P.120 OVERVIEW OF THE 28-29 APRIL 2014 TENNESSEE VALLEY TORNADO OUTBREAK

Anthony W. Lyza[1*], Todd A. Murphy[2], and Kevin R. Knupp[1]
[1]Severe Weather Institute and Radar & Lightning Laboratories (SWIRLL), University of Alabama in Huntsville, Huntsville, AL
[2]University of Louisiana at Monroe, Monroe, LA

1. INTRODUCTION

On 28-29 April 2014, a large-scale tornado outbreak impacted much of the southeastern United States as part of a more widespread, multi-day severe weather episode. The epicenter of this outbreak was located over Mississippi, Alabama, and southern Middle Tennessee, where over 50 tornadoes were documented. Thirteen tornadoes were documented across the Tennessee Valley region of northern Alabama and southern Middle Tennessee (Fig. 1).

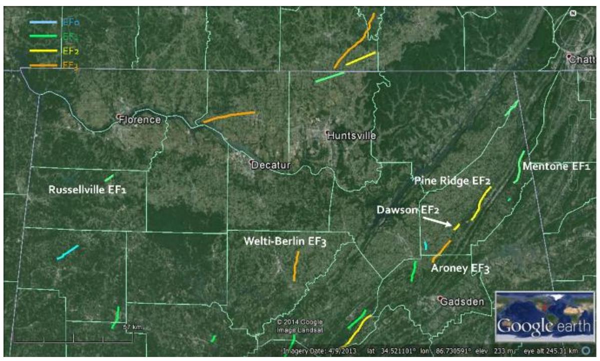

Figure 1: Overview of tornado tracks from 28-29 April 2014 focused on the Tennessee Valley of northern Alabama and southern Middle Tennessee. Tornadoes discussed in this paper are labeled.

This persistent tornado event transpired over a 10.7-hour period across the Tennessee Valley, with the first tornado forming at 2046 UTC on 28 April and the last tornado dissipating at 0725 UTC on 29 April (NCDC 2014). Notably, DeKalb County in northeastern Alabama was impacted by at least 7 separate tornadoes produced by a series of 4 supercells. These include the Aroney, Dawson, Pine Ridge, and Mentone tornadoes depicted in Fig. 1.

This paper serves as an overview of the observations gathered by the University of Alabama in Huntsville's (UAH's) Severe Weather Institute and Radar & Lightning Laboratories (SWIRLL) during this tornado outbreak. These observations include the first active tornado intercept in northern Alabama using the UAH Mobile Alabama X-band (MAX) radar, possible terrain influences on the behavior of several tornadoes in northeastern Alabama, and the likely role of a mid-tropospheric wave feature on the propagation of an EF3 tornado. Relationships to past work and current work are discussed, as well as plans for future work based off of observations from this outbreak.

*Corresponding author address:
Anthony W. Lyza, Department of Atmospheric Science, University of Alabama in Huntsville, 320 Sparkman Dr., Huntsville, AL 35805
Email: lyzaa@nsstc.uah.edu

2. DATA COLLECTION AND METHODOLOGY

Analysis of the 28-29 April 2014 tornado outbreak included a high-density network of remote sensing platforms around the Tennessee Valley. The platforms analyzed in this paper include the University of Alabama in Huntsville's (UAH's) Mobile Alabama X-band radar (MAX), UAH and WHNT's C-band Advanced Radar for Meteorological and Observational Research (ARMOR; Peterson et al. 2005), the Weather Surveillance Radar-88 Doppler (WSR-88D) located at Hytop, Alabama, (KHTX), and the UAH Mobile Integrated Profiling System (MIPS; Karan and Knupp 2006), which features a vertically-pointed X-band radar (XPR), a 915-MHz Doppler wind profiler, a 12-channel microwave profiling radiometer (MPR), and a lidar ceilometer. ARMOR was primarily operating in a three-tilt RAIN-1 scheme, providing data from 0.7°, 1.3°, and 2.0° tilts with a completion time of 66 to 69 seconds per complete RAIN-1 scan. This operating mode was selected to augment WHNT's severe weather coverage and supply frequent low-level updates during this dangerous event. MAX operations includes attempts to actively intercept tornado circulations with a myriad of supercells across northwestern Alabama, in a flatter, slightly more open area of the Tennessee Valley. The results of a successful tornado intercept are discussed in Section 2.

In addition to radar data, survey information is heavily utilized in this paper. National Weather Service survey data was collected through the Damage Assessment Toolkit (NWS 2014). Additionally, the lead author conducted a ground damage survey of areas of DeKalb County, Alabama, in the wake of the outbreak. Finally, Paula Tucker (UAH) flew over the Aroney and Pine Ridge, Alabama, tornado tracks and graciously provided aerial photography of the damage for research use.

3. ACTIVE INTERCEPTION OF A TORNADO WITH A MOBILE RADAR IN THE TENNESSEE VALLEY

Mobile tornado detection is a particular challenge in the southeastern United States for numerous reasons. Increased population density (and thus buildings), dense tree cover, significant topography, a tendency for linear or quasi-discrete storm modes all provide significant challenges to operations and detection with mobile radar. Because of these challenges, UAH SWIRLL normally operates MAX at a fixed location during severe weather events.

On 28 April 2014, the decision was made to attempt an active interception of tornadic supercells in northwestern Alabama. This decision was made for a couple of reasons. First, storms in this region were expected to be more discrete than when they reached the typical severe weather MAX deployment locations in north-central Alabama. In addition, portions of the Tennessee Valley in northwestern Alabama are more open and free of terrain than most of the surrounding areas of northern Alabama and southern Middle Tennessee, allowing for a better opportunity for mobile operations with limited low-level beam blocking. This active interception strategy proved successful, with the first tornado of the event in the state of Alabama captured at Russellville (Fig. 1).

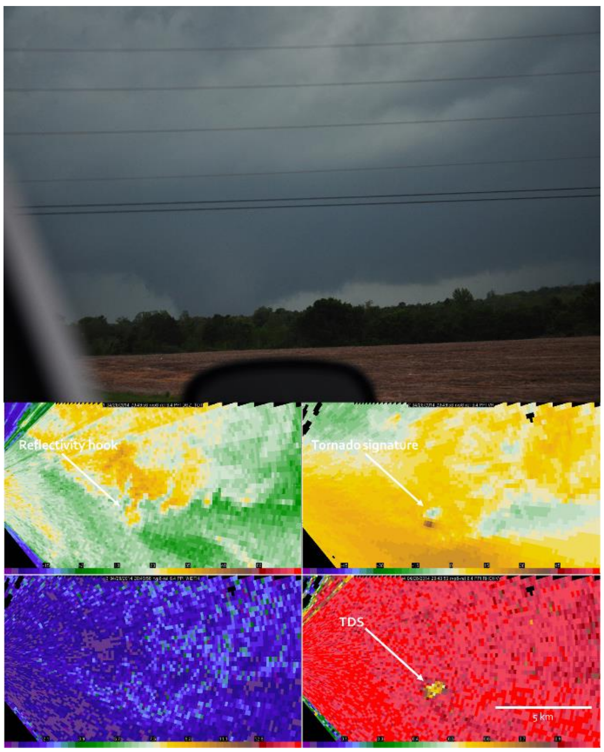

Figure 2: Picture of the wall cloud producing the Russellville EF1 tornado taken by Brian Freitag (UAH) of the MAX crew (top) and 6.4° plan position indicator plot of equivalent reflectivity factor (Z_e, middle-left), dealiased base velocity (V_r, middle-right), spectrum width (lower-left), and cross-polar correlation coefficient (ρ_{hv}, lower-right) at 20:49:56 UTC 28 April 2014.

Data were collected for the entire lifecycle of the tornado. The data from MAX were severely blocked between approximately 3.0°, with some partial beam blockage above 3.0°. Nonetheless, the Russellville case provides an important proof of concept for using portions of the Tennessee Valley in northern Alabama for active tornado intercept operations.

4. POSSIBLE TERRAIN INFLUENCES ON TORNADO BEHAVIOR IN NORTHEASTERN ALABAMA

As discussed in Section 1, DeKalb County, Alabama, was impacted by at least 7 separate tornadoes during the 28-29 April 2014 tornado outbreak. DeKalb County features several significant terrain features. Two large plateaus, Sand Mountain and Lookout Mountain, comprise the majority of the county. Between the plateaus lies the Wills Valley, a southwest-northeast oriented valley that lies approximately 150-200 m below the plateaus. Within the Wills Valley lies several small-scale ridgelines. The occurrence of numerous tornadoes in DeKalb County allows for an analysis of tornado behaviors in the presence of significant terrain during the outbreak.

One supercell that moved through DeKalb County was particularly prolific, producing 4 confirmed tornadoes, 3 of which were significant. The first tornado moved into DeKalb County from Etowah County and passed through the Aroney community, producing EF3 damage (Fig. 1). As the tornado moved northeast, it eventually began to descend Sand Mountain. As the Aroney EF3 tornado moved off of Sand Mountain, it rapidly dissipated (Fig. 3). After the Aroney tornado dissipated, the circulation regenerated back atop Sand Mountain, where the EF2 Dawson tornado occurred (Fig. 1, Fig. 4). As the Dawson tornado dissipated, a circulation formed in the Wills Valley and moved northeast. A tornado formed (Pine Ridge EF2, Fig. 1) and moved along the Wills Valley, with minor deviations in the path prior to reaching, but not ascending, the Shinbone Ridge. Instead, the Pine Ridge tornado paralleled the Shinbone Ridge until it dissipated northeast of Fort Payne (Fig. 5). Finally, a new mesocyclone formed within the supercell atop Lookout Mountain and produced the Mentone EF1 tornado (Fig. 1). The tornado began to curve to the north toward the northern slope of Lookout Mountain but changed direction to parallel the ridgeline atop Lookout Mountain (Fig. 6).

Figure 3: Aerial survey image of the end of the Aroney EF3 tornado track showing the dissipation of the tornado as it descends Sand Mountain. Photo provided by Paula Tucker (UAH). The white arrow depicts the tornado track. Picture is looking southwest.

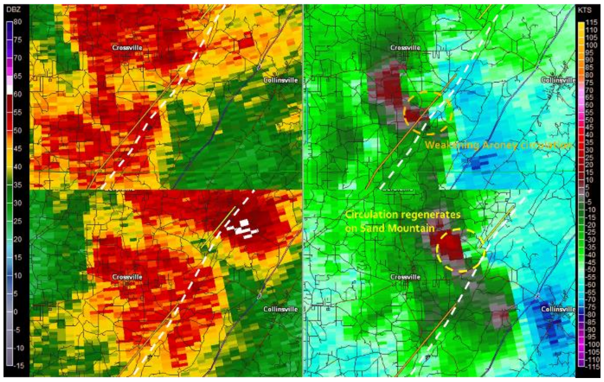

Figure 4: Hytop WSR-88D (KHTX) two-panel 0.5° PPI plots of Z_e (left) and V_r (right) from KHTX at 05:45:11 UTC (top) and 05:54:35 UTC (bottom) 29 April 2014, showing the evolution of the Aroney and Dawson circulations.

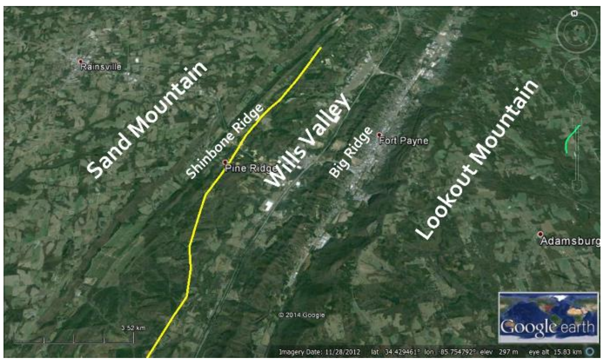

Figure 5: Map of the path of the last half of the of Pine Ridge EF2 tornado (yellow), showing the dissipation of the tornado as it parallels an embedded smaller-scale valley within the Wills Valley along Shinbone Ridge. Path synthesized from NWS survey data as well as aerial imagery provided by Paula Tucker (UAH). Note the path paralleling the Shinbone Ridge.

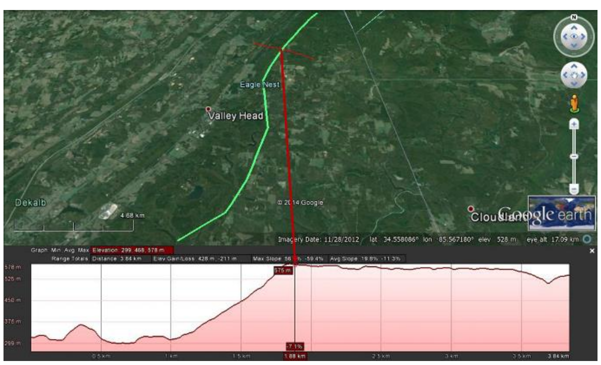

Figure 6: Google Earth map of the Mentone EF1 tornado track, with an elevation profile along the red line transecting the track. The location of the tornado along the highest ridge line of Lookout Mountain is evident.

Though a variety of behaviors are exhibited by these tornadoes, they are all consistent with numerous other cases documented by UAH SWIRLL. These behaviors include dissipation upon moving off a plateau (Aroney EF3), moving along the edge of a plateau (Dawson EF2 and Mentone EF1), and moving along a valley (Pine Ridge EF2). For more information on these and other documented possible terrain interactions, see Paper 11A.1A of these proceedings.

5. EFFECTS OF A MID-TROPOSPHERIC WAVE ON TORNADO MOTION

Wave interactions with mesocyclones and QLCS mesovortices have been noted to be significant contributors to tornadogenesis and intensification in past studies (e.g. Coleman and Knupp 2008). During the 28-29 April 2014 outbreak, an apparent wave interaction played a role in the evolution of a strong tornado.

The Welti-Berlin EF3 tornado occurred between 0239 UTC and 0258 UTC. The Hytop WSR-88D radar (KHTX) captured the evolution of the tornado and the parent supercell. The supercell moved into Cullman County with a northeasterly motion. As the tornado moved into south-central Cullman County, a band of enhanced reflectivity could be seen propagating toward the supercell. As the band reached the supercell, tornadogenesis occurred (Fig. 7). The tornado moved from a bearing of 188°, which was substantially more to the left than the majority of tornadoes during the outbreak, which had storm motions generally ranging from 210°-250° (Fig.1). The motion of the tornado appeared to more closely match the motion of the band of enhanced reflectivity as opposed to the motion of the supercell. Also notable was that the circulation was not particularly intense with the Welti-Berlin tornado, with a peak rotational velocity (V_{ROT}) of 18.4 m s^{-1}, despite producing multiple instances of EF3 damage at the surface (Fig. 8).

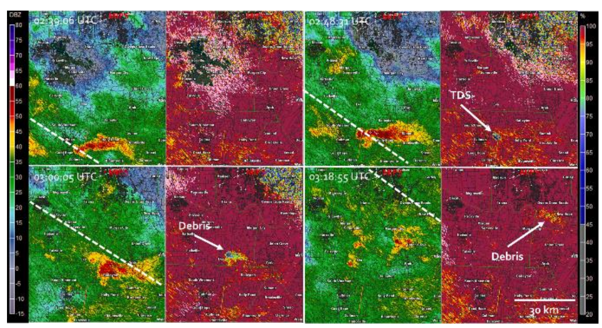

Figure 7: KHTX two-panel 0.5° PPIs of Z_e (left) and ρ_{hv} (right) at 02:39:06 UTC, 02:48:31 UTC, 03:00:05 UTC, and 03:18:55 UTC 29 April 2014. The white dashed line overlaying Z_e indicates the probable wave passage. The red dot and label indicates the position of the University of Alabama in Huntsville's (UAH's) Mobile Integrated Profiling System (MIPS).

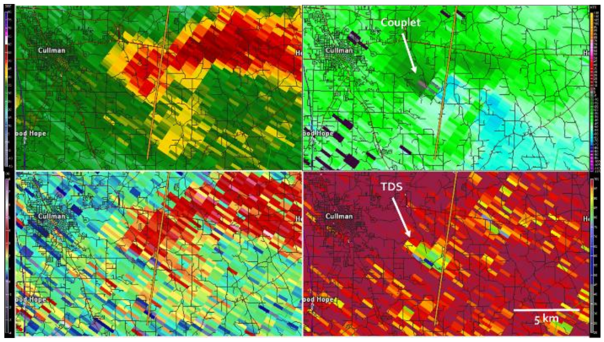

Figure 8: KHTX four-panel 0.5° PPI of Z_e (upper-left), V_r (upper-right), Z_{DR} (lower-left), and ρ_{hv} (lower-right) at 02:43:49 UTC 29 April 2014. The Welti-Berlin tornado was producing EF3 damage around this time.

After passing through the Welti-Berlin supercell, the enhanced reflectivity band moved into the Huntsville area and passed over the MIPS platform at UAH. The reflectivity from the XPR shows an enhanced band of reflectivity above the bright band with this feature's passage. In vertical particle velocity (W), a couplet of upward and downward vertical motion was observed at 4-7 km AGL, indicative of a wave passage (Fig. 9). Though this wave does not appear to be one of the typical low-level ducted gravity waves as in Coleman and Knupp (2008), it appears to have played a significant role in the evolution of the Welti-Berlin EF3 tornado.

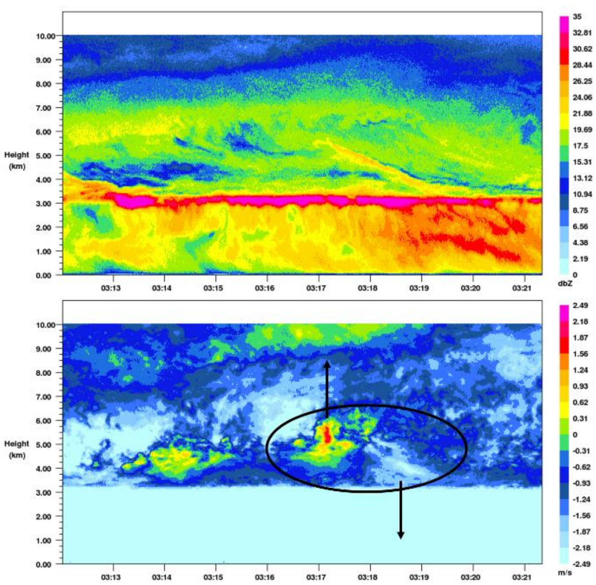

Figure 9: MIPS X-band Doppler profiling radar (XPR) profiles of Z_e (top) and vertical particle velocity (W, middle) from 03:12:00 UTC to 03:21:19 UTC 29 April 2014, showing the passage of the mid-tropospheric wave feature.

6. DISCUSSION

The 28-29 April 2014 tornado outbreak in the Tennessee Valley region of northern Alabama provided a wealth of data for further UAH SWIRLL research objectives. A successive active tornado intercept was accomplished at Russellville, numerous tornadoes appeared to be influenced by terrain in DeKalb County, and a wave interaction with a tornadic supercell in Cullman County. The possible terrain interactions have been incorporated into a larger-scale project to document patterns in the behavior of tornadoes in the presence of significant terrain features. In addition to furthering that work, the 28-29 April 2014 outbreak will be used as a background for utilizing mobile radars in active interception of tornadoes in the Tennessee Valley. Finally, the effects of the mid-tropospheric wave on the evolution of the Welti-Berlin EF3 tornado will be further examined, as well as other potential cases of such wave interactions with supercells and QLCSs.

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