The July 21, 2010 Severe Weather Event across Vermont and Northern New York

Part I: Introduction

On 21 July 2010 the second significant severe weather outbreak of the 2010 season occurred across northern New York and parts of Vermont. A very warm and moist air mass was in place across the North Country with temperatures in the 80s and surface dewpoints in the mid to upper 60s. This very unstable environment along with an approaching cold front helped to produce strong to severe thunderstorms across the North Country during the afternoon and evening hours on 21 July 2010.

This severe weather event included numerous reports of severe and damaging thunderstorm winds of greater than 60 mph, along with several report of large hail. Furthermore, the thunderstorms were accompanied by very heavy rainfall amounts of 3 to 4 inches, which caused some flooding. Most of the severe weather reports were concentrated along a line for near Brushton, New York in western Franklin County to Saint Johnsbury, Vermont in Caledonia County, associated with a long-tracked miniature supercell, which continued into New Hampshire and Maine. A supercell is a thunderstorm that is characterized by the presence of a mesocyclone; a deep, continuously-rotating updraft, supercells are the overall least common and have the potential to be the most severe. Supercells are often isolated from other thunderstorms, and can dominate the local climate up to 20 miles (32 km) away. The next area of damage and large hail occurred with a second long-tracked miniature supercell, which tracked from near Bristol to Brookfield, Vermont, then into western and central New Hampshire. As a result of the extensive wind damage, two National Weather Service (NWS) storm surveys were performed. The first survey was in Franklin County, New York, from Brushton to Malone, and found damage consistent with straight-line thunderstorm winds of 60 to 75 mph. The second survey near Brookfield, Vermont, also was a result of straight-line winds of 80 to 90 mph. Click here for the Public Information Statement associated with the storm surveys conducted by the NWS Burlington, Vermont.

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Figure 1 shows a Google Map display of the damaging wind reports and hail. The green bubble indicates the size of the hail in inches, while the orange bubbles in the image shows where damaging thunderstorm winds occurred. The damage reports included trees and power lines down through the region, along with structural damage in Franklin County, New York and in Orange County, Vermont. In addition, 1.50 inch diameter hail was observed at Bristol, Vermont and near 2.0 inch hail was reported in Brookfield, Vermont. Also, several reports of large hail were received across northern New York near Potsdam and Bangor. Click here for a complete listing of all severe weather report across Weather Forecast Office (WFO) Burlington, VT forecast area.

In this review, we will investigate the pre-storm synoptic and mesoscale features that contributed to the severe weather outbreak, along with several products issued by the Storm Prediction Center (SPC). This includes examining area soundings for instability and shear parameters, reviewing upper air data and water vapor for position of short waves and jet streaks, and surface data to indentify low-level boundaries and max instability as a focus for development. Finally, an in-depth radar review will be provided with detailed discussion about the reflectivity, velocity, and storm total precipitation signatures that contributed to producing the severe wind, hail and flooding reports.

SPC Products (Day 1 Outlook and Probability of Damaging Winds)

In this section we will examine the SPC Day 1 Convective Outlook (Figure 2), along with the probability of damaging winds (Figure 3).

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From Figure 2 you can see the SPC Day 1 Outlook had the Champlain Valley and all of Vermont highlighted in a moderate risk for severe thunderstorms, which is very unusual for our area. Click here for the Day 1 text product issued by SPC. 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. Meanwhile, the definition of a moderate risk day from SPC indicates a potential for a greater concentration of severe thunderstorms than the slight risk, and in most situations, greater magnitude of the severe weather. Typical moderate risk days include multiple tornadic supercells with very large hail, or intense squall lines with widespread damaging winds.

Click to enlarge

Meanwhile, Figure 3 shows the probabilistic forecast of severe thunderstorm winds to be 45% across our region on 21 July 2010. From SPC a probabilistic forecast represents the probability of one or more events occurring within 25 miles of any point during the outlook period. Therefore a 45% probabilistic forecast, means you have at least a 45% chance of receiving severe thunderstorm winds, within 25 miles of any point during the outlook period. It's very rare for SPC to place our region in a 45% or greater outlook for severe thunderstorm winds.

Part II: Pre-Storm Environment

Water Vapor Loop From 1131 UTC to 2253 UTC on 21 July 2010

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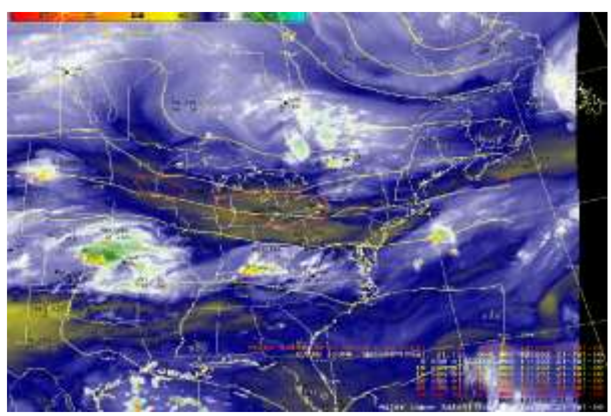

Figure 4 shows an eastern United States water vapor loop from 1131 UTC (Universal Time Constant: i.e., EDT plus 4 hours) to 2253 UTC on 21 July 2010, along with 500 hPa (20,000 feet above the ground level) heights (yellow lines) and wind speeds 50 knots or greater at 500 hPa (red lines). This shows a strong short wave trough across the eastern Great Lakes, along with a left front quadrant of a 500 hPa jet streak across western New York. These two features and associated cool pool aloft helped enhance upper level divergence and aided in the vertical development of thunderstorms. The closed height contours over the central Great Lakes into the Ohio Valley, suggests very strong jet stream winds aloft, helping to promote strong updrafts for long-lived thunderstorms. Also, plotted in the image below are 5, 10, 15, 20, 25 and 30 minute lightning strikes on 21 July 2010.

Upper Air Analysis

In this section we will discuss the pre-storm upper air conditions, which helped to produce severe weather across the Weather Forecast Office Burlington county warning area (CWA).

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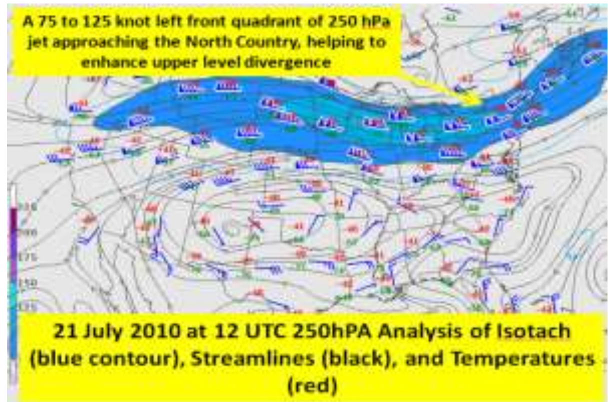

Figure 5 shows the 250 hPa (35,000 feet above the ground level) upper air analysis on 21 July 2010 at 12 UTC. Isotach, are lines of equal wind speeds (blue contours), streamlines (black lines), and temperatures (red) in Figure 5 below.

This shows a 75 to 125 knot westerly jet across the northern tier of the United States the left front quadrant of the jet approaching central New York into southern Vermont. This is a region of upper level divergence which aids in the development of tall thunderstorms with the potential to produce severe weather.

Sounding Data

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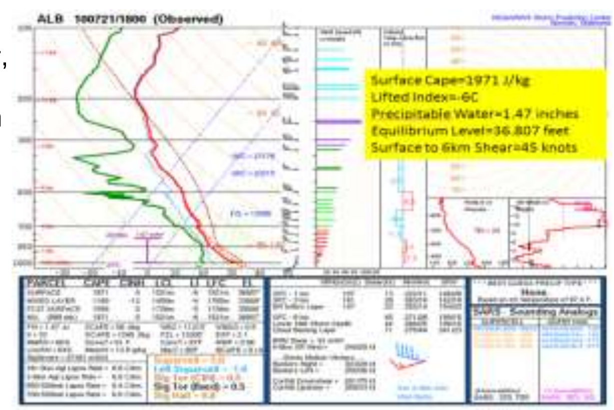

The 18 UTC May 21st rawinsonde observation at Albany, NY (Figure 6) shows modest instability, and strong deep layer shear, due to the placement of the strong mid to upper level winds across western New York into southern New England (as shown in the previous section). The combination of surface temperatures in the 80s and dewpoints in the mid to upper 60s created surface based convective available potential energy (CAPE) values of 1971 J/kg, with a lifted index (LI) of -6C (Celsius). CAPE values greater than 1500 J/kg, suggests moderately unstable environment, favorable for thunderstorm development. The large CAPE profile and very high equilibrium levels indicated thunderstorms would extend 35,000 to 45,000 feet into the atmosphere, and be capable of producing severe winds or large hail. 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 700 hPa. This deep mixed layer produced an environment favorable for transporting strong winds to the surface associated with thunderstorm convection.

In addition, the Albany sounding showed surface to 6km shear of 45 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 and derechos are commonly associated with vertical shear values of 35-40 knots and greater through this depth. Finally, the 18 UTC Albany sounding showed a precipitable water value of 1.47 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.

Surface Analysis

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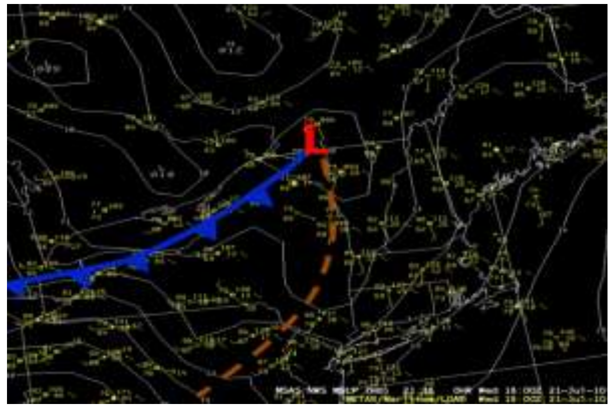

The surface analysis at 18 UTC on 21 July 2010 (Figure 7) from the Mesoscale Surface Assimilation System (MSAS), showed a weak pre-frontal trough (dotted brown line) across the Champlain Valley, with a surface cold front (blue line with triangles) approaching the Saint Lawrence River Valley. This cold front and pre-frontal trough helped to enhance low level convergence for the development of strong to severe thunderstorms. In addition, the surface observations (yellow), showed temperatures ahead of these features well into the upper 70s to lower 80s with dewpoints in the 60s, helping to create an unstable environment for thunderstorm development. The dewpoint is the temperature at which a given parcel of air is cooled to form condensation, and when the temperature and dewpoint are equal the air is saturated and the relative humidity value would be 100%. The white lines in figure 7 below are the National Weather Service mean sea-level pressure analysis, which identifies a weak surface low pressure near Rouses Point, New York and a meso-high approaching Montreal, Quebec.

Severe Weather Parameters

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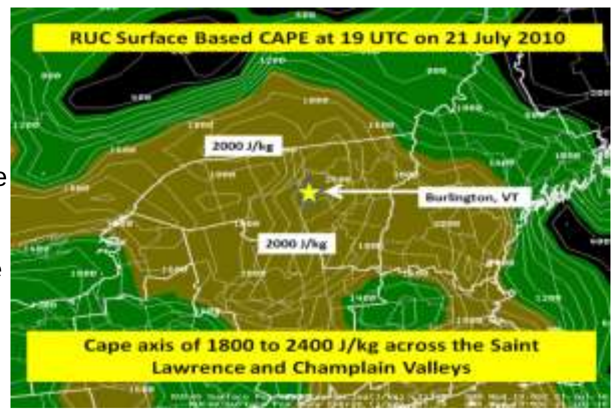

Figure 8 shows the 19 UTC RUC (Rapid Update Cycle) CAPE values across the North Country. The yellow color-filled image below indicates CAPE values greater than 1500 J/kg and suggests moderate instability. The RUC analysis indicated two maximum areas of CAPE; the first across the Saint Lawrence River Valley and the second across the Champlain Valley, where values approached 2500 J/kg. The potential instability was contributed to by insolational heating (surface temperatures in 80s), and surface dewpoint values in the mid to upper 60s, while southerly winds were 5 to 15 mph.

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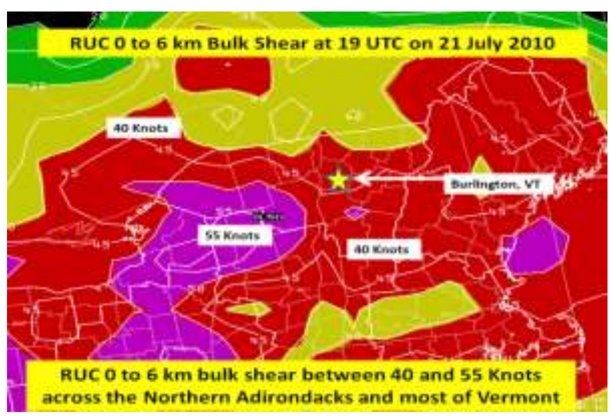
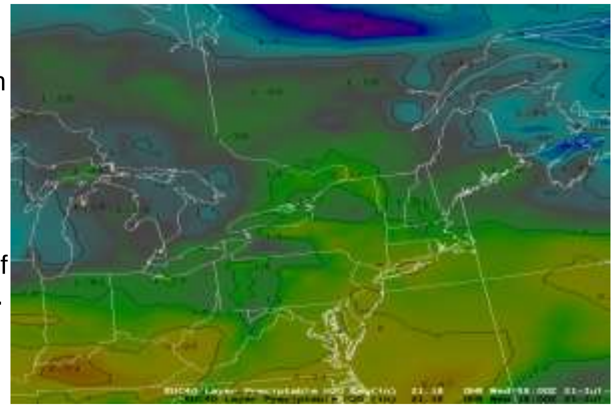


The surface to 6 km bulk shear (Figure 9) from the RUC at 19 UTC on 21 July 2010 revealed an area of increasing shear approaching the region from the southwest. The analysis showed values between 40 and 50 knots (pink color fill in Figure 9) approaching northern New York at 19 UTC. These strong values support organized and persistent thunderstorms, with a greater potential for supercells, capable of producing large hail and damaging winds. This increased shear was a result of the approaching mid/upper level trough and associated embedded upper level jet streak, which was highlighted in the 12 UTC upper air data.

Precipitable Water

Click to enlarge

Figure 10 shows the RUC 40 km precipitable water values across the northeast United States at 18 UTC on 21 July 2010. This analysis shows values between 1.75" and 2.0" across much of the North Country, and provides an excellent indicator that thunderstorms would have the potential to produce very heavy downpours. The deep southerly flow ahead of the approaching surface features and mid/upper level trough helped to transport this very moist/humid air mass into our region. As a result, thunderstorms developed, which produced hourly rainfall rates of 1 to 2 inches across the region, and caused some flash flooding.



Part III: Radar Analysis

Radar Mosaic Overview

In this next section we will discuss in-depth radar signatures and provide analysis for several storms, which produced significant wind damage and large hail across the region. The areas we will investigate are the Bangor, New York supercell, which tracked into the Champlain Valley, and produced damage near Milton, Vermont, followed by the supercell near Brookfield, Vermont. We will first discuss the big picture northeast radar mosaic of the widespread areal coverage and intensity of the storms, followed by a detailed examination of the Bangor, New York, Milton and Brookfield, Vermont storms, with reflectivity and velocity cross-sections, vertical integrated liquid (VIL), and low level plain view velocity displays.

Click to enlarge

Figure 11 is a Northeast region composite reflectivity mosaic from 1736 UTC to 2356 UTC on 21 July 2010 with 5 minute lightning plot (white crosses indicate positive polarity cloud to ground lightning strikes and dashes suggest negative polarity flashes carrying negative current to the ground). This loop shows the widespread areal coverage and intensity of the storms, along with the tremendous lightning activity during this severe weather outbreak. In addition, the radar loop shows multiple long tracked supercell thunderstorms across the region, several of which affected the WFO BTV forecast area.

Bangor/Brushton, New York Storm

Click to enlarge

Figure 12 shows a close-up composite reflectivity mosaic loop from 1605 UTC to 2055 UTC on 21 July 2010 with 5 minute lightning plot across the WFO BTV CWA. This loop clearly shows several long-lived supercells (yellow arrows) across our forecast area. The first cell develops near Massena, New York around 1605 UTC and tracks east into Brushton/Bangor, New York around 1701 UTC, then weakens across northern Clinton County, before redeveloping across Grand Isle County, due to warm moist inflow from winds coming up the Champlain Valley. This storm continued to produce severe winds and hail in the Milton/Essex Vermont areas, before tracking toward Morrisville and into central New Hampshire by 2030 UTC. Before exiting Vermont, the storm produced 1.0" hail in Danville, Vermont at 2025 UTC. The next long-tracked supercell developed across the higher terrain of the northern Adirondack Mountains, near Mineville, New York, then tracked into central Addison County and produced 1.50" hail in Lincoln, Vermont around 1915 UTC, before producing large hail and damaging winds near Brookfield, Vermont at 2000 UTC.

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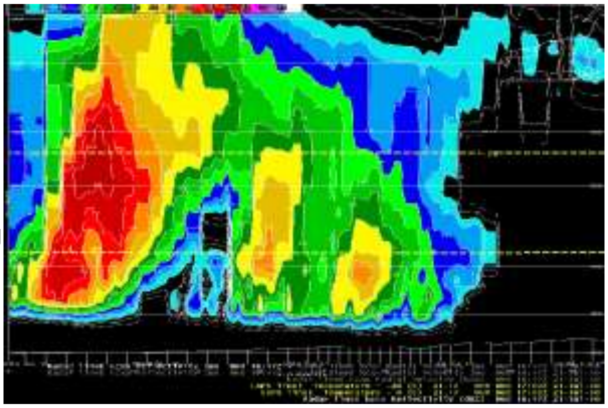

Figure 13 shows a reflectivity cross-section loop near Bangor, New York from 1647 UTC to 1725 UTC on 21 July 2010, along with LAPS 0C and -20C isotherms (yellow). This reflectivity cross-section loop clearly shows a tall, well vertically developed thunderstorm, with a strong reflectivity core of greater than 60 dBZ above the -20C. This very strong core aloft suggested a vigorous storm updraft and as the reflectivity core descended toward the surface, due to the storm collapsing, strong damaging thunderstorm winds occurred near Brushton/Bangor, New York. The loop clearly shows the greater than 60 dBZ core (bright red/pink color) collapsing toward the surface as the supercell tracked across central Franklin County, New York.

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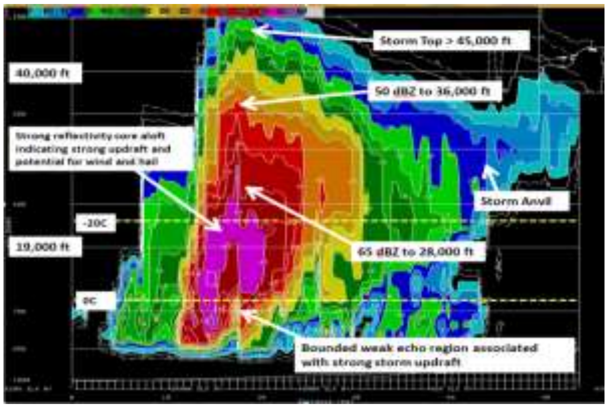

Figure 14 shows the KCXX radar composite reflectivity cross-section near Bangor, New York at 1701 UTC on 21 July 2010, along with LAPS 0C and -20C isotherms (dotted yellow lines). This image clearly shows 65 dBZ (pink color) well above -20C isotherm, with 50 dBZ to 36,000 ft, and a storm top of over 45,000 feet. This large and strong reflectivity core above the 0C and -20C isotherms indicates the storm is capable of producing large hail and very strong winds, which was observed in the Bangor and Brushton, New York area. In addition, the bounded weak echo region (BWER) suggests the storm had a very strong updraft and was still in the developmental stage, with very good storm relative inflow of a warm/moist air mass. A BWER is a radar signature within a thunderstorm characterized by a local minimum in radar reflectivity at low levels, which extends upward into, and is surrounded by, higher reflectivities aloft. This feature is associated with a strong updraft and is almost always found in the inflow region of a thunderstorm. Finally, the weaker dBZ returns (light blue) located between 20,000 feet and 35,000 feet on the right side of the image is associated with the storm anvil.

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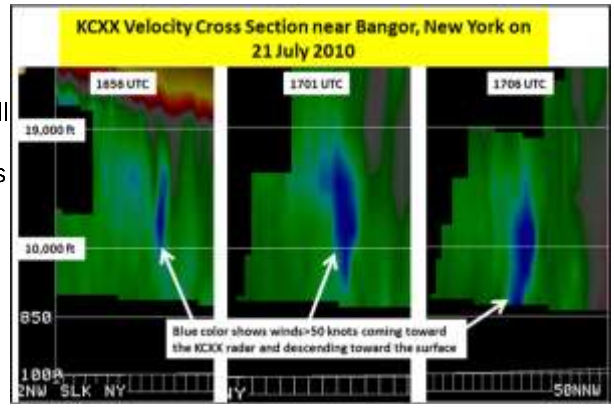

Figure 15 is the KCXX radar velocity cross section near Bangor, New York at 1701 UTC on 21 July 2010. This velocity cross section shows a descending inbound 50 knots or greater (dark blue) wind maximum moving toward the surface, as the supercell collapses between 1656 UTC and 1706 UTC near Bangor, New York on 21 July 2010. This descending core of very strong winds produced numerous trees and powerlines down across central and western Franklin County, along with copious amounts of hail. The lack of warmer colors (yellow/oranges) suggests the storm had limited rotation or outbound winds, which resulted in straight-line winds and the damage falling in one direction from west-northwest to east-southeast across the region.

Milton/Essex, Vermont Storm

In this section we will investigate the same supercell that affected the Brushton and Bangor, New York area, but now is located near Milton/Essex, Vermont. This supercell tracked across northern New York and weakened slightly across the higher terrain near Lyon Mountain, New York, before increasing in areal coverage and intensity over the Champlain Valley, due to warm/moist air advecting into the storm system. This cell produced damaging thunderstorm winds and some hail across the Milton/Essex, Vermont area on 21 July 2010. We will review a reflectivity cross-section, vertically integrated liquid (VIL) product, and a 0.5° KCXX velocity display to identify areas of the strongest inbound winds.

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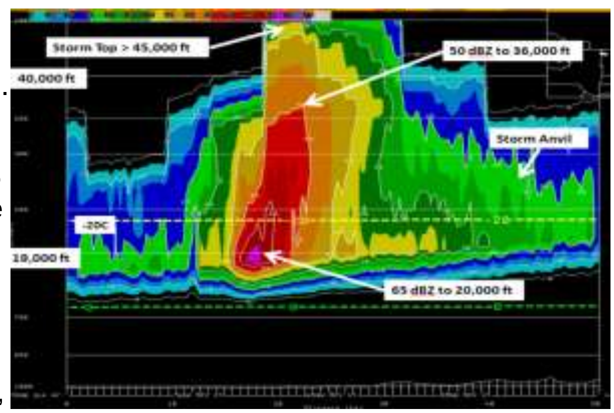

Figure 16 shows the KTYX radar composite reflectivity near Milton, Vermont at 1850 UTC on 21 July 2010 with LAPS -20C isotherm (yellow dotted line) and 0C isotherm (green dotted line). This image shows a very tall storm top with greater than 35 dBZ (yellow color) over 45,000 feet, along with a 50 dBZ (red color) core to 36, 000 feet, and a 65 dBZ (pink color) reflectivity core to 20, 000 feet, which indicates a very similar storm structure to the Brushton/Bangor Storm. These potent reflectivity cores aloft, suggests the potential for hail and damaging winds, which did occur in the Milton to Essex to Jericho, Vermont areas on 21 July 2010. We use the KTYX radar in Montague, New York to investigate storms near the radar located in Colchester, VT, due to the cone of silence, which limits the radar data aloft. However, due to the distance the KTYX radar is from the thunderstorm (>100nm), reflectivity and other radar data is not available below 10,000 feet. Therefore during warning operations, NWS meteorologists at WFO BTV use a combination of both KTYX and KCXX radars to investigate all layers of thunderstorms for potential impacts.

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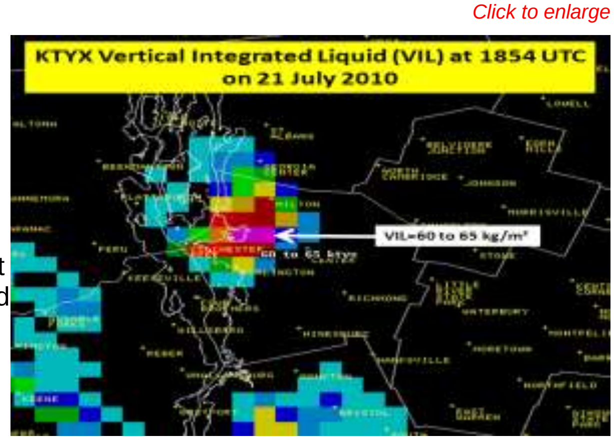

Figure 17 shows the KTYX Vertical Integrated Liquid (VIL) at 1854 UTC on 21 July 2010. VIL is an estimate of the total mass of precipitation in the clouds. The measurement is obtained by observing the reflectivity of the air as obtained by radar. This measurement is usually used in determining the size 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 imminent, resulting in the weakening of the storm's updraft and the storms inability to hold the copious amounts of moisture/hail within the storm's structure and a greater potential for the storm to produce damaging winds. Figure 17 shows VIL (pink color) values between 60 and 65 kg/m^2 near Milton, Vermont. This indicates a very well developed updraft, capable of producing large hail and damaging winds, especially when the storm collapses and weakens, which occurred between Colchester and Jericho, Vermont on 21 July 2010.

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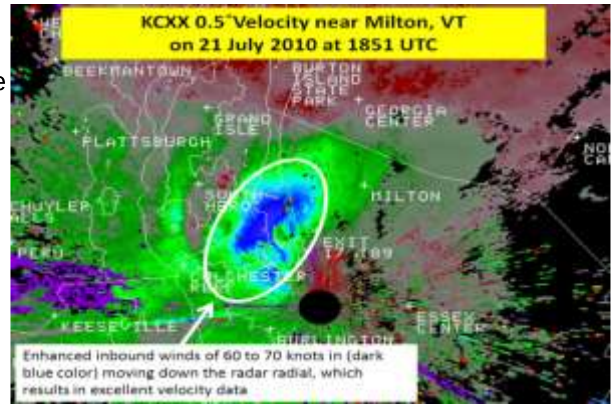

Figure 18 shows KCXX 0.5° velocity near Milton, VT on 21 July 2010 at 1851 UTC. The light to dark grayish blue color in the image shows inbound winds of 60 to 70 knots coming toward the radar located in Colchester, Vermont. These very strong thunderstorm winds were located between 300 and 400 feet above the ground and produced numerous trees and powerlines down from Colchester to Milton to Essex to Jericho, Vermont on 21 July 2010. The KCXX radar had excellent velocity quality for this storm at 1854 UTC, because the storm was moving directly down the radial, toward the radar tower, located in Colchester, Vermont. It's very rare to see such a widespread area of greater than 50 knot winds at such low levels, across our region. Also, note very limited outbound winds (yellow/red colors), indicating the storm had very limited rotation.

Brookfield/Chelsea, VT Storm

In this section we will investigate the supercell which developed across the higher terrain of the northern Adirondack Mountains, near Mineville, New York, then tracked into central Addison County and produced 1.50" hail in Lincoln, Vermont around 1915 UTC, before producing large hail and damaging winds near Brookfield, Vermont at 2000 UTC. We will review a reflectivity cross section near Brookfield, Vermont, along with the KCXX 1.3° velocity display to highlight the damaging winds.

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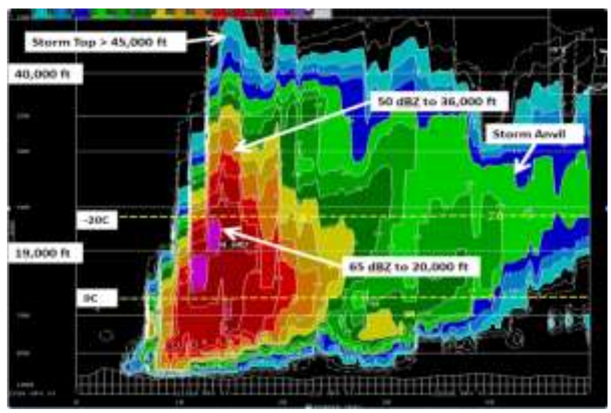

Figure 19 shows the KCXX radar composite reflectivity cross section near Brookfield, Vermont at 1953 UTC on 21 July 2010 with LAPS -20C and 0C Isotherm (yellow dotted lines). Once again the image shows a very tall storm top with greater than 35 dBZ (yellow color) over 45,000 feet, along with a 50 dBZ (red color) core to 36, 000 feet, and a 65 dBZ (pink color) reflectivity core to 20, 000 feet, which indicates a very similar storm structure to the Brushton/Bangor and Essex/Milton storms. This deep reflectivity core and storm structure indicates the potential for damaging winds and large hail, which occurred with 2.0" hail and numerous trees and powerlines down near Brookfield, Vermont. Also, like the other storms, this cell had a well defined storm anvil (light green color on right side of image), suggesting good outflow aloft.

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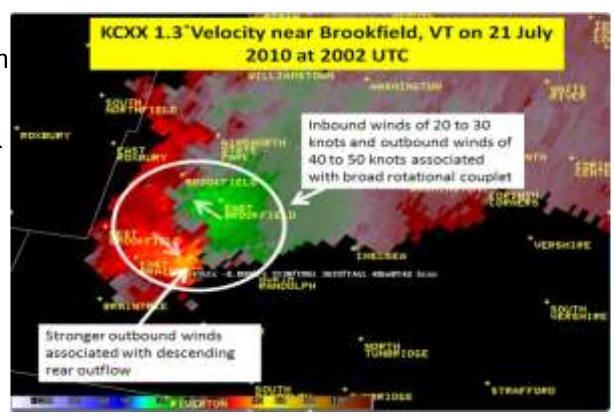

Figure 20 shows the KCXX radar 1.3° velocity near Brookfield, VT on 21 July 2010 at 2002 UTC. This image suggests the storm had some weak broad rotation, with inbound winds (light green) of 20 to 30 knots and outbound winds (yellow to orange colors) of 40 to 50 knots. However, given that the rotation occurred over a diameter greater than 10 nm (nautical miles), the height of the rotation was high above the ground, and no strong gate to gate couplet was present, no tornado occurred with this supercell (as was verified by the NWS storm survey team). Nevertheless a strong descending rear flank downdraft did produce numerous downed trees and powerlines near Brookfield, Vermont associated with winds between 80 and 90 mph. The radar has difficulties with beam blockage due to the Green Mountains, especially in the low elevation scans (0.5°, 0.9°, 1.3°), which results in reflectivity and velocity data being underestimated by the radar and very poor radar data quality.

Part IV: Hydrologic Analysis

Storm Total Precipitation with Flash Flood Warnings and Advisories

In this section we will quickly review the hydrologic analysis of the event, which will include the northeast radar mosaic storm total precipitation estimate and the local climate precipitation maps, produced by WFO BTV. The pre-storm environment featured precipitable water values between 1.50 and 1.75 inches, along with the potential for some training thunderstorms due to small relative storm vectors. Furthermore, a boundary approaching the region and good upper level dynamics helped to enhance the heavy rainfall threat across the North Country.

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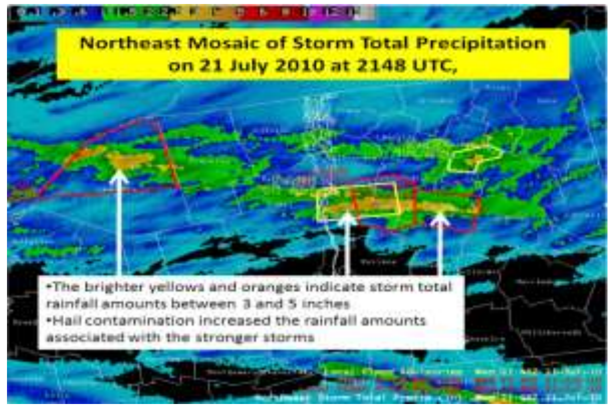

Figure 21 shows a Northeast mosaic of storm total precipitation on 21 July 2010 at 2148 UTC, along with Flash Flood Warnings (red) and Flood Advisories (yellow). The brighter yellow and orange colors in the image suggest storm total rainfall amounts between 3 and 5 inches. However, hail contamination occurred, which adversely affected the radar derived rainfall estimates, especially near Potsdam, New York in Saint Lawrence County, Bristol, Vermont in Addison County, and in Orange County near Brookfield, Vermont. All these locations received large hail. It's also interesting to see the higher storm total precipitation amounts outline very well the track of the long tracked supercells. Overall, based on surface observations from spotters and coop observers, the radar storm total precipitation estimates seemed reasonable.

Daily Climate Maps

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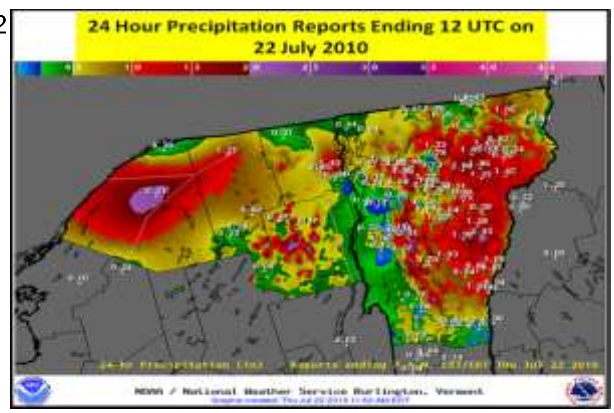

Figure 22 shows 24 hour precipitation (inches) reports Ending 12 UTC on 22 July 2010 from NWS Coop observers, CoCoRaHS (Community Collaborative Rain, Hail and Snow Network) and local mesonet observations across the North Country. Click here for a complete listing of 24 hour rainfall reports across the region. A couple of the higher 24 hour rainfall amounts included 2.91 inches at French Settlement in eastern Addison County, 2.86 inches in Brookfield, and 2.43 inches in Corinth, Vermont on 21 July 2010. This heavy rainfall in a short period of time associated with powerful thunderstorms caused some minor low lying and poor drainage flooding, along with some culverts and minor dirt road washouts.

Part V: Conclusion/Storm Surveys

The moderate instability with strong deep layer shear produced an environment favorable for thunderstorm development during the afternoon and evening hours on 21 July 2010 across WFO BTV forecast area. These storms first developed across the Saint Lawrence Valley and northern Adirondack Mountains, then tracked east into the Champlain Valley of New York and Vermont, then into central and southern Vermont and New Hampshire, before slowly weakening over the cooler waters of the Atlantic Ocean in the Gulf of Maine late on 21 July 2010. These long-tracked supercells produced 1 to 2 inch diameter hail at several locations across the North Country, along with numerous reports of trees and power-lines down, from straight-line winds up to 90 mph. The highest concentration of damage occurred from Brushton to near Malone, New York, with another maximum area of damage in the Brookfield, Vermont vicinity. The following pictures were taken by staff members from WFO BTV during two storm damage surveys in the areas of maximum damage.

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Acknowledgements

The NOAA NWS Storm Prediction (SPC) website (http://www.spc.noaa.gov/) was used for several severe weather definitions (CAPE and 0 to 6km Bulk Shear).

Several severe weather WIKI page website (http://en.wikipedia.org/wiki/Wiki) were used for definitions of vertically integrated liquid (VIL), bound weak echo region (BWER), precipitable water (PW), Supercells, and equilibrium level (EL).