Dual-Polarimetric Radar

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Dual-polarimetric radars have been available to the meteorological research community in a number of forms for decades. During the last few years, these radars have also made a limited appearance in the broadcast sector. In the near future, the National Weather Service will upgrade the NEXRAD national radar network to include dual-polarimetric (dual-pol) capabilities. The difference between the current horizontally polarized NEXRAD radars and dual-pol radars is the addition of a vertically polarized signal in dual-pol systems. With both the vertical and horizontal pulses, these radars are better able to determine hydrometeors' type, shape, and size than the current NEXRAD system. Enhanced characterization of hydrometeors' shape and size allows dual-pol radars to compute more accurate rainfall rates and to discriminate more reliably the presence of liquid and/or frozen precipitation. The enhanced quantitative precipitation estimation capabilities of dual-pol radar are accomplished through combined use of standard dual-pol variables including:

Z_H–Horizontal Reflectivity. This is the same as the reflectivity in the current NEXRAD system.
Z_{DR}–Differential Reflectivity. The ratio of the backscattered horizontal to vertical power returns. Z_{DR} values typically range from around 0 to 5+ dB. Z_{DR} values close to zero represent spherical hydrometeors such as hail while larger values are likely large, more oblate rain drops.
ρ_{HV}–Correlation Coefficient. The correlation between the reflected horizontal and vertical power returns. ρ_{HV} is measured on a scale from 0 to 1 with values above 0.96-0.98 indicating hydrometeors with consistent size, shape, orientation and/or phase and values below 0.96 indicating a mixture of these within the sampled volume. Very large hail and non-precipitation echoes often indicate values of ρ_{HV} below 0.8. Large depressions in the correlation coefficient are also a good indicator for mixtures of liquid and frozen hydrometeors (e.g., snow and rain) in winter situations and in radar bright-bands.
Φ_{DP}–Differential Phase. This is the measured difference in phase shift between horizontal and vertical polarized pulses. When the range-integrated horizontal phase shift is larger than vertical then Φ_{DP} is positive, similar to Z_{DR}. Φ_{DP} is largely immune to attenuation effects of hail and other more spherical scatterers since these targets produce approximately the same phase shift in both the horizontal and vertical.
K_{DP}–Specific Differential Phase. K_{DP} is the range derivative of Φ_{DP}, and therefore is not directly measured by the radar. Increases in K_{DP} (high values are > 2 °/km), imply the presence of significant amounts of liquid water and/or highly oriented (i.e., oblate) shapes. K_{DP} is a very good estimator for rainfall because it is also immune to attenuation.

The most important applications of dual-pol radar for operations include improved accuracy of precipitation estimation and the generation of hydrometeor identification (HID) products. Both of these applications are facilitated by combining the information present in individual dual-polarimetric variables. As an example, consider the radar range-height displays of reflectivity (etc.) depicted in Figure 1. Areas that have high Z_H values but low Z_{DR} values in the 50+ dBZ core between 3 and 5 km are suspected to be regions of hail. The hail subsequently begins to melt below the 3 km level and produces excessively large Z_{DR} in the core near the surface (where ρ_{HV} exhibited values of below 0.91 also indicated a mixture of large hail and rain). Other examples include regions of high K_{DP} and high Z_H values (not shown) which imply the presence of large amounts of liquid water (and large rain rates) in the analyzed volume.

Through the combined use of dual-pol variables, forecasters will realize an improved ability to discriminate areas of heavy rainfall rate and thus the potential for flash flooding. They will also be better able to detect echo regions with hail and to pinpoint regions of mixed-phase precipitation within radar echoes.

More information may be found at the following websites:
http://www.nsstc.uah.edu/ARMOR/ (University of Alabama – Huntsville)
http://www.nssl.noaa.gov/research/radar/dualpol.php (NOAA National Severe Storms Lab)
http://www.wdtb.noaa.gov/modules/dualpol/index.htm (NOAA Warning Decision Training Branch)

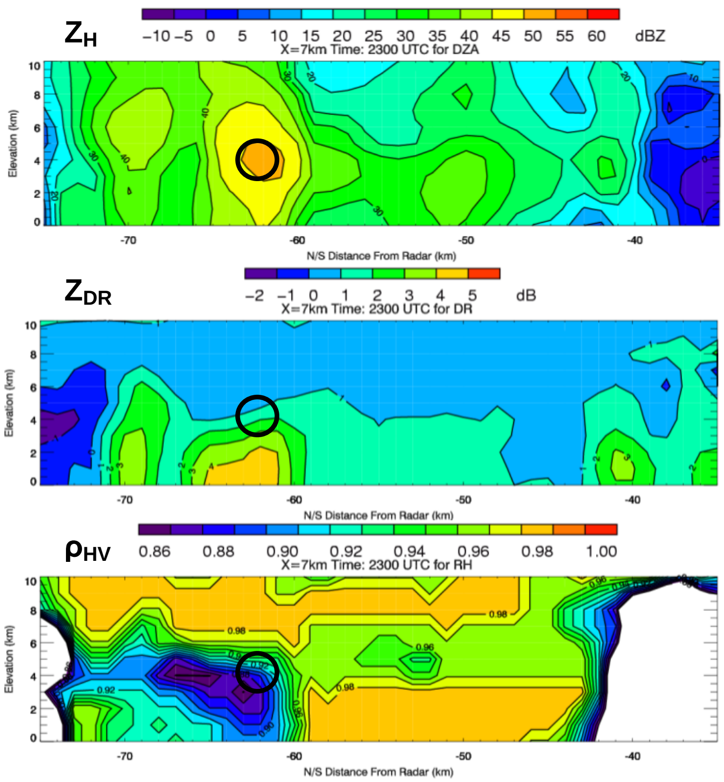

Figure 1 – Example of Z_H (top), Z_{DR} (middle), and ρ_{HV} (bottom) cross sections through a hail producing storm using data from ARMOR. On 17 August 2007 at 2301 UTC, golf ball size hail (estimated 1.75in.) was reported 1 mile SW of Hanceville, AL. The x-axis represents the distance south of the ARMOR while the X distance in the title of the image represents the distance east of ARMOR. The 50+ dBZ core between 3 and 5 km at about -60 to -63 km (area circled) south of ARMOR coincides with lower Z_{DR} values (below 2 dB) as well as low ρ_{HV} values (below 0.91). This suggests that there is possible hail between 3 and 5 km and a mixture of melting hail, hail, and rain near the surface where Z_{DR} values are large (~4 dB) and ρ_{HV} values are still below 0.91. This is confirmed when hail was reported at the surface near the time of this volume scan.

Contributed by the Remote Sensing Committee