P 6.14 A dual polarimetric and total lightning review of significant weather events across the Tennessee Valley from late March through May 2009

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1. Introduction

Multiple severe weather events occurred between late March 2009 and late early May 2009 across North Alabama and South Central TN in the UAH/NSSTC THOR Center and Hazardous Weather Tesetbed (Petersen et al. 2007; Figure 1). The purpose of this study is to briefly examine several cases from Spring 2009 across the Tennessee Valley using dual-polarimetric C-band radar and 3-D lightning mapping. A list of case days is presented in Table 1. Highlighted are dual-polarimetric examples of tornadic debris signatures and hail detection at C-band, and total lightning signatures using 3-D lightning mapping.

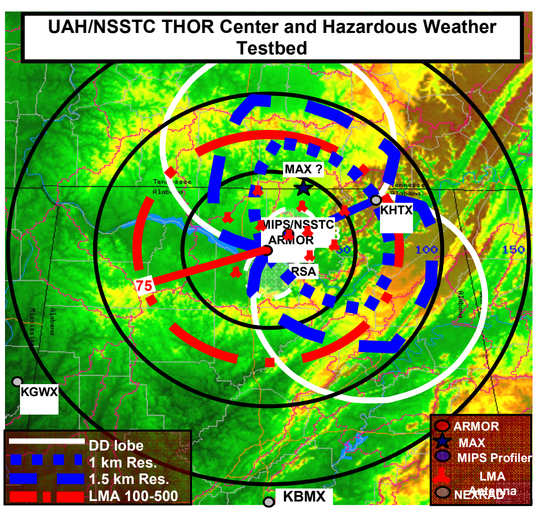

Figure 1 - The UAH/NSSTC THOR Center and Hazardous Weather Testbed.

2. Background

Tornadic debris signatures using polarimetric S-band radar have been

April 2-3, 2009
April 10, 2009
April 13, 2009
April 19-20, 2009
May 6, 2009

Table 1 – Event days from early April through early May 2009

well documented in Oklahoma (e.g., Ryzhkov 2002, Ryzhkov et al. 2005, Kumjian and Ryzhkov 2008) and EF-4 tornadoes at C-band in South Alabama (Kumjian and Ryzhkov 2008) and using ARMOR radar data in North Alabama (Petersen et al. 2008). The most consistent dual-polarimetric variable used for the detection of tornadic debris is correlation coefficient (ρ_{hv}). ρ_{hv} values below 0.5 have been found to be associated with tornadic debris signatures at S-band, while typical values of ρ_{hv} associated with tornadic debris signatures at C-band have been seen below 0.70.

Hail detection using dual-polarimetric variables has been well documented over the past few decades at S-band (e.g., Aydin et al. 1986, Bringi et al. 1986, Herzegh and Jameson 1992, Hubbert et al. 1998). One combination of variables used to detect hail is differential reflectivity (ZDR) and horizontal reflectivity. At S-band ZDR values near 0 dB coupled with horizontal reflectivity values greater than 50-55 dBZ tend to indicate the presence of large hail. ρ_{hv} is another way to detect the presence of hail at S-band. Typically ρ_{hv} values of pure hail are <0.90. In cases where rain and hail are mixed, ρ_{hv}

values can be between 0.90 and 0.95 (Brandes and Zrnic 2004).

Unfortunately using these same parameters at C-band does not necessarily result for the same observations of large hail. Several examples have been shown where large hail falls coincidently with high ZDR values of several dB collocated with horizontal reflectivity values greater than 55 dBZ (e.g., Meischner et al. 1991, Ryzhkov et. al. 2007, Kumjian and Ryzhkov 2008, Anderson et al. 2009, this conference).

Total lightning information has been shown to be a useful indicator of updraft strength and thunderstorm severity (e.g. Williams et al 1999, Goodman et al. 2005, Gatlin and Goodman 2009, Schultz et al. 2009).

3. Data and Methodology

Data were collected using the UAHuntsville ARMOR C-band dual polarimetric radar (Petersen et al. 2005, 2007) and the North Alabama Lightning Mapping Array (NALMA) for events between late March and early May 2009.

ARMOR dual-polarimetric radar variables available for each case are differential reflectivity (ZDR), correlation coefficient (ρ_{hv}), differential phase (Φ_{DP}), specific differential phase (KDP), as well as, traditional horizontal radar parameters of horizontal reflectivity (Zh) and radial velocity (Vr). ARMOR data were converted to sweep format and edited using NCAR SOLOII software. Velocity data were unfolded for accurate representation of the radial velocity field.

Tornadic debris signatures have been observed using the ARMOR C-band radar in several other N. Alabama cases in the past few years including two occurrences during the observation period. These two cases occurred on April 2, 2009 and May 6, 2009 and observations are presented in this poster.

A few examples of large hail at C-band are also presented in this poster. The largest outbreak of hail occurred on April 10, 2009, where 85 reports of severe hail (> 1.9 cm) were observed across the 14 county warning area covered by the National Weather Service in Huntsville (Anderson et al. 2009). For an in depth examination of the dual-polarimetric data for this case please see Anderson et al. this conference, poster 13.21.

Total lightning data were examined for each case to see if it provides useful insight into a thunderstorm's updraft and indication of potential severity. Very high frequency (VHF) source data from the NALMA were clustered into flashes using a flash clustering algorithm developed by McCaul et al. (2005) and minimum of 10 VHF sources per flash was applied to eliminate VHF singletons and smaller flashes. According to Wiens et al. (2005) and Deiering (2006) the chosen value of minimum source points per flash should not affect the flash rate trend.

4. Results

Two examples of tornadic debris signatures have been found in two cases from April 2, 2009 and May 6, 2009 (Figures 2 and 3). Both signatures have low ρ_{hv} values (>0.7) coupled with higher reflectivity values and collocated with the tornadic velocity couplet. Each of these cases were within 30 km of the ARMOR radar and were consistently seen for multiple volumes. These cases were on the lower end of the Enhanced Fujita Scale (EF), as the April 2nd

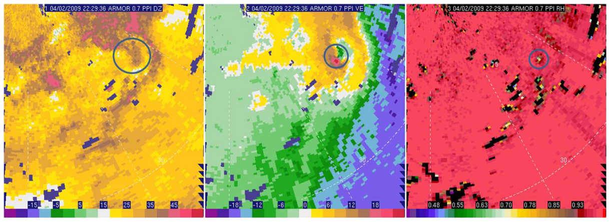

Figure 2 – Example of a tornadic debris signature from April 2, 2009 at 2229 UTC. Reflectivity (left), radial velocity (center) and ρ_{hv} (right) are represented here. ρ_{hv} values are below 0.7, and collocated with the velocity couplet for 4 consecutive volumes

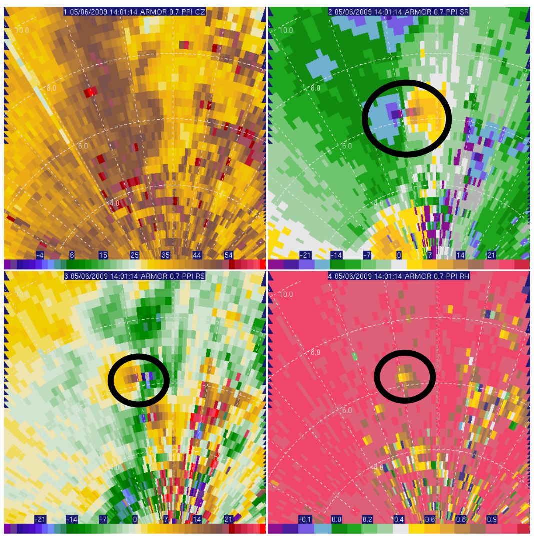

Figure 3 – An example from a tornado debris signature observed on May 6, 2009 at 1401 UTC. Reflectivity (upper left), corrected radial velocity (upper right), uncorrected radial velocity (lower left), and ρ_{hv} (lower right) are represented here. ρ_{hv} values are below 0.7, and collocated with the velocity couplet several consecutive volumes, as the tornado moved through Madison, AL.

tornado, was an EF-1 and the May 6th tornado was just within EF-2 criteria.

Several cases of large hail were observed during this period of observation, with the most notable being the hail producing supercells from April 10, 2009, specifically the supercell that affected parts of Limestone and Madison Counties between 1830 and 2000 UTC. High horizontal reflectivity values coupled with large ZDR values (>3 dB) were observed with thunderstorms on this case day, while ρ_{hv} values varied between 0.79 and 0.93 (Figure 4). Hail greater than two inches was observed between 1855 UTC and 1945 UTC within this particular storm. Mie and resonance effects were clearly present during this period of observation of very large hail at C-band. More information and results can be found in Anderson et al. 2009, P. 13.21, this conference.

Another example of large hail occurred on April 13, 2009, as a low topped supercell skirted the Tennessee/Alabama border (Figure 5). Dime size hail (0.71") was observed in Ardmore, TN at 1955 UTC. ZDR values were between 3-6 dB in this portion of the storm, while ρ_{hv} values were between 0.86 and 0.93. Once again, Mie and resonance effects are likely being sampled by the ARMOR C-band radar.

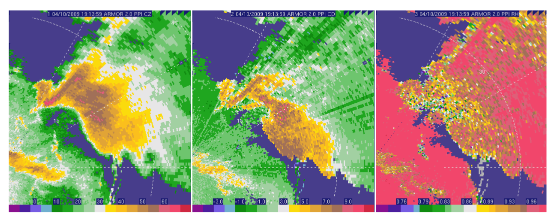

Figure 4 - This image is from 1913 UTC on April 10, 2009, and shows observations of very large hail with a dual-polarimetric C-band radar. Hail was ongoing at this time. Horizontal reflectivity (left), differential reflectivity (center) and ρ_{hv} (right) are represented in this figure. ZDR values are > 4 dB, while ρ_{hv} values vary from 0.79-0.93.

A final example is from a supercell on April 19, 2009 (Figure 6). At this time (2300 UTC) large hail (1.00"-1.75") is observed in Lawrence Co., AL, along with very heavy rainfall. Mie, attenuation, and non-uniform beam filling effects are clearly present behind the precipitation core. ZDR values in

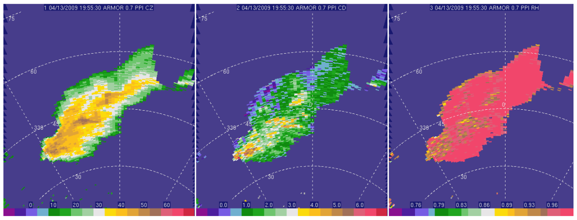

Figure 5 - This image is from 1955 UTC on April 13, 2009, and shows observations of dime size hail (0.71") with a dual-polarimetric C-band radar. Horizontal reflectivity (left), differential reflectivity (center) and ρ_{hv} (right) are represented in this figure. ZDR values are > 3 dB, while ρ_{hv} values are between 0.86-0.93.

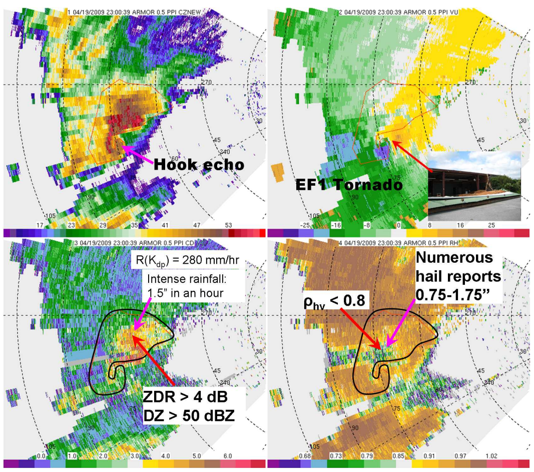

Figure 6 - This image is from 2300 UTC on April 19, 2009, and shows observations of large hail (>1.00") with a dual-polarimetric C-band radar. Horizontal reflectivity (upper left), differential reflectivity (lower left), radial velocity (upper right) and ρ_{hv} (lower right) are represented in this figure. ZDR values are > 3 dB, while ρ_{hv} values are as low as 0.8. Clearly present are attenuation and non-uniform beam filling effects just to the rear of the main precipitation core.

the hail and heavy rain are > 4 dB, while ρ_{hv} values drop below 0.8 dB. A EF-1 tornado touchdown occurred at 2303 UTC, however, no debris signature was observed due to the tornado's range from ARMOR (60 km).

Total lightning observations for this period of study reveals that total lightning information can be useful in diagnosing the potential severity of a thunderstorm. Several examples of increases in the total flash rate proceeded severe weather observed at the surface. However, three examples stand out from this dataset.

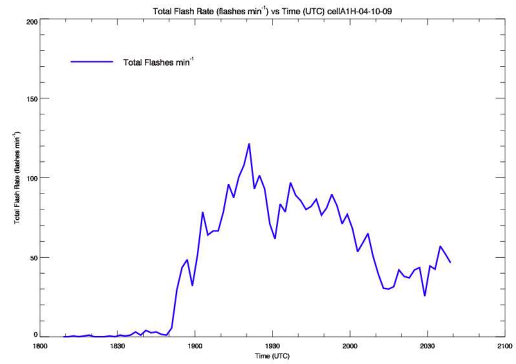

Figure 7 - Presented here is the total flash rate of the April 10, 2009 hail producing thunderstorm during its lifetime. A large increase in the total flash rate occurs between 1851 and 1854 UTC, prior to the onset of a prolonged period of very large hail. The total flash rate increases from 9 flashes min^{-1} to 46 flashes min^{-1} in three minutes. This increase in the total flash rate indicates that the thunderstorm's updraft is undergoing rapid intensification.

First, the hailstorm from April 10, 2009 exhibits a classic total lightning jump prior to the onset of severe hail at the surface. The lightning jump occurs between 1851 and 1854 UTC as the total flash rate increases from 9 flashes min^{-1} to 46 flashes min^{-1} in three minutes. Large increases in total lightning indicate when a thunderstorm's updraft is undergoing intensification.

A second example is from April 2, 2009, where little to no lightning was observed prior to the onset of a tornado near Lacy Springs, AL. The lack of lightning indicated that a strong updraft at the lower levels of the thunderstorm was the primary reason for tornadogenesis.

The third instance that stands out is from April 13, 2009, where a tornado warned thunderstorm produced little lightning during its lifecycle. However, there were several small pulses in total lightning activity which preceded vertical growth of the low topped supercell, thus showing that total lightning information can be useful in understanding the evolution of potentially severe thunderstorms.

5. Conclusions

Five events from Spring 2009 were briefly examined to highlight observations of severe weather at C-band Several examples of tornadic debris signatures and hail observations at C-band have been presented in this poster.

Two tornadic debris signatures were observed with EF-1 and EF-2 tornadoes. ρ_{hv} values below 0.7, coupled with high reflectivity values seemed to be the best indicator of tornadic debris. In each case the debris signature was coherent for several volume scans and collocated with the velocity couplet.

Three examples of large hail at C-band were also presented. In each example ZDR values were > 3 dB while ρ_{hv} values were below 0.93. ZDR values are different from dual-polarimetric observations of hail at S-band (~0 dB). ρ_{hv} was the best indicator of hail potential within these cases.

Total lightning information was a useful indicator of potential severity and updraft strength of the April 10, 2009, hail producing thunderstorm across Limestone and Madison counties. Total lightning was not a useful indicator prior to the Lacy Springs tornado on April 2. Total lightning information was useful in determining updraft evolution of a borderline severe thunderstorm on April 13, 2009.

The observations presented in this poster are very useful for the further understanding of severe weather using dual-polarimetric C-band radar. The observations presented here are consistent with other studies that utilize dual-polarimetric C-band radar. Further analysis is necessary to understand how large hail is affecting the dual-polarimetric observations to better quantify what is observed at the surface.

Total lightning information will also prove to be a useful tool for forecasters to discern a thunderstorm's updraft and evolution. Rapid increases in total lightning have been shown to precede severe weather in several instances (e.g., Schultz et al. 2009), and coupled with radar data will be very useful in the future of severe weather nowcasting.

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