P9R.13 POLARIZATION CHARACTERISTICS OF WINTER STORMS IN OKLAHOMA

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1. Introduction

While S-band polarimetric radars have been used to study a variety of precipitation systems over the past decade, relatively little work has focused on polarimetric signatures in winter precipitation. Using data from the NSSL Cimarron radar, Ryzhkov and Zrnic (1998) identified polarimetric signatures that might be used to distinguish between rain and snow. Trapp et al. (2001) also used data from Cimarron to study the precipitation structure of a winter precipitation event that occurred over northern Oklahoma in 1994. More recently, Ryzhkov et al. (2005) presented some of initial results of winter storm observations made by the National Severe Storms Laboratory KOUN WSR-88D radar, which was upgraded to include dual-polarization capabilities in the spring of 2002. Their study presented results that showed how polarimetric radar, when combined with surface observations, can be used to remotely identify regions of freezing rain.

As we move towards a national network of polarimetric WSR-88D radars, the opportunities to study winter precipitation events is sure to increase. Since the upgrade of the KOUN radar, polarimetric radar data have been collected in 15 winter weather events and several others where, though rain was observed at the surface, a low freezing level provided information on the transition from ice to water phase. Combined, these data provide statistical information that allows us to quantify the polarimetric characteristics of cold season precipitation in Oklahoma. In this study, we present results of preliminary analyses of recent winter weather events observed by the polarimetric KOUN radar. Particular attention is given to the discrimination between precipitation types. Radar reflectivity (Z), differential reflectivity (Z_{DR}), specific differential phase (K_{DP}), and correlation coefficient (ρ_{HV}) are used to characterize the polarimetric differences between regions of dry and wet snow, sleet, ice pellets, and freezing rain. Rain/snow transition lines and the polarimetric signatures of melting snow and low bright band regions are also investigated. While the dataset is now being examined in bulk, we present here examples of three events that occurred during the winter and early spring of 2004-2005.

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2. 5 January 2005 event

Over approximately a 24 hour period starting on 4 January 2005, a slow-moving trough of low pressure moving from southwest to northeast combined with a cold, moist air mass over the central eastern Oklahoma to produce an ice storm that blanketed the area with up to 3 cm of ice. As the cold air surged southward, freezing rain and sleet moved into northern and central Oklahoma. In total, some areas north of Interstate 40 in northwest Oklahoma received up to 5 cm of ice accumulation while other areas received from 3 to 5 cm of sleet. Fig. 1 shows a 0.43º elevation 4 panel display of KOUN Z, Z_{DR}, ρ_{HV}, and K_{DP} at 0804 UTC on 5 January 2005, while Figs. 2 and 3 show the 0000 UTC and 1200 UTC OUN (located in Norman, OK near the KOUN radar) soundings. Figs. 2 and 3 both show the evolution of the atmosphere over central Oklahoma as the cold air moved southward. At 0000 UTC, the 0°C level at OUN was located at a height of 3800 m MSL, a sharp inversion with a maximum temperature 14°C was located at a height of 930 m, and the surface temperature was approximately 3°C. At 1200 UTC, the 0°C level height had dropped about 400 m, but was still situated well above ground. The inversion, however, was higher and had weakened considerably, having a peak temperature of 7°C at a height of 1590 m MSL. More importantly, unlike the 0000 UTC profile, which had above freezing temperatures all of the way up to the inversion, the 1200 UTC profile exhibited an approximately 700 m deep layer immediately above the surface wherein the temperature was as much as -3.5°C below freezing. Combined, these profiles can be used to describe the transition in precipitation type from rain, to freezing rain and sleet as the cold air moved towards the southeast.

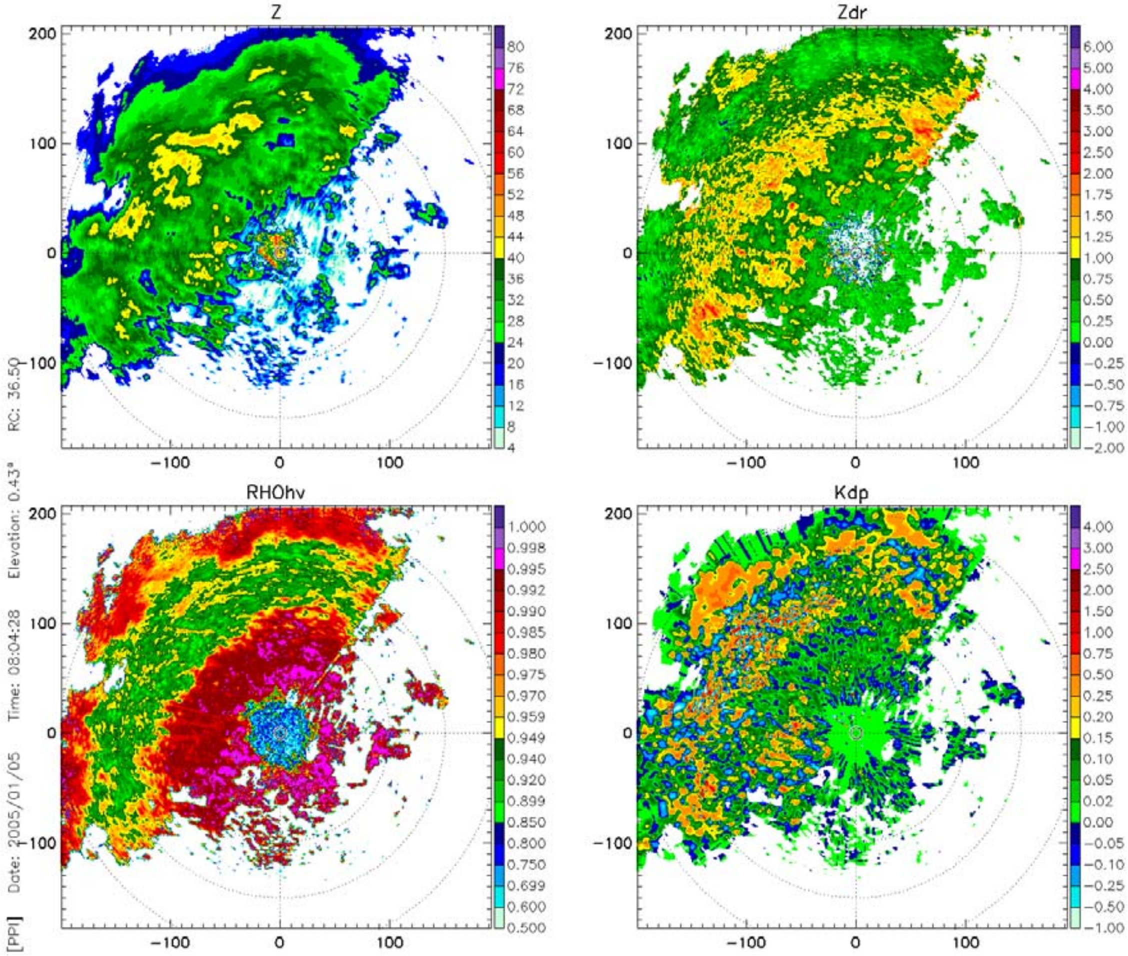

Fig. 1. Polarimetric KOUN WSR-88D at 0.43° elevation of radar reflectivity (Z), differential reflectivity (Z_{DR}), correlation coefficient (ρ_{HV}), and specific differential phase (K_{DP}) of the 5 January 2005 winter storm at 0804 UTC.

Fig. 1 shows the system to the northwest at 0804 UTC, approximately 4 hours prior to the second sounding. The location of the radar bright band can be clearly seen in the Z, Z_{DR}, and ρ_{HV} fields. As indicated by both soundings (Figs. 2 and 3), the 0°C level height appears to be well above ground level. This is particularly apparent in the ρ_{HV} field, which shows the first indication of bright band contamination at a range of 100 km (despite being collected at a 0.5 elevation and, at that distance, having a radar resolution volume width of 1.5 km). At closer distances, the ρ_{HV} field has a signature that is clearly indicative of rain, especially near the leading edge of the precipitation where a couple of pockets of high Z_{DR} indicates possible regions of enhanced rainfall. When combined with surface temperature data from the Oklahoma Mesonet (not shown), which has 107 sites located across the state of Oklahoma, the dual-polarization data presented here can be used to diagnose

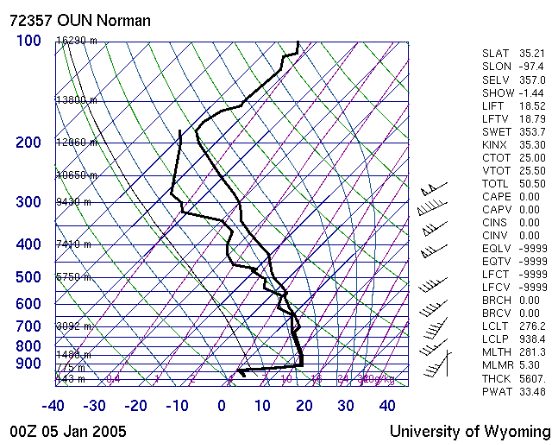

Fig. 2. 0000 UTC Norman, OK sounding on 05 January 2005.

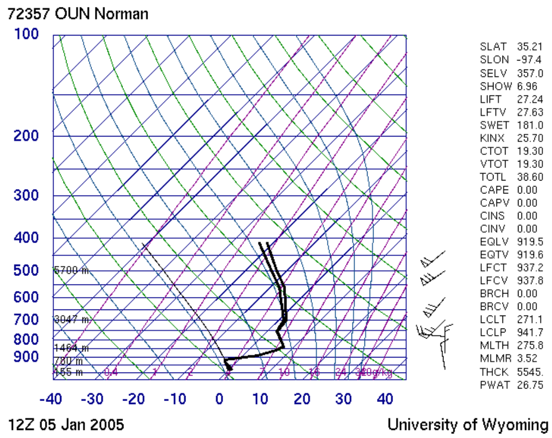

Fig. 3. 1200 UTC Norman, OK sounding on 05 January 2005.

locations where rainfall is occurring at sites where surface temperatures are sub-freezing. Additional analyses will focus on the identification of polarimetric signatures that might indicate re-freezing of liquid precipitation in regions where the sounding profile indicates a deep column of sub-freezing temperatures (such as indicated by Fig. 3).

3. 28 January 2005 event

The ability of the KOUN radar to discriminate between winter precipitation types is demonstrated well by Fig. 4, which shows a 0.43º elevation 4 panel display of KOUN Z, Z_{DR}, ρ_{HV}, and K_{DP} on 28 January 2005. The region of precipitation depicted in Fig. 4 formed in advance of an approaching 500 mb short-wave trough. At the time of the 1200 UTC OUN sounding (Fig. 5), which showed surface temperatures of approximately 3°C and a 0°C level that was a mere 300 m above the surface, central Oklahoma was experiencing light rainfall. Shortly after 0100 UTC, however, surface temperatures quickly cooled and the precipitation switched over to a heavy wet snow. We believe the sudden cooling and change in precipitation type on the southern edge of this system might have been due to microphysical processes such as the melting of snow under a region of enhanced mesoscale ascent.

Fig. 4 shows this system at 1603 UTC, approximately 3 hours after precipitation changed to a heavy wet snow in central Oklahoma. At that time, a band of heavy wet snow, as indicated by a 150 km long north-south oriented band of high Z_{DR} and low ρ_{HV}, is centered 110 due east of the KOUN radar. In contrast, precipitation to the northwest of the band has dramatically lower Z_{DR} and higher ρ_{HV}, indicative of a region of widespread light, dry snow.

4. 2 May 2005 event

The final example that we present is the 2 May 2005 precipitation event. Even though this was not a winter weather event, it was quite unusual in that it exhibited a very low melting layer/bright band for that time of year. Fig. 6 presents a 0.43º elevation 4 panel display of KOUN Z, Z_{DR}, ρ_{HV}, and K_{DP} at 1428 UTC on 2 May 2005, while Fig. 7 depicts the 1200 UTC sounding. The 0°C level for this event was 2100 m MSL, but the bottom of the radar bright band, as estimated by the 4-5°C level, was a mere 600 – 700 m above ground. While, to the best of our knowledge, no winter precipitation from this system reached the surface in Oklahoma, heavy snowfall occurred the previous day as the system passed over the Texas Panhandle.

From Fig. 6, it is immediately apparent that limited information on the systems precipitation structure is provided by Z alone but, when combined with the Z_{DR} and ρ_{HV} fields, several interesting features emerge, the most obvious of which is the low melting layer/bright band to the south of the radar. Perhaps most intriguing, however, is the banded structure that can be seen in both Z_{DR} and ρ_{HV}. This transient, wavelike structure appears to be related to regions where the melting layer was lower and/or more intense. The bands are characterized by somewhat stronger reflectivity (~30dBZ), higher Z_{DR} (~2dB) and lower ρ_{HV} (~0.9). The bands moved eastward and were seen for about 1 hour in radar data. Concurrent Doppler velocity observations (not shown) reveal strong vertical wind shear at about 2 km in height. Furthermore, in Fig. 7, it can be seen that the wind shifts from northeast (40°) at 1200 m MSL to southwest (220°) at 2100 m MSL, which is also the height of the 0°C level. The sounding also shows that the atmosphere is stable throughout the entire troposphere. Thus, the bright band is embedded in a wind shear layer. We therefore believe that the bright band might have been altered by Kelvin-Helmholtz waves (Kundu 1990).

Comparisons with data collected by a 2D-video disdrometer, which was deployed to a location approximately 29 km south of the KOUN radar, showed that the computed disdrometer Z_{DR} was slightly lower than the radar measured Z_{DR}. We believe this was related to bright band contamination in the radar resolution volume and the likelihood the largest drops were undersampled by the disdrometer measurements (due to the comparatively smaller sampling area of the disdrometer). This is event being investigated in more detail by Brandes et al. (2005).

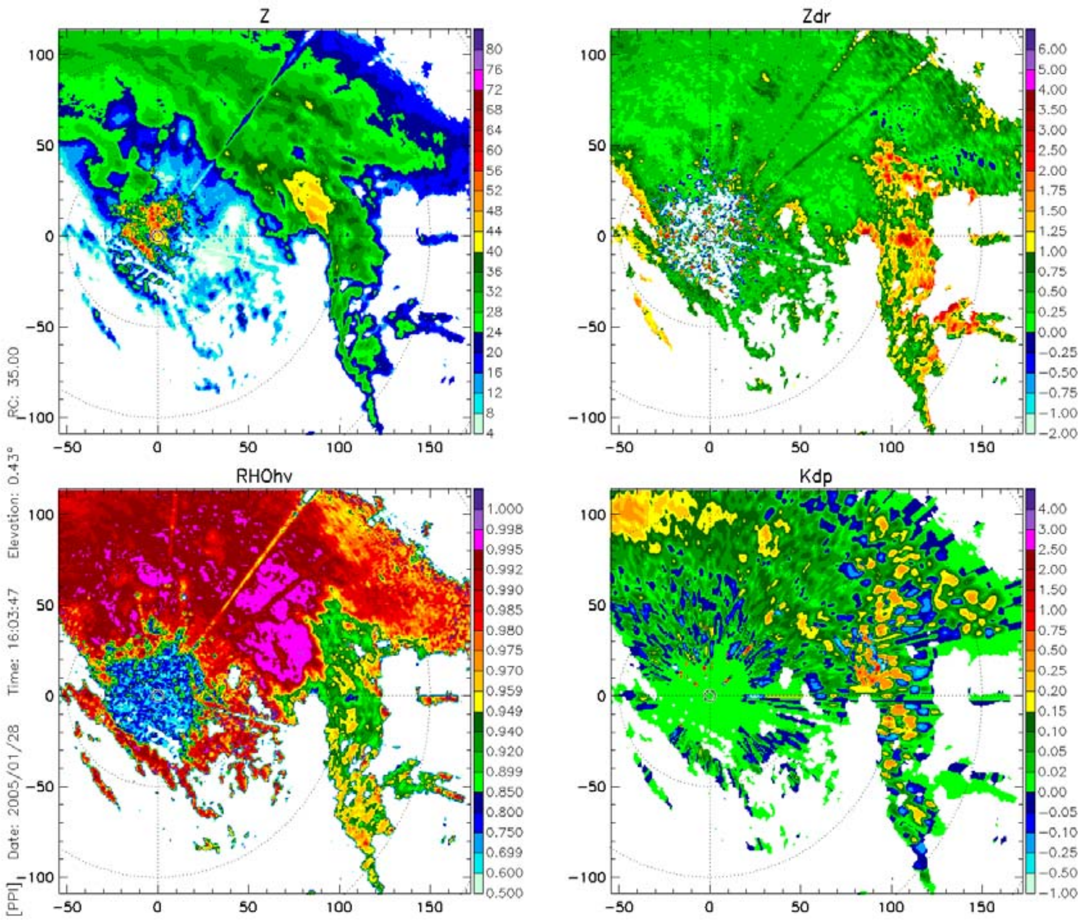

Fig. 4. Polarimetric KOUN WSR-88D at 0.43° elevation of radar reflectivity (Z), differential reflectivity (Z_{DR}), correlation coefficient (ρ_{HV}), and specific differential phase (K_{DP}) of the 28 January 2005 winter storm at 1603 UTC.

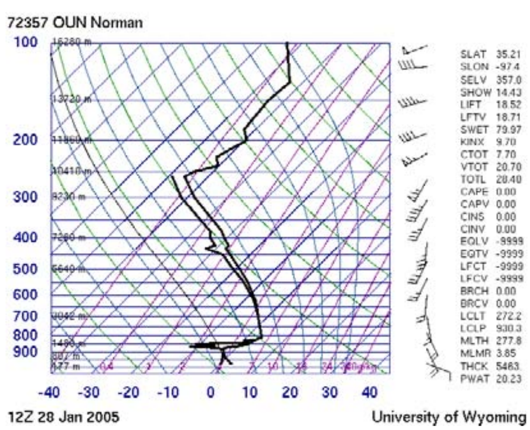

Fig. 5. 1200 UTC Norman, OK sounding on 28 January 2005.

5. Summary

Over the past 3 years, polarimetric KOUN WSR-88D radar data have been collected in 15 winter precipitation events, as well as several other events that can be used to study ice phase microphysics. The examples presented here provide further evidence that, when combined with automated surface information, polarimetric radars can be used to remotely identify regions of freezing rain. In another case, the polarimetric data also proved useful in identifying the location of bands of heavy snowfall. In an analysis of a spring time event, we have shown how the polarimetric measurements can be used to identify melting layer/bright band features that might lead to contamination of radar measurements, especially when the data are being used for rainfall estimation. These features are not immediately apparent when considering Z alone.

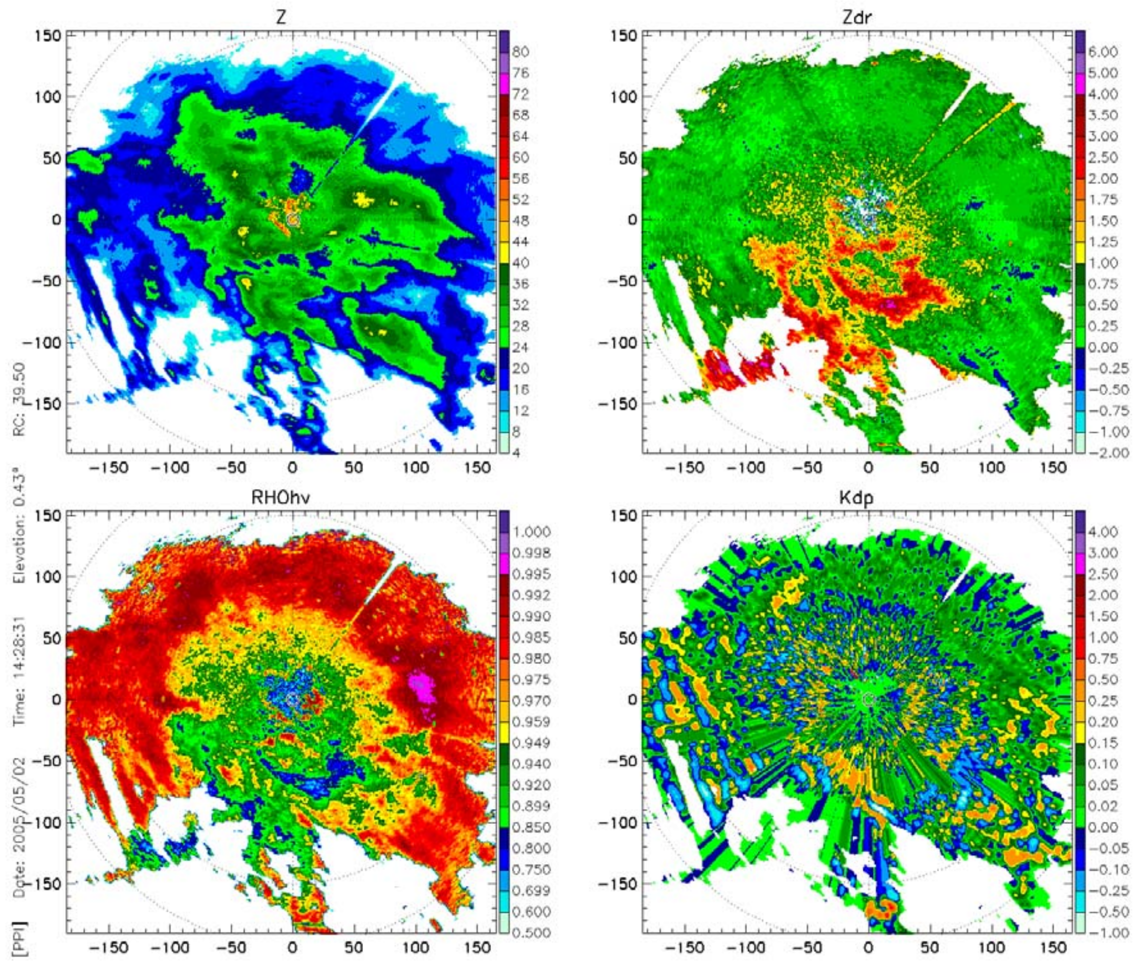

Fig. 6. Polarimetric KOUN WSR-88D at 0.43° elevation of radar reflectivity (Z), differential reflectivity (Z_{DR}), correlation coefficient (ρ_{HV}), and specific differential phase (K_{DP}) of the 2 May 2005 precipitation event at 1428 UTC.

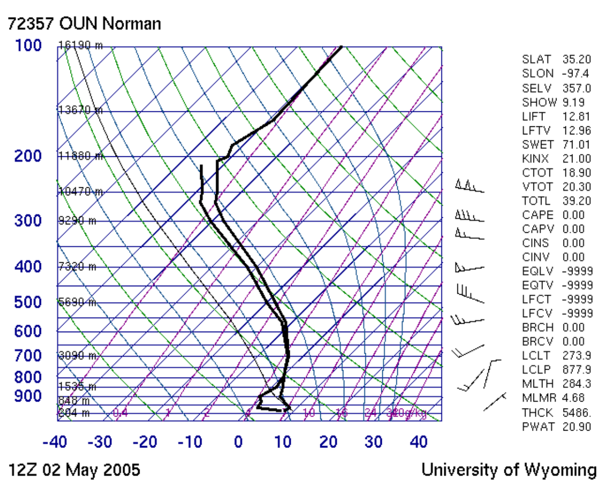

Fig. 7. 1200 UTC Norman, OK sounding on 2 May 2005.

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