P4.15 A STORM-SCALE ANALYSIS OF 16 JUNE 2008 SIGNIFICANT SEVERE WEATHER EVENT ACROSS NEW YORK AND WESTERN NEW ENGLAND

Thomas A. Wasula*
NOAA/National Weather Service, Weather Forecast Office, Albany, New York

1. INTRODUCTION

On 16 June 2008, a widespread severe weather event occurred across much of upstate New York (NY) and portions of New England. The Storm Prediction Center (SPC) posted a moderate risk that afternoon from the Mohawk River Valley, Greater Capital Region and southwestern New England southward into the Mid Atlantic region. The Northeast United States (including Pennsylvania (PA)) had over 200 severe reports (Fig. 1) of damaging winds in excess of 50 knots (58 mph), and severe hail (greater than 1.9 cm in diameter). There was also one confirmed tornado in the lower Hudson Valley. The vast majority of the severe reports were hail (165), with a few hail stones exceeding 5.0 cm in diameter (U.S. Department of Commerce, Storm Data 2008). The severe convection was focused ahead of a surface cold front and a potent short-wave trough rotating around a strong 500 hPa cutoff low, meandering southeast from Southern Ontario and Lake Superior.

Observational data, as well as short range deterministic and probabilistic model guidance suggested a major severe weather outbreak was about to occur. A cyclonically curved upper-level jet was located southwest of NY with a plume of divergence over the Northeast in the afternoon. Much of the southern portion of the Albany forecast area was in the favorable left front quad of a mid-and upper-level jet streak. An expected abundance of surface-based convective available potential energy (SBCAPE), steepening mid-level lapse rates, low wet bulb zero heights and high bulk shear values in the 0-6 km layer suggested the possibility of isolated to scattered supercells with very large hail. The forecaster thinking for the predominant convective mode this day, however, was for mainly multicellular convection with severe hail and damaging winds due to the steep mid-level lapse rates and strong jet dynamics.

This severe weather event was analyzed with some new tools available to operational forecasters during the past few warm seasons. Those tools include 3-D investigations of traditional base and derived products. The storm-scale analysis will focus on helpful techniques to determine the features that produced the copious hail reports.

2. DATA

Observational data used in the analysis include surface (LAPS) 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 charts and soundings are also used (www.spc.noaa.gov) from the severe weather thunderstorm archive. Standardized anomalies (Grumm and Hart 2001) calculated by using a 15-day (6-hour interval) mean of mid-level lapse rates over a 30-year period (1979-2008) using the NCEP-NCAR reanalysis are utilized. The 0.5°GFS analyses for this case are used to calculate the standardized anomalies with the respect to the background climatological fields created from the NCEP-NCAR reanalysis (Scalora 2009).

3. SYNOPTIC OVERVIEW

A cutoff low moved southward from south-central Ontario to the Great Lakes region at 1200 UTC 16 June 2008 (Fig. 2). The core of the coldest air at 500 hPa was -22 ºC over southwestern Ontario. Several short-wave troughs rotated through the neutral-tilted mid-level trough over the lower Great Lakes and into the Northeast. A strong mid-level jet streak of around 50 kts encroached the Northeast, as some mid-level ridging moved downstream of New England. Much of NY, PA, NJ, and southwestern New England in the afternoon were located near the favorable left front quadrant of mid- and upper-level jet streaks (Uccellini and Kocin 1987; Nemeth and Farina 1994) with strong divergence aloft (Fig. 3).

A short-wave trough and a weak warm front or prefrontal trough moved eastward across upstate NY and New England between 1000

*Corresponding author address: Thomas A. Wasula, NOAA/NWS Weather Forecast Office, 251 Fuller Rd, Albany NY, 12203. E-mail: tom.wasula@noaa.gov

UTC-1400 UTC with some showers and isolated thunderstorms. The shower activity helped moisten the boundary layer with surface dewpoints rising back into the 13-18°C range across eastern NY and western New England (not shown). Pronounced clearing occurred in the wake of the morning disturbance. This led to significant surface heating and destabilization out ahead of a cold front and a potent short-wave trough rotating around the cutoff low. This cold front and its associated upper trough were the key focusing mechanisms for the severe thunderstorms in the afternoon.

4. MESOSCALE AND SOUNDING ANALYSIS

The sounding at Albany at 1200 UTC 16 June 2008 (Fig. 4) had a SBCAPE value of less than 1000 J kg^{-1} but had a 0-6 km deep shear value of 49 kts. A prefrontal trough moved through eastern NY in the morning with scattered showers. The low and mid-level moisture associated with the showers was evident in the sounding. The mid-level lapse rates were not particularly steep initially, but the wet bulb zero heights were about 9.7 kft AGL. The sounding showed low-level veering from the surface to about 600 hPa. The amount of surface heating and abundance of instability was questionable for the development of isolated to scattered supercells at 1200 UTC.

A special 1800 UTC sounding was done at Albany. This sounding (Fig. 5) showed critical information pertaining to the changing mesoscale environment. The freezing level was 10.9 kft AGL, and the -20°C height was 20.2 kft AGL. The 850-500 hPa lapse rates steepened to about 7°C km^{-1}. The SBCAPE value was 1,324 J kg^{-1}. The 1800 UTC LAPS data had SBCAPEs in the 1000-3000 J kg^{-1} range (not shown) across central-eastern NY, northeastern PA, northern NJ, and western New England. The Lifted Index was -7°C. There was still 40-50 kts of shear in the 0-6 km layer indicative of possible supercells. The Lifting Condensation Level (LCL) height was a little high at 3.6 kft AGL. If the LCL heights were lower with more SBCAPE or MLCAPE, then the environment may have been more conducive for tornadic supercells (Thompson et al., 2003). The flow was fairly unidirectional in the 850 hPa to 300 hPa layer indicative that any multicellular or supercell development was likely to form into convective lines.

The mid-level lapse rates were very steep ahead of the cold front and its attendant short-wave trough. The 1800 UTC 16 June mid-level lapse rates steepened to 6.5 to 7.5°C km^{-1} according the LAPS data (Fig. 6) over PA, NY, NJ and portions of western New England. The use of standardized anomalies allowed for an assessment of these significant lapse rates. Previously, Grumm and Hart (2001), and Stuart and Grumm (2009) showed standardized anomalies to be an effective approach for analyzing and forecasting significant weather events. The Global Reanalysis standardized 850-500 hPa lapse rate anomalies calculated from the NCEP/NCAR 30-year baseline climatology from 1979 – 2008 (Scalora 2009) were very impressive. These lapse rates were 2 to 3.5 standard deviations greater than normal (Fig. 7). The precipitable water standardized anomalies were near normal, where values were common in the 20 to 30 mm range across the region (not shown). As a result, flash flooding was not a major threat.

Visible satellite imagery showed significant clearing occurred across central and eastern NY ahead of the cold front and the short-wave in the early afternoon (Fig. 8). Temperatures by 1800 UTC had warmed to around 25°C with surface dewpoints ranging from 14-17°C. The satellite picture indicated convective initiation was well underway in advance of the vigorous short-wave trough prior to 1745 UTC west of the Hudson River Valley.

5. STORM-SCALE RADAR ANALYSIS

Traditional 2-Dimensional and new 3-Dimensional graphical displays of radar data were analyzed during the warning decision making process. The 3-Dimensional software included GR2Analyst (Gibson Ridge Software, 2006) and the Four Dimensional Stormcell Investigator (Stumpf et. al 2006), otherwise known as FSI. Several strong to severe thunderstorms moved across western and central NY from 1600-1800 UTC producing several severe hail reports. The convection evolved into multicellular lines and clusters.

One multicellular cluster approached the city of Albany at 1832 UTC (Fig. 9), as it moved across southern Schenectady and extreme northern Albany counties. The cluster was located north of the KENX RDA. This cluster continued to strengthen with better vertical structure over the next few volume scans. The 1855 UTC 4-panel from FSI indicated with the Constant Altitude Plan Position Indicator (CAPPI) that the 50 dBZ reflectivity echo core height reached approximately 27 kft AGL (Fig. 10). This was around 7 kft above the -20°C height. The updraft strength with the high reflectivity core height increased the potential for severe hail. Past research has shown when interrogating a storm for potential hail that the height of the 50 to 60 dBZ reflectivity core can be a successful method to identify large hail (Donavon and Jungbluth 2007). Furthermore, at 1855 UTC, a cross-section was done in GR2Analyst for the same storm. The cross-section showed the 60 dBZ reflectivity echo extended to about 30 kft AGL (Fig. 11). A Bounded Weak Echo Region (BWER) was also present in the cross-section, where lower reflectivities are capped off by higher reflectivities at 15 kft AGL. The BWER extended down to about 10 kft AGL. The BWER indicated an intense updraft region, where a large hail vault developed, which increased significantly the probability of severe hail. Several reports of golf ball to lime-size hail (4.4-5.1 cm in diameter) were reported in the suburbs around the city of Albany, such as the cities of Guilderland and Colonie in northern Albany County. The large, destructive hail lasted on the order of 10-20 minutes. The use of the KBGM radar was helpful, since the storm was located near the KENX cone of silence. The KBGM radar recorded a peak gridded Vertically Integrated Liquid (VIL) value of 55-60 kg m^{-2}, whereas the KENX radar at that same time was only 45-50 kg m^{-2} (not shown). The office VIL of the Day (Kitzmiller and Breidenbach 1993) program yielded a threshold value for severe hail at 43 kg m^{-2} from the 1200 UTC sounding. At 1909 UTC, the same storm continued to maintain a strong updraft and its associated mid level rotation. The 50 dBZ reflectivity core continued to reach 30 kft AGL with more quarter to golf ball size hail reported (not shown).

At 1949 UTC, another severe thunderstorm moved southeast of the KENX RDA. In FSI, the PPI reference line through the cell in extreme northeastern Greene County yielded an impressive vertical cross-section with the 65 dBZ reflectivity core to approximately 24 kft AGL (Fig. 12). The CAPPI illustrates the height of this echo, where a report of golf ball size hail came in from the town of Hannacroix in northeastern Greene County.

The most impressive thunderstorm of the day passed north of the city of Poughkeepsie at 2142 UTC. This severe thunderstorm exhibited supercell characteristics with very strong mid-level rotation. The KENX radar started showing a Three-Body Scatter Spike (TBSS) or hail spike (Lemon 1998) at this time (not shown) for the lowest two elevation tilts of the radar which was in VCP-212. The derived data depicted an intense hail vault to the supercell at this time with gridded VIL values of excess of 60 kg m^{-2}, Echo Tops of 40-45 kft AGL, nearly 10 pixels of >57 dBZ in the Layer Reflectivity Maximum (LRM) 2 product between 24-33 kft AGL, and three pixels exceeding 57 dBZ's in the LRM 3 product between 33-60 kft AGL (Fig. 13). A 60 dBZ reflectivity 3-D isosurface display of the cell in GR2Analyst showed this reflectivity core to around 30 kft AGL (Fig. 14). This was well above the -20°C height from the KALY 1800 UTC sounding. Forecasters continued to use these 3-D products to issue timely warnings in conjunction with traditional D2D products. Multiple reports of golf-ball size came in from Hyde Park north of the city of Poughkeepsie prior to 2200 UTC.

The 2146 UTC volume scan of data continued to show a TBSS (Fig. 15a and b) with a maximum base reflectivity of 70 dBZ in the lower two tilts, however the storm started to show strong low-level rotation in the lower few tilts with a Tornado Vortex Signature (TVS). The TVS was showing up for the second consecutive scan with the current one showing with the Storm Relative Motion data 26.3 kts of rotation with a shear value of 0.030 s^{-1} at the 0.5° tilt (Fig. 15c), and 29.5 kts of rotation with a shear value of 0.034 s^{-1} on the 0.9° elevation angle (Fig. 15d). A tornado warning was issued, but not verified. Primarily large hail was reported with this storm with a few trees down also near Hyde Park, as the reflectivity core descended to the surface. This storm was located 48-50 nautical miles from the KENX RDA. The 0.5° tilt of the radar is 5.8-6.0 kft AGL near Hyde Park when the tornado warning was issued. It was determined the mid-level rotation of the updraft was being captured or there was an elevated TVS, but it never descended to the ground with this particular supercell. Many of the strong to severe thunderstorms continued to form into a line echo wave pattern, as they moved east of the eastern Catskills and mid Hudson Valley into western New England and Long Island later that afternoon into the early evening.

6. SUMMARY

A significant severe weather outbreak occurred across the Northeast on 16 June 2008 with over 200 severe weather reports. The majority of the severe reports were hail that caused millions of dollars of agriculture damage in a few NY counties. Sufficient deep shear and instability were in place ahead of a strong short-wave trough and cold front associated with a cutoff low north of the upper Great Lakes Region. Portions of NY were in the left front quadrant or cyclonic exit region of a vigorous mid- and upper-level jet streak with strong divergence aloft. Anomalously strong mid-level lapse rates contributed to the widespread severe convection. The convective environment was conducive for multicellular and supercellular convection that did eventually form into clusters and lines.

Forecasters used traditional 2-D radar products in conjunction with new 3-D visualizations from GR2Analyst and FSI. The 3-D radar displays greatly helped operational forecasters put out timely warnings for mainly severe hail producing thunderstorms. The most helpful 3-D displays were cross-sections and isosurfaces of reflectivity (Neitfeld 2006) and the use of the CAPPI in FSI. The ALY forecast office was able to yield timely storm-scale severe thunderstorm warnings (25.5 minute lead time average) with an excellent probability of detection (0.93), a low false-alarm ratio (0.17) and a high critical success index (0.78) with the new advanced technology. It is hoped these 3-D visualization tools will continue to aid forecasters in forecast operations and future research studies to enhance warning language with the new one inch hail criteria in place this year.

7. ACKNOWLEDGEMENTS

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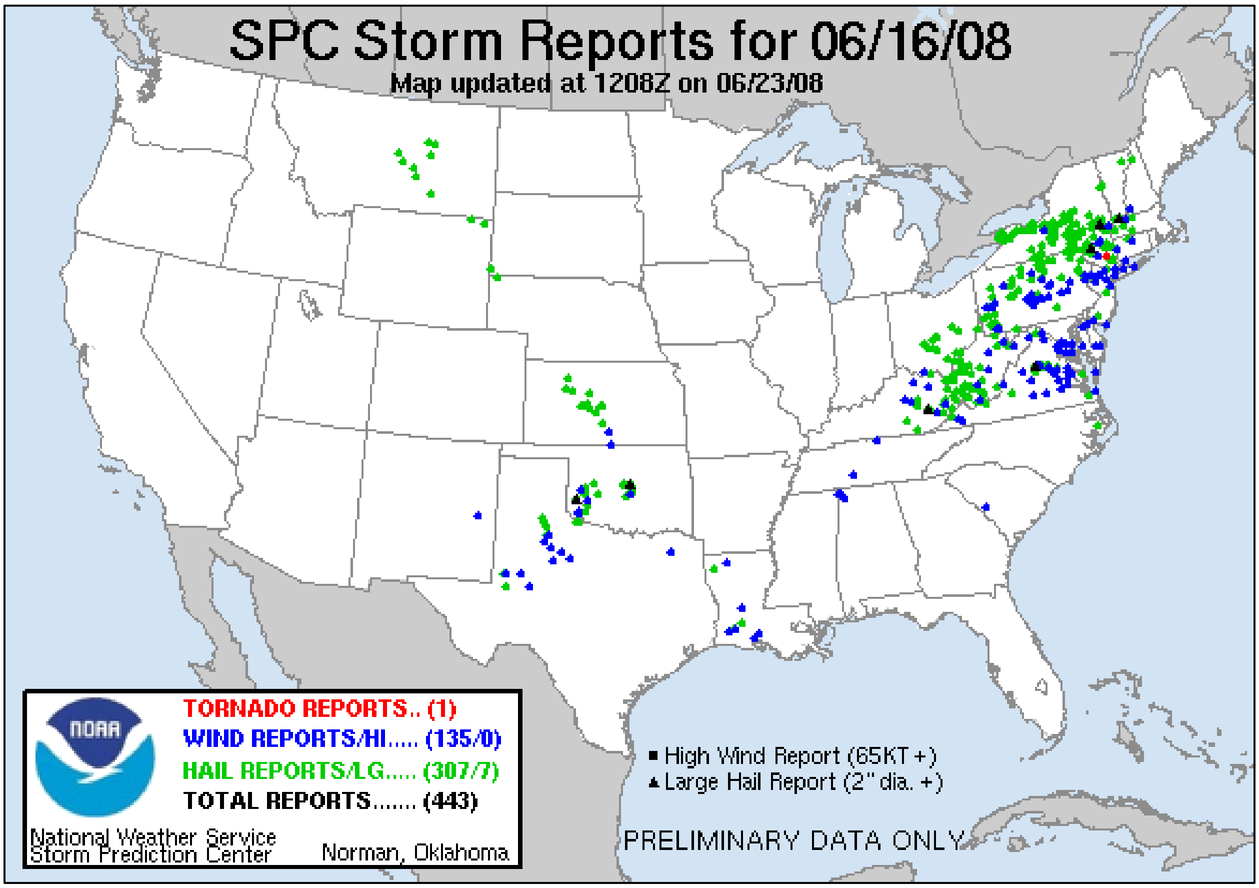

Figure 1: SPC Storm Reports for 16 June 2008 (www.spc.noaa.gov).

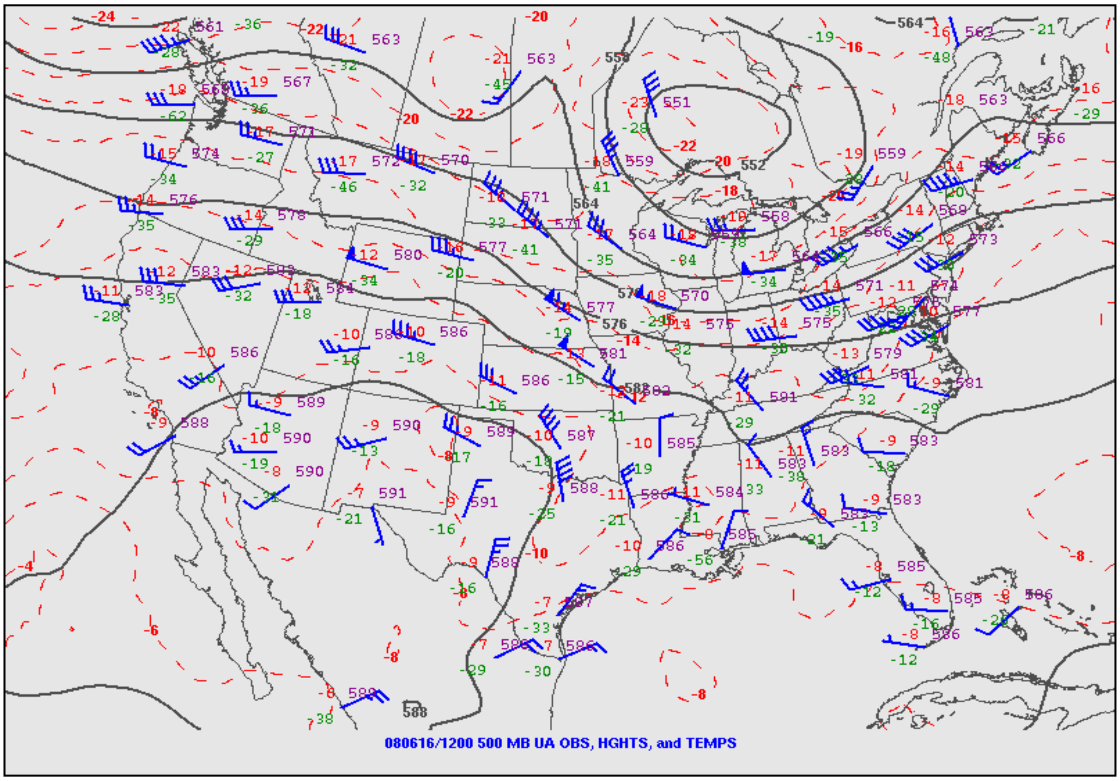

Figure 2: 500 hPa height (dam, solid), temperatures (°C, dashed red), winds (knots) and dewpoint depression from RAOB (green), valid 1200 UTC 16 June 2008 (www.spc.noaa.gov).

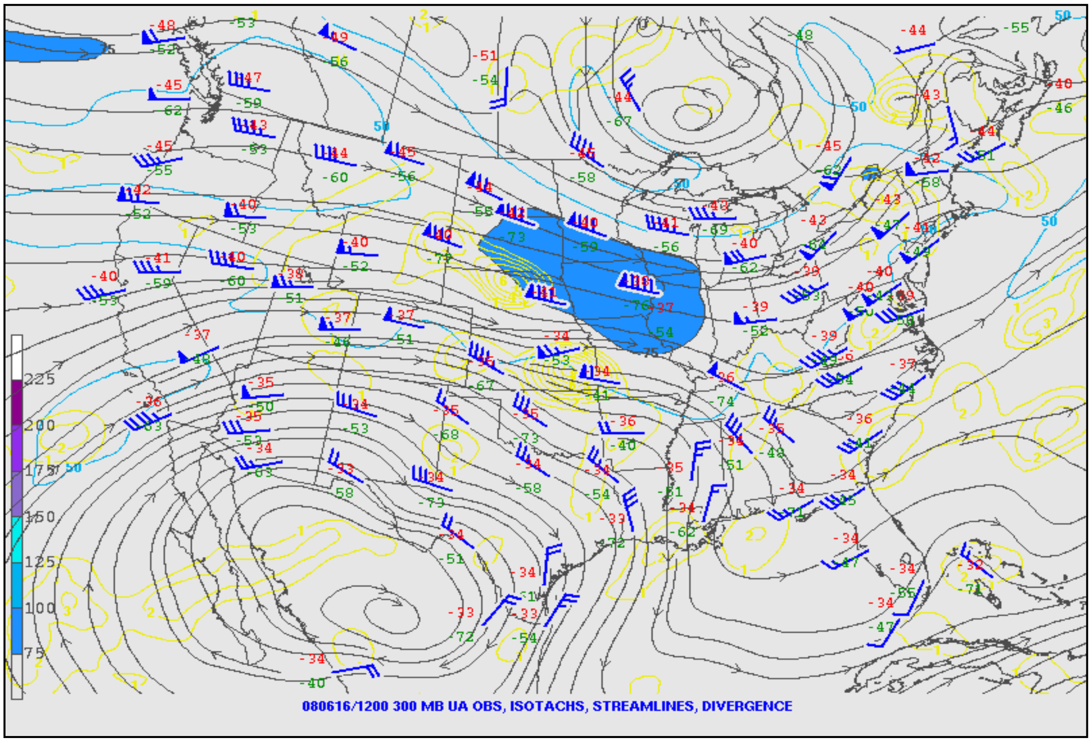

Figure 3: 300 hPa streamlines (black), temperatures and dewpoint depressions from RAOB (°C, red and green digits), isotachs (shaded, knots), winds (blue barbs, knots) and divergence (yellow), valid 1200 UTC 16 June 2008 (www.spc.noaa.gov).

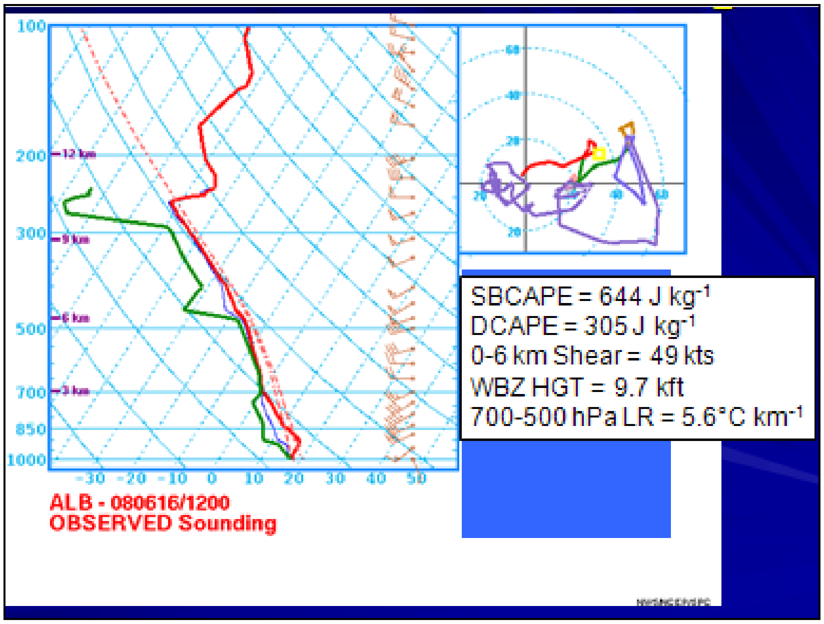

Figure 4: 1200 UTC 16 June 2008 Albany Sounding (http://www.spc.noaa.gov).

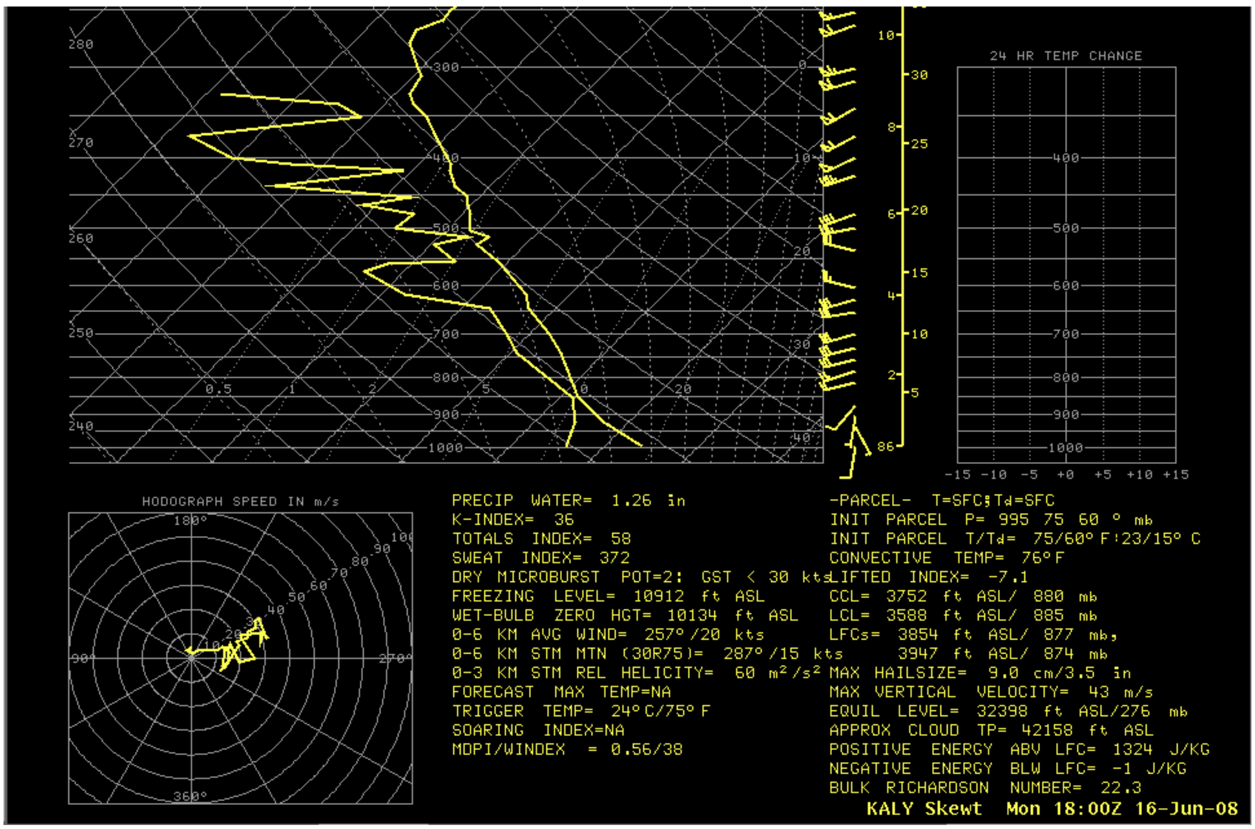

Figure 5: 1800 UTC 16 June 2008 Albany Sounding.

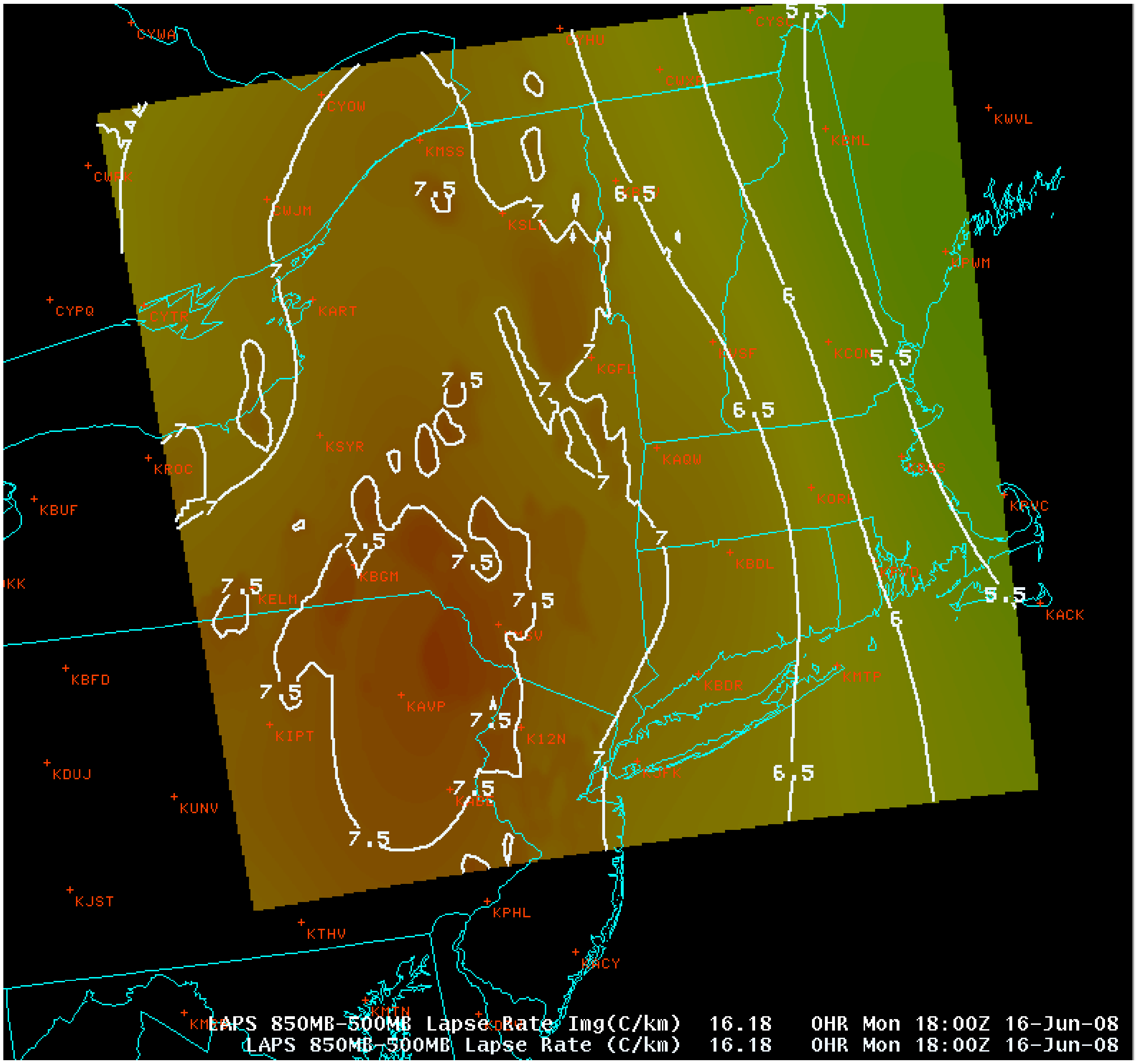

Figure 6: 1800 UTC 16 June LAPs 850-500 hPa lapse rates (°C km^{-1}).

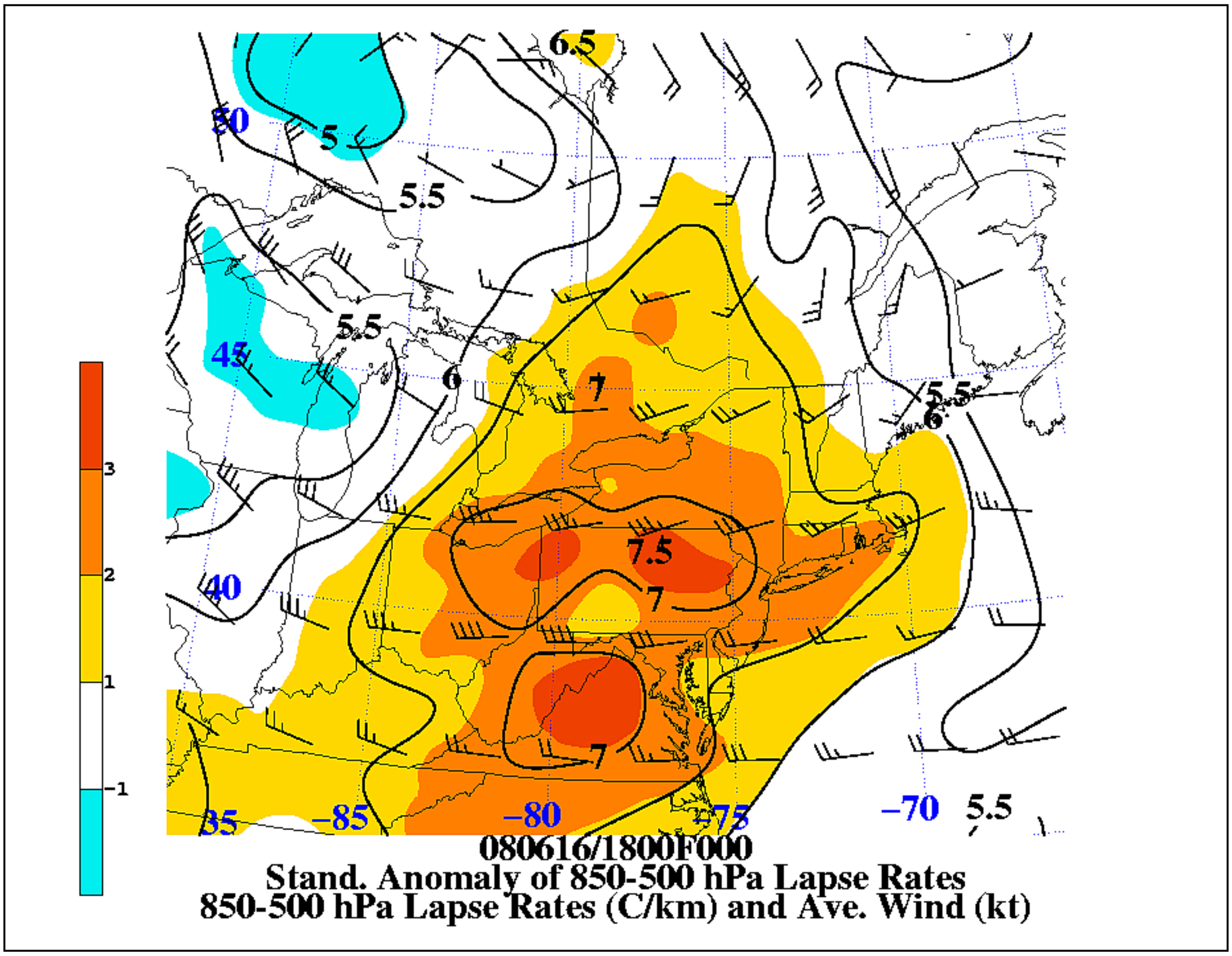

Figure 7: 1800 UTC 16 June 2008 Standardized Global Reanalysis Anomalies based on the 1979-2008 climatology for 850-500 hPa lapse rates (shaded), 0.5° GFS 850-500 hPa lapse rates (°C/km) , and layer average winds (barbs: kts). [Source: Scalora 2009]

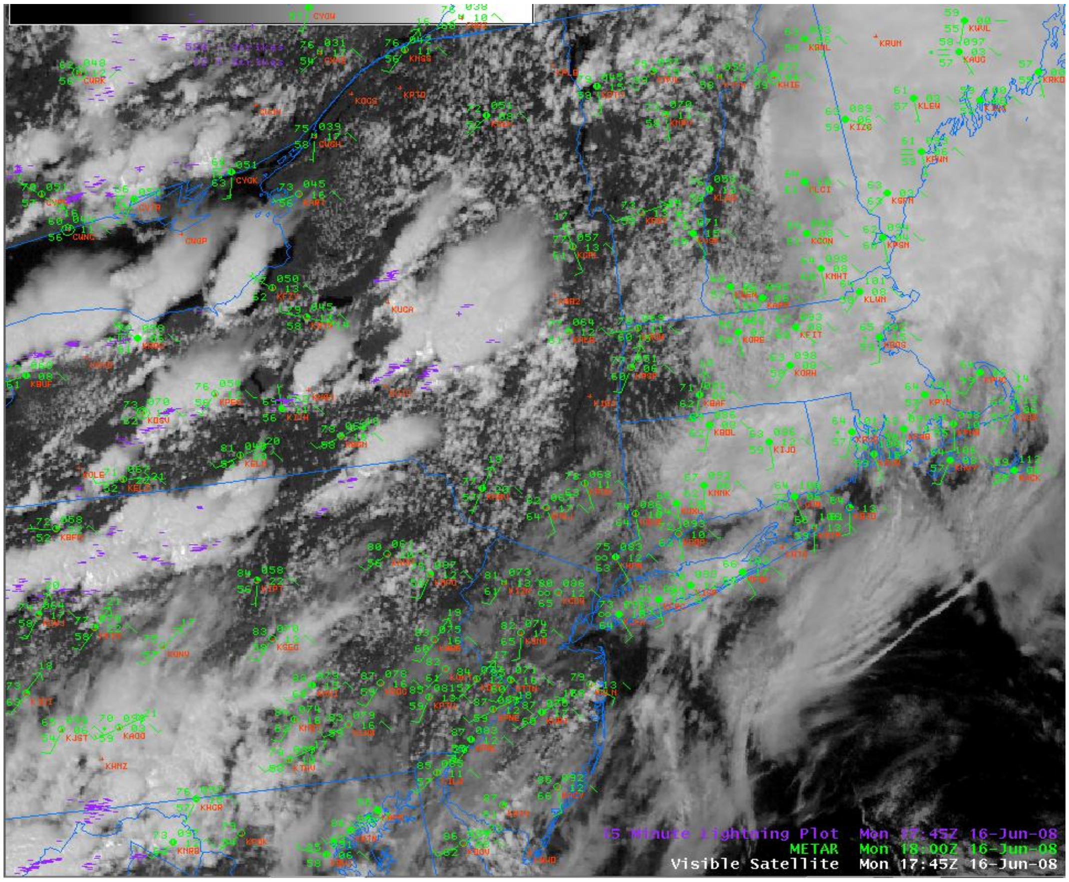

Figure 8: 1745 UTC Visible Satellite picture with cloud to ground lightning overlayed (purple) and the 1800 UTC metars (green).

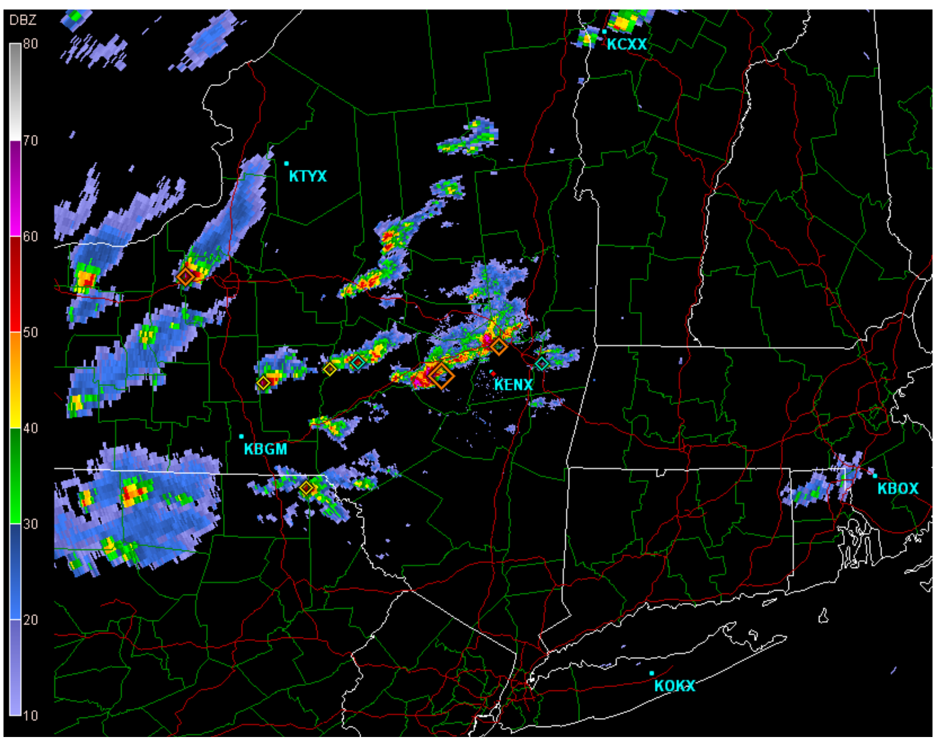

Figure 9: 1832 UTC 16 June 2008 0.5º KENX Base Reflectivity (dBZ) with Hail Icons from GR2Analyst.

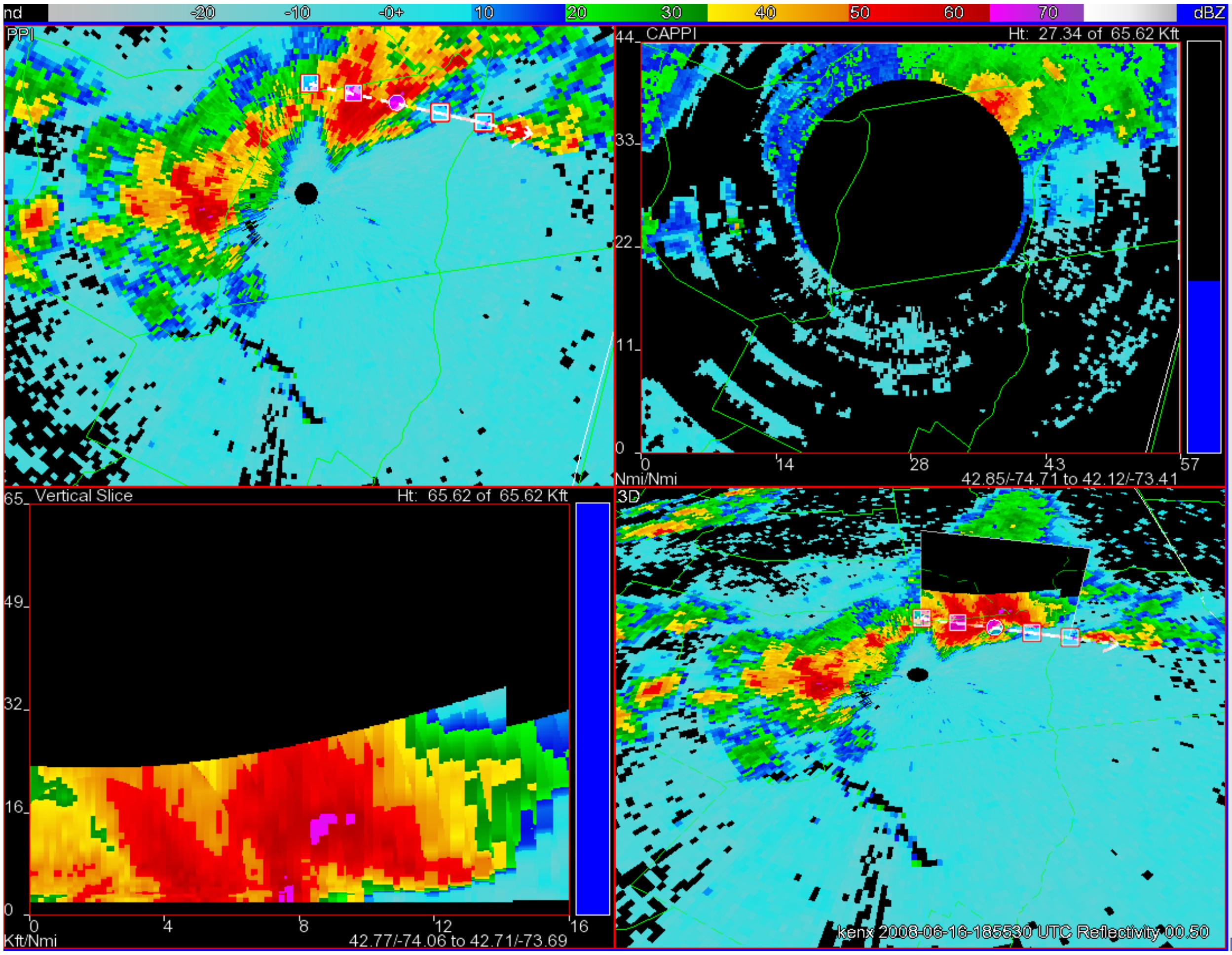

Figure 10: 1855 UTC 16 June 2008 KENX 4-Panel Display of Reflectivity (dBZ). The upper left panel is the Plan Position Indicator (PPI) panel showing radar data at a constant elevation angle of 0.5°. The vertical cross-section reference line is overlayed sampling a storm in northern Albany County. The upper right panel is the Constant Altitude PPI (CAPPI) panel showing radar data from several elevation angles at an altitude of 27.3 kft AGL above radar altitude. The lower left panel is the Vertical Dynamic XSection (VDX) depicting the radar data from the current volume scan and the corresponding position of the reference line from the upper left panel. The lower right panel is the 3D Flier panel where reflectivity textures represent elevation scan data, vertical cross-section data, and CAPPI data are shown.

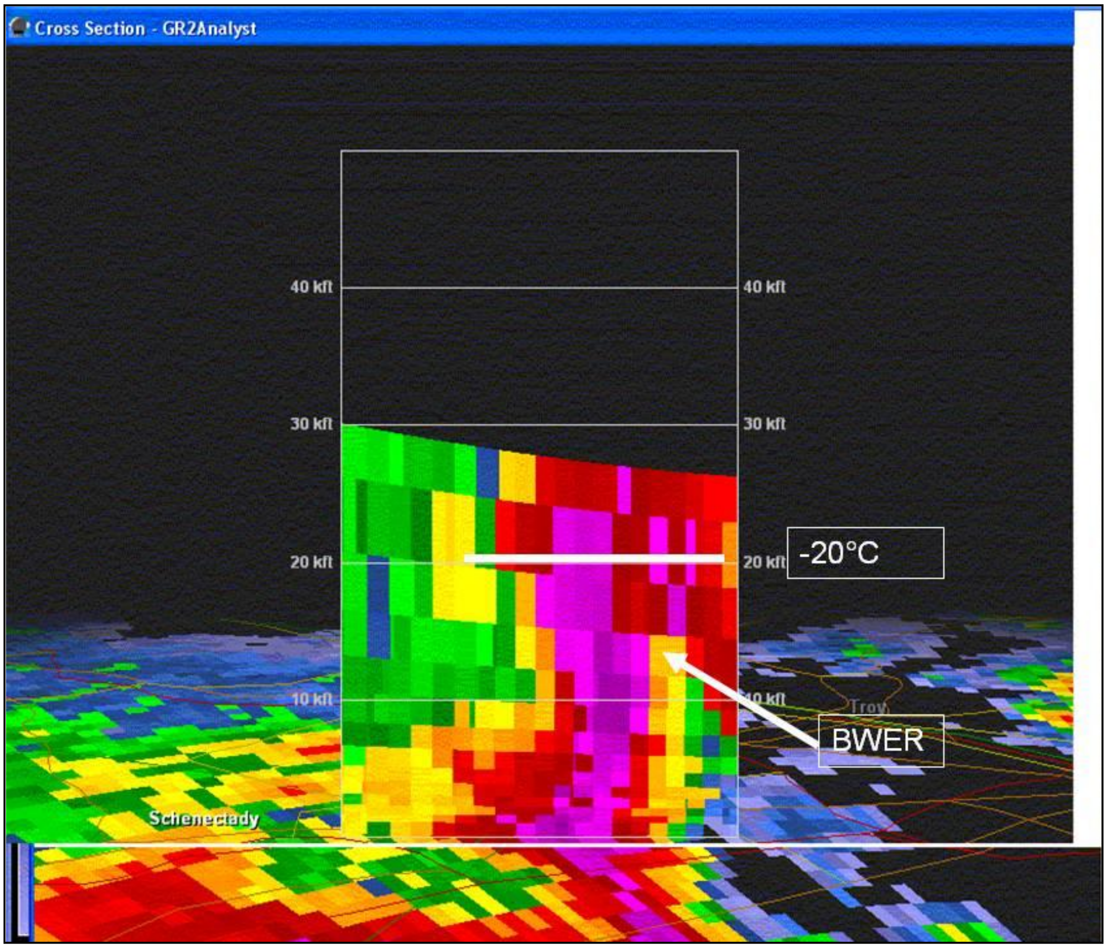

Figure 11: 1855 UTC 16 June 2008 GR2Analyst Cross-Section of a storm in northern Albany County. The -20°C height is annotated with the 60 dBZ echo (light purple reflectivities) reaching near 30 kft AGL. A Bounded Weak Echo Region (BWER) is at approximately 15 kft AGL. Hail was reported at golf ball to lime size in multiple locations.

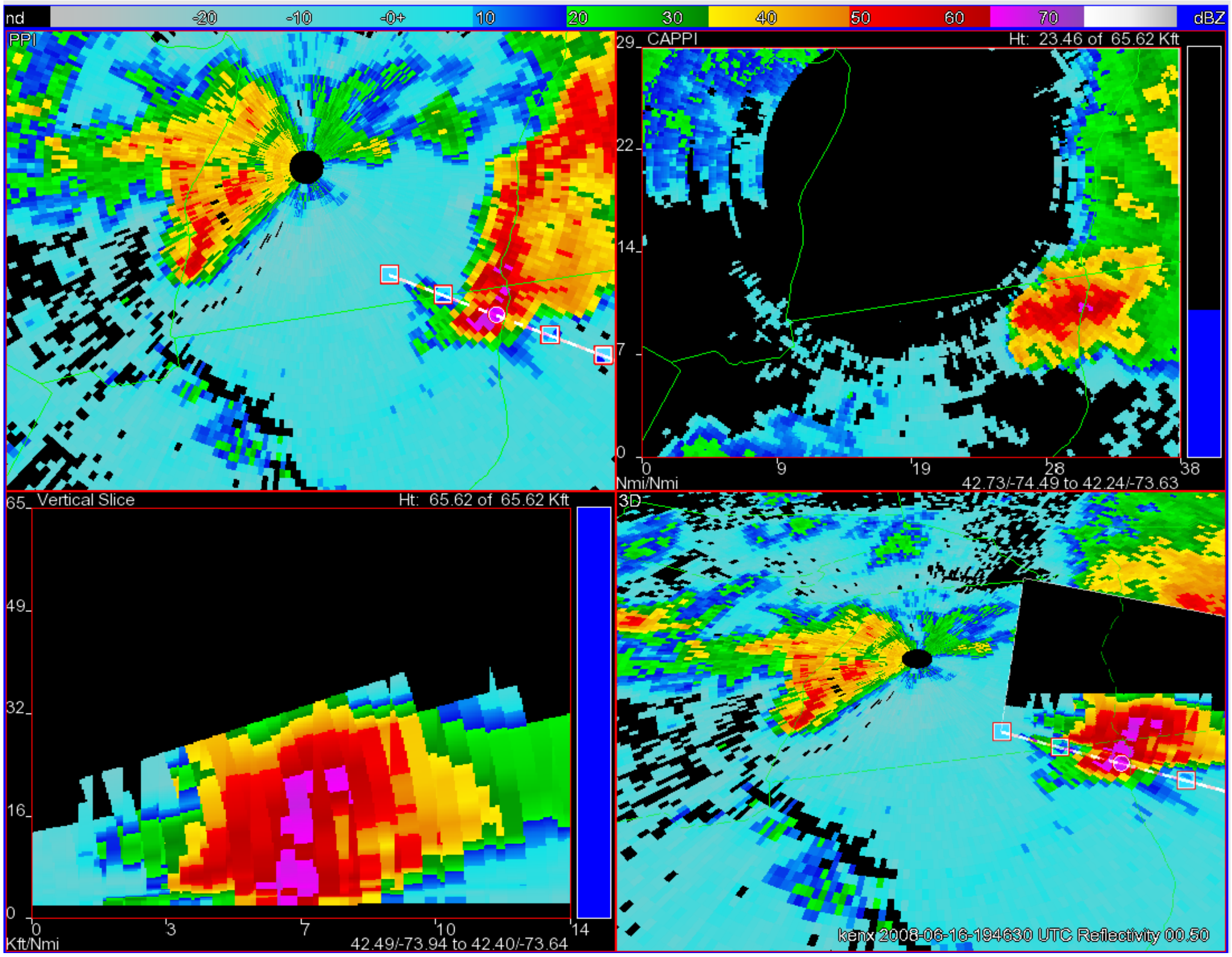

Figure 12: 1949 UTC 16 June 2008 KENX 4-Panel Display of Reflectivity (dBZ). The upper left panel is the Plan Position Indicator (PPI) panel showing radar data at a constant elevation angle of 0.5°. The vertical cross-section reference line is overlayed sampling a storm in northeastern Greene County southeast of KENX radar. The upper right panel is the Constant Altitude PPI (CAPPI) panel showing radar data from several elevation angles at an altitude of 23.5 kft AGL above radar altitude. The lower left panel is the Vertical Dynamic XSection (VDX) depicting the radar data from the current volume scan and the corresponding position of the reference line from the upper left panel. The lower right panel is the 3D Flier panel where reflectivity textures represent elevation scan data, vertical cross-section data, and CAPPI data are shown.

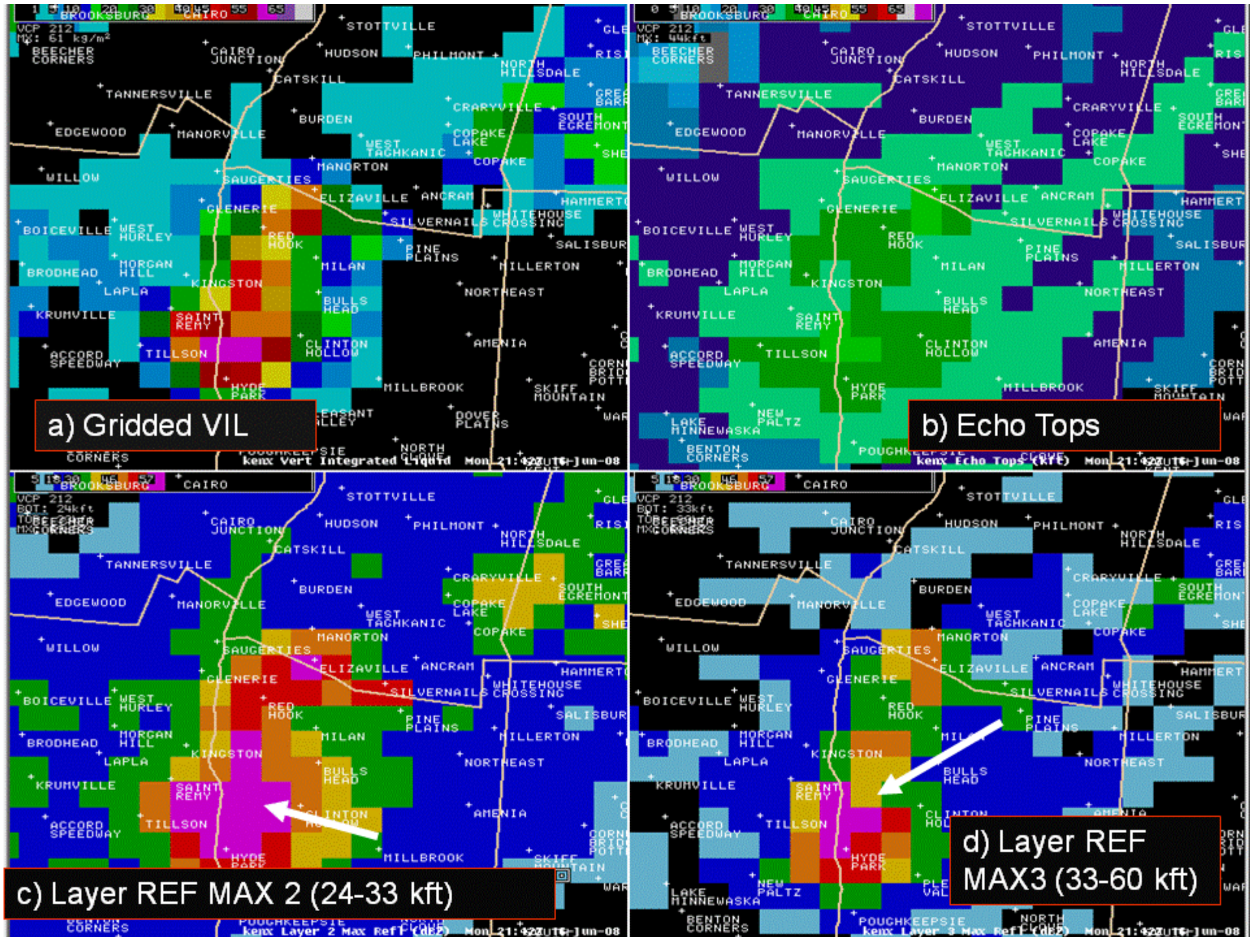

Figure 13: 2142 UTC 16 June 2008 KENX data a) Gridded VIL (kg m^{-2}), b) Echo Tops (kft AGL), c) Layer Reflectivity Maximum Level II (24-33 kft AGL) where pink values are greater than 57 dBZ and d) Layer Reflectivity Maximum Level III (33-60 kft AGL) product, where pink values are greater than 57 dBZ.

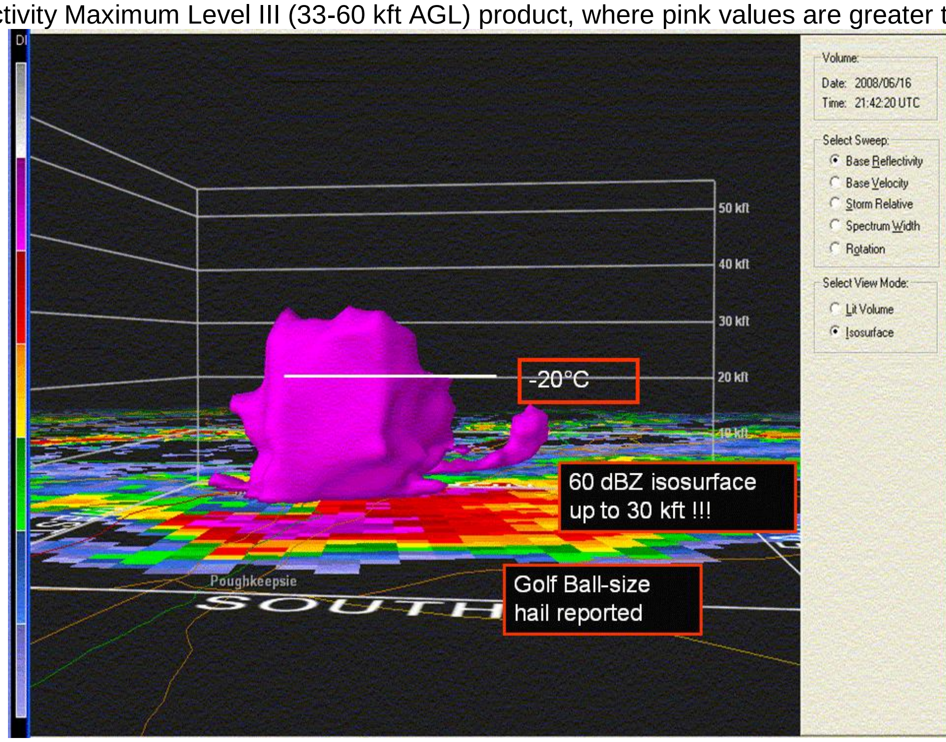

Figure 14: 2142 UTC 16 June 2008 GR2Analyst 60 dBZ Base Reflectivity isosurface display.

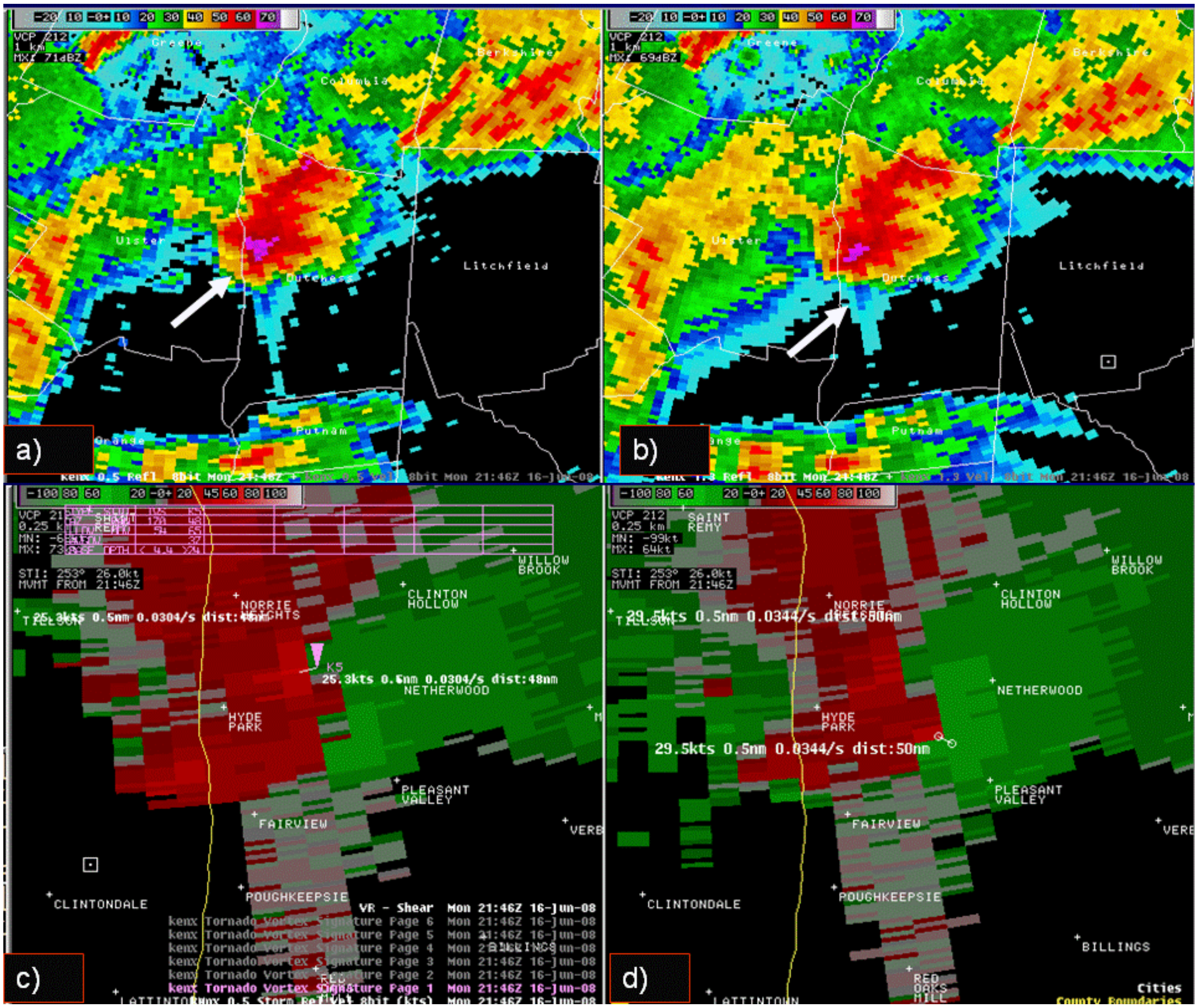

Figure 15: 2146 UTC 16 June 2008 KENX a) 0.5° Base Reflectivity (dBZ) b) 0.9 ° Base Reflectivity (dBZ), c) 0.5° Storm Relative Motion (SRM) with V-R shear (kts and s^{-1}) and TVS algorithm overlayed, and d) 0.9° SRM with V-R shear (kts and s^{-1}). The TBSS is indicated by the white arrows in the base reflectivity images.