THE 14-15 MARCH 2017 "Pi Day" SNOWSTORM ACROSS VERMONT & NORTHERN NEW YORK

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1. INTRODUCTION

This widespread late winter storm across the northeastern U.S. (Fig. 1) produced record snow for a single March storm in Burlington, Vermont (30.4") along with localized blizzard conditions across portions of the Champlain Valley of Vermont and New York during Tuesday afternoon, March 14th, 2017. Total snow accumulations generally ranged from 12-18" across far eastern portions of Vermont, and 18-36" elsewhere across Vermont and northern New York (Fig. 2). The axis of highest snowfall totals affected northern New York and northwestern Vermont, where localized snowfall totals in excess of 3 feet were observed (Fig. 2). The storm total snowfall of 30.4" is the second highest on record for Burlington, where records date back to 1883 (Table 1). Snowfall rates peaked at 3-5"/hr during the afternoon hours on March 14th, and nearly a foot of snow fell during just a 4 hour period during the height of the storm.

Storm impacts included difficult travel conditions and widespread school closures on both Tuesday (March 14th) and Wednesday (March 15th). The storm was well-advertised; lead times on National Weather Service (NWS) Winter Storm Watches issued Saturday (March 11th) approached 72 hrs. As a result of good planning, the overall societal impacts were mitigated for a snowstorm of this magnitude.

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 below for historic aspects of the storm).

2. OCCURRENCE OF BLIZZARD CONDITIONS

While not widespread, blizzard conditions were recorded at Plattsburgh, New York (PBG) and several mesonet stations in vicinity of Lake Champlain, where northerly gusts were locally enhanced owing to orographic channeling effects. At PBG, wind gusts in excess of 35 mph occurred between 3:42pm EDT and 10:53pm

Notable numbers from the storm:

- **1**: Biggest March snowstorm on record at Burlington, Vermont (BTV).
- **10**: Number of years between blizzard warnings in Vermont and northern New York (2/14/2007 to 3/14/2017)
- **22**: Maximum snow depth achieved during the event (2pm Wednesday, 3/15) at BTV.
- **30.4"**: Storm total snowfall, the 2nd greatest snowstorm on record at BTV.

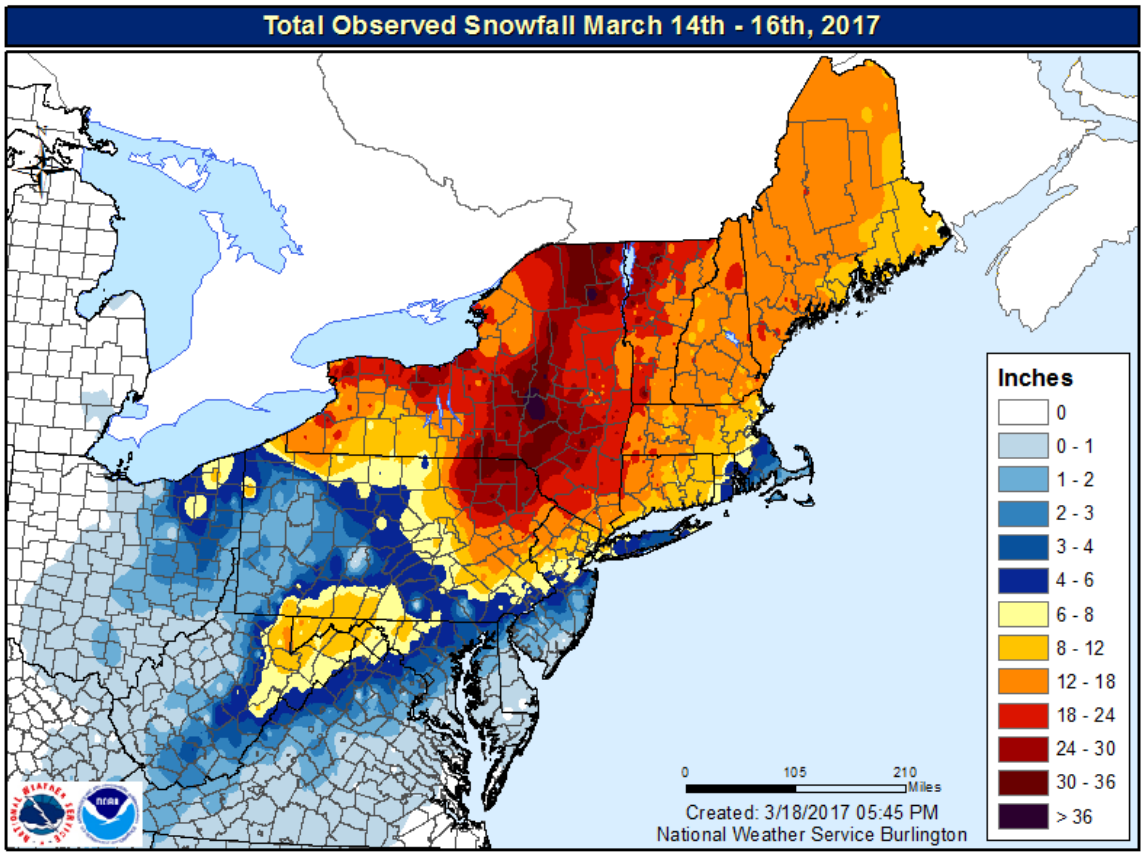

Figure 1. Storm total snowfall across the northeastern United States for 14-15 March 2017.

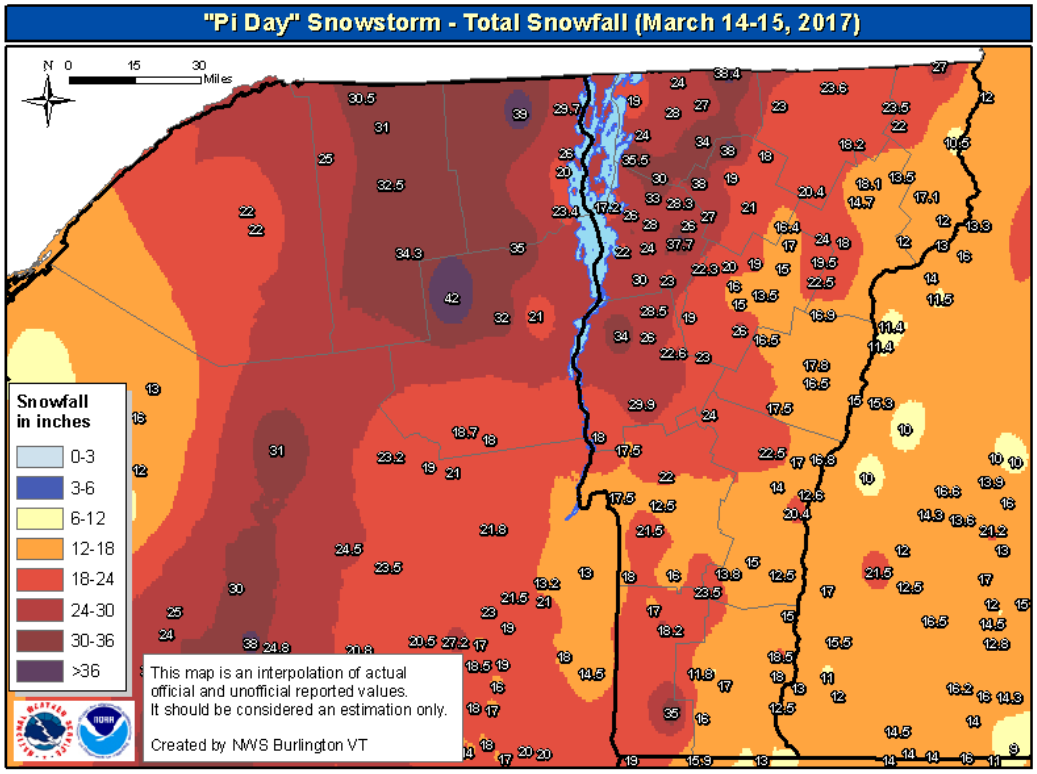

Figure 2. Storm Total Snowfall across Vermont and Northern New York. **Click here for Public Information Statement text.**

Table 1. Top 10 Snowstorms for Burlington, Vermont (Records since 1883)	
Date	**Storm Total Snowfall Amount**
January 2-3, 2010	33.1”
March 14-15, 2017	30.4”
December 25-28, 1969	29.8”
March 6-7, 2011	25.8”
February 14-15, 2007	25.7”
January 13-14, 1934	24.7”
March 5-6, 2011	22.9”
March 13-14, 1993	22.4”
November 25, 1900	20.0”
January 25-28, 1986	19.7”

Table 1. Summary of the Top 10 Snowstorms for Burlington, Vermont

EDT. Visibility was consistently one-quarter mile or less in heavy snow during the first 3 hours of that stretch (meeting blizzard criteria), and generally one-half mile in moderate snow later in the evening.

3. SYNOPTIC SETTING

The Pi-Day blizzard was a classic Nor’ Easter with a deep low pressure system south of Long Island phasing with a upper level closed low and overriding an Arctic air mass in place from the day before. The following is a discussion of the synoptic setup starting at the surface and then moving up through the atmosphere to 700hPa, 500hPa, and 250hPa.

Surface:

During the afternoon of March 13th, a surface frontal system was pushing eastward through the Tennessee Valley region as a secondary 1010hPa closed surface low developed just off the Georgia coastline (Fig. 3). The frontal system gradually dissipated over the Carolinas as the coastal low deepened rapidly and moved northward along the Atlantic coast. Through the overnight hours the coastal low went through “textbook” cyclogenesis as the low pressure system rapidly deepened to 986hPa (Fig. 4) within the low-level baroclonic zone near the coast. By 12z on the 14th the mature coastal cyclone continued north-northeastward moving towards Long Island, New York. At this point, snow was already beginning to fall over the North Country as warm advection processes were being supplied with moisture from the Atlantic and will be described more in detail in the 700hPa and Mesoscale discussions. By midafternoon, the 976hPa low center was just south of the Connecticut/Rhode Island border but still offshore (Fig. 5). Overnight on the 14th the center of the low pressure system tracked directly over Cape Cod and into the Gulf of Maine. By the morning of the 15th, the system had occluded as it moved onshore into Maine tracking slight to the northwest. With the low tracking into Maine the flow over much of the North Country had turned northwest which is optimal for the development of orographic snow over both the Adirondacks and the Green Mountains. Storms like the Pi-Day storm with a low pressure system tracking across southeastern Massachusetts, are typically optimal heavy snow producers for much of

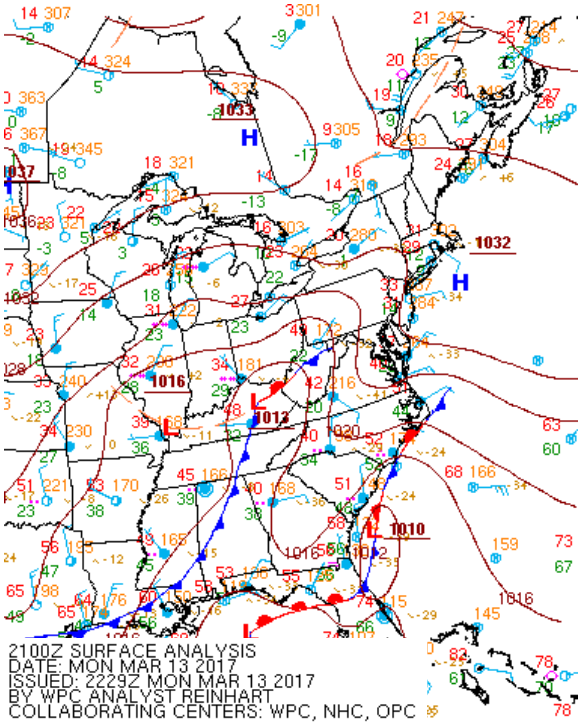

Figure 3. Surface analysis from 21z on March 13th. The coastal low is just developing off the coast of GA/SC.

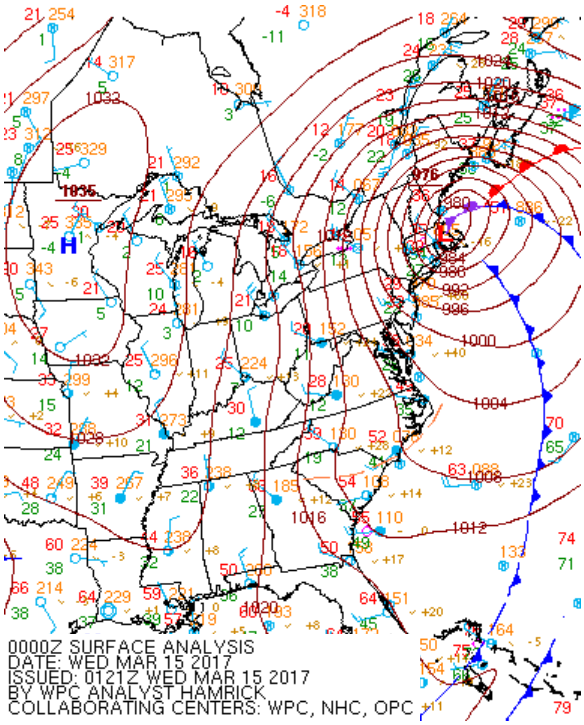

Figure 5. Surface analysis from 00z on March 15th. The surface low pressure system is located just off the MA coastline and is producing very heavy snowfall rates over the Champlain Valley.

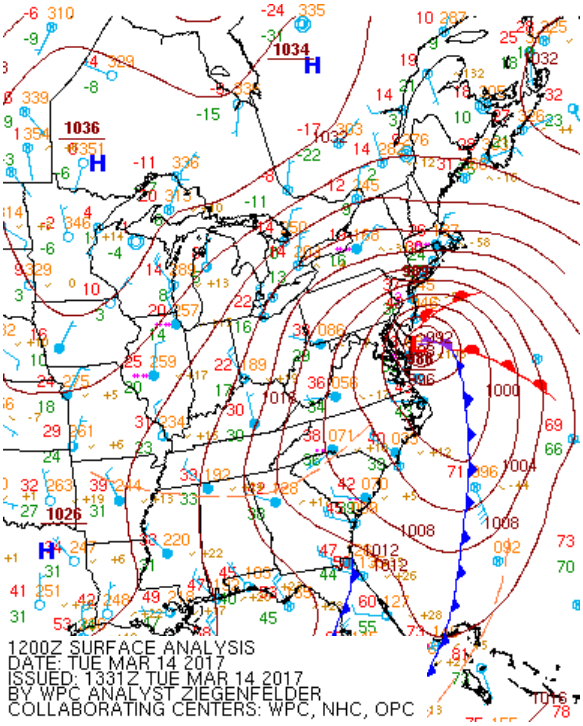

Figure 4. Surface analysis from 12z on March 14th. The mature cyclone is now producing snowfall across southern New England and pushing due north.

Vermont and northern New York, which was the case for this event.

700hPa Analysis :

The 700hPa flow was critical to the heavy snow. On the morning of March 13th a 700hPa full latitude trough developed over just west of the Ohio Valley region (Fig. 6). The resulting southwest flow brought warm air advection to the region as the trough transitioned from positively titled to a closed low on the morning the 14th. With the 700hPa low closed to the south of the North Country (Fig. 7), easterly flow developed and began advecting in the needed moisture over the North Country to produce the long period snowfall event. As the surface low tracked into Maine, it was the 850/700hPa flow turning northwest that continued to provide additional snowfall on the backside of the low. This additional snow is what added an extra 4" of snow at the

Burlington Airport taking the storm from a top 5 snowfall to 2nd (Table 1). It was critical that the low closed to our south because this allowed for ample advection of Atlantic moisture westward into the North Country.

500hPa Analysis:

The 500hPa pattern began with near zonal flow out of the west during the day on the 13th as an upper level trough began digging through the Great Lakes region. The trough continued to strengthen through the day on the 14th and becoming a closed low over the Ohio Valley region during the evening of the 14th. The closed 500hPa low ended up phasing with the 700/850hPa circulations on March 15th, producing a vertically stacked system.

250hPa Analysis:

At 250hPa the pronounced feature was the strong 250hPa jet with winds over 150kts oriented from southwest to northeast over the Saint Lawrence Valley (Fig. 8) during the day on March 14th. That put the North Country directly in the right rear entrance region promoting excellent surface convergence, synoptic lift, and upper level divergence. By the evening of March 14th, the 250hPa trough had closed off and the upper level jet had been pushed well to the north.

4. MESOSCALE SETTING

Several favorable mesoscale factors contributed to the heavy snow event on 14-15 March 2017. These included (1) strong low-level frontogenetic forcing, (2) rich moisture advection, and (3) favorable thermodynamic profiles, including a saturated dendritic snow growth.

The track of the Nor'easter across coastal New England allowed Vermont and northern New York to remain well into the colder air with subfreezing vertical temperature profiles in place. Precipitation fell entirely as snow across

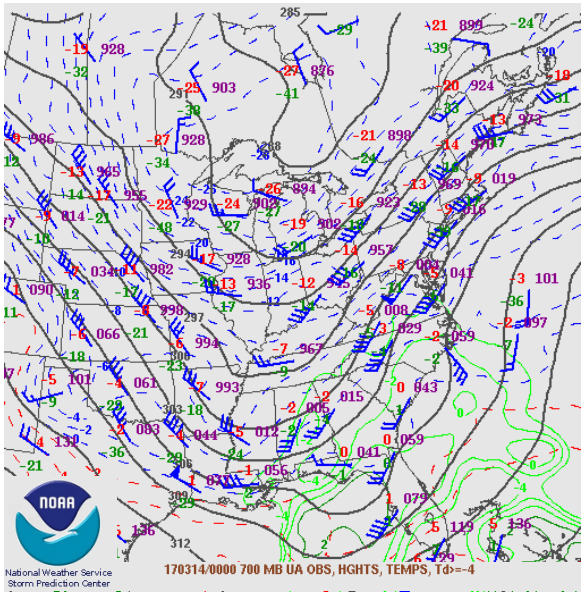

Figure 6. 700hPa analysis from 00Z March 14th. A full latitude trough is producing southwesterly warm air advection over the North Country the day before the storm.

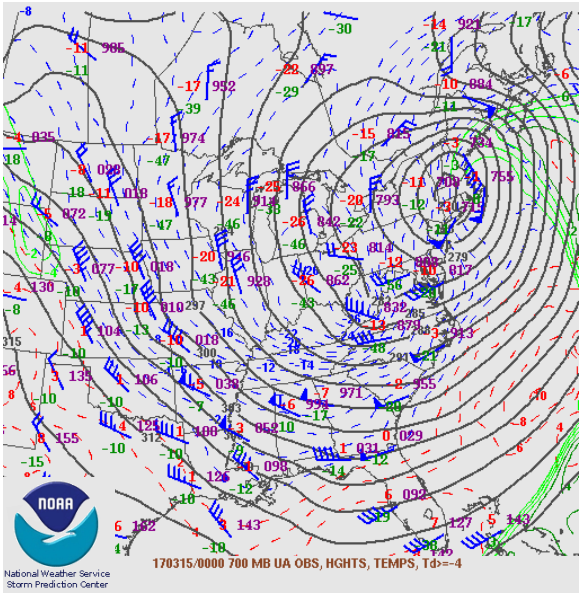

Figure 7. 700hPa analysis from 00Z March 15th. Strong height falls combined with a closed 700hPa low caused easterly mid-level flow to develop and advection in significant moisture enabling a long period snowfall event.

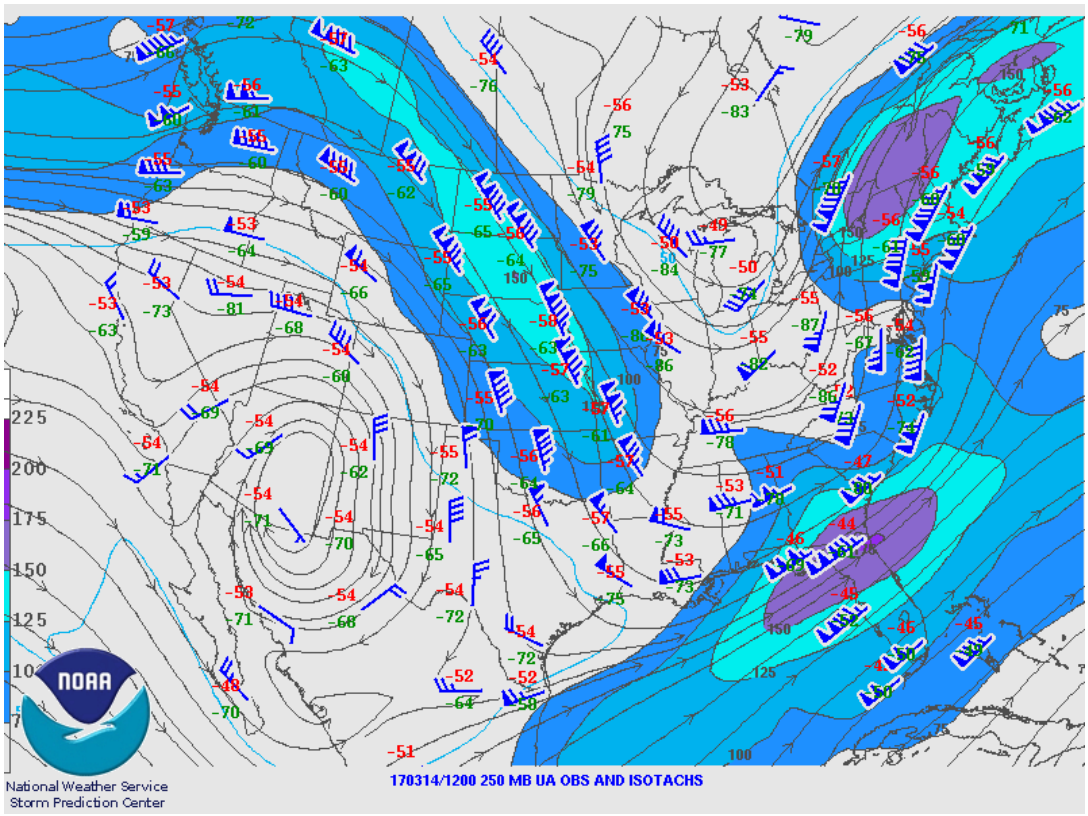

Figure 8. 250hPa analysis from 12Z March 14th. A strong upper level jet existed over the Saint Lawrence valley causing synoptic lift, strong upper level divergence and surface convergence as the snow began to fall.

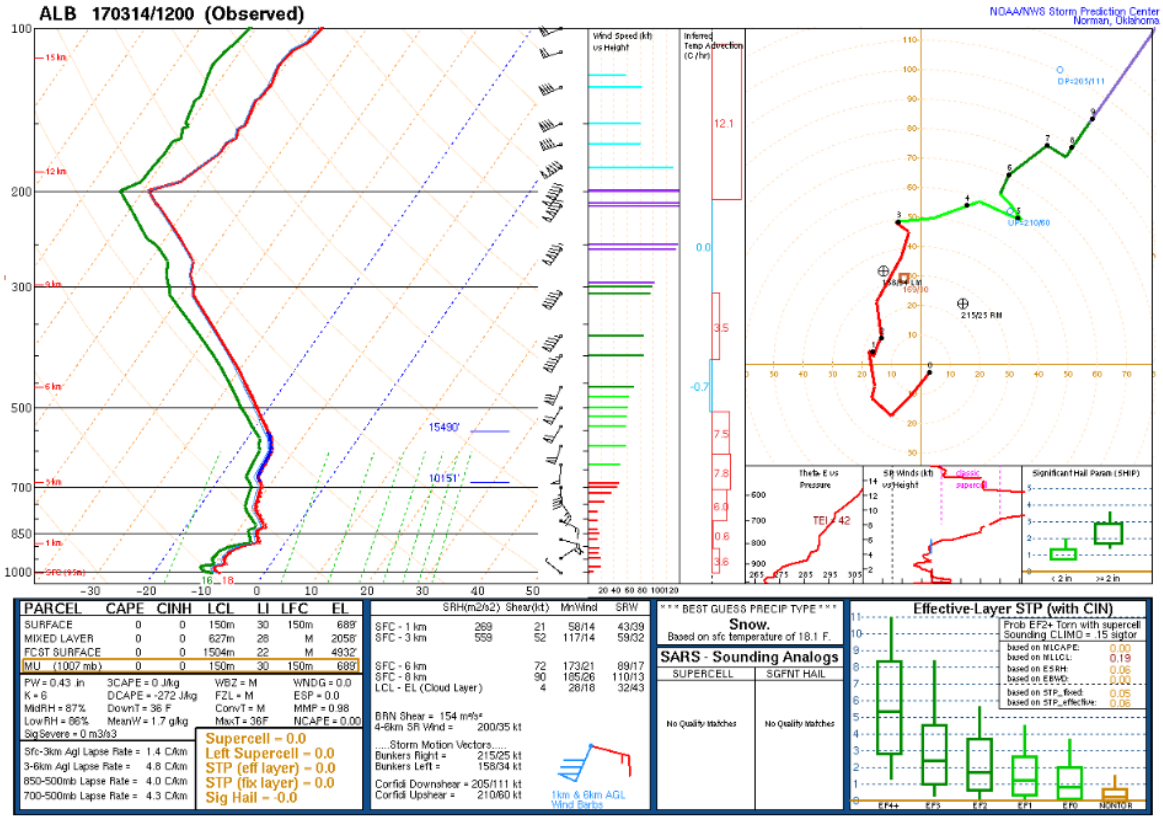

Figure 9. The 12 UTC 14 March 2017 sounding and associated analysis from Albany, NY (ALB).

the region 100-250mi northwest of the surface low track. The 1200 UTC 14 March sounding from Albany, NY (ALB; Fig. 9) was representative of the air mass during the event. Favorable microphysical conditions were present, with good deep-layer moisture and saturation through the dendrite growth zone (-12C to -18C, roughly 700-550hPa in the ALB sounding) (Fig. 9.). The optimal microphysical conditions enhanced snowfall rates and overall "fluff factor"; snow-to-liquid ratios early in the storm were around 12:1, and increased closer to 15:1 toward the later part of the storm.

As the low pressure system closed off at 700hPa (Fig. 10), westward and northwestward advection of moisture increased into Vermont and northern New York, and contributed to the long-duration of the snowfall over a period of 24-30 hours. There was also a well-defined deformation zone on the northwestern periphery of the cyclonic circulation, which contributed to strong frontogenetic forcing (Fig. 10), and mesoscale banded precipitation (Fig. 11) with intense snowfall rates. As the banded precipitation associated with frontogenesis forcing pivoted across the Champlain Valley around 20 UTC, snowfall rates reached 5"/hr (Fig. 12). The pivot point and residence time of the mesoscale banding was longest across northeastern New York, which was a main contributing factor to the highest snowfall totals across portions of the Adirondacks, where localized totals in excess of 40" were reported.

Lastly, there was a secondary increase in snowfall rates late in the storm across the Champlain Valley, with snowfall rates between

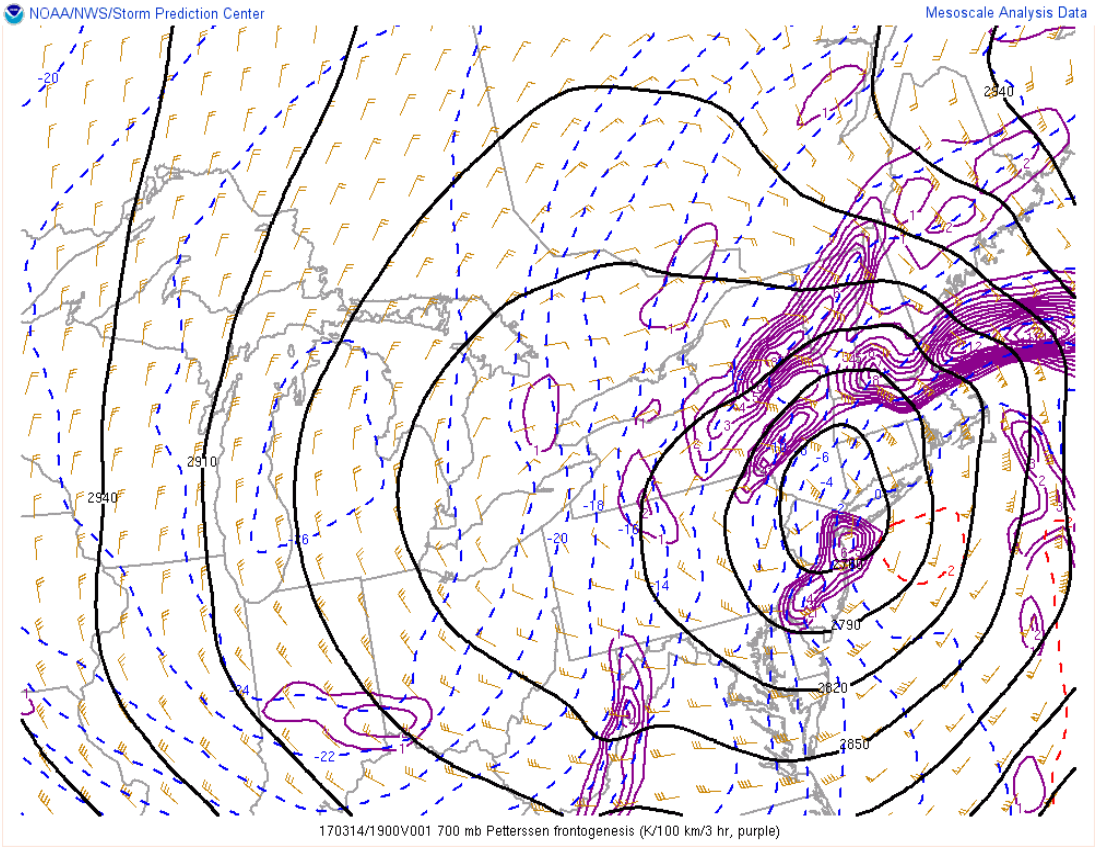

Figure 10. The 19 UTC 14 March 2017 700hPa frontogenesis forcing, from the RAP-based NCEP/SPC Mesoanalysis. (Click for loop).

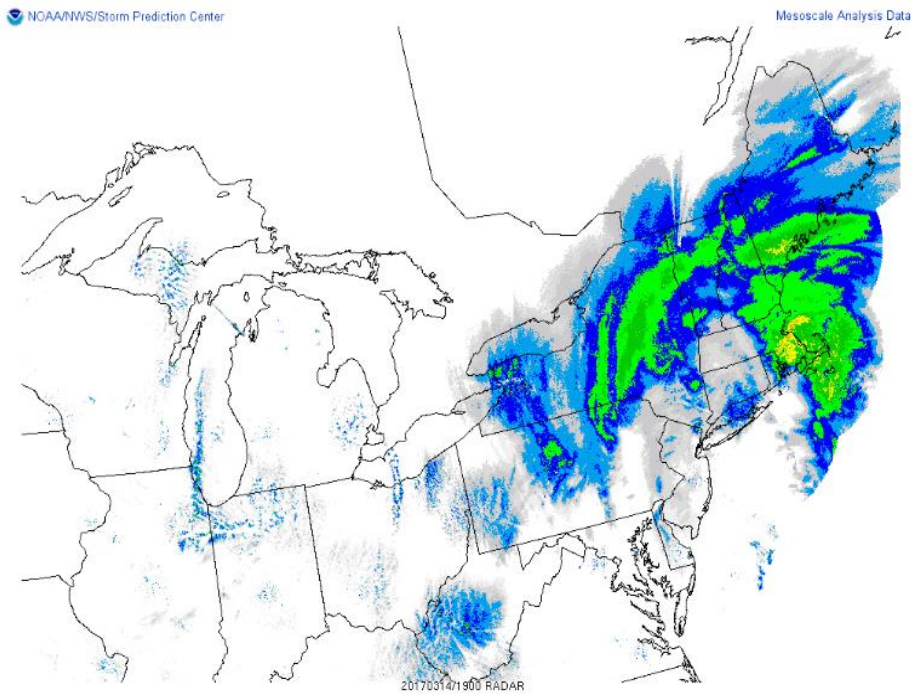

Figure 11. The 19 UTC 14 March 2017 mosaic composite reflectivity across the northeastern United States. (Click for loop)

1-2"/hr at times during the morning hours on 15 March (Fig. 12). As the low pressure system moved across Maine, low-level winds turned northerly across Vermont and northern New York. The northerly flow resulted in a "Champlain Valley Convergence Zone" (CVCZ), which is a result of the "V-shaped" nature of the local terrain features from north to south. The combination of continued saturation in the comma head portion of the low pressure system and enhanced upward vertical motion yielded a secondary increase in snowfall rates. Along with higher snow-to-liquid ratios late in the storm, snowfall totals were pushed upward to near 30" at BTV as snow ended during the early afternoon hours on 15 March.

5. SUMMARY AND POSTSCRIPT

The 14-15 March 2017 was a "textbook" Nor'easter with an intense surface low track over southeastern New England spreading heavy snowfall and strong winds inland across Vermont and northern New York. Rich moisture from the Gulf of Mexico and sub-tropical Atlantic was entrained into the system and advected across interior New England and New York as a closed low developed to our south. Combined with frontogenetic forcing/ mesoscale banding, the result was extremely heavy snowfall with hourly rates exceeding 3-5"/hr in many areas during the afternoon hours on Tuesday, March 14th. The slow departure of the system across northern Maine on March 15th resulted in considerable wraparound snowfall, and low-level convergence in the Champlain Valley with northerly deep-layer winds extended accumulating snowfall through much of the day Wednesday. Good dendritic snow growth resulted in snow-to-liquid ratios around 12:1 during the early part of the storm, before increasing to 15:1 or greater during the latter stages of the event. The end result was a

storm at #2 (Table 1) on the all-time list for Burlington, and localized totals in excess of 3 feet in the Adirondacks of New York and in northwestern Vermont.

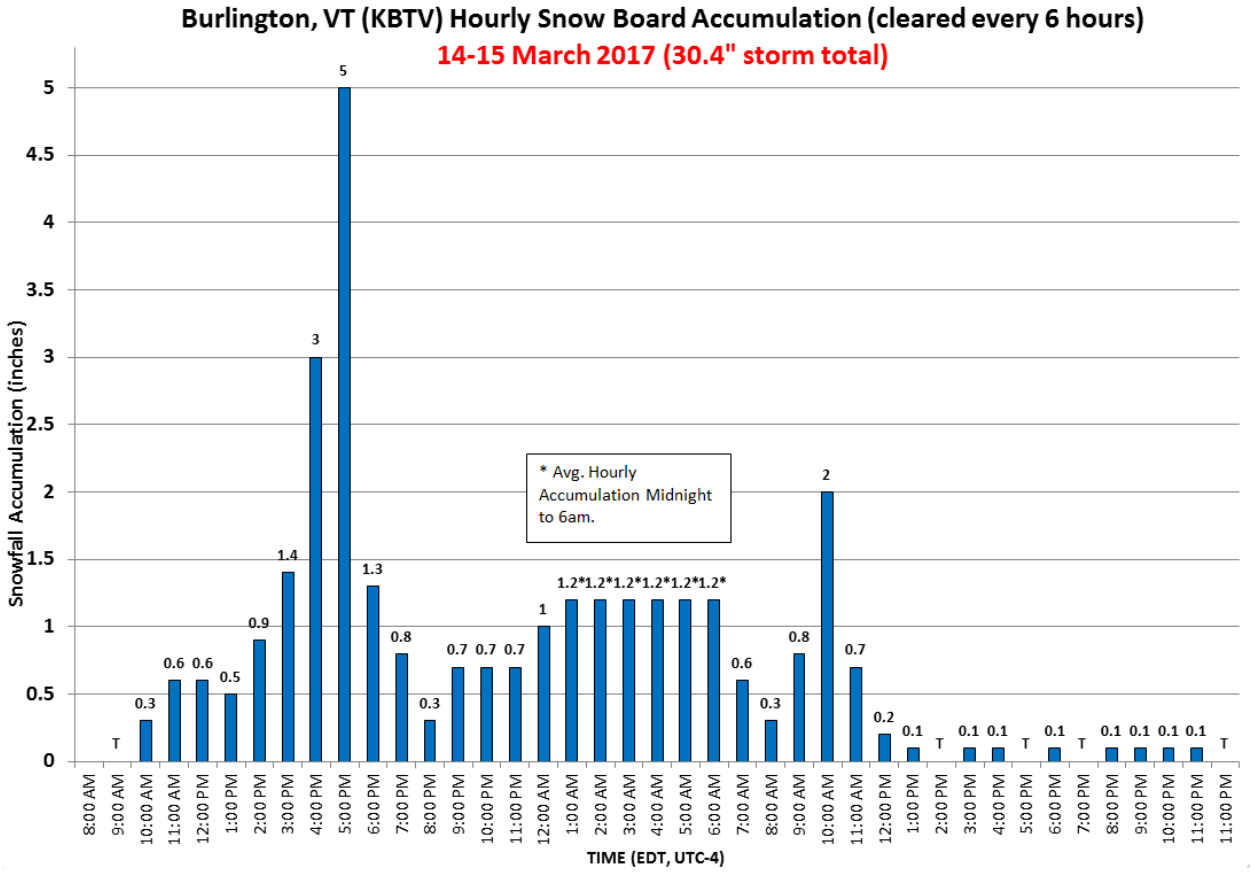

Figure 12. The hourly snowfall accumulation rates at the Burlington International Airport from 12 UTC 14 March 2017 through 03 UTC on 16 March 2017 (EDT is UTC-4 hours). The snowboard was cleared every 6 hours at the synoptic times (except at 04 UTC instead of 06 UTC to account for the station being unmanned at night).