Widespread Severe Thunderstorm Damaging Wind Event on 19 July 2013

1.) Introduction

On 19 July 2013 a line of fast moving severe thunderstorms impacted the North County with damaging winds. This line of storms formed along a cold front, which interacted with temperatures well into the 90s and dewpoint values near 70. A record high temperature of 98 degrees (last of 5 consecutive days above 90^{o}F) was observed at Burlington, VT on July 19th prior to the arrival of these storms. The highest concentration of damaging winds occurred from northern New York into parts of central and northern Vermont, including the Champlain Valley. A goal of this post-storm write up is to identify pre-storm environments favorable for bow echo producing thunderstorms and examine the associated radar reflectivity and velocity structures.

Figure 1 below shows a map of Local Storm Reports (LSRs) received by the National Weather Service (NWS) Burlington (BTV), Vermont Weather Forecast Office (WFO). Click here for a complete listing of all the severe weather reports across WFO BTV county warning area (CWA). In Wheelock, Vermont a 60 mph wind gust was measured, before the anemometer stopped working and a 55 mph wind gust was observed at Diamond Island on Lake Champlain during the event. The primary severe weather threat observed was damaging winds, which resulted in over 11,000 people losing power across Vermont and numerous trees down across the North Country from this bowing line of storms. Click here for additional information on bow echo type mesoscale convective systems.

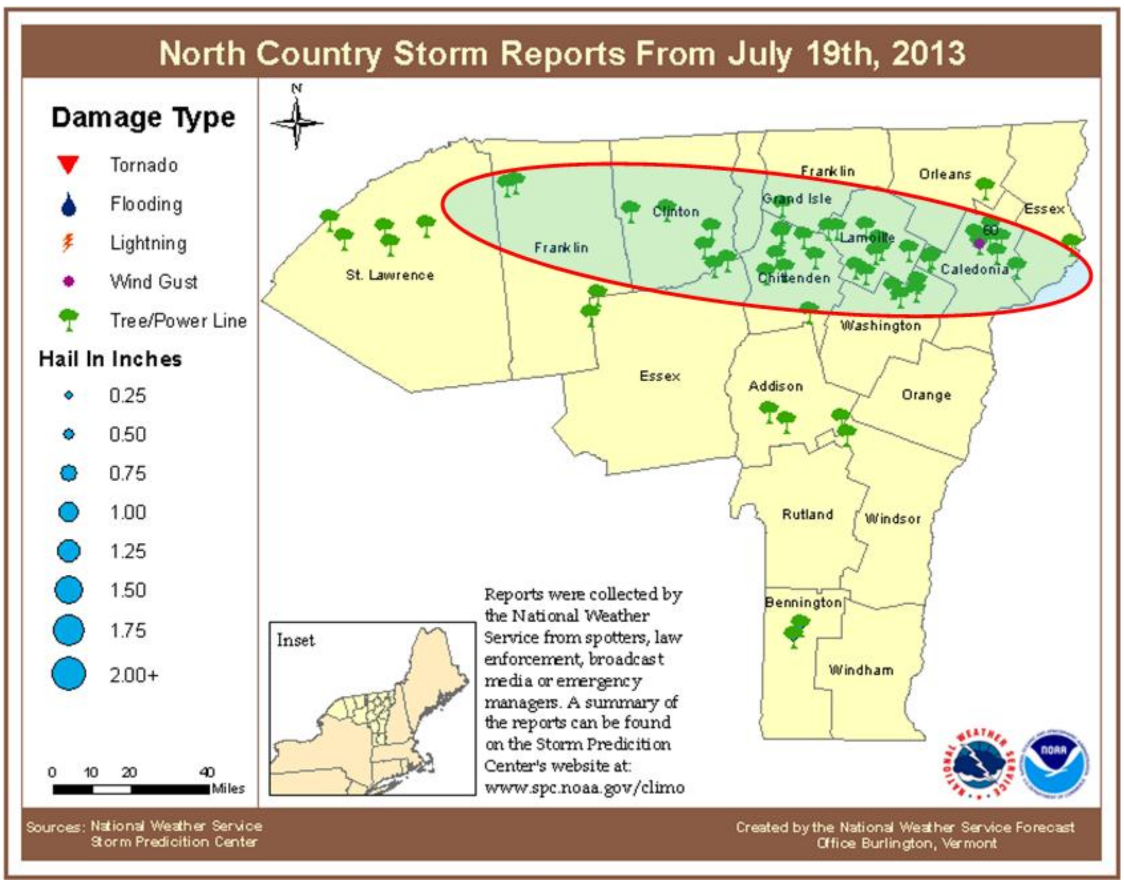

Figure 1: Map of Local Storm Reports on 19 July 2013. Oval indicates region of most concentrated wind damage.

2.) Storm Prediction Center Outlook Information

In this section we will discuss the products issues by the Storm Prediction Center (SPC) leading up and during the event, which will include the Day 1 outlooks and Mesoscale Discussions. Figure 2 below shows the SPC Day 1 categorical outlook (left image), day 1 wind outlook (middle image), and day 1 hail outlook (right image) on 19 July 2013 at 0600

UTC. Most of the BTV CWA was in a slight risk for severe thunderstorms, except extreme southern Rutland and Windsor counties. From SPC, a slight risk implies well-organized severe thunderstorms are expected, but in small numbers and/or low coverage. Depending on the size of the area, approximately 5-25 reports of 1 inch or larger hail, and/or 5-25 wind events, and/or 1-5 tornadoes would be possible. The probabilistic wind and hail forecast from SPC, showed a 15% chance of severe thunderstorm winds and hail within 25 miles of a given point during the outlook period across northern New York and central and northern Vermont. Click here for the 0600 UTC convective outlook text product from SPC on 19 July 2013.

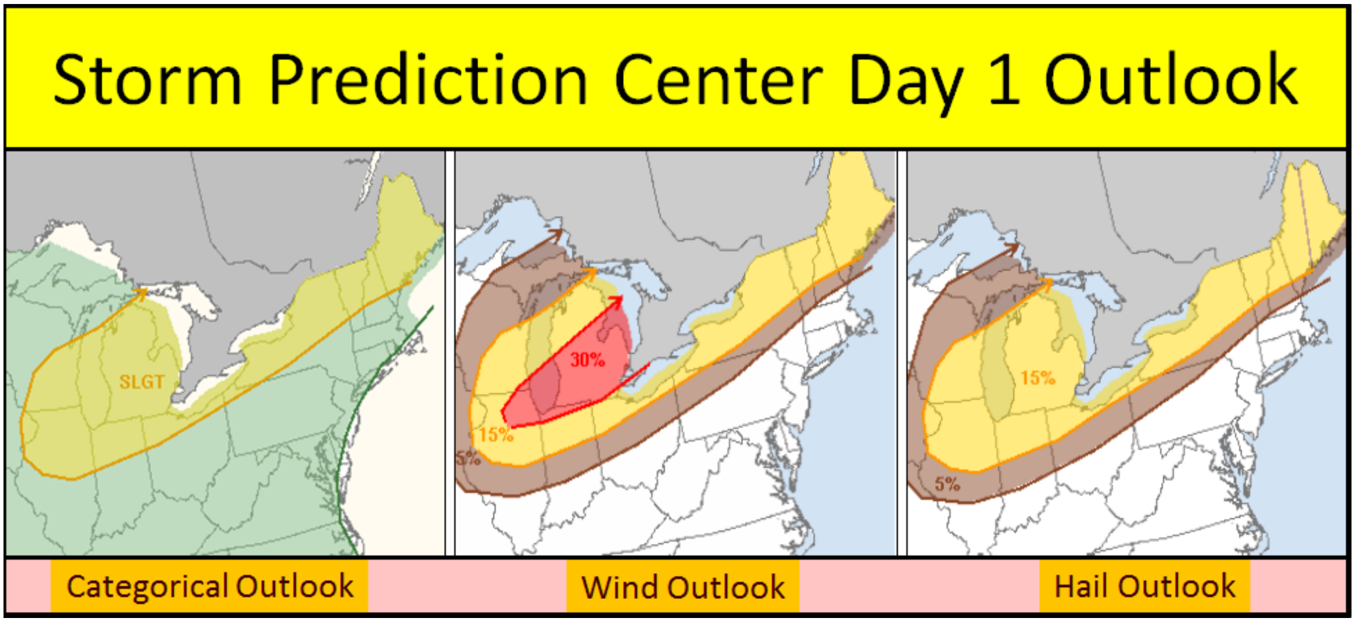

Figure 2: The Storm Prediction Center (SPC) Day 1 categorical outlook (left), SPC Wind Outlook (middle), and SPC Hail Outlook (right) issued at 0600 UTC 19 July 2013.

3.) Pre-storm Environment (Upper Air, Sounding, and Rapid Refresh CAPE and Shear)

In Section 3 of this post-storm write up we will investigate the pre-storm environment, including the upper air data, sounding, and Rapid Refresh (RAP) most unstable CAPE and effective shear. The 500 hPa (20,000 feet above ground level) showed a developing deep trough across the northern Great Lakes, with a ribbon of enhanced winds greater than 50 knots lifting from Buffalo, NY to southern Ontario Canada on 20 July 2013 at 00 UTC. In addition, Figure 3 below shows a potent shortwave trough across the eastern Great Lakes, which moved into the Saint Lawrence Valley by 00 UTC. This shortwave helped to produce large-scale lift for thunderstorm development, while the stronger winds aloft helped in the organization of storms and provided the severe weather wind threat across the WFO BTV CWA. In addition, helping to enhance the fast flow across the Mid-Atlantic States into southern Canada was the placement of the Bermuda high pressure off the East Coast and digging trough over the Great Lakes. This is clearly shown in Figure 3 below, with low pressure over the Great Lakes and high pressure off the East Coast.

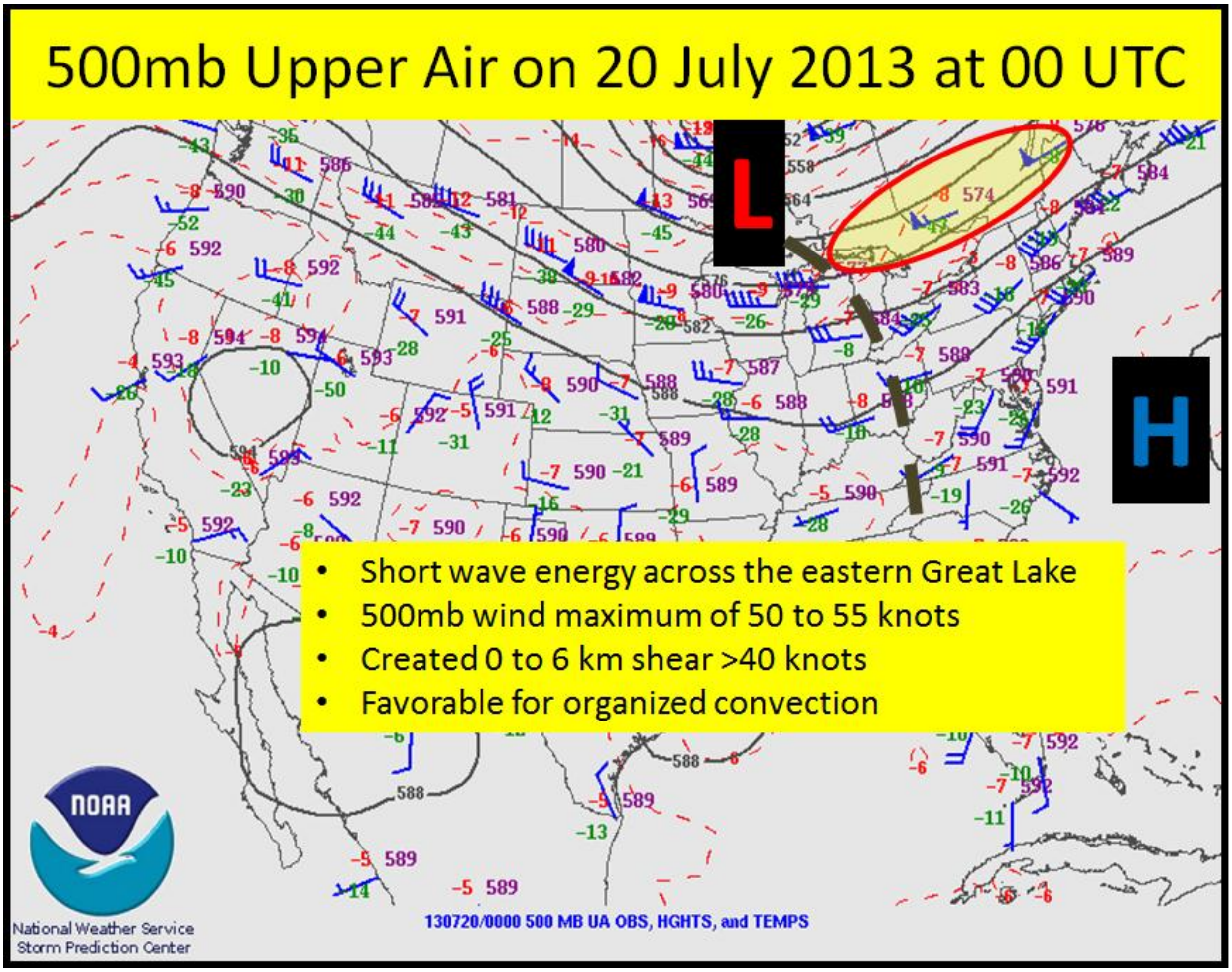

Figure 3: The 500 hPa (20,000 feet above ground level) upper air analysis on 20 July 2013 at 00 UTC. Wind barbs, (plotted in blue, 1 arrow=50 knots, 1 barb=10 knots, 1/2 barb=5 knots), 500 hPa heights (black lines), and temperatures (dotted red).

Figure 4 below shows the 250 hPa (40,000 feet above ground level) upper air analysis on 20 July 2013 at 00 UTC. A potent 125 knot jet was lifting northeast across southern Canada, placing our northern CWA in the right rear quadrant of favorable upper level divergence. These winds aloft helped to promote deep-layer ascent across northern New York into Vermont on the evening of July 19th, for the development of tall thunderstorms capable of producing severe weather.

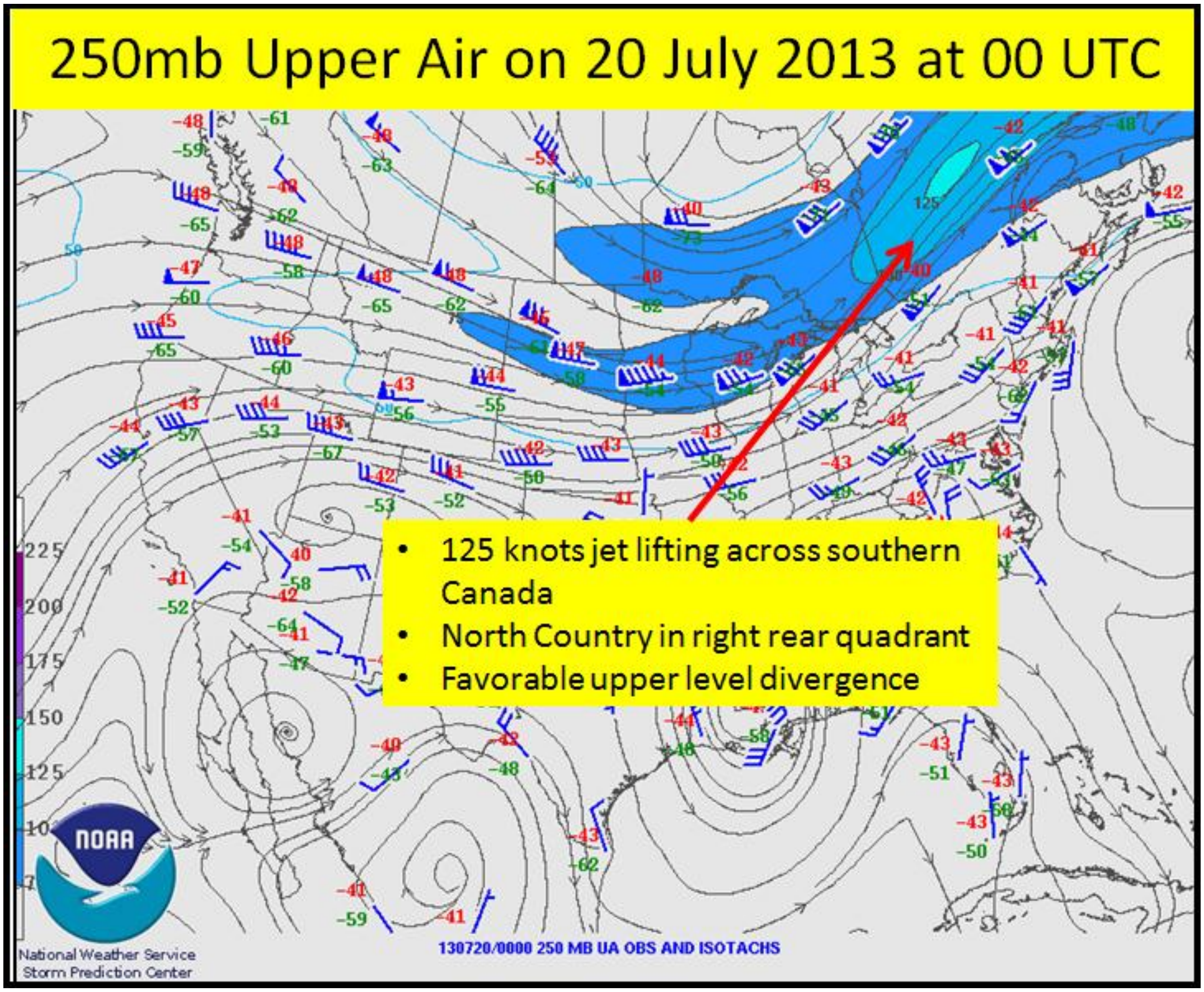

Figure 4: The 250 hPa (40,000 feet above ground level) upper air analysis on 20 July 2013 at 00 UTC. Wind barbs, (plotted in blue, 1 arrow=50 knots, 1 barb=10 knots, 1/2 barb=5 knots), Isotach (dark blue>75 knots, lighter blue>100 knots, and lightest blue>125 knots, streamlines (black), and temperatures (red).

The 12 UTC July 19th rawinsonde observation at Albany, NY (Figure 5) shows modest instability, and strong deep layer shear, due to the placement of the strong mid to upper level winds across southern Canada(as shown in the previous section). The combination of surface temperatures in the 90s and dewpoints in the upper 60s to lower 70s created surface based convective available potential energy (CAPE) values of 2291 J/kg, with a lifted index (LI) of -7C (Celsius). CAPE values greater than 1500 J/kg, suggests a moderately unstable environment, favorable for thunderstorm development. In addition, the Albany sounding showed surface to 6km shear of 35 knots. This shear was a result of the approaching mid/upper level trough and the embedded jet streaks. Thunderstorms tend to become more organized and persistent as vertical shear increases. Supercells and organized convection, such as squall lines with bow echoes are commonly associated with vertical shear values of 35-40 knots and greater through this depth.

Given the freezing level around 15,000 feet and high wet bulb zero heights >12,000 feet, severe hail was not expected to be a significant impact. However, large CAPE profile and very high equilibrium levels indicated thunderstorms would extend 45,000 to 50,000 feet into the atmosphere, and be capable of producing severe winds and localized heavy rainfall. The equilibrium level is the level at which the rising parcel equals the actual air temperature at that given height, and results in the rising parcel now becoming stable; it no longer accelerates upward. In addition, the Albany sounding showed a very deep and well mixed layer from the surface through 650 hPa. This deep mixed layer produced an environment favorable for transporting strong winds to the surface associated with thunderstorm convection.

Finally, the 12 UTC Albany sounding showed a precipitable water value of 1.59 inches, which suggests the potential for thunderstorms to produce very heavy rainfall. Precipitable water is the depth of the amount of water in a column of the atmosphere if all the water in that column were precipitated as rain. Values greater than 1.2 inches, suggests a greater potential for heavy rainfall, especially during the summertime.

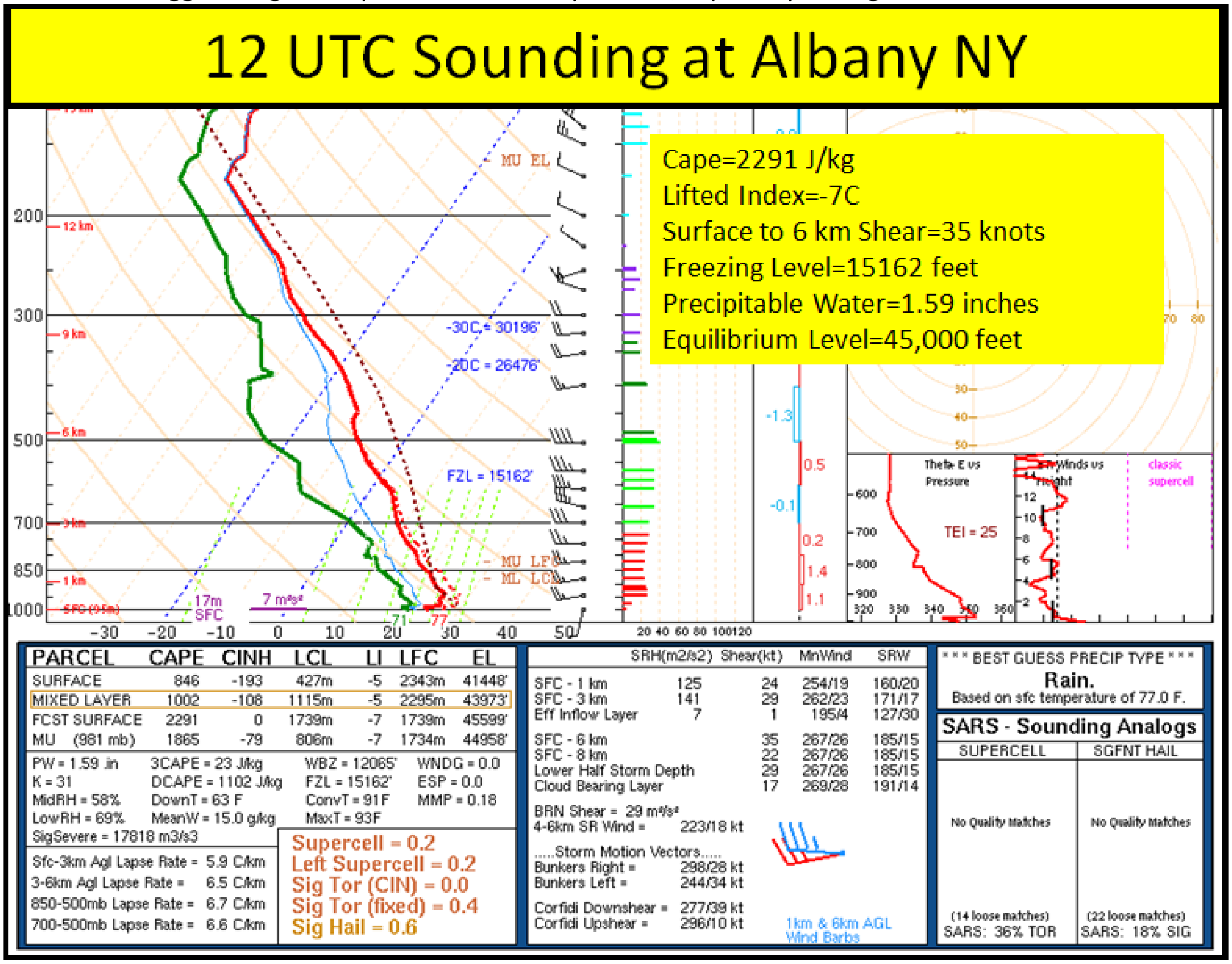

Figure 5: Albany, New York observed sounding on 19 July 2013 at 1200 UTC.

Figure 6 shows Rapid Refresh (RAP) analysis of CAPE and 0 to 6 km effective shear from SPC on 19 July 2013 at 2000 UTC. As the mid-level jet approached the region the deep layer shear increased to between 35 and 45 knots, while CAPE values ranged between 3000 and 4000 J/kg across most of our CWA. Note, the best combination of deep layer shear and highest instability (CAPE) was located across northern New York into parts of central and northern Vermont and closely matches the region of greatest concentration of damage.

This pre-storm environment was conducive for well-organized and persistent convection to develop, capable of producing damaging winds associated with a bow echo storm structure. Also, from Figure 6, you can see the Convective Inhibition (blue shaded areas) decreased significantly as surface temperatures warmed into the 90s and was only present over the cooler Lake Ontario and Atlantic Ocean waters.

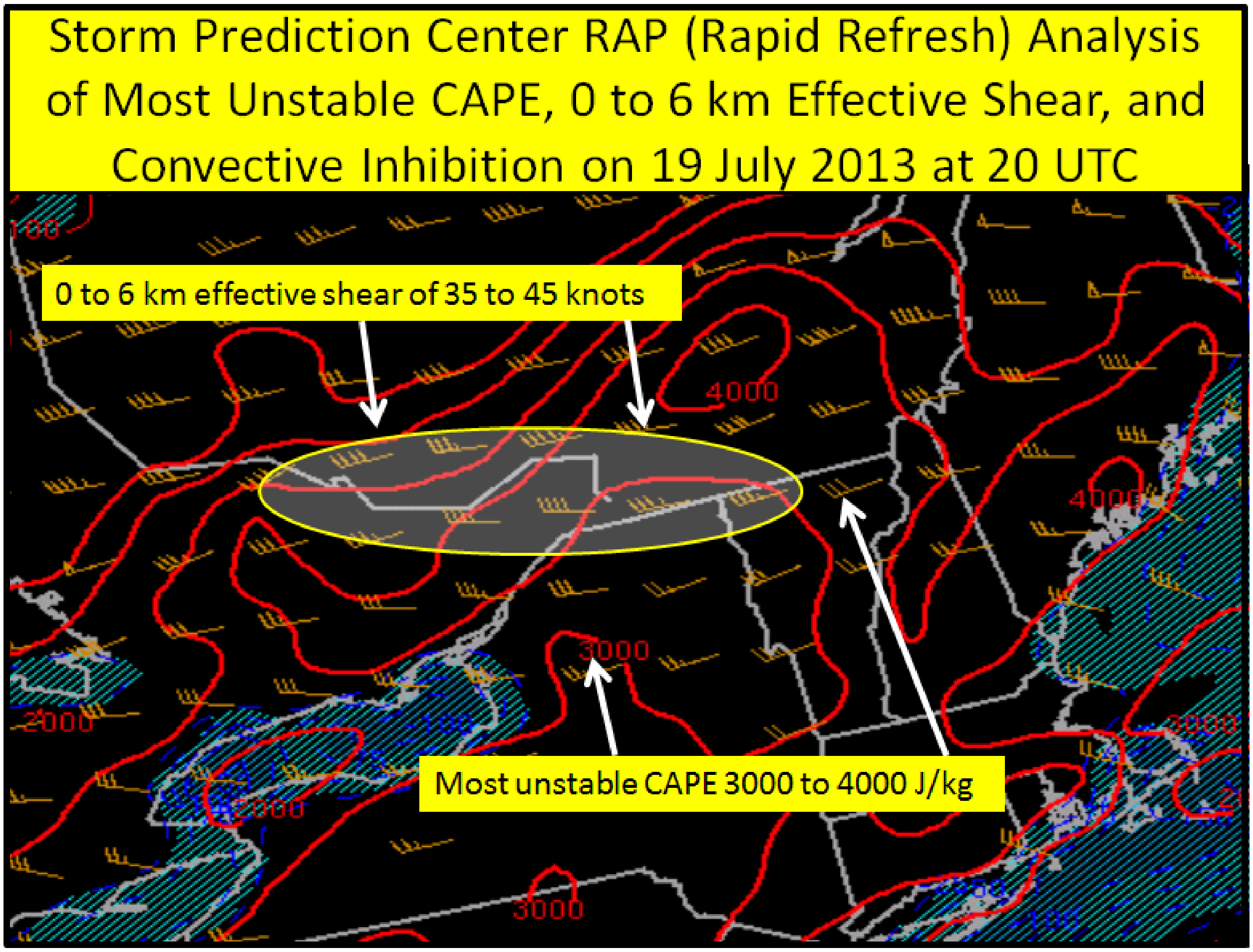

Figure 6: Storm Prediction Center (RAP) Rapid Refresh analysis of CAPE (red lines), 0 to 6 km effective shear (orange wind barbs), and Convective Inhibition (light blue shading) on 19 July 2013 at 2000 UTC.

4.) Storm Prediction Center Mesoscale Graphics and Discussion

Figure 7 below shows SPC's two mesoscale graphics issued prior to and during the severe weather event on 19 July 2013. The image on the left indicates severe storms are likely with the primary threat being damaging wind gusts as a line of thunderstorms approaches the Saint Lawrence Valley at 21 UTC. The right image shows several intersecting outflow boundaries and the continued threat for mainly isolated damaging winds across northern and central Vermont and most of northern New England through midnight on July 19th. Click here for the detailed mesoscale convective discussions #1435 and #1439, which were issued by SPC. At 1600 UTC the SPC issued severe thunderstorm watch #423 until 2300 UTC on 19 July 2013 for WFO BTV entire CWA, with damaging winds as the primary threat.

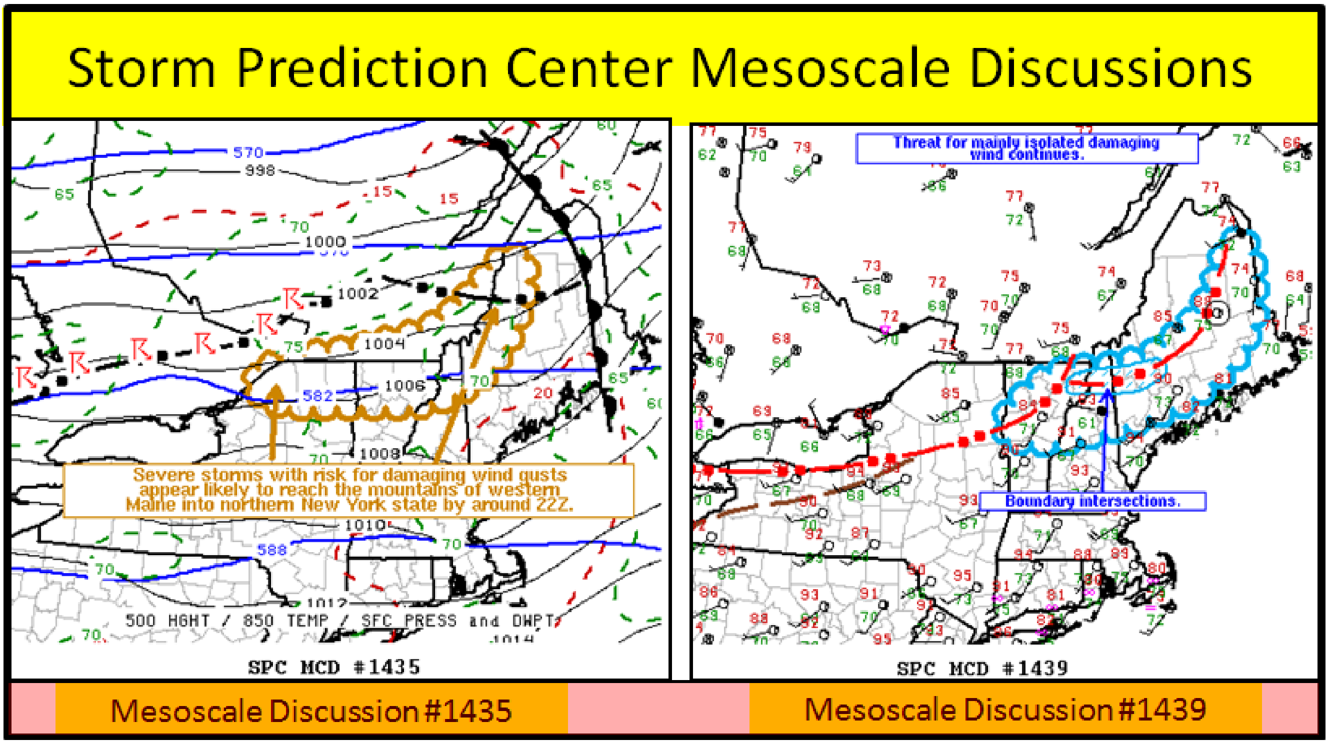

Figure 7: Storm Prediction Center Mesoscale Discussion #1435 (left image) and #1439 (right image).

5. Radar overview

The mosaic composite reflectivity loop (see figure 8 below) from 1836 UTC to 2354 UTC (3:36 PM to 7:54 PM EDT) shows the transition of a northeast-southwest line of thunderstorms across the Ottawa Valley into a more north-south oriented line exhibiting an increase in forward motion as it sweeps across northern New York and Vermont.

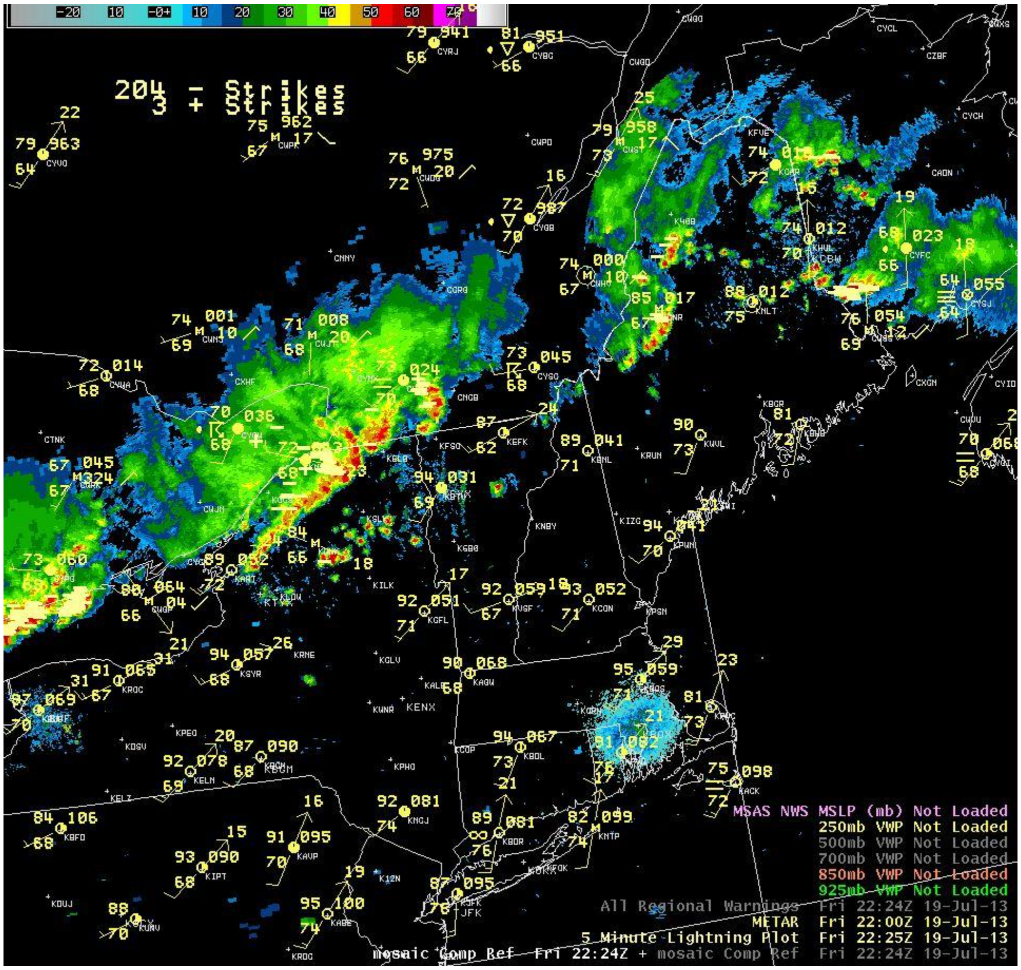

Figure 8: Mosaic composite reflectivity (dBZ) at 2224 UTC 19 July 2013 with surface observations taken at 22 UTC 19 July 2013. Click to launch radar reflectivity loop. (Click image to animate)

As is common with lines of convection in high instability environments, evaporatively cooled air stemming from heavy rainfall creates a mesoscale cold pool, which induces strong pressure gradients and accelerates the convective line. The rain-cooled air is evident in the overlaid surface observations; at 22 UTC note the temperature of 72^{o}F as the line passes Massena, NY while temperatures in advance of the line were still in the low to mid 90s. Consistent with the cold pool, a *pressure jump* occurred at Massena (+2.4 mb in 1 hour) as the thunderstorms passed, owing to relatively dense, convectively cooled air trailing the leading edge of thunderstorms activity.

The convective line evolved into a well-defined *bow echo* across Franklin and Clinton counties in northern New York between 2210 UTC and 2257 UTC (see Figure 9 below), in which the reflectivity structure resembled that of an archer’s bow.

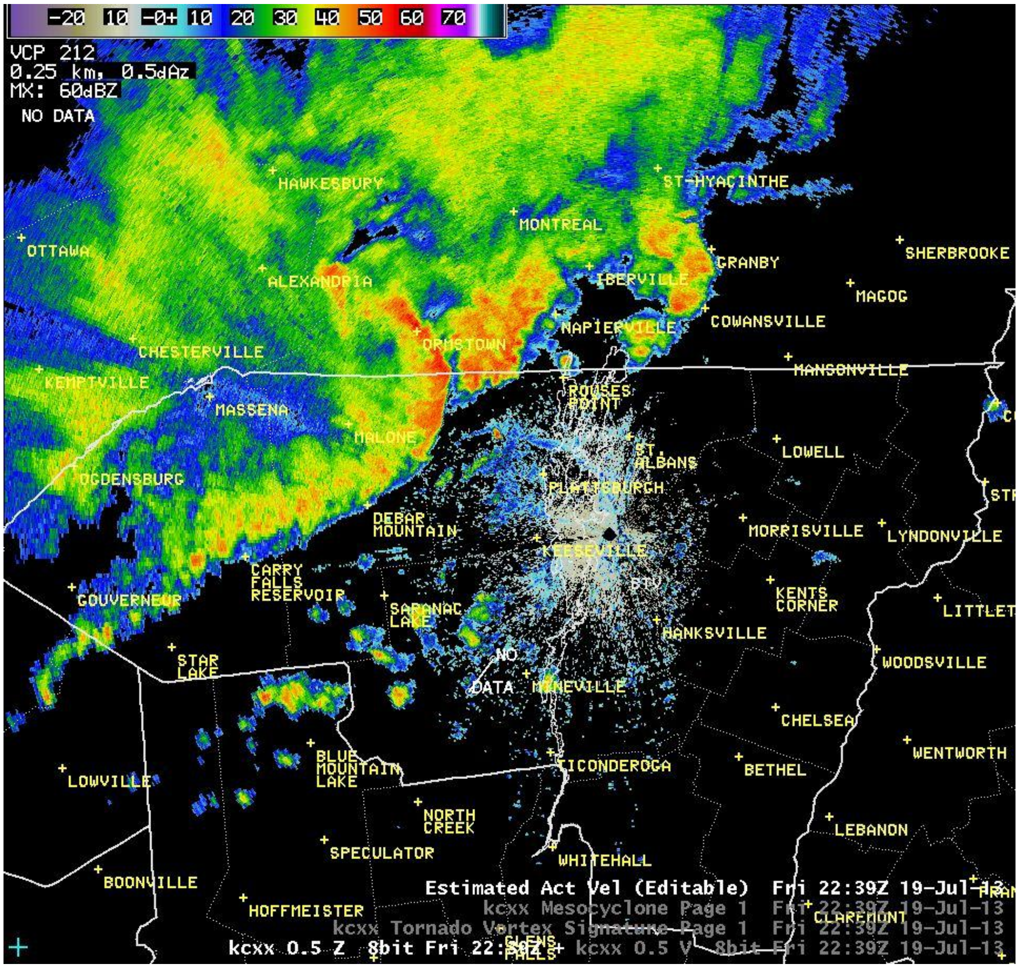

Figure 9: KCXX 0.5^{o} reflectivity (dBZ) at 2239 UTC 19 July 2013. Click to launch radar reflectivity loop. (Click image to animate)

This is an indication of potentially damaging straight line winds where a portion of the convective line "bows out" where downburst winds are strongest, typically near the apex of the bow echo (Figure. 10).

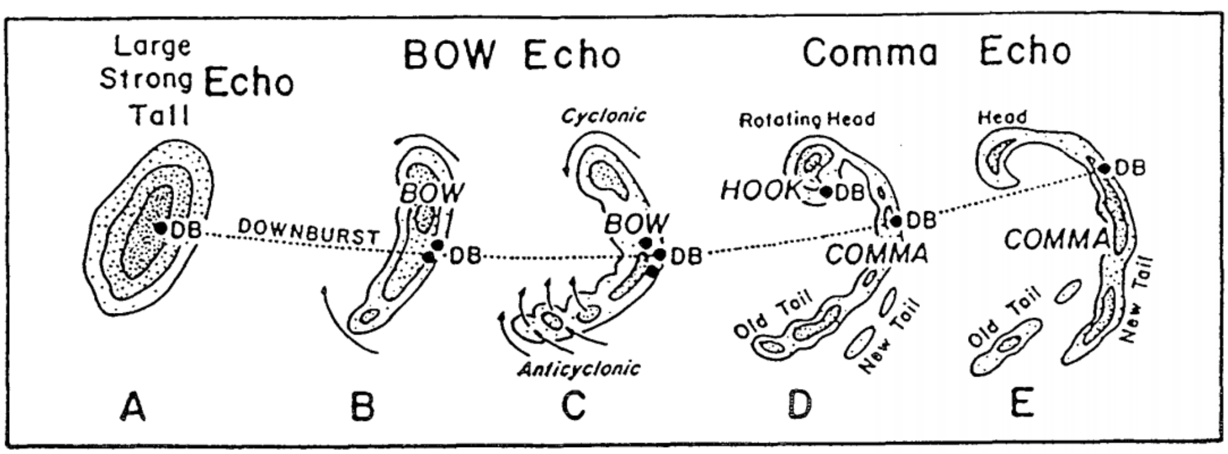

Figure 10: Idealized morphology of an isolated bow echo associated with strong and extensive downbursts. (from Johns 1993)

The direction of the highest winds occur perpendicular to the convective line, or from the west, in this case. The average forward speed of the bow echo increased to near 50 knots (58 mph) across Franklin and Clinton counties, with the apex of the bow moving up to 62 knots (71 mph) across that region. The forward speed of linear convective structures typically provide a rough estimate of the associated surface winds, and the forward motion exceeded NWS severe criteria of 50 knots in this case. Of course, Doppler velocity data is also utilized to remotely sense wind speeds within convective storms. Since the Doppler radar measures the speed of reflectors (e.g., raindrops) toward or away from the radar, the best velocity estimates occur when the line motion is perpendicular to the radar beam. In this event, the line becomes increasingly parallel to the beam as it approaches the Champlain Valley, resulting in underestimation of the actual wind speeds. Despite this geometric limitation, observed Doppler velocities were near 70 knots at 1800 feet AGL across west-central Clinton County at 2239 UTC, and between 50-55 knots at 1400 feet AGL between Plattsburgh and Beekmantown at 2302 UTC (See Figure 11).

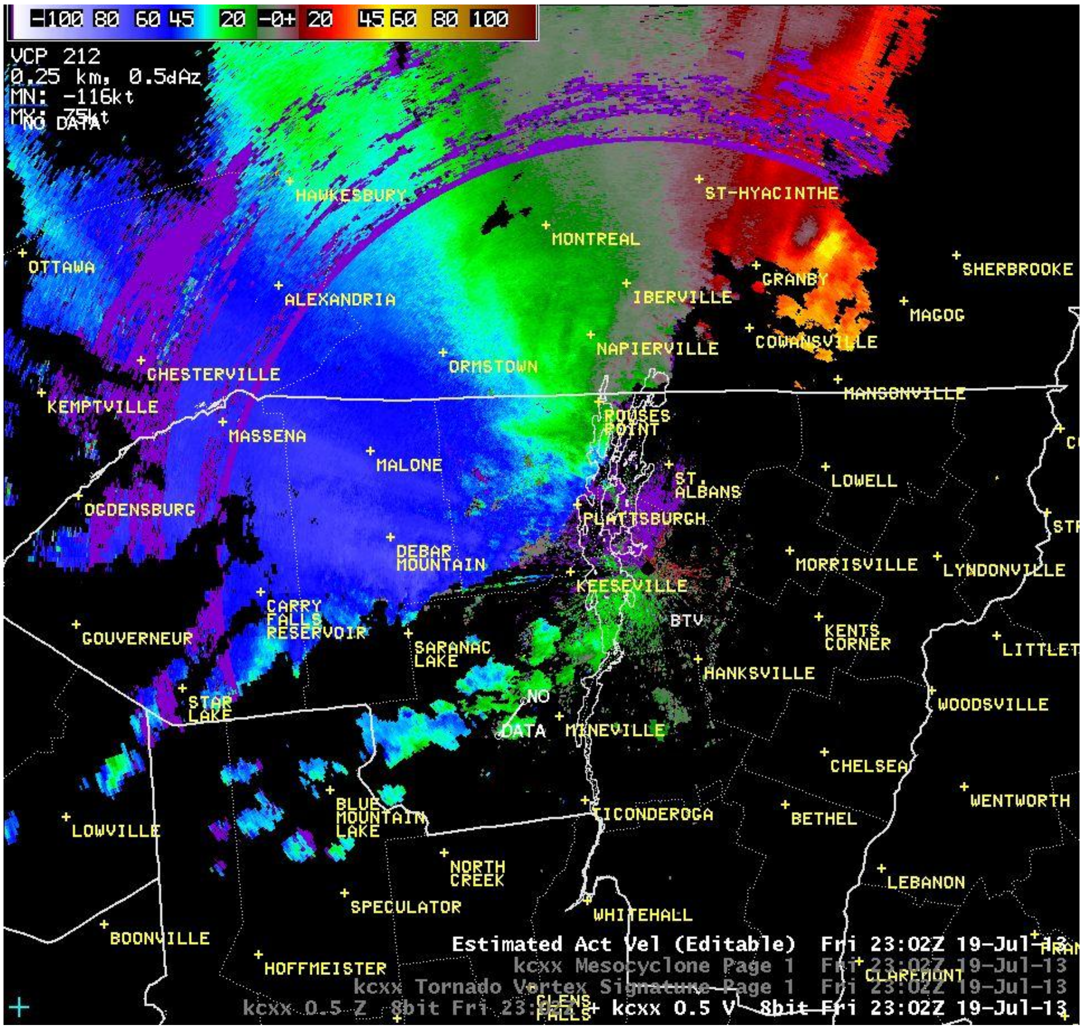

Figure 11: KCXX 0.5° velocity (knots) at 2302 UTC 19 July 2013. Click to launch base velocity loop. (Click image to animate)

Other organization structures that prompted forecasters to the severity of this bow echo included: (1) a sharp reflectivity gradient on the leading edge of the box echo, and (2) weak echo channels on the upstream side of the bow, an indication of a descending rear inflow jet that is resulting in locally enhanced winds along the line (Fig. 12).

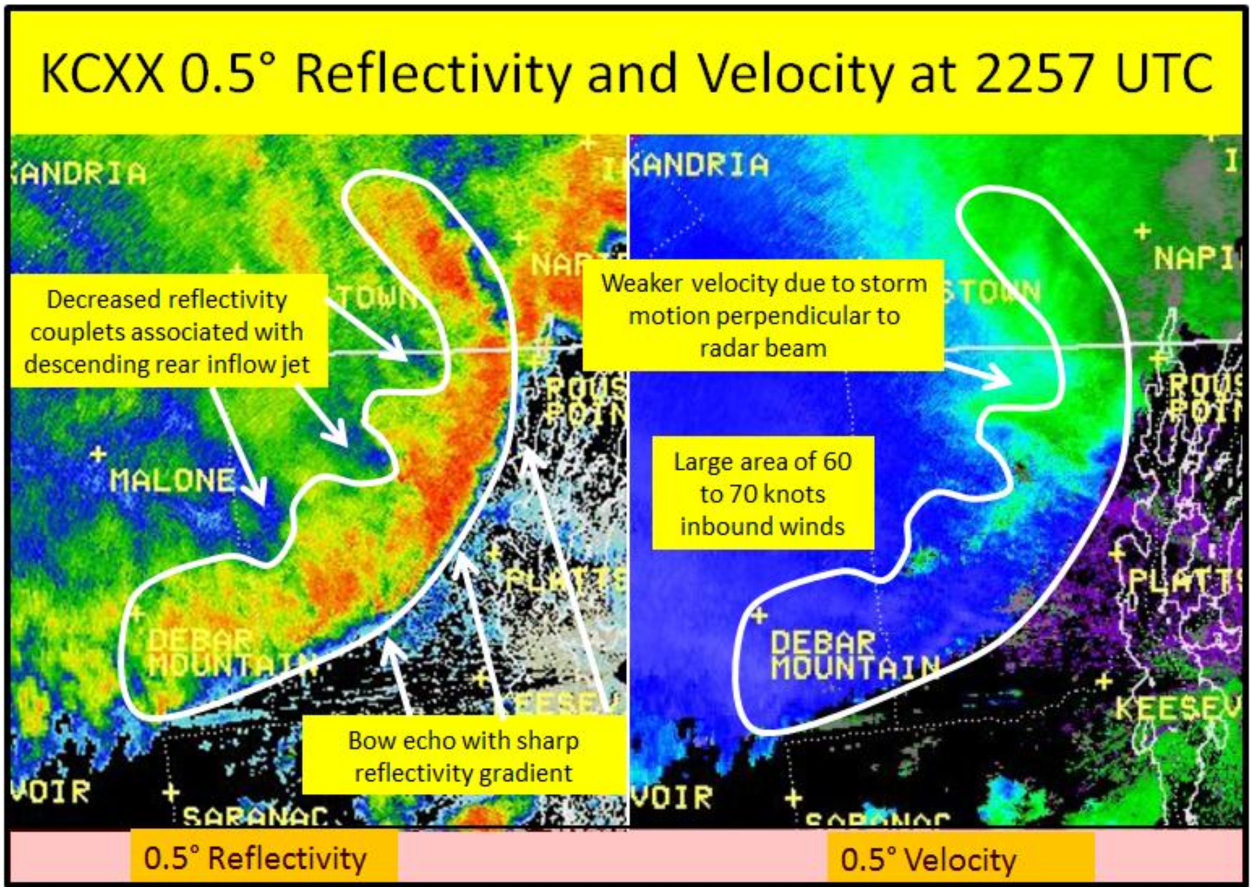

Figure 12: KCXX 0.5° reflectivity (left) and velocity (right) at 2257 UTC 19 July 2013 as bow echo moved across far northeastern New York.

As the bow echo moved eastward into northwestern Vermont, it intersected an outflow boundary which originated from earlier convective storms across southern Quebec. The outflow boundary became quasi-stationary in an east-west orientation across far northern Chittenden County in advance of the approaching bow echo (Fig. 9), and appeared to provide a focus for straight line wind damage resulting in toppled trees and removal of shingles from roofs in the Milton/Lake Arrowhead area. Further east, widespread tree damage was reported in Stowe around 2345 UTC and into the Northeast Kingdom of Vermont between 0000 – 0030 UTC 20 July 2013 as the fast-moving bow echo continued eastward. Increasing distance from the KCXX radar and beam blockage caused by mountain caused the convection to look less organized, but wind damage continued to the upper Connecticut River valley and into Coos County NH before the wind intensity diminished below severe limits.

The 19 July 2013 bow echo approached, but did not reach, the oft-cited criteria for a *derecho* (see: http://www.spc.noaa.gov/misc/AbtDerechos/derechofacts.htm for more information). While the wind-producing convective system covered a distance around ~250 miles from the Ottawa Valley of Ontario to northern New Hampshire, at least 3 measured wind gusts to hurricane force ≥ 65 kt (≥74 mph) spaced at least 40 miles apart are also needed in the traditional definition (see Johns and Hirt, 1987). It didn't appear from reports received and observations that this wind-producing system reached the significant wind speed criteria. That said, it is worth noting that the physical processes involved are the same between the bow echo on 19 July 2013 and higher-end systems that may be classified as derechos. Examples of rare derechos affecting portions of the North Country include the 14-15 July 1995 Adirondack derecho and 4-5 July 1999 derecho. The 19 July 2013 bow echo was more in line with the magnitude of the "Route 7 Runner" event observed on 26 May 2010.

6. Visual cloud patterns associated with Bow echoes

Ragged cloud structures associated with bow echoes and severe straight line winds can look quite ominous with vertically oriented filaments (Fig. 13). Such features are occasionally mistaken for tornadoes to the untrained observer. Strong forced ascent on the leading edge of the bow echo gust front and turbulent mixing with rain cooled air behind the gust front causes the warm and humid rising air to saturate and develop cloud fragments beneath the solid cloud layer associated with the main part of the convective system. Unlike a tornado, such clouds are not rotating in a horizontal fashion with respect to the ground. Instead, these dynamic clouds – generally called fractus or "scud" clouds - are generally moving up as the rain cooled air undercuts the region of cloud formation. Such motion can be quite dramatic as the leading storm gust front approaches the observer.

Figure 13: A photo of scud clouds along the leading edge of a thunderstorm gust front in central Vermont. Photo taken by NWS BTV trained spotter.

7. Summary

On 19 July 2013 a line of severe thunderstorms impacted many people across the North County with damaging winds, which caused power outages and trees to be uprooted. The greatest concentration of damaging winds from these fast moving storms occurred from northern New York into parts of the central and northern Vermont, including the Champlain Valley. Radar reflectivity clearly shows a well-defined squall line with several bowing segments occurred across WFO BTV CWA. In addition, numerous pictures and video from spotters and the public confirmed a well-established shelf cloud with gusty winds preceding the heavy rain. Figure 14 below shows a well- defined shelf cloud taken during this event over St. Albans Bay. Finally, this line of storms and associated surface cold front brought an end to our heat wave and provided much cooler and less humid air to the North Country. Figures 15 below shows a picture of a large pine tree uprooted in Milton, Vermont from the damaging thunderstorms winds on 19 July 2013**.**

Figure 14: Shelf cloud near St Alban's Bay on 19 July 2013. Photo taken by Matt Sutkosky of the Burlington Free Press.

Figure 15: Large pine tree uprooted along U.S. Route 7 in Milton, VT on 19 July 2013.

References

Johns, R. H., 1993: Meteorological conditions associated with bow echo development in convective storms. *Wea. Forecasting*, **8**, 294-299.

Johns, R. H., and W. D. Hirt, 1987: Derechos: widespread convectively induced windstorms. *Wea. Forecasting*, **2**, 32-49.