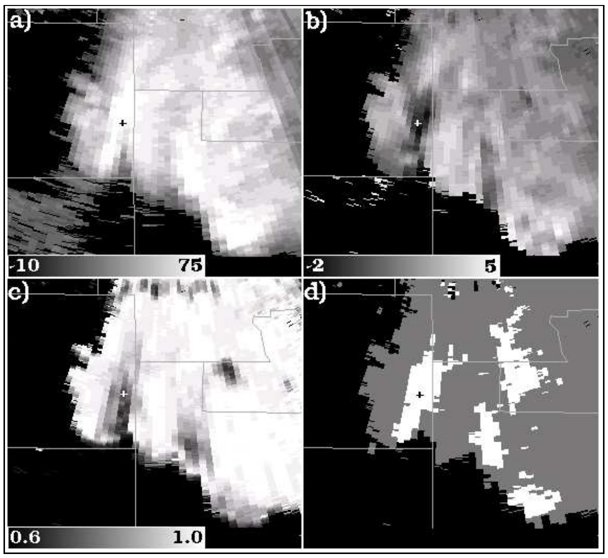

Figure 3. KOUN radar data at 0.5° elevation at 0834Z 14 May 2003. Location of 13 cm diameter hail report marked by cross on each panel. **a)** Reflectivity (dBZ); **b)** Differential reflectivity (Z_{DR}, dB); **c)** Correlation coefficient; **d)** Hydrometeor classification algorithm (HCA), where gray areas indicate regions of rain and white areas indicate regions of hail.

4. CONCLUSIONS AND FUTURE WORK

These and other cases, as well as feedback from forecasters at WFO Norman, suggest the addition of polarimetric data can add value to the warning decision-making process. Future enhancements to the HCA may include automated detection of tornado debris, improved mitigation of ground clutter, as well as improved estimation of hail size. The polarimetric QPEAs will continue to evolve as more cases are studied.

5. ACKNOWLEDGEMENTS

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