Observations of hail cores of tornadic thunderstorms with three polarimetric radars

Valery Melnikov, Dusan Zrnic, Donald Burgess, and Edward Mansell

*CIMMS, University of Oklahoma, CIMMS, and NOAA/OAR National Severe Storms Laboratory, Norman OK.

Goals:
- Adjacent WSR-88D radars operate at different frequencies. Observe hail cores with various radars to study frequency dependences of differential reflectivity (ZDR) and the correlation coefficient (CC = pHv).
- Study attenuation of X band radiation in tornadic thunderstorms.
- Study the utility of the Slant Differential Ratio (SDR) in tornadic thunderstorms.
- Study the utility of the Slant Differential Ratio (SDR) in tornadic thunderstorms.

Radar Systems

<table>
<thead>
<tr>
<th>Radar</th>
<th>Frequency, MHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>KOUN</td>
<td>S band, 2705</td>
</tr>
<tr>
<td>KTLX</td>
<td>S band, 2910</td>
</tr>
<tr>
<td>KCRI</td>
<td>S band, 2995</td>
</tr>
<tr>
<td>NOXP</td>
<td>X band, 9410</td>
</tr>
</tbody>
</table>

The data have been collected with three polarimetric S band WSR-88Ds and the mobile X band dual-polarization NOXP.

Fig. 1. The data have been collected with three polarimetric S band WSR-88Ds and the mobile X band dual-polarization NOXP.

Results of observations
1. X band radiation experienced severe attenuation so that NOXP was unable to observe hail cores in the tornadic thunderstorms (Fig. 3, bottom –left).
2. The maximal reflectivity in the hail cores at longer wavelength of S band is frequently higher than at shorter wavelengths (e.g., Fig. 5 above).
3. Differences in ZDR from the three WSR-88Ds reached 1 dB in the hail cores that cannot be attributed to radar miscalibration.
4. The measured CC are different in the hail cores (Figs. 4 and 5).

Fig. 2. A giant hailstone picked up by J. Coleman in City of El Reno, OK. 31 May, 2013 at 00:25 UTC.

Fig. 3. (below). Area ‘1’ of high reflectivity is close to the EF3 tornado (see also images of the Doppler velocities in the right top figure in this poster). The area of giant hail is shown with the circle.

Fig. 4. (below) Area ‘1’ of high reflectivity is close to the EF3 tornado (see also images of the Doppler velocities in the right top figure in this poster). The area of giant hail is shown with the circle.

SDR parameter in tornadic thunderstorms

The WSR-88Ds employ a polarimetric configuration with Simultaneous Transmission And Reception (STAR) of horizontally and vertically polarized waves.

SDR is a parameter calculated from Zdr in power units and pHv (CC) as,

\[
SDR = \frac{Z_{dr} + 1 - 2Z_{dr}^{1/2} \rho_{hv}}{Z_{dr} + 1 + 2Z_{dr}^{1/2} \rho_{hv}}
\]

In areas with hydrometeors, SDR is in an interval from -30 dB (almost spherical droplets) to -15 dB, (highly non spherical ice crystals).

If SDR > -15 dB, the scatterers are extremely non spherical, e.g., insects in the atmosphere (see the black areas in the lower right corners of the SDR panels).

Fig. 8. Areas of SDR > -15 dB in weather echoes indicate the presence of highly non spherical scatterers. See patches of high SDR in the tornado area.

Differential Doppler velocity as an indicator of inflow areas

Tornado event 31 May 2008 (Fig. 9)

CONCLUSIONS:
- There are frequency dependences of Z, ZDR, and CC in hail cores so that various WSR-88Ds operating at different frequencies can measure different values in the same hail area. (Figs. 4, 5, and 6)
- The measured differential phase and CC strongly depend upon the system differential phase in transmit. This phase can be different in various WSR-88Ds therefore measured CC can be different. (Fig. 7)
- SDR can be used to estimate non-sphericity of scatterers. Typical SDR values in rain are about -20 dB. SDR in tornado balls can reach -10 dB indicating the presence of highly non-spherical scatterers. (Fig. 8)
- Differential Doppler velocity (DDV) can be used to identify areas of inflow. Our observations show that inflow areas can reach 4 km in height. (Fig. 10)
- X band radiation experiences severe attenuation in hail thunderstorms. In the 2013 tornado thunderstorms in Oklahoma, X band radiation did not reach the hail cores at all (e.g., Fig. 3).