3.5 An Overview of the 28 April 2014 Tornado Outbreak in the Tennessee Valley

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1. Introduction

Although 2014 is generally considered to be an overall below-normal severe weather year, late April 2014 was marked by a typically-active period across the southeastern United States, including a record rainfall event along the Gulf Coast on 29 April, and a regional tornado outbreak on 28-29 April. That tornado outbreak affected primarily Mississippi (including an EF-4 tornado which struck the town of Louisville, MS) and Alabama, but also impacted Tennessee and western Georgia (Figure 1).

The National Weather Service weather forecast office (WFO) in Huntsville, Alabama covers 11 counties in northern Alabama and three counties in southern Tennessee. Within this 14-county region, the outbreak produced 13 tornadoes, including four EF-3 tornadoes, three EF-2s, five EF-1s, and a single EF-0 (Table 1, Figure 2). Of these 13 tornadoes, seven affected DeKalb County Alabama, in the extreme northeastern portion of the state along the Georgia border.

There is little doubt that this event would have been impressive in its own right. The number of tornadoes was large, and a large number of the tornadoes were classified as significant (EF-2 or higher) or strong (EF-3 or higher). However, the event also featured several supercells with deviant storm motions yet still produced tornadoes, some of which were strong; one of the supercells even occurred deep within a stratiform area, giving the public a false sense of security.

Perhaps the most remarkable aspect of the event, from a local perspective, was the date. The event fell one day after the third anniversary of the 27 April 2011 tornado outbreak (hereafter "27 April"). That event was incredible in its intensity, scope, and impact. Impacts from the 27 April event are still felt to this day across much of the southeastern U.S., and it undoubtedly affected public reactions to the 28-29 April 2014 event forecast.

2. Synoptic and Mesoscale Environment

The synoptic pattern at 0000 UTC on 29 April (during the heart of the event) was marked by a closed low pressure area centered over southeastern Nebraska at 500 hPa (Figure 3), resulting in a negatively-tilted trough across the Mississippi and Tennessee valleys. East of the low, modest ridging created diffluent flow from the Tennessee Valley into the eastern Great Lakes.

The surface map from 0000 UTC 29 April (Figure 4) indicated a cyclone directly under its 500 hPa counterpart with an occluded front extending eastward across Iowa into central Illinois. The primary cold front extended southward along the Mississippi River into Louisiana, then westward into south Texas. With the warm front stretched across the Ohio Valley and Carolinas, the Tennessee Valley region was in the warm sector, with 65°F dew points extending all the way to the Kentucky-Tennessee state line and southern North Carolina. There are two smaller features of note on the surface map: a subtle convergent zone (likely a pre-frontal trough) extending from central Illinois southward to the Mississippi-Alabama state line, and a subtle thermal boundary oriented east-to-west across southern Tennessee. North of this boundary, temperatures were consistently in the middle to upper 60s, while south of the boundary, temperatures were consistently in the middle 70s to near 80.

However, leading up to the event (in fact, as the first tornado was occurring), the 21 UTC sounding launched by the atmospheric science department at the University of Alabama in Huntsville (Figure 5) on the UAH campus was not indicative of an overly-favorable environment for significant tornadoes. While the instability parameters from the unmodified sounding were favorable for convection (surface-based CAPE 916 J kg^{-1} and CIN -12 J kg^{-1}), the shear was less impressive; 0-1 km storm-relative helicity (SRH) was just 88 $m^2\ s^{-2}$, 0-3 km SRH just 213 $m^2\ s^{-2}$, and 0-6 km shear just 19.5 m s^{-1} (38 kt). The 0-3 km SRH value is near the median of the significant tornadoes climatology in Thompson et al. (2003; hereafter T03). However, both the 0-1 km SRH and 0-6 km bulk shear were in the 10^{th} to 25^{th} percentile for weak tornadoes in T03 and in the same percentile range for southeastern spring events from Grams et al. (2012; hereafter G12). Furthermore, the lifted condensation level (LCL) of 1164 m was in the 75^{th} to 90^{th} percentile for significant tornadoes in both T03 and G12. The 0000 UTC unmodified sounding from Nashville, Tennessee (not shown) tells a different story, with more unstable conditions (mixed-layer CAPE of 1208 J kg^{-1} and mixed-layer CIN of -14 J kg^{-1}) and much greater shear (0-1 km SRH 391 m^2 s^{-2}, 0-3 km SRH 408 m^2 s^{-2}, and 0-6 km shear 32.4 m s^{-1}). While the Nashville MLCAPE is low for significant tornadoes in T03, the shear parameters are much higher (0-1 km and 0-3 km SRH both above 90^{th} percentile; 0-6 km shear 75^{th}-90^{th} percentile). The mixed-layer LCL height of 759 m was also more favorable (below 10^{th} percentile) in T03, or near the southeastern spring events median in G12.

Mesoanalysis graphics furnished by the Storm Prediction Center illustrate the disparity between the two soundings. The 0000 UTC mixed-layer CAPE analysis (Figure 6) indicates that instability reached a relative maximum compared to earlier hours, ahead of the prefrontal trough. The 0-3 km SRH (Figure 7) also reached a relative maximum as 0000 UTC approached, increasing from approximately 250 m^2 s^{-2} at 21 UTC, to over 500 m^2 s^{-2} at 0000 UTC, due partly to backing near-surface winds. SRH in the 0-1 km layer increased accordingly. Not surprisingly, then, the effective significant tornado parameter (Figure 8) reached a maximum at 0000 UTC, reaching a value of nearly 7 along the Alabama-Tennessee border.

3. Unique Meteorological Aspects

a. Tornado Intensity and Frequency

While the sample size is quite small, the distribution of tornado intensity with the 28 April event is skewed higher than climatology. A recent national climatology (1997-2009) indicates that an overwhelming number of tornadoes (90%) are considered "weak", rated EF-0 or EF-1 (Edwards and Brooks 2010). The 28 April event included a higher percentage of stronger tornadoes compared to the national climatology from Edwards and Brooks (2010; Table 2). Less than half (six of 13) of the confirmed tornadoes were weak, with the remaining seven being considered significant (EF-2 or greater).

b. Deviant Storm Motion

There were several tornadoes on 28 April which did not follow the mean southwesterly flow. Three tornadoes are particularly noteworthy: the strongest tornado of the event, an EF-3 affecting Lincoln County, Tennessee, which moved left of the mean flow but still in a southwest-to-northeast direction; an EF-3 affecting Cullman County, Alabama, which moved south-southwest to north-northeast; and an EF-0 affecting extreme southern DeKalb County, Alabama, which moved south-southeast to north-northwest. These tornadoes stand out on a track map (Figure 2) as being particularly unusual. At least two other tornadoes may have also featured deviant motions, including the Franklin County, Alabama EF-1, which moved slightly left of the mean flow, and the Limestone County, Alabama, EF-3, which moved slightly right of the mean flow.

Research on the deviant storm motion is still ongoing. Hodographs from Nashville, Tennessee and Birmingham, Alabama at 0000 UTC on 29 April (Figure 9) were not favorable for splitting supercells, and none were observed in the Huntsville county warning area (CWA) during the outbreak. Kirkpatrick et al. (2007) note that significant differences can occur with modest adjustments in LCL and LFC heights, and such adjustments may have been possible depending on the location of the storm relative to instability and moisture maxima and other precipitation. Regardless of cause, the deviant motion affected warning decision-making in at least one case. During the Franklin County EF-1 noted above, warning meteorologists at NWS Huntsville held off on a tornado warning because the supercell appeared to be a "left-mover", and thus unlikely to produce a tornado. However, velocity data still indicated cyclonic convergence, and eventually produced the brief EF-1 tornado touchdown.

c. Storm Locations

The Lincoln County, Tennessee EF-3 was unusual from another standpoint. The supercell appears to evolve from a constructive cell merger around 0046 UTC, rapidly intensified over the following 15 minutes, and began producing a tornado at 0109 UTC. All of this occurred deep within a stratiform precipitation region with scattered embedded convection out ahead of the supercell (Figure 10). The lull in activity (the previous tornado had lifted about 90 minutes earlier at 2324 UTC), coupled with the light stratiform precipitation, convinced at least one group of sheltering citizens in southern Lincoln County that the event was over for them. Instead, two people were killed when the tornado struck their mobile home since they no longer had safe shelter.

It is difficult to prove conclusively why the Lincoln County tornado was so strong in such an unusual location. One possible explanation is the presence of an east-west-oriented mesoscale boundary, perhaps the quasi-frontal structure noted with the 0000 UTC surface analysis in section 2, although the thermal and wind changes would have been very subtle within the stratiform rain shield. Given the relatively short duration of the most intense damage, it is possible that the tornado crossed the boundary at a large angle as in Langmaid and Riordan (1998). Another explanation could stem from the constructive cell merger, though additional intense research on the updraft and rotational characteristics would be necessary to validate this possibility.

4. Relationship to 27 April 2011 Event

The most interesting aspect of this event stems from its date: the event occurred three years and one day after the 27 April 2011 tornado event. Within the Huntsville CWA alone, the 2011 event featured 39 tornadoes in 17 hours (Figure 11), seven of which were violent. These tornadoes killed 101 people, and knocked out power to hundreds of thousands of people when tornadoes destroyed electrical transmission towers (NOAA 2011). As a result, many more people across the region may have felt impacted by the tornadoes, even if they were not directly affected.

Like 27 April, the 28 April event was well-forecast, with the potential for severe thunderstorms mentioned in the WFO Huntsville hazardous weather outlook five days in advance, and briefings of emergency managers, government officials, and other decision-makers began four days in advance. Unlike 27 April, there was a larger need for impact-based decision support services from the NWS. There were several anniversary events and memorials from 27 April, and multiple other outdoor events that were scheduled for the weekend of 26-27 April 2014. Indeed, for two days leading up to the 28 April event, WFO Huntsville maintained extra staffing for ongoing public safety purposes as well as planning ahead for the tornado event expected the following Monday. Fortunately, the 28 April event was much less serious than the 27 April event. As previously noted, 13 tornadoes occurred in 10 hours, and though four were strong, none were violent; furthermore, only four fatalities occurred within the Huntsville CWA. However, the similarity of the two dates prompted a strong reaction from many.

a. Public Response

Phone calls to WFO Huntsville were plentiful in the days leading up to the 28 April event. Nearly everyone asked the same question: “Is it going to be as bad as April 27?” While this same question has been asked leading up to many of the severe weather events that occurred in the three years between 27 April and 28 April, the date seemed to encourage a newfound sense of urgency. Questions asked by most callers reflected fear, and a need to compare this forecast to what had been predicted three years prior (and what the caller had experienced from that event). Many of the callers displayed an availability bias, worried that a late-April event naturally had to be just as serious as the biggest or most recent event in that time period (in this case, 27 April). Many in the meteorological community, including television stations and other NWS offices, replied to this common question with a similar response: “If it hits your house, it will be just as bad, if not worse.” However, callers seemed to be less tolerant of such an uncertain or indirect answer, often pressing for a more definitive response.

b. Customer and Partner Responses

Local television meteorologists were, as usual, the most visible face of the event, and found themselves in a difficult situation. The chief meteorologist at the Huntsville CBS affiliate said, “April 28th required a lot of ‘handle with care’ language. We knew there would be strong tornadoes, but they wouldn’t be as numerous as April 27th. There’s not really a good way to communicate that” (J. Simpson 2014, personal communication).

Local government officials’ responses were mixed. While emergency managers consistently felt that their planning was unaffected by the date or the effects of the event three years earlier, one comment in the heat of the moment stands out. “We *can’t* get tornadoes on April 28,” one official told an NWS meteorologist four days before the event occurred. Additional comments suggested that the official was indeed aware that tornadoes could form on any date, but there was great concern that fear and panic stemming from the previous event would override proper preparation and response. “You can’t be scaring people on this day,” the official said later.

The longer-term effects remain uncertain, though the chief meteorologist at the NBC affiliate aid, “I don’t think the public response after the tornadoes was as robust because it wasn’t as bad as the one in 2011. This does concern me for future outbreaks” (B. Travis 2015, personal communication).

5. Summary and Future Work

The 28 April 2014 tornado outbreak was a significant tornado outbreak that affected mainly portions of Mississippi, Alabama, and southern Tennessee. Thirteen tornadoes affected the counties served by NWS Huntsville, Alabama, seven of which were considered significant (EF-2 or greater). While the event is remarkable primarily for its date (three years and one day after the 27 April 2011 “Super Outbreak”), it featured a number of intriguing meteorological aspects: a larger number of significant tornadoes, several storms which featured deviant storm motion yet still produced tornadoes (some of which were strong), and at least one storm which occurred deep within a stratiform precipitation region yet still produced the strongest tornado of the event (for the Huntsville CWA). Furthermore, the date of the event affected public and local government perception of the event, with many responding strongly as if the similarity in dates would affect the outbreak’s intensity.

There is a clear need for additional research into this event. In particular, a more detailed mesoscale analysis is warranted, to examine the possible causes of the deviant storm motion, as well as the unusual storm location. The public and customer response is also worth exploring in greater detail, since three outbreaks have occurred in this time period since 2010 (24 April 2010, as well as 27 April 2011 and 28 April 2014), and additional outbreaks are likely to occur during the same general timeframe in the future.

References

Edwards, R., and H.E. Brooks, 2010: Possible Impacts of the Enhanced Fujita Scale on United States Tornado Data. Preprints, *25th Conf. Severe Local Storms*, Denver, CO, Amer. Meteor. Soc., P8.28.

Grams, J.S., R.L. Thompson, D.V. Snively, J.A. Prentice, G.M. Hodges, and L.J. Reames, 2012: A Climatology and Comparison of Parameters for Significant Tornado Events in the United States. *Wea. Forecasting*, **27**, 106-123.

Kirkpatrick, J.C., E.W. McCaul, and C. Cohen, 2007: The Motion of Simulated Convective Storms as Function of Basic Environmental Parameters. *Mon. Wea. Rev.*, **135**, 3033-3051.

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NOAA, 2011: Service assessment: The historic tornadoes of April 2011. U.S. Department of Commerce/NOAA/NWS Rep., 76 pp. [Available online at www.nws.noaa.gov/os/assessments/pdfs/historic_tornadoes.pdf.]

Figures and Tables

Start Time	**End Time**	**Rating**	**Peak Wind**	**Path Length**	**Counties Affected**	**Areas/Cities Affected**
2056 UTC 3:56 PM CDT	2102 UTC 4:02 PM CDT	EF-1	110 MPH	5.13 km (3.19 mi)	Franklin, AL	Russellville
2147 UTC 4:47 PM CDT	2214 UTC 5:14 PM CDT	EF-3	140 MPH	25.04 km (15.56 mi)	Limestone, AL	Bay Hill Marina, Coxey, Athens
2250 UTC	2305 UTC	EF-1	105 MPH	14.34 km	Madison, AL	Hazel Green

5:50 PM CDT	6:05 PM CDT			(8.91 mi)		
2309 UTC 6:09 PM CDT	2324 UTC 6:24 PM CDT	EF-2	115 MPH	15.34 km (9.53 mi)	Lincoln, TN	Flintville
0109 UTC 8:09 PM CDT	0133 UTC 8:33 PM CDT	EF-3	160 MPH	43.07 km (26.76 mi)	Lincoln and Moore, TN	South Lincoln, Champ
0118 UTC 8:18 PM CDT	0129 UTC 8:29 PM CDT	EF-1	100 MPH	9.87 km (6.13 mi)	Jackson and DeKalb, AL	Shiloh, Higdon
0239 UTC 9:39 PM CDT	0258 UTC 9:58 PM CDT	EF-3	145 MPH	14.29 km (8.88 mi)	Cullman, AL	Welti, Berlin
0532 UTC 12:32 AM CDT	0547 UTC 12:47 AM CDT	EF-3	155 MPH	19.15 km (11.9 mi)	DeKalb, AL	Aroney
0554 UTC 12:54 AM CDT	0600 UTC 1:00 AM CDT	EF-2	115 MPH	3.98 km (2.47 mi)	DeKalb, AL	Dawson
0606 UTC 1:06 AM CDT	0627 UTC 1:27 AM CDT	EF-2	115 MPH	18.85 km (11.71 mi)	DeKalb, AL	Fort Payne/Pine Ridge
0628 UTC 1:28 AM CDT	0632 UTC 1:32 AM CDT	EF-0	85 MPH	3.88 km (2.41 mi)	DeKalb, AL	Aroney
0636 UTC 1:36 AM CDT	0651 UTC 1:51 AM CDT	EF-1	105 MPH	16.42 km (10.2 mi)	DeKalb, AL	Mentone
0723 UTC 2:23 AM CDT	0725 UTC 2:25 AM CDT	EF-1	100 MPH	1.72 km (1.07 mi)	DeKalb, AL	Pumpkin Center

Table 1: A list of tornadoes affecting the County Warning and Forecast Area of the National Weather Service forecast office in Huntsville, ordered by start time. Counties affected include only NWS Huntsville counties.

Rating	National Climatology	28 April 2014
EF-0	12,145 (63.8%)	1 (8%)
EF-1	4,950 (26.0%)	5 (38%)
EF-2	1,440 (7.6%)	3 (23%)
EF-3	419 (2.2%)	4 (31%)
EF-4	85 (0.4%)	0 (0%)
EF-5	7 (0.04%)	0 (0%)

Table 2: Comparison between the national tornado climatology (all tornadoes 1997-2009) from Edwards and Brooks (2010), and the confirmed tornadoes from 28 April 2014.

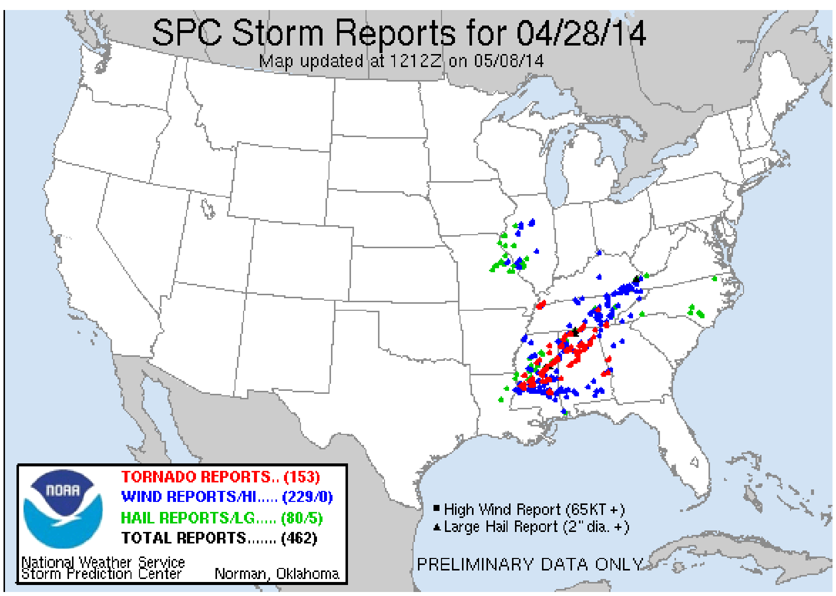

Figure 1: Storm reports from the 28-29 April 2014 tornado event. Red dots mark tornado reports; blue dots mark wind reports; green dots mark hail reports; black circles mark a “high wind” report (65 kt or greater)

and black triangles mark “large hail” reports (2 in. in diameter or greater). Courtesy of the National Weather Service Storm Prediction Center (SPC).

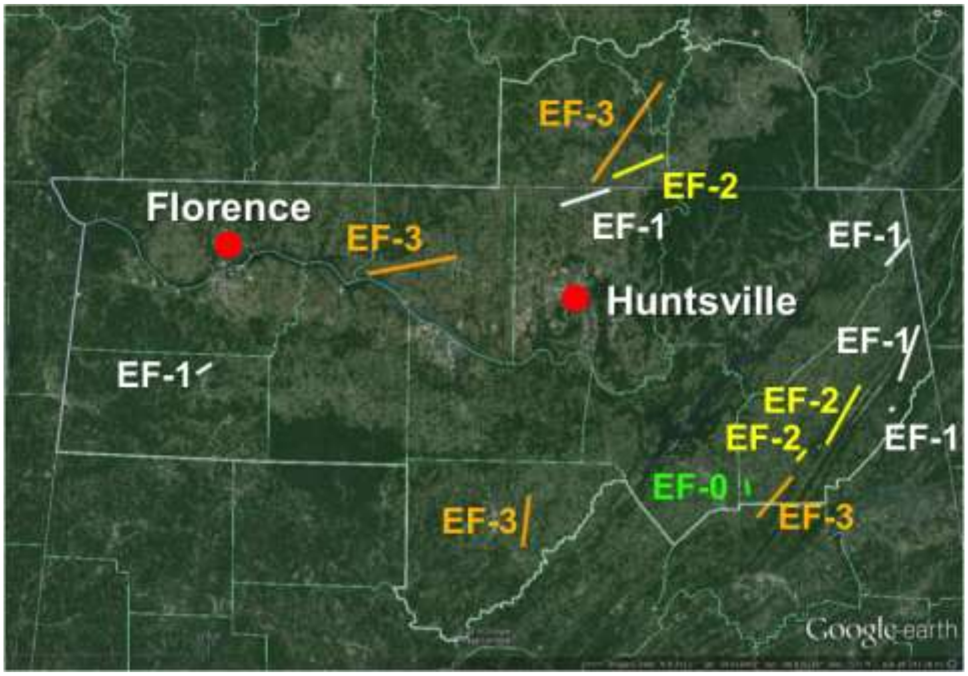

Figure 2: A map of the straight-line tornado tracks impacting the WFO Huntsville CWA on 28-29 April 2014. EF-0 tracks are colored green; EF-1s white; EF-2s yellow; and EF-3s orange. The Huntsville CWA is outlined in a light gray. Background imagery courtesy Google Earth.

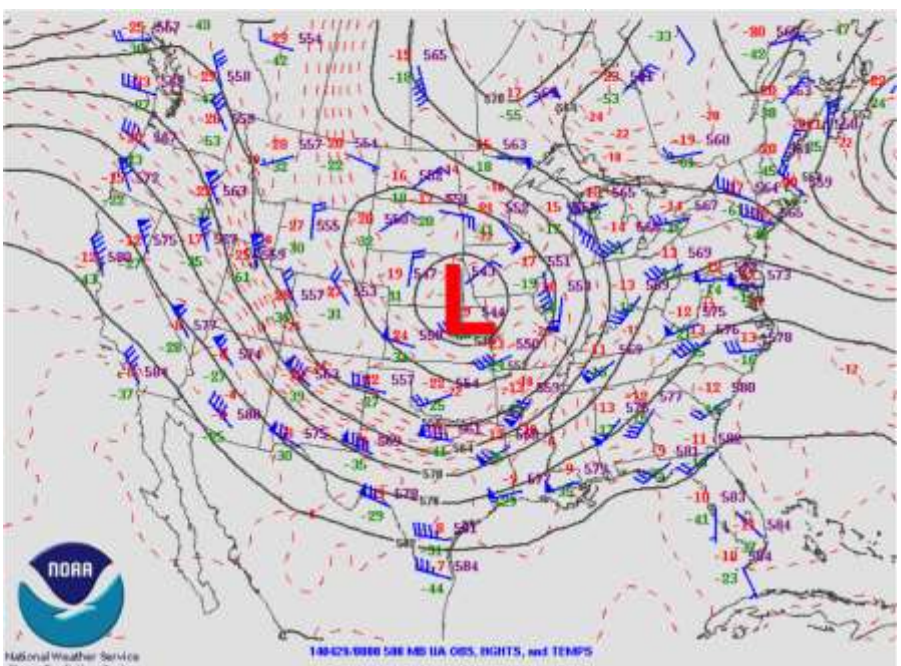

Figure 3: 500 millibar analysis, valid 0000 UTC on 29 April 2014 (during the heart of the outbreak). Background analysis courtesy SPC.

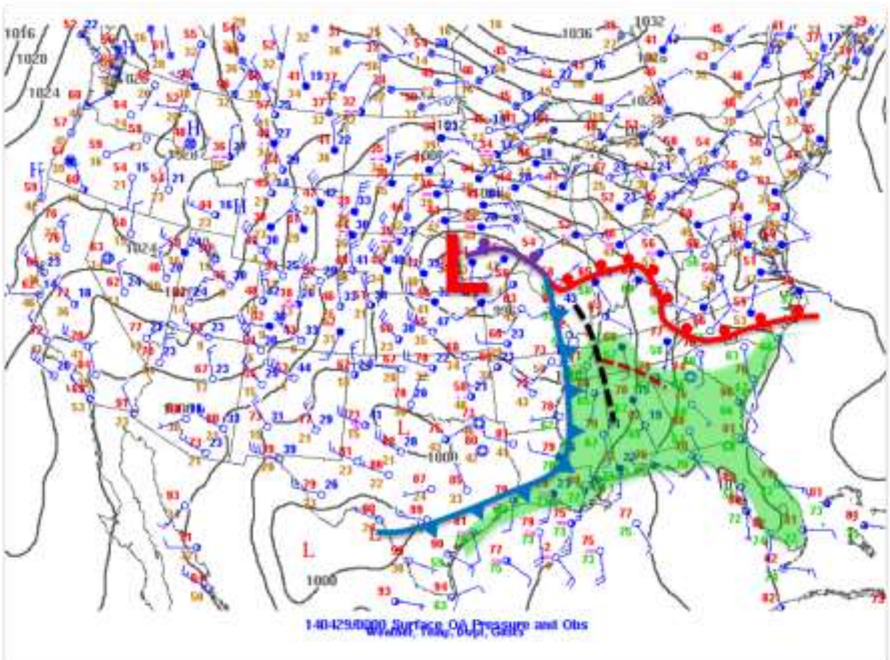

Figure 4: Surface analysis, valid 0000 UTC 29 April 2014. Green-shaded areas indicate surface dewpoints of 65°F or greater. Background analysis courtesy SPC.

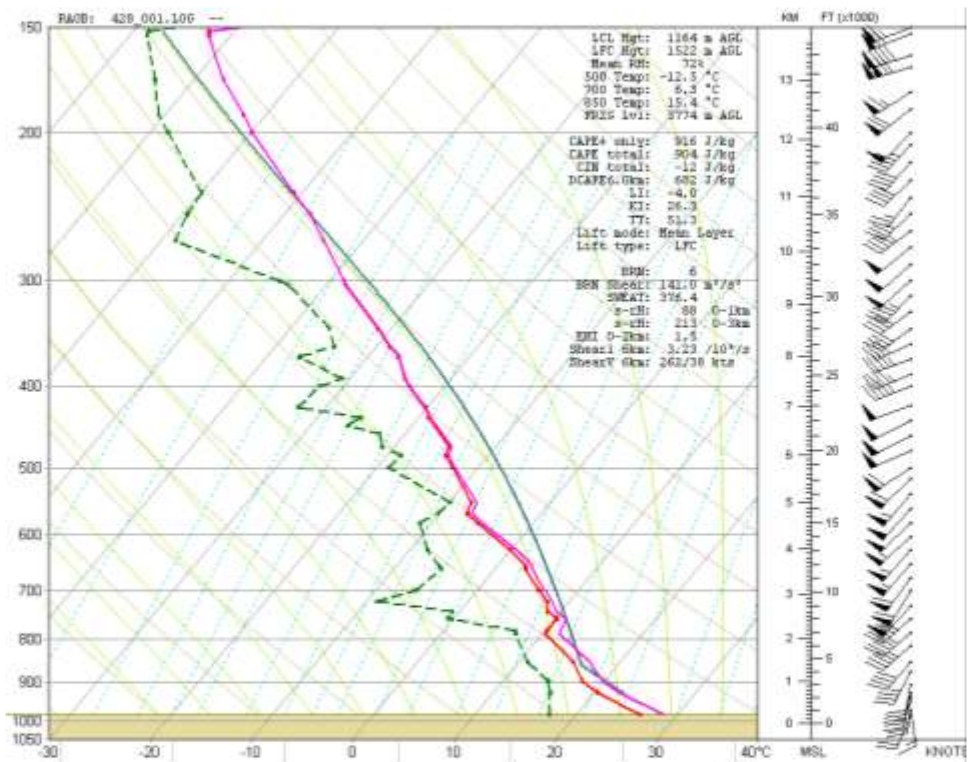

Figure 5: Sounding from the University of Alabama in Huntsville Department of Atmospheric Science, valid 2100 UTC 28 April.

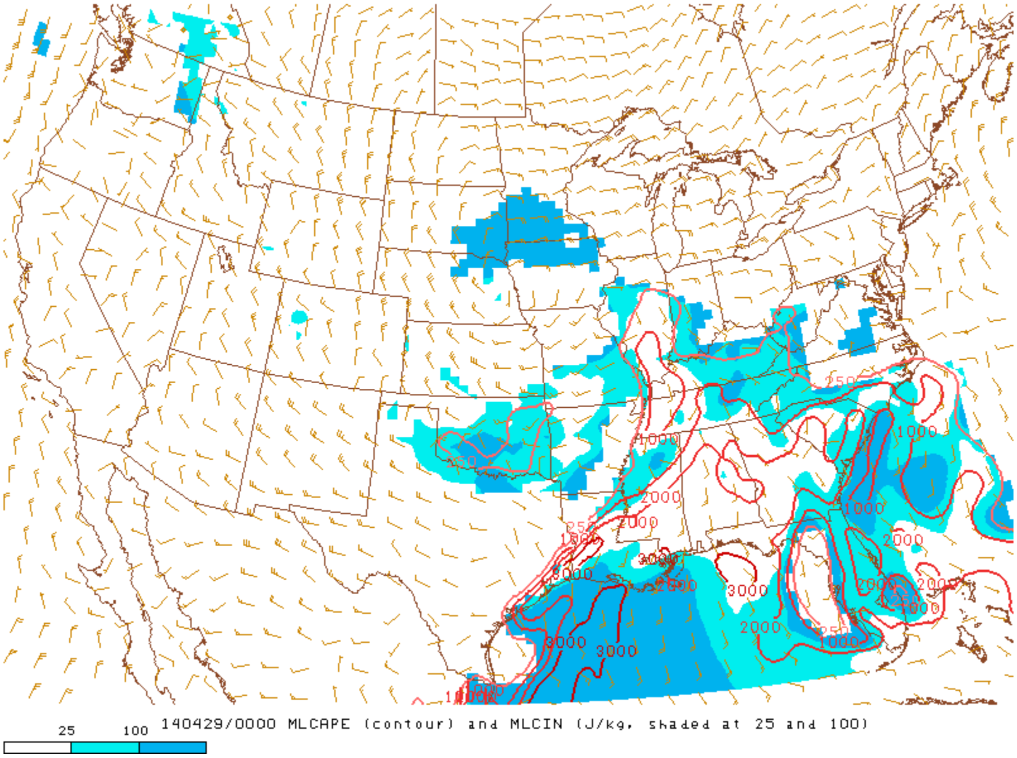

Figure 6: Mixed-layer CAPE (contoured) and mixed-layer CIN (shaded) from the SPC Mesoanalysis Archive, valid 0000 UTC 29 April.

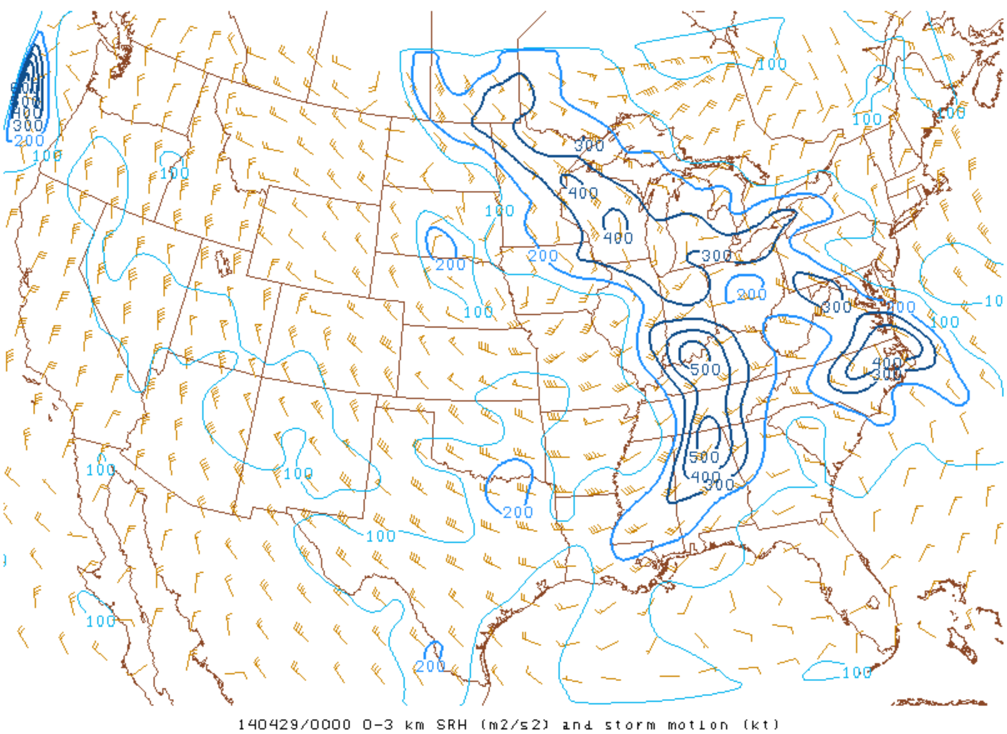

Figure 7: As in Fig. 6, except contours reflect the 0-3 km Storm-Relative Helicity (SRH), and wind barbs reflect the storm motion used to calculate SRH.

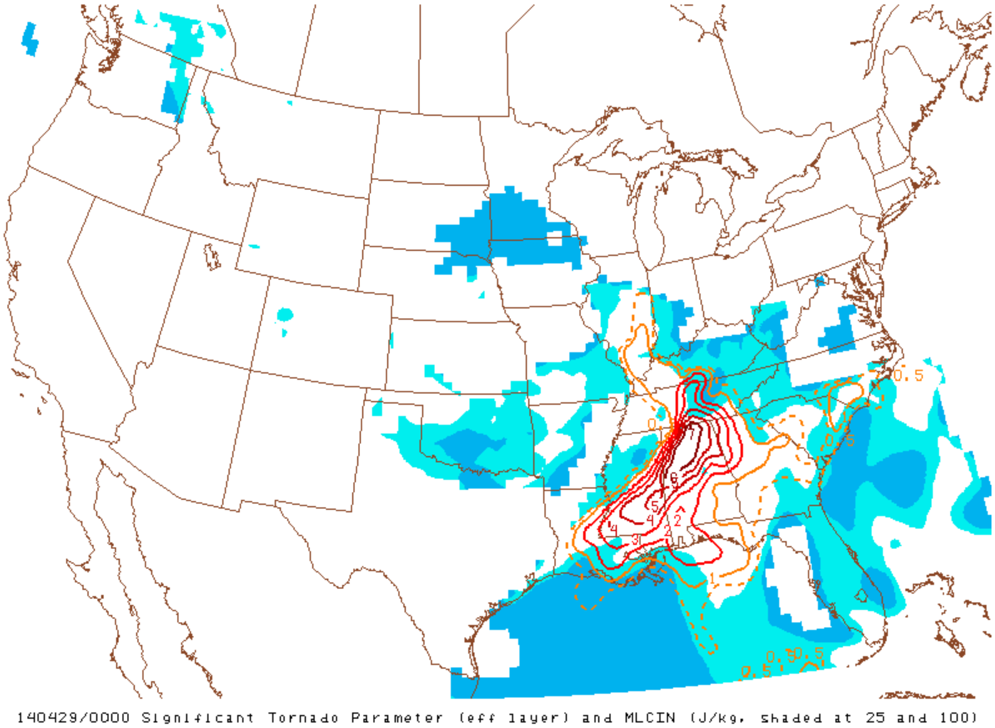

Figure 8: As in Fig. 6, except contours reflect the effective-layer significant tornado parameter, and shading reflects the mixed-layer CIN.

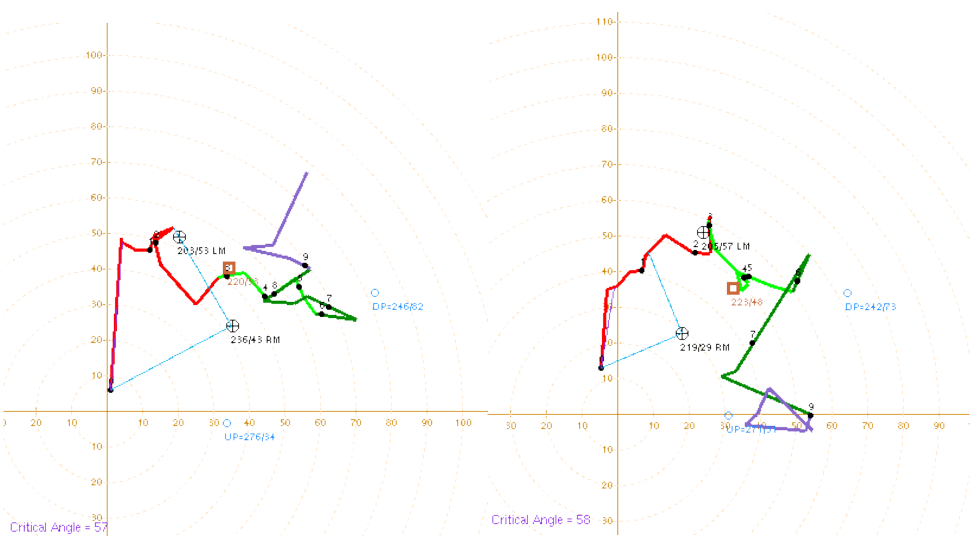

Figure 9: 00 UTC 29 April 2014 sounding hodographs from Nashville, Tennessee (left) and Birmingham, Alabama (right). Sounding data courtesy SPC.

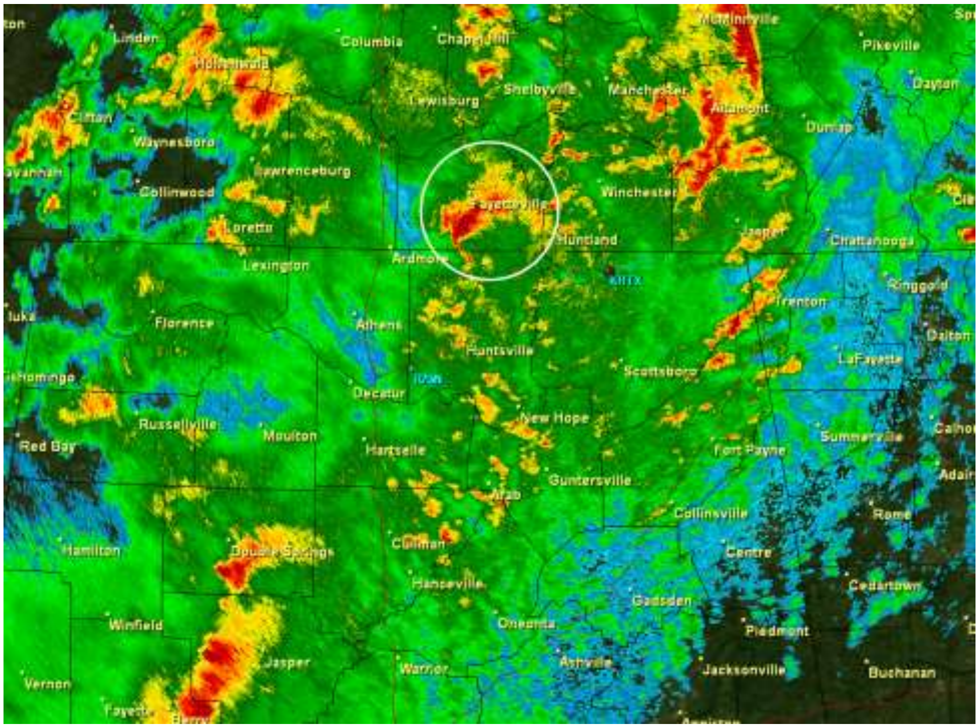

Figure 10: KHTX WSR-88D reflectivity, valid 0109 UTC 29 April. The supercell producing the Lincoln County EF-3 tornado is circled in white.

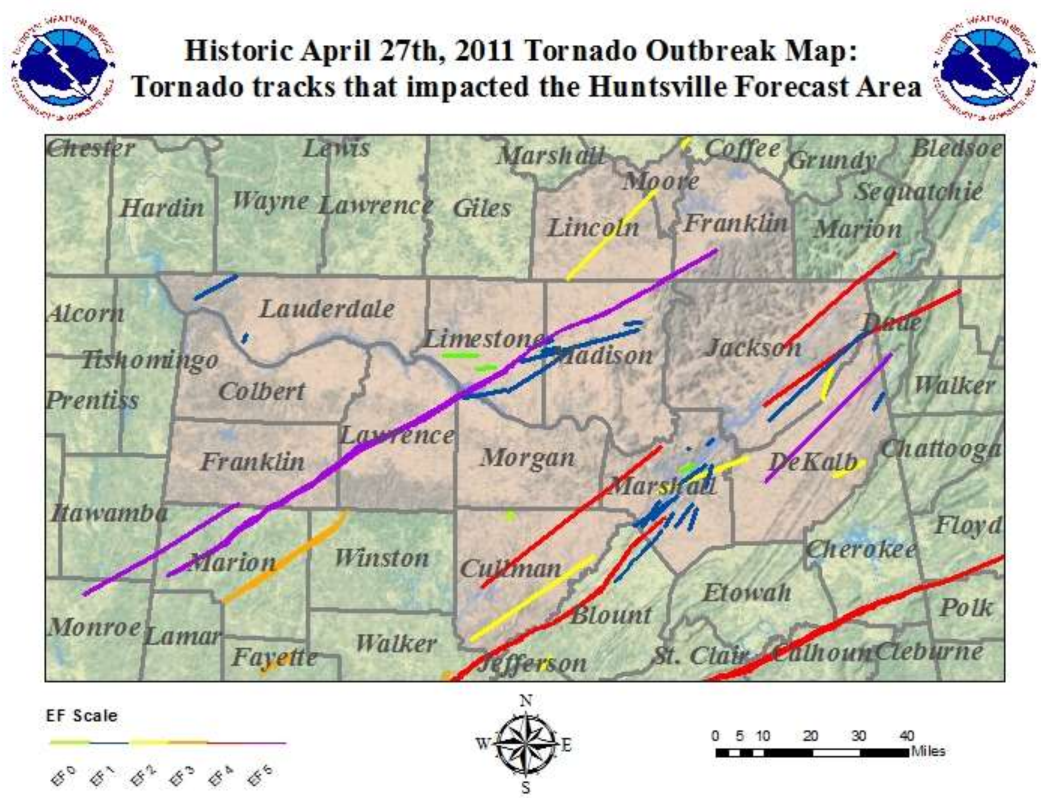

Figure 11: A map of the tornado tracks impacting the WFO Huntsville CWA on 27 April 2011. EF-0 tracks are colored green; EF-1s blue; EF-2s yellow; EF-3s orange; EF-4s red; and EF-5s purple. The Huntsville CWA is shaded pink.