A Review of the 03-04 April 2007 Severe Weather Event

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I. Introduction

On the 33rd anniversary of the 3-4 April 1974 "Super Outbreak" and 30th anniversary of another tornado outbreak and plane crash on 4 April 1977, the Huntsville (HUN) County Warning Area (CWA) experienced yet another severe weather event. This event was less damaging than the others, with most of the severe activity occurring in the form of large hail, wind damage (downed trees), and two relatively weak tornadoes. The most significant severe weather occurred near the Macedonia community in extreme southern Jackson County, where an EF-1 tornado touched down at approximately 11:34 pm CDT. The other tornado that occurred in the Huntsville CWA touched down in extreme southern Lincoln County near the Alabama state line and moved into northwest Madison County northeast of Toney, causing EF-0 damage along the way. The same parent storm caused further damage across northern and eastern Madison County, where straight-line winds of 70 to 80 mph created scattered wind damage and snapped telephone poles. Also noteworthy was a large hailstorm that moved across the Huntsville metropolitan area earlier in the day, dropping hailstones to the size of quarters in and around the city.

II. Synoptic Overview & Pre-Event Forecasts

The days and weeks prior to the 3-4 April event were marked by some of the warmest March and April weather on record. A prolonged period of southwesterly flow and amplified mid- and upper-level ridging led to record-breaking heat and worsening drought conditions. A significant change in the weather pattern came in the first few days of April in the form of a deep trough and continental polar air mass plunging southward into the continental United States. By 0000 UTC on 3 April 2007, the trough was deepening over the upper Midwest region, with a surface front draped from the Great Lakes across the Mid-South into the Red River Valley (Figure 1, 0000 UTC surface analysis). Behind the front was a 1052mb surface high centered over central Canada, while strong southwest flow and abundant sunshine were pushing temperatures into the middle and upper 80s ahead of the front.

The HUN CWA was not in a particularly favorable location for jet dynamics; initially the region was under the left entrance of the 70-80kt southern-stream jet streak, but came under the influence of the right exit of the 110kt northern-stream jet streak rounding the base of the upper trough (Figure 2, 0000 UTC 300mb analysis). The more impressive pattern came at 850mb where 12-14ºC dew point temperatures were being advected ahead of the cold front on the nose of a 30kt low-level jet (Figure 3, 0000 UTC 850mb analysis).

Forecasts and outlooks from WFO HUN prior to the event mentioned "stronger thunderstorms" being possible as early as Saturday evening, though there was considerable uncertainty in the days leading up to the event regarding the strength of the wind fields and their effects on the severe weather threat. SPC included only a small portion of northwest Alabama in a slight risk

of severe thunderstorms with their 0800 UTC Day 2 Outlook on Monday, but expanded it with the 1730 UTC outlook to include most of the HUN CWA (Figure 4). Probabilistic outlooks highlighted mainly the mid and upper Mississippi Valley, where a better combination of jet dynamics, wind shear, and instability was expected to occur. The 0600 UTC Day 1 Outlook (Figure 5) continued this theme by including the central Tennessee Valley in a slight risk, with a moderate risk to the northwest; this moderate risk would gradually be expanded southeastward to touch the northwest tip of Alabama.

III. Pre-Squall Line Thunderstorms

Two rounds of showers and storms moved across the Tennessee Valley prior to the primary line of activity which makes up the main focus of this review. The first was during the early afternoon hours, and produced numerous hail reports. Initial thinking was that supercells would develop during the afternoon hours across northwest Alabama, but updrafts were unable to penetrate the inversion present at around 925mb (Figure 6, KBMX 12 UTC sounding). Consequently, isolated convection began east of Interstate 65 around 1800 UTC. The first (and strongest) storm developed initially near Decatur and underwent rapid vertical growth as it moved east-northeast along Interstate 565. A severe thunderstorm warning was issued at 1843 UTC as the storm moved into Madison. Small hail was reported near Greenbrier around 1840 UTC, and then one inch hail was reported at UAH at 1851 UTC. A non-rotating "wall cloud" was observed with this storm between Madison and Huntsville, but no rotation was indicated by the KHTX radar. Additional occurrences of 1/4-inch to 1-inch hail were reported around the Huntsville area as the storm moved through the metro area. The storm remained strong enough to prompt another severe thunderstorm warning at 1912 UTC, and another report of 3/4-inch hail in Brownsboro came in at 1925 UTC. Severe thunderstorm watch #113 was issued at 1915 UTC (Figure 7) for these hail-producing pulse severe thunderstorms. Additional severe thunderstorms occurred in Franklin County, Tennessee and southern DeKalb County (where golf ball-sized hail was produced near Collinsville at 1915 UTC).

The elevated reflectivity cores exceeding 60 dBZ and total lightning flash data from the lightning mapping array (LMA) were the most useful data sets in the warning decision-making for the afternoon storms. Each storm exhibited either an elevated core around 10kft, or a rapid increase in total lightning prior to warning issuance and the hail reports. An interesting observation was that the high reflectivity values caused problems with the velocity dealiasing algorithm, thus causing one or two of the storms to appear to be rotating.

Just after sunset, showers and storms developed along and ahead of what on satellite appeared to be a low-level boundary. Most of this activity was "garden variety," with the exception of the final storm of the series, which moved across northern Limestone and Madison Counties. Just after crossing I-65 in Limestone County, the storm pulsed up, attaining 54 dBZ at 24kft. Being the first storm of the night for the warning forecaster, a conservative move of issuing an SPS was chosen. That storm weakened as it moved into Madison County, but a new cell developed behind it and quickly strengthened to 56.5 dBZ at 22kft near the Limestone/Madison County border. A report of nickel sized hail was received at 0130 UTC in the Toney community. Radar at that time actually shows the storm weaker than it was when crossing the county border ten

minutes earlier and also weaker than 10 minutes later as it approached US 231/431. But no reports were received anywhere else with the storm.

The VIL was higher with the storm *after* the received report, reaching a DVIL of ~76 kg/m^2 at 0137 UTC. Additionally, a spike in intracloud lightning via LMA data did not occur until around 0140 UTC. LMA data indicated nothing around the time of the report.

IV. Tuesday Night QLCS

While WFO HUN had been concerned with the pulse activity well ahead of the front Tuesday afternoon, a lengthy squall line had developed across Illinois and Indiana, prompting SPC to issue multiple severe thunderstorm watches as early as 9:50am. The western portion of the line grew in length across Missouri as discrete cells began merging with the main line, and SPC transitioned to tornado watches for this area as the line entered a region of stronger shear. This quasi-linear convective system (QLCS) moved across western Tennessee and approached northern Alabama by the mid-evening hours. A tornado watch, #117, was issued for middle and east Tennessee, north Alabama and northwest Georgia at 8:05pm (Figure 8).

Tornadoes were not expected to be the primary threat with the evening squall line. A quick glance at the KBMX 0000 UTC sounding (Figure 9) sends mixed messages regarding the tornado threat. Of cause for concern: 0-1km SRH of 152 m^2/s^2, mixed-layer CAPE of 2068 J/Kg, corresponding 0-1km EHI of 1.96 (calculated), as well as mixed-layer CIN of just -7 J/Kg. However, the LFC height of 1138 m (3734 ft) and LCL height of 868 m (2848 ft) were not necessarily favorable for the low-level lift and vorticity stretching needed for tornadogenesis. Despite the issuance of the tornado watch, SPC's watch probabilities table seems to agree with this lower tornado threat, with a 40% or "moderate" probability indicated of two or more tornadoes, and a 20% or "low" threat of one or more strong (EF2-EF5) tornadoes.

The warning decision-making for the evening event was quite challenging. As is often seen in the central Tennessee Valley, the more contiguous and coherent QLCS over the Ohio Valley degenerated into a linear group of discrete cells by the time it arrived in the HUN CWA. Forecasters at WFO HUN have long debated whether issuing a "blanket" severe thunderstorm warning along the leading edge of the line might be more appropriate than trying to interrogate all of the various individual cells. Given the reports upstream, which indicated more of a hail threat, and the organization and orientation of the line, the blanket approach did not appear to be appropriate for this situation. There actually appeared to be very few bowing segments or LEWP signatures in the line; instead, most of the cells displayed pulse characteristics with elevated cores, and several displayed mini-supercellular characteristics. Frequent cell mergers and interactions as well as boundary influences greatly complicated the storm motion and overall WDM. Range folding from nearly all the available radars, including the UAH ARMOR, had a negative influence on WDM for storms with less distinct signatures.

A. Primary Squall Line

Numerous reports of hail and wind damage were received with the primary squall line as it moved across western and middle Tennessee. The two strongest portions of the line upstream were where individual cells merged into the line in McNairy County and Lawrence County, TN. Both locations reported severe weather (1.5" hail near Selmer, and trees down in Lawrence County).

The McNairy County report occurred at 9:15pm, and there was a report of 'trees down in Lawrence County' at approximately 9:45pm. No additional reports were received from the portion of the line which affected the WFO HUN CWA prior to its arrival. Later, between 9:45pm and 10:10pm, there was a sharp weakening of reflectivities along the portion of the line affecting Wayne and Lawrence Counties in Tennessee.

The report from Lawrence County, TN was not received by WFO HUN until an hour later, when it was sent by OHX in a Local Storm Report, and therefore was not available for warning decision making purposes. The first squall-line-related warning in the WFO HUN CWA was issued for Lauderdale County at 9:48pm, primarily based on the storm moving out of McNairy County, which slowed its eastward progress and, as previously mentioned, weakened before reaching Lauderdale County.

A sequence of 4-panel displays from KHTX shows a rapidly-developing reflectivity core aloft that was in advance of the line of storms but was quickly absorbed. The core is first visible at 0301 UTC at 2.4 degrees (Figure 10), and is absorbed by the squall line by 0314 UTC (Figure 11). By the 0318 UTC scan, there are few high-level reflectivity returns remaining; just a 55 dBZ echo at 0.5 degrees – still around 8 kft. The damage reported in "Cloverdale" (actually about halfway between Cloverdale and Florence, near the green "x" in the figures) corresponds to this developing cell merging with the line. Storm-Relative Velocity data from KGWX on the 0307 UTC and 0311 UTC scans also shows velocities greater than 50 kts.

Around the same time, there was a noted "pulse-up" in the portion of the line moving into Lauderdale County, and a 55 dBZ core was noted just east of Green Hill in the 0314 UTC scan from KHTX (Figure 12). Although nothing of note shows up in the velocity data, it is at this point that damage was reported at Green Hill. Based on the velocity data and the time of the received report, it does not appear that this is a continuation of the Lawrence County damage (which was noted "to the state line") but a separate report. There was also a report of one tree down in Limestone County near Elkmont.

It is important to note that numerous cell mergers were ongoing over the portion of the line moving through Franklin, Lincoln, and Moore counties in Tennessee as well; yet no storm reports were received in these areas. Whether the orientation of the squall line – which was west-east oriented in northwest Alabama, but southwest-northeast oriented further east – played any role in this occurrence is unclear.

The high SRM returns and upstream reports prompted the issuance of a SVR for Franklin (AL), Colbert, and Lawrence counties at 10:42pm. Again it appears that a cell merging with the line produced the only severe report in this region, but this time it was a hail report rather than wind. An individual cell developed in rural northeast Franklin County, as seen on the 0339 UTC scan

from KHTX (Figure 13), and merged with the line just north of Moulton (Figure 14; 0401 UTC KHTX). The DVIL on KHTX also spiked to over 50 at this point (Figure 15). A report of penny size hail was received at 11:04pm.

The same phenomenon occurred as an individual cell developed in Winston County and merged with the line over the Bankhead National Forest, very near the RAWS site in Lawrence County. Dime sized hail was reported at 11:30pm, right when the cell merged with the line (Figure 16, 0427 UTC KHTX). Wind was not a factor; the highest wind gust recorded by the RAWS was approximately 22 mph. The same phenomenon occurred once again just after midnight, in southern Cullman County, but no reports were received from this area.

LMA data indicated nothing on any portion of this line throughout the event, until cells developed in Cullman County, however since no reports were received from Cullman County, no conclusions can be drawn on the effectiveness of the LMA data for the primary squall line.

Analysis
"Blanket-warning" this portion of the line was not the way to go for this event, as the only severe reports occurred when individual cells were absorbed into the line. However, some of these individual cells were tough, if not impossible, to recognize in real-time. In the case of the eastern half of the squall line, there was a need to seek out specific features within the line (see below); but in the western half of the line, the line had already weakened enough such that enhancement from entrained cells was the primary factor in creating severe or near-severe conditions.

B. Tornadic Storms (Madison and Jackson Counties): 0340 and 0440 UTC

The eastern portion of the squall line showed mainly strong elevated cores indicative of large hail as it moved into Lincoln and Moore Counties. One cell in particular in southwest Lincoln County displayed the most impressive elevated core of the night for this sector; 60 dBZ was indicated up to 23,600 feet from KHTX, corresponding to a large area of digital VIL greater than 80 kg/m^2 and estimated echo top of 45 to 50 kft, and the LMA indicated more than 100 flashes per minute. (Interestingly, no hail reports were received with this storm until almost half an hour later when it moved into southeastern Lincoln County.) Despite an overall southeasterly storm motion, the elevated core actually moved due *east* across extreme southern Lincoln County, while an appendage or pendant-type feature with tremendous overhang built across the state line into Madison County starting with the 0327 UTC scan (Figures 17, reflectivity, & 18, SRM). While it is difficult to make out, subsequent scans suggest that this pendant feature formed on the leading edge of an outflow boundary.

Similar pendant or hook structures (though not as pronounced) continued in subsequent scans as well but the SRM and velocity data was largely obscured by range folding. By 0335 UTC, a clear but weak and small mesocyclone became apparent in the SRM data, but it corresponded to a weak shower that had developed well ahead of the main storm along the outflow boundary (Figures 19 & 20). The Vr shear tool in AWIPS indicated a maximum of 34 knots of rotation over 1.2 nautical miles, 27 nautical miles from the radar site (classified as a "minimal mesocyclone" using the mesocyclone nomogram). The following scan (0339 UTC) showed a

small hook feature extending from the most intense part of the storm, and what may be construed as a large, broad hook extending further south towards the Gladstone community. However, the mesocyclone detected by KHTX corresponded with the end of the hook in a moderate shower near the Gladstone community, which by this time more clearly coincides with an outflow boundary. This feature and mesocyclone correspond to the EF-0 tornado damage found by WFO HUN storm survey teams.

The Madison County storms weakened as they moved southeast of Hazel Green and Meridianville. However, the 0352 UTC scan (Figures 23a-b) shows an abrupt tightening of the rotation. While the reflectivity data remained unremarkable, it showed another weak hook-type echo corresponding to the rotation. The timing and location of the stronger rotation roughly corresponded to reports of power poles being snapped along Homer Nance Road and an uncorroborated weather station report of a 113 mph wind gust. Beyond this point, the rotation weakened permanently, and the tornado warning was permitted to expire; a severe thunderstorm warning was issued in its place at 10:58pm for eastern Madison and all of Jackson County.

Storms with stronger rotation developed as the line advanced into Jackson County. The range folding cleared itself up as the line passed the KHTX RDA, which greatly aided in the interrogation process. The first area of rotation appeared just south of the KHTX radar near Larkin with the 0401 UTC scan, and was more visible in the base velocity data than the storm-relative motion data. The tightening of this rotation near Skyline with the 0413 UTC scan (Figure 24) prompted the issuance of a tornado warning for "central" Jackson County. Due to the proximity of the storm to the RDA site, the reflectivity data is nearly incomprehensible, though a shape which may be construed as a hook or pendant is somewhat visible southeast of Skyline. (Unfortunately, all other area NWS Doppler radars overshot the storm at 0.5 degrees.) This rotation quickly diminished within two volume scans and quickly became difficult to differentiate from other storms along the leading edge of the squall line.

Another area of rotation developed as a result of a cell merger between Woodville and Lim Rock in southwest Jackson County with the 0413 UTC scan, and quickly strengthened in subsequent volume scans. The lower base velocity scans with the 0422 UTC scan in particular (Figure 25) showed an intensifying mesocyclone particularly at the 1.3 and 1.8 degree angles. The 11:26 pm SVS issued for the warning removed the mention of "central" Jackson County and expanded the warning to mention this storm. Reflectivity structure with the 0426 UTC scan displayed a weak, broad hook echo coincident with the rotation, with the leading edge of the hook forming in the vicinity of another outflow boundary—much like the reflectivity structure displayed with the Madison County storm. Subsequent scans yielded similarly unimpressive reflectivity structures while velocity and SRM data intensified. The 0434 UTC SRM data showed an "unbalanced" couplet (strong inbound velocities vs. weak outbound velocities) just northeast of the Langston community; this trend continued with the next scan (Figure 26) as the rotation passed south of Section. This scan yielded an interesting reflectivity signature that was almost an "inverted" hook or what might be termed a "wrench" structure rather than a traditional supercell signature at that time. The rotation detected with this cell coincided with the EF-1 tornado that struck the Macedonia community.

Analysis

Initial analysis focused on the evolution of an apparent mini-supercell along the state line in Madison and Lincoln Counties, but further examination of the reflectivity and velocity data indicates that boundary interaction had to at least be partially responsible for tornadogenesis near the Toney community. The EF-0 tornado damage coincided with some of the least-impressive reflectivity signatures occurring that evening, and unfortunately much of the coincident velocity data was obscured by range folding. A severe thunderstorm warning for northern Madison County would have been warranted, but even a more extended, thorough review of the radar data has implied that a timely tornado warning would have been difficult if not impossible. The Jackson County storm appears to have had a much better-defined mesocyclone for a longer period of time, but again boundary interaction appears to have been the tipping point for tornadogenesis in Macedonia.

C. Lessons Learned

One of the greatest concerns with warning decision-making with a degenerating squall line is the need to scour reflectivity data for signals that may possibly be construed as a bowing segment or supercell, and this event shows the need to be particularly cognizant of such signals. Fortunately, forecasters at WFO HUN have access to radar data from local television stations which can provide additional insights on difficult storms. While excess time should not be spent examining these data, forecasters should make use of them, particularly in difficult situations and when NWS radar data is undesirable or obscured. Unfortunately, LMA data was not particularly useful for this non-traditional tornado event. A review of the LMA data indicates that it peaked several times, but with other storms along the line or 5 to 10 miles behind the tornadic circulation.

Acknowledgements

Thanks to Chris Darden for his assistance in assembling the WES and ARMOR data for this review and for his recent review and case study of thunderstorm parameters.
Thanks to Patrick Gatlin for his insights on the afternoon hail storms (most of which were used verbatim for this review).

Figures

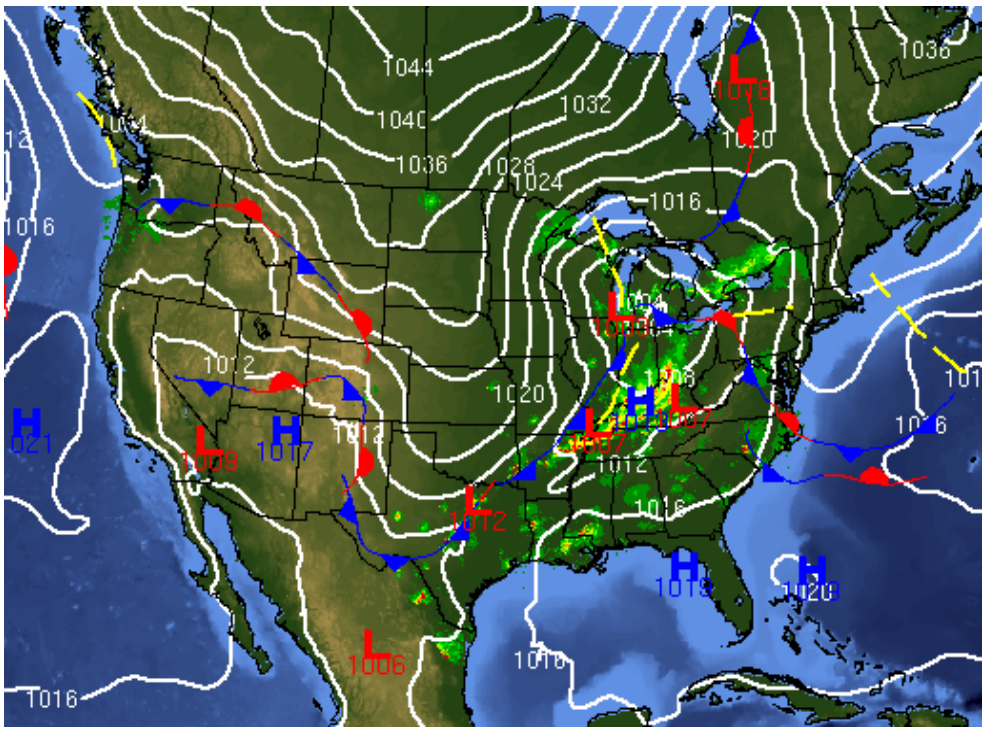

Figure 1: Surface analysis, fronts, and radar composite, valid 00 UTC 4 April 2007 (University of Wyoming).

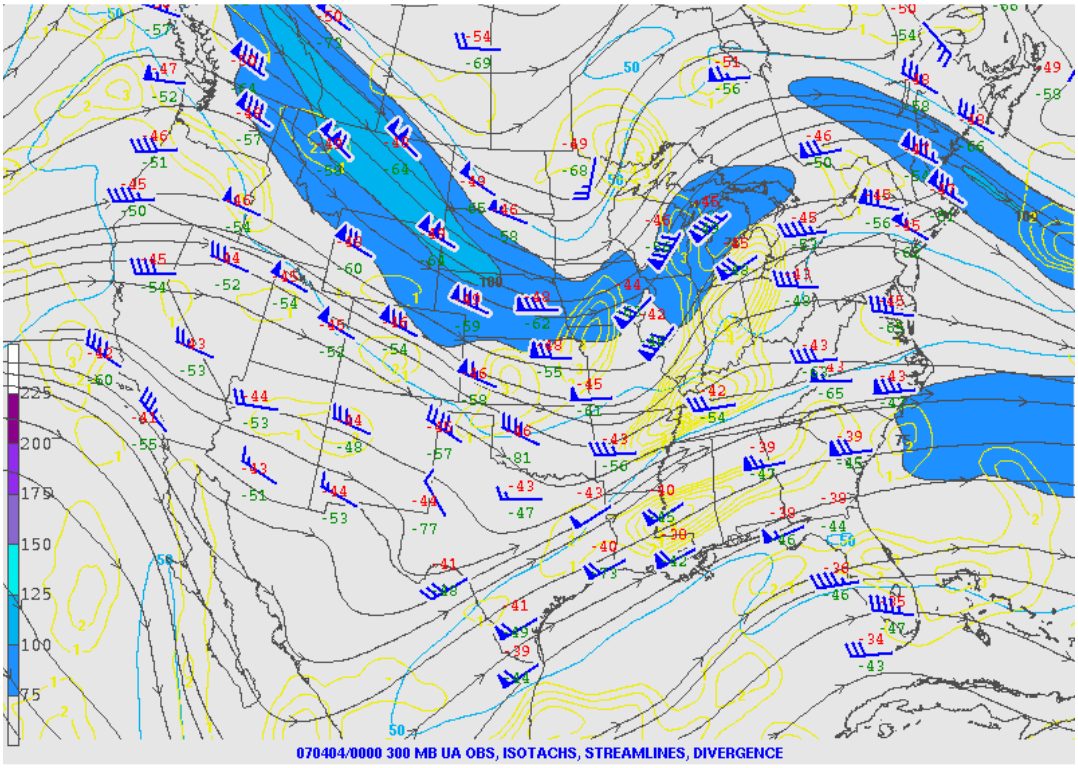

Figure 2: 300mb streamline analysis, with isotachs shaded and divergence contoured in yellow, valid 00 UTC 4 April 2007 (Storm Prediction Center).

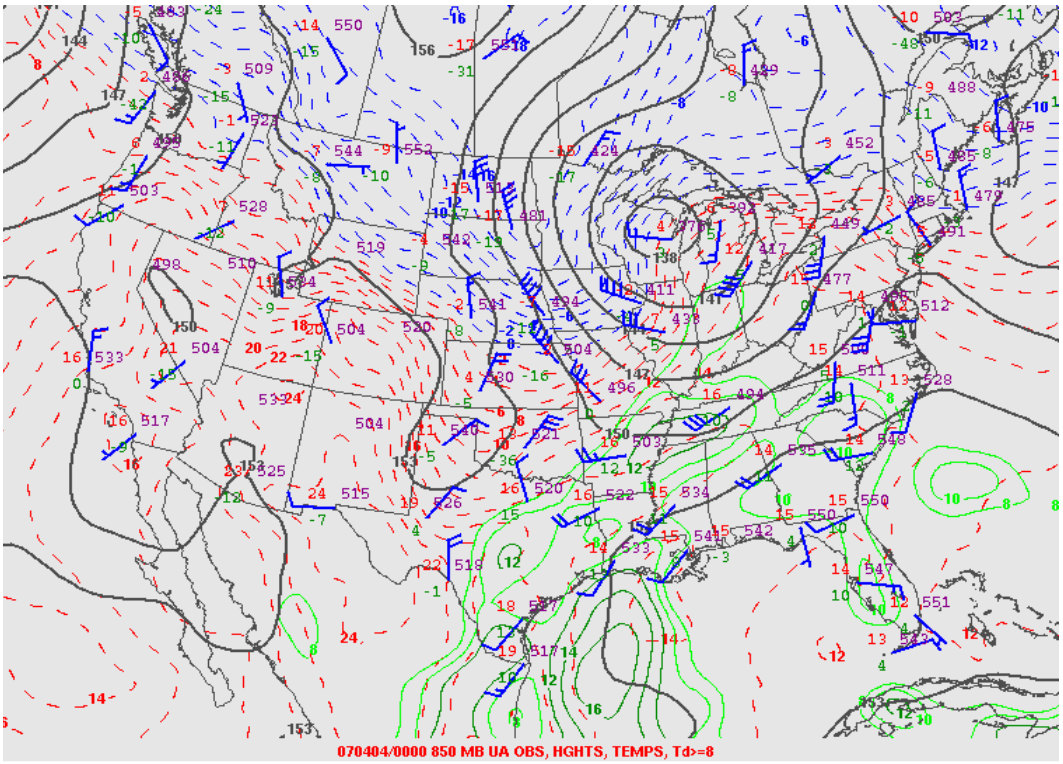

Figure 3: 850mb analysis, with isotherms dashed in red and blue, and isodrosotherms in green, valid 00 UTC 4 April 2007 (SPC).

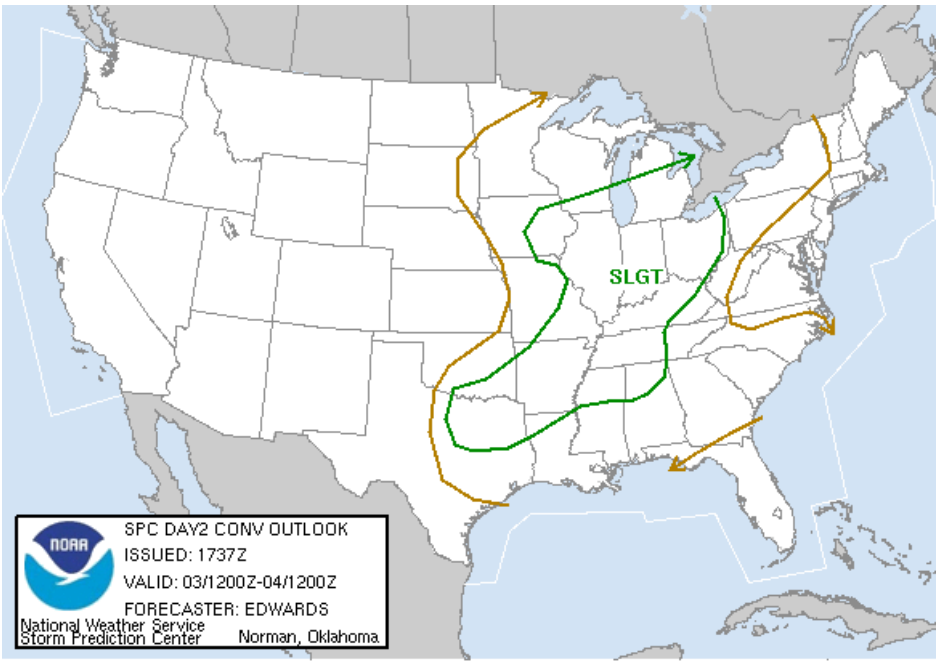

Figure 4: SPC day 2 convective outlook, issued 1737 UTC 2 April 2007.

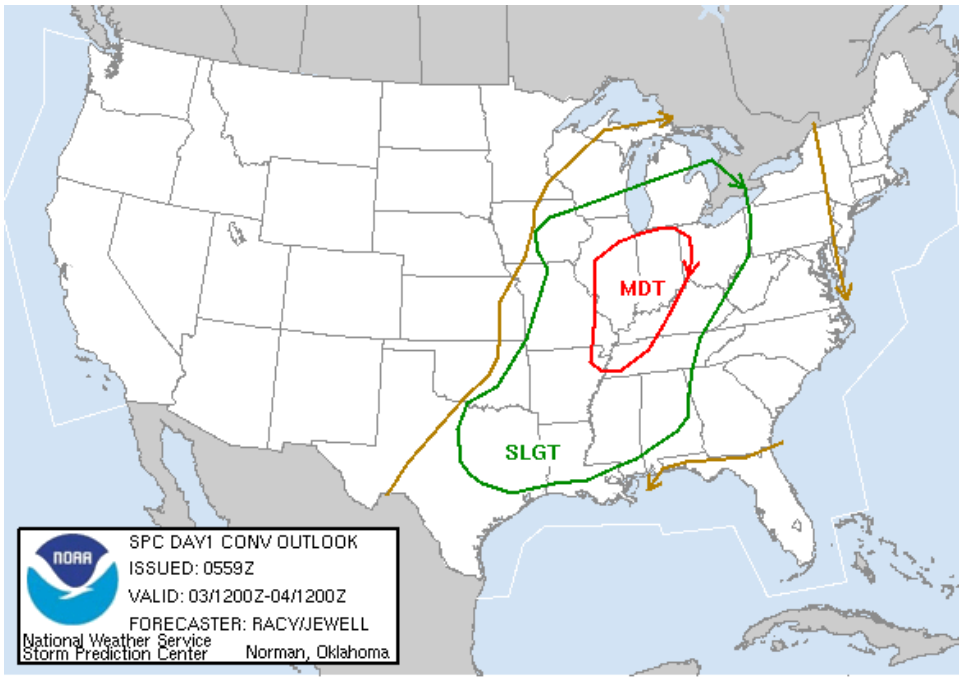

Figure 5: SPC day 1 convective outlook, issued 0559 UTC 3 April 2007.

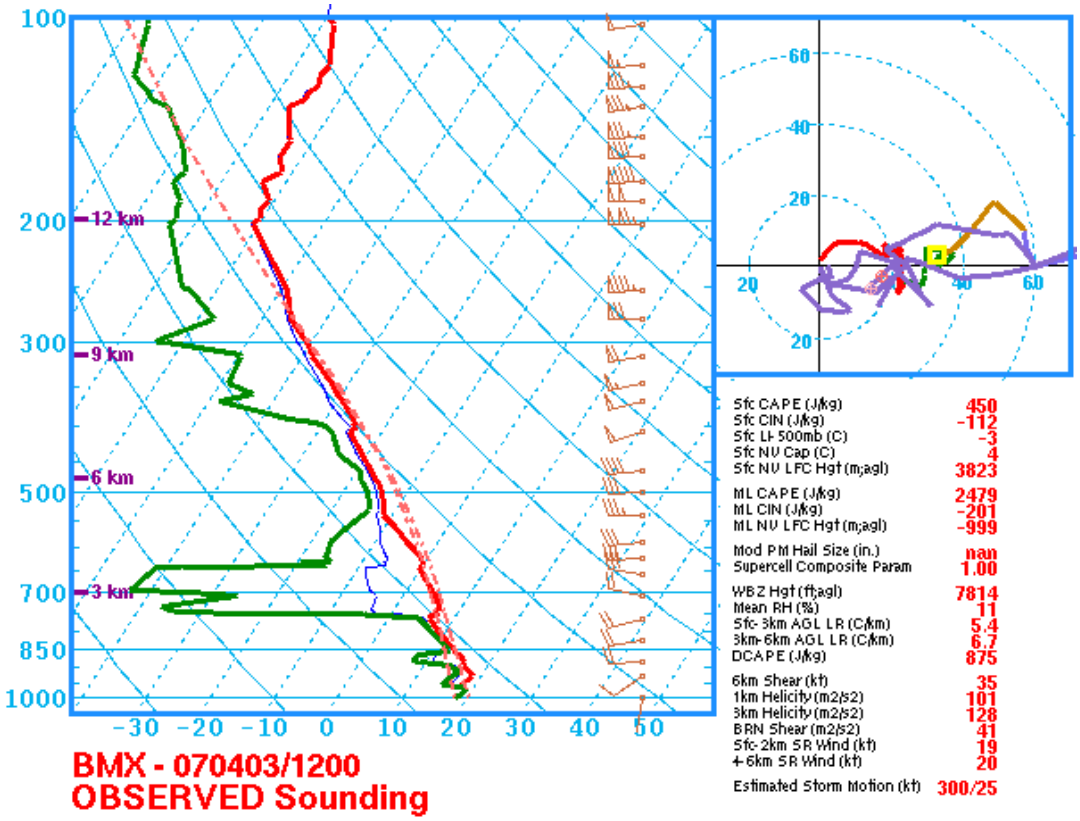

Figure 6: 12 UTC sounding on 3 April 2007 from KBMX (SPC).

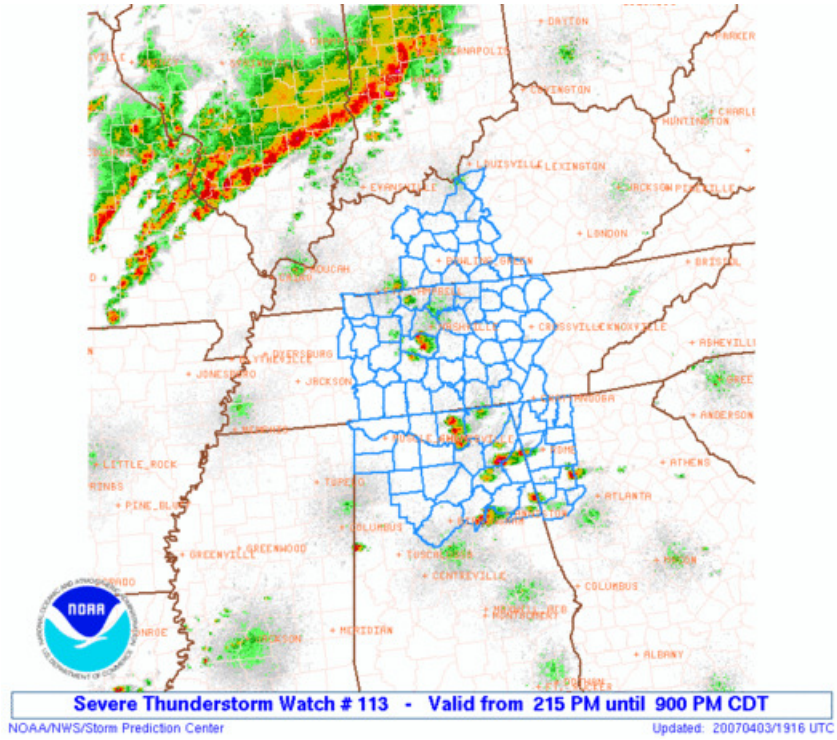

Figure 7: The initial radar image and county outline for severe thunderstorm watch #113 (SPC).

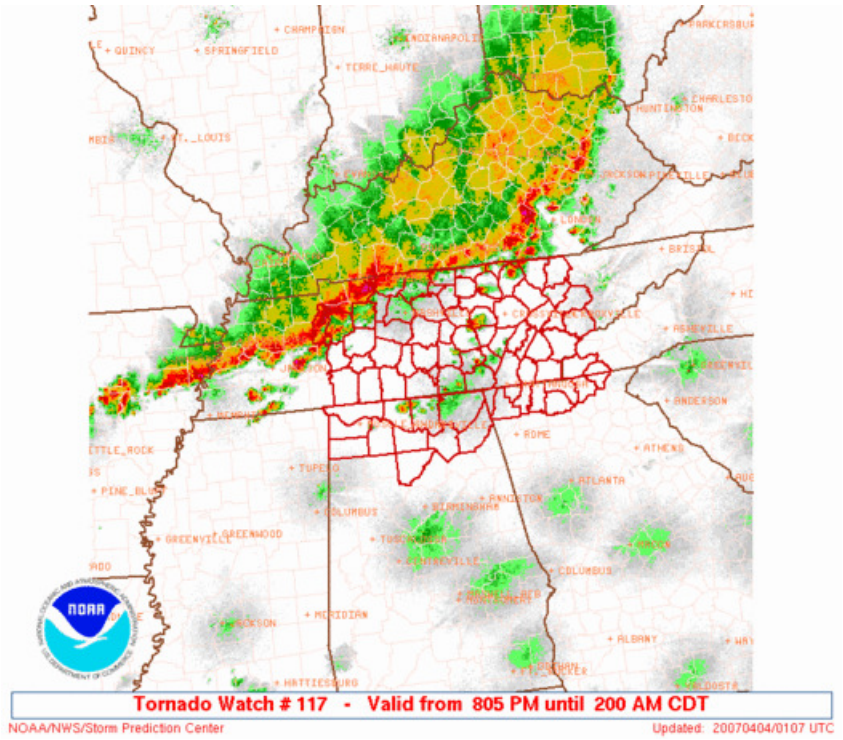

Figure 8: The initial radar image and county outline for tornado watch #117 (SPC).

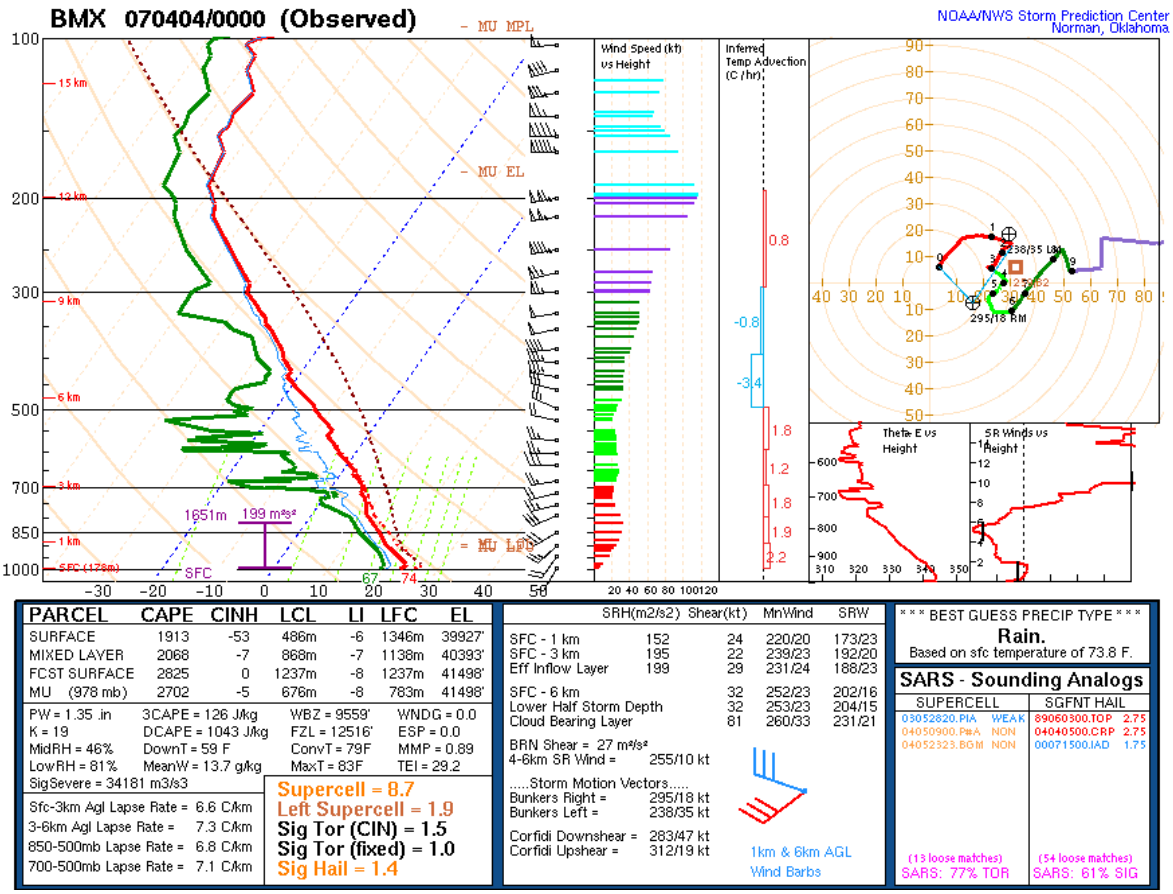

Figure 9: 00 UTC sounding on 4 April 2007 from KBMX (SPC).

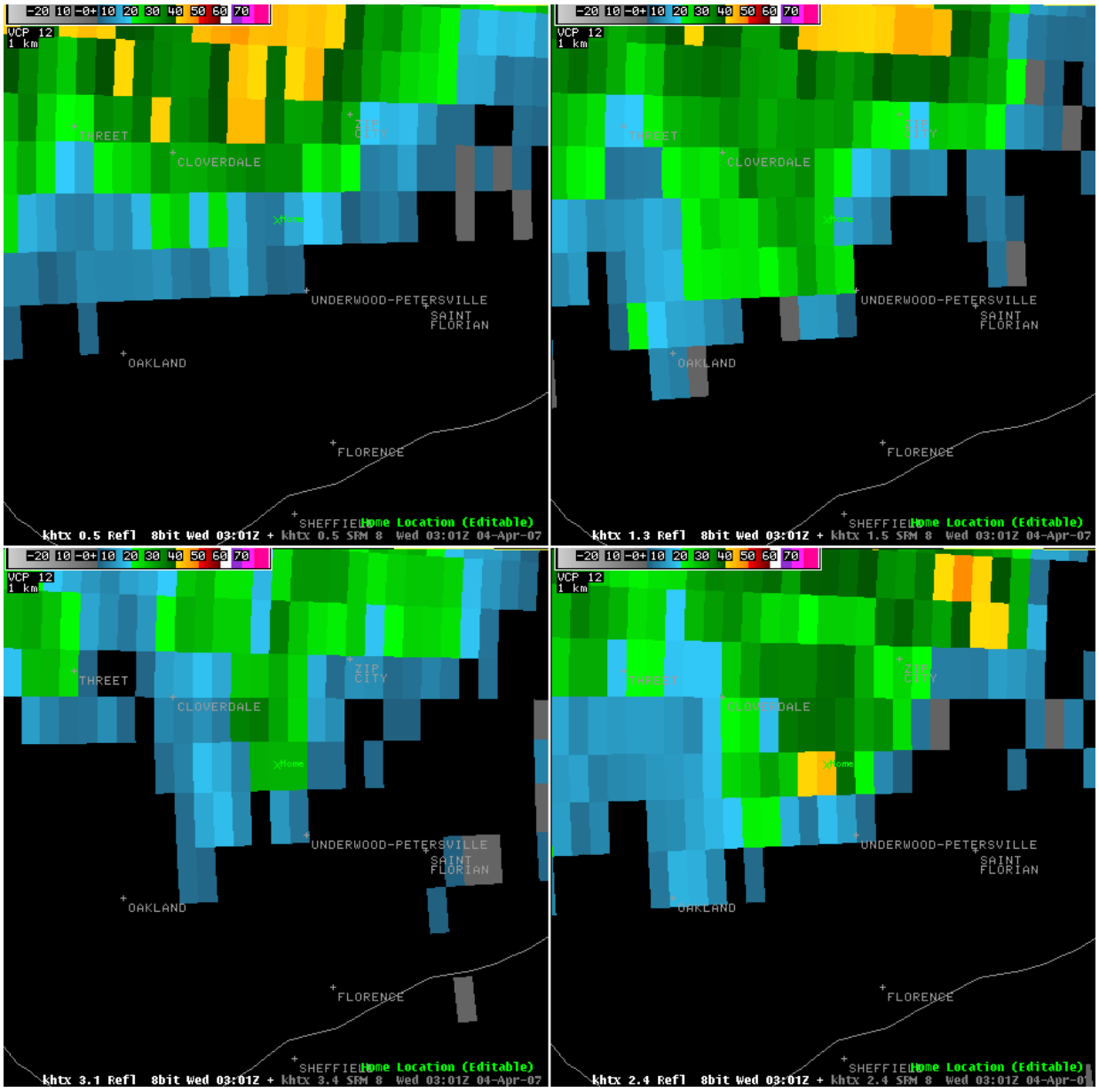

Figure 10: KHTX reflectivity from 0301 UTC 04 April, centered on the Cloverdale community of Lauderdale County. Elevation angles, clockwise from top left, are 0.5, 1.3, 2.4, and 3.1.

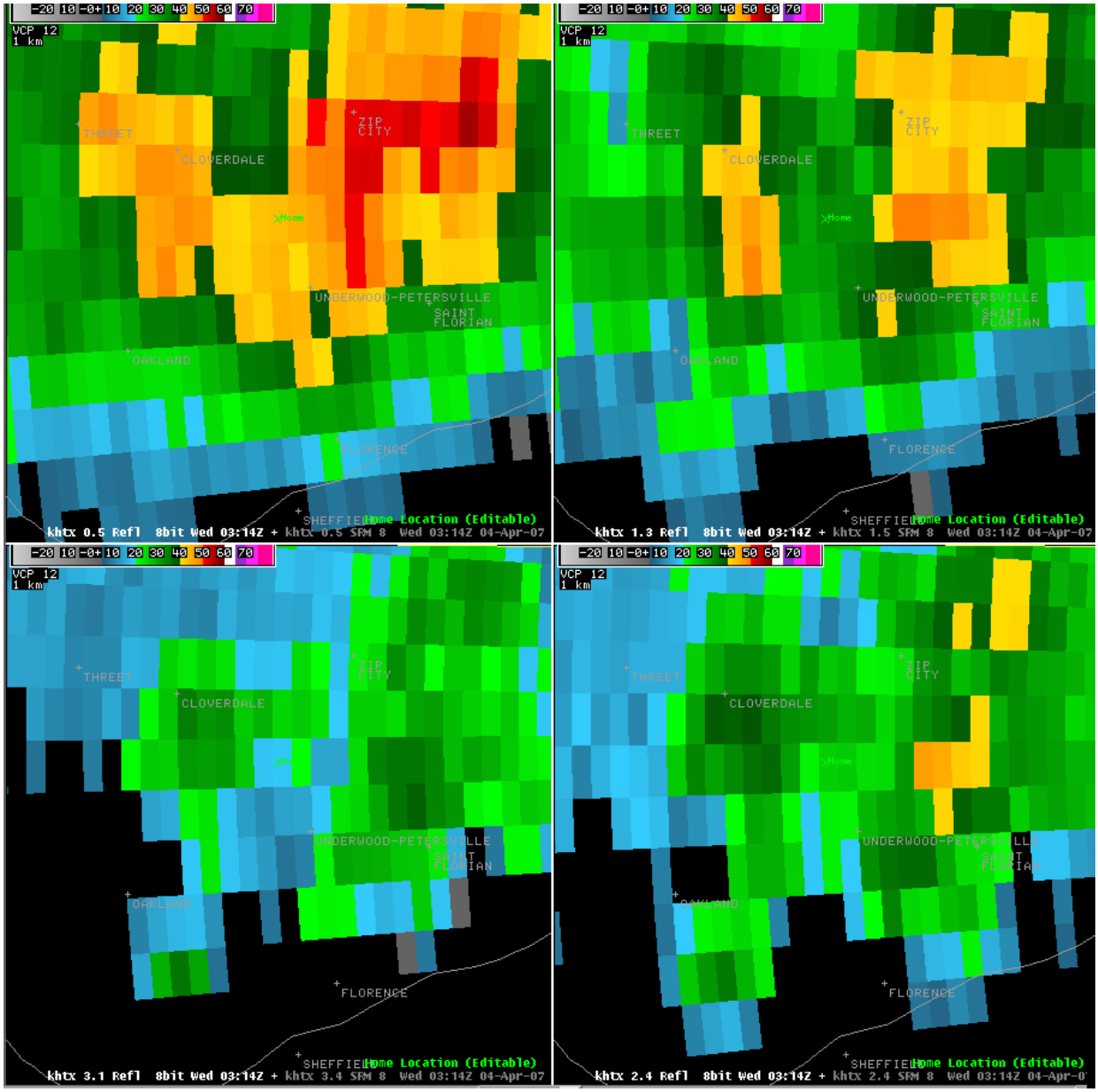

Figure 11: As in Figure 10, except from 0314 UTC 04 April.

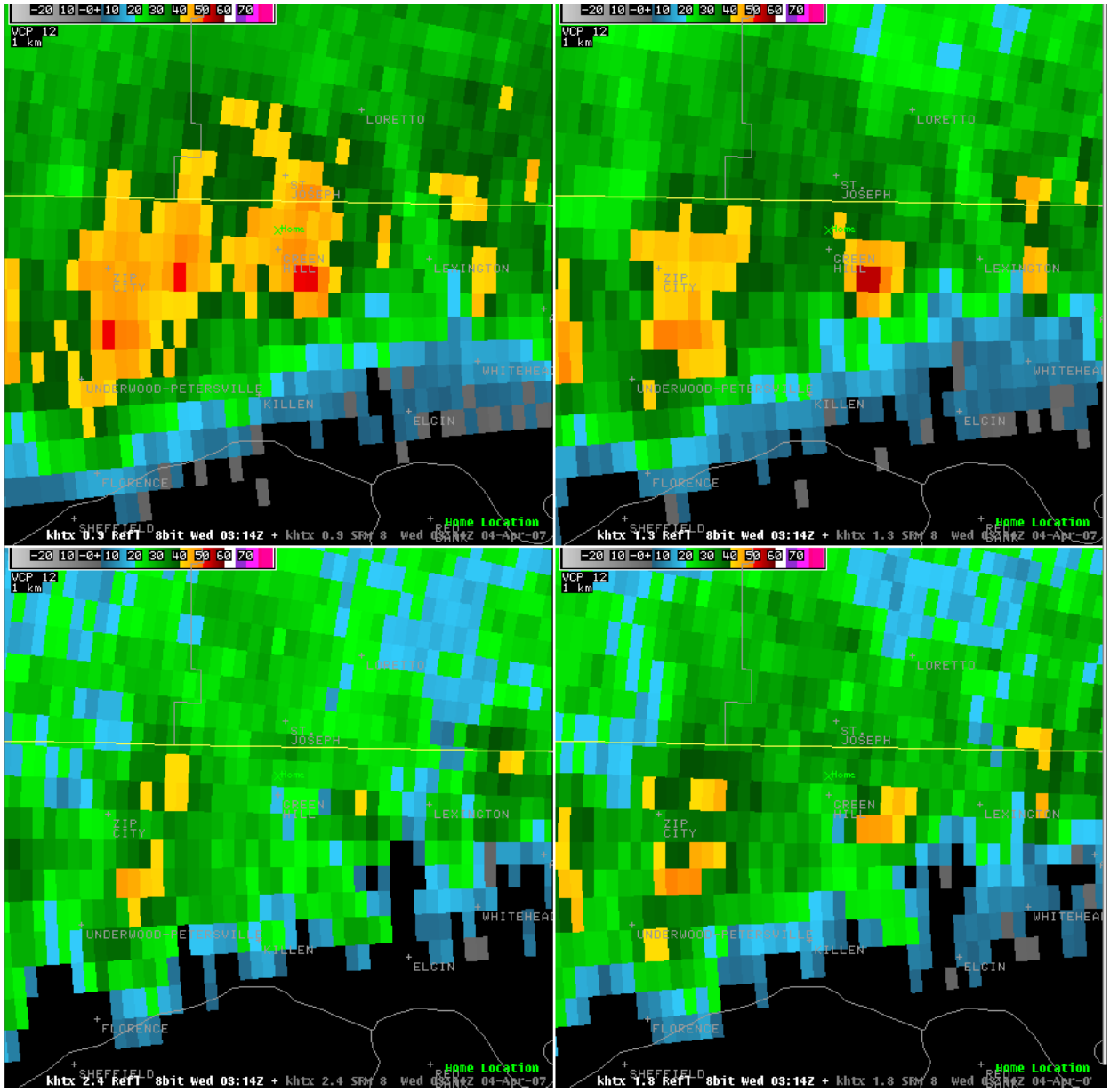

Figure 12: As in Figure 11, except centered on the Green Hill community of Lauderdale County.

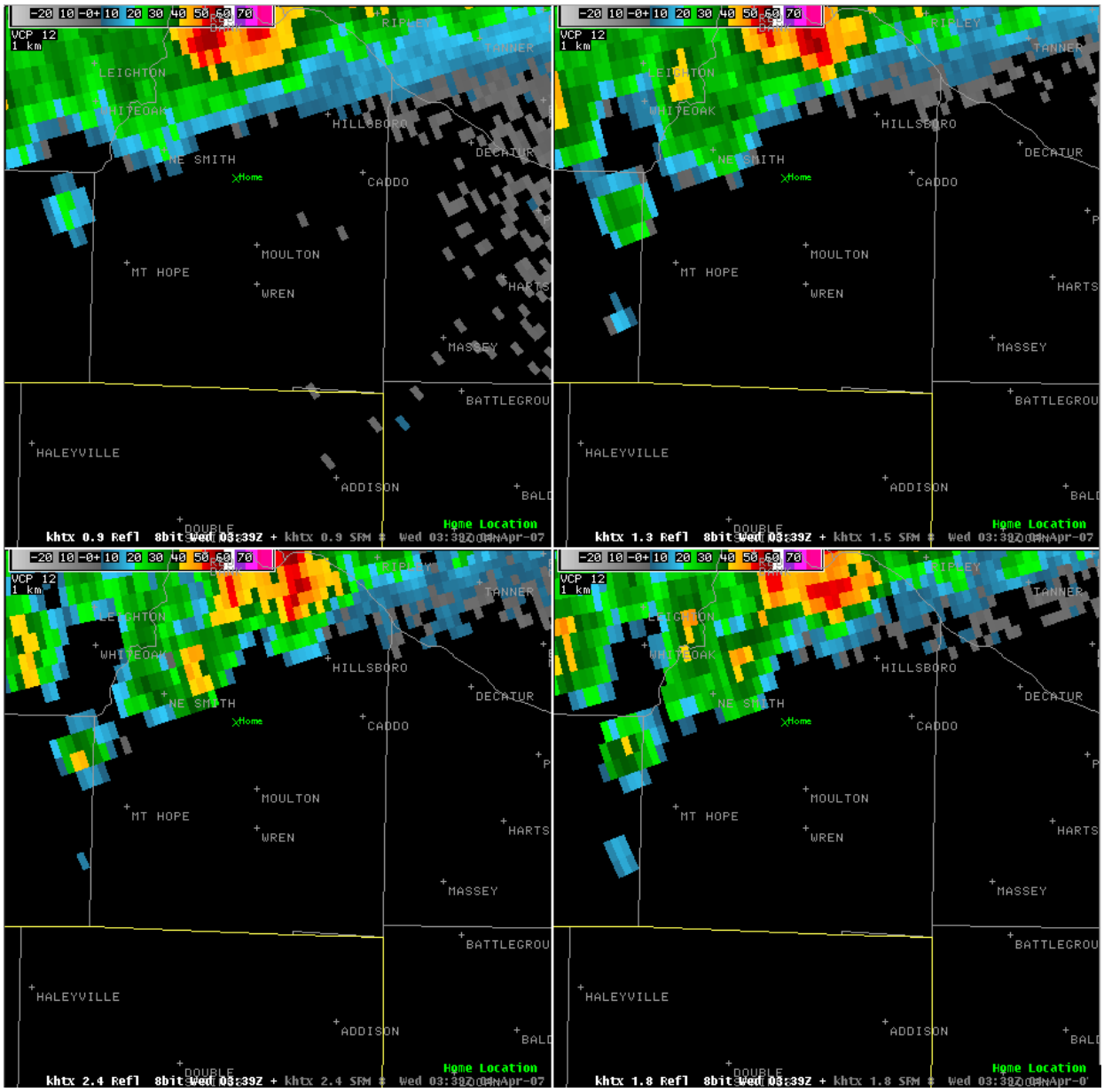

Figure 13: KHTX reflectivity from 0339 UTC 04 April, centered on Moulton. Elevation angles, clockwise from top left, are 0.5, 1.3, 1.8, and 2.4.

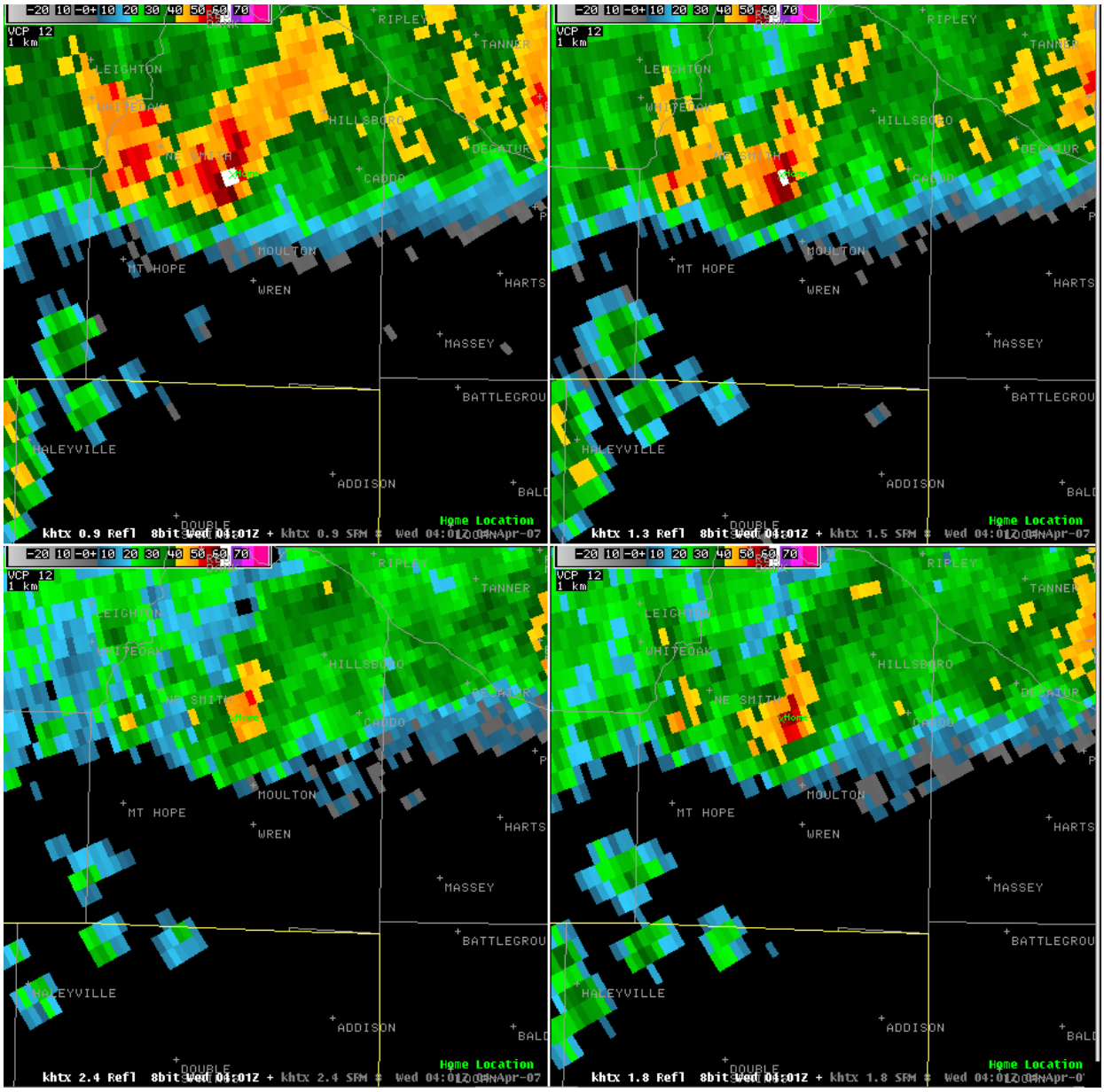

Figure 14: As in Figure 13, except from 0401 UTC 04 April.

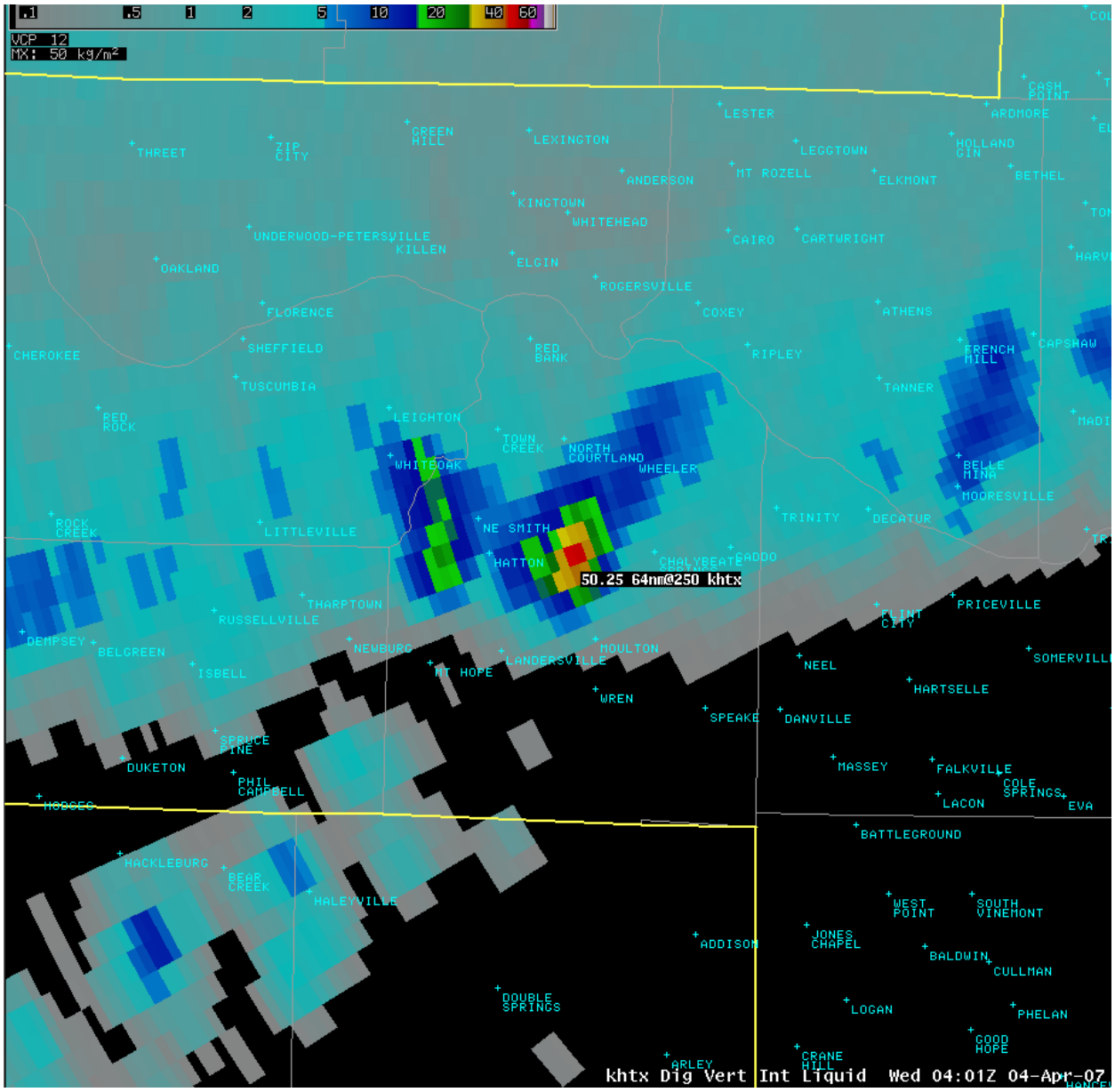

Figure 15: KHTX digital Vertically Integrated Liquid (DVIL) 0401 UTC 04 April, centered on Moulton.

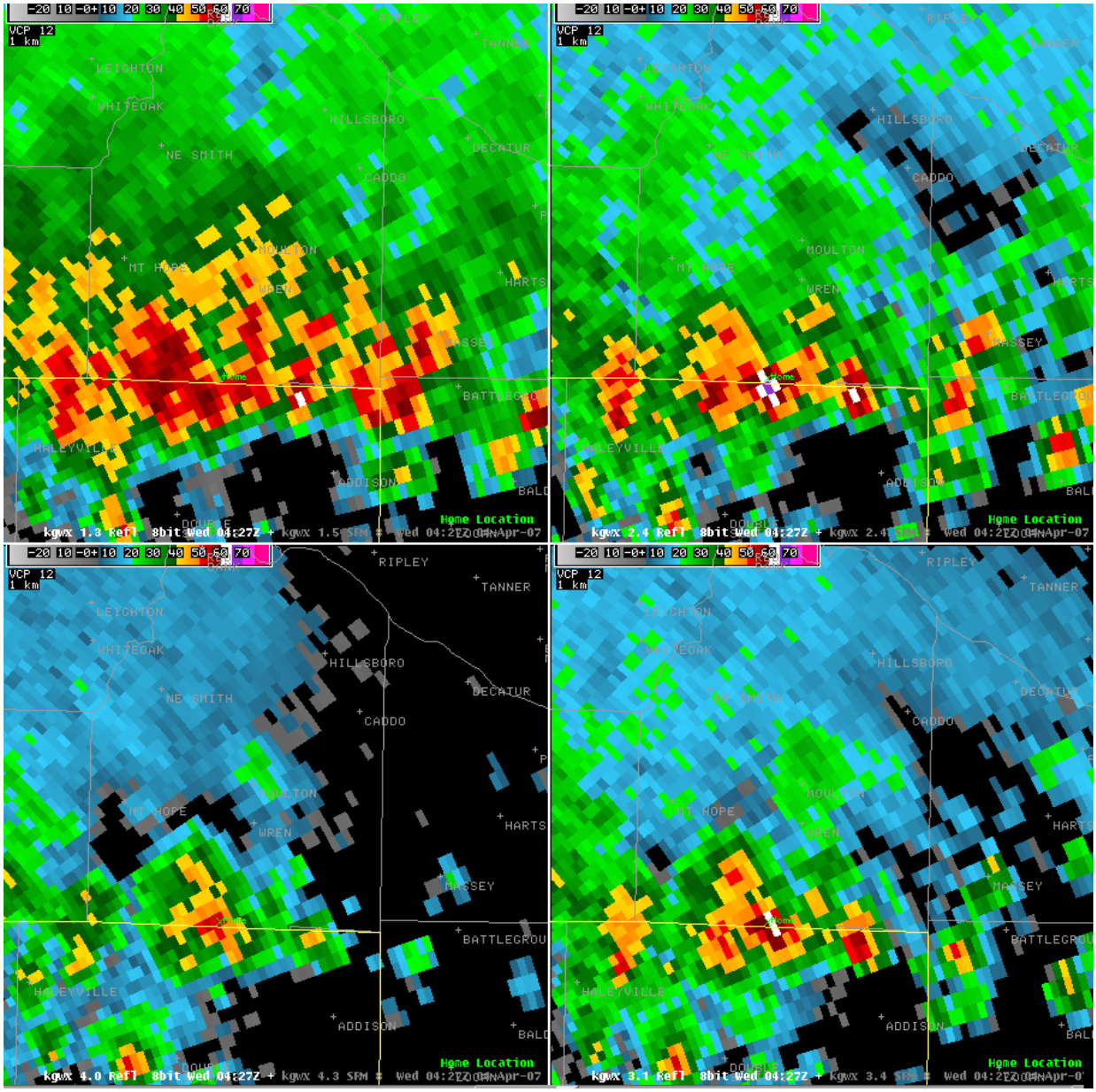

Figure 16: KGWX reflectivity from 0427 UTC 04 April, centered on the Bankhead National Forest. Elevation angles, clockwise from top left, are 1.3, 2.4, 3.1, and 4.0.

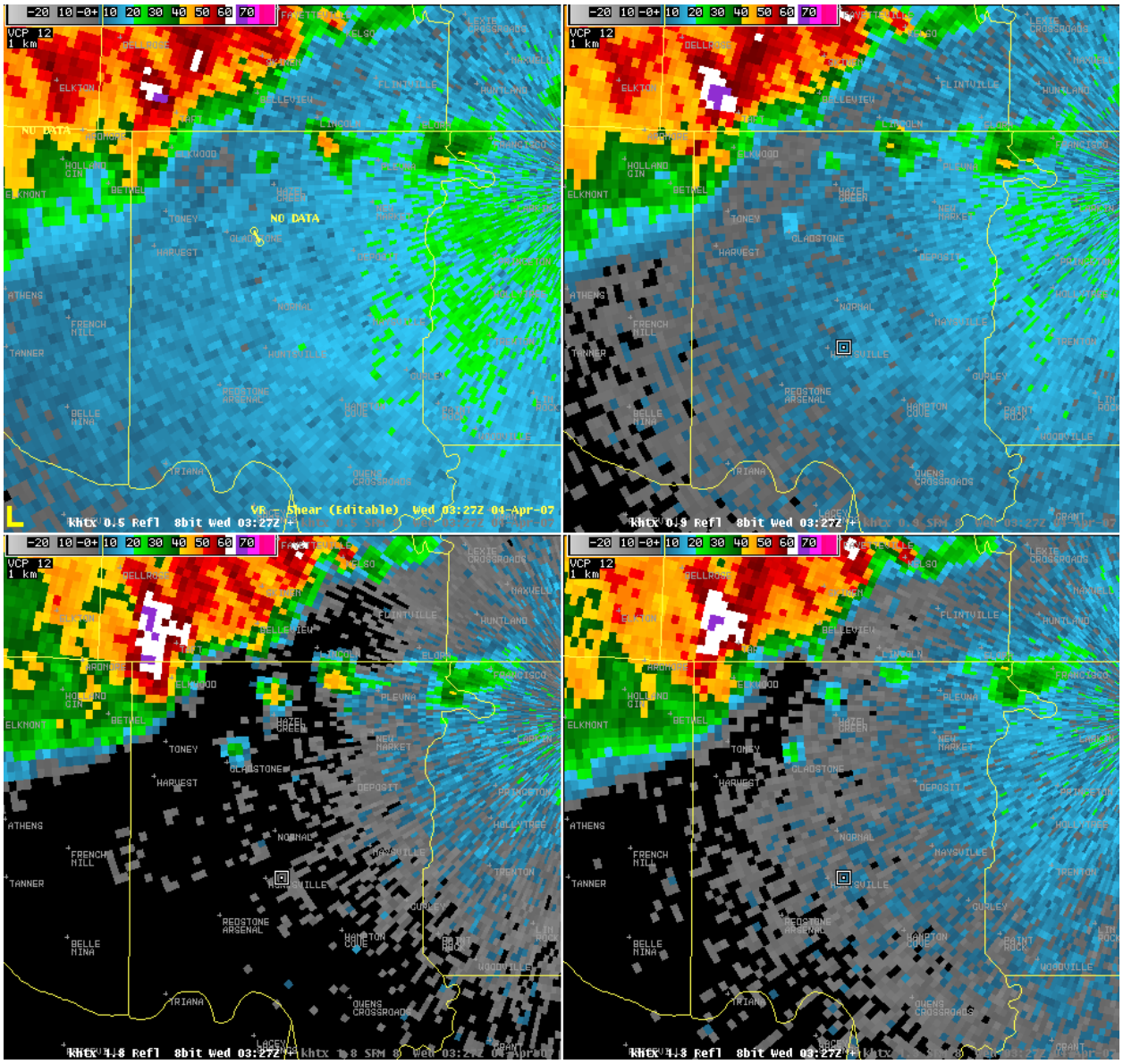

Figure 17: KHTX reflectivity data from 0327 UTC 04 April. Elevation angles, clockwise from top left, are 0.5, 0.9, 1.3, and 1.8.

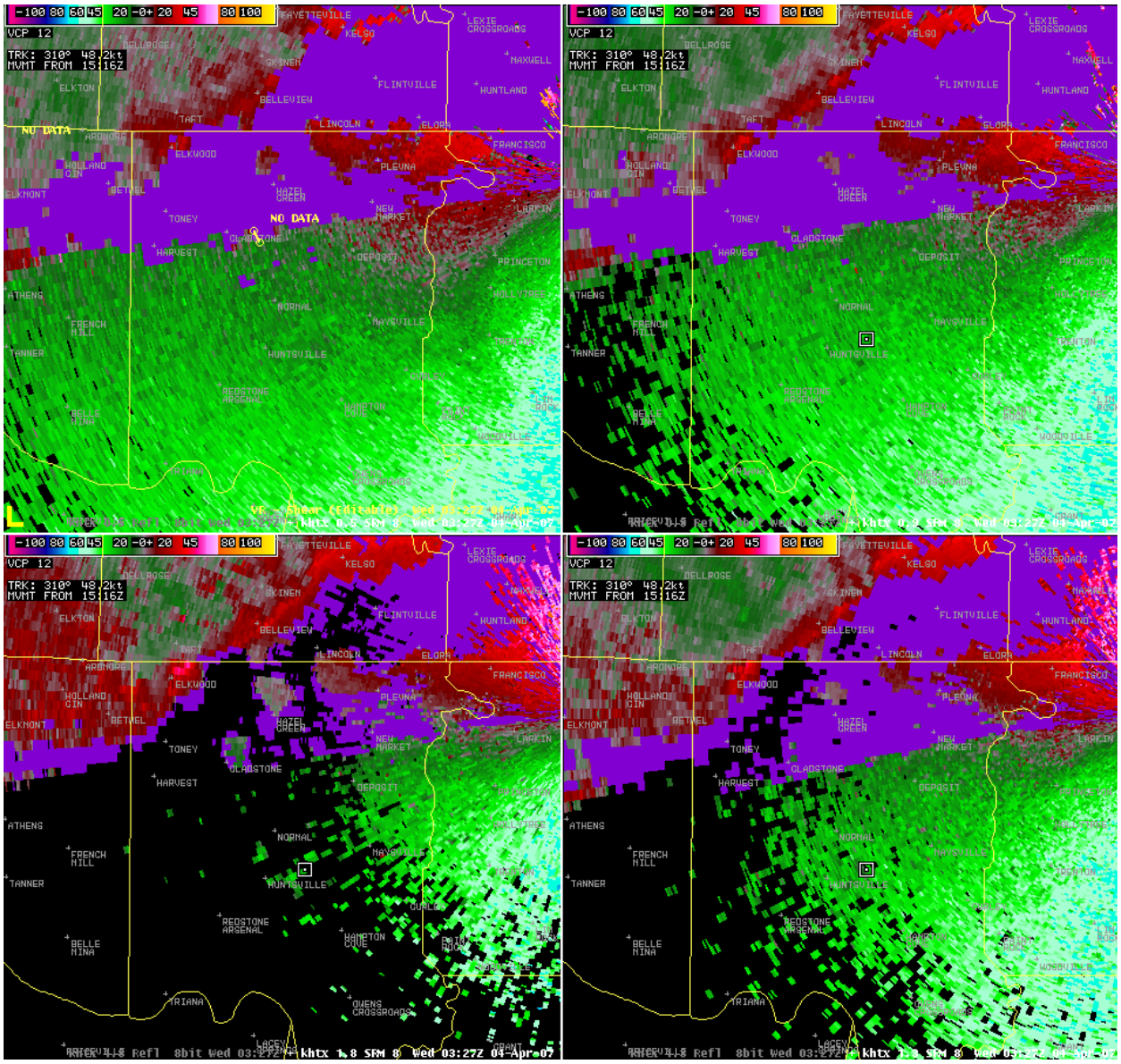

Figure 18: KHTX storm-relative motion data from 0327 UTC 04 April. Elevation angles, clockwise from top left, are 0.5, 0.9, 1.3, and 1.8.

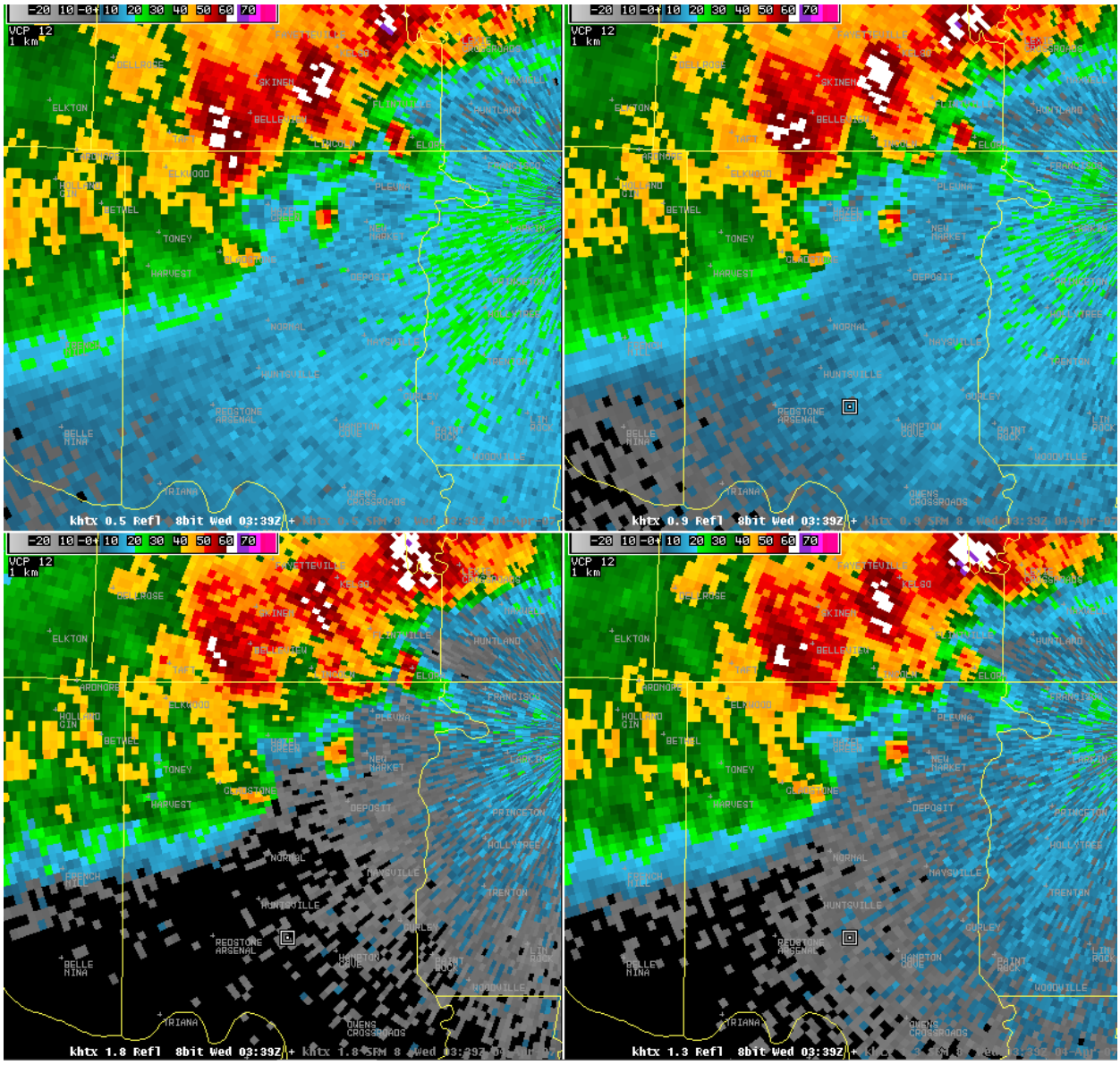

Figure 19: KHTX reflectivity data from 0339 UTC 04 April. Elevation angles, clockwise from top left, are 0.5, 0.9, 1.3, and 1.8. Note the broad "hook" extending from near Elkwood to Gladstone, the outflow boundary preceding the storms in central and western Limestone and Madison Counties, and the moderate shower at the intersection of the boundary and hook.

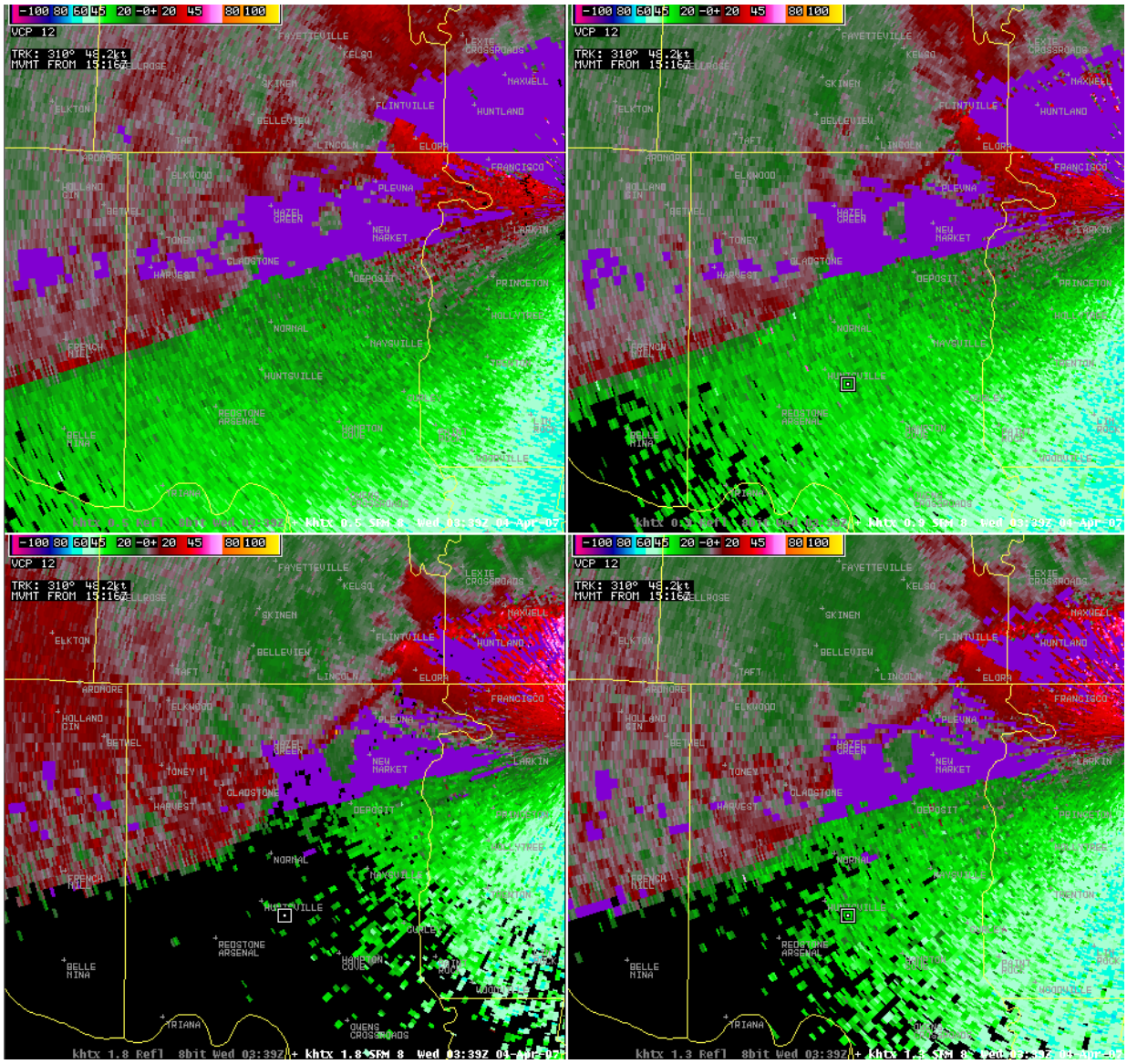

Figure 20: KHTX storm-relative motion data from 0339 UTC 04 April. Elevation angles, clockwise from top left, are 0.5, 0.9, 1.3, and 1.8. The rotation notable amidst the 0.5 degree range folding corresponds to the moderate shower noted in figure 19.

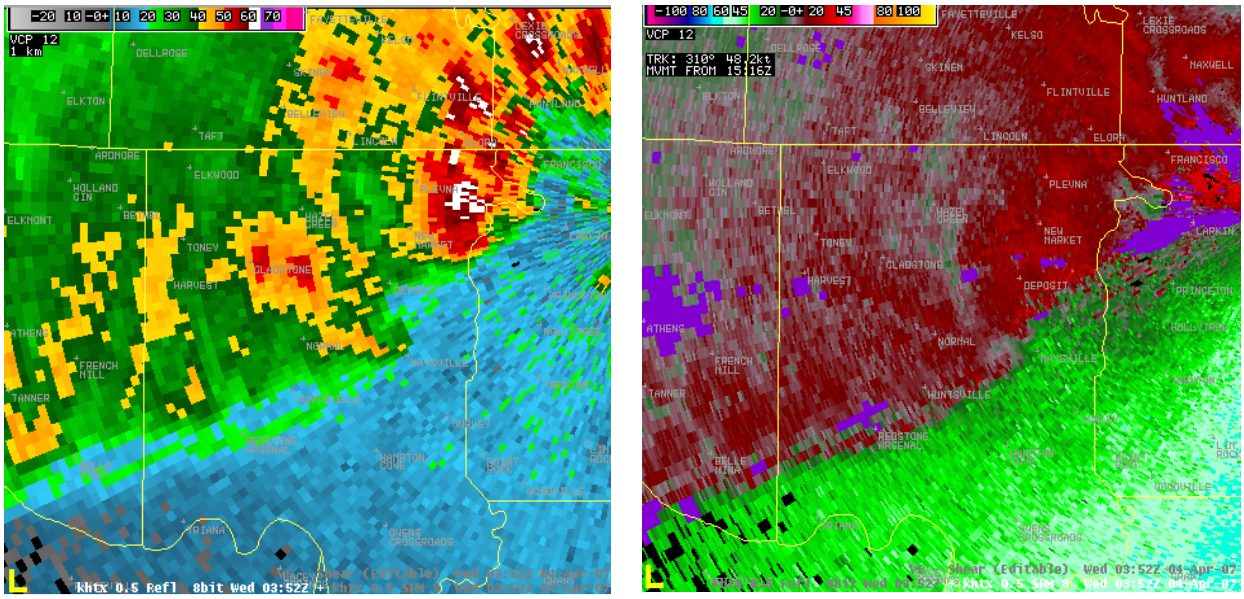

Figure 23a-b: KHTX reflectivity (left) and storm-relative motion (right) data from the 0.5 degree scan, 0352 UTC 04 April. Strong rotation is noted south of Deposit (right of center image).

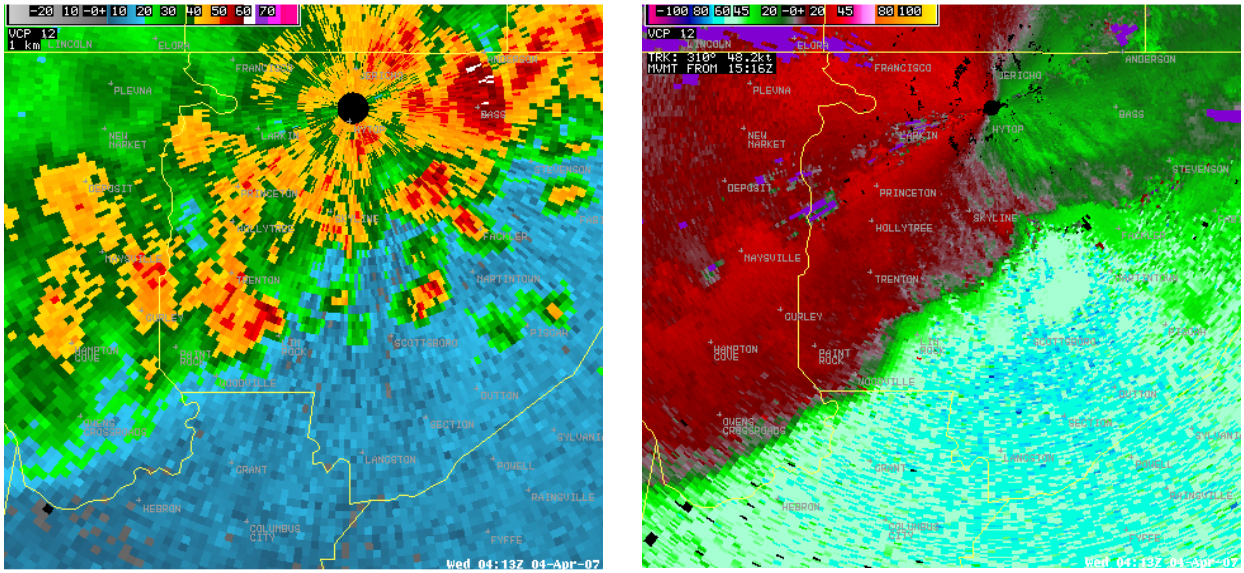

Figure 24a-b: KHTX reflectivity (left) and storm-relative motion (right) data from the 0.5 degree scan, 0413 UTC 04 April. Note the strong rotation southeast of Skyline (right of center image).

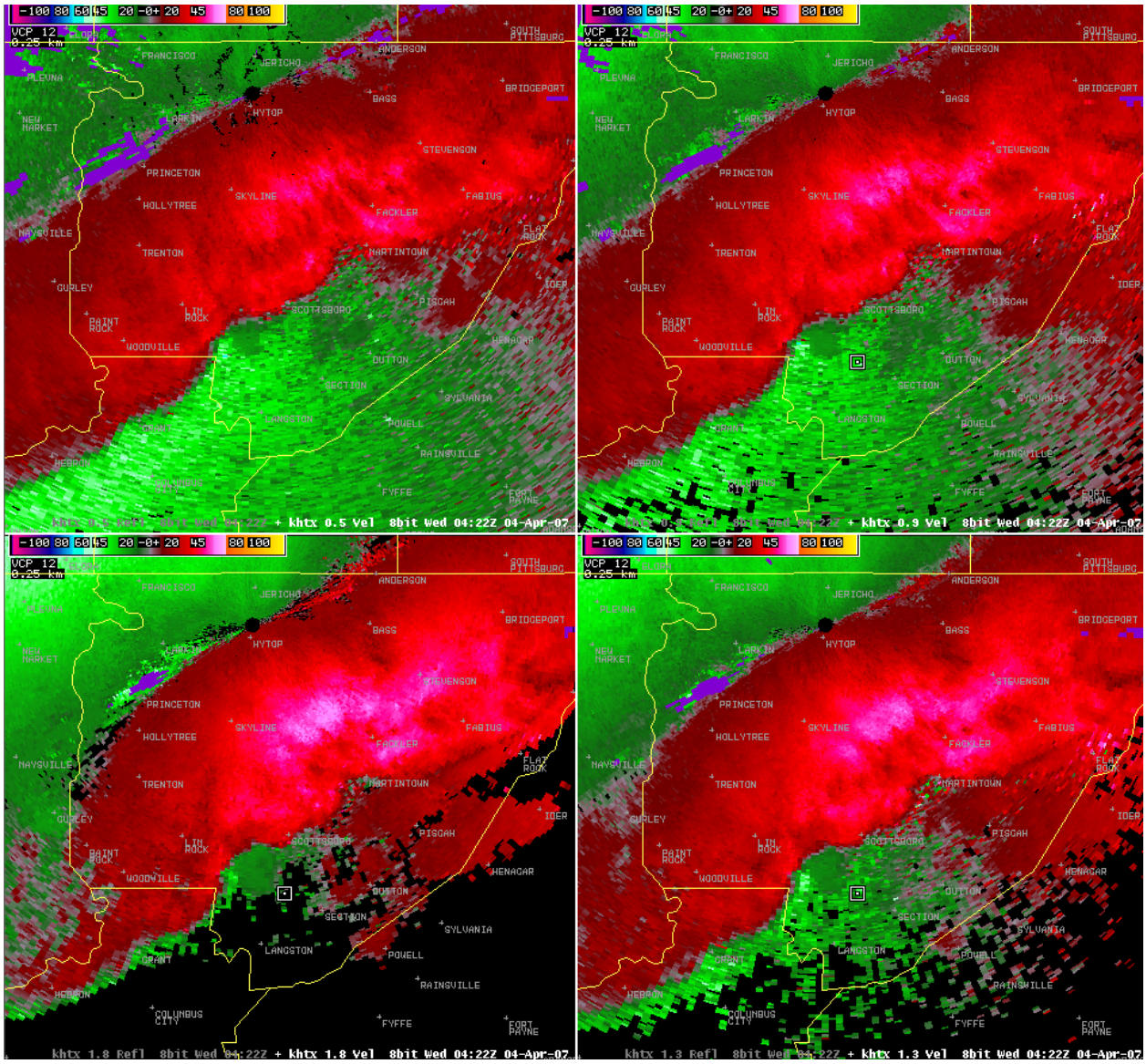

Figure25: KHTX base velocity data from 0422 UTC 04 April. Area of note is near where Marshall County juts into Jackson County just north of Lake Guntersville. Elevation angles, clockwise from top left, are 0.5, 0.9, 1.3, and 1.8. Strong rotation is noted east of Woodville near where Marshall County juts into Jackson County (below-left of center image).

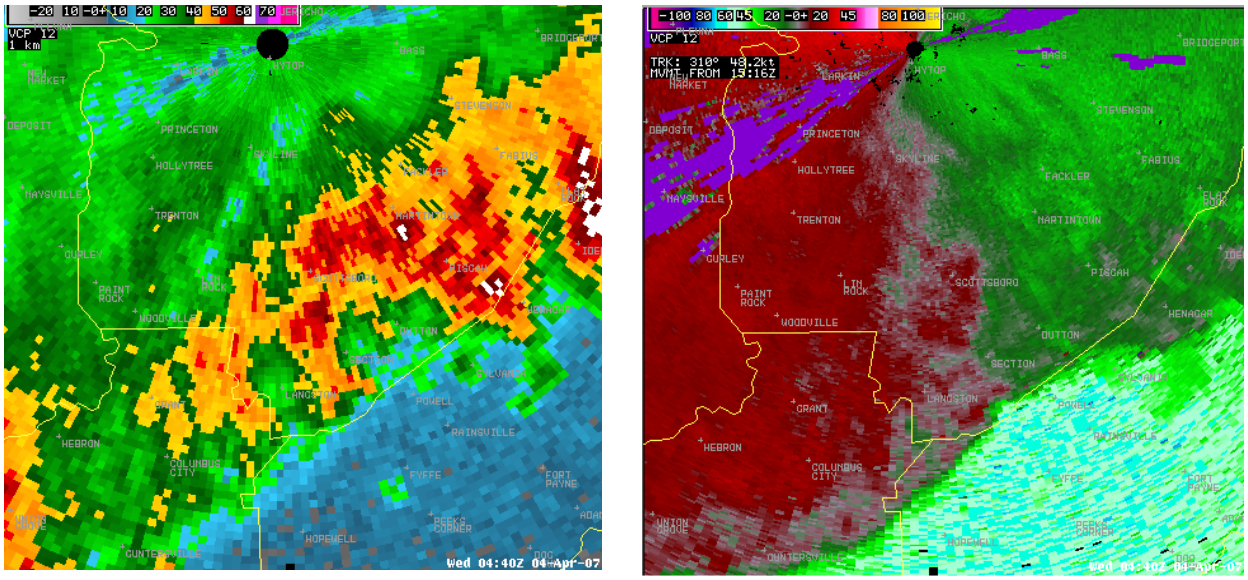

Figure 26a-b: KHTX 0.5 degree base reflectivity (left) and storm-relative motion (right) data from 0440 UTC 04 April. Strong rotation is again noted east of Langston and south of Section near the Jackson-DeKalb county line in the Macedonia community.