P1.15 The May 26-27, 2010 Eastern New York and Western New England Backdoor Cold Front Severe Weather Event

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1. INTRODUCTION

On the evening of 26 May 2010, an anomalously warm and humid air mass was in place over much of the Northeast. Several record maximum temperatures were achieved across New York (NY) and New England that afternoon with widespread readings of 32-37°C. Surface dewpoints were between 15-21°C. A backdoor cold front approached late in the afternoon from eastern New England and southeastern Quebec. Forecasters were challenged as to whether active or widespread severe weather was going to occur at night, since convective initiation was unclear with the loss of the peak diurnal heating, and an initial convective complex over southeastern Ontario and northern NY weakened. The NWS/Storm Prediction Center (SPC) maintained a Slight Risk into the overnight period for much of eastern NY and New England. Convection rapidly developed ahead of the cold front and its associated mid-level short-wave trough. The strong to severe thunderstorms first developed in the vicinity of the Champlain River Valley around 0000 UTC 27 May 2010 and moved southward across extreme eastern NY and western New England to Long Island, NY by 0600 UTC. There were a total of 70 severe weather reports of damaging winds in excess of 50 knots (kts) and severe large hail (greater than 2.5 cm) that occurred across eastern NY and New England (U.S. Department of Commerce, Storm Data 2010).

Eastern NY and western New England were located near the right rear quadrant of a 300 hPa, 105 kt jet streak over eastern Maine (ME) and New Brunswick. This jet streak enhanced a plume of upper-level divergence over the region impacted by the severe weather. There was a plethora of instability in place ahead of the backdoor cold front. The 0000 UTC Local Area Prediction System (LAPS) analysis showed surface-based convective available energy (SBCAPE) values of 1000-5000 J kg^{-1} over eastern NY and western New England. The KALB (Albany, NY) sounding that evening exhibited steep mid-level lapse rates and a deep elevated mixed layer from the surface to around 600 hPa, indicative of the potential for strong winds to mix to the surface with the convection. The 0-6 km deep layer bulk shear was only approximately 25 kts. However, the stronger deep layer 0-6 km bulk shear was found over central and eastern New England. The KGYX (Gray, ME) sounding had a 0-6 km shear value of 62 kts. The shear increased westward associated with the deep cutoff cyclone over the Canadian Maritimes (Atlantic Canada). The 0-6 km deep layer shear intersected the abundance of instability for a mesoscale convective system (MCS) to develop over western New England. The MCS produced several bowing convective elements which resulted in widespread straight-line wind damage. There were also some embedded supercells within the organized linear severe convection.

This paper will take a multi-scale approach in analyzing the event from the synoptic-scale to the storm-scale, in order to understand the convective environment associated with the backdoor cold front that produced the severe weather outbreak on 26-27 May 2010. Significant emphasis is placed on the use of observational data to find clues that led to the active weather with the backdoor cold front. A storm-scale analysis will focus on some impressive outflow boundaries with the cold pool to the MCS that focused some of the severe convection.

2. DATA

Observational data used in the 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 charts and soundings are also used (www.spc.noaa.gov). The Rapid Update Cycle (RUC) real-time initialized data will be analyzed. Standardized temperature and precipitable water (PWAT) anomalies (Grumm and Hart 2001) calculated over a 30-year period (1970-1999) using the

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North American Regional Reanalysis (NARR) data (Mesinger et al. 2006) are examined.

3. MAY 26-27 2010 SYNOPTIC OVERVIEW

A high amplitude 500 hPa ridge (a large area of mid-level heights greater than 583 dm) was over portions of Ontario, Quebec, the Midwest, the Great Lakes Region, and the Northeast for late May (Fig. 1). 500 hPa temperatures were in the -8°C to -11°C range over a large portion of NY and New England. A large cut-off low was over portions of northern ME, eastern Quebec, New Brunswick, Nova Scotia, and the Canadian Maritimes. An impressive mid-level jet streak of 60-85 kts approached eastern NY and western New England from near the Gulf of St. Lawrence and northern ME. A series of short-wave troughs rotated through the downstream cut-off low. The 1200 UTC 26 May 2010 Maniwaki (CWNW) sounding indicated an Elevated Mixed Layer (EML) near the eastern flank of the upper ridge (Fig. 2). The sounding was also very unstable with CAPE in excess of 2500 J kg^{-1} in the early morning hours near southeastern Quebec. EMLs have been documented as a precursor for significant weather event over the Northeast (Banacos and Ekster 2010).

At 2300 UTC 26 May 2010, a surface cold front was moving slowly west or southwest from west-central New England towards the Hudson River Valley. This backdoor cold front focused two rounds of strong to severe thunderstorms. The first MCS that developed over southern Ontario that approached northern NY actually weakened in time with a new MCS forming over northern and central VT near Lake Champlain around 0000 UTC 27 May (Fig. 3).

The 0000 UTC 27 2010 upper air data showed some clues to help explain the development of a second MCS. The 500 hPa cutoff upper-level low continued to retrograde west southwest across New England (Fig. 4). The mid-level flow increased to 40-55 kts over western ME and Cape Cod. At 300 hPa, an area of upper-level divergence expanded over NY and New England (Fig. 5) in association with the anticyclonic entrance region (right rear quadrant) of a 100+ kt jet streak (Uccellini and Kocin 1987) over New Brunswick and northern ME. This jet streak coupled with the volatile thermodynamic environment in place enhanced the chances for severe weather that evening. The 850 hPa temperature reading over Albany was 21°C at 0000 UTC 27 May 2010 (Fig. 6). It is unusual to have 850 hPa temperatures exceeding 20°C across NY and New England in the spring. The low-level jet was also increasing from the northwest at 20-30 kts over portions of New England in association with the cold front.

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 NARR temperature and PWAT anomalies were notable ahead of the backdoor cold front. The 850 hPa (and 700 hPa) temperatures were 1 to 2 standard deviations above normal over most of eastern NY and New England (not shown). The 2-meter (m) temperature anomalies were just as impressive. At 0000 UTC 27 May 2010, the 2-meter temperature anomalies were 2 to 3 standard deviations above normal over a large portion of NY, eastern PA, NJ, and western New England (Figs. 7a-b). There was even an area of 3 to 4 standard deviations above normal in terms of 6-hour 2-m maximum temperatures ending 0000 UTC 27 May 2010 over southern NH. The NARR PWAT anomalies were also 1 to 3 standard deviations above normal over a large portion of eastern NY and New England too (Fig. 8).

Numerous record maximum temperatures were set across NY and New England this day. Some record highs included: 34.4°C (94°F) at Albany, NY; 33.3°C (92°F) at Glens Falls, NY and Burlington, VT; 32.8°C (91°F) at Bennington, VT and Pittsfield, MA; 35.0°C (95°F) at Poughkeepsie, NY; 37.2°C (99°F) at Hartford, CT, 36.1°C (97°F) at Worcester, MA; and 35.6°C (96°F) at Massena, NY. Overall max temperatures exceeded 32°C (90°F) over a large portion of eastern NY and west central New England. Maximum temperatures across much of central and eastern ME were only in the 21-25°C range (70s) closer to the cold front. The anomalous heat and humidity were in place to fuel the nocturnal MCS.

4. MESOSCALE AND SOUNDING ANALYSIS

The RUC at 0000 UTC 27 May 2010 indicated that the best 0-6 km deep shear of 40 kts or greater was over eastern New England (Fig. 9a), while the steepest mid-level lapse rates (7-7.5°C km^{-1}) in the 700-500 hPa layer were over much of upstate NY and western New England (Fig. 9b). The LAPS data indicated much of the Albany forecast area had a plethora of instability in place ahead of the backdoor cold front. The 0000 UTC LAPS SBCAPE values were in the 3000-5000 J kg^{-1} range over a large portion of the Hudson River Valley and western New England (Fig 10a). The cold front also showed up well in the LAPS MSLP analysis, which indicated the front slicing through VT and was east of the CT River Valley. The instability values dropped off dramatically across eastern New England. The LAPS DCAPE values were also anomalously high early that evening (1000-1500 Jkg^{-1}), which was indicative of the strong downdraft or microburst potential with bowing convective segments (Fig 10b). Also, the 0-6 km bulk shear with the LAPS data concurred with the RUC that the shear was increasing along the NY-VT border to 35-45 kts for the potential of deep organized convection.

The 0000 UTC sounding taken at KALB indicated that a very unstable atmosphere was in place. This sounding (Fig. 11) showed critical information pertaining to the mesoscale environment. The freezing level was 13.0 kft AGL, the -20°C height 22.6 kft AGL, and the wet-bulb zero height just under 11 kft AGL. The 850-500 hPa lapse rates were close to 8°C km^{-1} (which is unprecedented for KALB), and the SBCAPE and Most Unstable CAPE values were 3,948 J kg^{-1}, the Mixed Layer CAPE was slightly less at 3018 J kg^{-1}, and the best Lifted Index was -10°C. The DCAPE value was 1697 J kg^{-1}. There was 23 kts of shear in the 0-6 km layer indicative of mainly multicellular thunderstorm development maintained within an MCS. The atmosphere would have been more conducive for widespread discrete supercells for potential tornadoes, if there were lower lifting condensation level heights and stronger deep shear (Thompson et al. 2003).

The flow was fairly unidirectional from the top of the boundary layer to 500 hPa. The strong north to northwesterly flow in the lower to mid troposphere indicated the potential for thunderstorms to move quickly from the north-northwest to the south-southeast with a short burst of heavy rainfall in association with the anomalous PWATs (KALB 0000 UTC sounding PWAT = 36.5 mm (1.44 inches)). The unidirectional flow also indicated that multicellular or supercellular thunderstorms would quickly form into a line or lines with numerous bowing segments within the MCS. The initial MCS started to dissipate shortly after 0000 UTC, but a new one started to form over Lake Champlain and north-central VT between 0000 UTC and 0130 UTC (Fig. 12). This new MCS was moving into the extremely unstable air mass with surface dewpoints in the 15-20°C range. A Severe Thunderstorm Watch was issued for most of the ALY forecast area early that evening with locations from the Hudson River Valley east into western New England (Fig. 13) the most vulnerable for widespread damaging winds and large severe hail.

5. BRIEF STORM-SCALE RADAR ANALYSIS

A cluster of convection formed ahead of the backdoor cold front as it slowly moved westward across west-central New England. At 0200 UTC, widespread wind damage occurred over northern and central VT. The discrete convective cells formed into a line extending from Lake Champlain and the Adirondacks to southern NH (Fig. 14). Many of the cells exhibited rotation due to the abundance of instability and the increasing shear; a few tornado warnings were issued, but no tornadoes were confirmed in VT. An impressive outflow boundary migrated southwest of the cluster of convection over central VT. The outflow boundary quickly moved across north-central Washington County near Lake George. At 0230 UTC, the outflow boundary continued to move along extreme eastern NY towards the Capital Region. The outflow boundary propagated with the cold pool from the main area of convection approaching Bennington County in southern VT (Fig. 15a). The KENX radar depicted a broad area of enhanced winds with velocities of 45-50 kts at 4.5-5.0 kft AGL with the convection over northern and central Bennington County spreading eastward of the southern Green Mountains into Windham County, VT (Fig. 15b). Numerous trees and limbs were knocked down, blocking roads in the town of Dorset. A short time later at 0246 UTC, several bowing segments on the convective line impacted Windham County, VT (Fig. 16a). The 0.5° KENX base velocity data continued to indicate strong winds of 35-45 kts at 7.5-9 kft AGL over Windham County, VT (Fig. 16b). A half dozen towns had extensive straight line wind damage, with trees and wires down in Windham County, VT from the severe thunderstorms.

The severe weather with the MCS continued into western MA and CT. The convection associated with the outflow boundary produced non-severe weather as it propagated west of the Hudson River Valley of NY. However, the main line of convection continued to produce impressive cells with damaging winds and even large hail. The Four Dimensional Stormcell Investigator (FSI) at 0418 UTC showed impressive vertical structure with a storm capable of producing large severe hail in Litchfield County, CT (Figs. 17a-d). The Constant Altitude Planned Position Indicator (CAPPI) depicted approximately 60 dBZ's at 27.6 kft MSL (Fig. 17b). The cross-section of the storm in FSI displayed a vigorous hail core. There was a 61 dBZ reflectivity echo to 26.0 kft MSL (Fig 17c). These reflectivity values were approximately 13-15 kft above the freezing level, and above the -20°C height from the 0000 UTC Albany sounding. A report of quarter-size hail (2.54 cm) came from Terryville in Litchfield County, CT. The gridded Vertically Integrated Liquid value was 70 kg m^{-2} and the Echo Tops reached 50-55 kft AGL with this particular storm (not shown). Extensive wind damage occurred with the line across much of Litchfield County too.

6. SUMMARY

A backdoor cold front moved from northeast to southwest from southeastern Canada and eastern New England to eastern NY and western New England on the evening of 26 May 2010. Widespread severe weather occurred with the backdoor cold front across extreme eastern NY and much of central and western New England with 70 reports of hail and wind damage (Fig. 18). The state of VT was hit particularly hard with widespread wind damage. The extensive wind damage extended along a narrow corridor from Lake Champlain and upstate VT to southwestern New England and Long Island.

An anomalously hot and humid air mass was over much upstate NY and New England with several record highs set. Extreme low level temperature anomalies were noted with the NARR data. A large cut-off low backed west-southwest in the Canadian-Atlantic Maritimes to force the cold front and favored jet dynamics (anticyclonic entrance region of a 100+ kt jet streak) into the region. There was an abundance of instability in place with the presence of an impressive EML in the 1200 UTC 26 May 2010 CWNW sounding, and the 0000 UTC 27 May 2010 KALB sounding. The mid-level lapse rates were anomalously steep for late May (close to 8°C km^{-1}). The 0-6 km shear increased considerably with the west-southwest propagation of the backdoor cold front. The main severe threat was damaging winds due to momentum mixing from aloft to the surface (EML) with the multicellular and supercellular convection that formed into a line with the MCS that migrated from north-northwest to south-southeast along the cold front. An outflow boundary moved from VT to southern NY down the Hudson River Valley with severe weather to the east, and general convection (non-severe) mainly west of it.

Operational forecasters were challenged in this event, since the initial MCS actually diminished over Lake Ontario and northern NY. SPC continued a Slight Risk into the evening for the threat of severe weather with the back door cold front. Based on previous work (Banacos and Ekster 2010) situational awareness was patiently continued high due to the presence of the EML prior to the issuance of short fuse warnings. The ALY Weather Forecast Office issued 10 severe thunderstorm polygons with a probability of detection of 0.94, false alarm ratio of 0.10, critical success index of 0.86, and an average lead-time of 31.6 minutes. In the future, it is hoped that forecasters in the Northeast will formulate and utilize a conceptual model for the potential severe weather impacts with backdoor cold fronts and EMLs.

7. ACKNOWLEDGEMENTS

Thanks to ALY Science Operations Officer, Warren R. Snyder, Dr. Alicia C. Wasula from Hudson Valley Community College, and Dr. Dave Radell from Eastern Region Scientific Services Division for reviewing this extended manuscript publication. The authors would also like to acknowledge the Collaborative Science, Technology and Applied Research (CSTAR) program for examining backdoor cold fronts and their significant weather in the Northeast, as a part of the CSTAR IV grant (Grant Number: NA01NWS4680002) in 2010-2013.

DISCLAIMER

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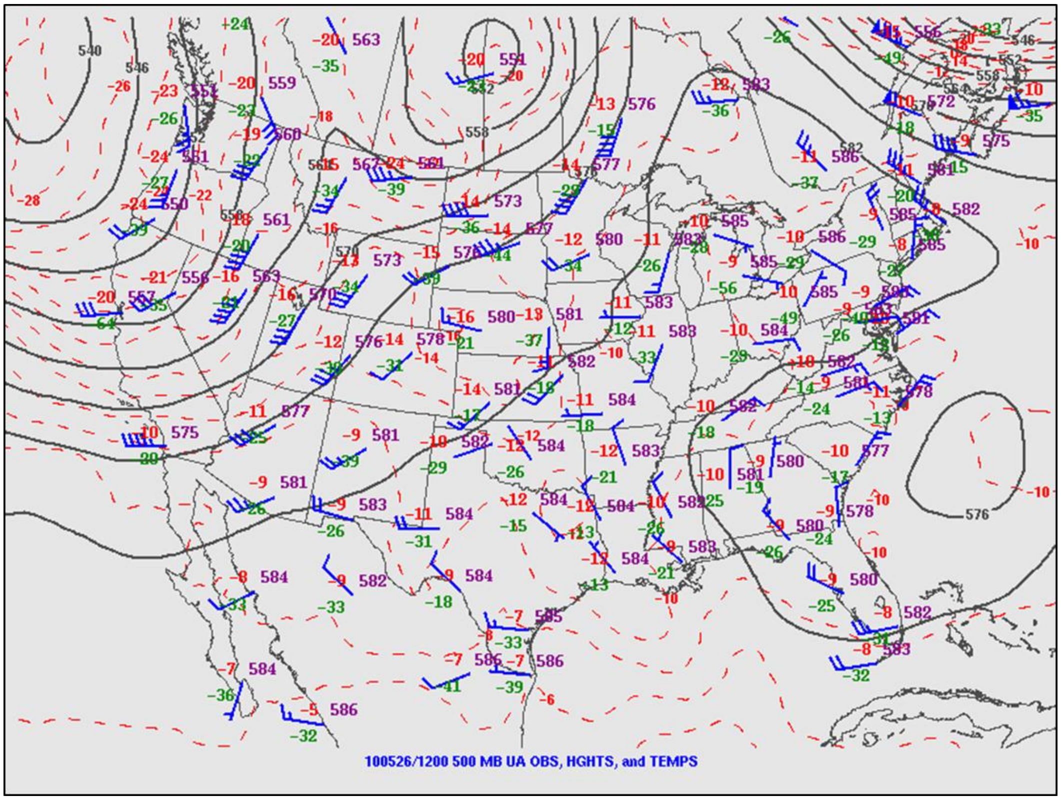

Figure 1: 500 hPa height (dam, solid), temperatures (°C, dashed red), winds (knots) and dewpoint depression from RAOB (green), valid 1200 UTC 26 May 2010 (www.spc.noaa.gov).

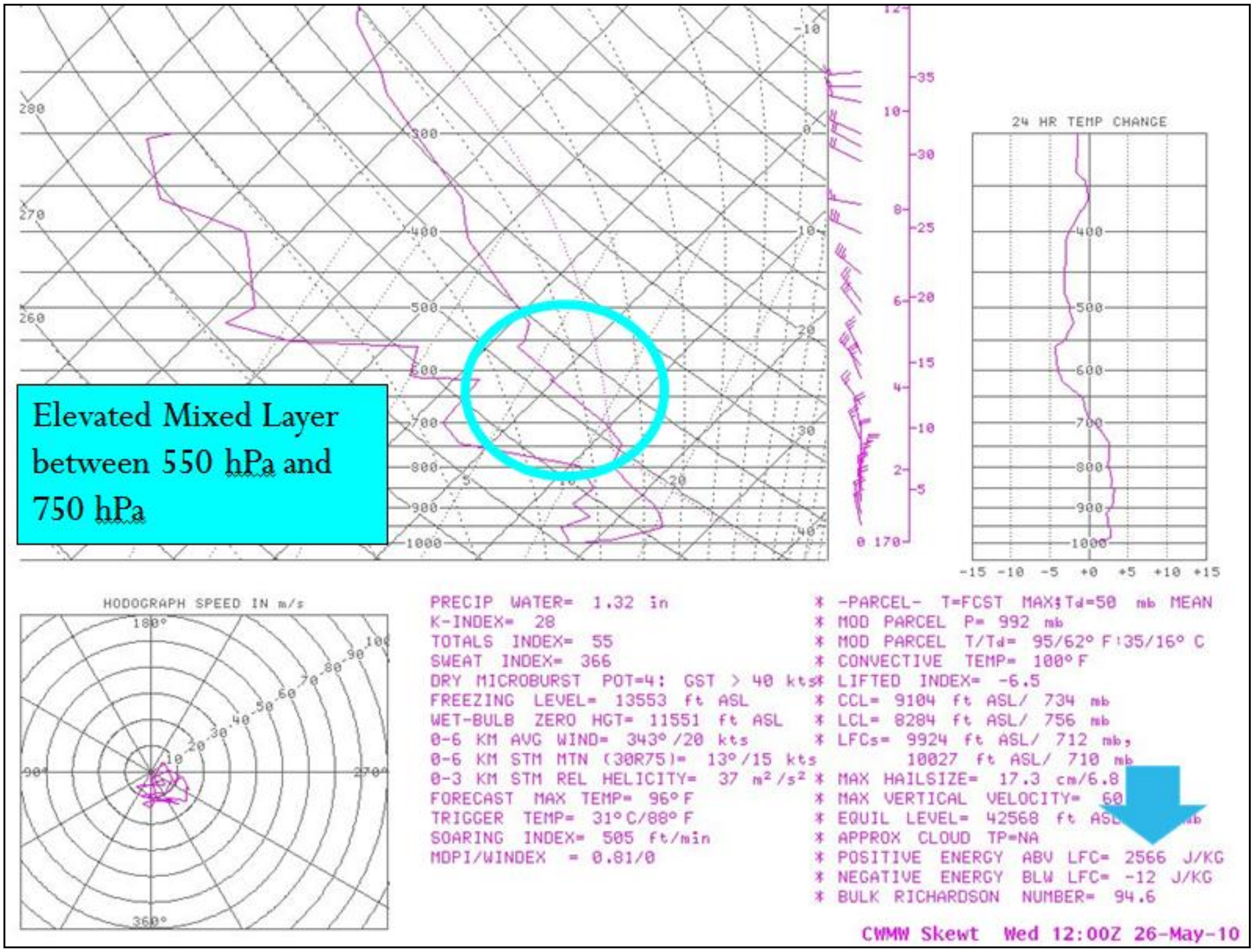

Figure 2: 1200 UTC 26 May 2010 CWMW (Maniwaki) sounding in Quebec indicating a strong Elevated Mixed Layer.

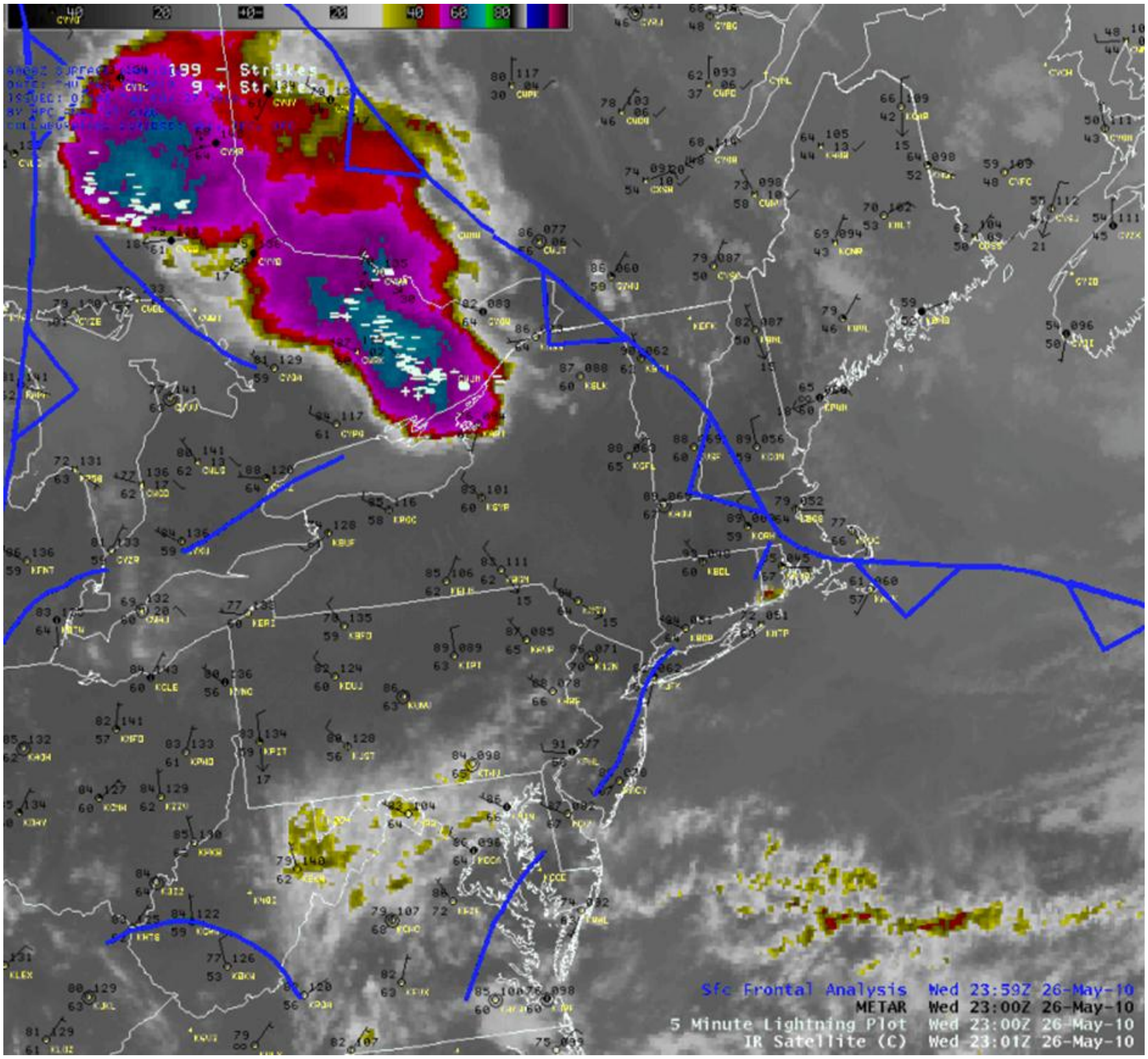

Figure 3: 2300 UTC 26 May 2010 GOES_13 Infrared Satellite Picture with 5-minute Lightning data overlayed. The 2300 UTC METARS are also shown with the 0000 UTC frontal analysis.

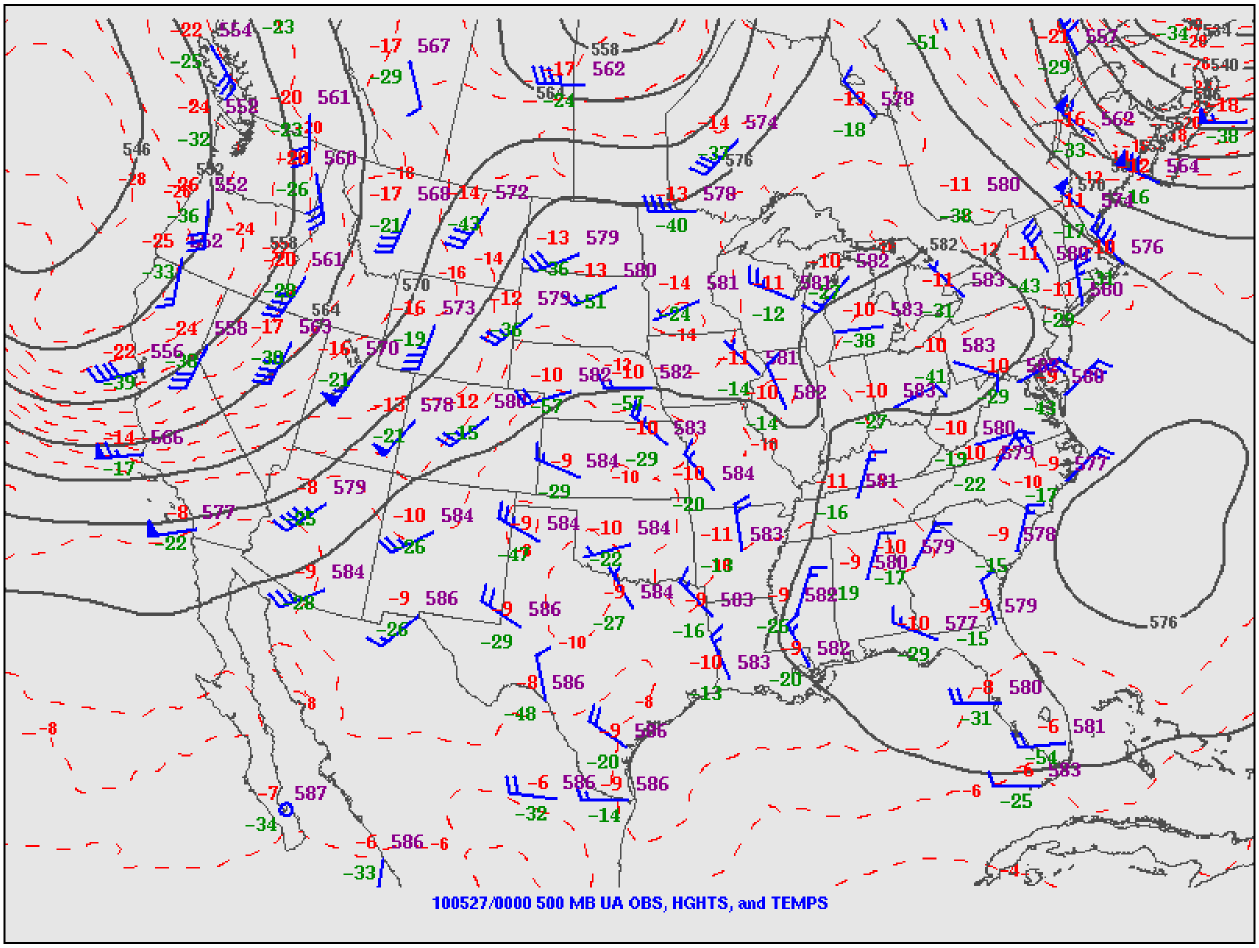

Figure 4: 500 hPa height (dam, solid), temperatures (°C, dashed red), winds (knots) and dewpoint depression from RAOB (green), valid 0000 UTC 27 May 2010 (www.spc.noaa.gov).

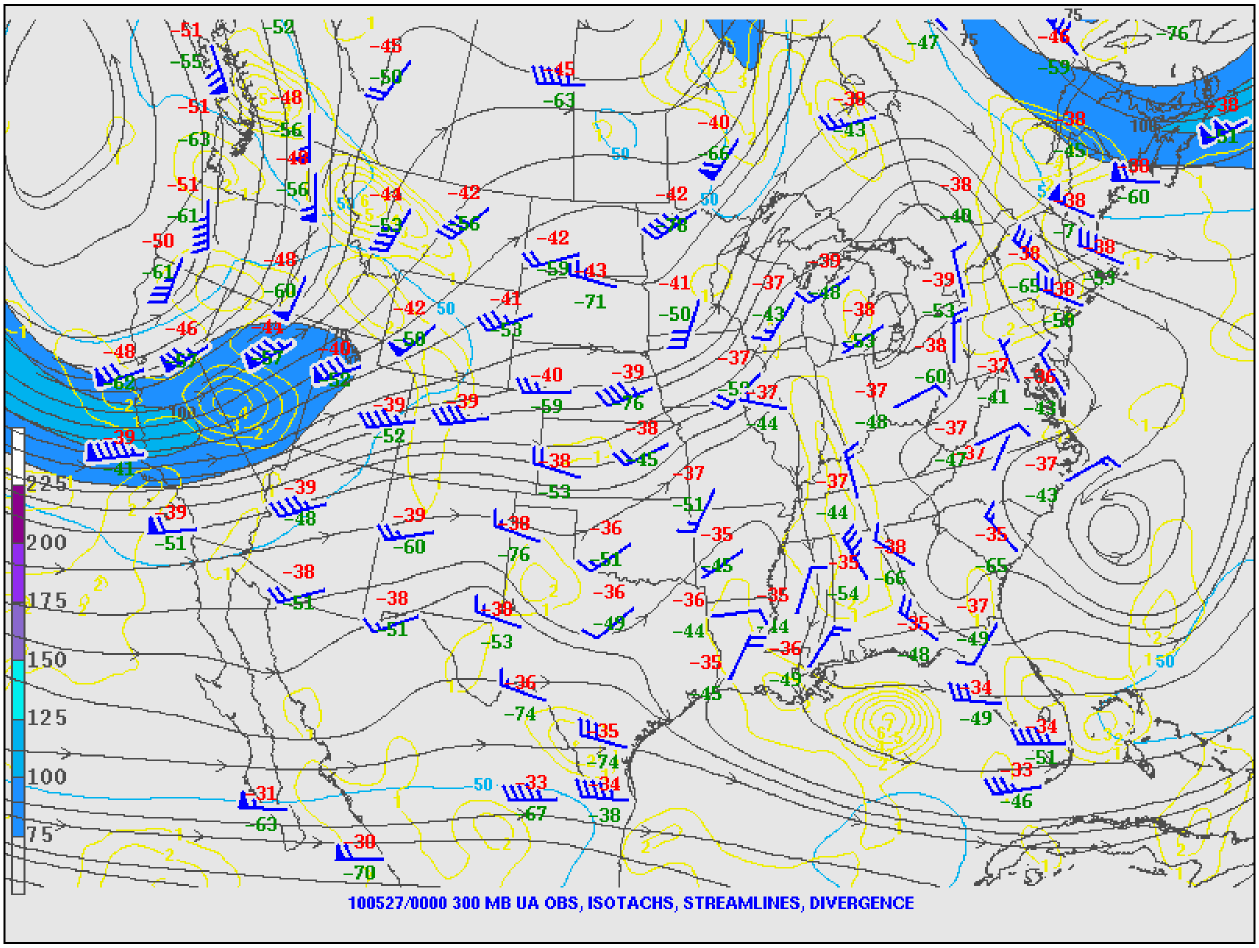

Figure 5: 300 hPa streamlines (black), temperatures and dewpoint depressions from RAOB network (°C, red and green digits), isotachs (shaded, knots), winds (blue barbs, knots) and divergence (yellow, x10^{-5} s^{-1}), valid 0000 UTC 27 May 2010 (www.spc.noaa.gov).

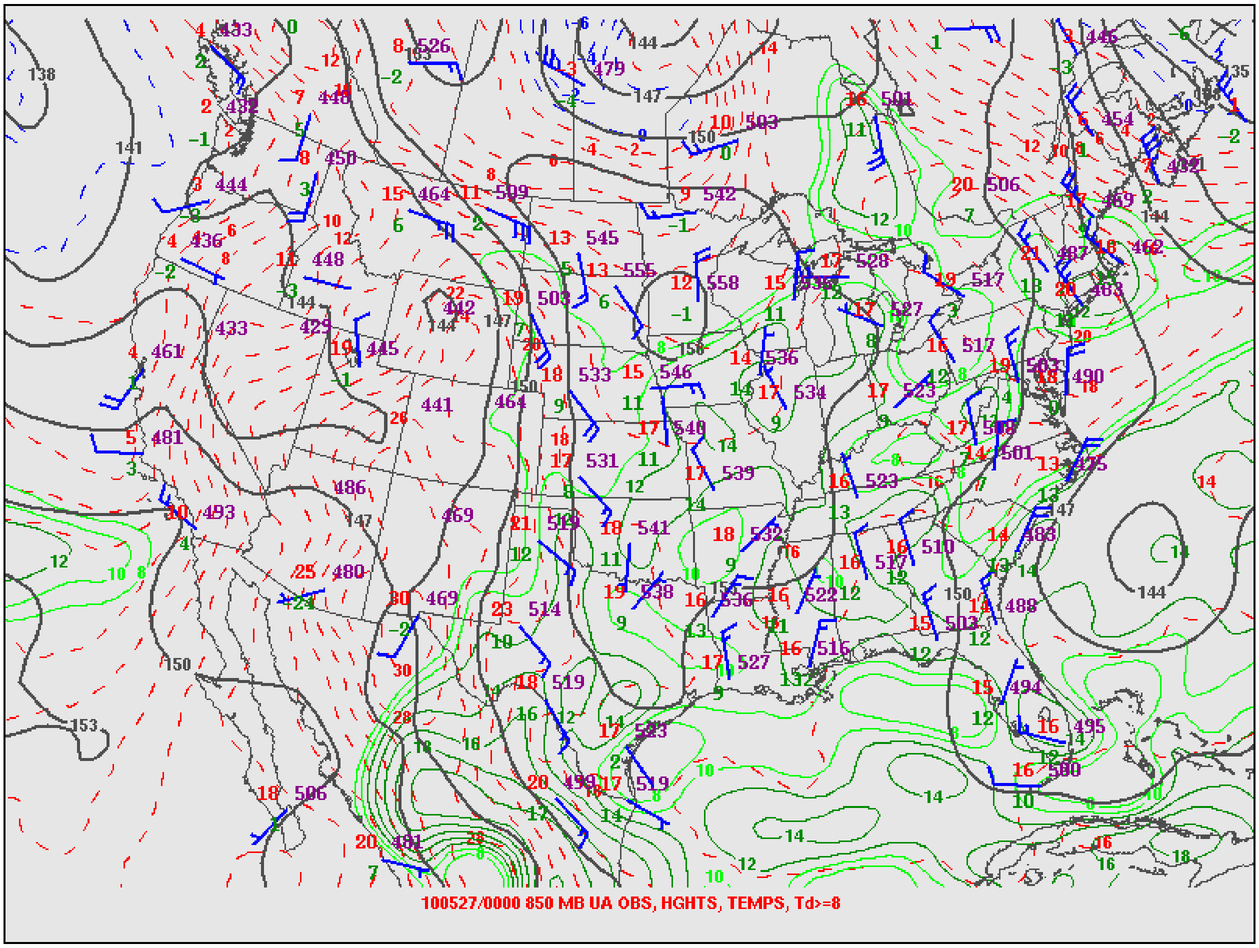

Figure 6: 850 hPa height (dam, solid), temperatures (°C, dashed red), winds (knots) and dewpoint (≥8°C) from RAOB (green), valid 0000 UTC 27 May 2010 (www.spc.noaa.gov).

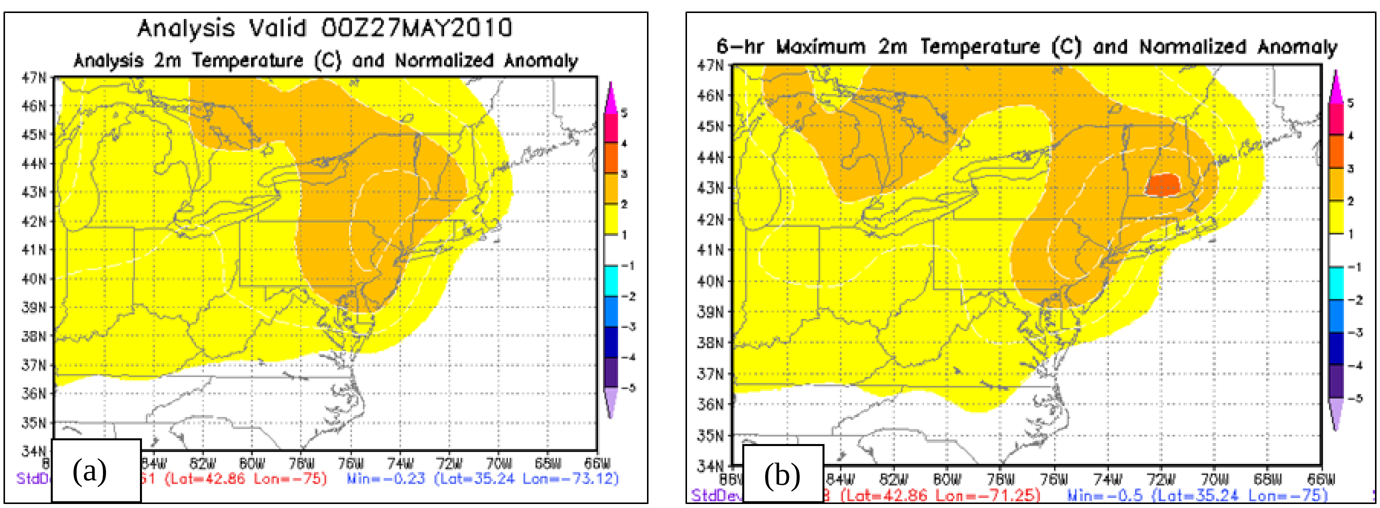

Figure 7: (a) 2-m Temperature (°C) and (b) 6-hr Maximum 2-m Temperature (°C) NARR Anomalies valid 0000 UTC 27 May 2010. Areas in orange are 2 to 3 standard deviations above normal based on the 1970-1999 climatological period (Source:http://hart.met.psu.edu/meteo497/patternmap).

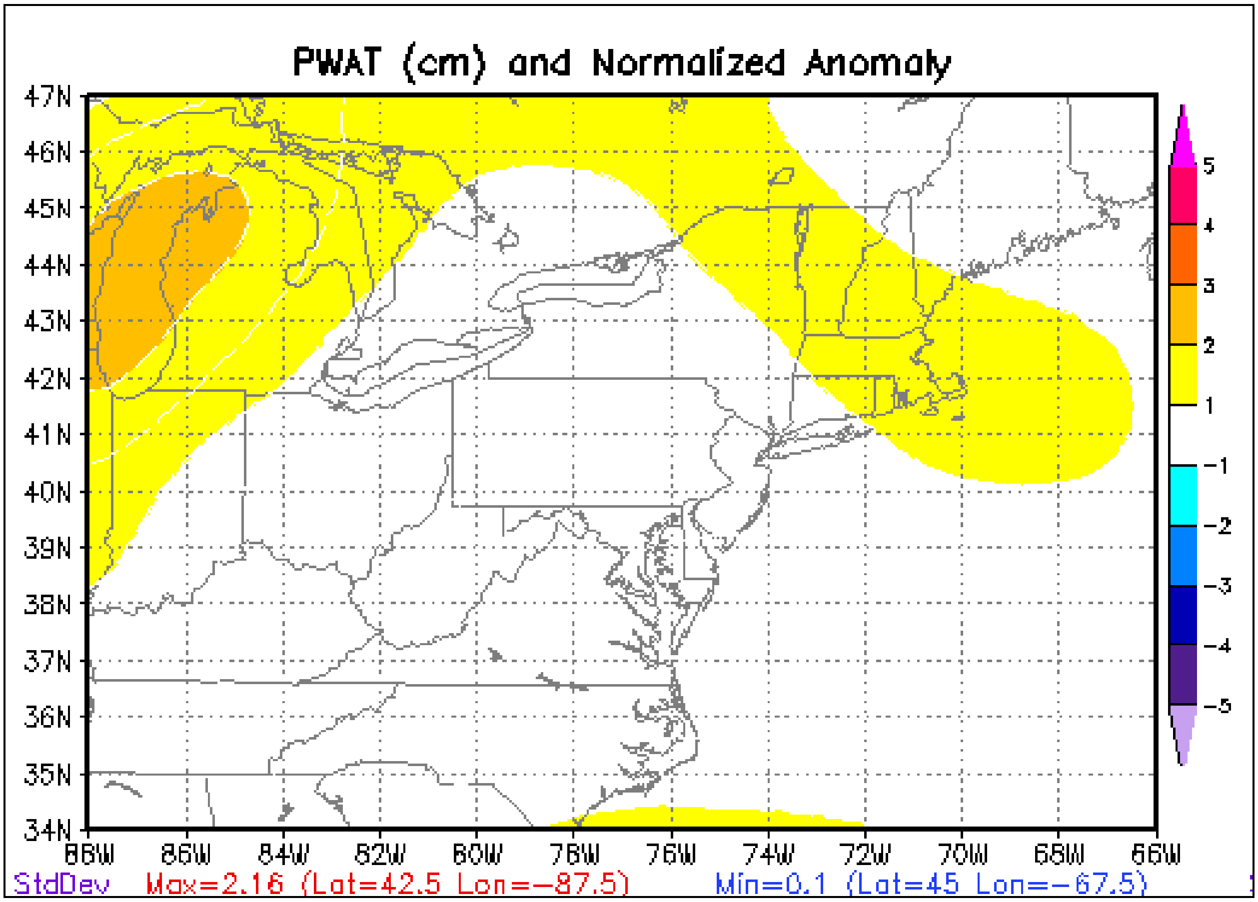

Figure 8: 850 hPa NARR Temperature Anomalies valid 0000 UTC 27 May 2010. Areas in yellow are 1 to 2 standard deviations above normal based on the 1970-1999 climatological period (Source:http://hart.met.psu.edu/meteo497/patternmap).

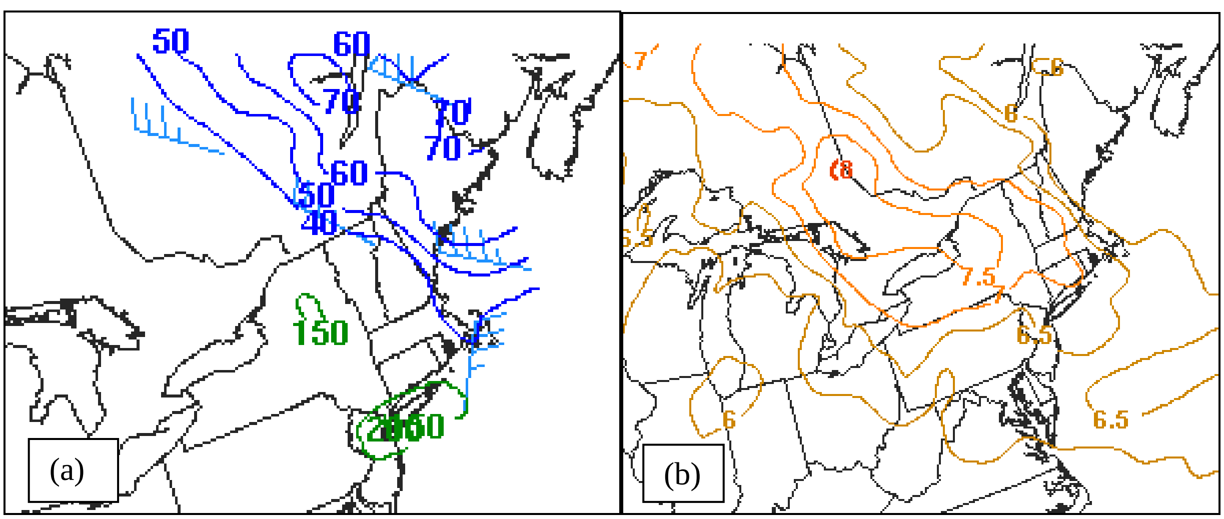

Figure 9: (a) 0000 UTC 27 May 2010 0-6 km RUC Bulk Shear (kts) and Effective Storm Relative Helicity ($m^2 s^{-2}$) and (b) RUC 700-500 hPa lapse rates (°C km^{-1}) from (www.spc.noaa.gov).

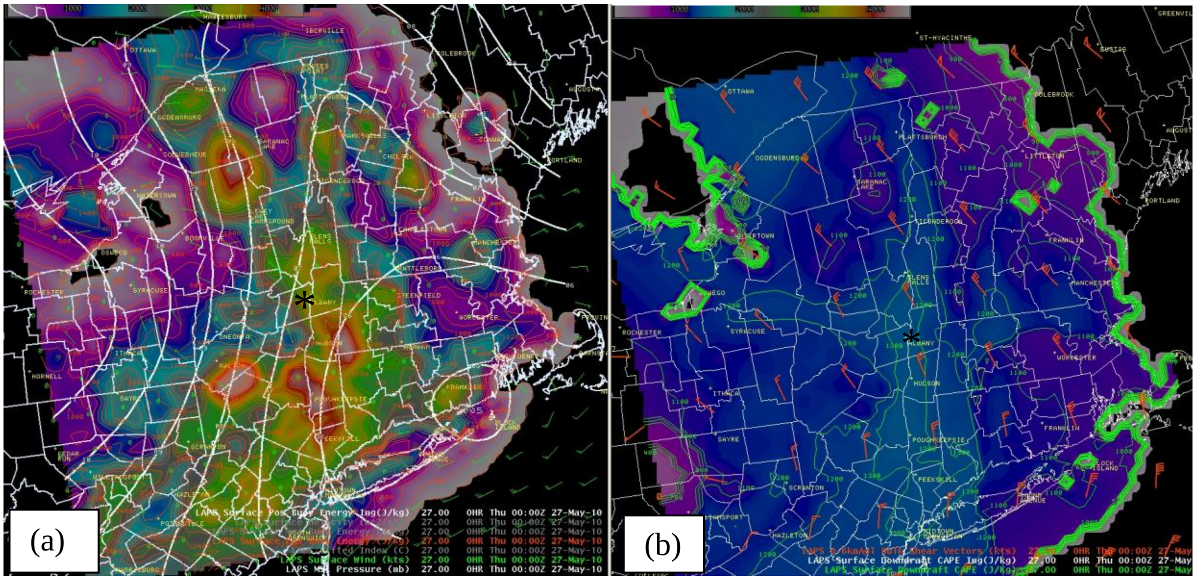

Figure 10: (a) 0000 UTC 27 May 2010 LAPS SBCAPE (J kg^{-1}) where areas shaded in yellow are greater than 3000 J kg^{-1} and MSLP (hPa) are white contours, (b) LAPS DCAPE (J kg^{-1}) where areas shaded in lighter blue are greater than 1200 J kg^{-1} and 0-6 km bulk shear values (kts) are red barbs. Albany is starred (*) on the panels.

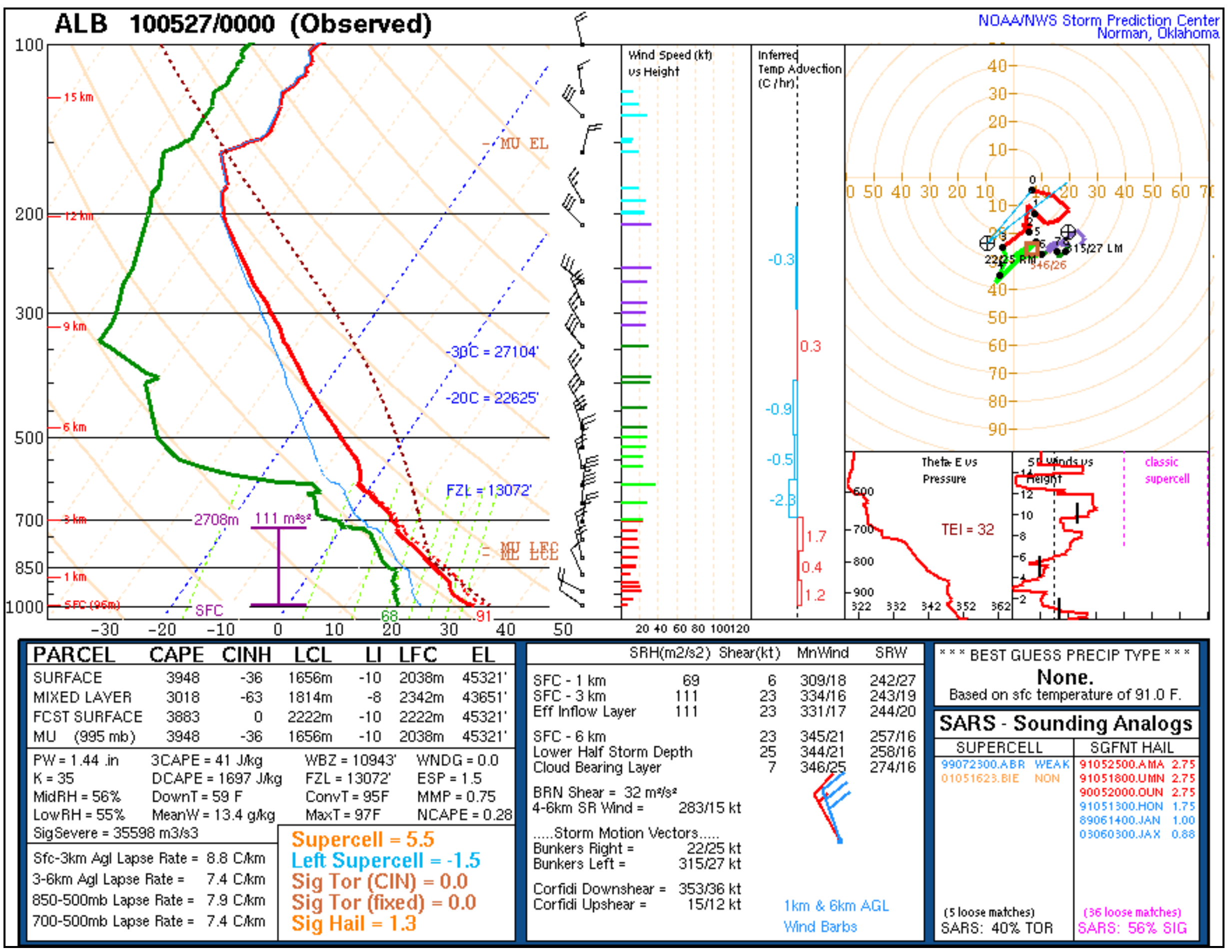

Figure 11: 0000 UTC 27 May 2010 Albany, NY (ALB) Sounding (www.spc.noaa.gov).

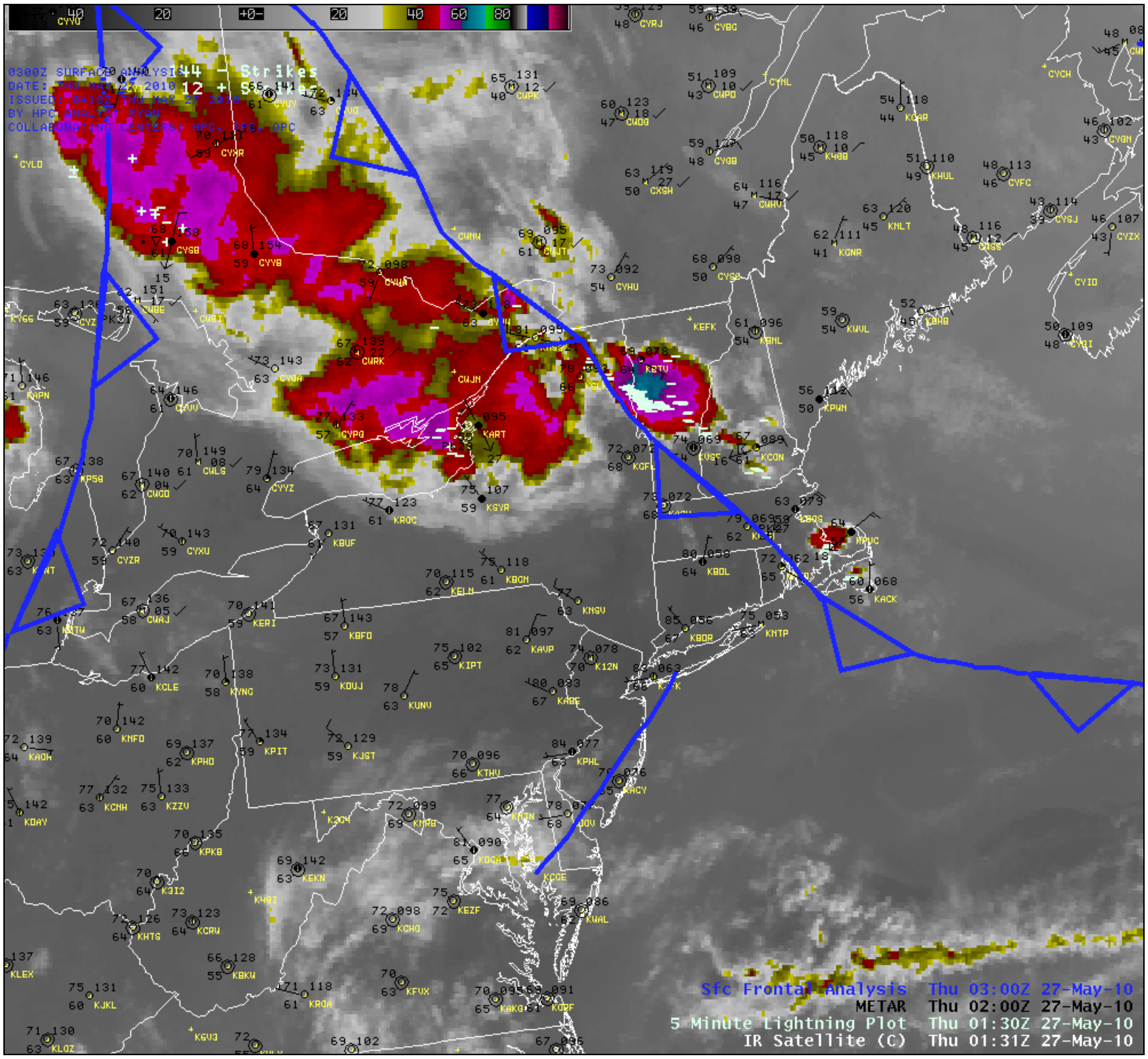

Figure 12: 0131 UTC 27 May 2010 GOES-13 Infrared Satellite Picture with 0130 UTC 5-minute Lightning Data, 0200 UTC METARs and 0300 UTC Surface Frontal Analysis.

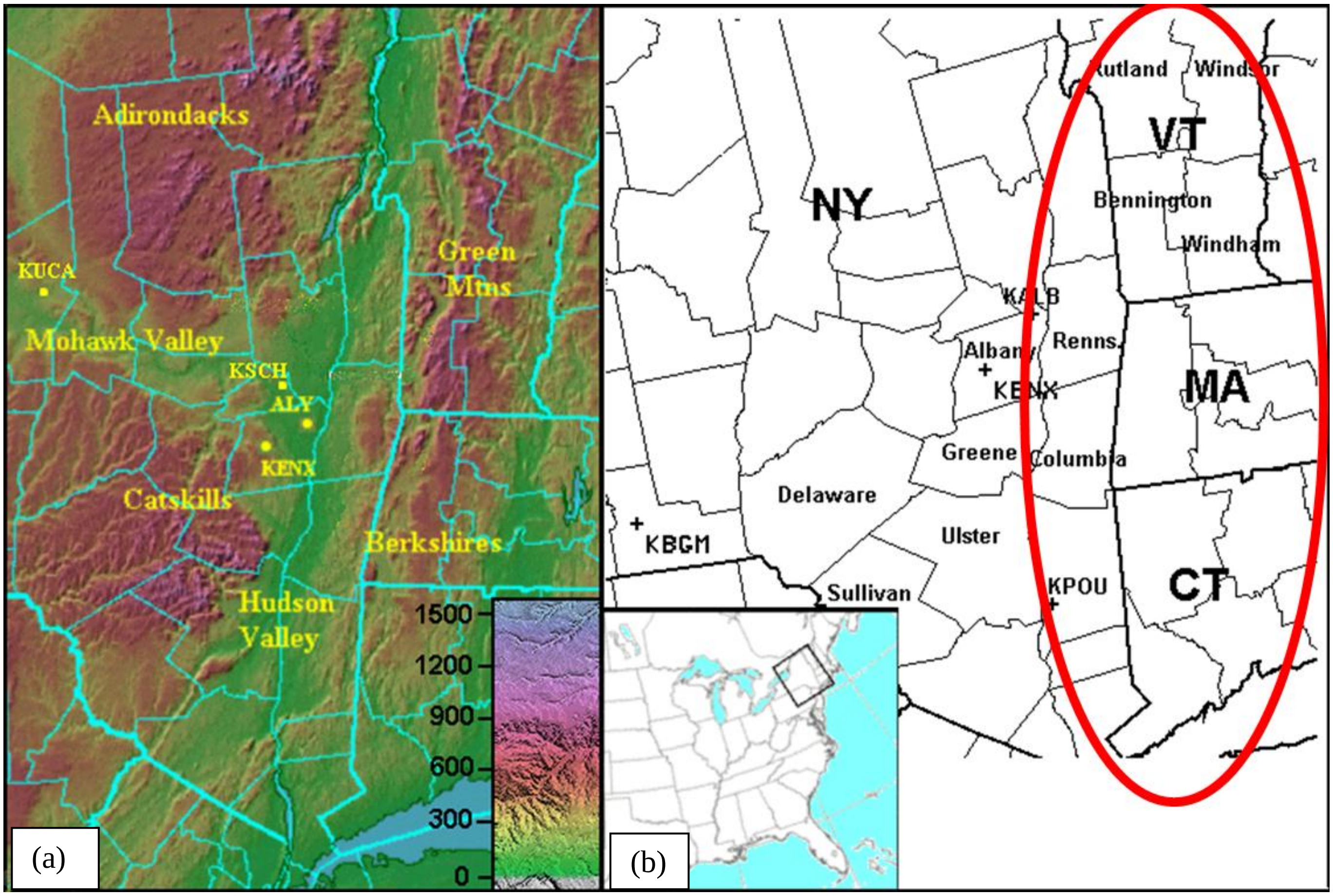

Figure 13: (a) WFO at Albany forecast area, where (b) red circle indicates where damage occurred with back door cold front MCS.

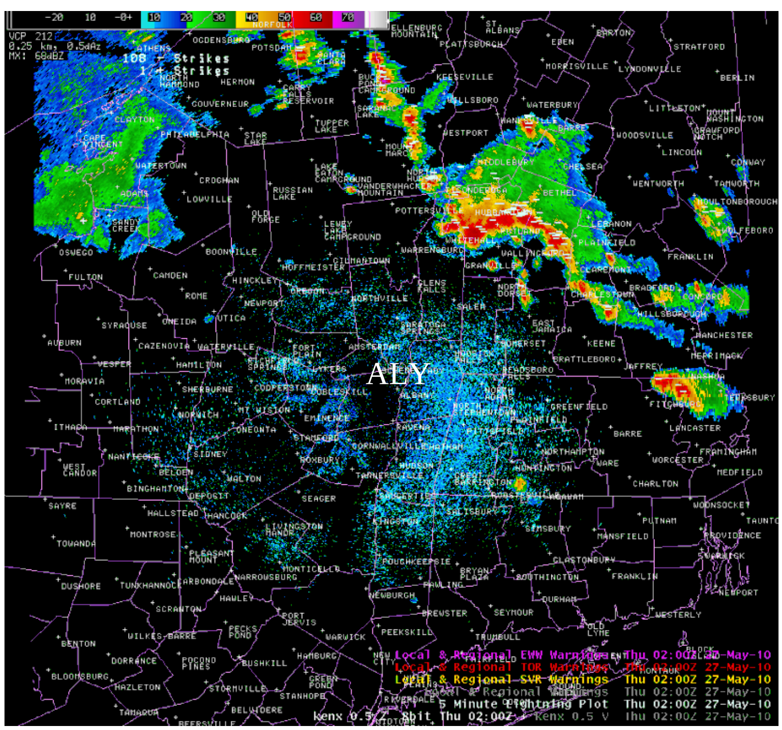

Figure 14: 0200 UTC 27 May 2010 0.5° KENX Base Reflectivity (dBZ) and 5-min Lightning. ALY denotes where Albany is located.

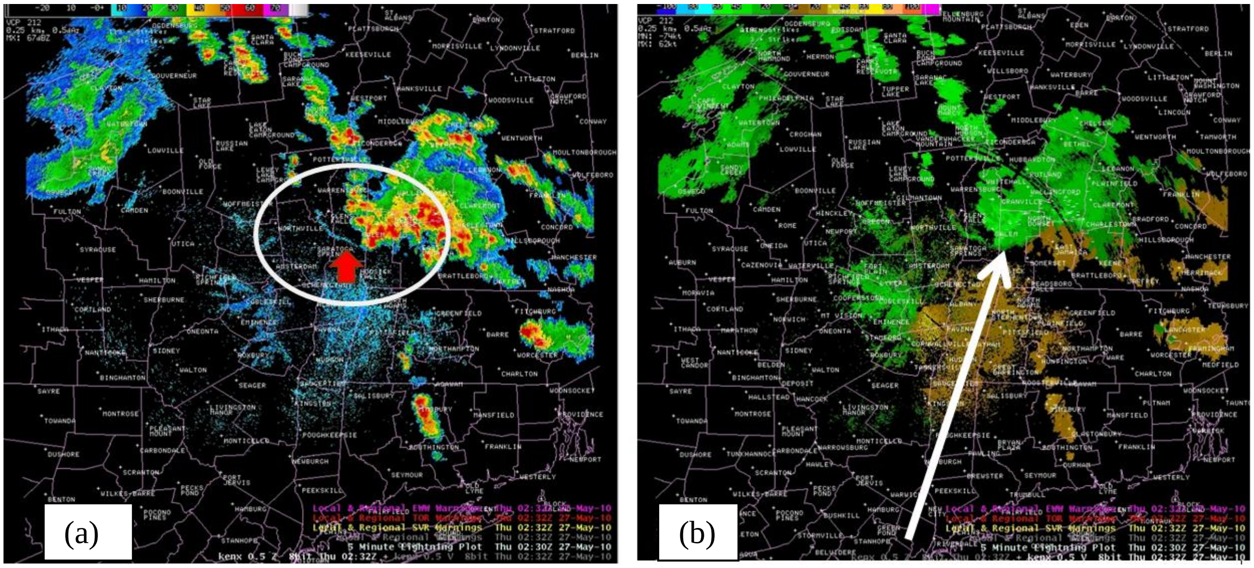

Figure 15: 0230 UTC 27 May 2010 KENX (a) 0.5°Base Reflectivity (dBZ) where outflow boundary is circled, and (b) 0.5°Base Velocity (kts) where wind max is moving across Bennington County, VT.

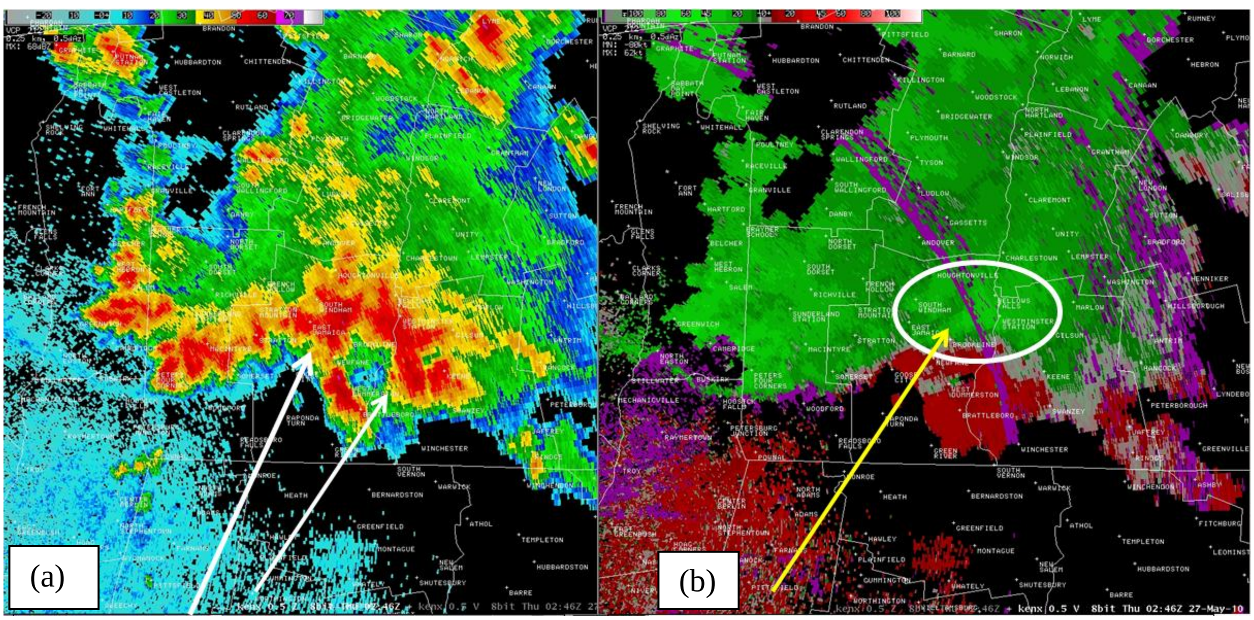

Figure 16: 0246 UTC 27 May 2010 KENX (a) 0.5°Base Reflectivity (dBZ), and (b) 0.5°Base Velocity (kts) where wind max (35-45 kts at 7.5-9 kft AGL) is moving across east/northeast Windham County, VT.

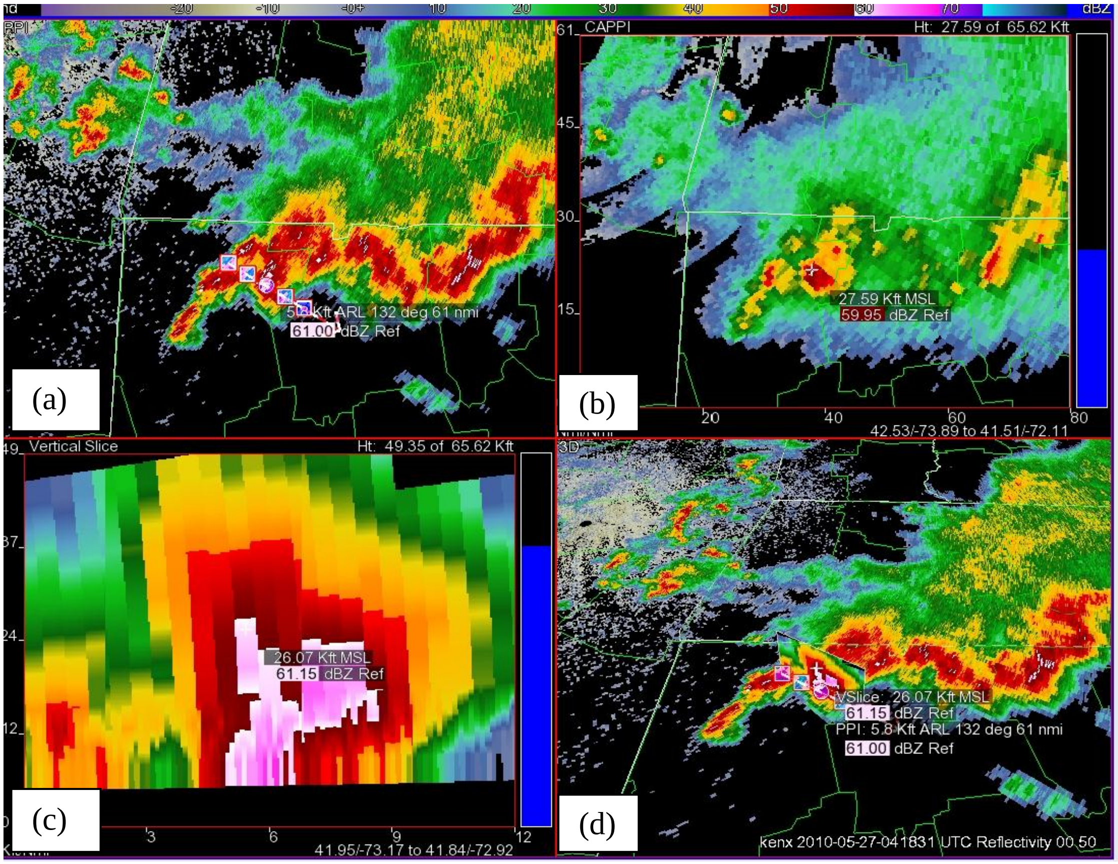

Figure 17: (a) 0418 UTC 27 May 2010 KENX 4-Panel Display of Reflectivity (dBZ). The upper left panel is the Plan Position Indicator (PPI) panel showing radar data at a constant elevation angle of 0.5°. The vertical cross-section reference line is overlayed sampling a storm in northeastern Litchfield County, CT southeast of the KENX radar. (b) Constant Altitude PPI (CAPPI) panel showing radar data from several elevation angles at an altitude of 27.6 kft MSL above radar altitude. (c) 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. (d) 3D Flier panel where reflectivity textures represent elevation scan data, vertical cross-section data, and CAPPI data are shown. The VDX shows the 60+ dBZ reflectivity echo to 26.0 kft MSL which produced quarter-size hail.

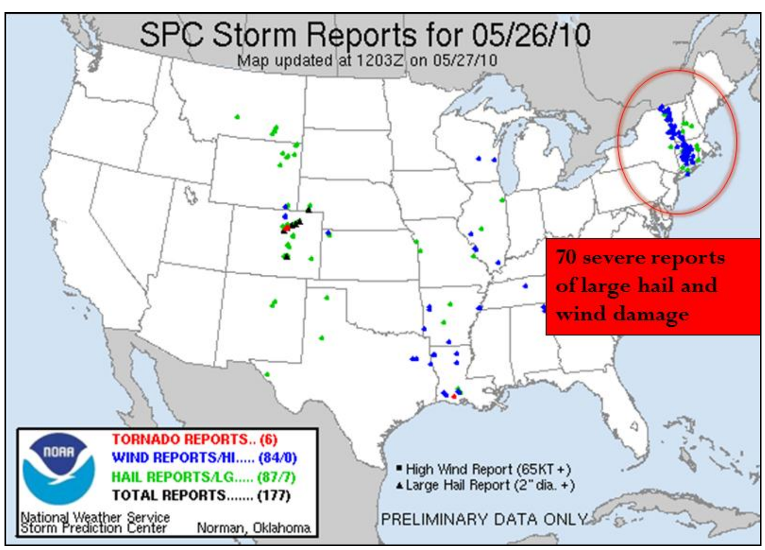

Figure 18: SPC Storm Reports for 27 May 2010 (www.spc.noaa.gov)