The Widespread Damaging Wind Event on 8 July 2014 across Northern New York and Most of Vermont

1.) Introduction

On the evening of July 8th 2014 a line of fast moving severe thunderstorms impacted the North County with damaging winds. This large convective complex was characterized by numerous small-scale bow segments within the line, which formed along a cold front and interacted with temperatures well into the 80s and dewpoint values near 70. The highest concentration of damaging winds occurred from the Saint Lawrence Valley in 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). The severe thunderstorm winds were estimated between 60 and 80 mph across many locations in the North Country during this event. The primary severe weather threat observed was damaging winds, which resulted in over 30,000 people losing power across Vermont and numerous trees down across the North Country. Click here for additional information on bow echo type mesoscale convective systems.

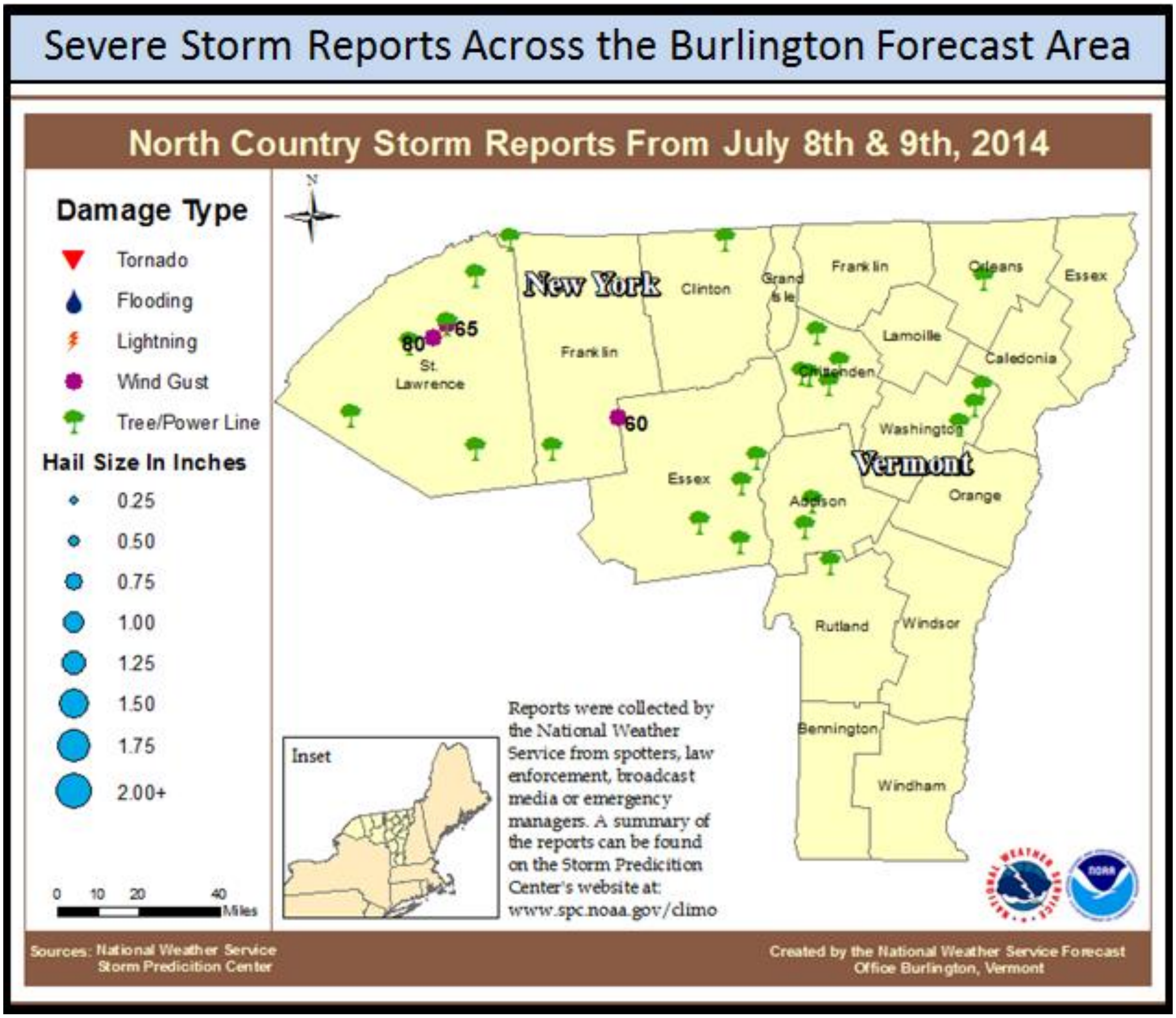

Figure 1: Map of Local Storm Reports on 27 May 2014. Green trees indicate trees or power lines down, light blue circles show locations of large hail, and red dots denote measured wind gusts.

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 tornado outlook (right image) on 08 July 2014 at 1630. Most of the BTV CWA was in a slight risk for severe thunderstorms, except extreme eastern Vermont. 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. Click here for the Day 1 SPC Outlook. The probabilistic wind and tornado forecast from SPC, showed a 15% chance of severe thunderstorm winds within 25 miles of a given point during the outlook period across northern New York and central and northern Vermont. The tornado probability was 2% for all of northern New York into the Champlain Valley. This meant that as high as a 2% probability of tornadoes occurring with 25 miles of any point was expected in the 2% probability area. It should be noted SPC did upgrade parts of western New York and Pennsylvania to a moderate risk for the expected widespread convection.

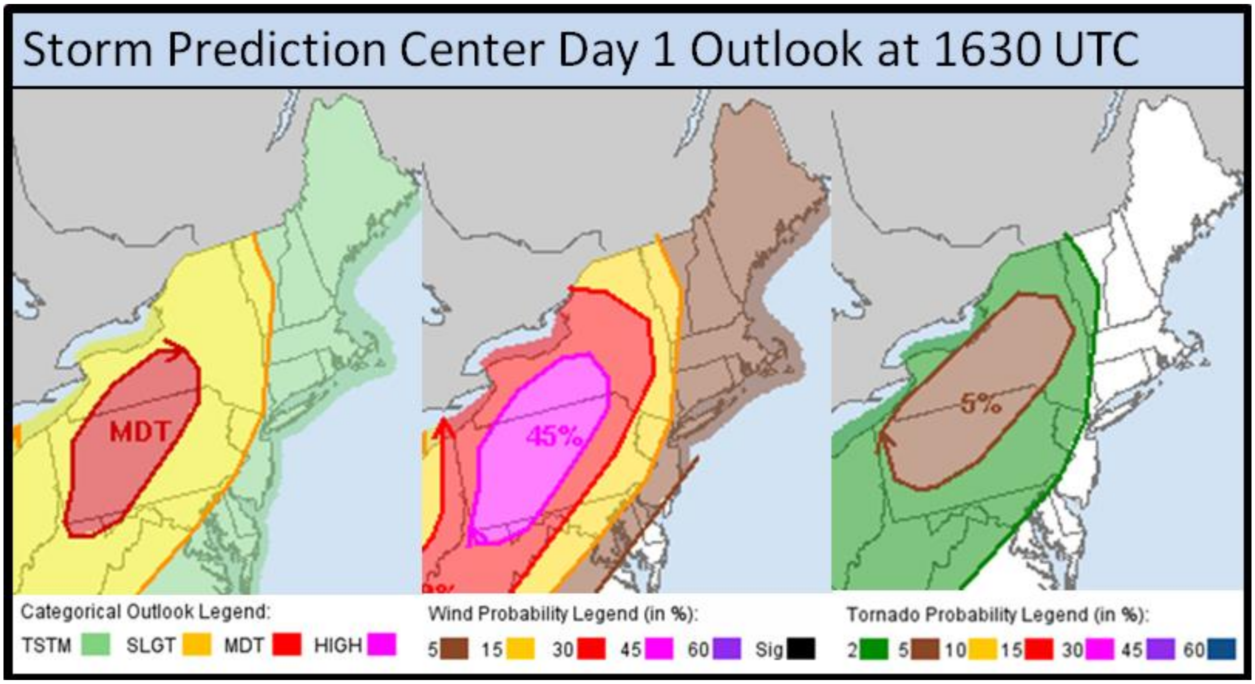

Figure 2: The Storm Prediction Center (SPC) Day categorical outlook (left), SPC Wind Outlook (middle), and SPC Tornado Outlook (right) issued at 1630 UTC on 08 July 2014.

At 2145 UTC (05:45 PM local), the SPC issued a Mesoscale Discussion addressing the potential for a severe thunderstorm watch as conditions were becoming favorable for thunderstorm development. The combination of extremely strong deep layer shear, modest instability, and a well-defined short wave trough would help expand the areal coverage and intensity of thunderstorm activity across the North County. At 2230 UTC on 8 July 2014, SPC issued a Severe Thunderstorm Watch for most of interior New England, effective through midnight local time.

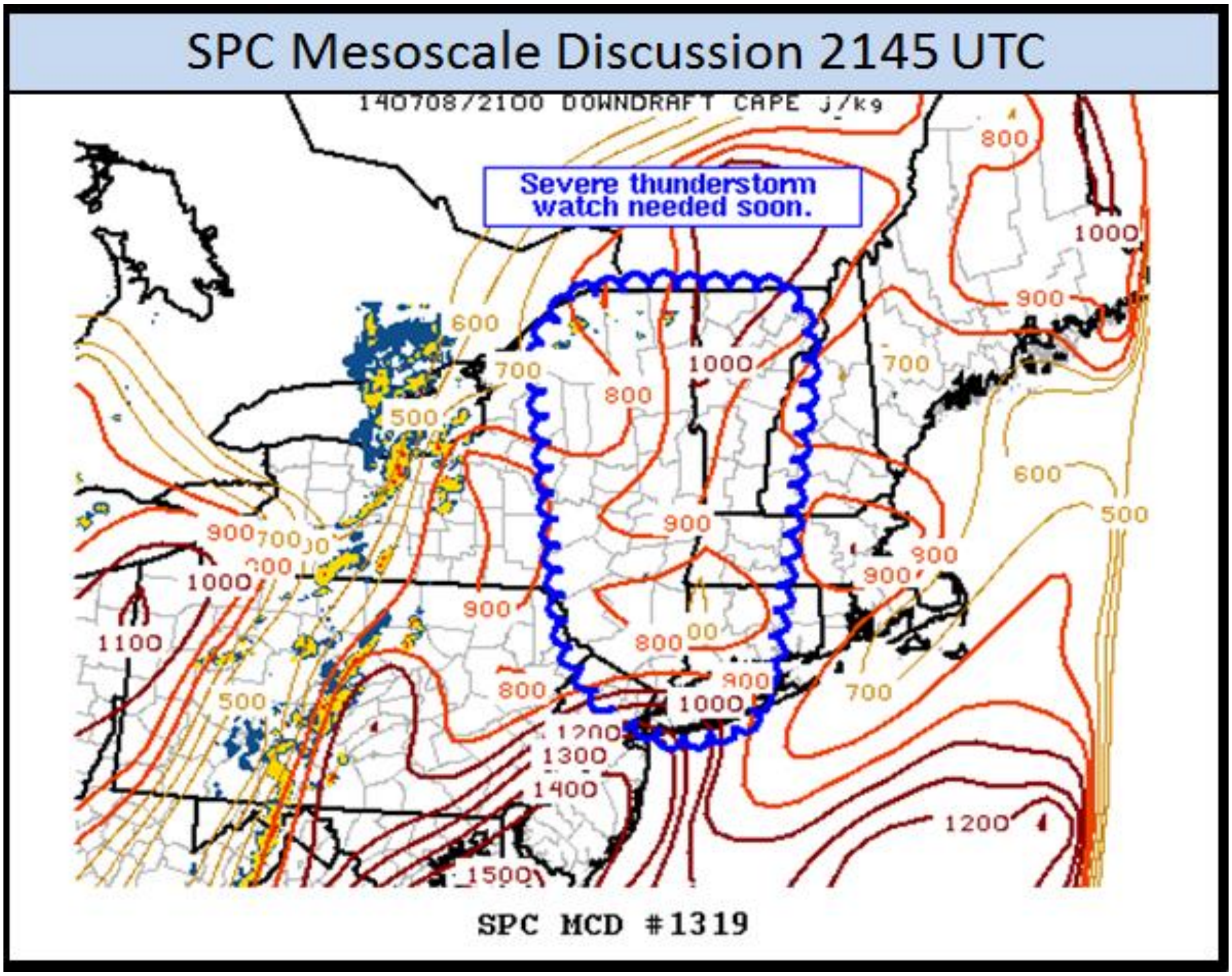

Figure 3: Storm Prediction Center Mesoscale Discussion # 1319.

3.) Pre Storm Environment (Surface Map, Sounding, and CAPE/Shear Parameters)

In this section we will review the pre storm environment, including a surface analysis map, a 500 hPa upper air analysis, and model sounding, along with shear and instability parameters. Figure 4 shows the 2300 UTC surface map and associated analysis on 8 July 2014. A well-defined cold front extended from a convectively induced meso surface low pressure across the Saint Lawrence Valley, while a weak warm front was lifting across northern New York and Vermont. The air mass in the warm sector was characterized by temperatures in the 80s and dewpoint values near 70^{o}F, even into the evening hours on July 8th. This cold frontal boundary provided the necessary surface convergence and lift to produce multiple bowing line segments which resulted in severe thunderstorms across the North Country.

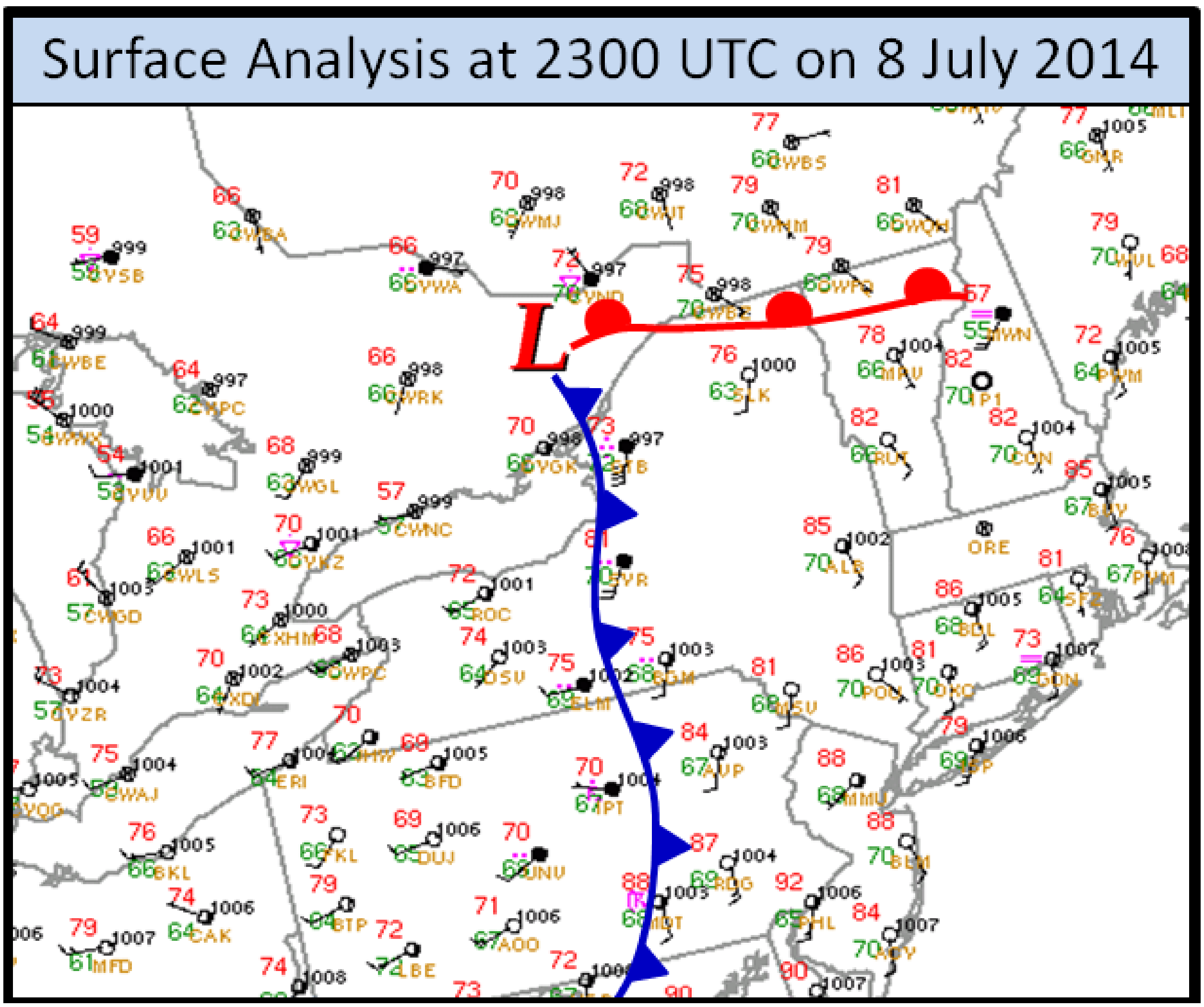

Figure 4: Surface Map at 2300 UTC on 08 July 2014 with surface plots, cold front (light blue line with triangles) and warm front (red half circles).

Figure 5 below shows the 500 hPa (~18,000 feet above the ground level) upper air analysis on 8 July 2014 at 1200 UTC. A potent short wave trough was moving across the Ohio Valley and central Great Lakes, along with a ribbon of enhanced wind speeds. This vigorous short wave 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 forecast area. The 500 hPa winds across the Ohio Valley into western New York were between 45 and 60 knots and with a good upper level divergent pattern in the height fields, which promoted deep vertical lift for thunderstorm development.

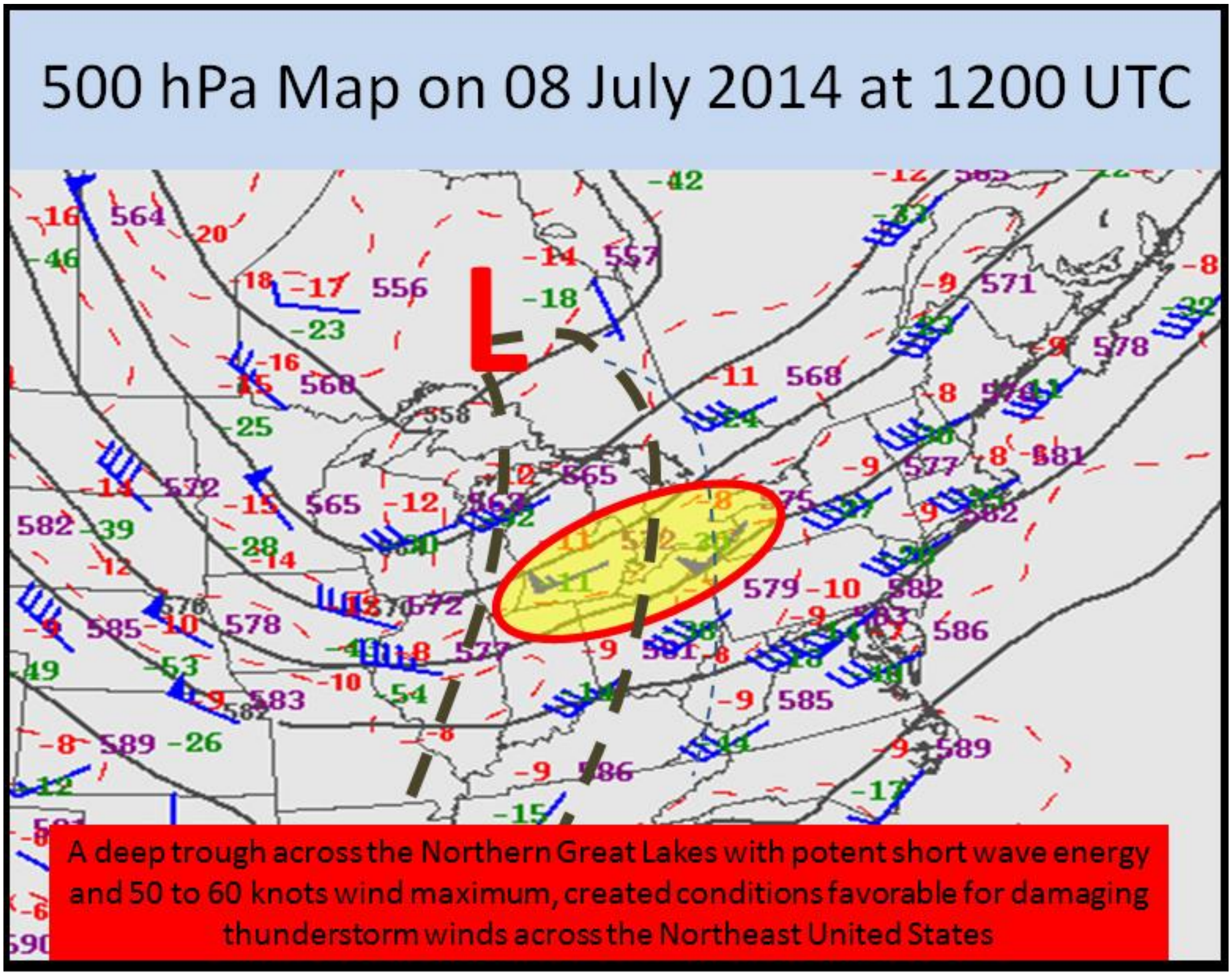

Figure 5: The 500 hPa (~18,000 feet above the ground level) upper air analysis on 8 July 2014 at 12 UTC. Wind barbs, (plotted in blue, 1 arrow=50 knots, 1 barb=10 knots, 1/2 barb=5 knots, 500 hPa heights (black lines), and temperatures (dotted red).

Figures 4 and 5 below show the BTV 4km-WRF Bufkit sounding at Massena, NY at 0100 UTC and Burlington, VT on 09 July 2014. Based on observational data, the 1200 UTC run of the local BTV 4km resolution model sounding at Massena, NY and Burlington, VT did the best at representing the pre-storm thermodynamic environment and associated wind fields. In addition, the close proximity of theses soundings to the track of the mesoscale convective complex and associated bow echoes, provided forecasters with the best gage of the available CAPE and shear. This forecast sounding showed CAPE values of 713 J/kg and a lifted index of -2 Celsius at Massena and similar values at Burlington. Given the limited instability expected storm tops were only between 28,000 and 35,000 feet above the ground (during high CAPE events, storms can grow to be over 50,000 feet tall).

Both locations had extremely strong winds between 2000 and 5000 feet above of the ground of 45 to 55 knots, which were brought to the surface during the heavy downpours. The surface to 6 km bulk shear values were between 55 and 62 knots with a unidirectional profile, supporting a damaging wind threat. The combination of strong deep-layer shear and modest instability helped produce and sustain the convective line with embedded small-scale bow echoes across the region. Also, precipitable water values of 2.10 inches suggested the potential for 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 1.5 inches, suggest a greater potential for heavy rainfall, especially during the summertime. Burlington, VT recorded 1.25” of rainfall associated with the line of thunderstorms during the evening of July 8th.

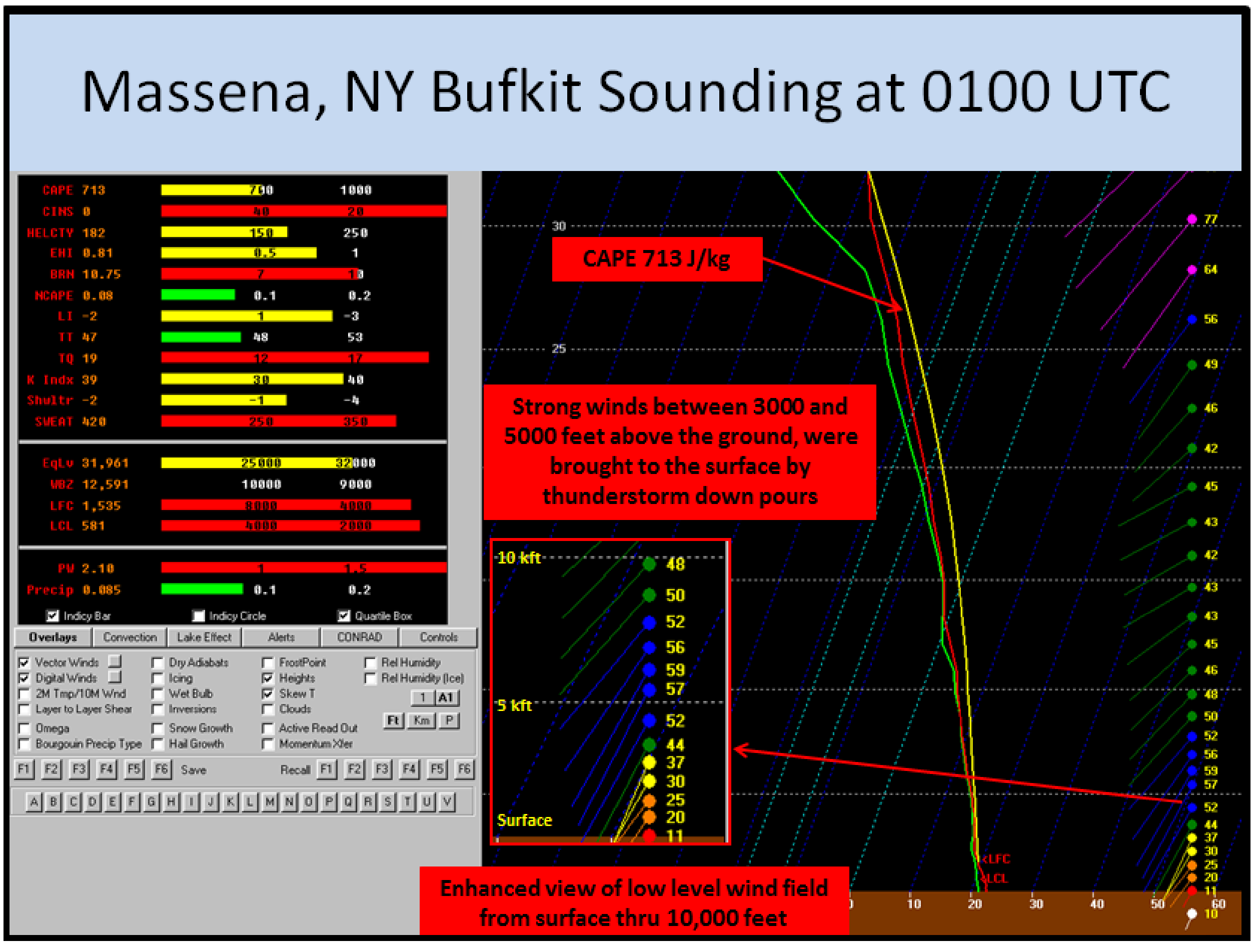

Figure 6: BTV 4-km WRF Bufkit Sounding at Massena, NY at 0100 UTC on 09 July 2014 (4 hour forecast based on 12 UTC run).

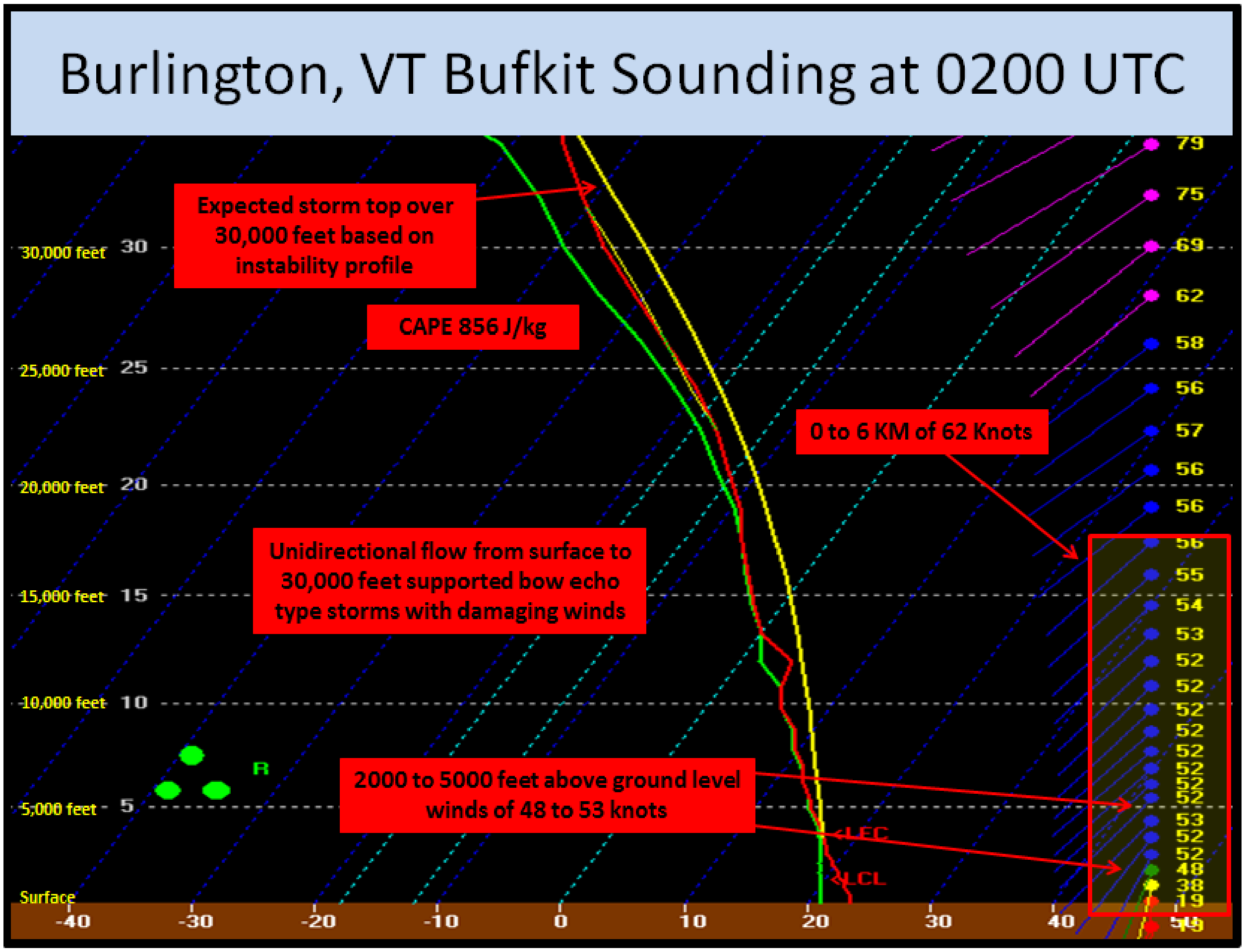

Figure 7: BTV 4-km WRF Bufkit Sounding at Burlington, VT at 0200 UTC on 09 July 2014 (4 hour forecast based on 12 UTC run).

Figure 8 shows Rapid Refresh (RAP) analysis of CAPE and 0 to 6 km effective shear from SPC on 08 July 2014 at 2300 UTC. As a mid-level jet approached the region the deep layer shear increased to between 45 and 55 knots, while modest CAPE values were across our CWA. From SPC, the definition of effective bulk shear is “similar to the 0-6 km bulk shear, though it accounts for storm depth (effective inflow base to EL) and is designed to identify both surface-based and ‘elevated’ supercell environments. Supercells and organized convection becomes more probable as the effective bulk shear vector increases in magnitude through the range of 25-40 knots and greater”. The RAP most unstable CAPE showed values between 1000 and 2000 J/kg across northern New York into Vermont. Note, the best combination of deep-layer shear and highest instability (CAPE) was located across the Saint Lawrence Valley into the Champlain Valley, and closely matches the region of greatest concentration of wind damage and large hail.

The combination of moderate instability and effective shear values between 45 and 55 knots helped to produce an environment favorable for organized thunderstorms, with damaging winds being the primary severe weather threat, due to the magnitude of wind shear through a deep layer of the atmosphere.

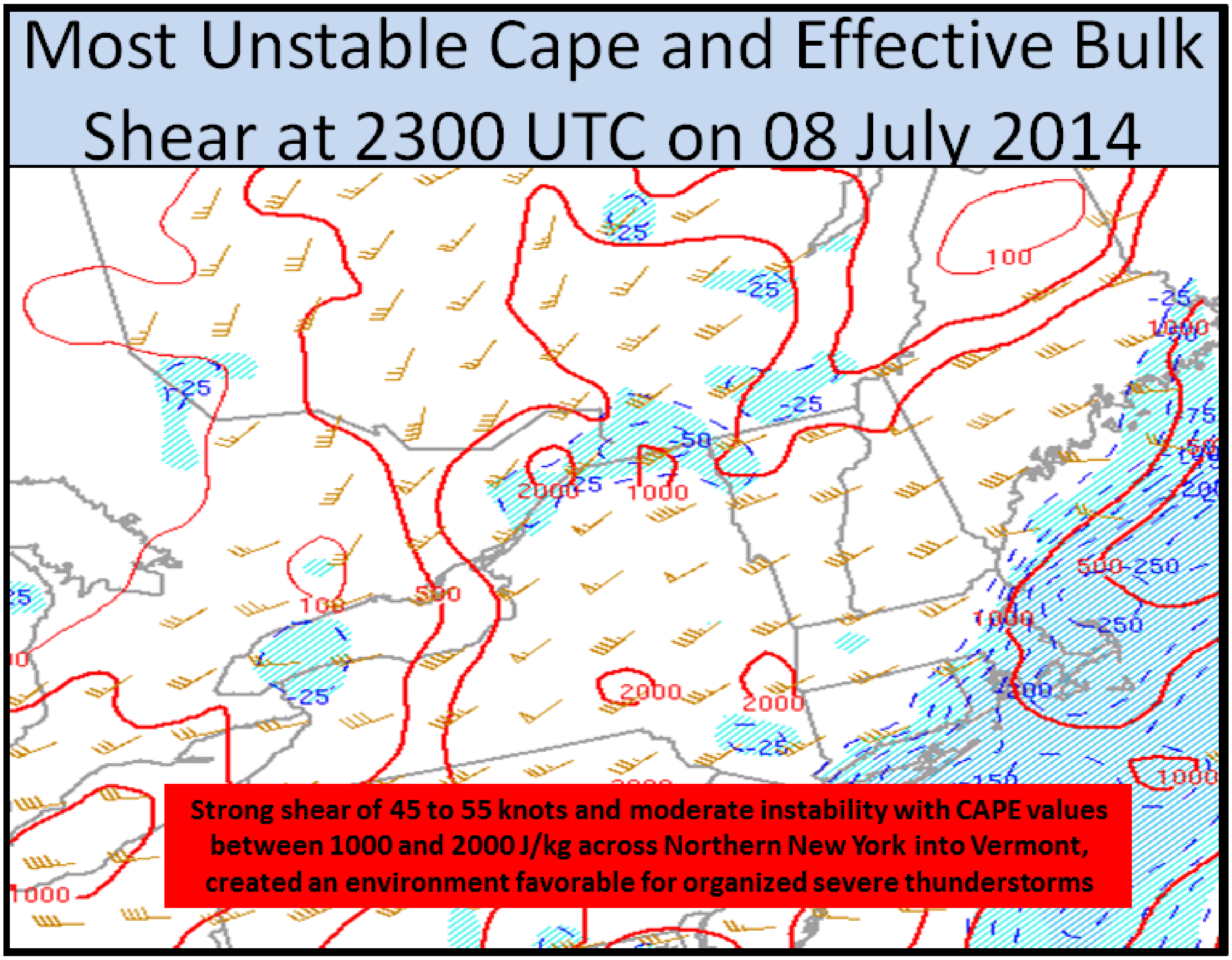

Figure 8: Storm Prediction Center Rapid Refresh (RAP) mesoanalysis of Most Unstable CAPE (red lines), Convective Inhibition (CIN) (light blue fill), and effect bulk shear > 25 knots (orange wind barbs) at 2300 UTC on08 July 2014.

4.) Radar Overview

In this section we will discuss a bow echo radar structure, followed by a large scale overview of the multiple bow echoes that occurred across the Mid Atlantic and northeast United States, as well as an upclose investigation of several bows and the associated downbursts across the North Country.

As is common with lines of convection in unstable and highly sheared 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 surface observations; at 0000 UTC the temperature was 70^{o}F as the line passes Watertown, NY while temperatures in advance of the line were still in the low to mid 80s. Consistent with the cold pool, a pressure jump occurred at Watertown (+3.4 mb in 2 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 southern Saint Lawrence and Franklin counties in northern New York between 2330 UTC and 0030 UTC (see Figure 9 below), in which the reflectivity structure resembled that of an archer's bow.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.

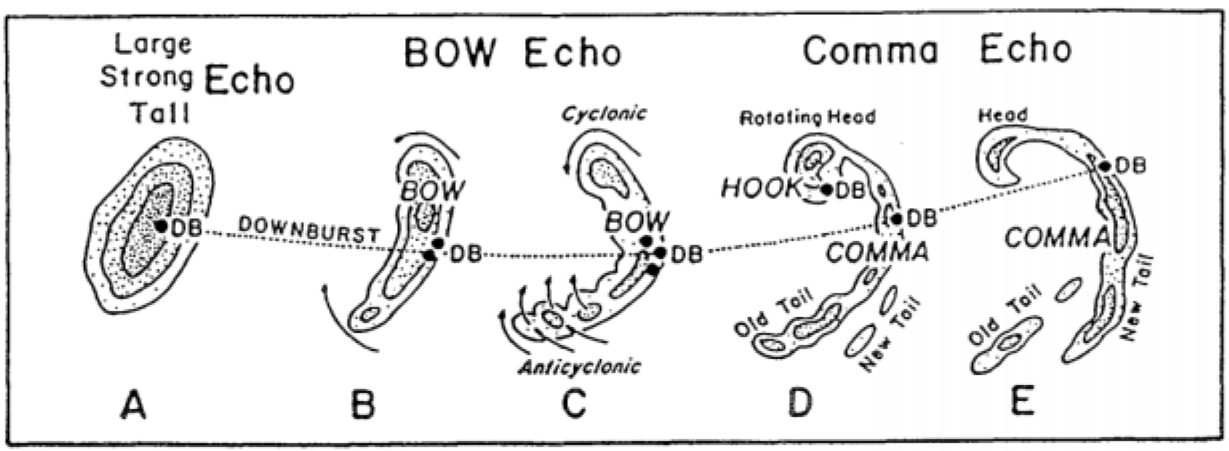

Figure 9: Idealized morphology of an isolated bow echo associated with strong and extensive downbursts. (from Johns 1993)

The direction of the highest winds occur perpendicular to the convective line, or from the southwest, in this case. The average forward speed of the bow echo was 50 knots (58 mph) across northern New York into the Champlain Valley, with the apex of the bow moving up to 60 knots across this 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.

Figure 9A shows the evolution of multiple bow echoes within a large convective complex across the northeastern United States on July 8th. It should be noted that ahead of the main line, several isolated supercells developed across parts of central New York and produced a deadly tornado near the Syracuse area. Given these are 1 hour snap shots of the line evolution and the associated comma head, the isolated supercells are hard to detect. The large scale environment associated with this system indicated not only favorable shear and instabilitiy parameters were present, but also very potent dynamics were associated with this complex of storms.

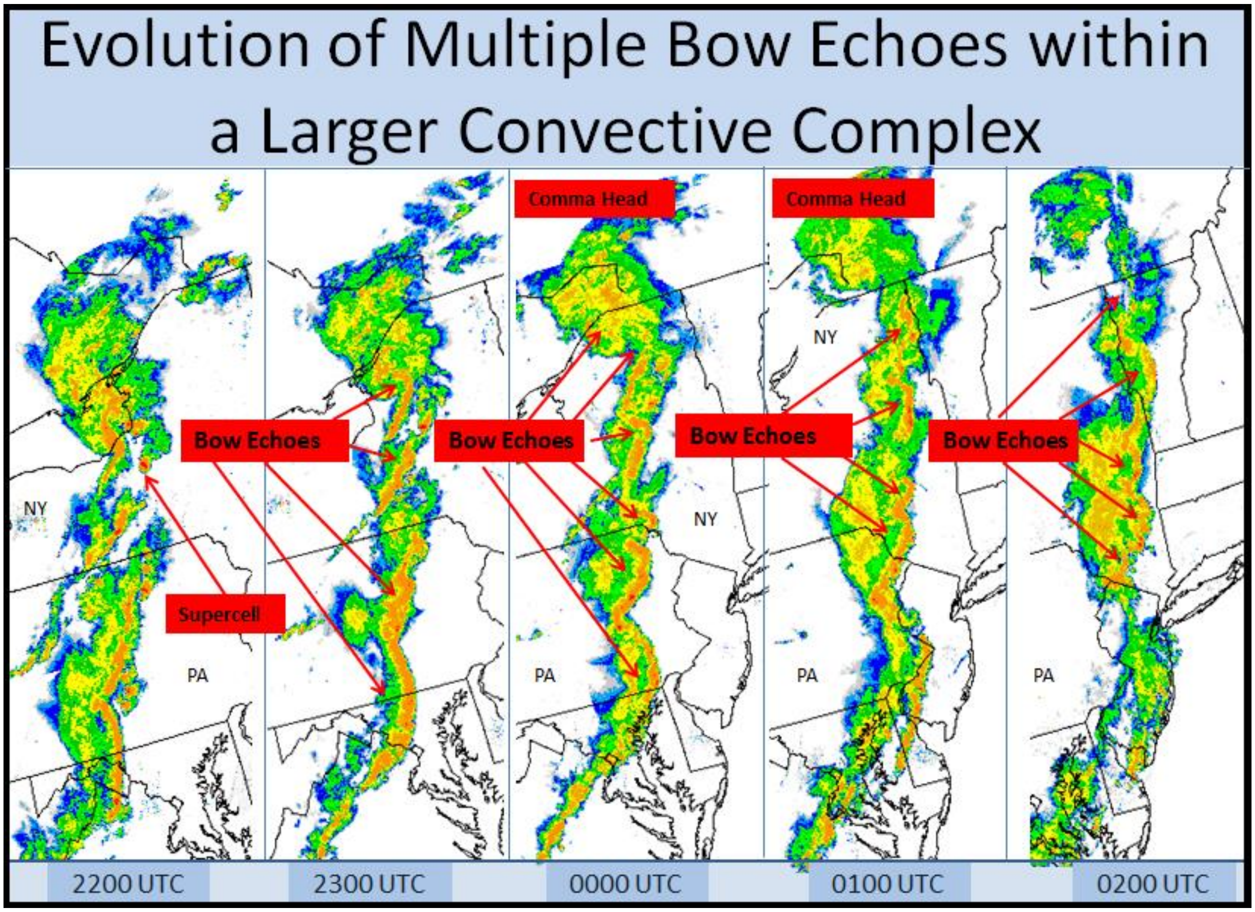

Figure 9A: 0.5° Mosaic reflectivity across the Mid Atlantic to northeast United States from 2200 to 0200 on the evening of 08 July 2014.

In this section we will investigate the radar data and storm structures of the bow echoes that produced widespread wind damage across the North Country on 08 July 2014. Figure 10 below shows the KTYX 0.5° base reflectivity loop from 2202 UTC to 0001 UTC on 08 July 2014. This loop clearly shows a well-defined bow echo and associated comma head tracking northeast at 45 to 55 mph, from the Tug Hill Plateau to southern Saint Lawrence County. The decreasing reflectivity returns on the southwest flank of the storm, indicated an extremely strong rear inflow jet, which was verified by the KTYX VAD measuring 75 knots at 1000 feet above ground.

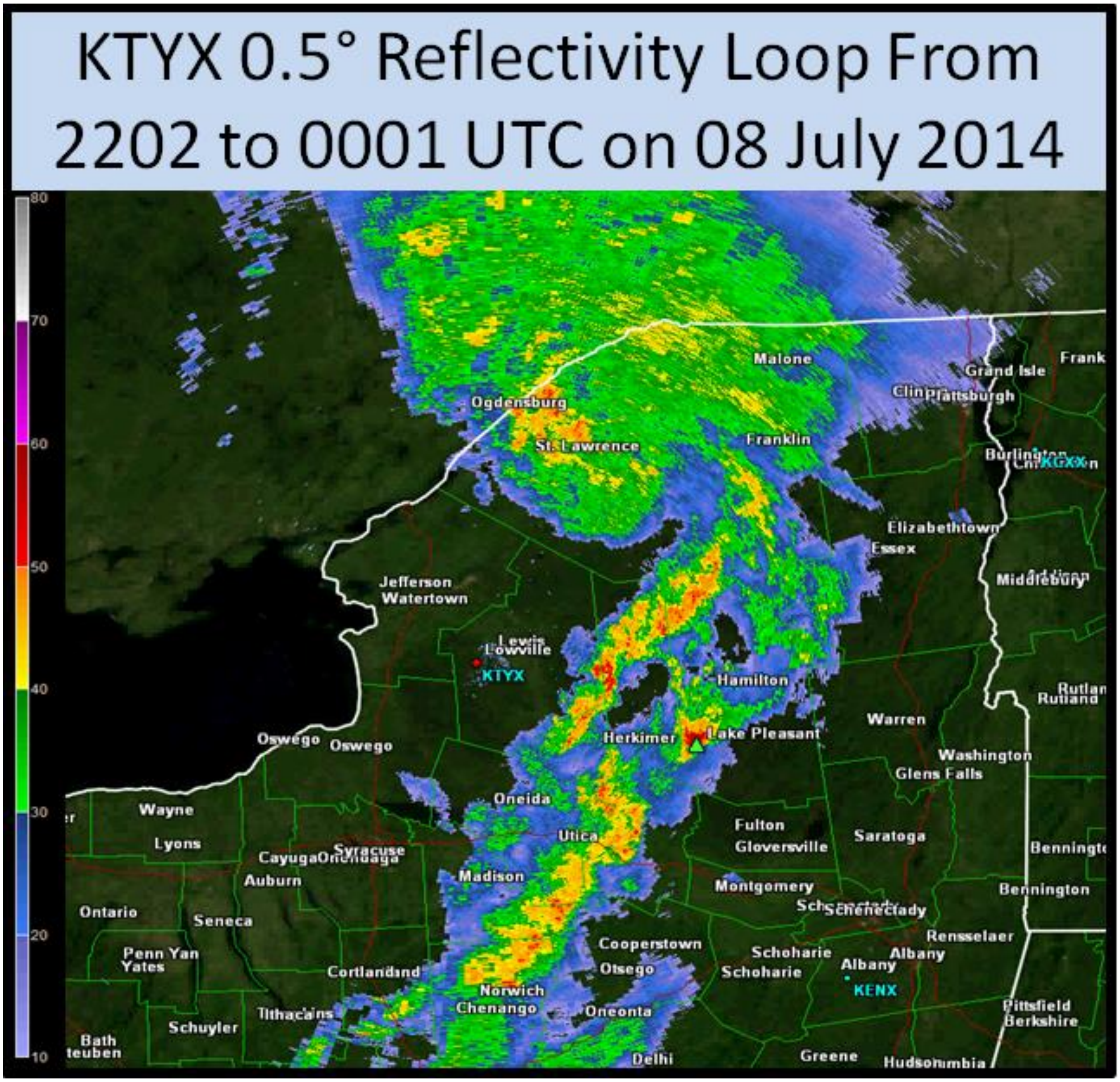

Figure 10: KTYX 0.5° base reflectivity loop from 2202 UTC 08 July 2014 to 0001 UTC 09 July 2014. (Click image to open loop)

a. Bow Echo/Comma Head across Saint Lawrence Valley

Figure 11 below shows the KTYX 0.5° reflectivity (lower right) and velocity (lower left) at 2258 UTC on 08 July 2014. This shows a large-scale bow echo and associated comma head approaching southern Saint Lawrence County, along with numerous embedded mini bows or meso vortices within the larger complex. Each of these smaller mini bows produced damaging winds across the region. In addition, multiple weak echo channels on the upstream side of the bow echoes are present, indicating a descending rear inflow jet that resulting in widespread damaging winds with numerous trees and power line down across Saint Lawrence County. The green velocity colors in Figure 11 (lower right), indicated outbound winds (moving away from the radar) at 60 to 80 knots, just 1000 to 3000 feet above the surface. These winds were brought to the surface by the localized heavy rainfall and associated downdrafts associated with the bow echo.

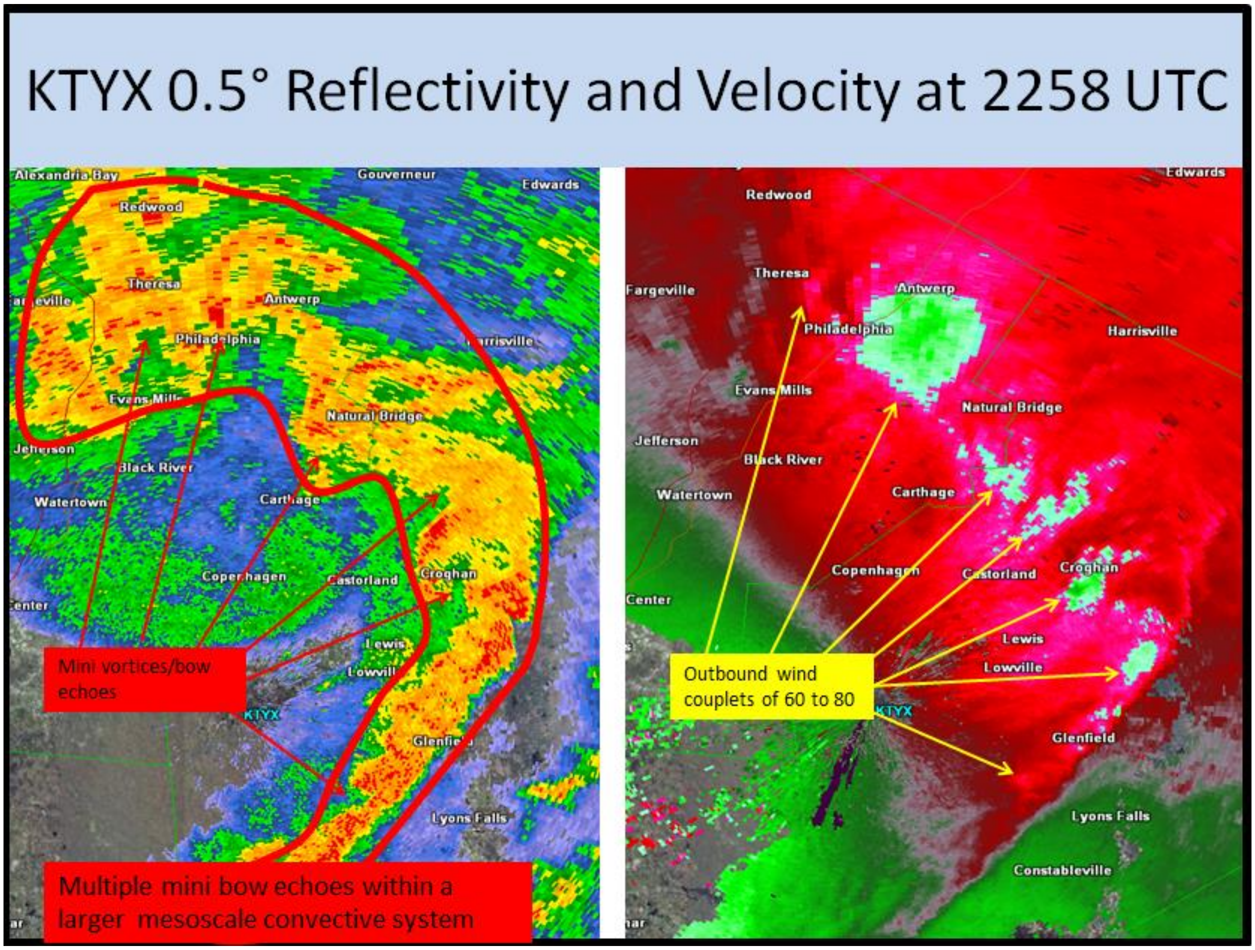

Figure 11: KTYX 0.5° reflectivity (left) and velocity (right) at 2258 UTC near southern Saint Lawrence County on 08 July 2014.

Figure 12 shows the KTYX 0.5° velocity at 2319 UTC across southern Saint Lawrence County on 08 July 2014. This clearly shows the large area of 60 to 80 knots of outbound wind impacting communities across this region, from Edwards to Star Lake to Cranberry Lake. These winds were located approximately 2000 to 4000 feet above the ground according to the radar, and had no problem mixing to the surface, as evidenced by the widespread wind damage. Also, note that the majority of the winds are outbound, with very limited inbound velocities, indicating minimal rotation associated with this bowing line of storms. Some broad mid-level rotation was present associated with the comma head portion of the storm, which tracked from Watertown to Massena, NY.

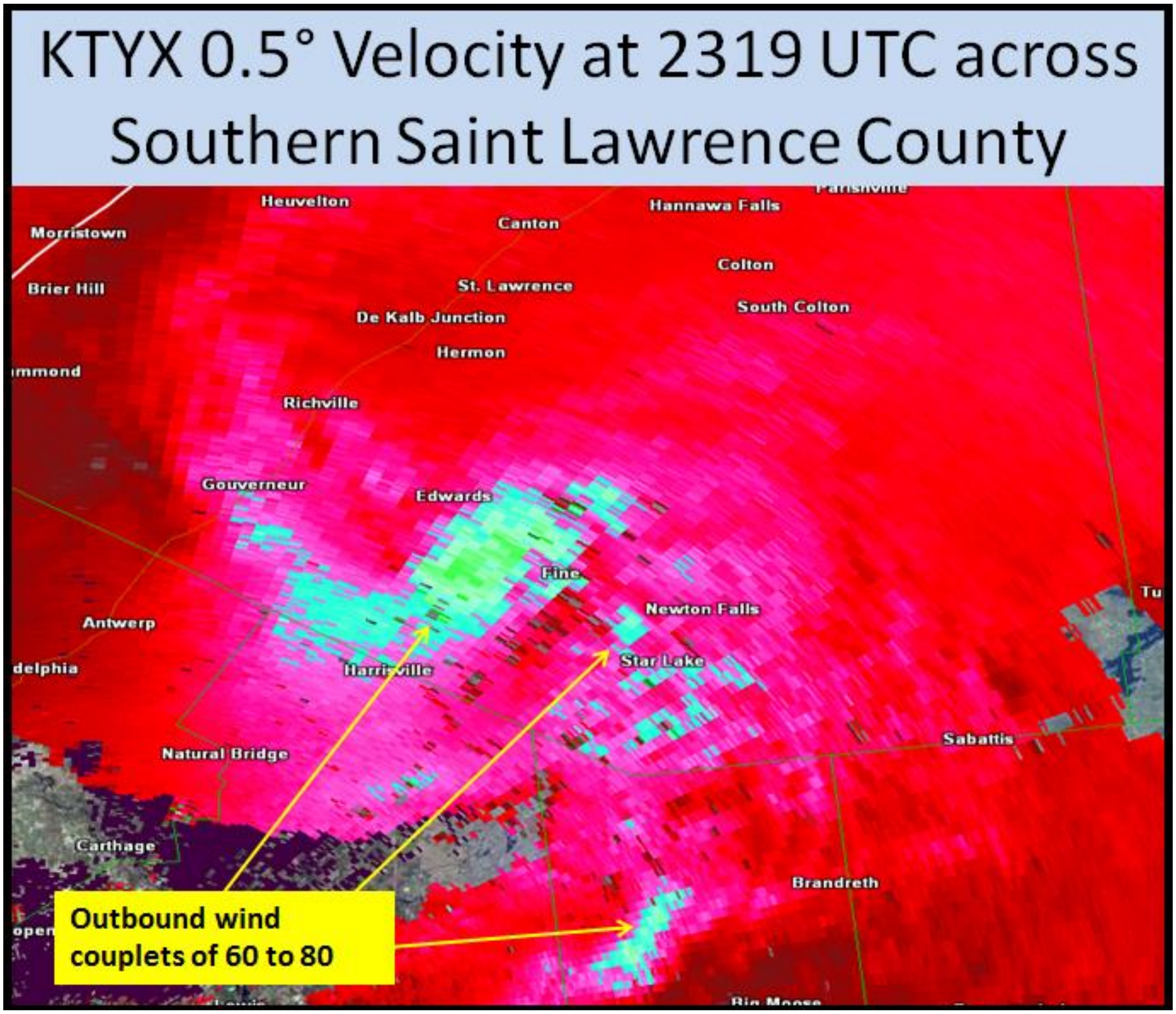

Figure 12: KTYX 0.5° velocity at 2319 UTC across southern Saint Lawrence County on 08 July 2014.

b. Downburst near South Burlington

The next storm we will investigate resulted in scattered trees down in the Burlington/South Burlington areas of the Champlain Valley on the evening of July 8th. Figure 13 below shows the KCXX reflectivity and velocity cross section at 0110 UTC over central Lake Champlain, as the storm approached the Burlington vicinity. From the image you can see a two pulse reflectivity structure of the descending weak reflectivity region, along with the very strong velocity couplet. A region of enhanced 50 to 60 dBZ (lower right) around 15,000 to 20,000 feet above the ground is co-located with inbound velocity values of 50 to 60 knots (lower left). The 1st pulse produced tree damage near Red Rocks Park in South Burlington, while the 2nd pulse created additional wind damage and very heavy rainfall from near Dorset/Spear Streets to the Burlington International Airport. Unfortunately, we lost our surface observation data here at the Airport, but just before the power went out, the airport measured at 37 knot or 42 mph wind gusts. It was estimated by observers and meteorologists at the airport winds ranged between 50 and 60 mph associated with this downburst.

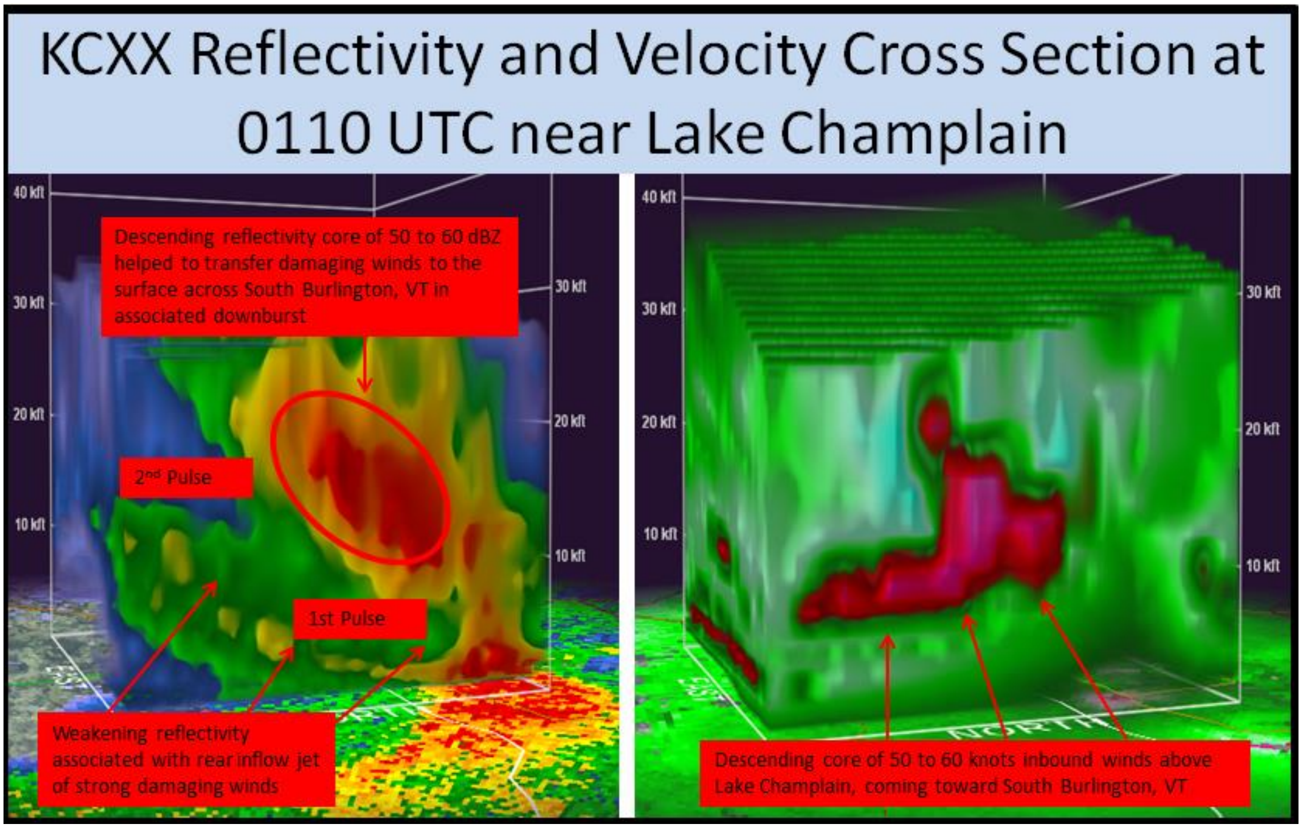

Figure 13: KCXX reflectivity (left) and velocity (right) cross section over Lake Champlain as storm approaches South Burlington, VT at 0110 on 09 July 2014.

Figure 14 below shows the KCXX 0.5° velocity from 0119 UTC to 0128 UTC on the evening of July 8th across the greater Burlington area. This shows a relatively large area of 35 to 45 knots of inbound velocities over Lake Champlain at 0119 UTC, but as several pulses associated with the downbursts occurred, the velocities increase between 50 and 60 knots across Red Rocks Park toward the airport between 0124 UTC and 0129 UTC. This is clearly shown by the reddish color in the velocity images below. It should be noted; we had excellent radar coverage of this storm as it moved directly toward the radar or down the radial. Also, these high velocity values were only 100 to 300 feet above the ground, because of how close they were located to the radar in Colchester, Vermont.

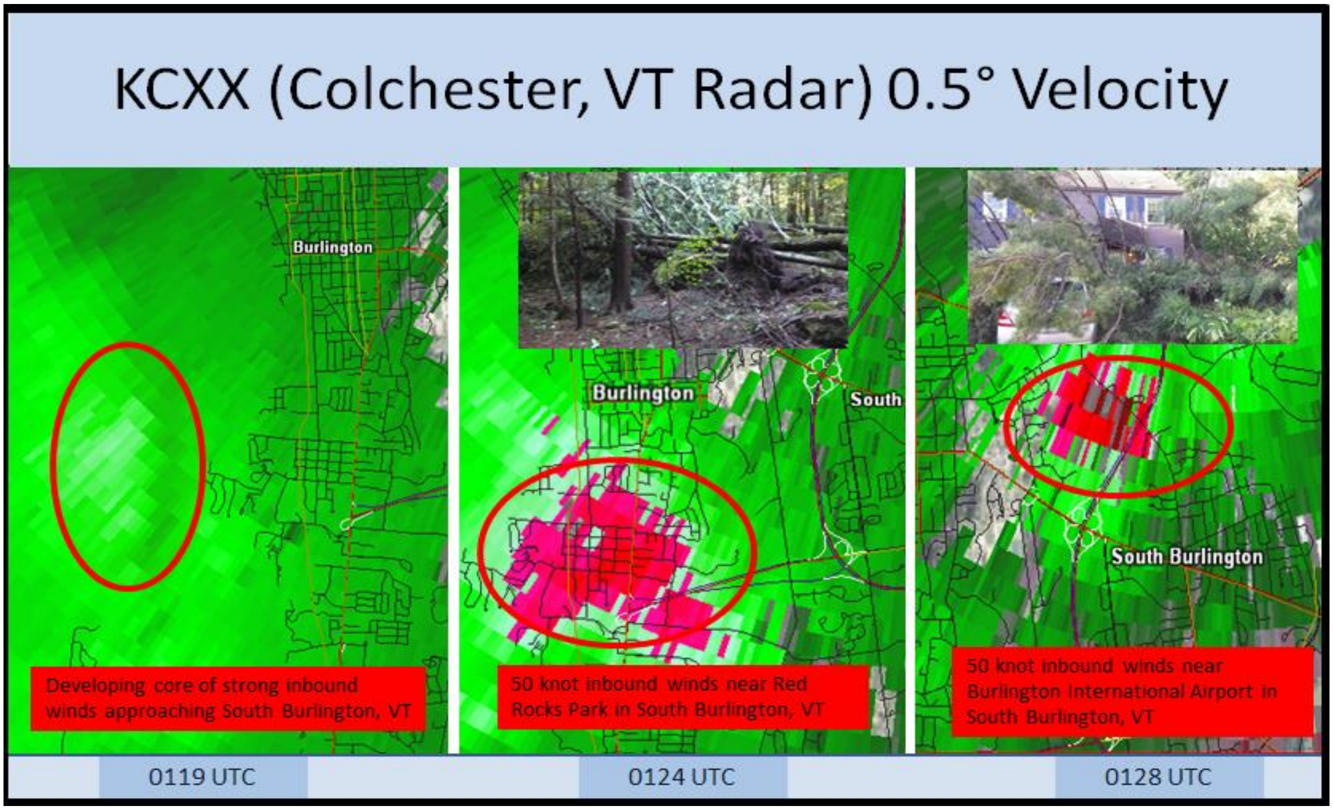

Figure 14: KCXX 0.5° Velocity from 0119 UTC to 0128 UTC on 09 July 2014.

c. Bow Echo near Middlebury to East Montpelier to Cabot/Marshfield

Figure 15 below shows the KCXX 0.5° reflectivity (lower right) and velocity (lower left) at 0137 UTC on 09 July 2014. This shows a large scale bow echo and associated comma head across the central Champlain Valley, approaching Middlebury, VT. A weak echo channel was also present on the upstream side of the bow echo, indicating a descending rear inflow jet that resulted in damaging winds with numerous trees and power line down in Middlebury, VT. The reddish velocity colors in Figure 15 (lower right), indicated inbound winds (moving toward the radar) at 45 to 55 knots, just 1000 to 3000 feet above the surface. These winds were brought to the surface by the localized heavy rainfall associated with the bow echo. Finally, note the apex of the bow-like reflectivity structure was heading right toward Middlebury/East Middlebury in the image below, and this is typically the region where the strongest winds are located.

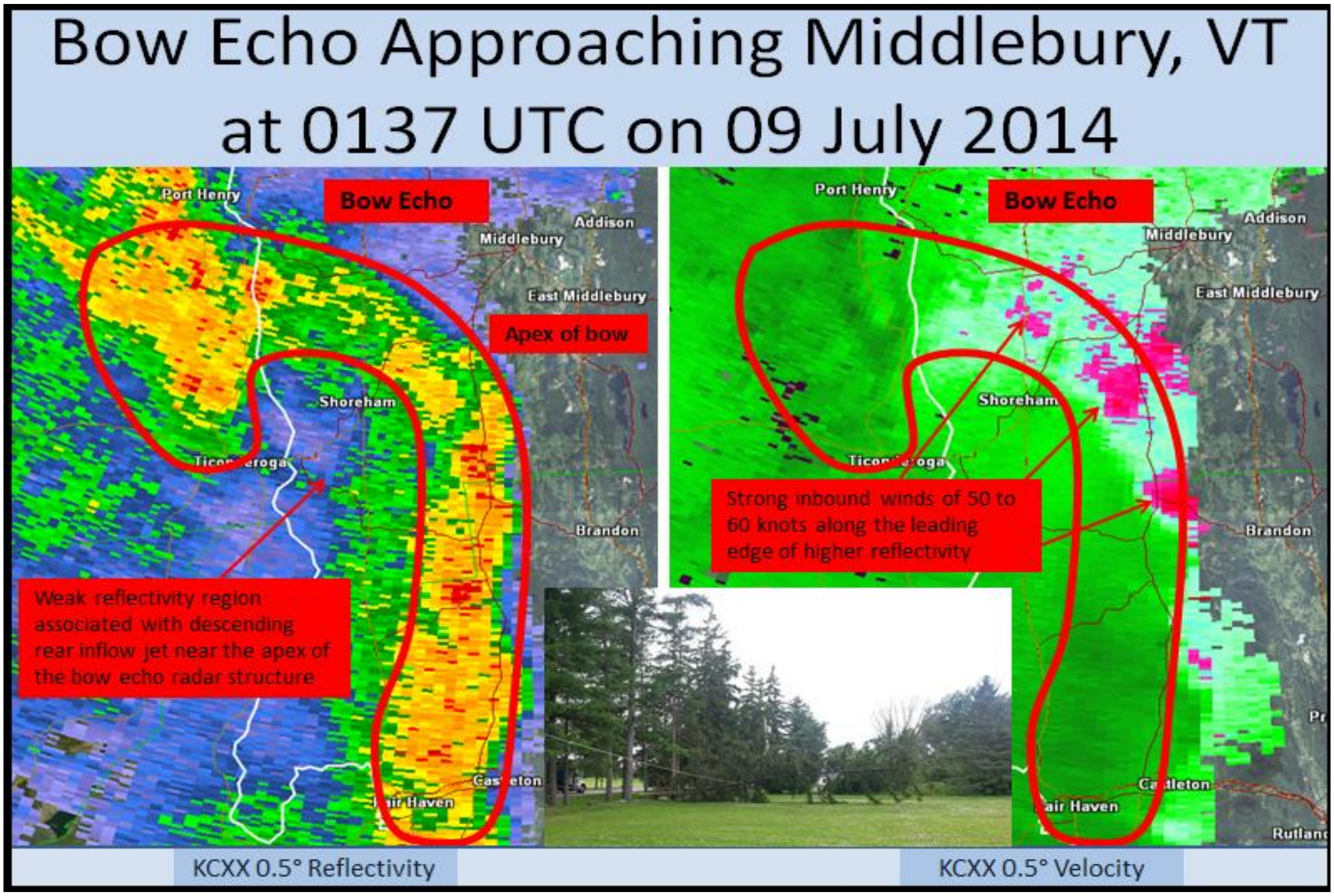

Figure 15: KCXX 0.5° reflectivity (left) and velocity (right) at 0137 UTC near Middlebury, VT on 09 July 2014.

The bow echo that impacted Middlebury, VT region continued to track rapidly northeast at 45 to 55 mph and produced additional scattered wind damage from Montpelier to Plainfield to Cabot across central Vermont. Figure 16 below shows the KCXX 0.5° reflectivity (lower right) and velocity (lower left) at 0222 UTC on 09 July 2014. This shows a large-scale bow echo and associated comma head across central Vermont, approaching Plainfield, VT. Just like the Middlebury storm, a weak echo channel was also present on the upstream side of the bow echo, indicating a descending rear inflow jet that resulted in damaging winds with numerous trees and powerlines down from Montpelier to Cabot. The apex of the bow-like reflectivity structure was heading right toward the Montpelier area and traveled along the U.S. Route 2 corridor. KCXX radar measured outbound velocities values of 40 to 50 knots near the apex of the bow. However, across this region of central Vermont, poor low-level reflectivity and velocity sampling occurs owing to beam blockage from the Green Mountains. In addition, with the storms moving perpendicular to the radial beam, velocities were under-estimated by the KCXX radar by 20 to 30% based on the damage observed.

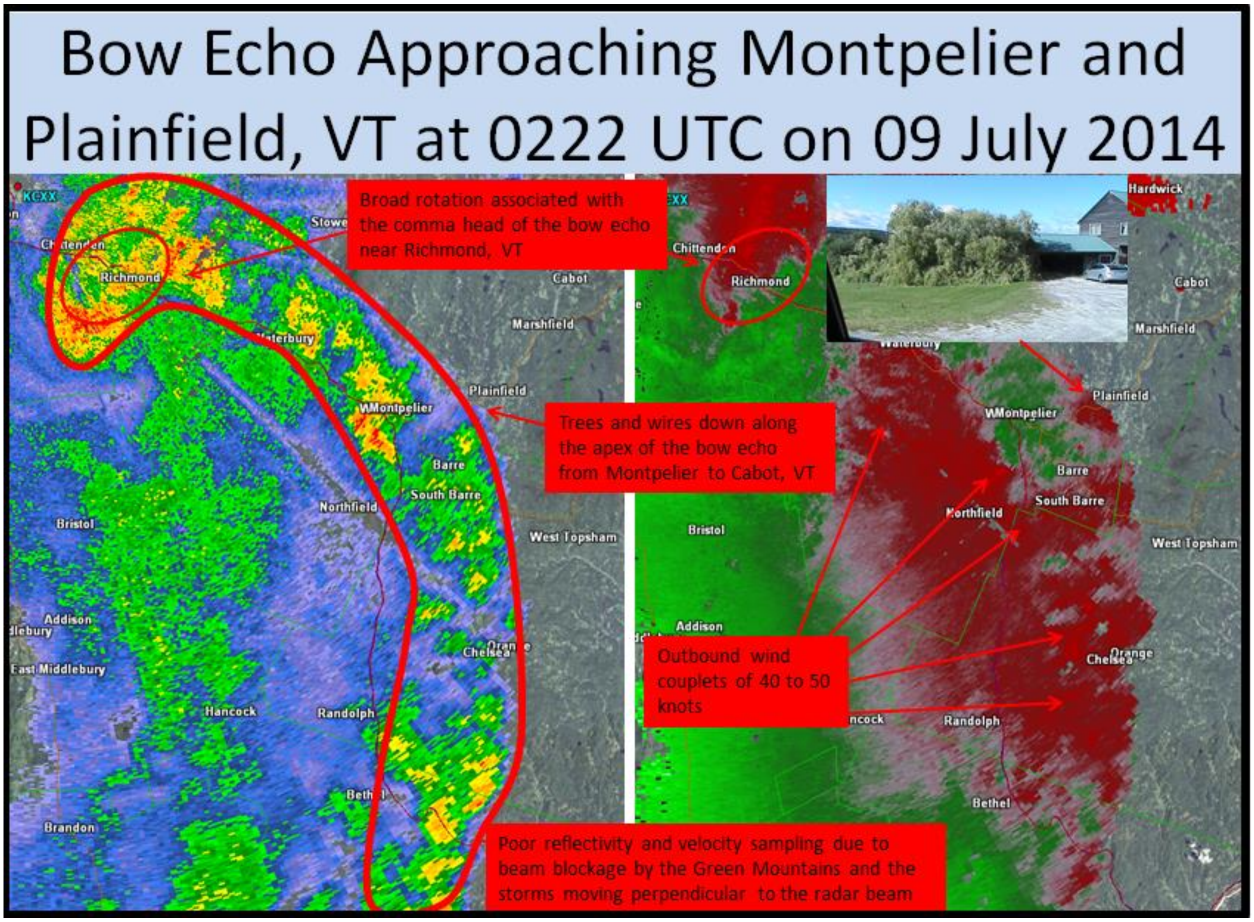

Figure 15a: KCXX 0.5° reflectivity (left) and velocity (right) at 0222 UTC near Montpelier, VT on 09 July 2014.

Conclusion and summary

The mesoscale convective system of July 8-9 was the first widespread, significant severe weather event of the 2014 season across the North Country. The event featured a long swath of damaging winds, which caused numerous communities across northern New York and Vermont to lose power. At the height of the storm, over 30,000 people were without power in Vermont along with nearly 6,000 across extreme northern New York. Several ingredients contributed to the severity and widespread nature of this event, including (1) strong vertical shear resulting from a potent mid-level jet, (2) vigorous energy aloft from a shortwave trough creating large-scale ascent for thunderstorms, and (3) a warm/humid air mass which yielded moderate surface-based instability for vigorous convective updrafts and downdrafts. These factors resulted in a mesoscale convective system with numerous embedded small-scale bow echoes producing swaths of damaging wind. Lastly, Figures 16 and 17 show a mosaic of storm damage photographs taken across northern New York and Vermont following the event.

References

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

Figure 16: Storm damage photos from 08 July 2014.

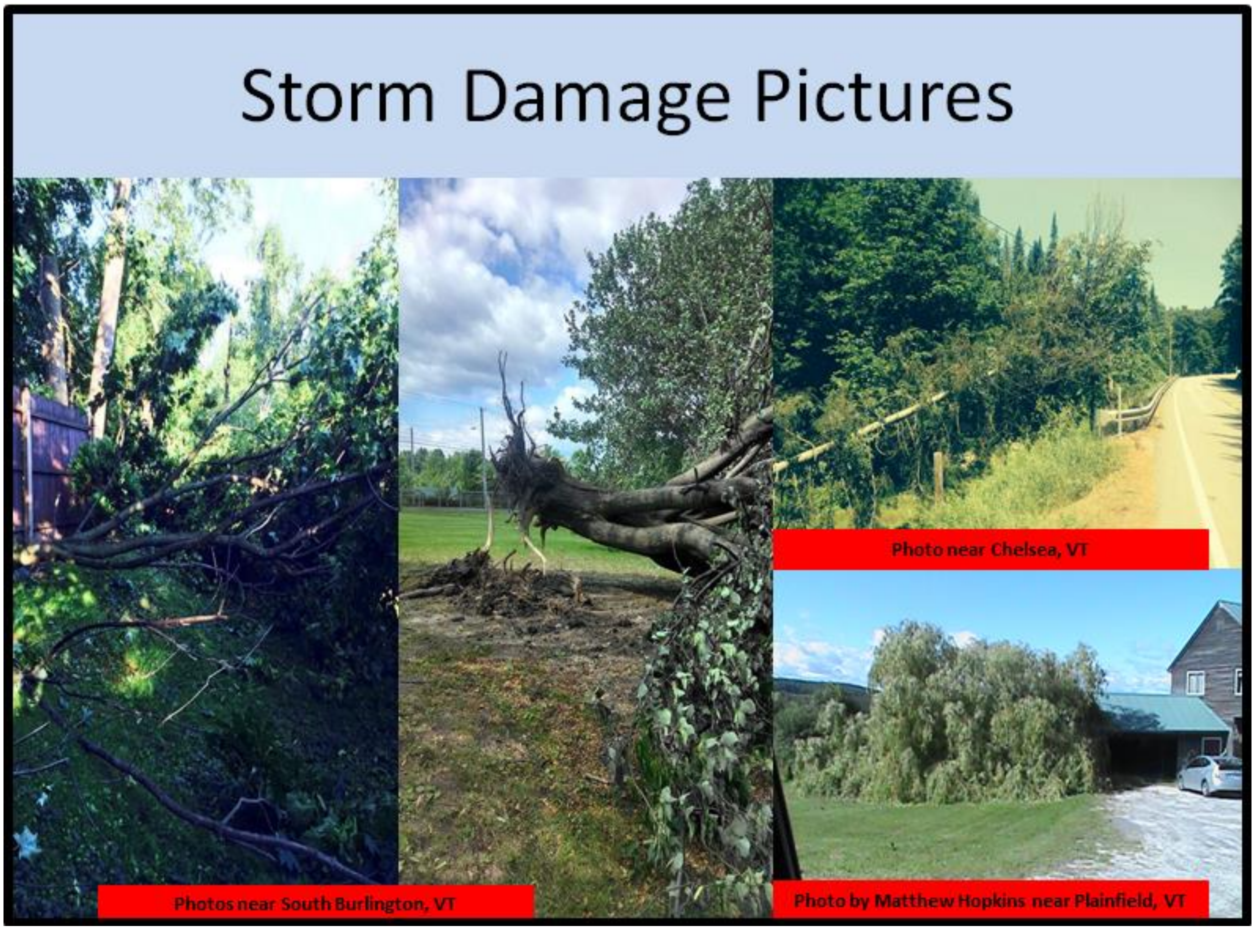

Figure 17: Storm damage photos from 08 July 2014.