P10.10 ANALYSIS OF DUAL-POL WSR-88D BASE DATA COLLECTED DURING THREE SIGNIFICANT WINTER STORMS

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1. INTRODUCTION

Over the next several years, the U.S. network of WSR-88D weather radars is expected to undergo significant hardware and software upgrades to allow the acquisition of dual-polarimetric (“dual-pol”) data. These upgrades are expected to result in improvements to echo classification, precipitation rate estimation, and data quality.

The Joint Polarization Experiment (JPOLE) (Ryzhkov et al. 2005) demonstrated the operational utility of dual-pol radar information in operational forecasting and decision-making (Scharfenberg et al. 2005). These findings were made with KOUN, the prototype dual-pol WSR-88D located at the National Severe Storms Laboratory in Norman, Oklahoma. Unfortunately, there was little winter precipitation recorded at the surface in central Oklahoma during JPOLE, leaving many unanswered questions regarding operational uses of dual-pol WSR-88D during significant winter storms.

One potential use of dual-pol radar information during high-impact winter precipitation is the improvement of operator situation awareness of rapid spatial and temporal changes in precipitation type at the surface. While this clearly requires the use of data from multiple sources, it is important to identify the potential advantages dual-pol WSR-88D data may provide before the network upgrade begins.

Elmore et al. (2007) describe a project involving the collection of public reports of surface precipitation type in winter storms in central Oklahoma during the winter of 2006-2007. Data were collected during three winter storms, and this paper offers some preliminary observations of the corresponding dual-pol WSR-88D products.

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2. DATA AND METHODOLOGY

Three significant winter storms struck central Oklahoma during winter 2006-2007. Public reports of surface precipitation type were collected during each event, totaling about 2149 good data points, most of which were within 150 km of the radar. An example of observations within a 30 minute period on 30 November 2006 is provided in Fig. 1.

Fig. 1. Example of surface precipitation type reports from the public on 30 November 2006 between 0330 UTC and 0400 UTC. The data analyst can display reports from any 30-minute period in Google Earth GIS software, and can click on any icon to view the full report, as shown.

KOUN dual-pol WSR-88D data were available throughout the three events. This analysis focuses on analysis of the horizontal reflectivity (Z_h) product, differential reflectivity (Z_{DR}), correlation coefficient (ρ_{hv}), and specific differential phase shift (K_{DP}). Information about these KOUN products can be found in Scharfenberg et al. (2007).

This preliminary qualitative analysis focuses on a few key observation times in each of the three events. A more thorough quantitative analysis of the base data for each event is ongoing. We chose to focus for this paper on times during which significant changes and/or mixtures in precipitation type at the surface near the radar were observed, and at times of critical forecast decision-making.

3. CASE STUDIES

3.1. 29-30 November 2006

KOUN dual-pol WSR-88D data and 708 surface precipitation type reports were collected during this winter storm. Liquid precipitation was observed at the beginning of the event (~1500 UTC 29 November), with some icing reported on exposed surfaces in central Oklahoma. Around 0100 UTC 30 November, convective cells had developed with moderate to heavy showers of ice pellets and lightning observed. Scattered convective ice pellet showers were observed for many hours until a brief changeover to light snow at the end of the event, around 1530 UTC 30 November. A significant accumulation (up to 10 cm) of ice pellets was observed at the surface in the vicinity of KOUN.

This event was generally well-forecast. The light freezing rain at the beginning of the event transitioned quickly to heavy showers of ice pellets, according to the public reports. The dual-pol base products at a high elevation angle were examined as one of these thunderstorms moved directly over the radar site (Fig. 2). Moderately-high Z_h, high Z_{DR}, and high ρ_{hv} were noted, which is consistent with relatively large liquid drops.

This observation is consistent with several other convective ice pellet showers that passed over or near the radar site. Thermodynamic soundings at 00Z and 06Z on 30 November 2006 (not shown) determined the low-level temperature minimum of approximately -6°C only about 500 meters above the surface, so it is likely the liquid drops did not completely refreeze into ice pellets until reach the last few hundred meters before the surface. Apparently this could not be adequately sampled by the radar due to the very-low-altitude nature of the refreezing. In this case, the dual-pol product output might be considered misleading if the radar sampling limitations were not considered. Also in Fig. 1, lower Z_{DR} values were observed in the lighter precipitation outside of the thunderstorm core. Given the altitude of these echoes, it is likely these are much smaller liquid drops.

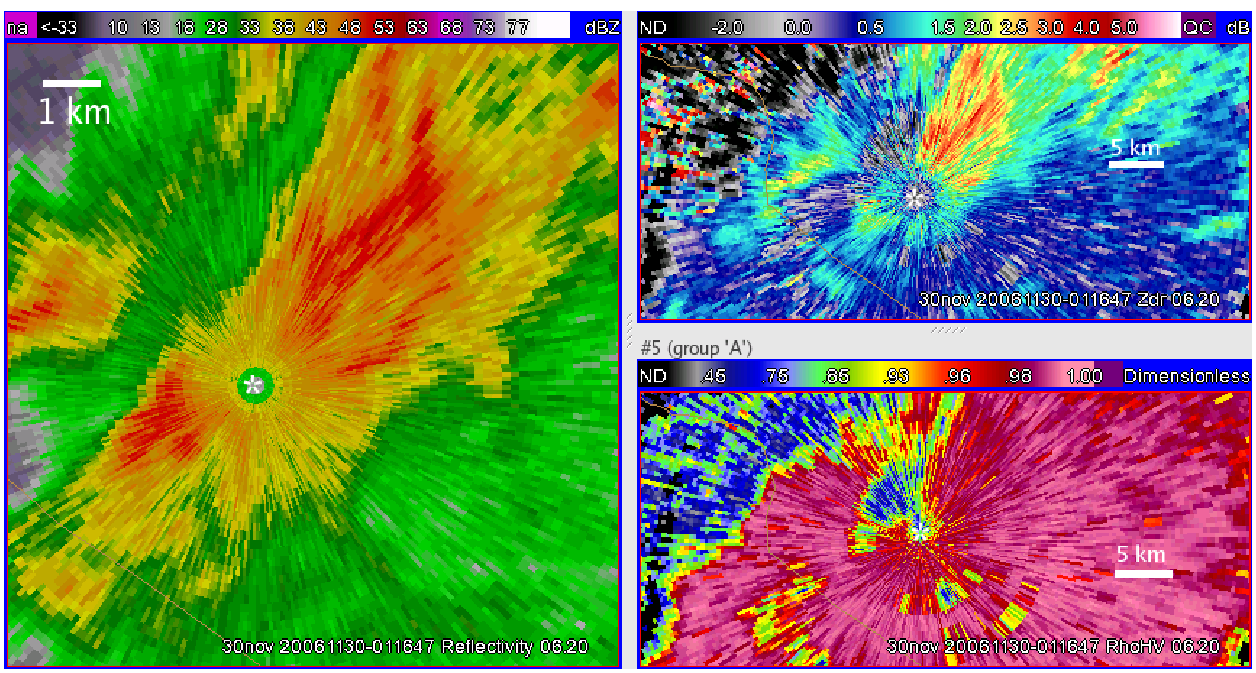

Fig. 2. Horizontal reflectivity (left), differential reflectivity (upper-right), and correlation coefficient (lower-right) from KOUN dual-pol WSR-88D at 0117 UTC 30 November 2006, 6.2 degree elevation angle. The radar location is marked by the asterisk.

Late in the event, as precipitation came to an end, the predominant ice pellets transitioned to light snow from west to east according to numerous public and official observations. At the time of this transition near the radar site, the dual-pol products revealed a subtle change in characteristics (Fig. 3). A well-defined melting layer was being sampled around the radar site in all but the west quadrant, with a ring of relatively high Z_h, high Z_{DR}, and low ρ_{hv}.

To the west at the same altitude, however, a region of low Z_h, high Z_{DR}, and high ρ_{hv} was observed moving toward the radar. This is indicative of an area of sparse, horizontally-oriented snow crystals developing in the shallow cold layer near the surface.

As is usually the case with dual-pol radar, the transition to light snow could only be detected by using multiple products in unison, and understanding the change in physical processes leading to changes in precipitation radar characteristics. In this case, there was a change from deep lift and precipitation falling through a warm layer, to lift and precipitation developing in the shallow surface-based cold layer.

Differentiation between ice pellets and freezing rain was much more challenging. The inherent limitation of radar sampling at very low altitudes would lead a forecaster to have to use other methods to anticipate and detect the temporal and spatial changes.

3.2. 12-14 January 2007

During this event, KOUN data and 1038 surface precipitation type reports were collected. The location of the delineation between freezing rain and sleet at the surface was a major forecasting challenge during this event. As it turned out, significant icing due to freezing rain occurred in a band from about 50 km south of the radar to 150 km east of the radar, with extremely damaging ice accumulations of 5 to 8 cm in many areas southeast and east of the radar. Some icing reported in tree tops as close as 10 km southeast of the radar, and on the tops of radio and TV transmission towers in the immediate vicinity of KOUN. Otherwise, significant accumulations of ice pellets were observed in all areas near and north of the radar site.

Fig. 4 shows a typical radar image during this event. A layer of melting hydrometeors is clearly evident above the radar. As was the case on the 29-30 November 2006 event, thermodynamic soundings indicated the refreezing of the liquid

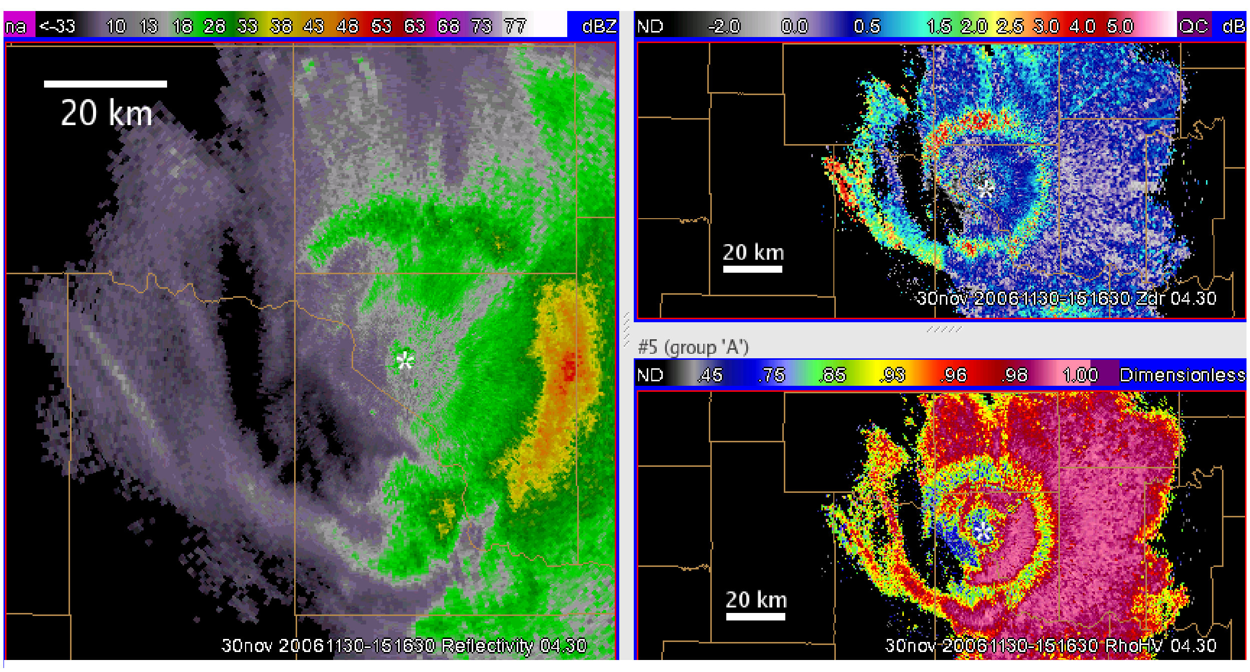

Fig. 3. As in Fig. 2, but 1517 UTC, 30 November 2006, 4.3 degree elevation angle.

drops was likely occurring in the last few hundred meters above the surface. In fact, the reports of icing in treetops and on transmission towers suggest the refreezing was likely occurring in the lowest tens of meters, so this phenomenon could not be sampled by the radar.

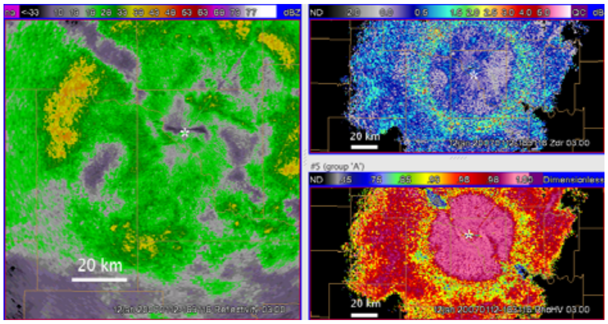

Fig. 4. As in Fig. 2, but at 1631 UTC 12 January 2007, 3.0 degree elevation angle.

A brief period of columnar needle snow crystals was observed within 15 km of KOUN by numerous participants around 1800-1830 UTC 14 January. One observer documented the event with a photograph and exact time (Fig. 5).

Fig. 5. Photograph of columnar needle snow crystals observed about 1830 UTC approximately 10 km southeast of KOUN. Photograph and observation courtesy Greg Stumpf.

The band of precipitation responsible for the surface snow reports had slightly different radar characteristics compared to the earlier liquid precipitation observed (Fig. 6). Z_h was still moderately high (~20 to 35 dBZ) and ρ_{hv} was still large (~0.99), but low-altitude Z_{DR} was slightly higher than before (~1.5 dB). It is important to note these dual-pol characteristics overlap those of light to moderate rain, so surface reports were critical in detecting this event.

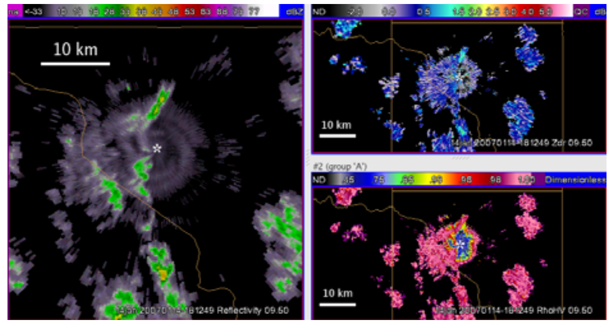

Fig. 6. As in Fig. 2, but at 1813 UTC 14 January 2007, 9.5 degree elevation angle.

3.3. 20 January 2007

Dual-pol data from KOUN and 403 surface precipitation type reports were collected during this winter storm. Precipitation type was again a major forecasting challenge, with a saturated, nearly-isothermal layer at about 0°C through a deep layer simultaneously experiencing significant lift, warm air advection, and heavy precipitation. It was unclear whether heavy rain/freezing rain or heavy snow would be the predominant precipitation type in the vicinity of KOUN.

As light precipitation began, it was clear from dual-pol data a melting layer was present aloft (Fig. 7), and this feature remained fixed throughout the event as rain and some light icing of exposed objects was observed at the surface.

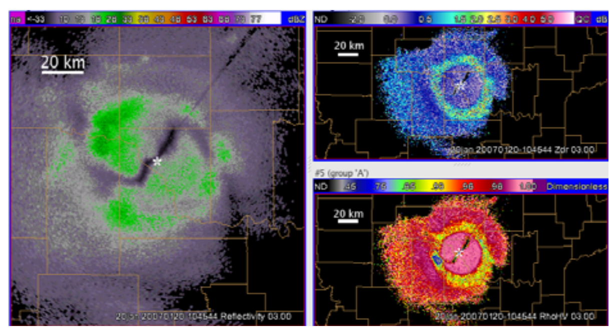

Fig. 7. As in Fig. 2, but at 1046 UTC 20 January 2007, 3.0 degree elevation angle.

Late in the event, as the air mass aloft apparently cooled sufficiently, light snow showers were observed at the surface. Though reflectivity was similar in the showers as what was observed in the rain earlier, the dual-pol data suggested precipitation was of uniform type throughout the column (Fig. 8). This transition was easily observed via radar, as the dissipating melting layer was still observed in the northeast quadrant at the time of the figure.

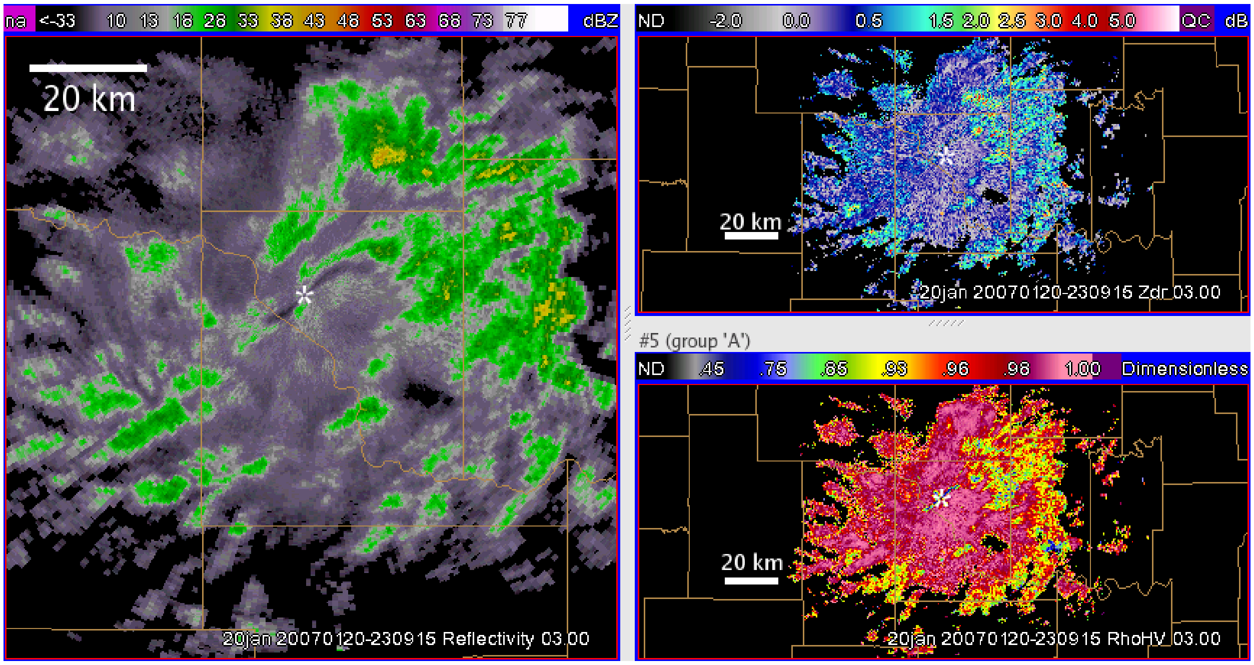

Fig. 8. As in Fig. 2, but 2309 UTC, 20 January 2007, 3.0 degree elevation angle. A melting layer is clearly evident in the northeast quadrant, where rain was reported at the surface, and a uniform precipitation type in the column was indicated elsewhere, where snow was being reported at the surface.

4. DISCUSSION

Spatial and temporal changes between snow and non-snow precipitation types at the surface within 150 km of the radar could be implied using dual-pol radar at sufficient precipitation rates. This could be done via the detection (or lack) of a melting layer. Differentiation between ice pellets and liquid precipitation at the surface was difficult in these cases due to the refreezing of falling rain into ice pellets at extremely low altitudes. Light snow crystals developing near the surface happened to have subtle differences in Z_{DR} with nearby light liquid drops in one case observed, but there is generally so much overlap in these characteristics that real-time differentiation using radar alone would not be reliable.

In this preliminary analysis we also viewed the specific differential phase (K_{DP}) product, but this product output tends to be noisy in low SNR (light) precipitation echoes, near the radar, and in the melting layer. Because of these complications, and the subtle temporal and spatial changes in the radar characteristics typical of winter storms, phase information will require further study before operational conclusions can be offered.

Further, hydrometeor classification algorithm output is available for these cases, but we chose to focus only on base data for this study. One use of this analysis might be to further refine this algorithm's output.

It is clear that dual-pol products must all be used in unison during winter weather events to form a 4D conceptual model of what kinds of scatterers the radar is sampling, and the spatial and temporal changes thereof. The meteorologist must use knowledge of the physical processes causing the precipitation to understand the radar product output, and vice/versa. Therefore, understanding of the thermodynamic and kinematic environment is necessary. Finally, it is clear that ground truth information from spotters and surface sensors will continue to be critical.

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