**P5.5** THE USE OF THE "$Z_{dr}$ COLUMN" SIGNATURE IN SHORT-TERM THUNDERSTORM FORECASTS

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## 1. INTRODUCTION

The United States' WSR-88D network is expected to be upgraded to include polarimetric technology during the next several years. Polarimetric radars are capable of simultaneously transmitting and receiving both horizontally- and vertically-polarized electromagnetic radiation. Among other benefits, this upgrade will allow accurate detection of bulk hydrometeor characteristics (Straka et al. 2000) and better discrimination between meteorological and nonmeteorological scatterers (Zrnić and Ryzhkov 1999).

Recently, the prototype WSR-88D at the National Severe Storms Laboratory in Norman (KOUN), Oklahoma was upgraded to include polarimetric diversity. KOUN data were collected using volume scan strategies similar to those used by the operational WSR-88D network, and delivered to the Norman forecast office of the National Weather Service in real time for operational testing and evaluation as part of the Joint Polarization Experiment (JPOLE; Schuur et al. 2004).

One measurement available from polarimetric radar is differential reflectivity ($Z_{dr}$), or the ratio between the backscattered horizontal reflectivity ($Z_h$) and backscattered vertical reflectivity ($Z_v$),

$$Z_{dr} = 10 \log (Z_h/Z_v). \qquad (1)$$

$Z_{dr}$ is used to determine the reflectivity-weighted mean shape of scatterers in a sample volume. Negative values of $Z_{dr}$ indicate a mean vertical orientation, while scatterers with a primarily horizontal orientation (e.g., falling rain drops or flying insects) yield positive values of $Z_{dr}$.

Research polarimetric radars have often observed a narrow column of enhanced $Z_{dr}$ values above the ambient 0°C level near the region of thunderstorm updrafts, a signature dubbed the *$Z_{dr}$ column* (Fig. 1). This signature appears to be associated with rising motion within the thunderstorm. Enhanced $Z_{dr}$ and low $Z_h$ imply the presence of oblate hydrometeors (liquid drops), and *in-situ* data confirm the presence of low concentrations of 1-3 mm diameter liquid drops, or drops with ice cores, and rising motion within $Z_{dr}$ columns (Bringi et al. 1991; Brandes et al. 1995; Loney et al. 2002).

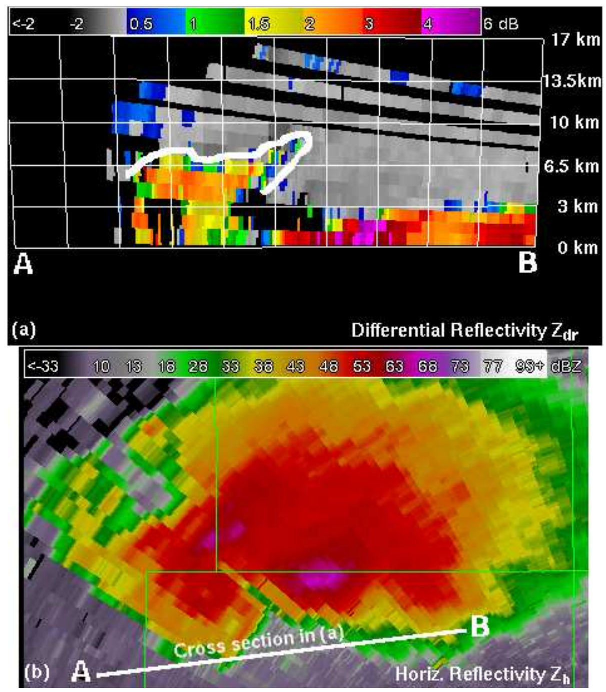


**Figure 1. a)** Vertical cross-section of differential reflectivity ($Z_{dr}$) in the updraft region of a supercell thunderstorm, 30 May 2004 at 0058 UTC. The top of the $Z_{dr}$ column is marked by the thick white line, and extends up to 8.9 km above radar level (4.5 km above the ambient 0°C level) in this case. The horizontal scale from A-B is 50 km. **b)** Corresponding horizontal reflectivity ($Z_h$) image at 0.0° elevation angle (70 km range, 0.3 km above radar level at the center of the image). The thick white line marked A-B denotes the corresponding cross-section in panel **a)**.

## 2. OBSERVATIONS OF $Z_{dr}$ COLUMNS

Numerous thunderstorms have been observed by KOUN polarimetric radar, and $Z_{dr}$ column signatures have been frequently noted. Three cases with significant and/or widespread convection during or

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after JPOLE were examined using the NSSL's Warning Decision Support System – Integrated Information (WDSS-II; Lakshamanan 2002).

### 2.1 *8 May 2003 Convection*

On 8 May 2003, a supercell thunderstorm moved across the Oklahoma City area producing a violent tornado, two weak tornadoes, and several reports of large hail. In addition, several short-lived, anticyclonic storms split off from the main cyclonic supercell.

The supercell thunderstorm produced a single $Z_{dr}$ column along its right flank with a horizontal diameter over 6 km at times (Fig. 2), the widest observed in this small study. This storm evolved from a region of initial development consisting of scattered, much more narrow, and short-lived $Z_{dr}$ columns. The anticyclonic storms featured well-defined, but more narrow $Z_{dr}$ columns (Fig. 3), and dissipated soon after moving away from the parent, cyclonic supercell.

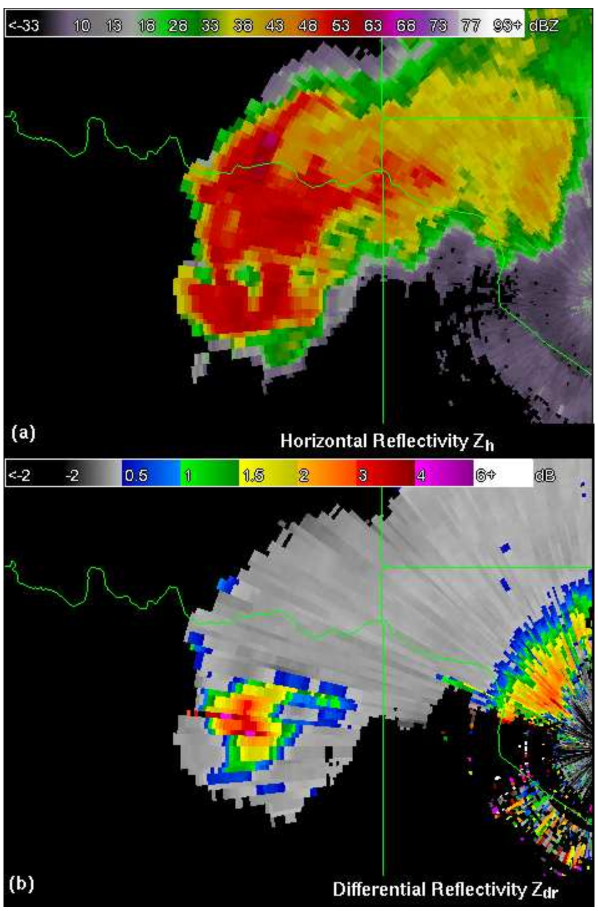


**Figure 2. a)** Horizontal reflectivity ($Z_h$) and **b)** Differential reflectivity ($Z_{dr}$) from KOUN polarimetric WSR-88D, 8 May 2003 at 2144 UTC, at 12° elevation angle (31 km range, about 6.7 km above radar level at the center of the frames).

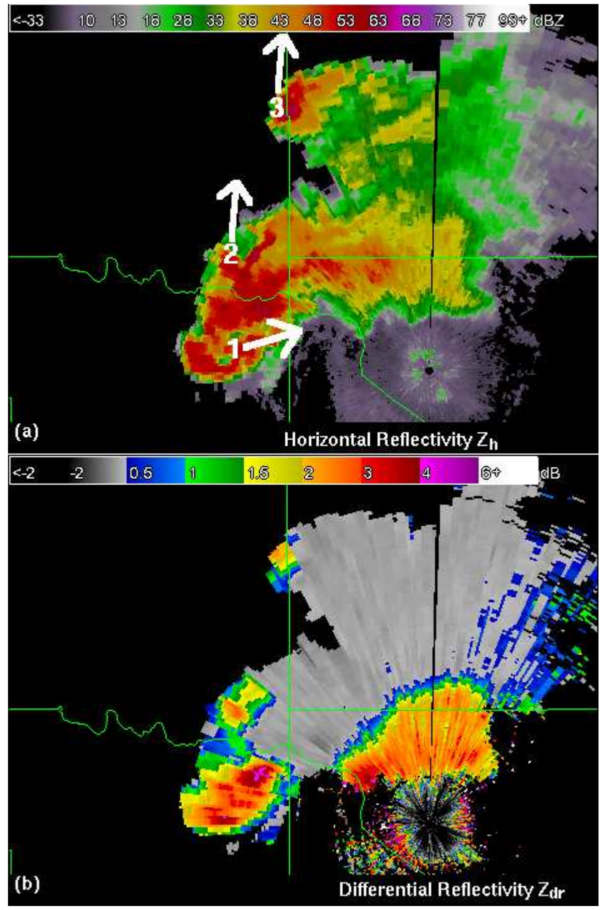


**Figure 3. a)** Horizontal reflectivity ($Z_h$) and **b)** Differential reflectivity ($Z_{dr}$) from KOUN polarimetric WSR-88D, 8 May 2003 at 2149 UTC, at 8.5° elevation angle. The intense cyclonic supercell (marked 1) has shed two anticyclonic storms (marked 2 and 3). $Z_{dr}$ columns are evident with all three storms. White arrows mark approximate direction of motion.

### 2.2 *9-10 May 2003 Convection*

For the second consecutive day, severe thunderstorms occurred in Oklahoma on 9-10 May 2003. One supercell produced several tornadoes, damaging winds, and large hail. Also observed were nontornadic supercell thunderstorms, multi-cellular thunderstorms, an anticyclonic supercell that produced widespread, destructive hail, and convection that failed to develop into significant thunderstorms.

A multi-cellular cluster was observed, characterized by as many as five $Z_{dr}$ columns simultaneously over a relatively small region (Fig. 4). These columns were generally quite narrow (only 2.2 km on average) and transient. Although no significant severe weather was ongoing at the time of this observation, it is important to note that one supercell thunderstorm, responsible for hail to nearly 7 cm in diameter at the surface, evolved from this multi-cellular cluster during the 30 minutes following the "snapshot" in Fig. 4.

The long-track supercell, responsible for most of the damage, was observed to take on a variety of $Z_{dr}$ column characteristics during its lifespan (Fig. 5). The physical processes behind these changes are not readily apparent. One consistent characteristic of the $Z_{dr}$ column in this storm was its depth, reaching at times up to 8.2 km above radar level (ARL), or 4 km above the 0°C level.

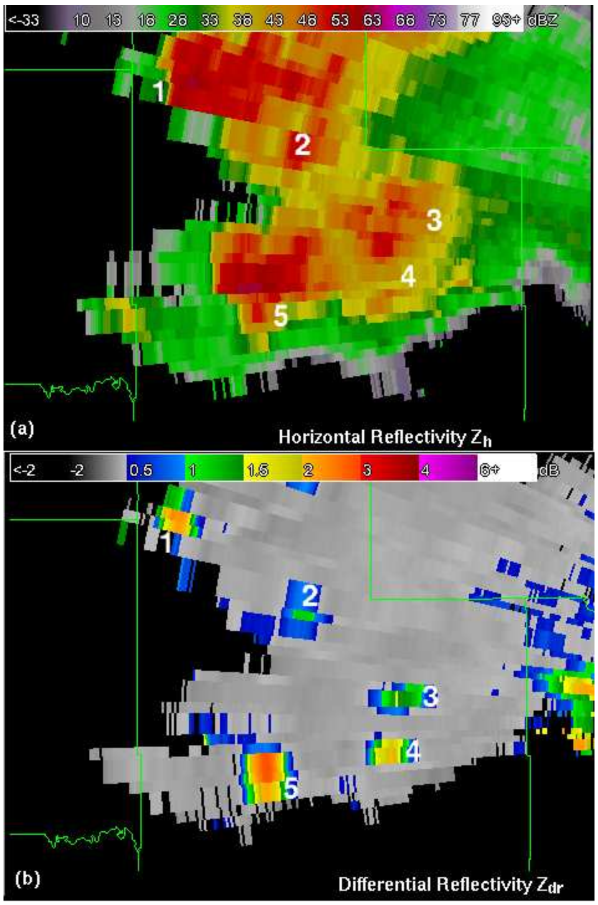


**Figure 4. a)** Horizontal reflectivity ($Z_h$) and **b)** Differential reflectivity ($Z_{dr}$) from KOUN polarimetric WSR-88D, 9 May 2003, at 2334 UTC, at 3.5° elevation angle (about 83 km range, 5.5 km ARL at center of frames). Multiple $Z_{dr}$ columns (labeled 1 through 5) are apparent, illustrating the multi-cellular nature of this convection. These columns were generally more narrow and transient than those observed in typical supercell thunderstorms.

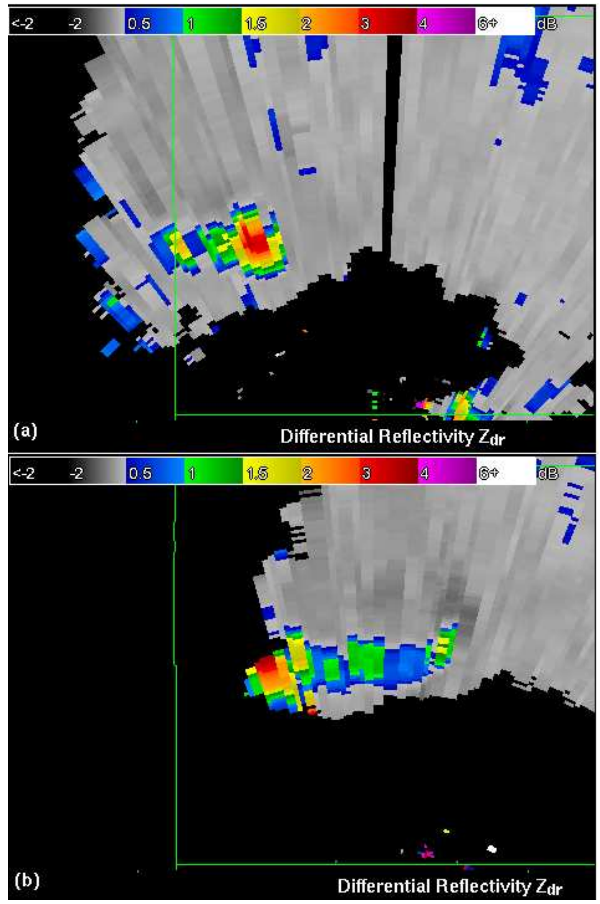


**Figure 5.** Differential reflectivity ($Z_{dr}$) from KOUN polarimetric WSR-88D at 10° elevation angle (approximately 35 km range, 6.1 km ARL) on 10 May 2003 at **a)** 0315 UTC, and **b)** 0337 UTC. The $Z_{dr}$ column has evolved from nearly circular to elongated along the right and upshear flanks of the supercell.

### 2.3 *29-30 May 2004 Intense Supercell*

On 29-30 May 2004, numerous thunderstorms developed in western Oklahoma, but only one supercell persisted long enough to move into central Oklahoma. This storm produced a swath of significant severe weather, including multiple tornadoes, giant hail, and destructive nontornadic winds.

The $Z_{dr}$ column associated with this supercell (Fig. 1) was the deepest of any observed to date, extending as high as 8.9 km ARL (4.5 km above the ambient 0°C level). At the time of the deepest observed signature (Fig. 6), the top of the column was coincident with a significant local minimum (to 0.5) in co-polar correlation coefficient ($\rho_{hv}$), and was slightly upshear of a bounded weak echo region observed in the $Z_h$ field. The low $\rho_{hv}$ values suggested a mixture of hydrometeors was present at this altitude (Straka et al. 2000).

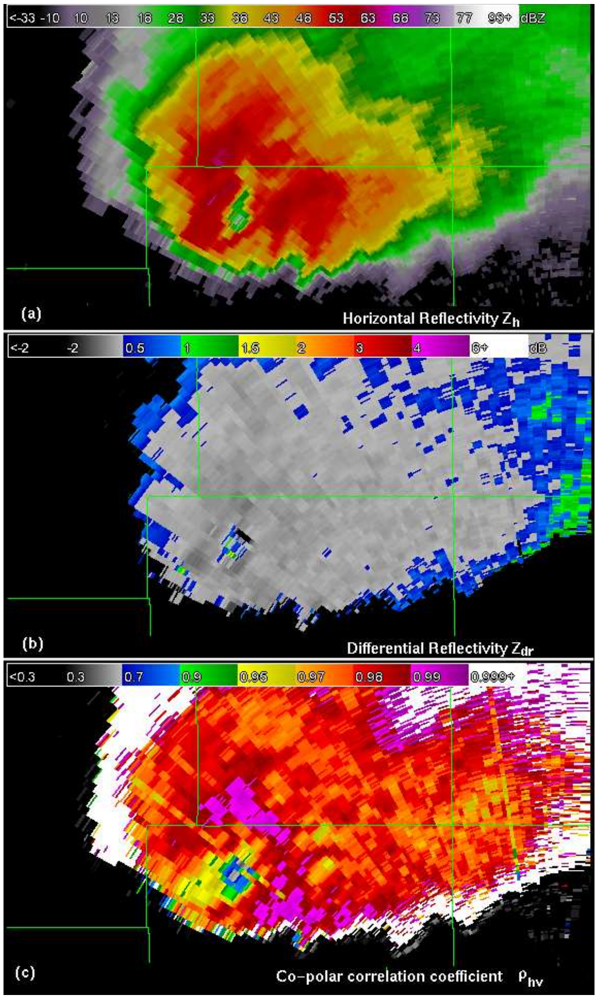


**Figure 6. a)** Horizontal reflectivity ($Z_h$), **b)** Differential reflectivity ($Z_{dr}$), and **c)** Co-polar correlation coefficient ($\rho_{hv}$) from KOUN polarimetric WSR-88D, 30 May 2004, at 0058 UTC, at 6.5° elevation angle (about 74 km range, 8.9 km ARL at center of frames). The top of the $Z_{dr}$ column is apparent, just upshear of a bounded weak echo region in $Z_h$ and a significant local minimum in $\rho_{hv}$.

## 3. DISCUSSION

Differential reflectivity data from polarimetric WSR-88Ds will provide new diagnostic information on the location, strength, and structure of thunderstorm updrafts, an improvement over the current practice of inferring updraft information from horizontal reflectivity data alone. This information can have significant application in the aviation community, better enabling pilots and ground personnel with air space management and turbulence avoidance. In addition, the cloud microphysical information provided by this technique may enhance future storm-scale numerical weather prediction models and radar algorithms, yielding better convection forecasts.

Though more storms will need to be observed to better understand the $Z_{dr}$ column signature, the preliminary results from this small sample of significant convective cases suggest the diameter, depth, and orientation of $Z_{dr}$ column(s) can help users better anticipate the short-term evolution of convection.

## 4. ACKNOWLEDGMENTS

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