A REVIEW OF THE 6-7 MARCH 2011 SNOWSTORM ACROSS VERMONT AND NORTHERN NEW YORK

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1. INTRODUCTION

Synoptic and mesoscale (frontogenetic) forcing combined with rich Atlantic moisture to produce a snowfall of historic significance across central and northern Vermont and northern New York on 6-7 March 2011 (Fig. 1, and sidebar). Snowfall accumulations exceeded 24" (60 cm) across portions of northern and northwestern Vermont and into the Adirondacks of New York, with localized amounts in excess of 30" (76 cm). Liquid equivalent precipitation amounts exceeded 2" (5 cm) with the snowfall, and low snow ratios due to the moisture laden nature of the event made this storm particularly crippling for transportation and business on a Monday morning. The snow was preceded by an unseasonably warm air mass and rain, which yielded partial breakup of ice on area rivers and streams resulting in ice jam flooding. The most significant flooding occurred in the village of Ausable Forks, NY where an ice jam produced flash flooding and forced evacuation of the village. Most of the remaining ice jam flooding was minor, but the evolution of events posed a challenge as forecasters contended with hydrological warnings followed by a heavy wet snowfall in an unusual rain-to-heavy snow scenario.

The purpose of this write-up is to provide a multi-scale overview of factors that contributed to the heavy snow portion of the event (see sidebar for historic aspects of the storm).

Notable numbers from the storm:

- **25.8"**: Storm total snowfall, the 3rd greatest on record at BTV. (#1: 33.1", 2-3 Jan 2010; #2: 29.8", 25-28 Dec 1969)
- **2.05"**: The liquid equivalent precipitation, following the changeover to frozen precipitation at 1529 UTC on 6 March through the end of the storm on 7 March.
- **1**: Greatest March snowfall on record at BTV.
- **2**: The storm pushed the 2010-11 season into 2nd place all-time for snowfall at BTV. The season ended with 128.4" of snowfall, behind only the 145.4" that fell in 1970-71).
- **51:** Temperature in °F in Worcester, MA while heavy snow was occurring in Vermont.

2. MID AND UPPER-TROPOSPHERIC FLOW

The 6-7 March 2011 was unusual in that it was preceded by a mild spell with a mid-tropospheric ridge and surface temperatures well in the mid to upper 40s on 5 March and into the morning hours on 6 March (Fig. 2). The hemispheric flow was also absent the downstream blocking over the North Atlantic which often precedes significant snowstorms over New England and New York; the North Atlantic Oscillation was in a positive phase during the period 5-8 March 2011. The mean 500mb height pattern on 6 March (Fig. 3) shows that the height ridge had moved east of New England with a large positive height anomaly across the Canadian Maritimes. A closed upper low over Baffin Island in northern Canada and southwestern extending trough into Hudson Bay resulted in an unusually strong height gradient between the associated negative and positive height anomalies across Quebec, and an upper level jet streak over the area. The right entrance region of this jet was over the central Appalachians at 06/12 UTC (Fig. 4) and would move northward later in the day on 6 March and contribute to strong upper divergence/ upward vertical motion and cyclogenesis.

Meanwhile, a 500mb trough is noted upstream across the Great Lakes into the lower Mississippi Valley with the strongest negative height anomalies across the northern Gulf Coast states (Fig. 3). This approaching trough would also be a contributing factor to developing surface low pressure late in the day on 6 March.

3. LOW-LEVEL FRONTAL STRUCTURE

As noted, unseasonably mild surface temperatures in the 40s preceded the snowfall. The arrival of a strong arctic front caused 2-m temperatures to drop rapidly during the mid-to-late morning on 6 March 2011 (Fig. 2). At BTV, temperatures decreased 16 degrees Fahrenheit between 13-14 UTC and fell below freezing. At 06/15 UTC, the strongest 925-mb temperature gradient was over northwestern Vermont southwestward across central NY and the central Appalachians. The front slowly shifted southeastward through the mid-afternoon hours on 6 March before eventually stalling (Fig. 5) owing to incipient cyclogenesis along the front over Virginia and North Carolina and an associated strengthening and backing of winds in the warm sector along the coast of the northeastern United States.

4. CYCLOGENESIS AND PRECIPITATION TRENDS

During the afternoon and evening hours on 6 March 2011, the combination of the strong low-level baroclinic zone from the central Appalachians northeast into New England, upper-trough and associated potential vorticity (PV) maximum lifting northeastward from the Gulf Coast, and right entrance region of the upper tropospheric jet centered across Quebec provided favorable conditions for the development of a strong surface low along the front. Cyclogenesis occurred as the potential vorticity maximum and associated PV advection crossed the low-level baroclinic zone during the afternoon and evening hours on 6 March (Fig. 6). The movement of the surface low northeast along the coast would produce the heaviest snowfall rates during the overnight/early morning hours on Monday, 7 March 2011.

Mosaic composite reflectivity shows that precipitation occurred in three waves across the North Country (Fig. 7). There was an initial increase in precipitation rate during the mid-morning hours on 6 March as the cold front moved across the region and rain changed to snow (Fig. 8 and Fig. 9). As the front settled to the south, snow fell at a light rate during the afternoon and early evening hours (≤0.5”/hr). Then, as the surface low translated northward, there was a pronounced increase in 850-700mb mean wind speed and temperature advection (Fig. 10), as well as low-level moisture advection (Fig. 11) across the frontal zone into Vermont and northern New York. The system entrained rich Atlantic moisture with precipitation water values in excess of 1” (2.5 cm) across southern New England (Fig 11b). The baroclinic zone intensified, with temperatures in the low-to-mid 50s across southern New England while snowfall rates increased with temperatures falling through the low 20s into the teens across northwestern Vermont during the pre-dawn hours on 7 March. Reflectivity bright banding associated with sleet and freezing rain is evident at 07/04 UTC (Fig. 7d) across southern Vermont where the depth of sub-freezing air was relatively shallow and lower snow accumulations occurred (Fig. 1).

The increasing wind fields led to an 850-700 mb deformation zone north of the low across Vermont and northern New York (Fig. 12a), and strong frontogenetic forcing (Fig. 12b) that yielded periodic banded precipitation structures (Fig. 7e) and focused intense mesoscale ascent across the region. This resulted in snowfall rates exceeding 2”/hr at times and with liquid equivalent rates of 0.25”/hr as measured by ASOS at MPV between 05-06 UTC (Fig. 9). With the snow, an impressive 0.96” liquid equivalent precipitation occurred in just 5 hours (03-08 UTC) at MPV associated with the combined synoptic and mesoscale (frontogenetic) ascent.

At BTV, a third surge in precipitation was noted during the late morning and early afternoon hours on 7 March (Fig. 8) as the surface low was translating northeastward along the Maine coast (Fig. 7f). The remnant synoptic deformation zone and a strong north (340^{o}) low-level flow produced topographically forced low-level convergence in the V-shaped Champlain Valley, known colloquially as the *Champlain Valley Convergence Zone*. The terrain-induced convergence prolonged snowfall accumulations into the mid-afternoon hours on 7 March. This contributed to snowfall rates of 1-1.5”/hr during the 16-18 UTC time frame (Fig. 8). After a 30 hour period of snow, accumulation ended at 07/22 UTC, with a storm total accumulation at BTV of 25.8” (65.5 cm), the 3rd greatest storm total on record.

5. SUMMARY AND POSTSCRIPT

The 6-7 March 2011 snowstorm across the North Country was caused by a favorable juxtaposition of synoptic and mesoscale forcing mechanisms, and with the unusual evolution of a strong cold frontal passage immediately preceding the storm. The stalled frontal zone established a long duration (~ 30 hour) event with the strong synoptic ascent during the overnight hours on 7 March producing the heaviest snowfall rates across the region. The rich moisture plume from the Atlantic was also a key ingredient and the associated low snow ratios resulted in significant impacts for transportation and made snow removal difficult. This storm moved 2010-11 into 2nd place on the all-time seasonal snowfall list at BTV, which ended with 128.4” (326.1 cm). This event also marked the last ≥ 6” snowfall at BTV until 27 December 2012 (a period of 661 days).

Acknowledgements: Figure 3 is based on NCEP/NCAR Reanalysis Data. Imagery was produced by NOAA/ESRL Physical Sciences Division, Boulder Colorado from their Web site at http://www.esrl.noaa.gov/psd/.

A CTS wagon sits buried in drifted snow at the BTV airport on 8 March 2011. (Photo NWS BTV)

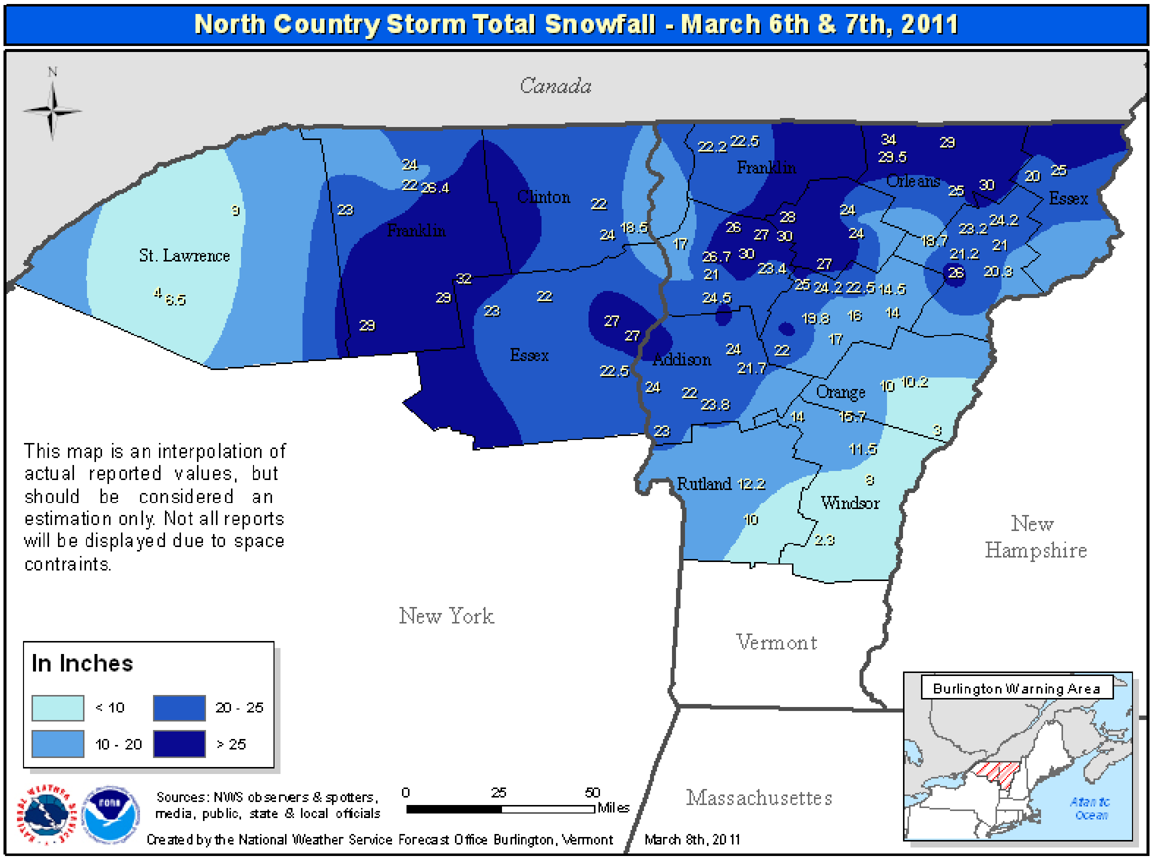

Figure 1. Storm total snowfall across the WFO Burlington forecast area on 6-7 March 2011. [(click for full list of snow totals)]

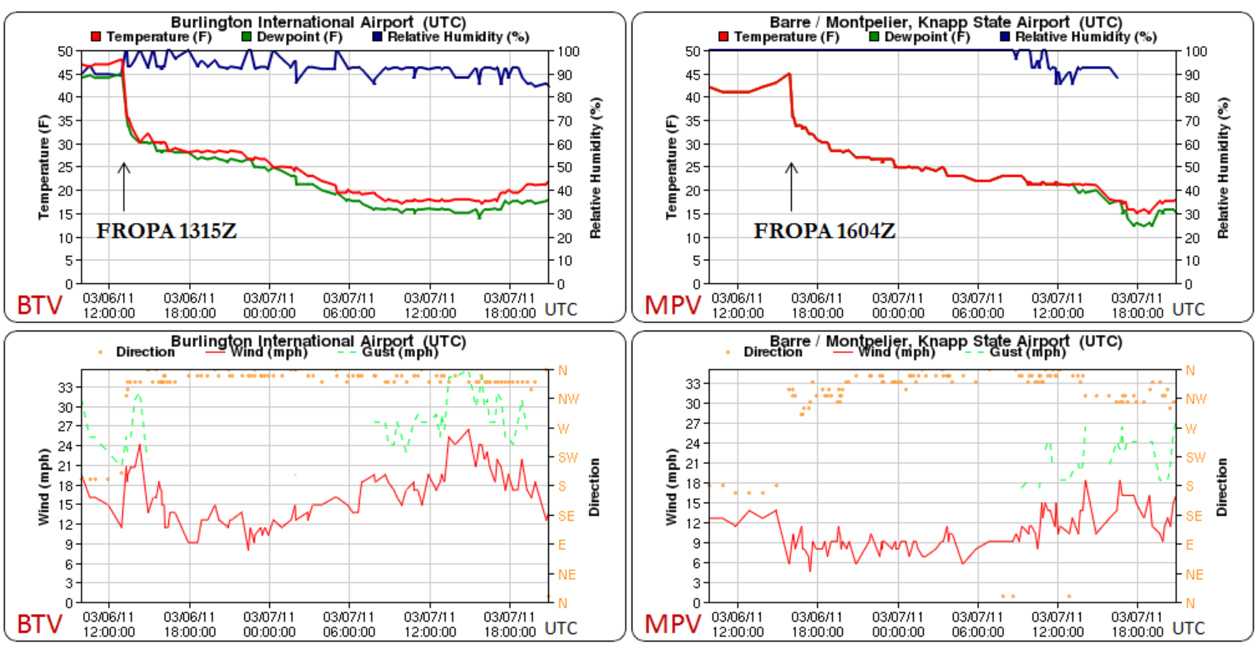

Figure 2. Time series analysis (meteograms) at Burlington, VT (BTV, left) and Montpelier, VT (MPV, right) for the period 09 UTC on 6 March 2011 through 21 UTC on 8 March 2011. Temperature is shown in red, dewpoint is in green, and relative humidity in blue in top panels. Bottom panels indicate wind speed (solid line), wind gust (dashed line), and wind direction (dotted line). Timing of arctic frontal passage on the morning of 6 March is denoted.

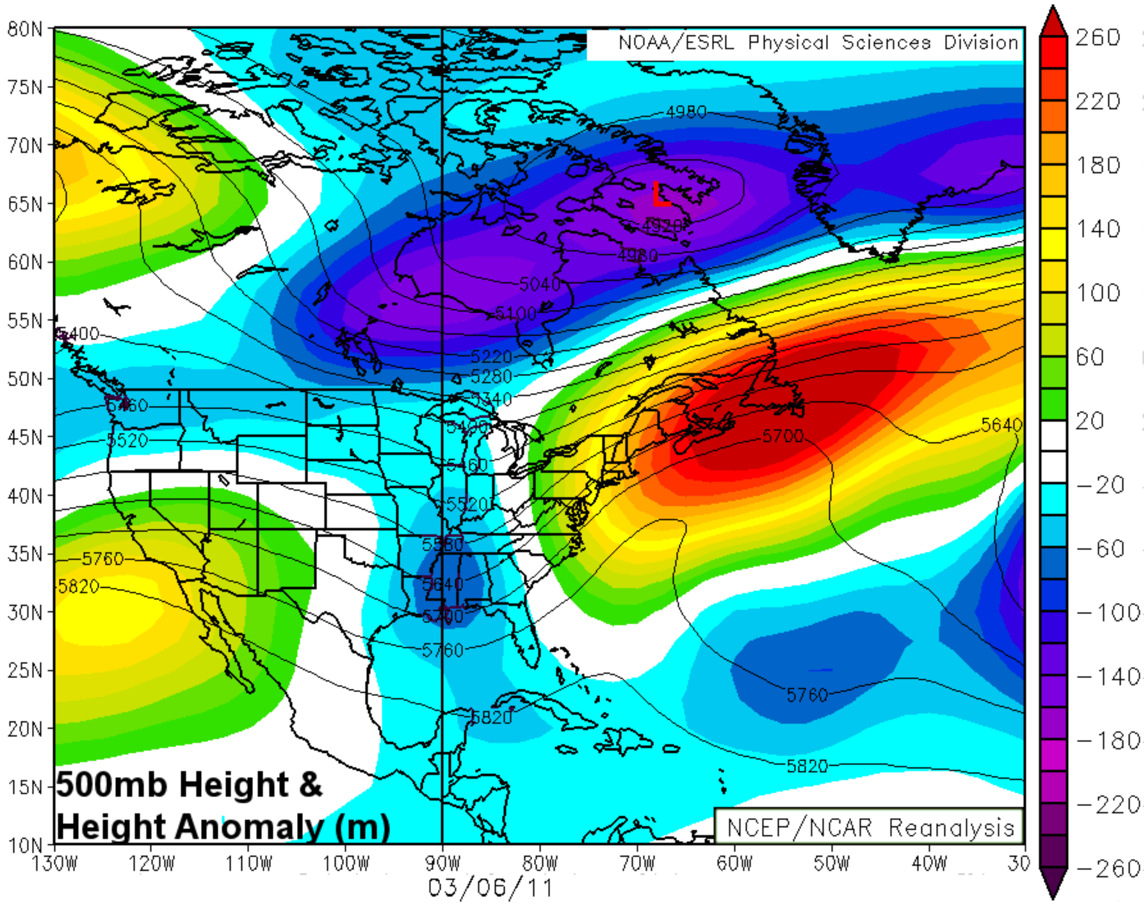

Figure 3. NCEP/NCAR Reanalysis of the mean 500mb height (m) and height anomaly (m, color filled) on 6 March 2011.

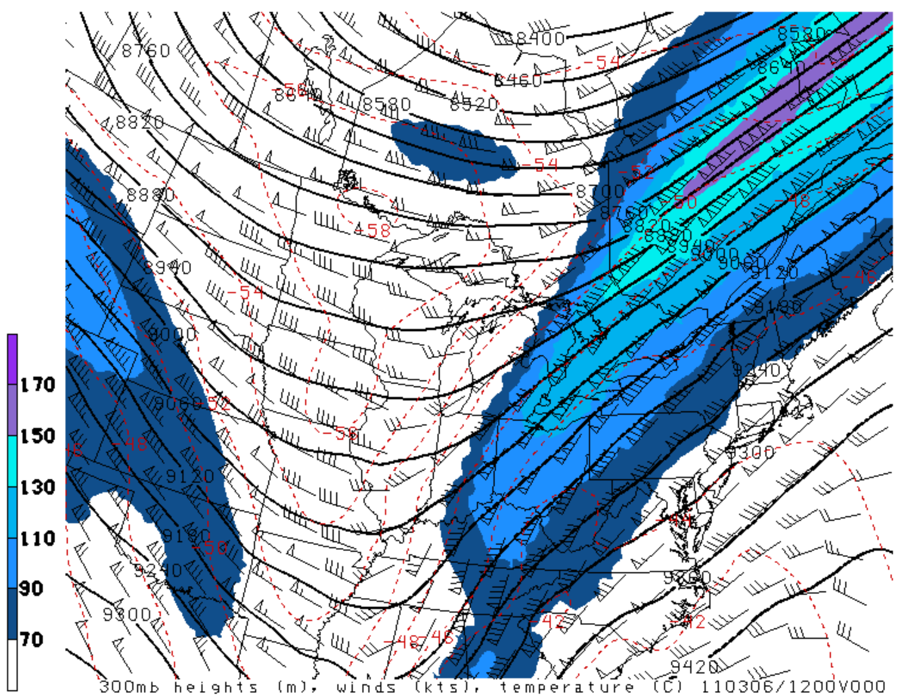

Figure 4. The 300mb geopotential heights (black lines, m) , isotachs (color-filled, kts), and temperature (red dashed lines, C) from the North American Reanalysis (NARR) at 12 UTC on 6 March 2011. [Click for loop]

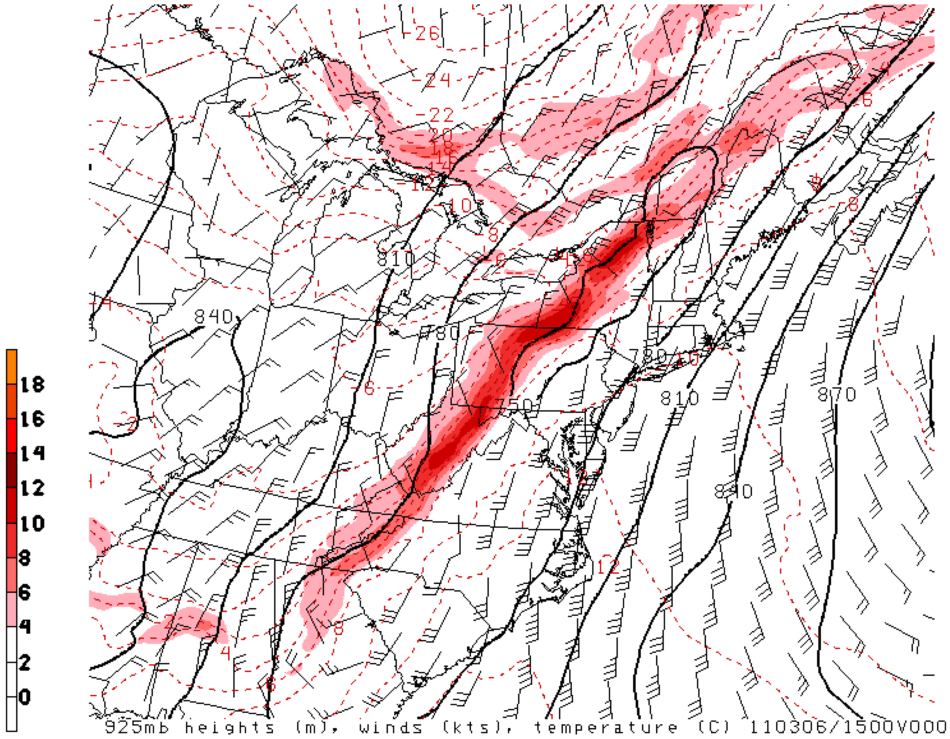

Figure 5. The 925mb geopotential heights (m, black lines), temperature (C, red dashed lines), winds (kts, barbs), and temperature gradient (C/100km, color filled) from the NARR at 06/15 UTC. [Click for loop]

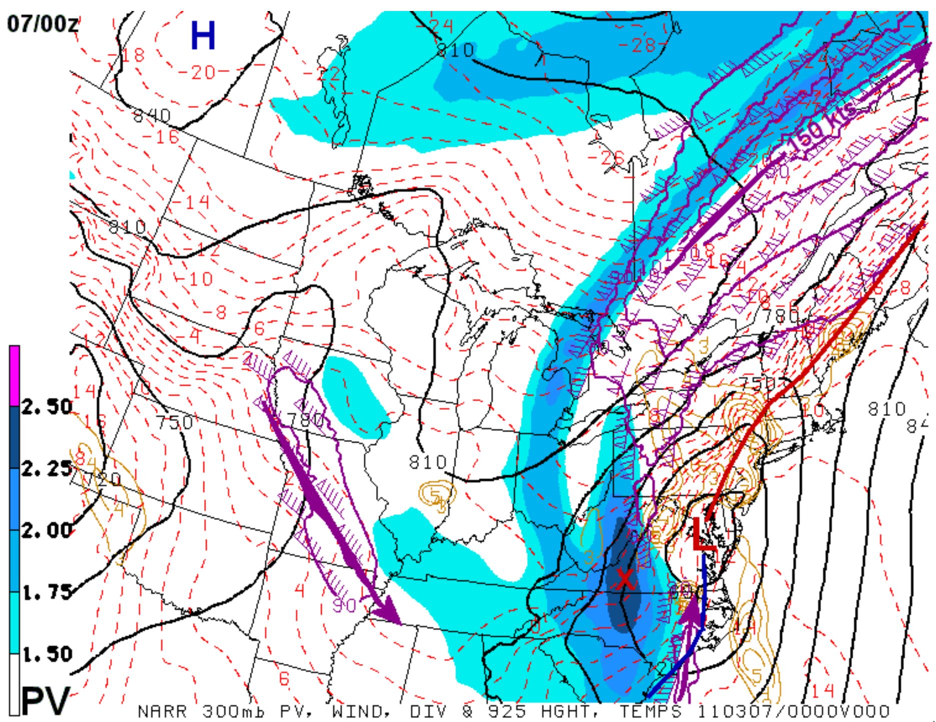

Figure 6. A NARR-based synoptic composite at 07/00 UTC showing the 925mb heights (m, black lines) and temperatures (C, red dashed lines) with low-level frontal positions annotated, along with the 300mb isotachs ≥90 kts (purple lines and barbs) and 200-300mb layer potential vorticity (PVU, color filled). [Click for loop]

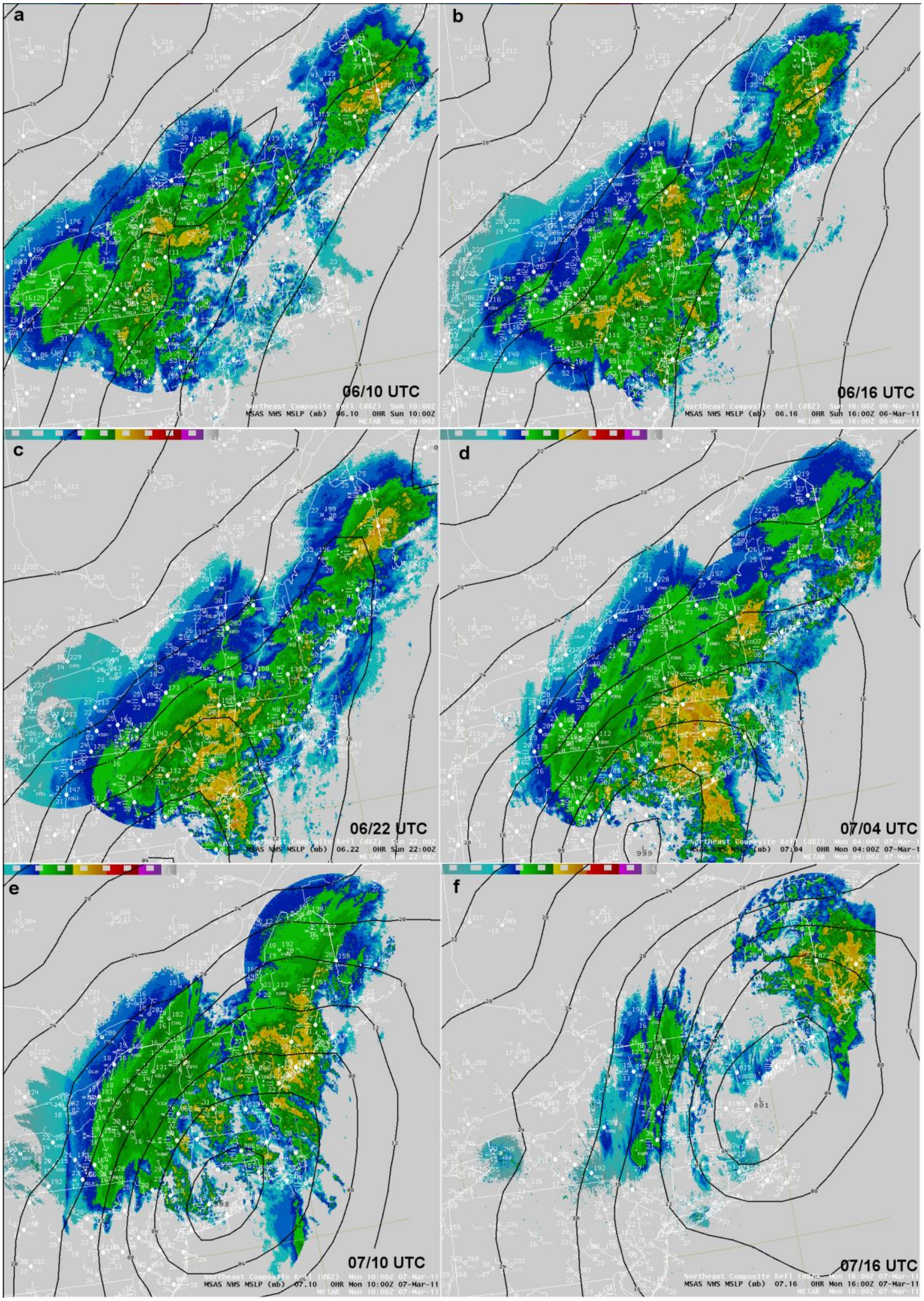

Figure 7. Mosaic composite reflectivity and sea-level isobars in 6-hrly increments at (a) 06/10 UTC, (b) 06/16 UTC, (c) 06/22 UTC, (d) 07/04 UTC, (e) 07/10 UTC, and (f) 07/16 UTC. [Click for radar loop from 07/0000 UTC through 07/1600 UTC]

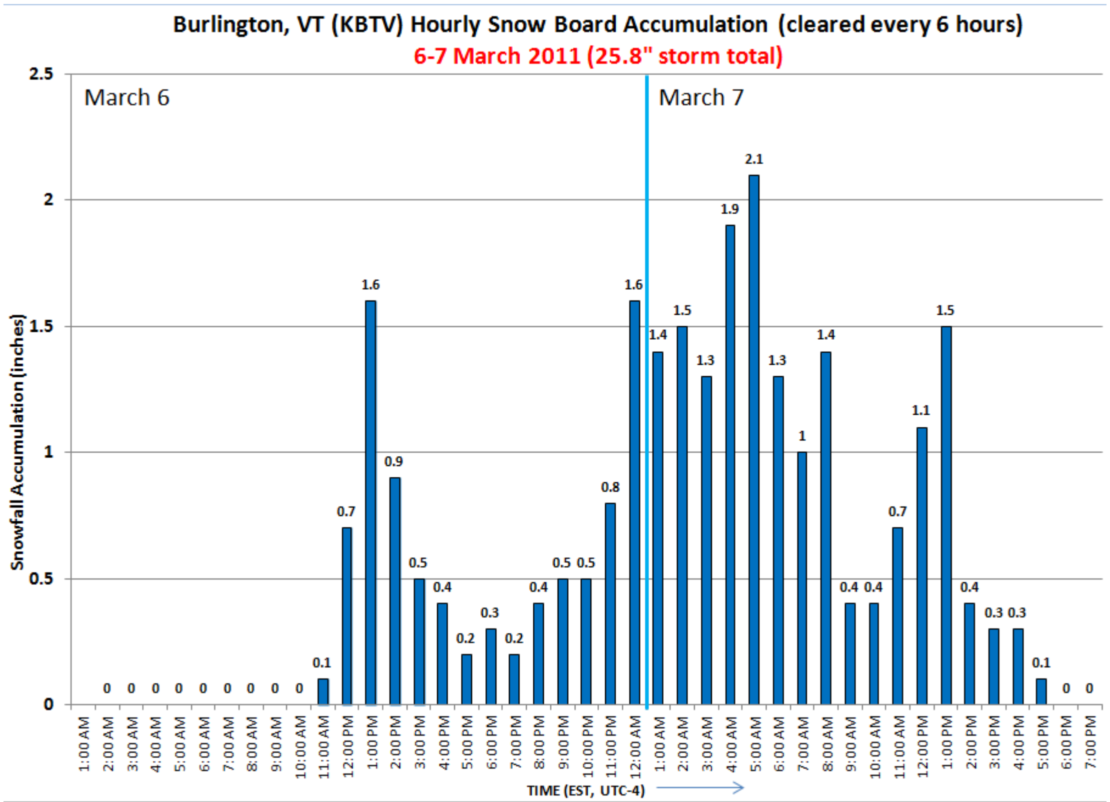

Figure 8. Hourly snowfall accumulations on snow board at BTV on 6-7 March 2011.

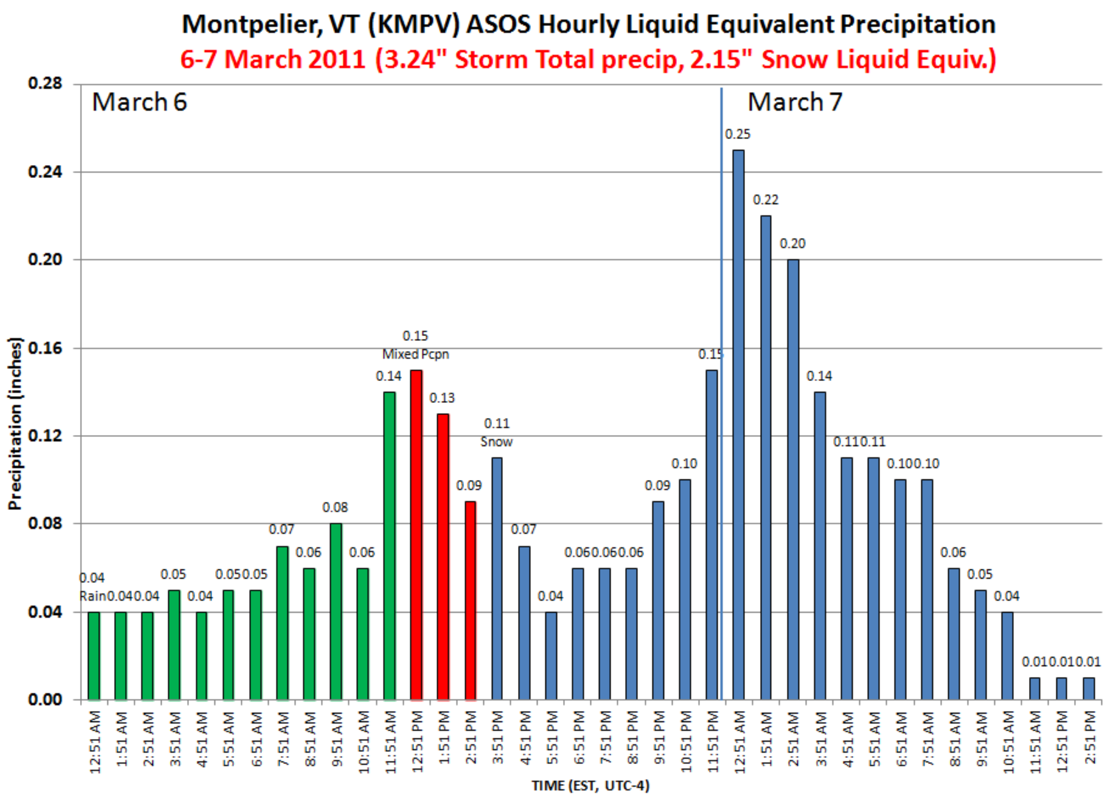

Figure 9. Hourly liquid/liquid equivalent precipitation rates at MPV on 6-7 March 2011. Bar colors indicate precipitation type for that hour (rain - green, mixed - red, snow - blue).

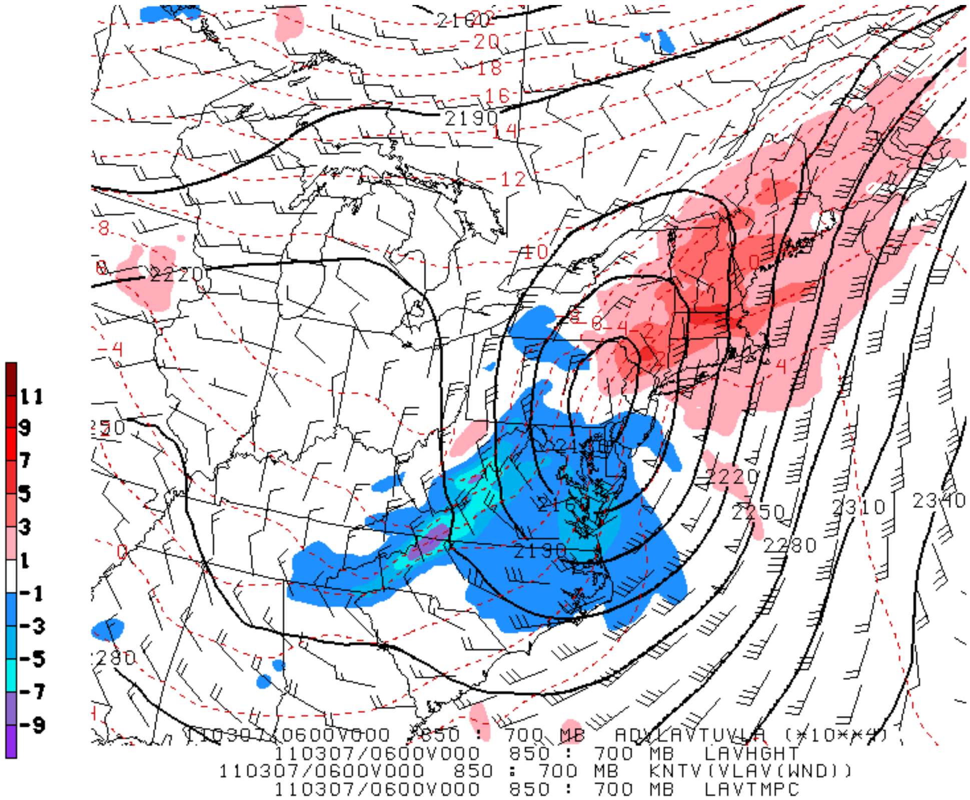

Figure 10. The 850-700mb layer averaged geopotential heights (m, black lines), temperatures (C, red dashed lines), winds (kts, barbs), and temperature advection (color filled, C km^{-1} 10^{-4}) at 07/06 UTC from the NARR. [Click for image loop]

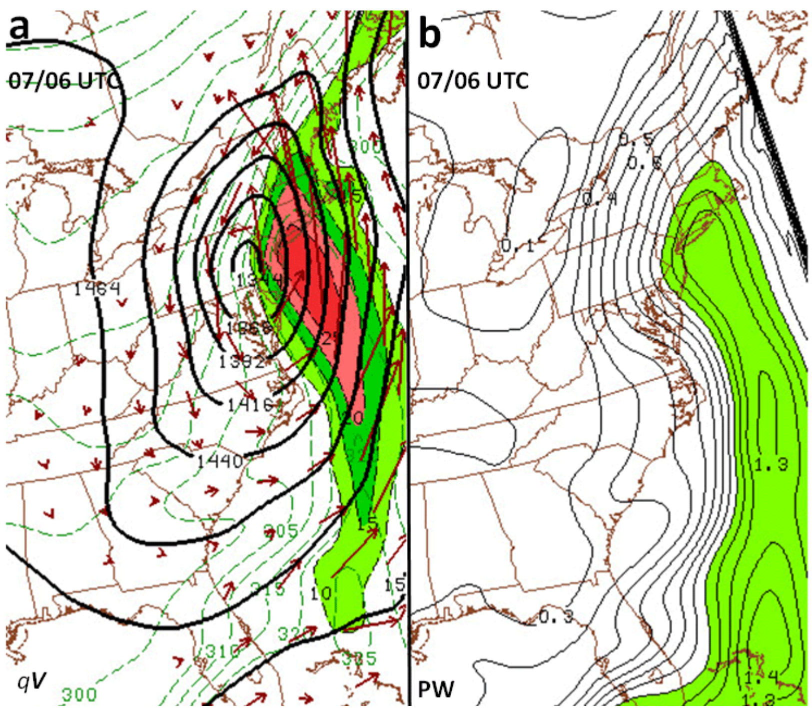

Figure 11. The RUC-based Storm Prediction Center (SPC) mesoanalysis maps of (a) 850mb height (m, black lines), moisture transport (vectors, and color filled magnitude) and (b) precipitable water (in) at 07/06 UTC.

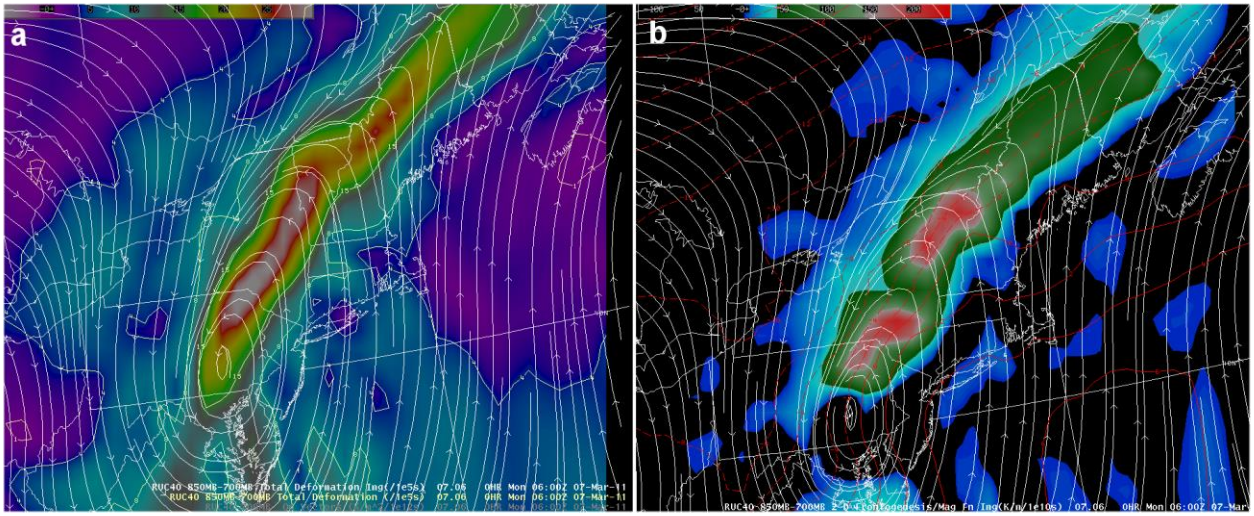

Figure 12. The 0-h RUC analysis of 850-700mb streamlines and (a) layer deformation (10^{-5} s^{-1}) and (b) layer frontogenesis (Km^{-1} $s^{-1}10^{-10}$, with positive values shaded). [Click for Panel a loop and Panel b loop]