The Damaging Wind and Large Hail Event on 2 June 2013

1.) Introduction:

On 2 June 2013, the first significant severe weather outbreak of the 2013 season occurred across portions of central and eastern Vermont. A very warm, moist, and unstable air mass was in place from the Adirondack Mountains eastward into Vermont with surface temperatures in the 80s and dewpoints in the 60s. This very unstable environment along with a cold front approaching the region from the west helped to produce strong to severe thunderstorms across portions of the North Country during the afternoon hours on 2 June 2013.

This severe weather event included numerous reports of trees and powerlines down across parts of central and eastern Vermont due to powerful severe thunderstorm wind gusts. In addition, hail up to ping pong ball size (1.5 inches) was reported in West Fairlee Center, Vermont and over 14,000 people lost power during the height of the convective outbreak. Figure 1 below shows a map of power outages during the peak of this severe weather event, with the circles in the image below indicating the highest concentration of power outages.

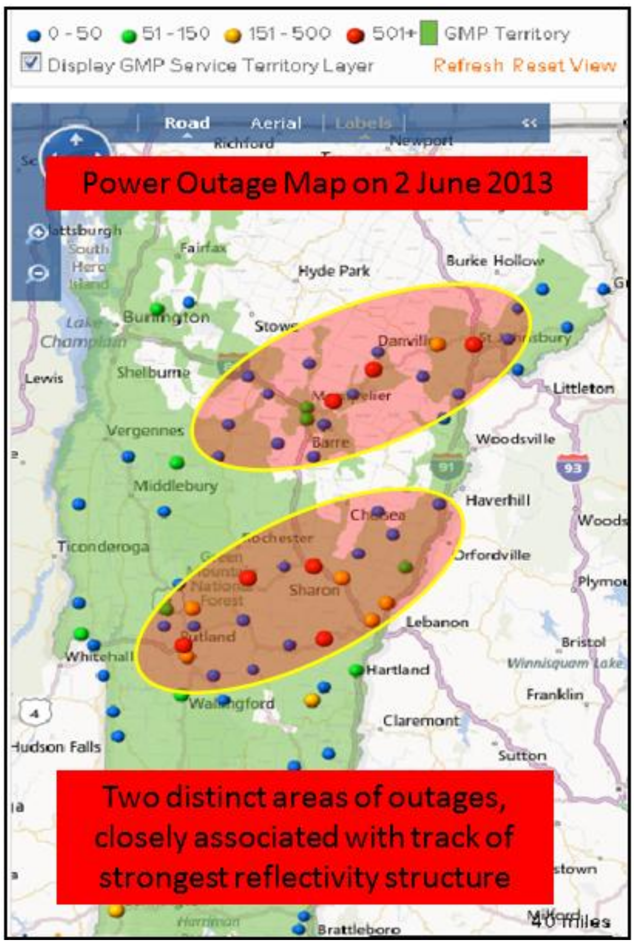

Figure 1: Power outage map on 2 June 2013.

Furthermore, the thunderstorms were accompanied by very heavy rainfall amounts of 1 to 2 inches with localized radar estimates near 2.5 inches across the southern Champlain Valley. Click here for the local storm report, which shows the locations of the severe weather. Furthermore, figure 1 below shows a map of the local storm reports across the region. Note the two distinct areas of damage, one along the Route 2 corridor from Montpelier to Danville to Saint Johnsbury and the other damage path from near Rutland to just east of Chelsea, Vermont.

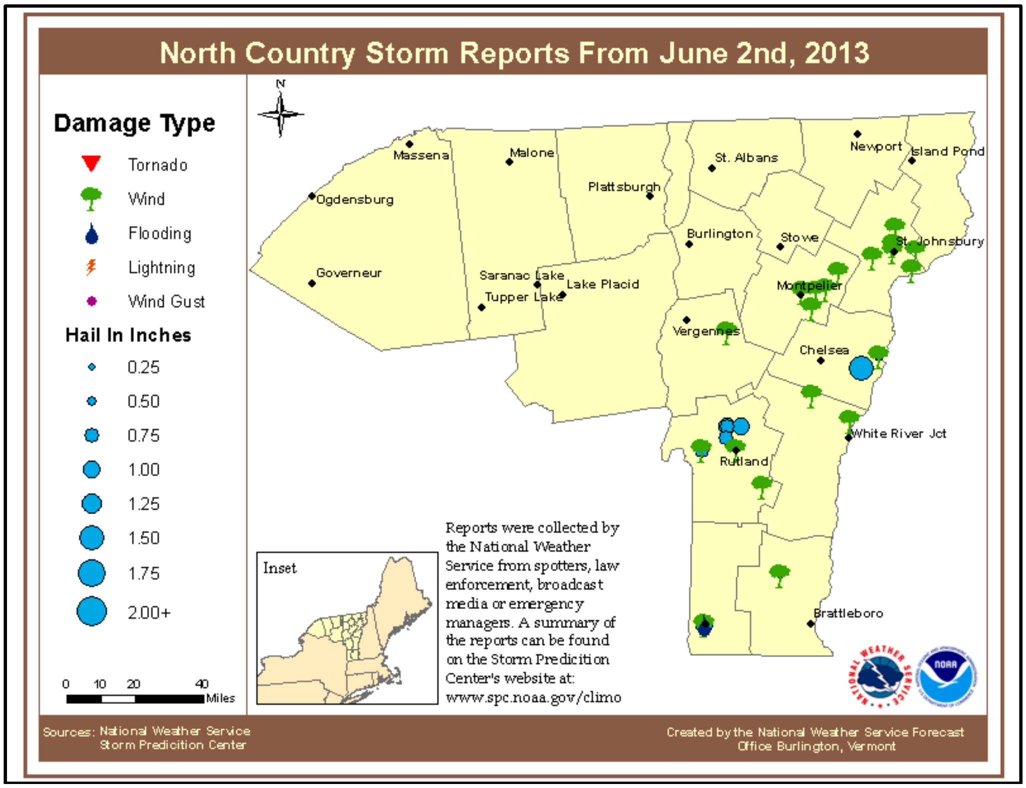

Figure 2: North Country storm reports from 2 June 2013.

2.) Storm Prediction Center Products:

The NOAA/NWS Storm Prediction Center (SPC)'s Day 1 Convective Outlook on the morning of Sunday June 2nd indicated a "Slight Risk" of severe thunderstorms from the Adirondacks eastward across all of Vermont. As the morning unfolded, it became increasingly clear that a significant severe weather event was likely.

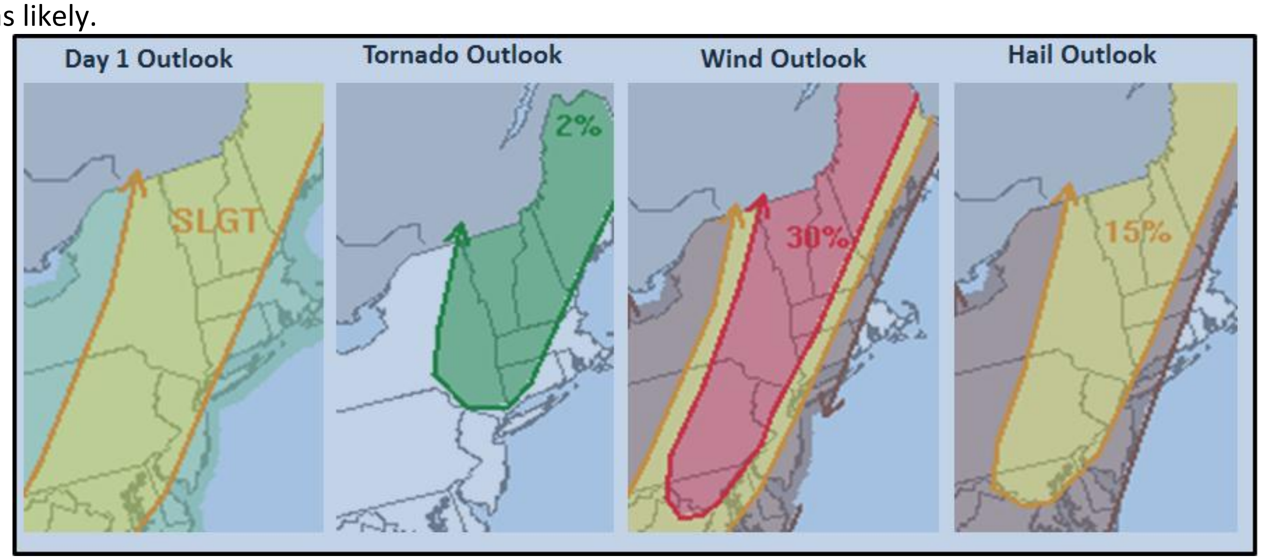

Figure 3: Storm Prediction Center Day 1 Severe Weather Outlook issued at 06 UTC, valid at 12 UTC on 2 June 2013.

Figure 3 above shows the 12 UTC 2 June 2013 Day 1 Convective Outlook and the associated probabilities of tornadoes, damaging winds, and severe hail. The "Slight Risk" area, shown in the left-most panel, highlighted most of the interior Northeast. The tornado probability was 2% for all of Vermont and 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. Severe hail probabilities were up to 15% across the entire North Country (i.e., there was a 15% probability of at least 1 severe hail report occurring within 25 miles of any point in the 30% probability area, shaded in red). The Severe Wind Outlook forecast included 30% severe wind probabilities across Vermont and portions of eastern/northeastern New York.

At 1448 UTC (10:48 AM local), SPC issued Mesoscale Discussion, addressing the potential for a severe thunderstorm watch as conditions were becoming favorable for thunderstorm development. The combination of surface heating and a well-defined short wave trough would help expand the areal coverage and intensity of thunderstorm activity across the North County. Shortly before noon on 2 June 2013, SPC issued a Severe Thunderstorm Watch for most of interior New England, effective through 8:00 PM local time. The watch and mesoscale discussion graphic are shown in Figure 4 below.

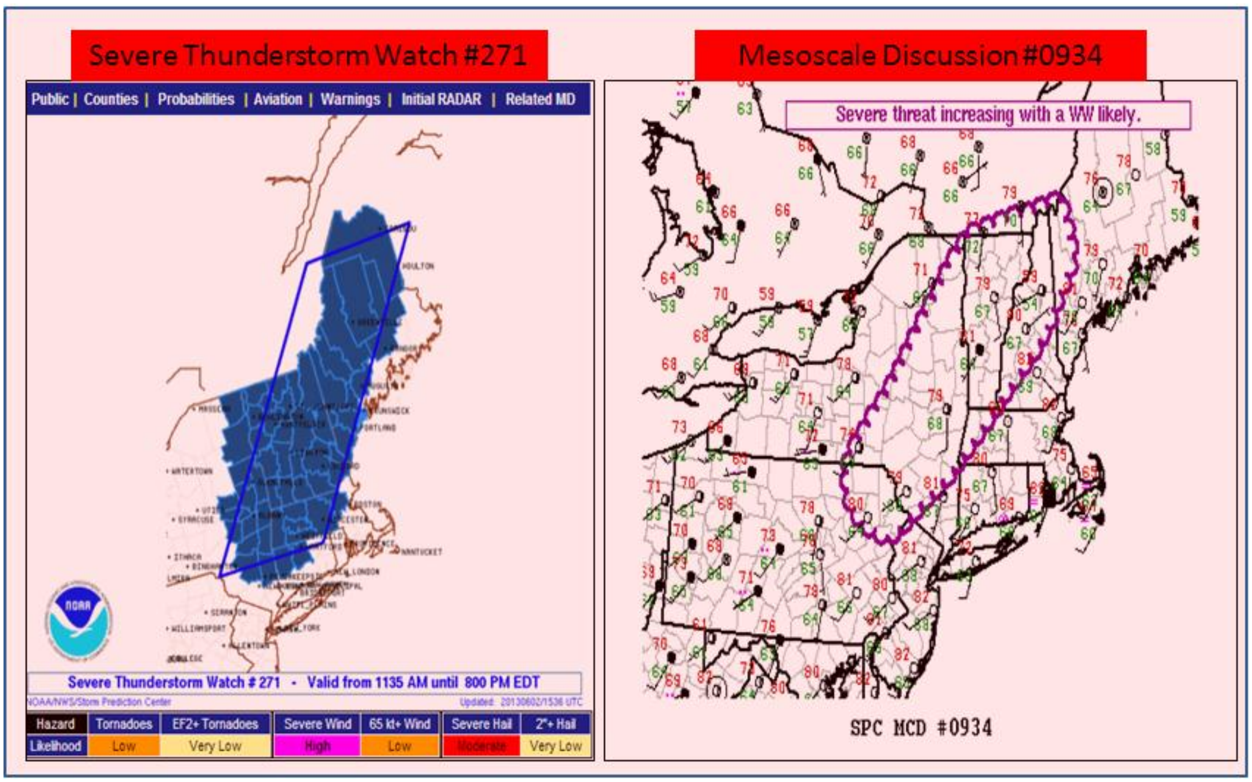

Figure 4: Severe Thunderstorm Watch #271 (left panel) and Mesoscale Discussion #0934 issued by the Storm Prediction Center on 2 June 2013.

3.) Pre-Storm Environment:

Figure 5 below shows the 500 hPa (20,000 feet above the ground level) upper air analysis on 2 June 2013 at 12 UTC. A potent short wave trough was moving across the Ohio Valley, along with a ribbon of enhanced wind speeds. This 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.

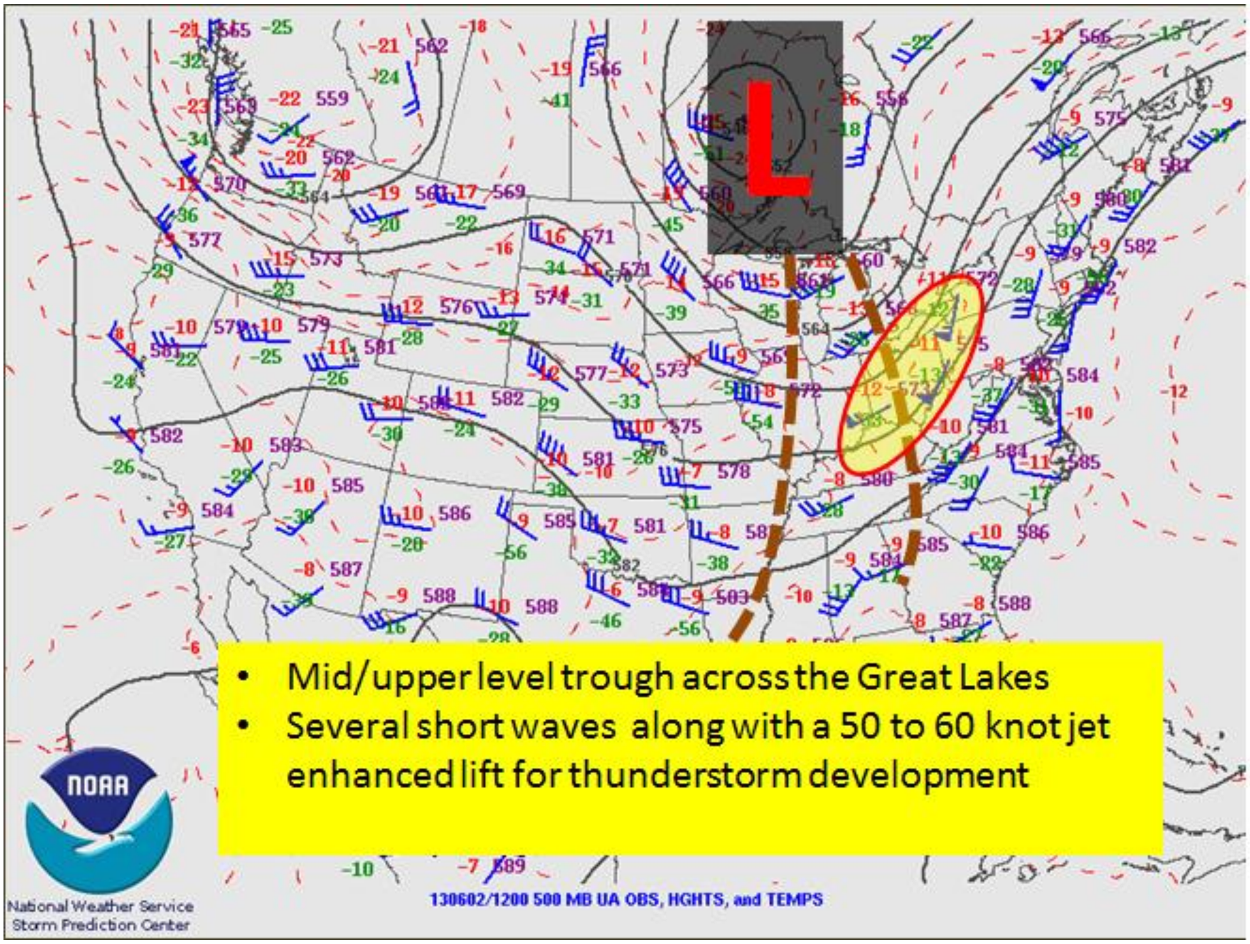

Figure 5: The 500 hPA (20,000 feet above the ground level) upper air analysis on 2 June 2013 at 12 UTC. Wind barbs, (plotted in blue, 1 arrow=50 knots, 1 barb=10 knots, 1/2 barb=5 knots, 500 hPA heights (black lines), and temperatures (dotted red).

The 1600 UTC June 2nd rawinsonde observation at Gray, Maine (Figure 6) shows modest instability, and moderate deep-layer shear, due to the development of a strong mid-level jet from the Ohio Valley northeastward into western New York (as shown in the previous section). The combination of surface temperatures in the lower 80s and dewpoints in the 60s, created surface-based convective available potential energy (CAPE) values of 1950 J/kg and a lifted index (LI) of -6C (Celsius). CAPE values greater than 1500 J/kg, suggest a moderately unstable environment, favorable for thunderstorm development. The large CAPE profile and very high equilibrium levels (42,000 feet) indicated thunderstorm tops would extend to 40,000 to 45,000 feet above ground level, and be capable of producing severe winds or large hail, along with very heavy rainfall. The equilibrium level is the level at which the rising parcel equals the actual air temperature at that given height. The rising air parcel becomes stable at the equilibrium level; it no longer accelerates upward.

The Gray sounding also showed surface to 6-km shear of 33 knots. This shear increased through the day, as the embedded mid-level jet approached the forecast area. Thunderstorms tend to become more organized and persistent as vertical shear increases. Supercells and organized convection, such as squall lines and derechos are commonly associated with vertical shear values of 30 to 40 knots or greater through this depth, which developed across our region as jet stream winds increased. The high freezing levels around 13,000 feet, suggests only the strongest/tallest storms would be capable of producing large hail, with damaging winds as the primary threat.

Finally, the 1600 UTC Gray sounding showed a precipitable water value of 1.35 inches, which suggests the potential for thunderstorms producing 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, suggest a greater potential for heavy rainfall, especially during the summertime.

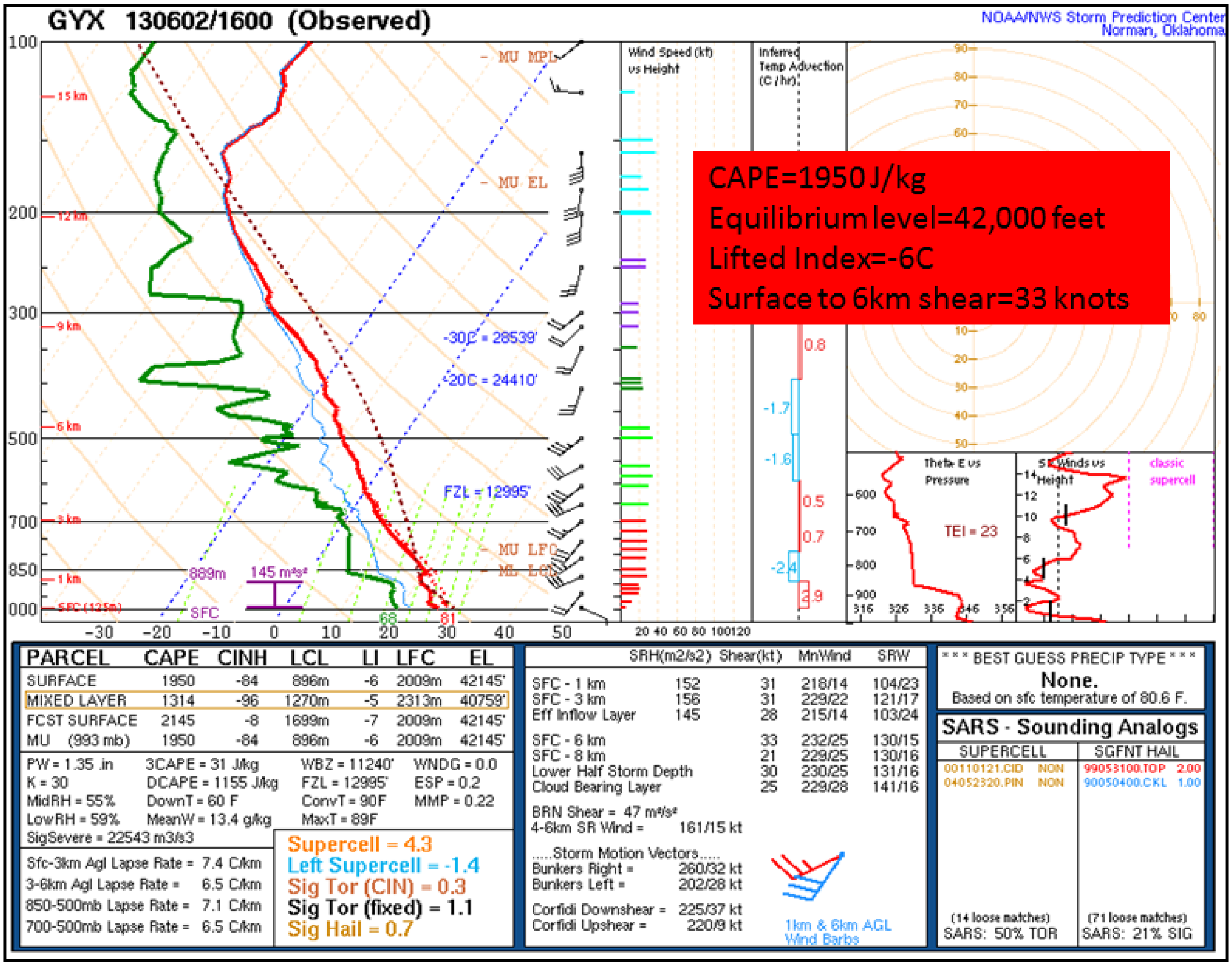

Figure 6: Gray, Maine observed sounding on 2 June 2013 at 1600 UTC.

The Storm Prediction Center (SPC) Rapid Refresh Analysis (RAP) of surface based CAPE shown in Figure 7 below shows an axis of 2000 to 3000 J/kg across central and eastern Vermont at 1900 UTC on 2 June 2013. These values indicate conditions were favorable for thunderstorm development, with very little convective inhibition (CIN) present. The tight CAPE gradient in the image below, suggested a surface boundary was approaching the area, and would serve to initiate thunderstorms.

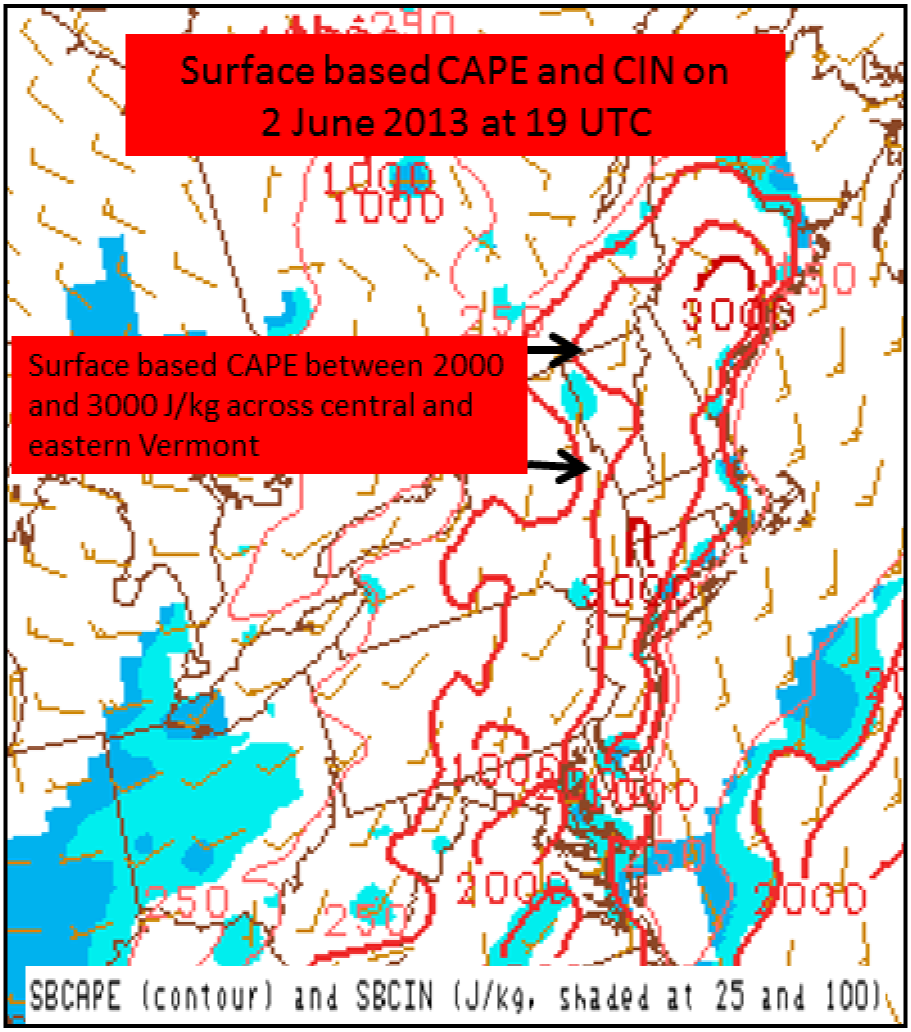

Figure 7: Storm Prediction Center (RAP) Rapid Refresh Analysis of Surface Based CAPE (red lines), Surface Based Convective Inhibition (CIN) shaded at 25 and 100 and surface winds.

Figure 8 below shows the SPC mesoanalysis of Effective Bulk Shear contoured at 30, 40, and 50 knots. This shows enhanced values of shear across northern New York into the Champlain Valley, associated with a 500 hPa wind maximum (shown in previous section) approaching the region. The combination of modest instability and effective shear values between 30 and 50 knots helped to produce organized thunderstorm activity with damaging winds as the primary severe weather threat. The magnitude of the wind shear through a deep layer of the atmosphere is an important parameter to analyze in looking at the severe thunderstorm environment. Sufficient instability and strong vertical wind shear (greater than 40 knots) can lead to long-lived, persistent updrafts, even favoring supercells or derechos. 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 become more probable as the effective bulk shear vector increases in magnitude through the range of 25-40 knots and greater”.

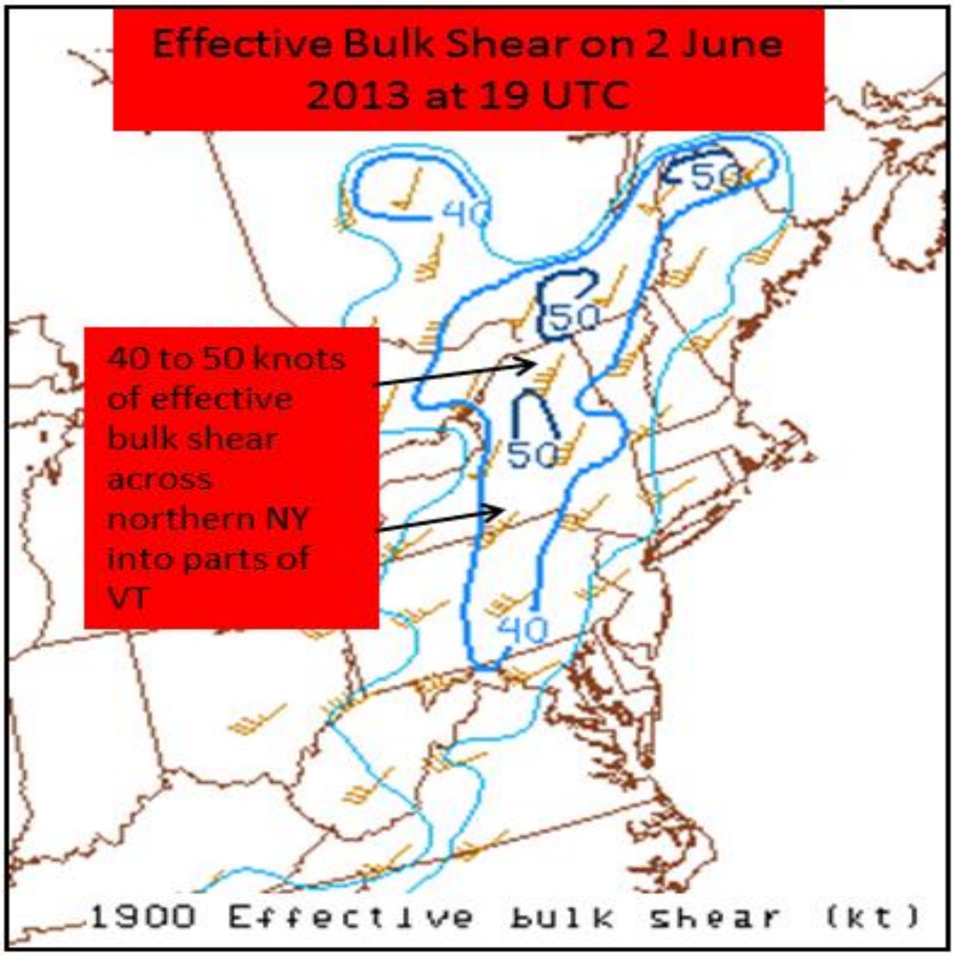

Figure 8: Storm Prediction Center RAP analysis of Effective Bulk Shear (contoured at 30 knots, 40 knots, and 50 knots) on 2 June 2013 at 19 UTC.

The surface analysis on 2 June 2013 at 1200 UTC showed a complex area of low pressure across the northern Great Lakes, with a surface cold front extending southward into the Ohio Valley. This cold front approached northern New York during the afternoon hours on June 2nd, and interacted with the moist and unstable air mass to produce a broken line of showers and thunderstorms across most of Vermont. Surface temperatures ahead of the cold front were in the 80s with dewpoints well into the 60s, producing CAPE values between 2000 and 3000 j/kg across central and eastern Vermont.

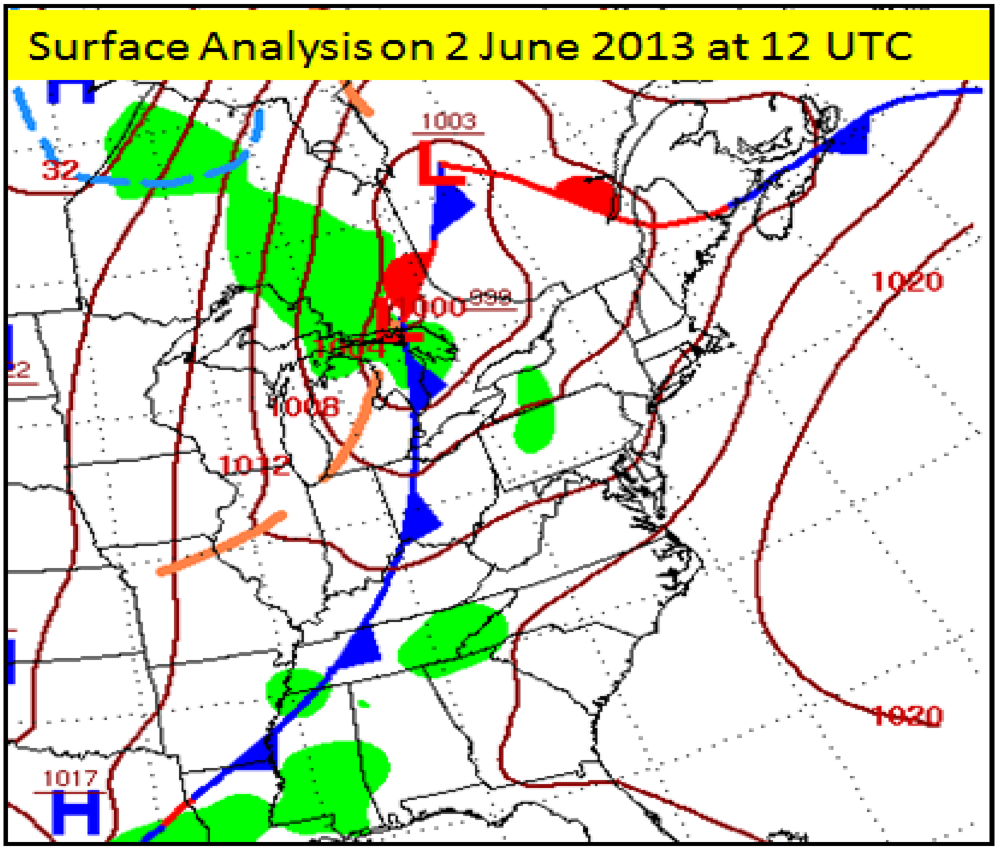

Figure 9: Surface analysis map on 2 June 2013 at 12 UTC.

4.) Radar Review:

In this section we will investigate the radar data and storm structures of the thunderstorms which impacted the North Country on 2 June 2013, and produced significant severe weather. Figure 10 below shows a composite radar mosaic loop from 1601 to 2001 UTC on June 2nd. The strongest storms have dark red and/or purple/pink colors in the images, which is associated with very strong reflectivity cores of 60 to 70 dBZ. These strong cores represent very heavy rainfall and the potential for hail and strong winds. Isolated storms developed across the eastern Adirondacks in New York around 1600 UTC and grew into a broken line of strong to severe thunderstorms across the southern Champlain Valley and parts of southern and eastern Vermont during the afternoon hours of June 2nd. One of the stronger and longer lived storms we will examine in this section is a cell that tracked just north of Glens Falls, New York to Rutland, Vermont, then through southern Orange County, Vermont, before crossing the Connecticut River Valley and weakening in central New Hampshire. This storm produced widespread wind damage along its path and 1.5 inch diameter hail in West Fairlee Center, Vermont. Another very intensity storm we will discuss, tracked along the Route 2 corridor from just west of Montpelier to Danville to Saint Johnsbury, Vermont, and produced scattered reports of trees and powerlines down, due to severe thunderstorm winds. Click here for a Google Earth map showing a composite reflectivity loop for this severe weather event.

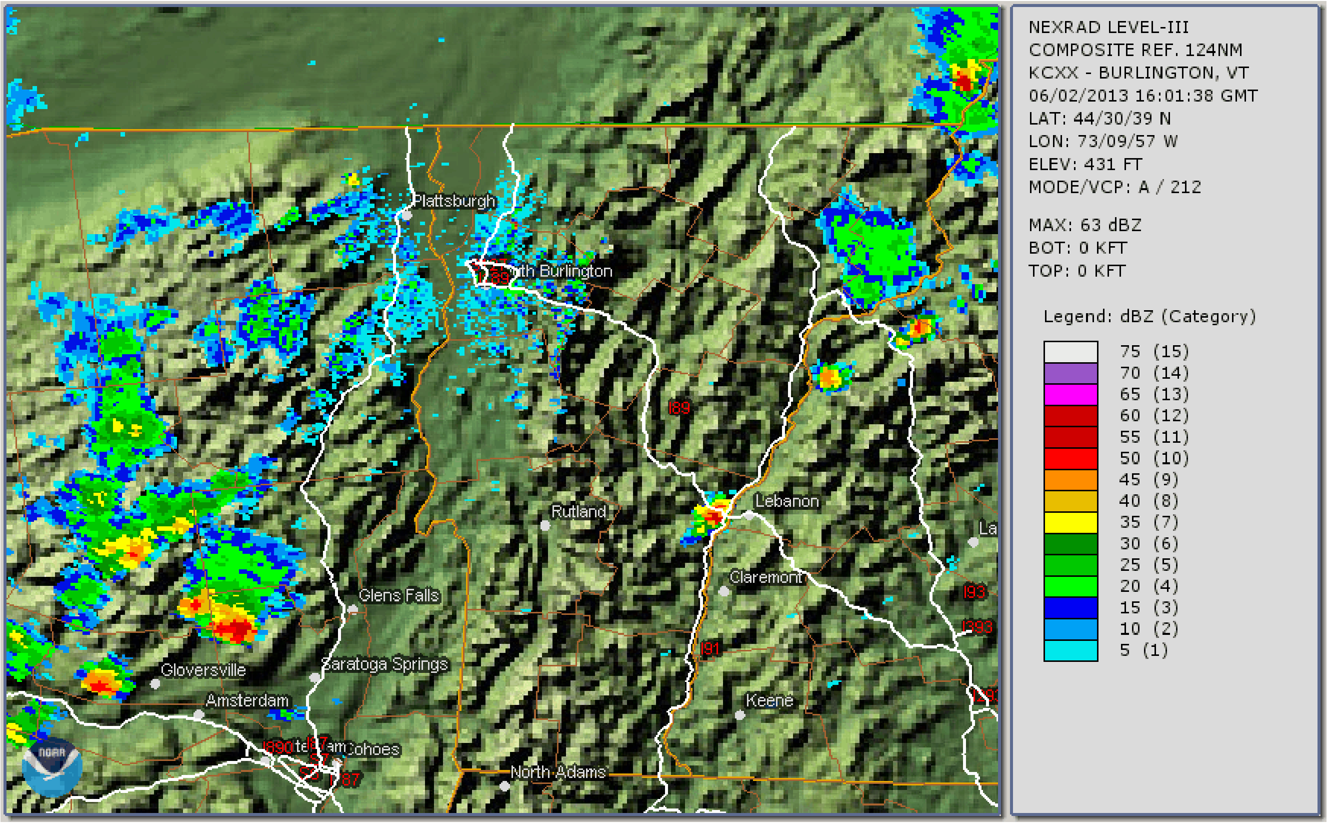

Figure 10: KCXX composite reflectivity radar from 1601 UTC to 2001 UTC on 2 June 2013. (click image for animation)

4a.) Rutland Storm:

Figure 11 below shows KCXX reflectivity cross section of a thunderstorm near Rutland, Vermont at 1748 UTC on 2 June 2013. This storm clearly had a well defined updraft, with an over-shooting top depicted. The echo top reached over 50,000 feet above the ground or almost 9 miles tall in the atmosphere, indicating the amount and depth of instability present. In addition, a 60 to 70 dBZ core was observed up to 10,000 feet and a 50 dBZ reflectivity core to 30,000 feet, suggesting the potential for large hail. The greatest potential for strong and damaging wind would be when this core of higher reflectivity collapses and transfers stronger winds aloft toward the ground. This storm produced numerous trees and wire down near Pittsford, Vermont, along with 1 inch diameter hail.

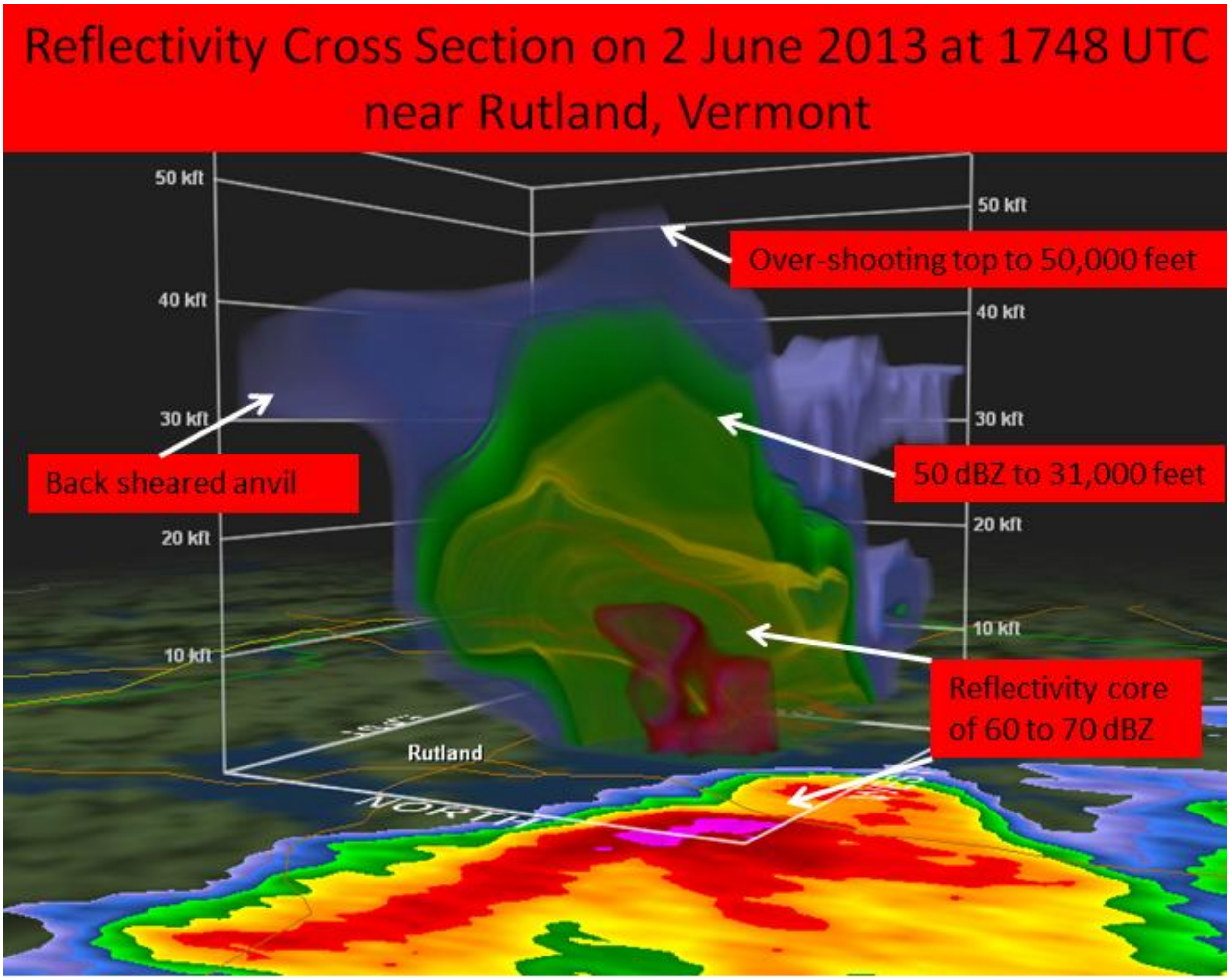

Figure 11: KCXX reflectivity cross section on 2 June 2013 at 1748 UTC.

Figure 12 shows the KCXX 0.5° reflectivity at 1748 UTC on 2 June 2013. A bow echo reflectivity structure was present across central Rutland County, which caused extensive thunderstorm wind damage. Trained weather spotters and the general public reported widespread trees and powerlines down from near Castleton to Rutland to Pittsford, Vermont associated with this bow echo. Typically, the strongest winds are found near the apex of the bow or closely associated with the stronger reflectivity cores. This bow-like reflectivity structure moved quickly northeast at 30 to 40 mph, another indication of the strong wind potential. The 60 to 70 dBZ in the reflectivity image below lined up with observed reports of dime to quarter size hail across central Rutland County.

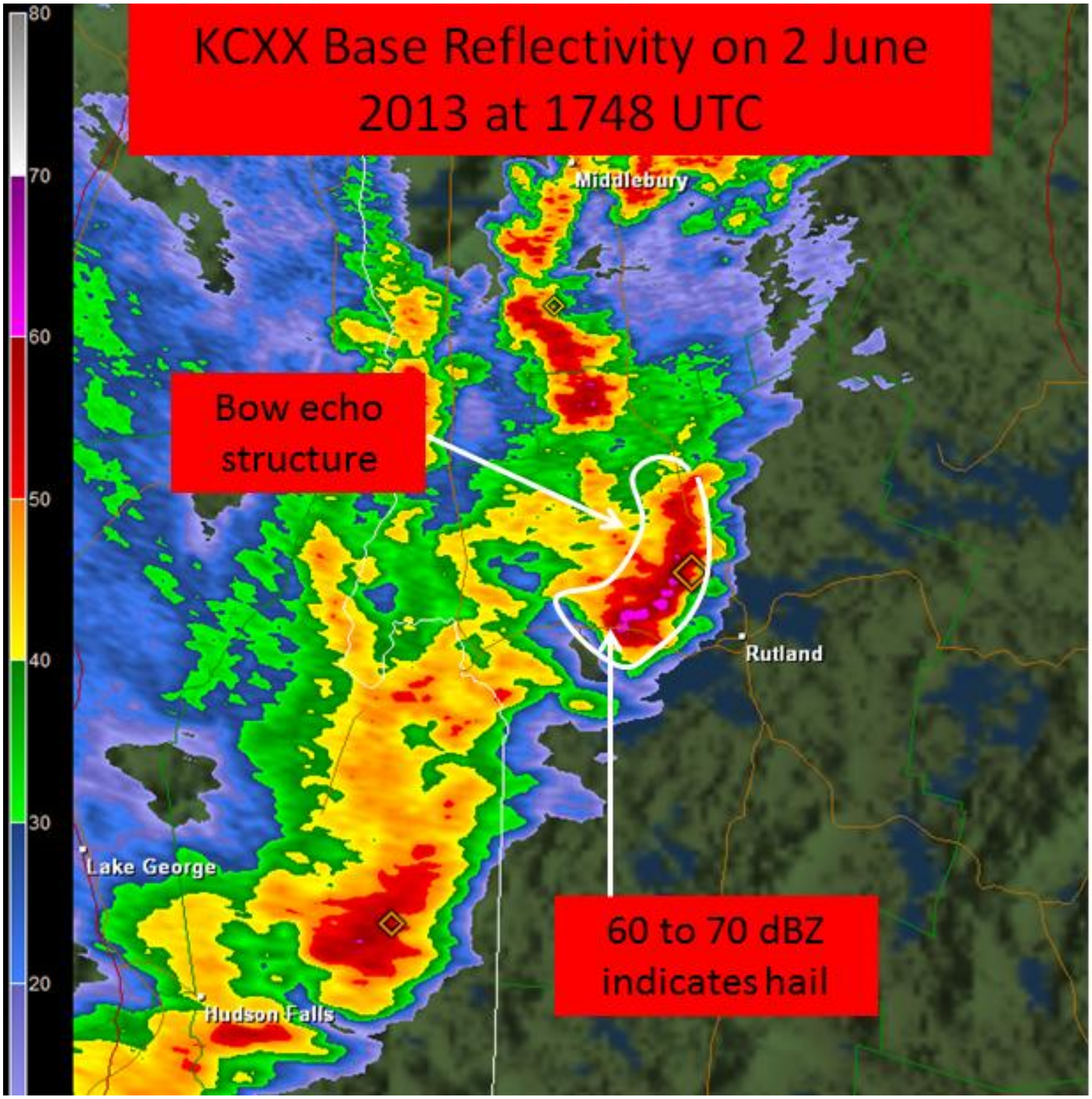

Figure 12: KCXX Base reflectivity on 2 June 2013 at 1748 UTC.

4b.) West Fairlee Center Ping Pong Size Hail Storm:

The storm discussed in the previous section across central Rutland County tracked northeast and further intensified over southern Orange County. We will examine a reflectivity cross section and vertically integrated liquid (VIL) product of this storm, and show why large hail was observed just east of Chelsea, Vermont. Figure 13 below shows a KCXX reflectivity cross section at 1854 UTC on 2 June 2013 near West Fairlee Center, Vermont. This image shows a wide and deep reflectivity core of 50 to 60 dBZ to 30,000 feet with embedded values of 60 to 70 dBZ to 26,000 feet. This very strong reflectivity indicates the potential for large hail. Also, note the limited reflectivity below 8,000 feet, a result of beam blockage caused by the Green Mountains. This storm did produce 1.5 inch (ping pong) diameter hail at West Fairlee Center, Vermont at 1854 UTC on 2 June 2013. Also, some trees and powerlines were down near Bradford, Vermont in Orange County, associated with this powerful storm. This storm exceeded the equilibrium level by nearly 5,000 feet based on sounding data from Gray, Maine, which supports this storm had a very strong updraft, along with an over-shooting top.

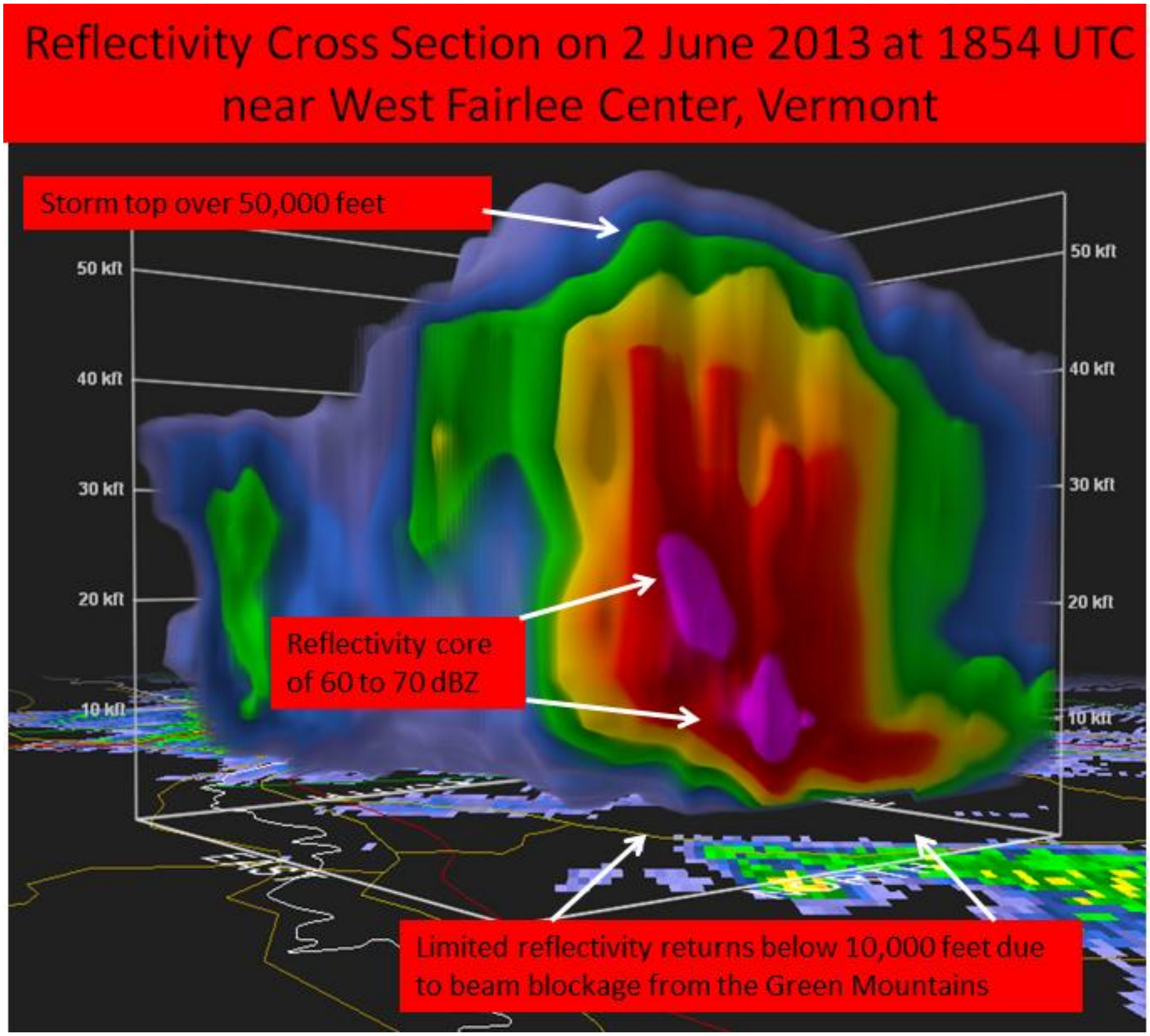

Figure 13: KCXX reflectivity cross section on 2 June 2013 at 1854 UTC near West Fairlee Center, Vermont.

Figure 14 below shows the KCXX Vertical Integrated Liquid (VIL) at 1854 UTC on 2 June 2013 near West Fairlee Center, Vermont. VIL is an estimate of the total mass of precipitation in the clouds. The measurement is obtained by observing the reflectivity of the vertical column as obtained by radar. This measurement is usually used in determining the size of hail, the potential amount of rain under a thunderstorm, and the potential downdraft strength when combined with the height of the echo tops. When VIL values quickly fall, it may mean that a downburst is occurring, a result of a weakening of the storm's updraft and the storms inability to hold the copious amounts of moisture/hail within the storm's structure. This means greater potential for the storm to produce damaging winds as the downburst descends to the surface. Figure 14 shows VIL (pink/purple and white color) values between 65 and 75 kg/m2 just east of Chelsea, Vermont. This indicates a very well developed updraft, which produced ping pong ball size hail at West Fairlee Center, Vermont. In addition, hail was observed in Rutland County associated with VIL values between 45 and 55 kg/m2, earlier in the afternoon.

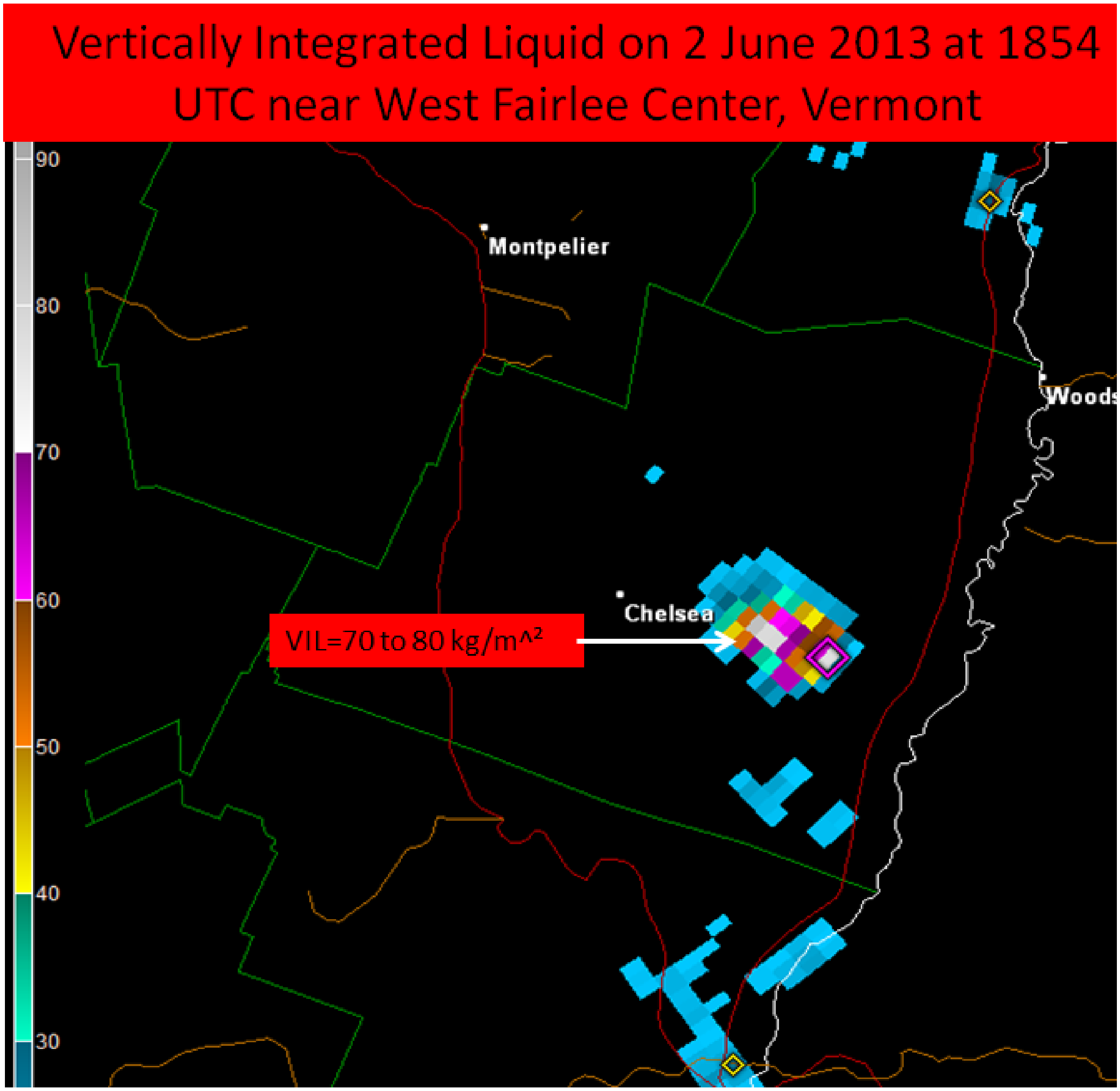

Figure 14: Vertically integrated liquid on 2 June 2013 at 1854 UTC near West Fairlee Center, Vermont.

4c.) Montpelier to Saint Johnsbury Damaging Wind Storm:

Figure 14 shows the KCXX 3.1° velocity (left) and reflectivity (right) at 1854 UTC on 2 June 2013. A strong reflectivity core moved across central Vermont from Montpelier to Danville to Saint Johnsbury, which caused widespread thunderstorm wind damage. Given the potent mid-level winds present, the stronger storms with dBZ > 65 were able to transfer these winds to the surface and produce areas of trees and powerlines down. In addition, a bowing line segment was present across central Orange County along with a descending rear inflow, evidenced by the limited reflectivity returns behind the line segment. This storm was discussed in the previous section. The 3.1° velocity image shows values between 35 and 50 knots, which supported damaging thunderstorm surface winds. The combination of distance from the radar, low level beam blockage caused by the Green Mountains, and storm motions perpendicular to the radar beam, created very poor radar sampling of this storm. In addition, the distance from the KGYX radar in Gray, Maine and the height of the White Mountains, resulted in poor radar sampling from the KGYX radar. This storm produced widespread trees and power lines down across eastern Vermont and parts of the Northeast Kingdom of Vermont.

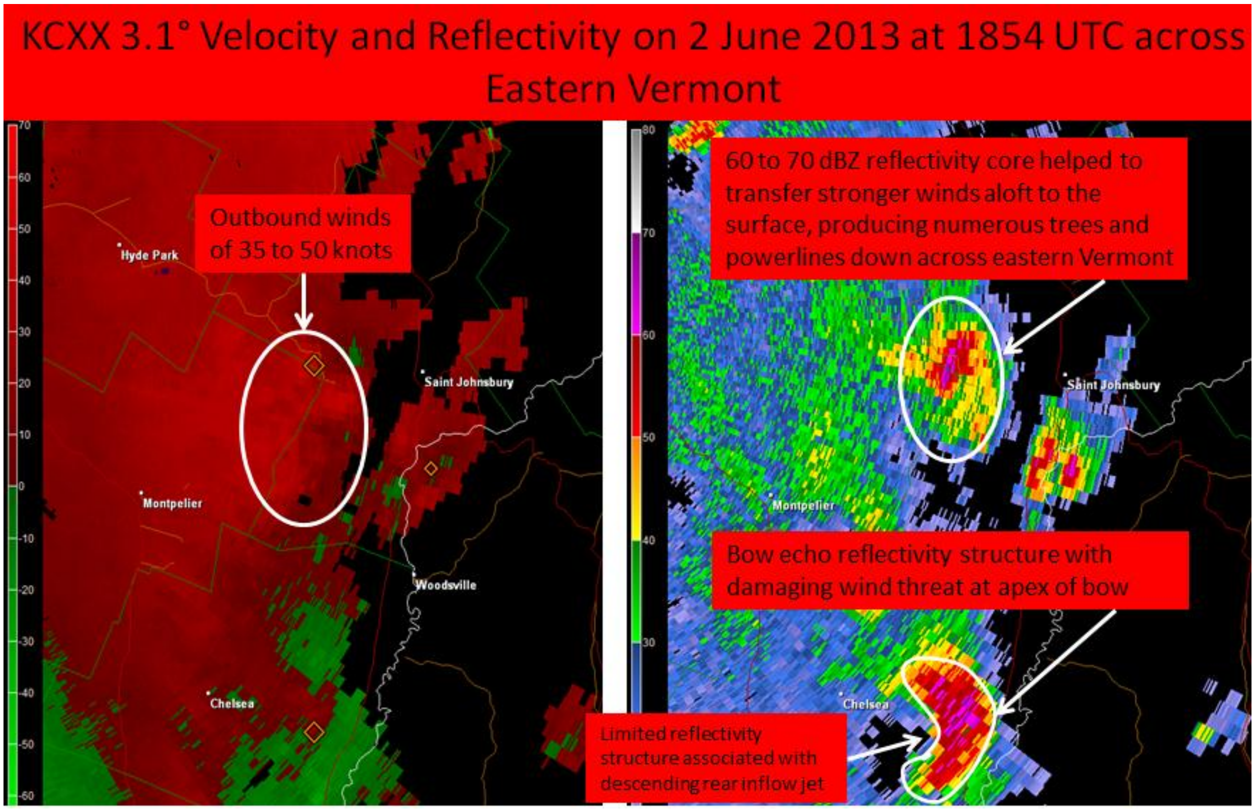

Figure 15: KCXX 3.1 velocity (left) and reflectivity (right) on 2 June 2013 at 1854 UTC across Eastern Vermont.

5.) Summary:

This was the first major severe weather outbreak of the 2013 season, which featured two concentrated areas of widespread trees and powerlines down across parts of central, eastern, and southern Vermont. In addition, up to 14,000 people lost power during the height of this severe weather outbreak. The primary damage was caused by strong gusty thunderstorms winds, with a few reports of large hail. Finally, some brief heavy rainfall occurred with this broken line of thunderstorms, but only minor low lying and poor drainage flooding was observed. Overall, rainfall amounts across the region were an inch or less.