P9.112 A STORM-SCALE ANALYSIS OF THE 29 MAY 2013 TORNADO EVENT ACROSS EAST-CENTRAL NEW YORK

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1. INTRODUCTION

On 29 May 2013, a major severe weather outbreak occurred across much of upstate New York (NY), and portions of western New England. NY and New England had a few dozen severe reports of damaging winds in excess of 50 knots (58 mph) and large hail greater than 2.5 cm (1 in) in diameter. In addition to several reports of large hail and damaging winds, 3 tornadoes were confirmed in the Albany forecast area ranging from EF1 (winds of 86 to 110 mph) to EF2 (winds of 111 to 135 mph). F2/EF2 tornadoes are rare in eastern NY and western New England with less than ten recorded in a 1980-2014 forecast area climatology. These three tornadoes affected portions of Montgomery, Schenectady, Schoharie and Saratoga Counties late that afternoon. One of these was a long-tack tornado that touched down at 2247 UTC (6:47 p.m. EDT) in the town of Florida, situated on the border of Montgomery and Schenectady Counties (Fig. 1a). This tornado continued on towards the east-southeast for 13 miles across most of Schenectady County before ending in the city of Schenectady, at 2304 UTC (7:04 p.m. EDT). The tornado had a narrow path at the beginning of its track in the town of Florida. The damage was more impressive and widespread in Schenectady County, where the tornado was around a mile wide at times, with EF1 to EF2 damage observed at Mariaville Lake in Schenectady County with a well-built barn destroyed, numerous hardwood and softwood trees sheared and uprooted, and high tension power line towers crushed and destroyed. This was the first F2/EF2 tornado in the WFO Albany forecast area since 21 July 2003. Two shorter path length tornadoes touched down in Schoharie (Fig. 1b) and Saratoga Counties (U.S. Department of Commerce Storm Data 2013).

Observational data, as well as short range deterministic SPC Mesoscale Analysis Rapid Refresh data suggested a significant severe weather outbreak would occur. Forecasters were challenged as to whether isolated or widespread severe weather was going to occur late that afternoon, since convective initiation and maintenance was unclear with the peak diurnal heating decreasing, and a lack of abundant instability. Much of the impacted area had just entered a warm sector with a warm front just north of the Mohawk Valley and Greater Capital Region. Upstate NY and New England were situated near the right entrance region of a 250 hPa 90 kt jet streak with an approaching strong upper level short-wave for the afternoon. A moderate instability and high shear pre-convective environment was in place before the severe weather. Surface based convective available potential energy values ranged from 500 to 1500 J kg^{-1} with increasing effective bulk shear values of 35 to 50 kts. 0-1 km Storm-Relative Helicity values were in the 150-200 m^{2} s^{-2} range. The effective bulk shear values in the 0-6 km layer suggested the possibility of supercells with rotating updrafts capable of producing large hail and tornadoes.

This paper will focus on a detailed radar analysis of the event, utilizing the relatively new dual polarization data (differential reflectivity, correlation coefficient, and specific differential phase). The impressive tornadic debris signature with the EF2 tornado will be shown with the correlation coefficient data showing debris detected up to 6200 ft AGL. Traditional base and derived WSR-88D radar products will also be shown in conjunction with the Dual-Pol data. The storm-scale analysis will focus on helpful forecast techniques, including applying results from a local rotational velocity (Vr)-shear study, to determine what caused the tornadoes with an emphasis on the long track rare F2/EF2 tornado and how the tornado warning process can be improved.

2. DATA

Observational data used in this case analysis include surface and upper air observations, satellite imagery, and KENX WSR-88D data. The WSR-88D data is high resolution 8-bit data from KENX. SPC upper air

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charts and soundings are also used (www.spc.noaa.gov). The Rapid Refresh mesoscale data from the SPC Mesoanalysis page will also briefly be shown in the mesoscale analysis.

For the northeast United States tornado climatology, tornadoes were examined between 1980 and 2014 with data from *StormData (*US Department of Commerce 1980-2014). The date, location, strength, and time of occurrence were all recorded into spreadsheets. Fatalities, injuries, and damage estimates were also recorded as well (Frugis and Wasula, 2013).

3. TORNADO CLIMATOLOGY

A climatology of tornadoes done from 1980-2012 across the northeastern US revealed an interesting areal and spatial distribution (Fig. 2). The study by Frugis and Wasula (2013) showed the number of tornadoes broken down by Weather Forecast Office (WFO) County Warning Areas (CWAs). As expected, the total number of tornadoes was higher for the southwestern corner (State College 252 tornadoes) of the northeastern domain, as compared to the far northern and eastern areas (Caribou 22 tornadoes) due to the geographic location, terrain, and population density. For example, mountainous and low-populated areas (such as in the Burlington and Caribou CWAs), had fewer tornadoes than more populated areas (such as the Mount Holly CWA).

The climatology expanded a few years from 1980-2014 indicated about 3 tornadoes per year for the Albany (ALY) CWA (Fig. 3). There were relative maximums in 1992 and 2003, but it should be stressed that results can be skewed, since several reports from one tornado case or event are entered in separately in *Storm Data*. For example, all 4 tornadoes in 2013 were the May 29th case in the ALY forecast area. When broken down for the Albany CWA by month, tornadoes occurred generally between May and August, as shown in Fig. 4. The apex in tornado occurrence across eastern NY and western New England occurred in the month of July. However, a few tornadoes have occurred as early as April and as late in the early cool season in the month of November. There were no reports of tornadoes in the heart of the cool season (December to March) due to generally stable and cold conditions.

As anticipated, tornadoes have a tendency to form in the afternoon and early evening hours, with the majority of reported tornadoes between 12:00 and 20:00 Eastern Standard Time (EST). Fig. 5 shows the times in EST for all tornadoes that have formed between 1980 and 2014 in the ALY CWA. There is a peak of tornado occurrence between 15:00-16:00 EST, and a secondary maximum between 19:00-20:00 EST. Although very rare and seldom there have been reported tornadoes in the early morning hours in the Albany CWA.

Fig. 6 shows the strength of the reported tornadoes for the Albany CWA between 1980 and 2014. Storms are generally on the weaker side of the scale, with the majority being F0/EF0 and F1/EF1. 80% of the ALY CWA tornadoes are F0/EF0 and F1/EF1. F2/EF2 and greater tornadoes are somewhat rare (less than 15 events since 1980). While no F5/EF5 tornadoes were recorded in the climatology, there were a few F4/EF4 tornadoes, which show that violent tornadoes have occurred in this region in the recent past. The May 29, 2013 event had an F2/EF2 tornado, which does not occur often in the ALY CWA (only 9 cases from 1980-2014).

4. SYNOPTIC OVERVIEW

A mid-level 500 hPa ridge was over southern Quebec, NY and New England with a potent short-wave trough approaching from the Great Lakes Region and southern Ontario at 1200 UTC 29 May 2013 (Fig. 7). 500 hPa temperatures were in the -11°C to -13°C range over a large portion of NY and New England. An impressive mid-level jet streak of 55 kts approached eastern NY and western New England from Michigan and the eastern Great Lakes Region. The upstream short-wave trough helped focus the strong to severe convection late in the afternoon. A 250 hPa upper level jet streak was situated upstream over northern Michigan of 90 kts (Fig. 8). Locations in upstate NY were near the anticyclonic entrance region (right entrance region) of the strong jet streak (Uccellini and Kocin 1987) later in the day with sufficient instability and strong 0-6 km shear in place for deep organized convection and the potential for tornadoes. The low-level jet at 850 hPa increased from the west to southwest at 35 to 45 kts (not shown).

At 1800 UTC 29 May 2013, a surface warm front moved slowly north to northeast across western and central NY (Fig. 9a). The warm front was just west of the Hudson River Valley in eastern NY at this time, and cloud cover and lack of sufficient heating were some potential problems for widespread severe weather. By 2100 UTC (Fig. 9b), the warm front moved north of the Hudson River Valley and towards the Champlain Valley and upstate VT. Most of upstate NY and parts of western New England were in a warm sector. A surface wave moved along the boundary east of Lake Ontario. The initial convection began from a lake breeze, but intensified as it approached the western reaches of the Mohawk River Valley. With the frontal boundary nearby and the surface to 850 hPa winds indicating a south to southwest flow upstream, this helped with the directional shear profiles for convective initiation for some rotating updrafts.

5. MESOSCALE AND SOUNDING ANALYSIS

The Rapid Refresh data from the SPC Mesoanalysis indicated between 2200-2300 UTC 29 May 2013 that a gradient of instability had set up over central and eastern NY with SBCAPES of 500-1500 J kg^{-1} (Fig. 10a). The instability axis was also very pronounced when moving south of the Mohawk River Valley, as the locations to the south had more sunshine for surface destabilization. The best effective bulk shear at 2300 UTC 29 May 2013 of 40-50 kts was across extreme eastern NY and western New England, though a broad area of 35 kts was over central NY (Fig. 10b). The deep shear interacting with the moderate instability allowed supercells to form. The 0-1 km shear vectors increased to 20-30 kts just downwind of Lake Ontario into the Mohawk River Valley (Fig. 11a). The 0-1 km Storm-Relative Helicity values were in the 150-200 m^2 s^{-2} range (not shown). The strong to severe convection that formed in the warm sector migrated along the strong surface theta-e gradient over east-central NY. The theta-e values from the Mohawk Valley, Capital Region and Berkshires south into the Mid-Hudson Valley and Eastern Catskills ranged from 334 K to 342 K (Fig. 11b). The low-level baroclinic zone was a focusing mechanism for the supercells and mini-squall line or Quasi-Linear Convective Segment (QLCS) to intensify and move along during the late afternoon and early evening.

The 0000 UTC sounding taken at KALY indicated that a fairly unstable atmosphere was in place, though the severe convection had just moved east of the upper air site. This sounding (Fig. 12) showed critical information pertaining to the mesoscale environment. The freezing level was 12.4 kft AGL, the -20°C height 24.2 kft AGL, and the wet-bulb zero height just under 12 kft AGL. The 850-500 hPa lapse rates were close to 6.2°C km^{-1} (SPC Mesoanalysis indicated around 6.5°C km^{-1}) and the Most Unstable CAPE values were 453 J kg^{-1}, and the best Lifted Index was -2°C. There was 38 kts of shear in the 0-6 km layer indicative of supercell formation and maintenance within a potential Mesoscale Convective System (MCS). The 0-1 (0-3) km shear was 30 (40) kts on the sounding. The atmosphere was conducive for deep organized convection and discrete supercells with the lifting condensation levels (LCL's) generally lowering under 1.5 km (Thompson et al. 2003).

The flow was fairly unidirectional between 700 hPa to 500 hPa. The strong west to northwesterly flow (45-50+ kts) in the lower to mid troposphere indicated the potential for thunderstorms to move quickly to the east-southeast with a short burst of very heavy rainfall in association with the anomalous precipitable water values (KALB 0000 UTC sounding PWAT = 41.9 mm (1.65 inches)). The unidirectional flow also indicated that the supercellular thunderstorms would quickly form into a mini-line or a QLCS with potential bowing segments within the MCS (Fig. 12). A Severe Thunderstorm Watch was issued for the entire ALY forecast area for the late afternoon into early evening with locations from the Mohawk River Valley and the Capital Region south (Fig. 13) most vulnerable for widespread damaging winds, some large hail and the possibility of tornadoes.

6. STORM-SCALE RADAR ANALYSIS

A cluster of convection moved into central NY and the western Mohawk Valley between 2200 and 2300 UTC. Initially, severe thunderstorm warnings were issued for damaging winds and large hail. However, a discrete supercell moved into Montgomery County after 2230 UTC. A hook echo began to form with the supercell ahead of the main severe convective cluster at 2242 UTC (Fig. 14a). This hook echo showed strong rotation with a low-level rotational value (V_r) of 39.6 kts over a distance (D) of 0.5 nm with a shear (S) value of 0.0406 s^{-1} (Fig. 14b). A tornado warning was quickly issued by the warning decision forecaster based on a nomogram from the recent V-R Shear local study (Frugis and Wasula 2013).

The reflectivity cross-section through the hook echo showed an impressive Bounded Weak Echo Region (BWER). The BWER depicted lower reflectivities capped off by higher reflectivities aloft (Fig. 15a) with large hail up to golf-ball size reported from spotters with the tornado in extreme eastern Montgomery and western Schenectady Counties. A fairly deep mid-level mesocyclone developed with strong rotation up to 10-15 kft AGL. The maximum mid-level mesocyclonic velocity V_m was calculated from the cross-section (within 3.5 km across the storm) in the Four Dimensional Storm Cell Investigator (FSI) to be 98.8 kts (Fig. 15b).

The rather high confidence tornado warning continued when the 2247 UTC KENX radar scan came in. The hook echo was well-defined in the reflectivity data which is depicted with the white circle around it in Fig. 16a. A mini-squall line and a bow echo were catching up to the lead supercell with the hook echo. Meanwhile, the GR2Analyst (Gibson Ridge Software 2013) 0.5° normalized rotation (NROT) data had a spike with the TVS to 1.36. This value based on the local V-R shear study was well-above both the mean and median values of 0.90 and 0.81 (Frugis and Wasula 2013). In addition, NROT values were as high as almost 0.90 at three radar scans prior to tornado formation at 2232 UTC. The GR2Analyst guide indicates NROT values greater than 1.0 to be significant and greater 2.5 to be extreme for tornadoes.

At 2252 UTC, the tornado reached its peak intensity with a low-level V_r = 48 kts, and S = 0.0526 s^{-1} gate to gate across the couplet at D = 0.5 nm at a distance of 15 nm from the RDA, and a beam height of 1.5 kft AGL (Fig. 17a). A cross-section through the tornadic couplet in FSI showed the well-defined rear inflow jet, the low-level tornadic circulation, and the mid and upper-level mesocyclone (V_m = 108 kts) to the storm (Fig. 17b). The tornado warning was a high confidence one for Schenectady County at this point based on the newly developed Gate to Gate Shear vs. Mesocyclone Rotational Velocity nomogram (Fig. 18) based on 41 cases from 2003-2013 in or near the ALY CWA (Frugis and Wasula 2013). The distance across the mesocyclonic rotational couplet (D) was normalized to 0.5 nm for all events from 2008-13. A previous local studies work was followed for 2003-08 in terms of the calculation of D (LaPenta et al. 2000). This tornado fit into the 100% confidence of at least an F1/EF1 tornado in Region III of the nomogram. All but one F2/EF2 tornado occurred in this region. The EF2 Mariaville tornado was impacting the community at this time.

At 2257 UTC a 2nd tornado briefly touched down in the mountainous terrain of Schoharie County (not shown). The ALY CWA had two tornadoes on the ground at the same time for the first time since 31 May 1998. The impressive long track tornado was moving across central Schenectady County at this time. The 2257 UTC KENX 0.5° reflectivity scan showed signs of the tornadic supercell being absorbed by the upstream bow echo. The 0.5° Dual Polarization (Dual Pol) Correlation Coefficient (CC) data showed a well-defined Tornadic Debris Signature (TDS). The TDS showed depressed CC values at the 0.5°, 1.5°, 2.4°, and 3.4° radar elevation angles to less than 0.70 (Fig. 19a-d). The actual value at 6.2 kft AGL was 0.685 on the 3.4° radar elevation slice. The differential reflectivity (ZDR) values were also low at 0 to -0.3 dB in the lowest few tilts (not shown). The TDS was evidence of shingles, siding, insulation, leaves, etc. being lifted by the tornado. At the same time, a cross-section through the storm revealed depressed CC values of less than 0.80 to about 8 kft AGL (Figs. 20 a and b). At this time, a well-built barn was heavily damaged at Mariaville Lake. This was the first EF2 tornado with a TDS in the Dual Pol era in the ALY CWA.

The entire MCS evolved into a Line Echo Wave Pattern (LEWP) with a northern bookend vortex (Fig. 21). A wall of wind was associated with it, as the long track tornado was absorbed in the line (not shown). Extensive wind damage with trees and power lines down occurred downstream of the tornado in the Greater Capital Region, Taconics, and Berkshires (Fig. 22). Winds were estimated to be between 50-60 kts at many locations. A weak EF1 spin-up tornado occurred in southern Saratoga County (Fig. 1). The corridor of damage was very intense downwind of Lake Ontario and the Mohawk River Valley.

7. SUMMARY

A major severe weather event occurred over east-central NY on the 29 May 2013 with several dozen severe weather reports including 3 tornadoes in the ALY CWA. One tornado was a long track one extending 13 nm from extreme eastern Montgomery County into much of Schenectady County. This was the first F2/EF2 tornado in the ALY CWA since 21 July 2003. The ALY forecast area covering eastern NY and western New England has only had nine F2/EF2 tornadoes since 1980. The severe weather developed in a warm sector in a moderate instability and high shear pre-convective storm environment. The initial severe convection fired downwind of Lake Ontario and migrated and intensified along a low-level theta-e gradient in the Mohawk Valley, Capital Region and Berkshires. The eventual MCS evolved into a QLCS or mini-squall line merging with a tornadic supercell in the Mohawk River Valley. A LEWP then raced across eastern NY into western New England before dissipating.

Application of Collaborative Science, Technology and Applied Research (CSTAR) IV work from a recently completed V-R shear tornado study (Frugis and Wasula 2013) was applied by the warning decision makers for the severe thunderstorm and tornado warnings. The Shear vs. Maximum Rotational Velocity nomogram (Fig. 18) was very helpful for the initial tornado warning and subsequent severe weather statements. Tornado warning lead times varied from a few minutes to as much as 10+ minutes.

The EF2 tornado was rare for the ALY forecast area, since 80% are usually F0/EF0 and F1/EF1 based on a 1980-2014 climatology. The maximum winds were estimated by the damage to be close to 110 kts (125 mph). A couple of barns were destroyed (Fig. 23a) and four high tension power line towers were twisted, crushed and destroyed (Fig. 23b). There were no fatalities, and only one serious injury near Mariaville Lake. This was the first EF2 tornado with a TDS in the Dual Pol era within the ALY CWA with the debris ball detected as high as 6-8 kft AGL in the CC data.

Determining the threat for tornadoes was challenging for forecasters in advance due to the lack of abundant instability (amount of surface heating was questionable) downstream over a large portion of eastern NY and the lack of an elevated mixed layer. In the future, it is hoped that forecasters will be able to better diagnose the pre-convective storm environment in the Northeast (Tornado vs. Severe Thunderstorm Watch threat), and continue the application of the V-R Shear local study results and new Dual Pol concepts (i.e. mentioning TDS's in severe weather statements).

8. ACKNOWLEDGEMENTS

Thanks to ALY Science Operations Officer, Warren R. Snyder, Dr. Alicia C. Wasula from Hudson Valley Community College and Shade Meteorology LLC, and Brian Miretzky from Eastern Region Scientific Services Division for reviewing this extended manuscript publication. The authors would also like to acknowledge the CSTAR program (Grant #: NA01NWS4680002).
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DISCLAIMER

9. REFERENCES

Frugis B. J., and T. A. Wasula, 2013: An updated version of the V-R Shear technique for issuing tornado warnings. Extended Abstract, *38th Natl. Wea. Assoc. Annual Meeting*, Charleston, SC, P1.28.

Gibson Ridge Software, 2013: GRlevel2Analyst Version, 2.0. [Available online at http://www.grlevelx.com/.]

LaPenta, K. D., G. J. Maglaras, J. S. Quinlan, H. W. Johnson, L. F. Bosart, T. J. Galarneau, 2000: Radar observations of northeastern United States tornadoes. Preprints, 20th Conference on Severe Local Storms, American Meteorological Society, Orlando, Fl., 356-359.

Thompson, R.L., R. Edwards, J.A. Hart, K.L. Elmore, and P.M. Markowski, 2003: Close proximity soundings within supercell environments obtained from the Rapid Update Cycle. *Wea. Forecasting*, **18**, 1243-1261.

Uccellini, L. W., P. J. Kocin, 1987: The interaction of jet streak circulations during heavy snow events along the East Coast of the United States. *Wea. Forecasting,* **2**, 289–309.

U. S. Department of Commerce, 1980-2014: StormData, National Climatic Data Center, Federal Building, 151 Patton Ave., Asheville, NC 28801-5001.

U. S. Department of Commerce, 2013: Storm Data*,* **55** (5). [Available from National Climatic Data Center, Federal Building, 151 Patton Ave., Asheville, NC 28801-5001].

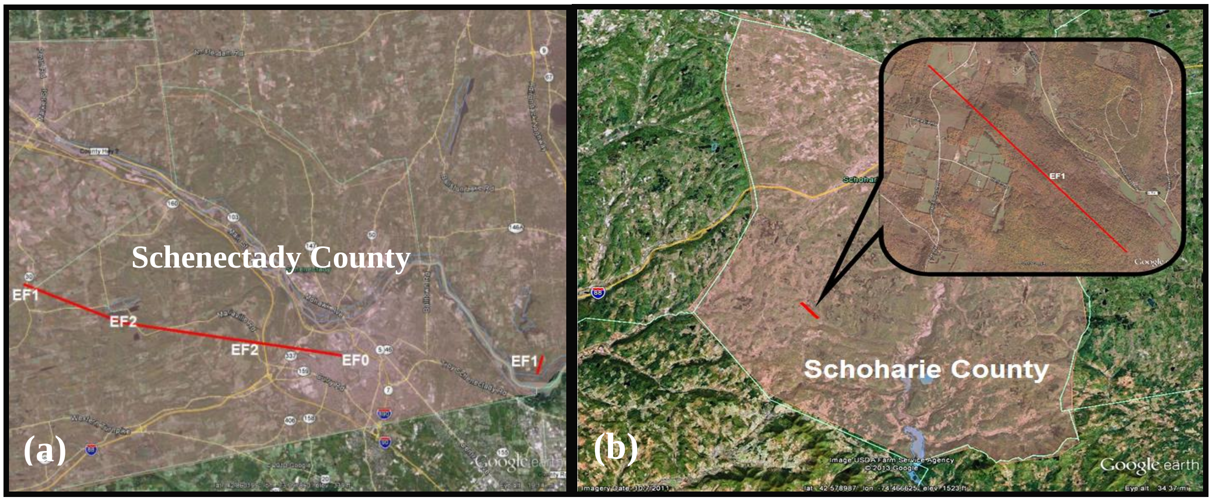

Figure 1: (a) Long Track Tornado in eastern Montgomery, and Schenectady Counties, and brief E1 tornado in southern Saratoga County, (b) Brief EF1 tornado in Schoharie County.

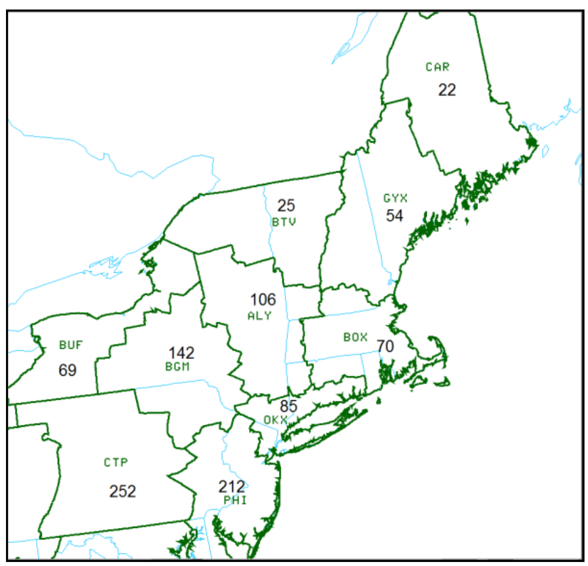

Figure 2: Number of tornados between 1980 and 2012 broken down by WFO CWA for the Northeastern United States (Frugis and Wasula 2013).

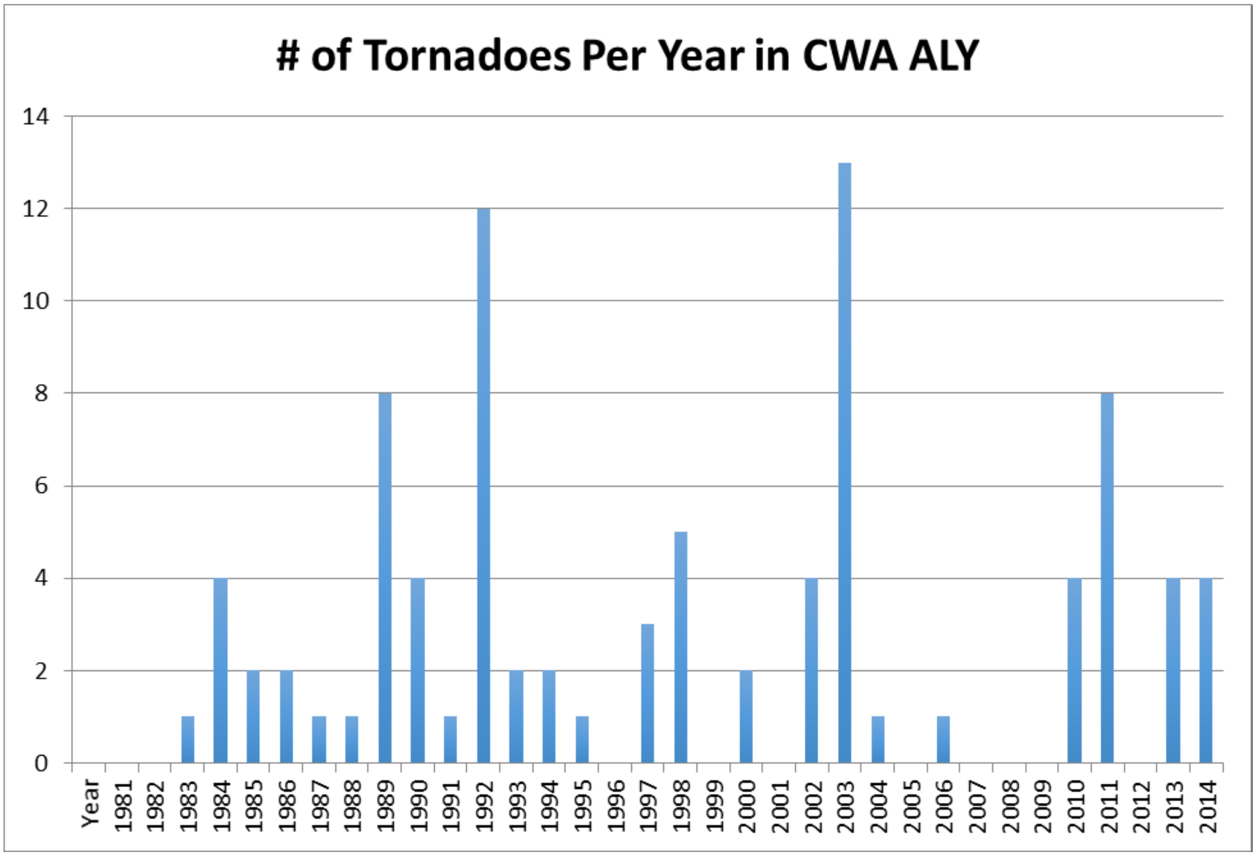

Figure 3: Number of Tornadoes by year in the Albany CWA from 1980 to 2014.

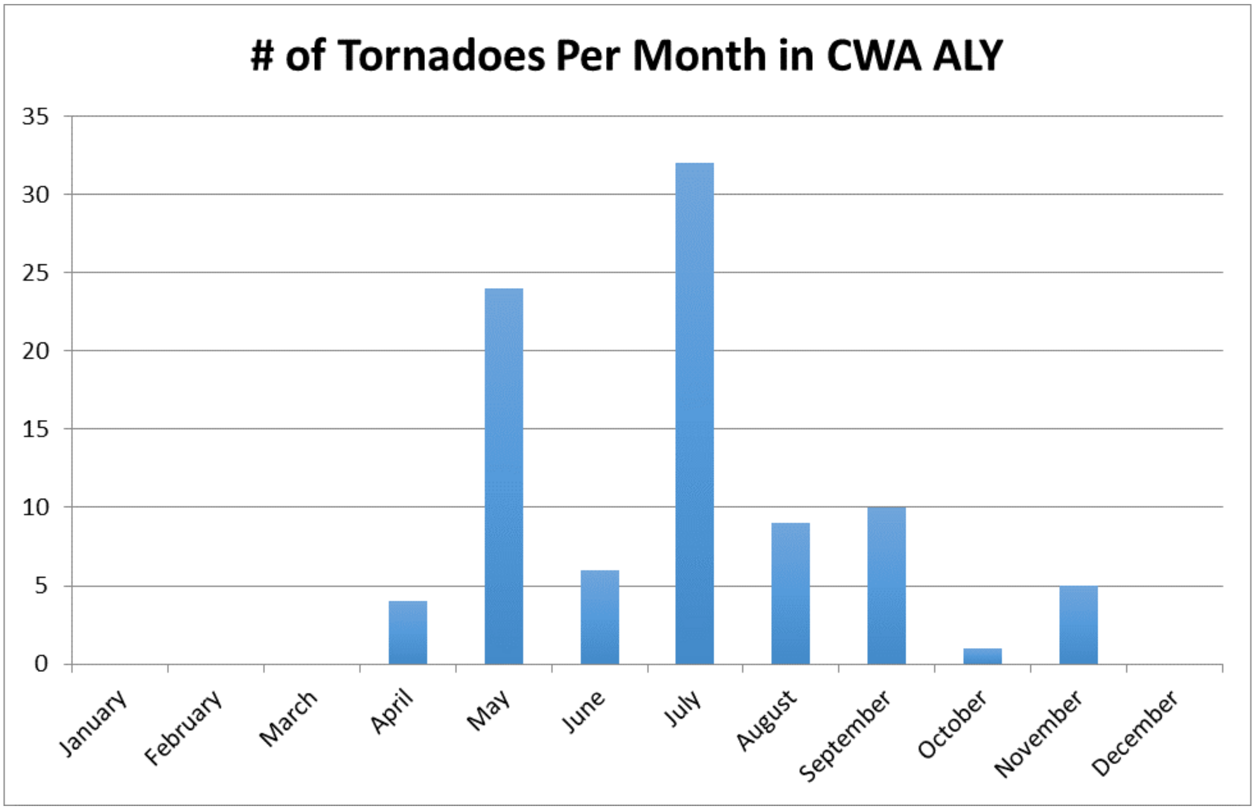

Figure 4: Number of Tornadoes by month in the Albany CWA from 1980 to 2014.

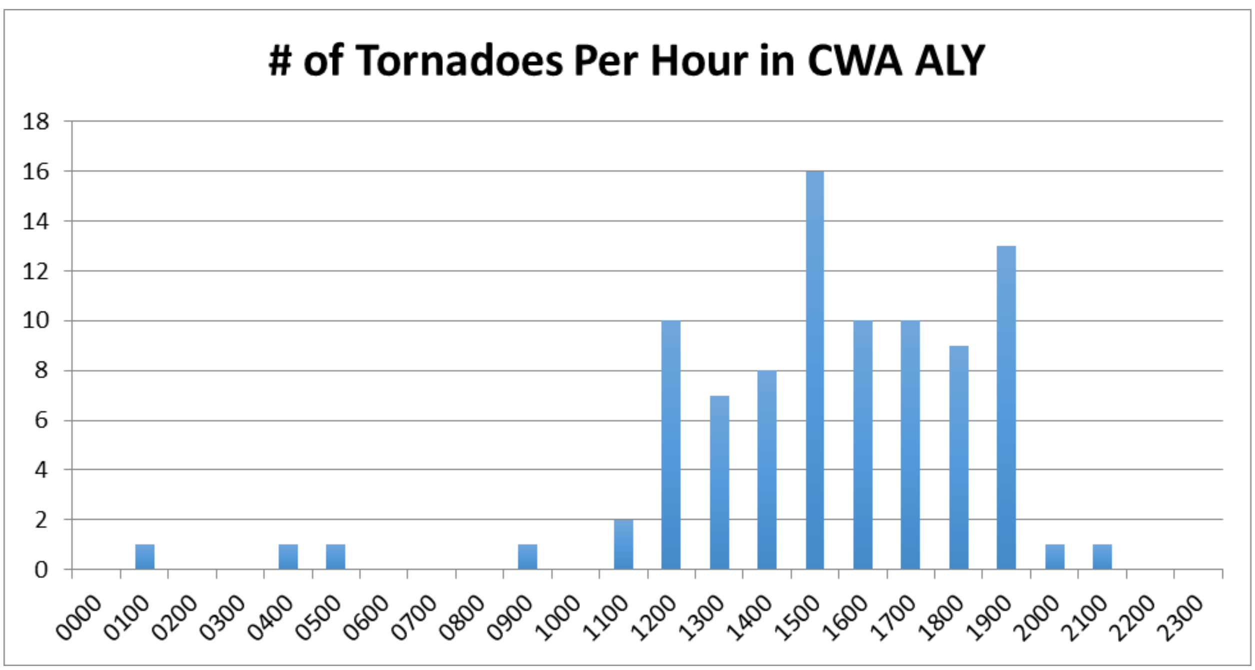

Figure 5: Number of Tornadoes by Time in EST for the Albany CWA from 1980 to 2014.

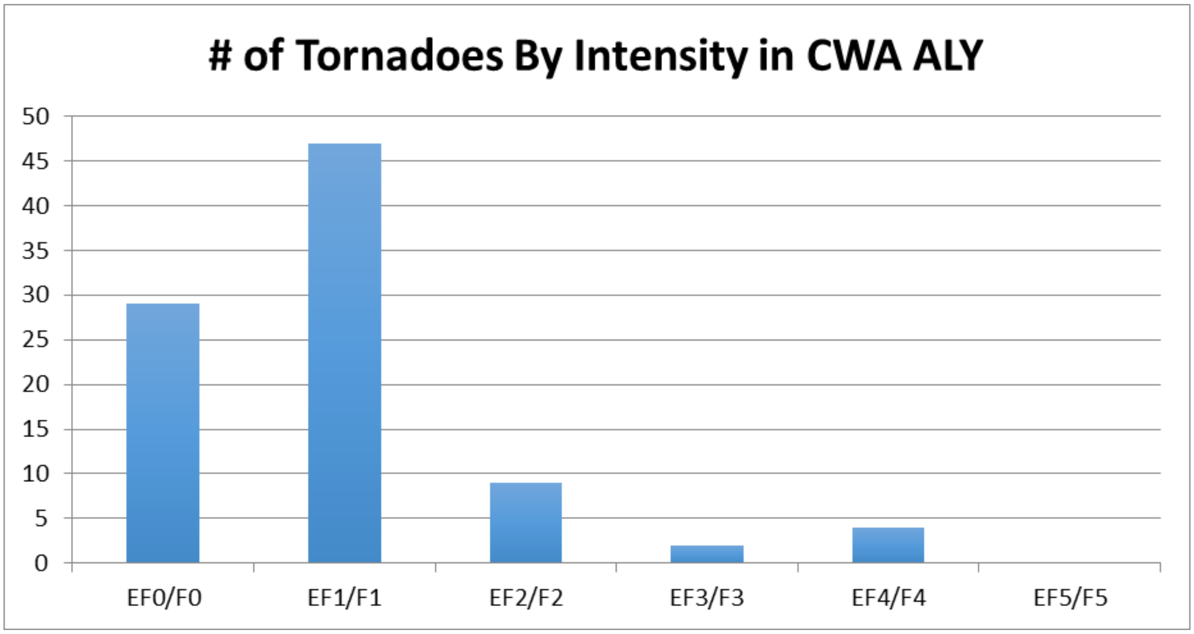

Figure 6: Number of Tornadoes by intensity or strength in the Albany CWA from 1980 to 2014.

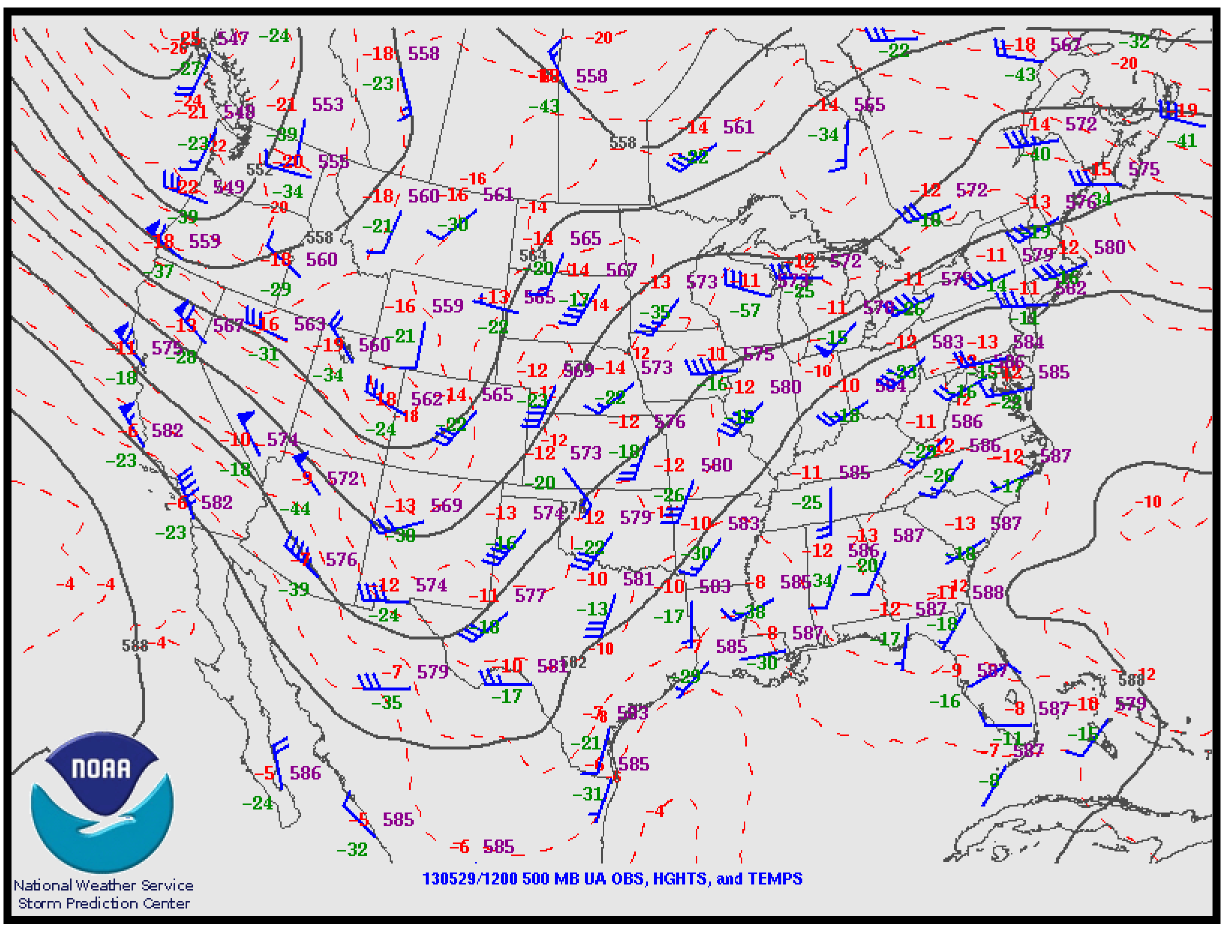

Figure 7: 500 hPa height (dam, solid), temperatures (°C, dashed red), winds (knots) and dewpoint depression from RAOB (green), valid 1200 UTC 29 May 2013 (www.spc.noaa.gov).

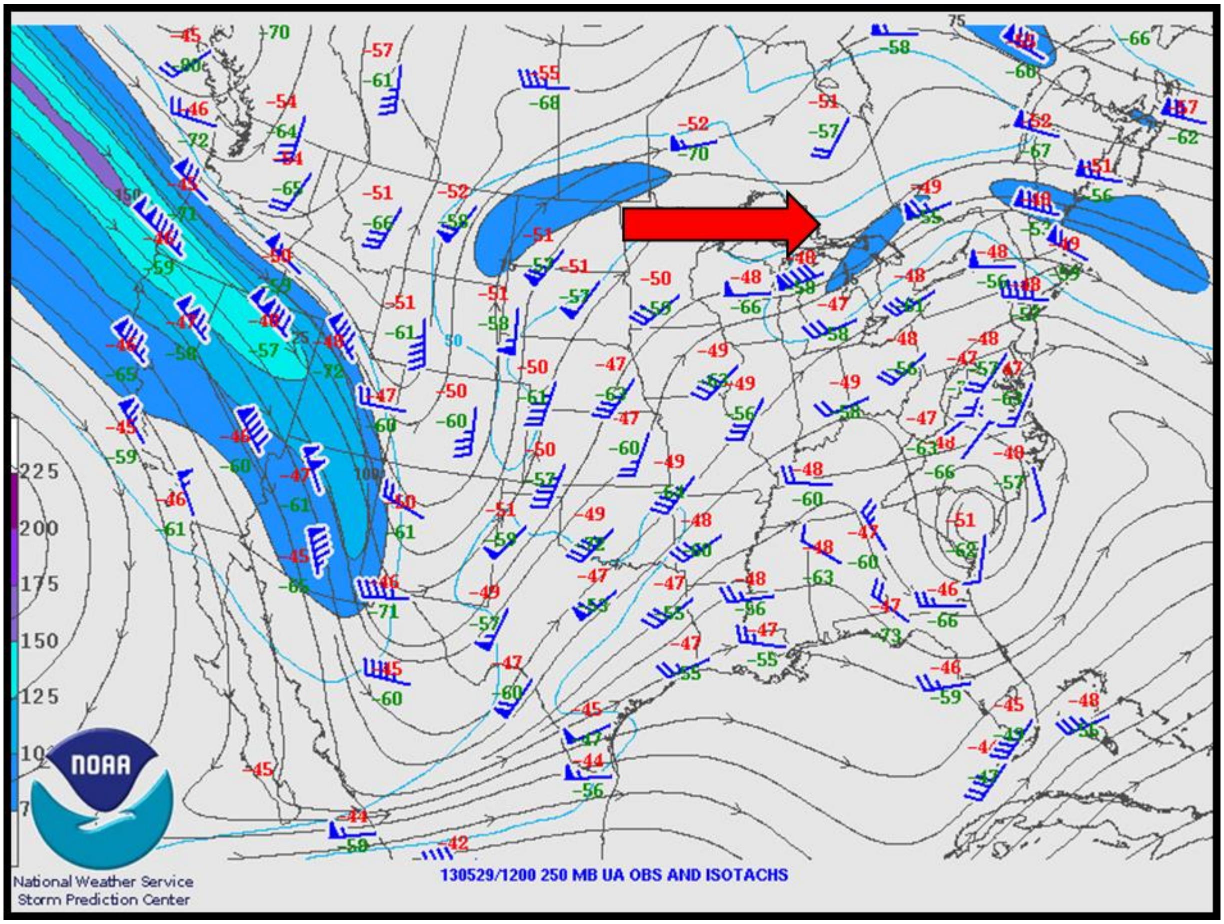

Figure 8: 250 hPa streamlines (black), temperatures and dewpoint depressions from RAOB network (°C, red and green digits), isotachs (shaded, knots), and winds (blue barbs, knots) valid 1200 UTC 29 May 2013 (www.spc.noaa.gov).

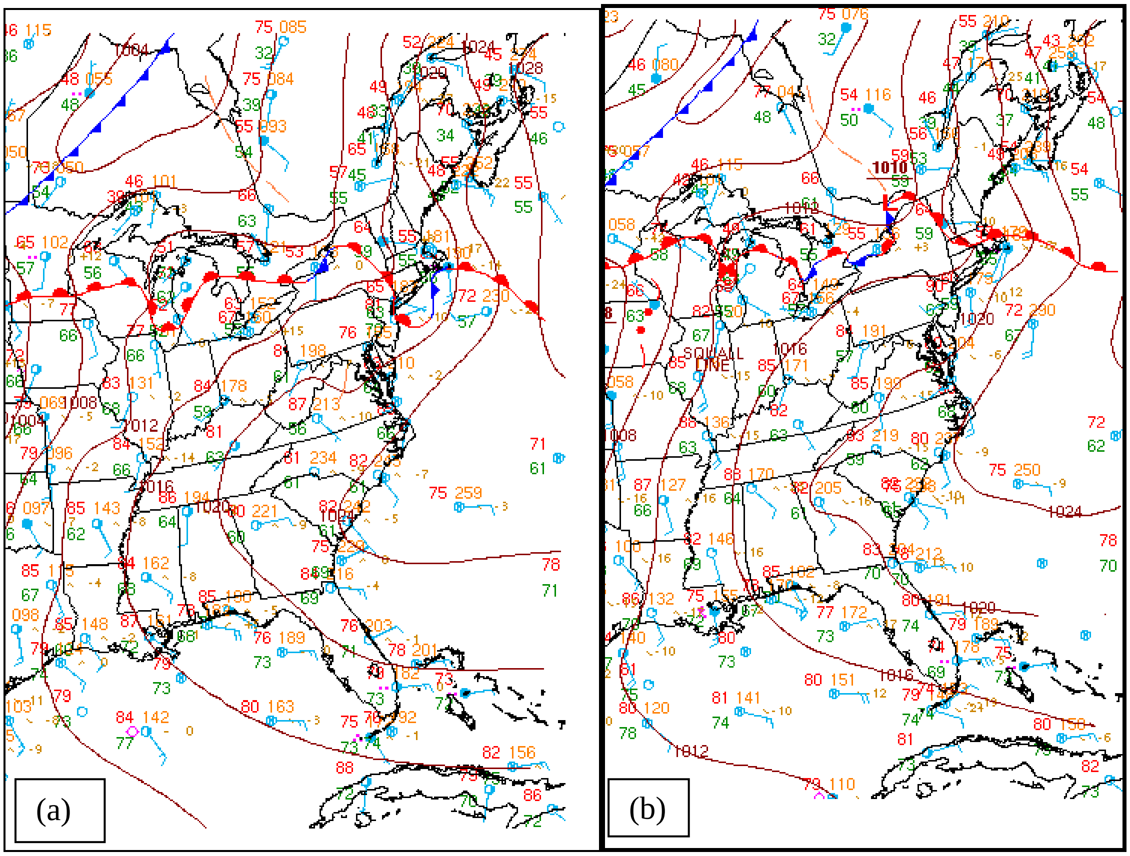

Figure 9: (a) 1800 UTC 29 May 2013 WPC Surface Map and (b) 2100 UTC 29 May 2013 WPC Surface Map.

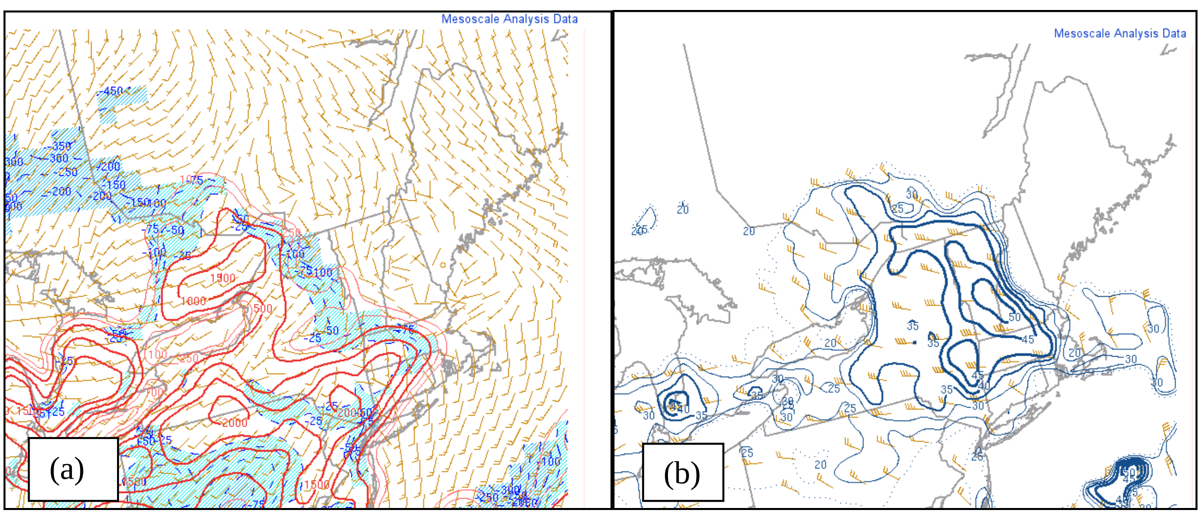

Figure 10: (a) 2300 UTC 29 May 2013 SPC Mesoanalysis Page (Rapid Refresh) SBCAPE (J kg^{-1}) red contoured every 500 J kg^{-1} and SBCIN (J kg^{-1}) and (b) Effective Bulk Shear (kts) from (www.spc.noaa.gov).

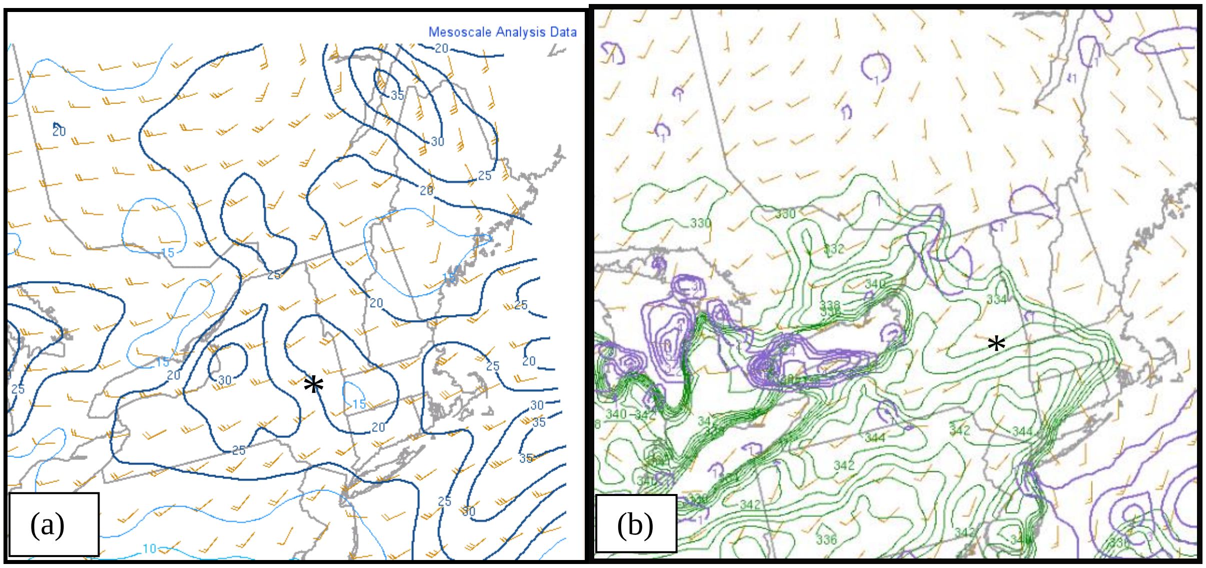

Figure 11: (a) 2300 UTC 29 May 2013 SPC Mesoanalysis (Rapid Refresh) 0-1km shear vectors (kts) contoured every 5 kts, and (b) Surface theta-e (K) and Advection every 2 K. Albany is starred (*) on the panels.

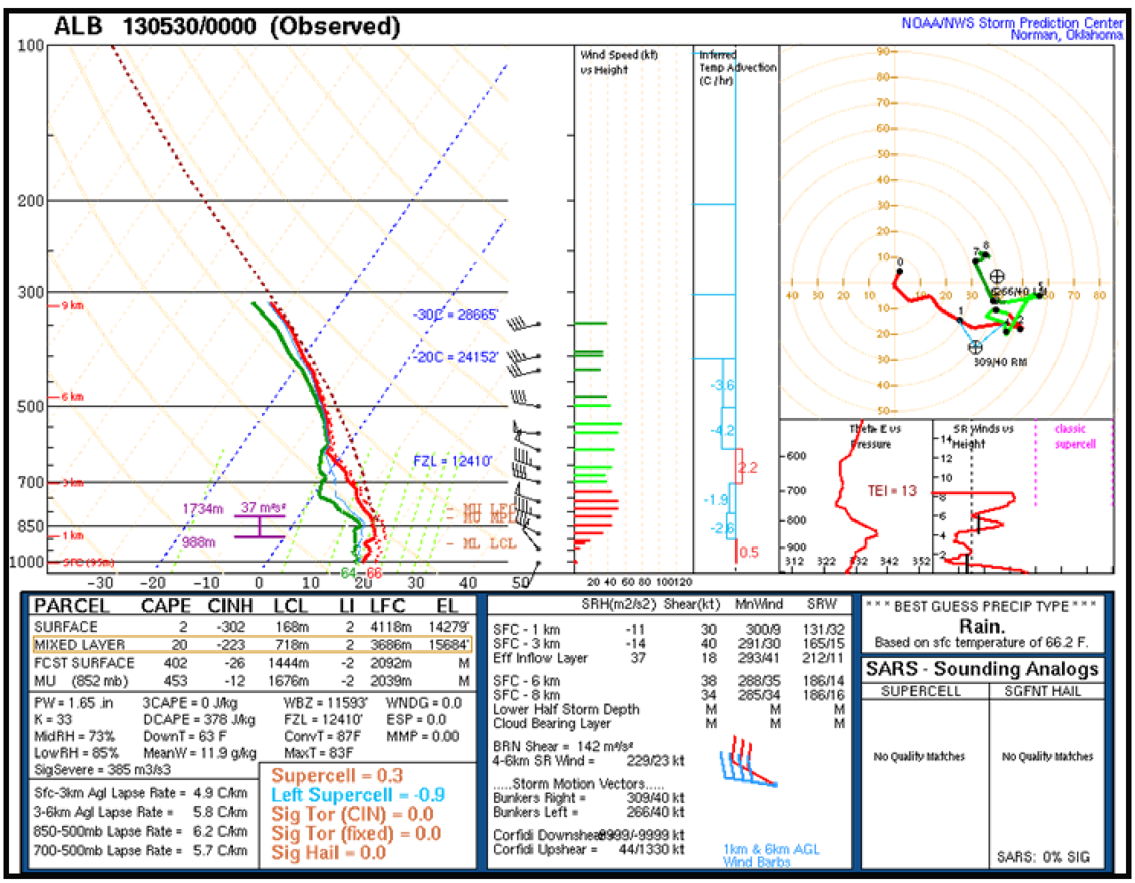

Figure 12: 0000 UTC 30 May 2013 Albany, NY (ALB) Sounding (www.spc.noaa.gov).

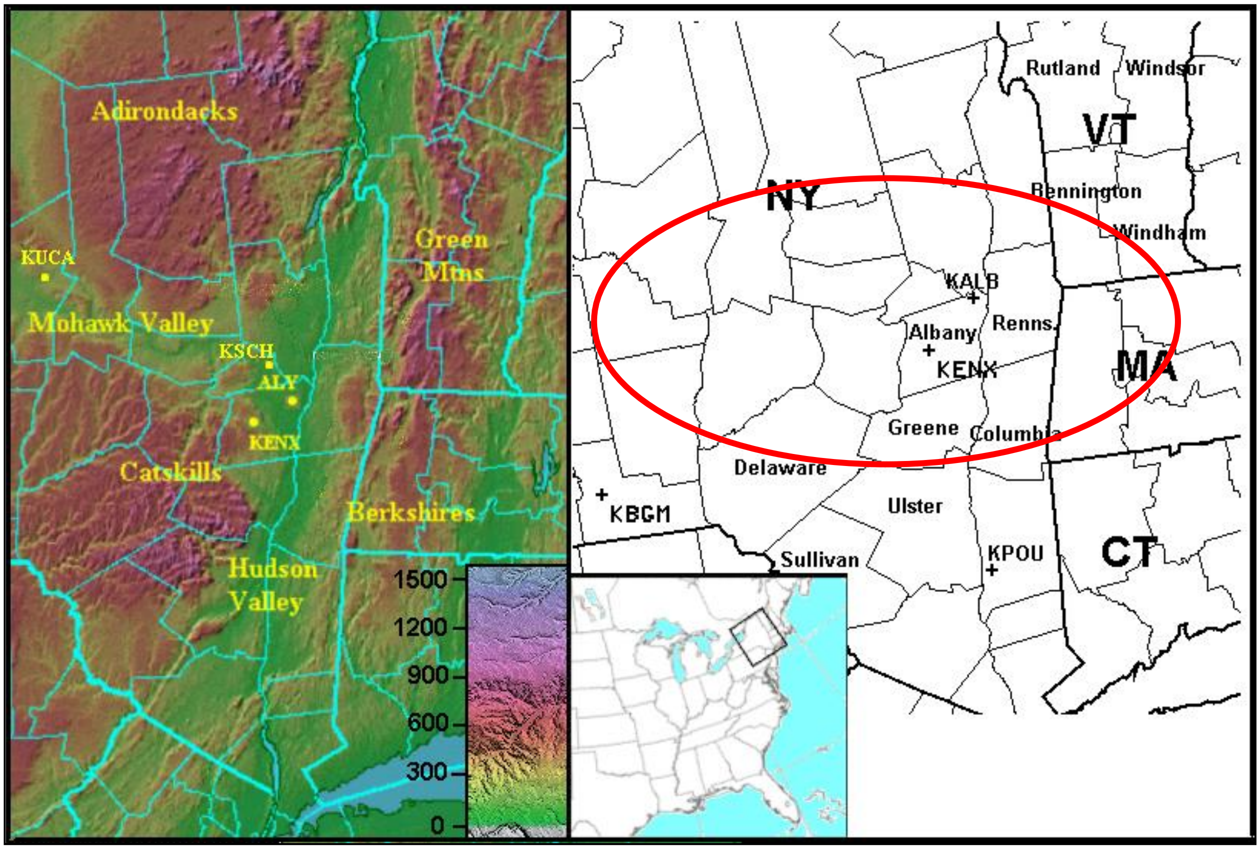

Figure 13: Map of eastern NY and western New England. The red circle denotes where tornadoes occurred and bow echo to line echo wave pattern.

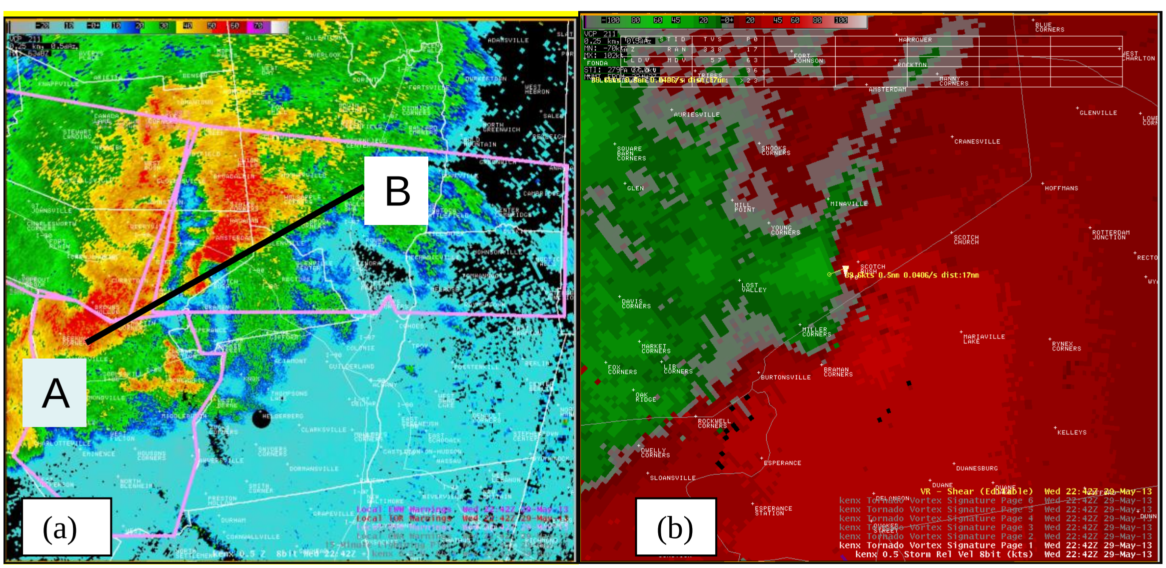

Figure 14: (a) 2242 UTC 29 May 2013 0.5° KENX Base Reflectivity (dBZ) and (b) SRM data with a TVS and V-R shear values overlayed. The line A-B in (a) will be shown in the next figure as a cross-section.

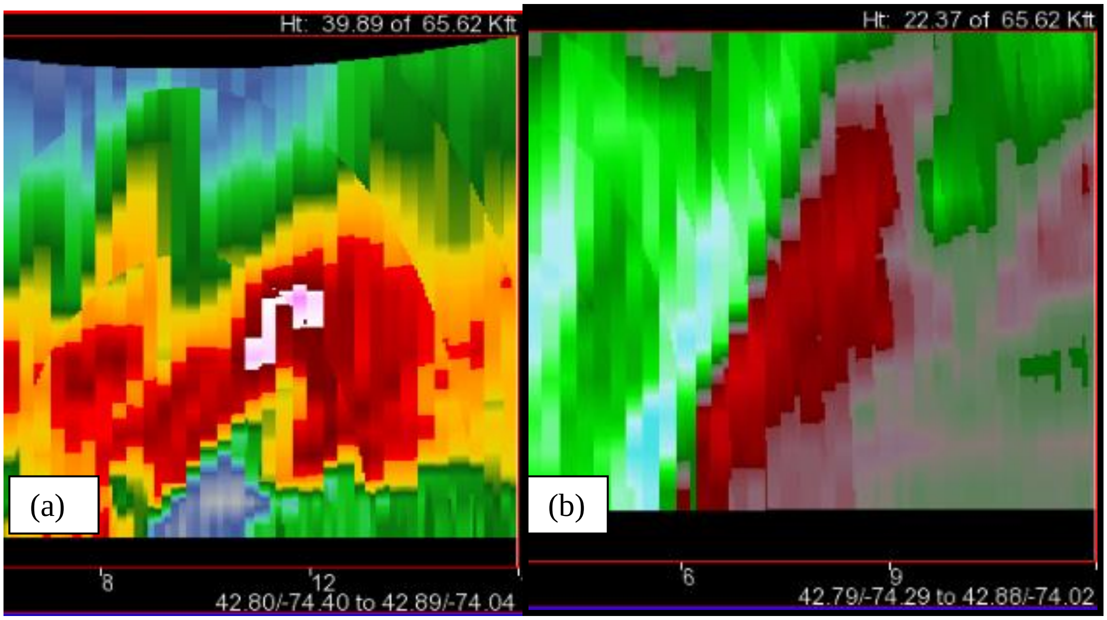

Figure 15: 2242 UTC 29 May 2013 KENX cross-section through Fig 14 (a) hook echo (a) 0.5°Base Reflectivity (dBZ) reflectivity cross-section shows the BWER and (b) the strong mid-level mesocyclone is shown where the mesocyclonic couplet had a V_m = 98.8 kts.

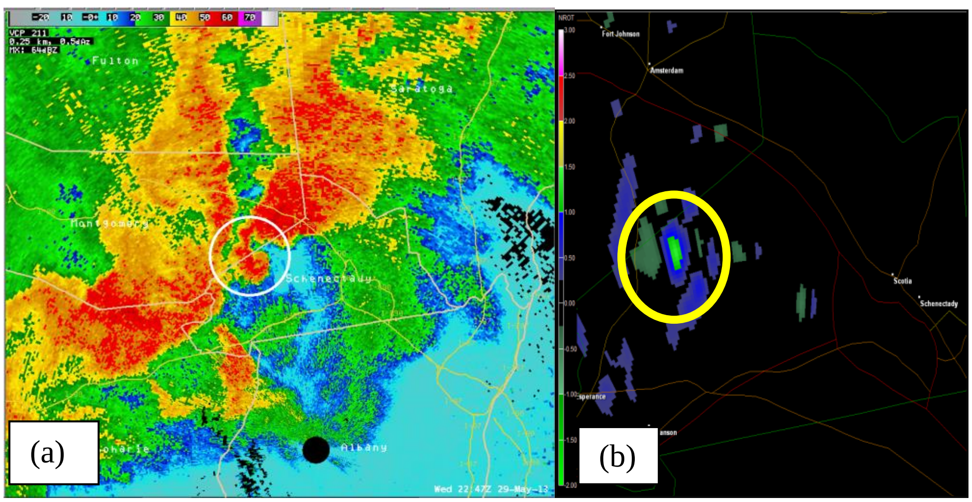

Figure 16: 2247 UTC 29 May 2013 KENX (a) 0.5°Base Reflectivity (dBZ) with hook echo in the white circle, and (b) GR2Analyst NROT value of 1.36 (yellow circle) over western Schenectady where the tornado was moving from extreme eastern Montgomery County into western Schenectady County as of 2245 UTC. Typically NROT values > 1.0 are significant for a possible tornado, and >2.5 is extreme based on the GR2Analyst guide.

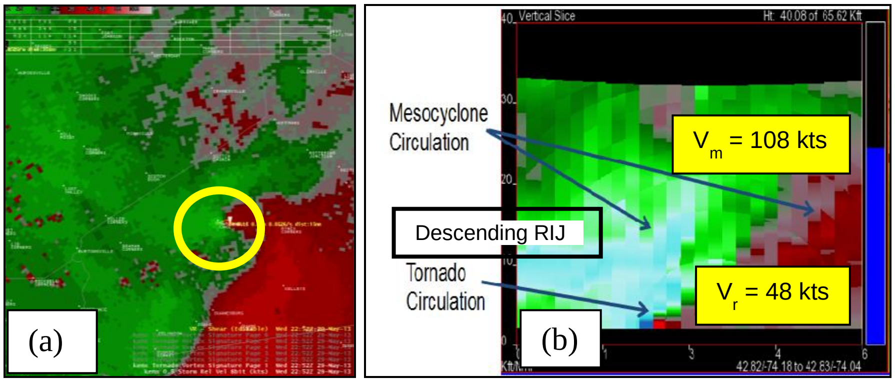

Figure 17: 2252 UTC 29 May 2013 KENX (a) 0.5° SRM (kts) where the TVS had a Vr = 48 kts and a shear value (S) = 0.0526 S^{-1} gate to gate over 0.5 nm at a distance of 15 nm from the RDA and a beam height of 1.5 kft AGL, and (b) SRM Cross-section of the TVS and the mesocyclone across Schenectady County (Frugis and Wasula 2013).

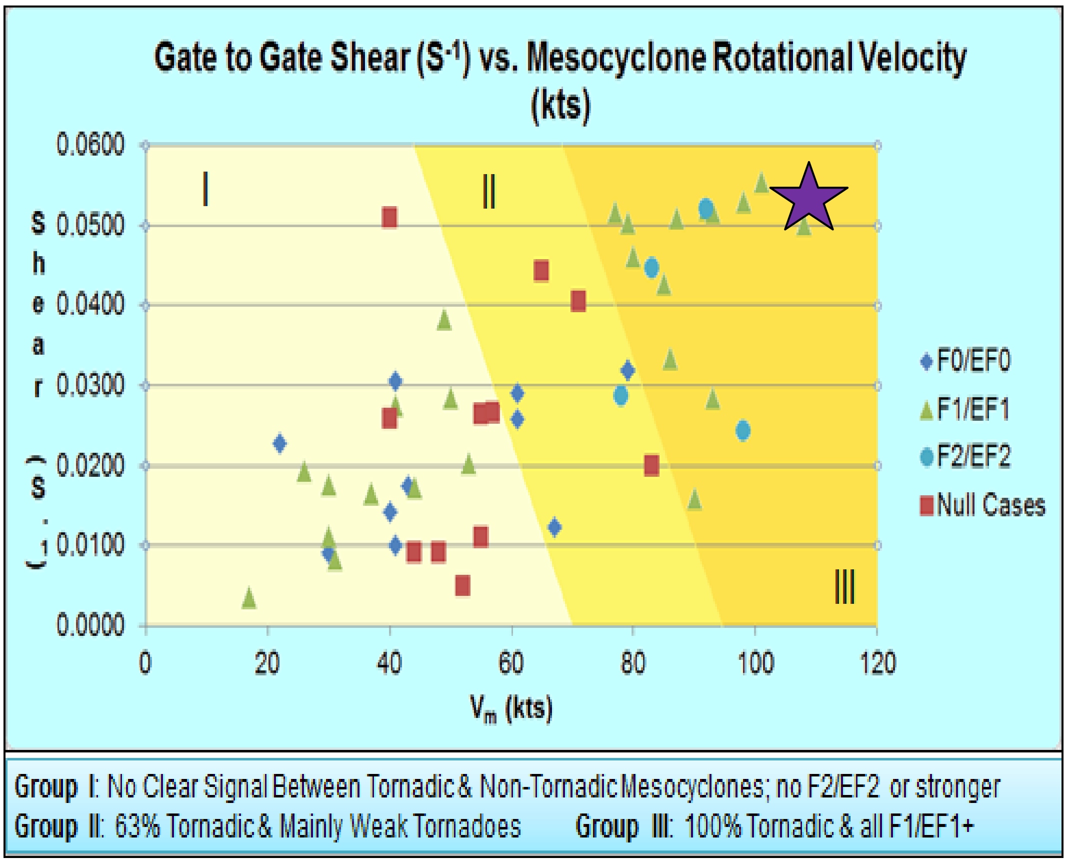

Figure 18: Gate to gate shear vs. Mesocyclone Rotational Velocity based off 41 tornadoes in or near the Albany CWA from 2003 to 2013. D (gate to gate shear calculation) was set to 0.5 for all storms from 2008 to 2013. The previous study methodology was used for D for events between 2003 and 2008. The large purple star is the placement for the EF2 Mariaville Lake tornado in Schenectady County (Frugis and Wasula 2013).

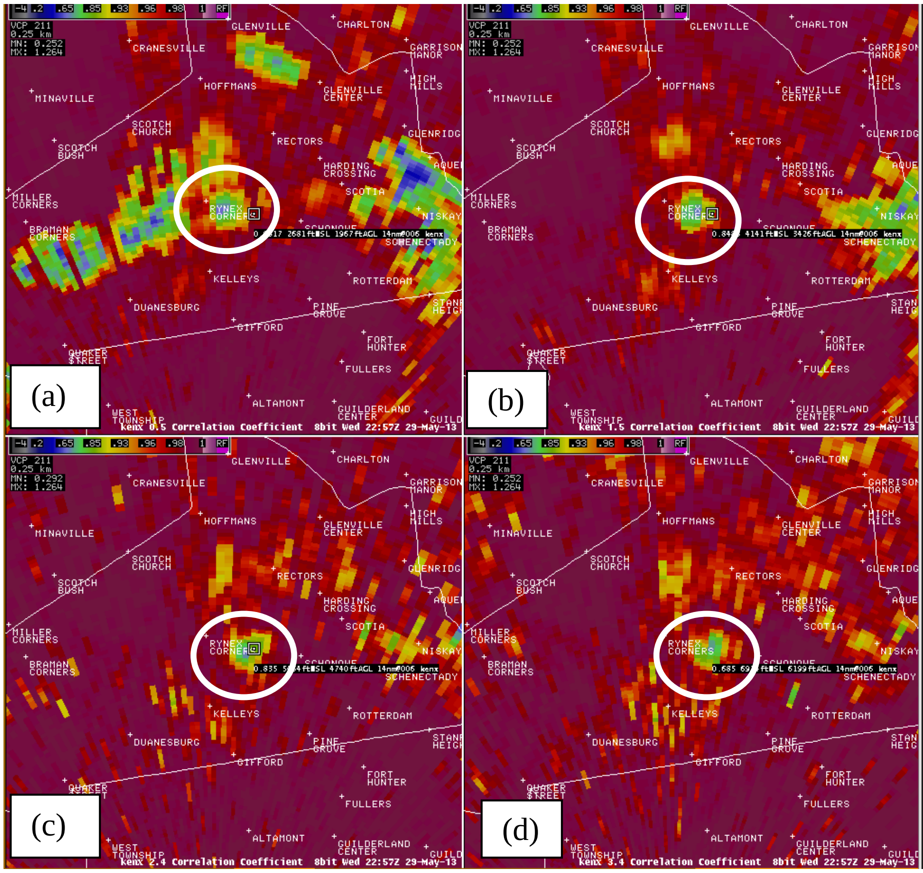

Figure 19: 2257 UTC 29 May 2013 KENX (a) - (d) 0.5⁰, 1.5⁰, 2.4,⁰ and 3.4⁰ correlation coefficient (CC) images of the tornadic debris signature with the tornado. The corresponding CC value on the 3.4⁰ elevation slice was 0.685.

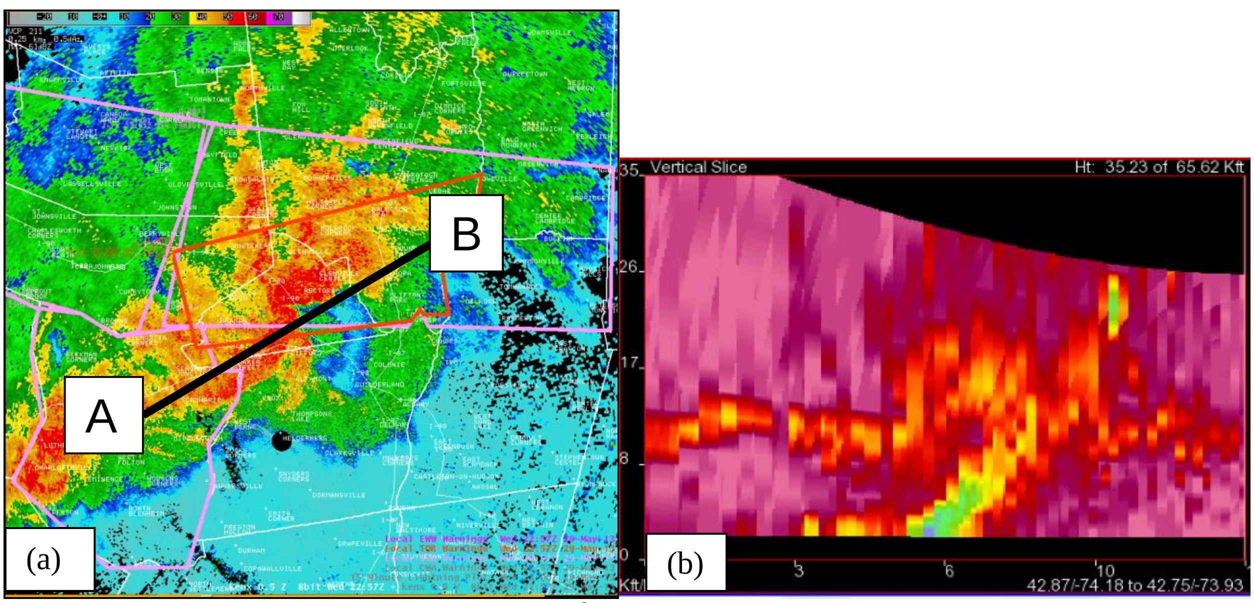

Figure 20: 2257 UTC 29 May 2013 KENX (a) 0.5⁰ Base Reflectivity (dBZ) and line A-B cross-section of the CC with the Four-Dimensional Storm Cell Investigator. The depressed CC values (0.8 or less) in the cross-section extended up to 8 kft AGL.

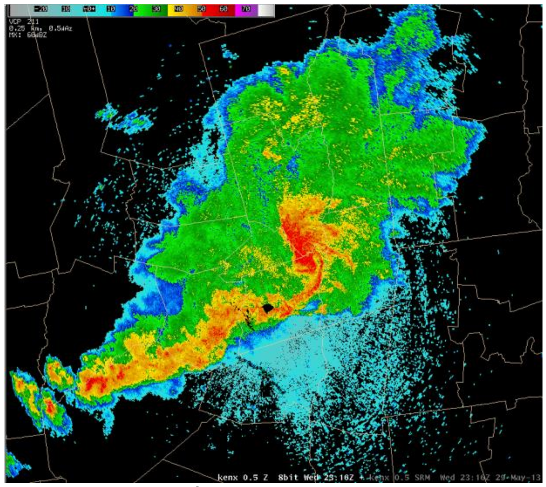

Figure 21: 2316 UTC 29 May 2013 KENX 0.5^0 Base Reflectivity (dBZ) depicting LEWP with northern bookend vortex.

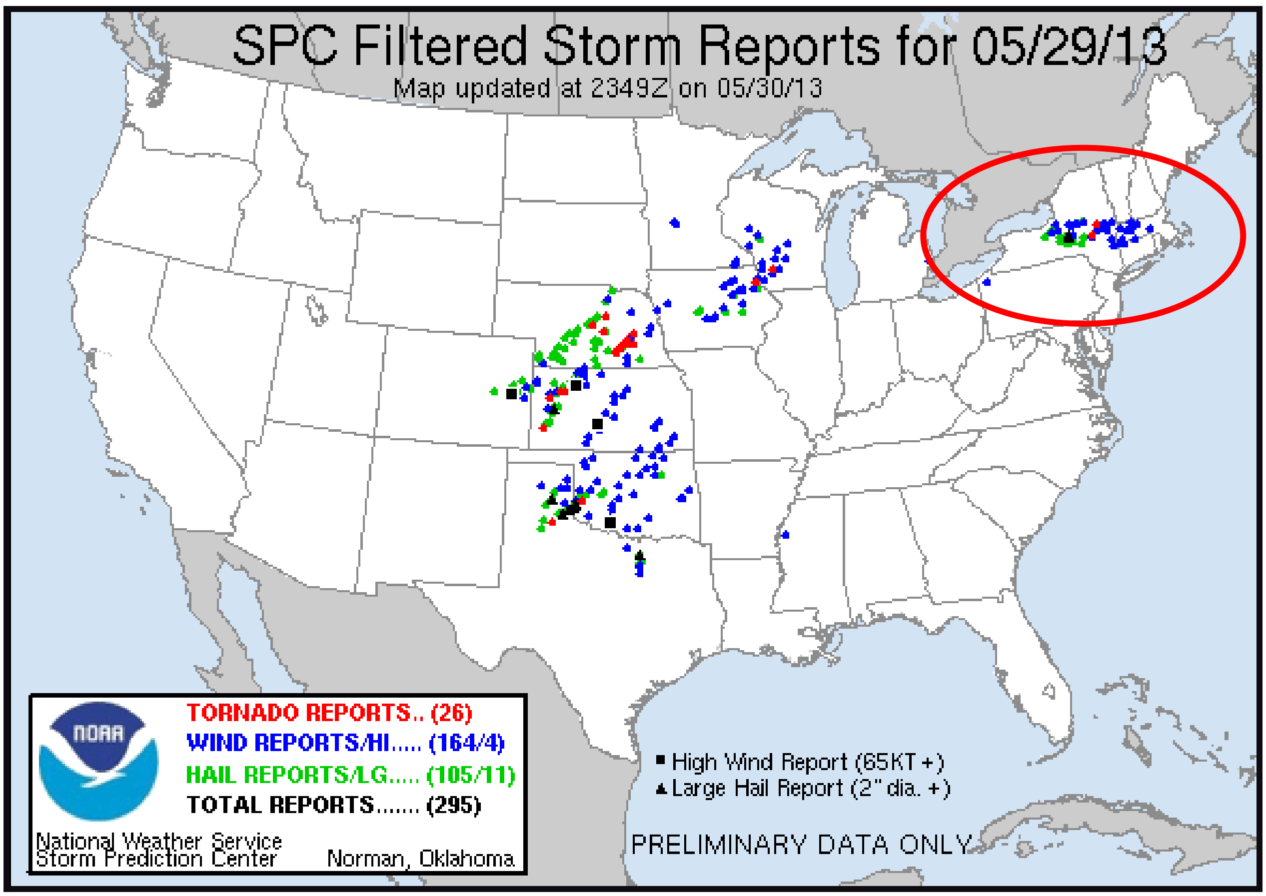

Figure 22: SPC Storm Reports for 29 May 2013 (www.spc.noaa.gov). The red circle indicates the numerous wind and large hail reports. There were 3 tornadoes in the ALY forecast area.

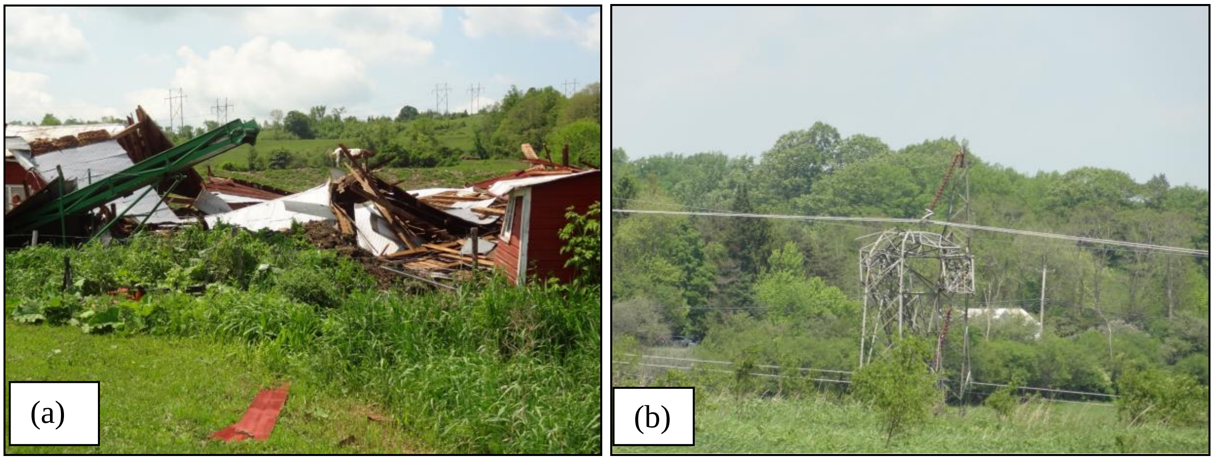

Figure 23: Damage from the long track tornado in extreme eastern Montgomery and Schenectady Counties: (a) EF1 damage in Scotch Bush, Montgomery County with a barn destroyed and (b) EF2 damage near Mariaville Lake where a high tension power line tower (one of four) was completely twisted and crushed.