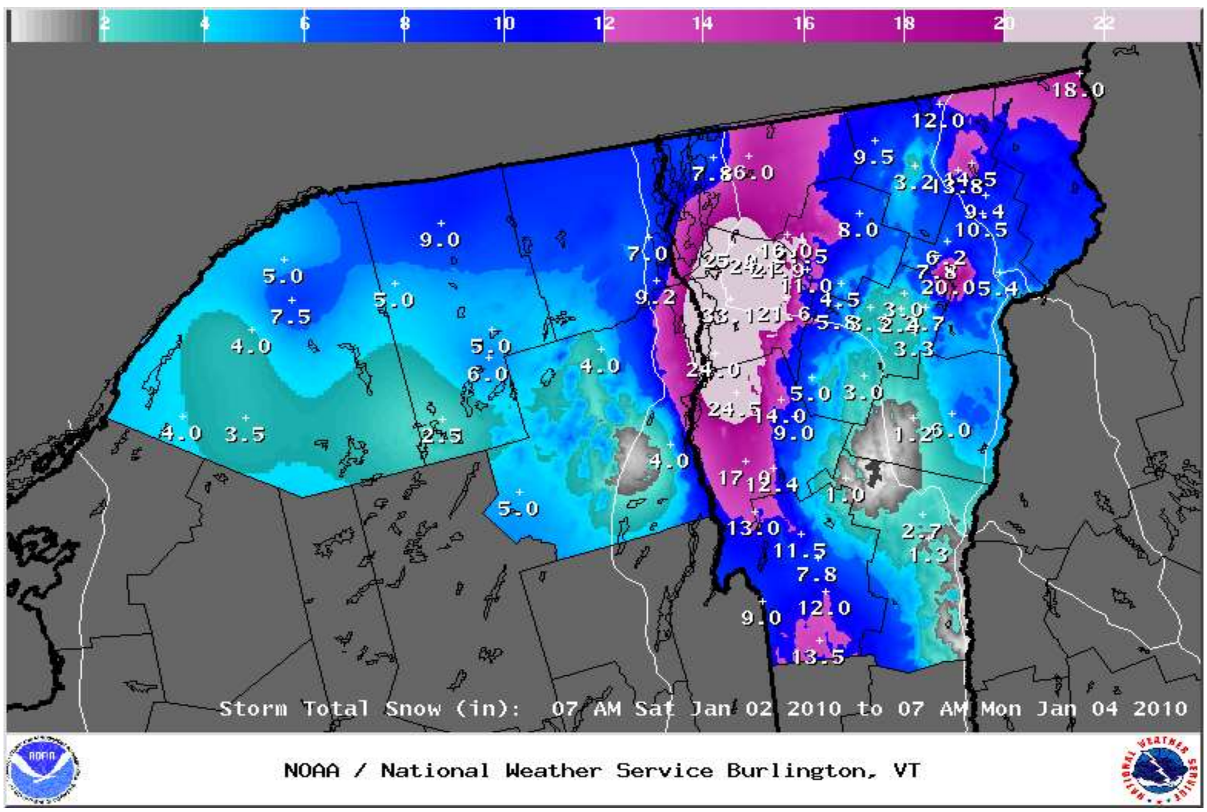
Champlain Powder:
The Historic Burlington Vermont Snowfall of 2-3 January 2010

A record breaking continuous snowfall occurred from 902 AM EST January 2nd through 810 PM EST on January 3rd, producing a historic 33.1 inches of snow at Burlington, Vermont during this time period. The three day total snowfall at Burlington, Vermont was 37.6 inches from 1-3 January, 2010. This extraordinary event featured several large and small-scale weather systems, which produced very localized heavy snowfall amounts, especially across the eastern Champlain Valley. Figure 1 below shows the storm total snowfall reports from 7 AM EST January 2nd through 7 AM EST January 4th, across Weather Forecast Office Burlington, Vermont county warning area. This figure clearly shows the wide variation in snowfall amounts across the region. Plattsburgh, New York received only 7.0 inches of snow, while Burlington, Vermont, just 20 miles received 33.1 inches during this storm. The axis of heaviest snow occurred across the Eastern Champlain Valley from southern Franklin County through Chittenden into Addison and Rutland Counties, with many locations receiving between 20 and 33 inches. Another maximum in snowfall occurred across portions of the Northeast Kingdom of Vermont with isolated totals in excess of 12 inches. Portions of the lower Passumpsic Valley southward across most of east-central and southeastern Vermont received only 2 to 6 inches of snow from this event. Click here to view the public information statement of snowfall reports.



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Upper Air Analysis

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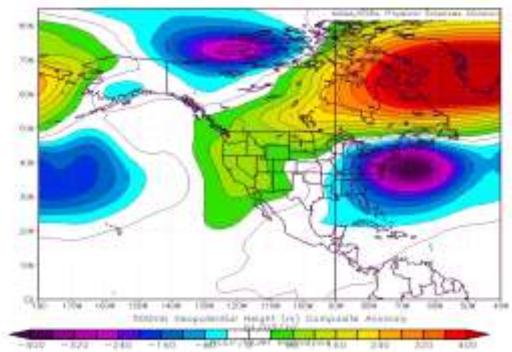

The large scale pattern featured a deep developing trough across the Eastern United States, while a highly amplitude ridge associated with the North Atlantic Oscillation (NAO) occurred over Greenland. This blocking pattern helped to capture a strong developing ocean storm well off the New England coastline and forced it to move west or retrograde back toward our region. During negative phases of the NAO, a large mid/upper level ridge builds across the Northern Atlantic, while a deep trough is present over the Eastern United States, often resulting in a cold snowy pattern. Figure 2 shows the 500 hPa height Global Reanalysis anomaly on 3 January 2010. This shows a large scale blocking pattern with 300 to 400 meter above normal 500 hPa heights across Greenland and 300 to 400 meter below normal heights across the western Atlantic associated with the highly negative phase of the NAO. This pattern helped to produce a deep cutoff cyclone with the surface low near the 40 degree North latitude and 60 degree West longitude. The cyclone then tracked 300 to 400 miles westward to the Gulf of Maine, before slowly moving into Eastern Canada by January 5th. The deep vertically stacked surface to 200 hPa counter-clockwise circulation transported mid/upper level Atlantic Moisture into the North Country during this event from the northeast.

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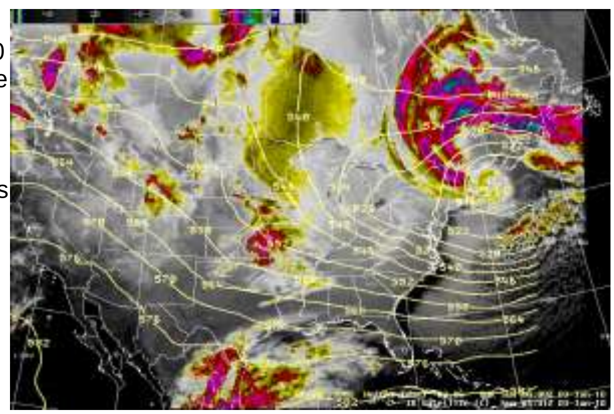

Figure 3 shows an infrared satellite loop from 0115 Universal Time Constant (UTC) on 1 January to 2300 UTC on 3 January 2010, along with the Rapid Update Cycle (RUC) 80 km 500 hPa analysis (yellow contours). This satellite loop shows a potent closed 500 hPa circulation tracking across the Mid Atlantic States on January 1st, which intensifies and becomes closed off across the Gulf of Maine by January 2nd as southern stream energy interaction takes places off the Mid Atlantic Coast. This circulation becomes stationary and cutoff from the main flow, because of downstream blocking caused by a strongly negative NAO. The colder cloud tops (brighter colors) in the image below shows the moisture rotating back into the North Country. As lobes of deep and relatively warm Atlantic moisture is pulled back into our region, and interacts with very cold low-level temperature profiles, conditions become favorable for a fluffy accumulating snow event. This large scale system and associated moisture aloft combined with several low-level mesoscale features to produce a historic snowfall event across the Eastern Champlain Valley.

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Figure 4 shows the NAM (North American Model) 12 km sounding at Burlington, Vermont at 0600 UTC 3 January 2010. The model sounding shows a deep surface to 30,000 feet above ground level layer of near saturated conditions, along with a large favorable region of snowflake dendrite growth from near the surface to 13,000 feet above ground level (purple box). Furthermore, upward motion favorable for producing precipitation was indicated by the sounding. These factors in the temperature, moisture, and vertical motion profiles were all favorable for large snow flake production, and were a significant factor in snow-to-liquid ratios approaching 40:1 compared to a normal value closer to 13:1 in the Burlington area. The wind profiles showed a strong east to northeast flow between 15,000 and 30,000 feet (AGL) of 40 to 50 knots, which transported mid and upper level moisture into New England. Between the surface and 10,000 feet (AGL) a favorable north to northwest upslope/Champlain Valley convergent flow of 25 to 35 knots was present. This combination of moisture from the Atlantic aloft, and low level moisture from Lake Champlain, along with impacts of the terrain, helped to produce greater precipitation amounts across the Eastern Champlain Valley.

Mesoscale Analysis

The next section will provide a mesoscale analysis of the event, including investigating radar data and the impacts Lake Champlain and the surrounding terrain had on total snowfall amounts.

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Figure 5 shows the animation of the National Weather Service (NWS) Weather Surveillance Radar - Doppler 1988 (WSR-88D) composite reflectivity, surface observations, and sea level pressure analysis from 0048 UTC 2 January 2010 through 2354 UTC 2 January 2010 over the northeast United States.
The main features to note are the increase in areal coverage and intensity of radar reflectivity greater than 20 dBZ across northern New England Saturday afternoon through Sunday morning. The period of heaviest snow occurred during this time as the deep cyclone moved west into the Gulf of Maine toward the Maine coast accompanied by a large precipitation shield.

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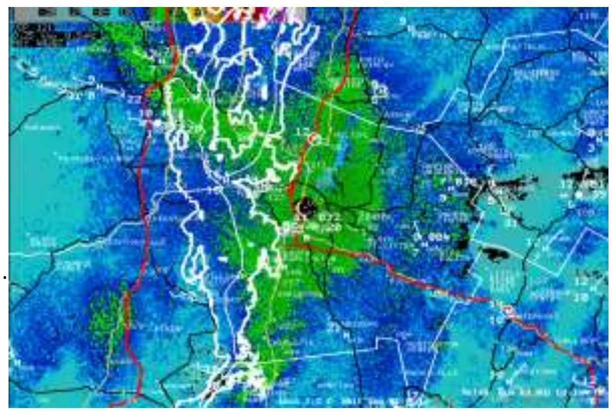

By looking at animation of the WSR-88D reflectivity (Figure 6), persistent higher reflectivity can be seen along and east of Lake Champlain. Further east near the Green Mountains, radar reflectivity elements can be seen moving in from the northeast with higher reflectivity confined mainly west of the spine of the mountains westward to the lake.
The low-level northwesterly airflow into the Champlain valley is blocked by the surrounding terrain and the inversion (stable layer) present below the summit level. This resulted in heavy precipitation displaced from the Green Mountains westward.

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Figure 7 shows the 1.5 degree elevation radar doppler velocity from KCXX at 0245 UTC 3 January 2010. The velocity shows the airflow of 30 to 40 knots across water of Lake Champlain which slowed to 15 to 25 knots east of the radar over the land indicating convergence (sometimes referred to as speed convergence). Additionally, the air was forced to ascend upslope to the summits of the Green mountains rising to 4395 feet above mean sea level (msl) at Mt. Mansfield east of Burlington. Figure 7 also shows a band of high outgoing velocity (greater than 50 kt in the pink shading) along and just downwind (east) of the summits of the Green mountains as the cold stable air flowed up and over the mountains, which led to less precipitation and gusty winds to over 40 mph east of the mountains. This high speed animation of the Doppler velocity shows the relative slowing of the wind coincident with the higher reflectivity in the small lake effect band streamers and the adjacent higher velocities between them. It is evident from the velocity animation that these velocity features extend across Lake Champlain then over the land to the east and are turned southward as the flow follows the shape of the valley.

Conclusions

A combination of many factors led to this historic event. A deep, retrograding cyclone in the Gulf of Maine was responsible for the large scale lift and moisture transport into Vermont at mid and upper levels. A persistent flow of Arctic air over the relatively mild Lake Champlain resulted in the convergence of small-scale lake-effect snow bands into a single band in the funnel-shaped Champlain Valley. Orographically blocked flow (due to an inversion below summit level) also contributed to (speed) convergence across the Vermont side of the Champlain Valley during the event, with the maximum upward vertical motion and precipitation displaced upwind of the Green Mountains into the more populated area around Burlington. Precipitation microphysics were also favorable. Dendritic snow growth was optimized by a deep saturated temperature profile in the -12C to -18C range, coincident with the layer of strong upward vertical motion. This maximized precipitation efficiency and led to a low density snowfall with snow to liquid equivalent ratios approaching 40:1. These factors led to an epic snow event - including the record 33.1 inches recorded at Burlington International Airport - which stands as the new record snowfall for a single storm since official observations began in 1883.

The following images were taken in South Burlington Sunday, January 3, 2010.

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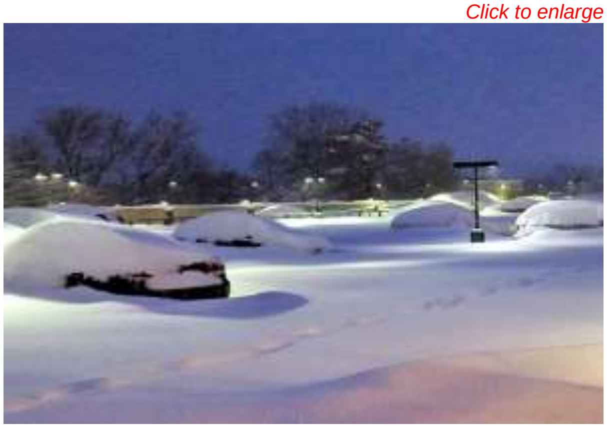

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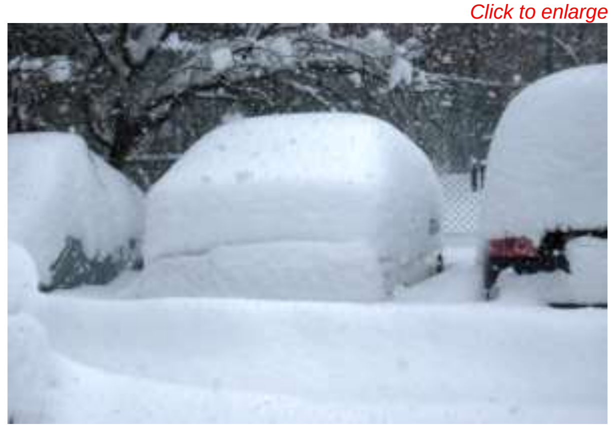

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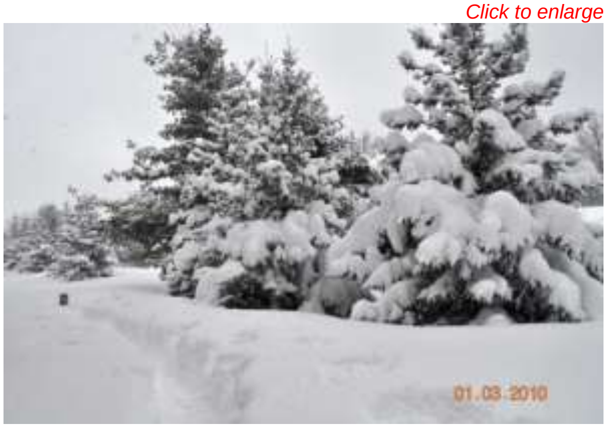

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