28-29 October 2008 Snowstorm Case Review

An early season Nor'easter produces up to 19 inches of snow across the North Country

I. Overview

A strong Nor'easter (minimum 3-hourly pressure 978mb) brought a significant early snow accumulation across much of northern New York as well as the higher elevations of Vermont over a two day period on 28-29 October 2008. The surface low tracked from the coast of North Carolina northward through the Connecticut River valley and into Quebec. Impacts included scattered power outages due to the high liquid water content of the snow, and difficult travel conditions especially in the higher elevations. Snowfall amounts were heaviest in the colder air well west of the low track, and also exhibited a strong elevational dependence which is typical of early and late season storms. Total snowfall amounts (Fig. 1) ranged from 14-19 inches along the north side of the Tug Hill plateau east-northeastward across the northern Adirondacks. In the WFO Burlington forecast area, the greatest snowfall reports came from the Star Lake, Cranberry Lake, and Wanakena areas of southern St. Lawrence County. Lesser snowfall amounts were observed in the immediate St. Lawrence Valley around Massena (3-4"). There was little or no snow accumulation in the immediate Champlain valley of New York. In Vermont, where temperatures were generally warmer during the event, snowfall amounts varied even more strongly with elevation. The highest snowfall totals were reported at the top of Mt. Mansfield (12") and from the cooperative observer at the base of Jay Peak (11"). Areas adjacent to the central and northern Green mountains generally received 3-8 inches of snowfall with lesser amounts in the valleys. A snow accumulation of 0.3" was recorded at the Burlington International Airport with little or no accumulation across the Lake Champlain Islands.

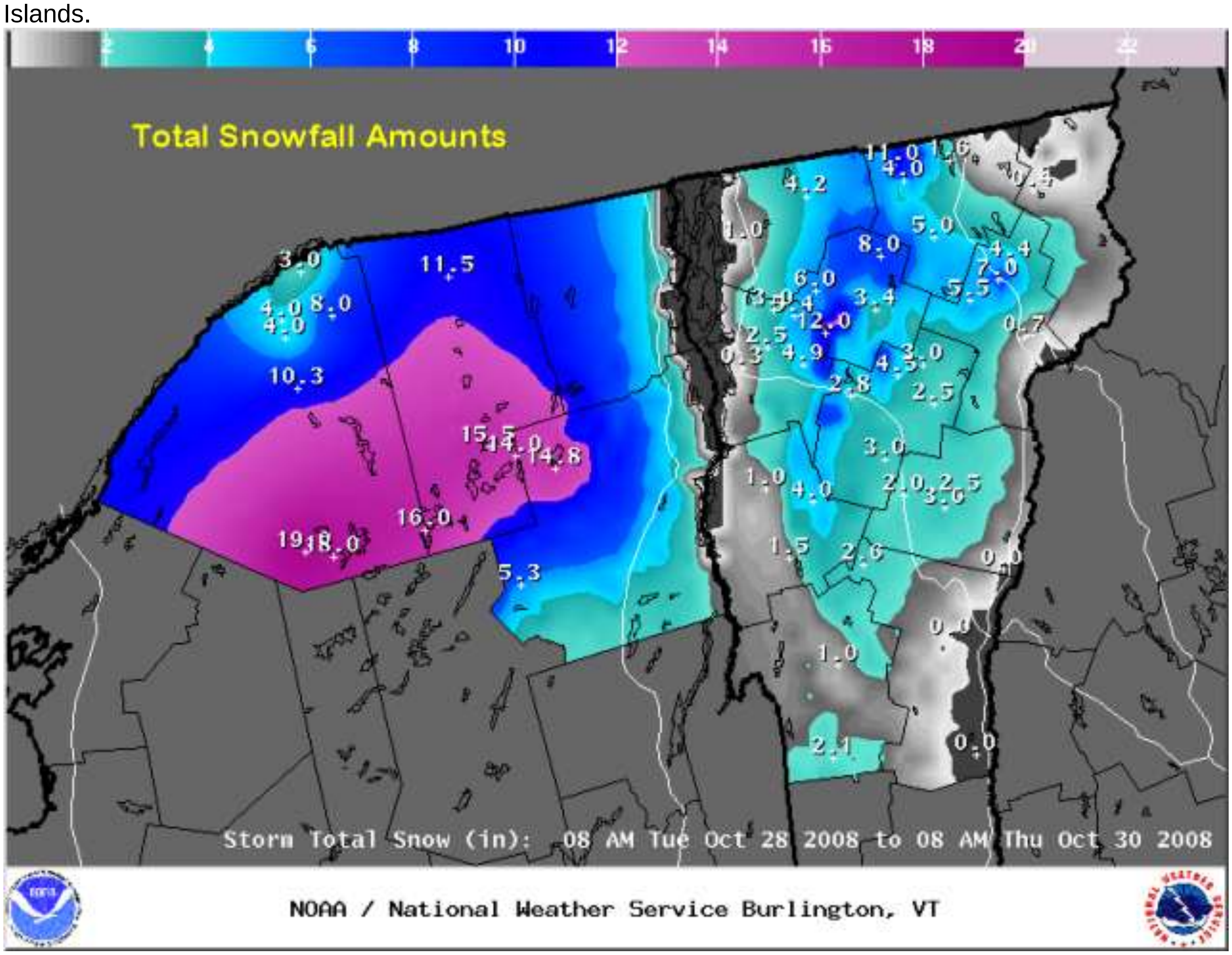


Fig 1. Objective analysis of storm total snowfall reports (in inches) across northern New York and central and northern Vermont for the period 8am on 28 October through 8am on 30 October (28/12z through 30/12z). The maximum snowfall report of 19 inches was from Star Lake in southern St. Lawrence County, NY (click on image for enlargement).

Note: The data included in this review come from the National Weather Service in Burlington, VT, the Hydrometeorological Prediction Center surface analysis archive, and the Storm Prediction Center mesoscale analysis archive.

II. Surface Analysis

Several days preceding the heavy snow episode, on 25-26 October, a strong frontal system and an antecedent moist air mass brought rainfall accumulations ranging from 1-3 inches across the North Country. The NCEP/Hydrometeorological Prediction Center's (HPC) surface analysis at 00z on October 26th (date/time format noted as 26/00z through the remainder of this review) shows an occluded front extending from north to south across northern New York southward to the mid-Atlantic coastline (Fig. 2). This front would stall just east of New England, and would become a factor in the organization of the precipitation of the subsequent storm system, as described in the mesoscale analysis section of this write-up.

A relatively mild air mass remained in place behind the occlusion across the North Country; the high temperature on October 26th and 27th at Burlington (KBTV) was 59^{o}F and 55^{o}F, respectively. Meanwhile, a cold front was moving quickly southeastward across the northern Plains states, and would play a key role in the development of the storm.

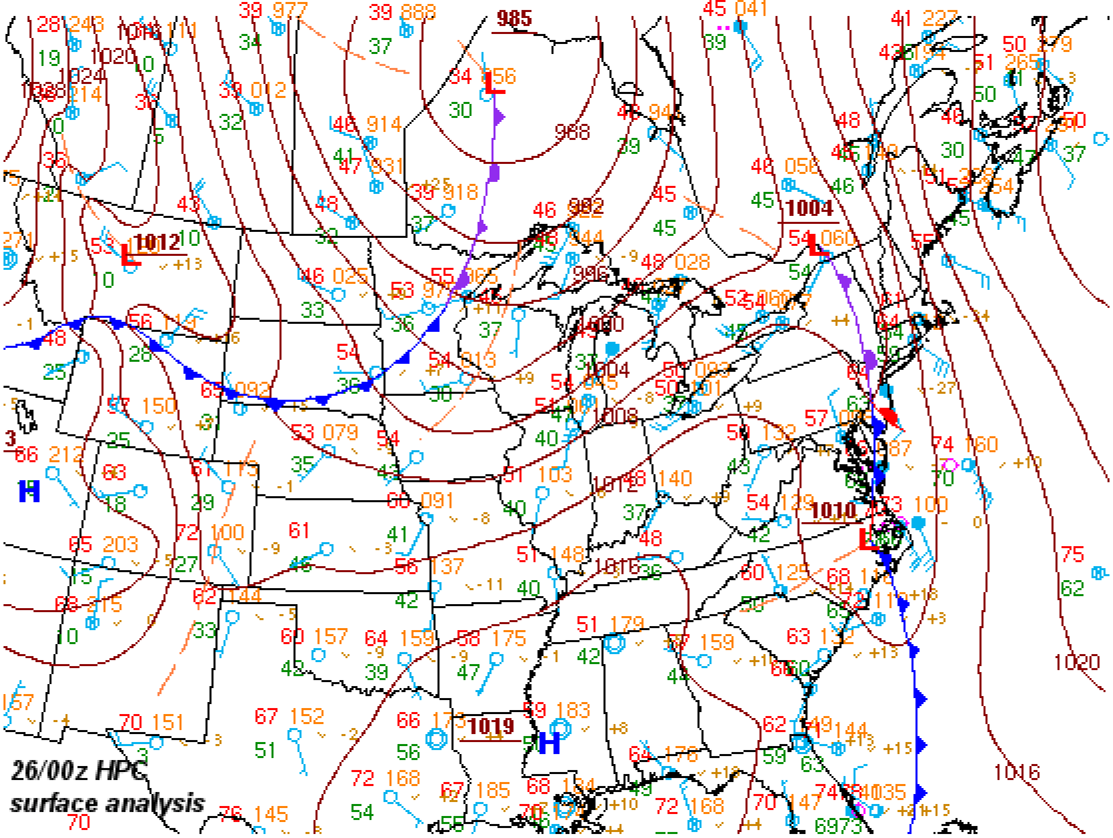


Fig 2. Portion of HPC surface analysis for 00z October 26th. Isobars are every 4 mb. Standard meteorological frontal symbols and surface station model apply.

By the evening hours on October 26th (27/00z), the cold front had moved to the eastern Great Lakes region southwestward across the Tennessee River valley and into central Texas (Fig. 3).

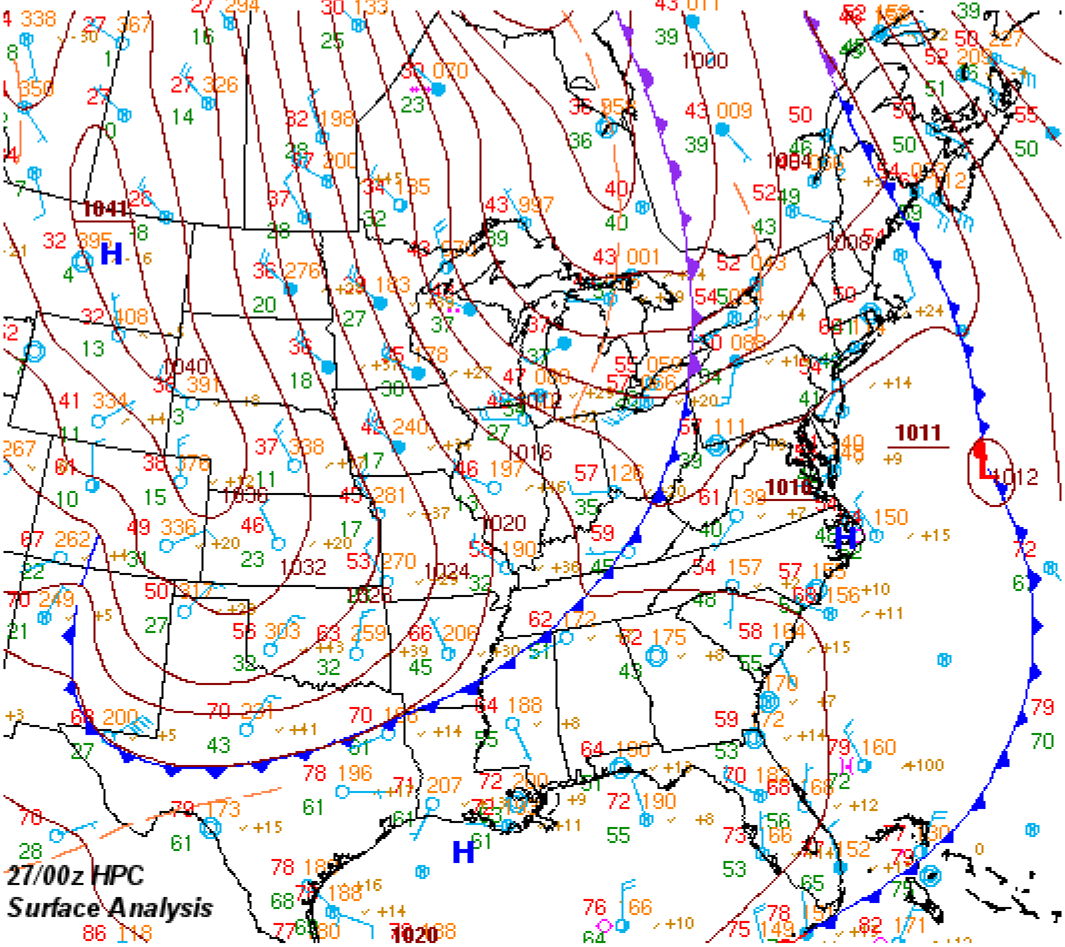


Fig 3. As in Fig. 2, except for 27/00z.

The front pushed eastward to the East Coast during the morning hours on 27 October. A weak frontal wave (1013mb) was analyzed at 27/15z near the southeastern Virginia and northeastern North Carolina border (not shown). The low pressure area would deepen slowly as it shifted to near Cape Hatteras, North Carolina at 28/00z (Fig. 4). Meanwhile, to the north, the surface front pushed eastward and became quasi-stationary across central New England.

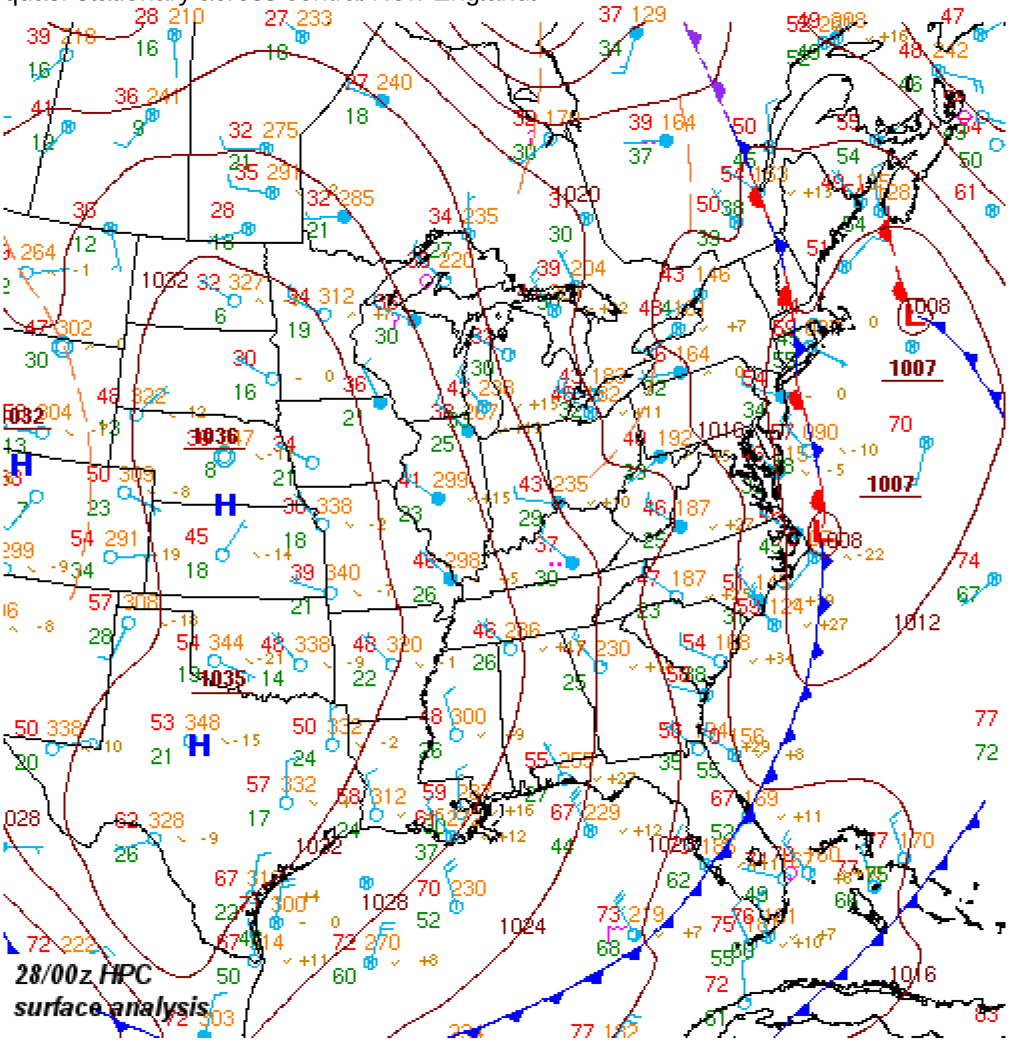


Fig 4. As in Fig. 2, except for 28/00z.

A period of rapid deepening would ensure over the next 12 hours as the surface low tracked northward along the frontal zone to just south of Long Island at 28/12z (Fig. 5). During this 12 hour period, the lowest analyzed sea-level pressure value associated with the system dropped from 1007 to 991 mb.

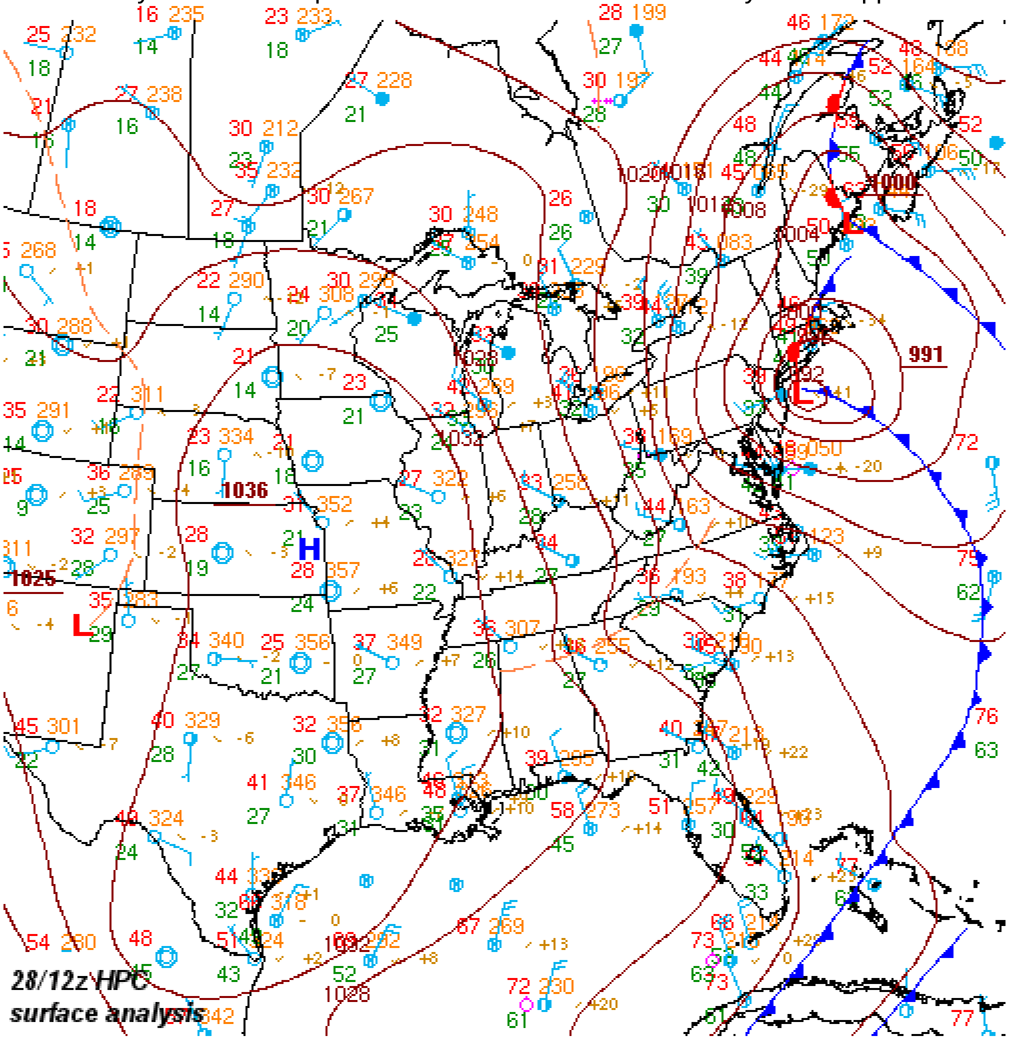


Fig 5. As in Fig. 2, except for 28/12z.

The low pressure system began the occlusion process as it tracked northward during the daylight hours on the 28th. The low center reached the upper Connecticut River valley at 28/21z (Fig. 6).

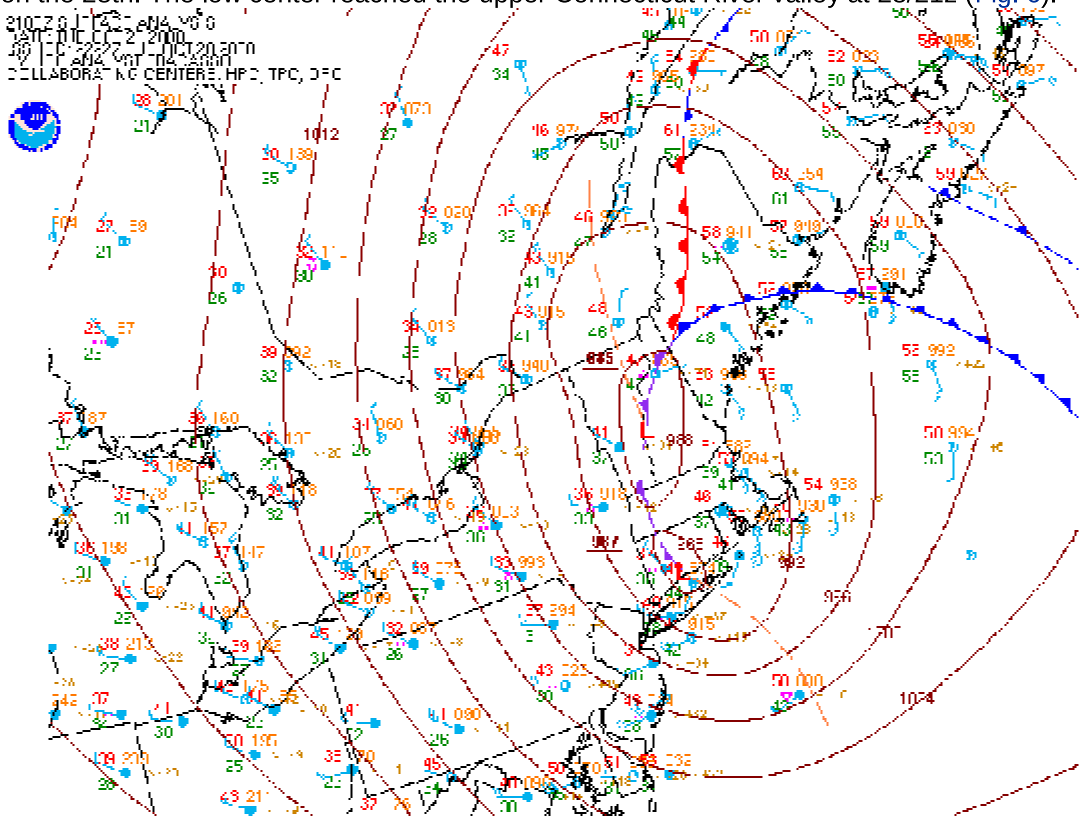


Fig 6. As in Fig. 2, except for 28/21z. Click on image for enlargement.

The surface low would continue to deepen as it tracked to near Sherbrooke, Quebec at 29/00z. The low pressure system migrated slowly northward across Quebec reaching peak intensity around 29/09z (Fig. 7), and then slowly filling during the daylight hours on 29 October. A pressure trough analyzed just north of the St. Lawrence valley at 29/09z (Fig. 7) would sweep southeastward across northern New York later that morning and was associated with a prolonged period of steady snowfall following the passage of the low during the day on 29 October.

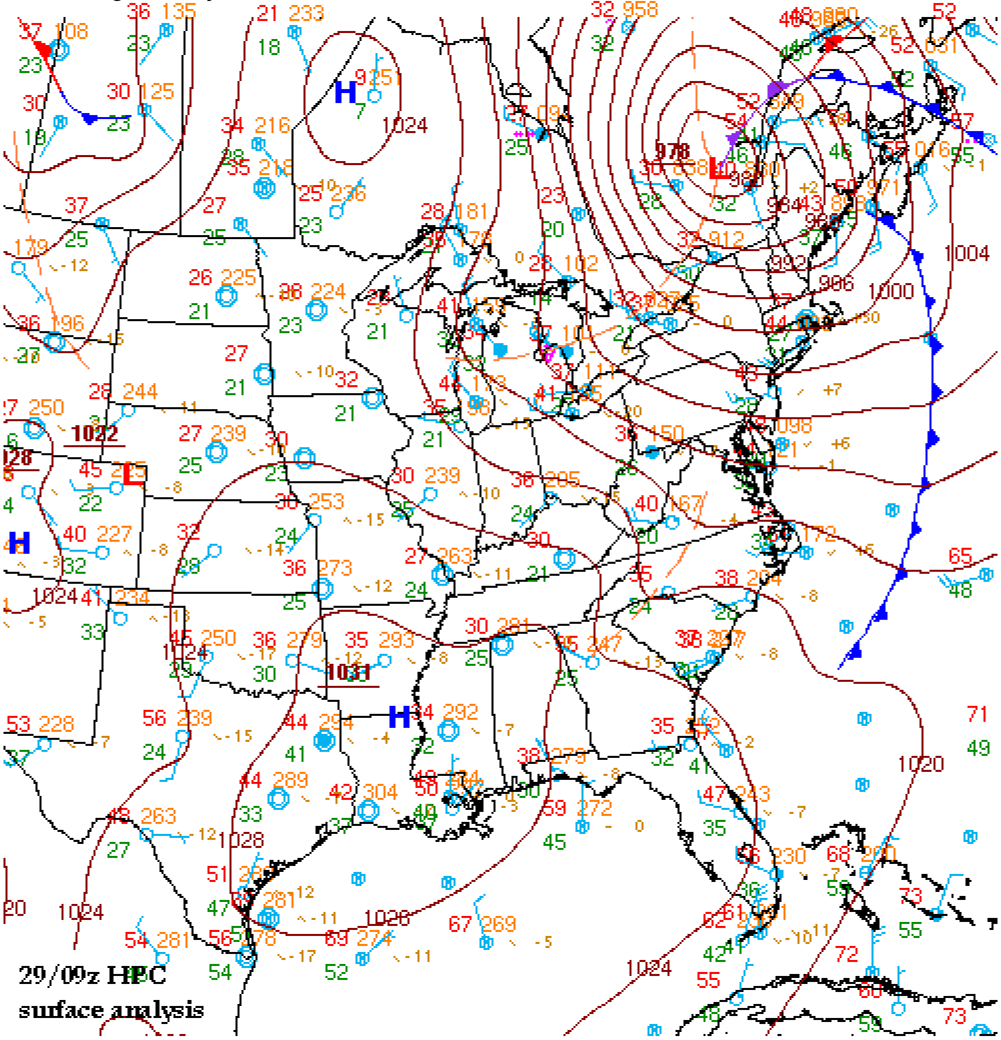


Fig 7. As in Fig. 2, except for 29/09z.

The low pressure system associated with the heavy snow episode met the criterion typically used for explosive cyclogenesis, that is, an average deepening rate of at least 1mb/hr over a period of 24 hours. As shown in Figure 8 below, the 24 hour pressure change associated with the analyzed minimum HPC surface pressure reached -25 mb at 29/03z.

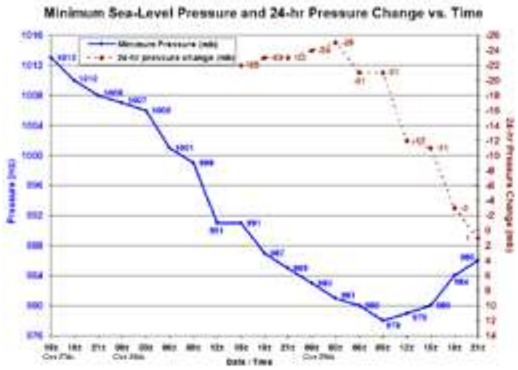


Fig 8. Plot of minimum sea-level pressure (solid line) and 24 hour pressure change (dashed line) versus time, from 27/15z through 29/21z. Sea-level pressure values are based on 3-hourly HPC surface analyses. Click on image for enlargement.

A loop of HPC surface analyses from 26/00z through 30/00z is available here.

III. Upper Air Analysis

(a) 850mb analysis
A broad region of 850mb cold advection accompanied the surface cold front across the north-central United States at 26/12z, aided by northwesterly 850mb winds up to 65 kt at Aberdeen, SD, and 50-60 kt elsewhere across Minnesota and the Dakotas.

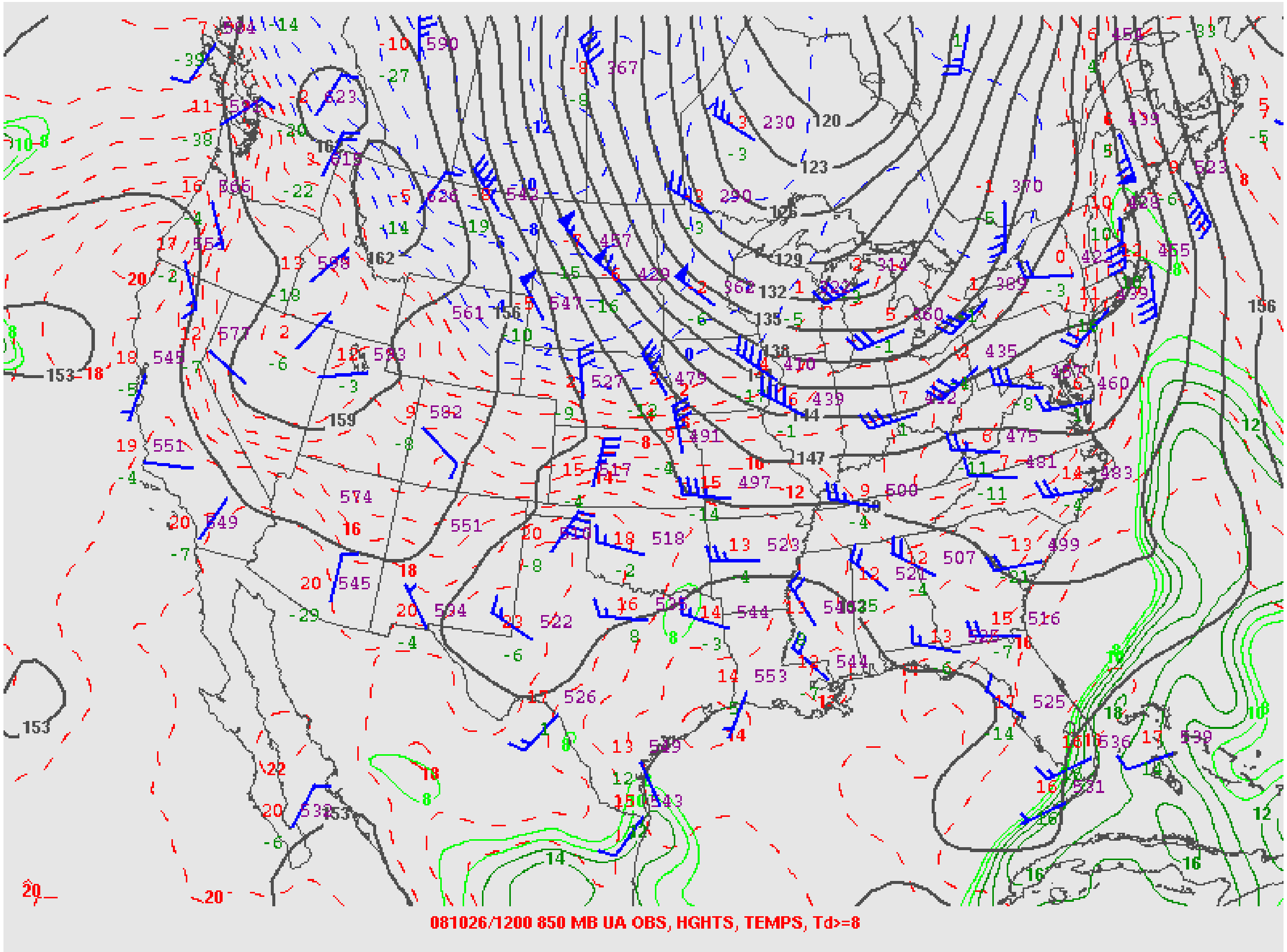


Fig 9. The 850mb analysis based on rawinsonde observations and RUC background field at 12z October 26th. Height contours (solid lines) are every 30m. Isotherms (red, dashed lines) are every 2C, isodrosotherms (green solid lines) are analyzed every 2C at values of 8C or greater. Standard upper air station model is shown. Click on image to enlarge.

The strong band of 850mb cold advection migrated rapidly east and south before stalling across northeastern New York and Vermont at 27/18z. The 850mb baroclinic zone extended southward across eastern Pennsylvania, Virginia, the Carolinas, and southern Georgia at 27/18z. At this time, there was evidence of developing 850mb convergence in the mid-Atlantic region along the baroclinic zone (Fig. 10):

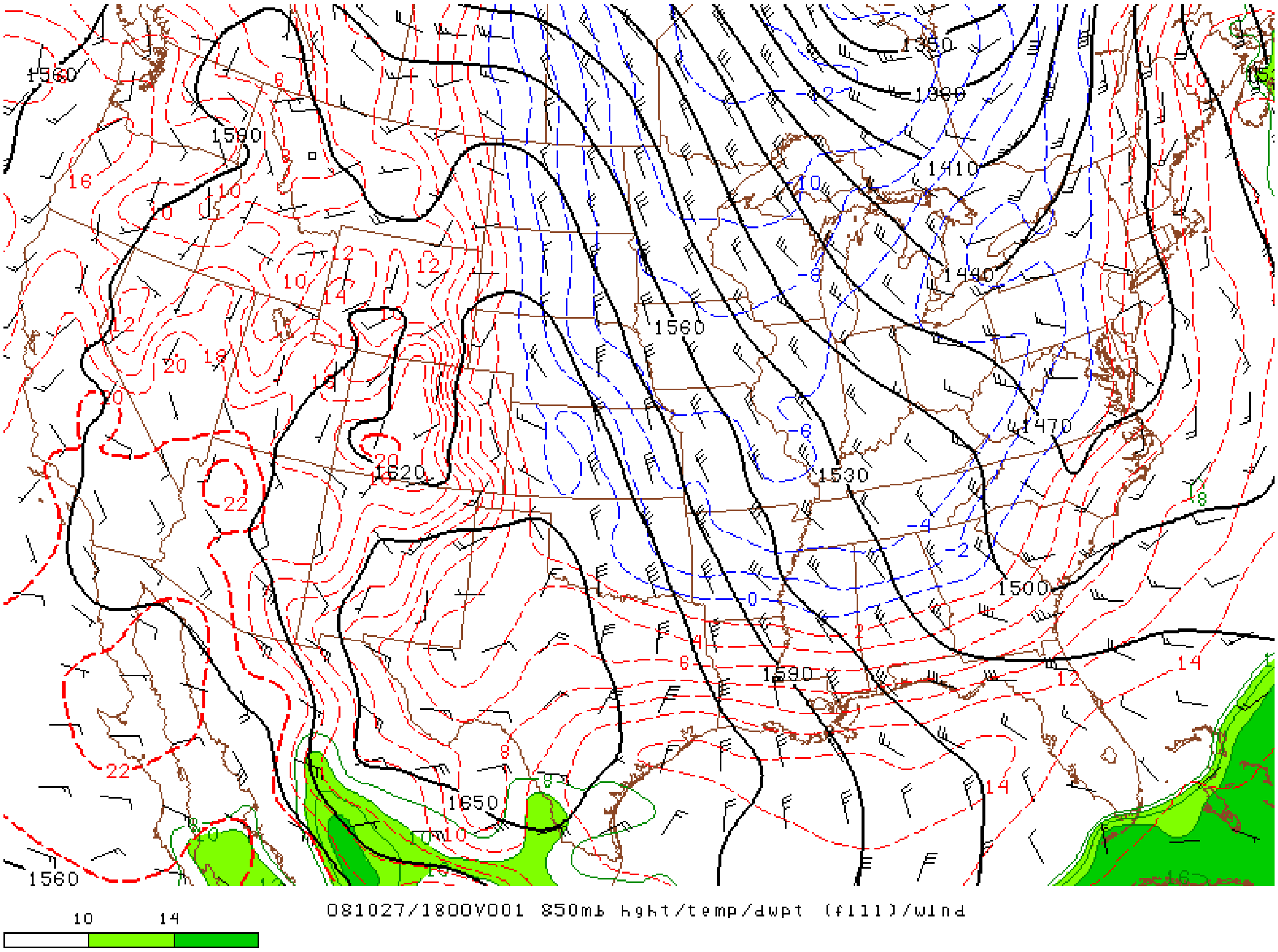


Fig 10. RUC based 850mb analysis valid at 18z October 27th. Wind barbs are shown in kts, solid lines represent 850mb geopotential height every 30m, dashed lines are isotherms every 2C, and green filled areas are 850mb dewpoint 10C or greater, contoured every 2C. Click on image to enlarge.

During the next 12-18 hours, an 850mb low would develop and deepen rapidly along the 850mb baroclinic ribbon and in vicinity of the initial area of low-level convergence. By 28/06z, the 850mb low was located over New Jersey (Fig. 11), with a noticable increase in the strength of the zonal temperature gradient along the east coast.

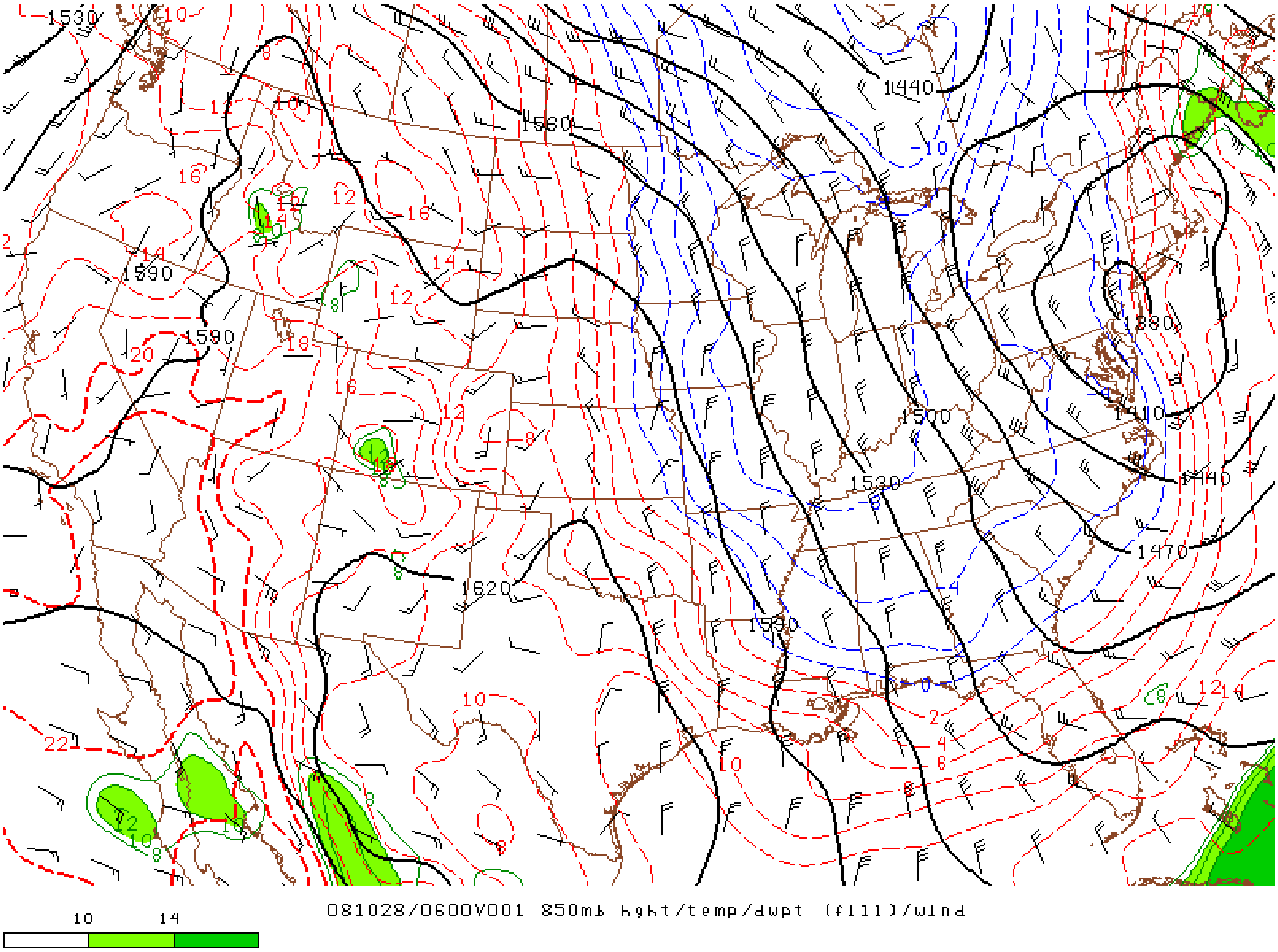


Fig 11. As in Fig. 10, except for 06z October 28th. Click on image to enlarge.

The low development and frontogenesis would also allow for the rapid increase in 850mb warm advection between 28/00-12z from New Jersey northward across New England which resulted in rapid increase in large-scale forcing for ascent and developing precipitation north of the low center. The warm advection would also keep thermal profiles relatively warm across the North County during the early states of the storm. As seen in Fig. 12, 850mb temperatures at 28/12z ranged from -2C to -3C across St. Lawrence County in the western part of the WFO Burlington forecast area, to +2 to +3C across the far eastern portion of Vermont.

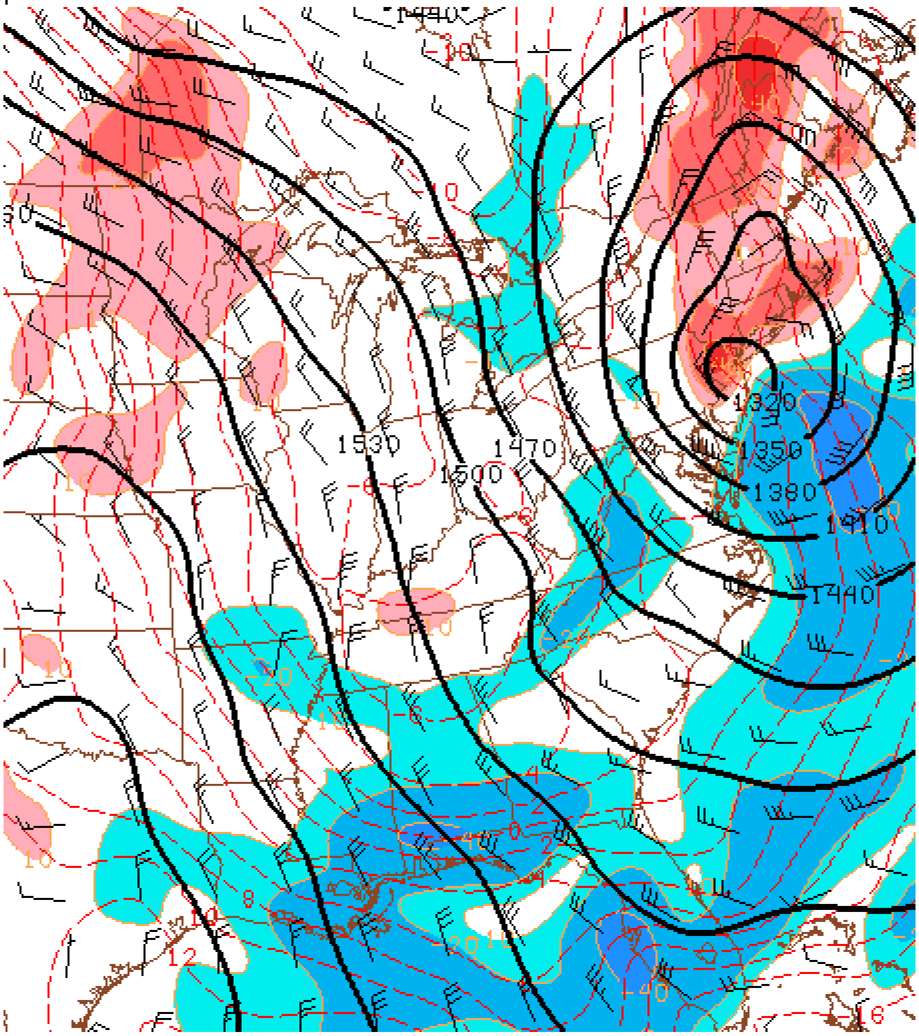


Fig 12. As in Fig. 10, except valid for 12z October 28th, and with temperature advection shaded (Red for warm advection, blue for cold advection). Click on image to enlarge.

A TROWAL airstream (see mesoscale analysis section) would result in a prolonged period of 850mb warm advection and low-level ascent (through 29/06z) across northern New York as the 850mb low tracked northward and passed to the east of the heavy snow area in northern New York. Temperature advection gradually weakened as the 850mb low tracked northward through Quebec and as the storm became fully occluded and began to fill.

- Click here for loop of 850mb height, temperature, wind, and dewpoint from 26/00z through 30/00z.
- Click here for loop of 850mb height, temperature, wind, and shaded temperature advection from 27/00z through 30/00z.

The low-level ascent can also be seen in the NOAA HYSPLIT 40km ETA Data Assimilation system (EDAS40) trajectory analysis ending near Wanakena, NY at 28/20z (Fig. 13). The trajectories ending at 2-3 km show ascent of 1-2 km as they accelerate from northeast to southwest between 28/12z and 28/20z on the west side of the 850mb low track. The speed increase is particularly strong in the 3 km trajectory (green) late in the period from western New Brunswick to northern New York. This large-scale ascent corresponded to periods of heavy snowfall in the Adirondack region late in the afternoon on the 28th.

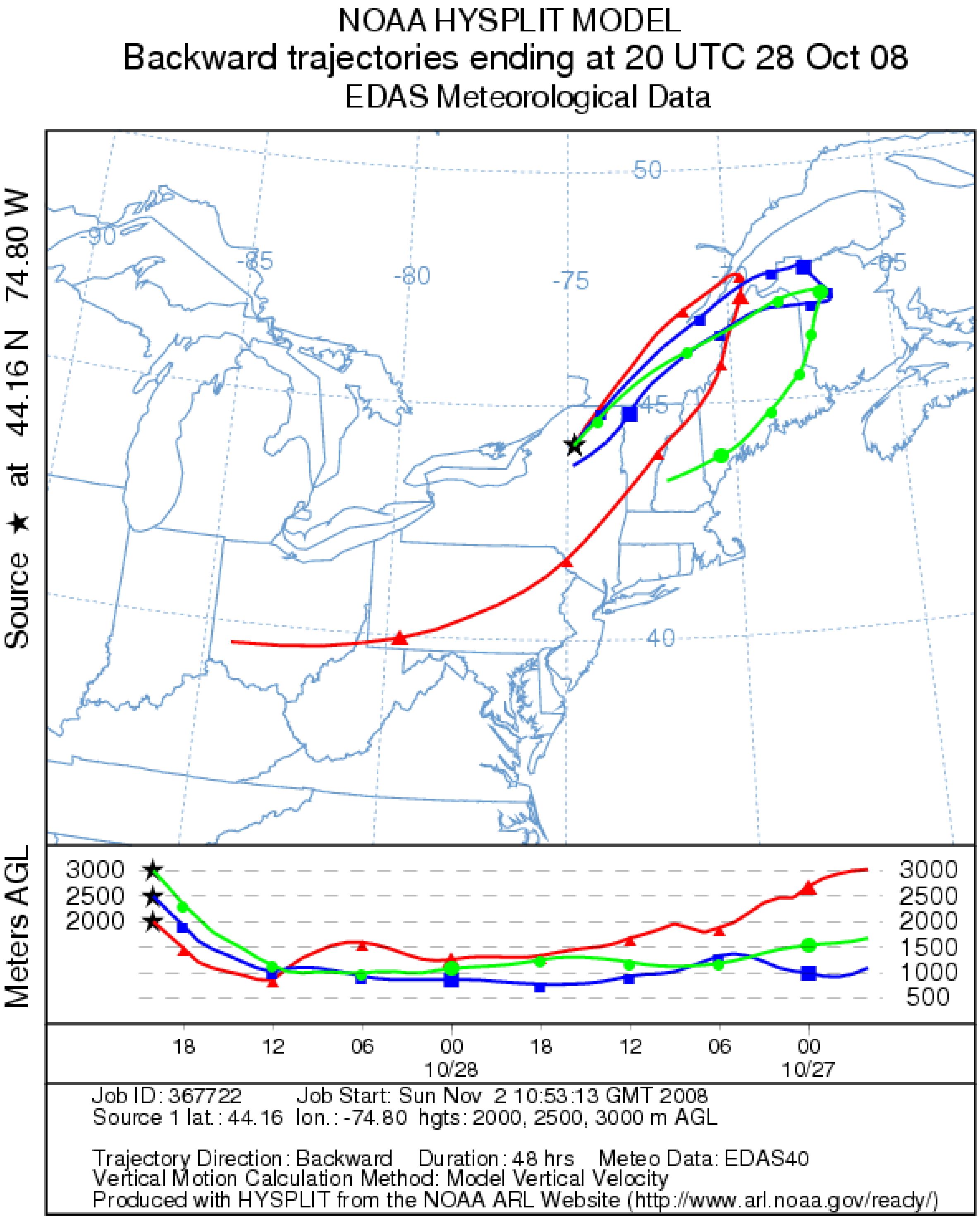


Fig 13. EDAS40 backward trajectory analysis produced with HYSPLIT model from the NOAA ARL website. Ending point is near Wannakena, New York. Star represents ending point at 20z October 28th. Green line is backward trajectory at 3 km. Markers are placed at 6 hour intervals (00, 06, 12, 18z). Click on image to enlarge.

(b) 700mb analysis

The 700mb analysis at 26/12z also showed an impressive area of cold advection and strong northwesterly winds (up to 80 kt at Glasgow, MT) associated with a shortwave trough digging southeastward into the central United States (Fig. 14).

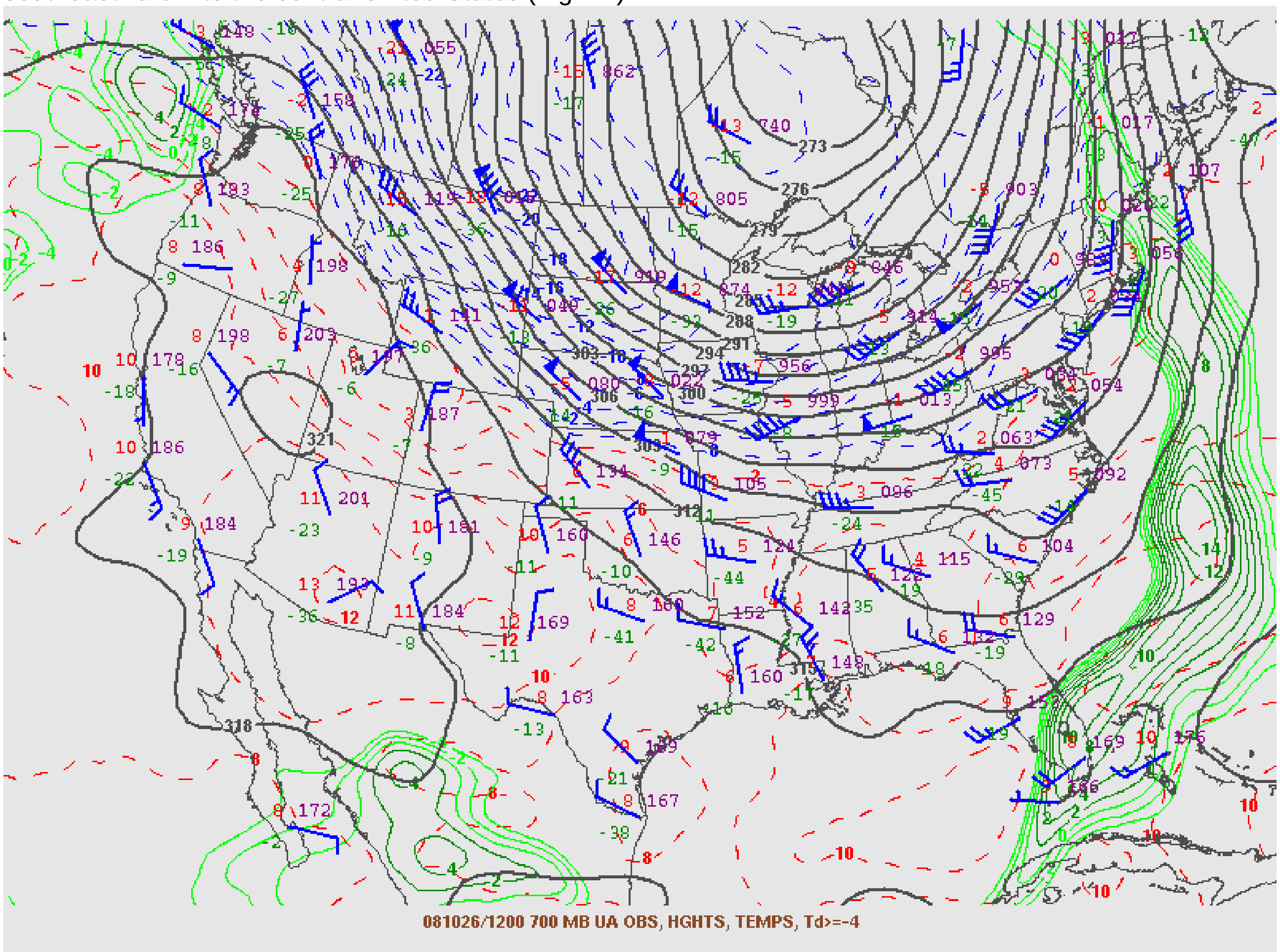


Fig 14. As in Fig. 9, except for 700mb, at 12z October 26, and with dewpoint contours every 2C for values of -4C and greater. Click on image to enlarge.

The trough axis itself would become more sharply defined at 27/00z across Illinois, Missouri, and eastern Kansas, with a diffluent flow pattern eastward into the Tennessee Valley (Fig. 15).

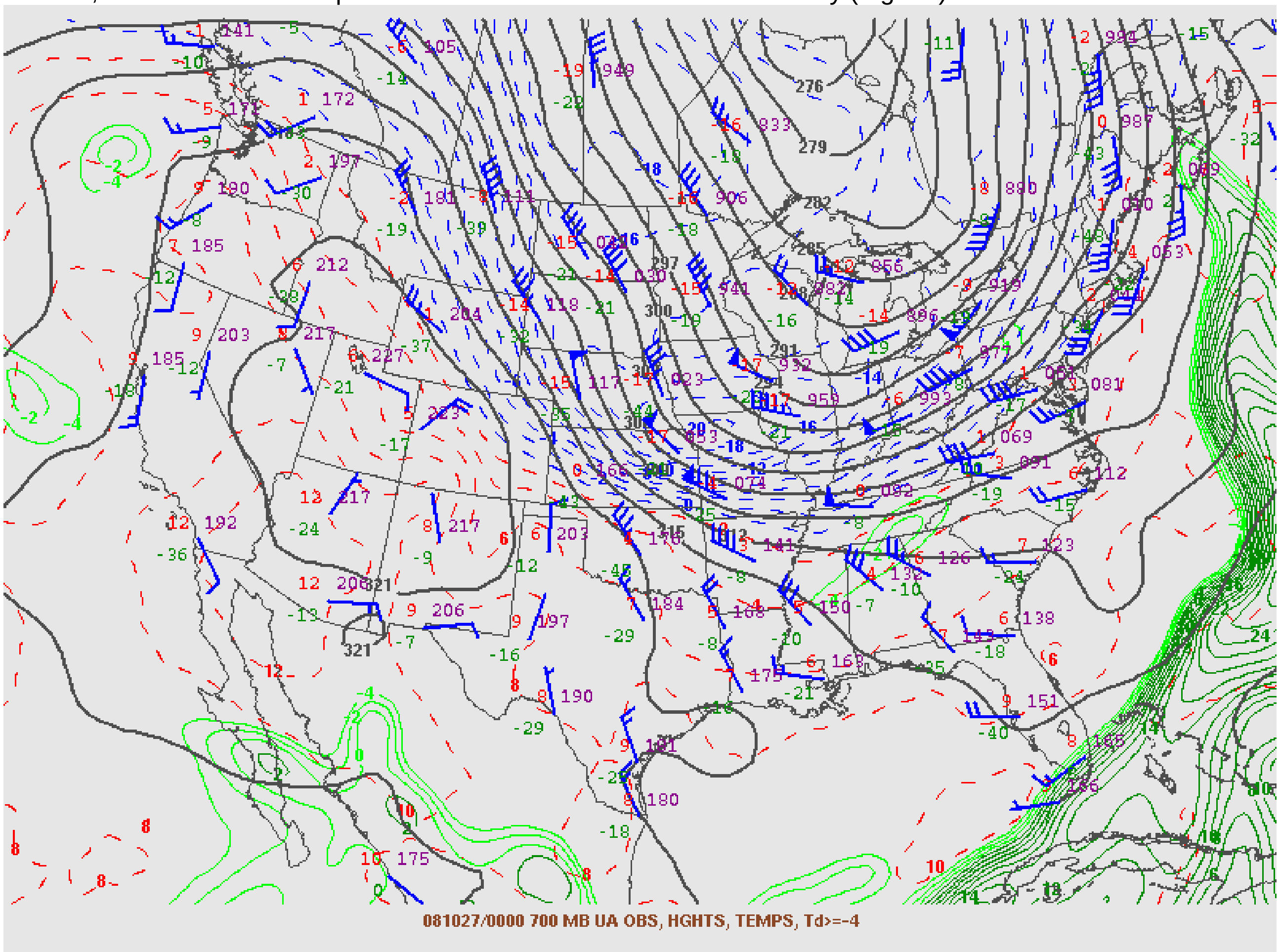


Fig 15. As in Fig. 14, except at 00z October 27. Click on image to enlarge.

The shortwave trough axis reached the Tennessee Valley by 27/12z (Fig. 16), with an intense cross-flow temperature gradient (0C at HUN to -12C at BNA) and strengthening wind of 50-55 kt across the mid-Atlantic states downstream of the trough axis. The strong increase in across-flow horizontal temperature gradient in the vicinity of the trough axis was likely driven by an indirect vertical circulation in the exit region of the strong northwesterly mid-level jet streak, with warm air sinking to the south of the jet axis, and cool air rising to the north. The strength of the temperature gradient had also tightened from North Carolina to New York compared to the previous 12 hours as the strength of the upstream trough increased and amplified.

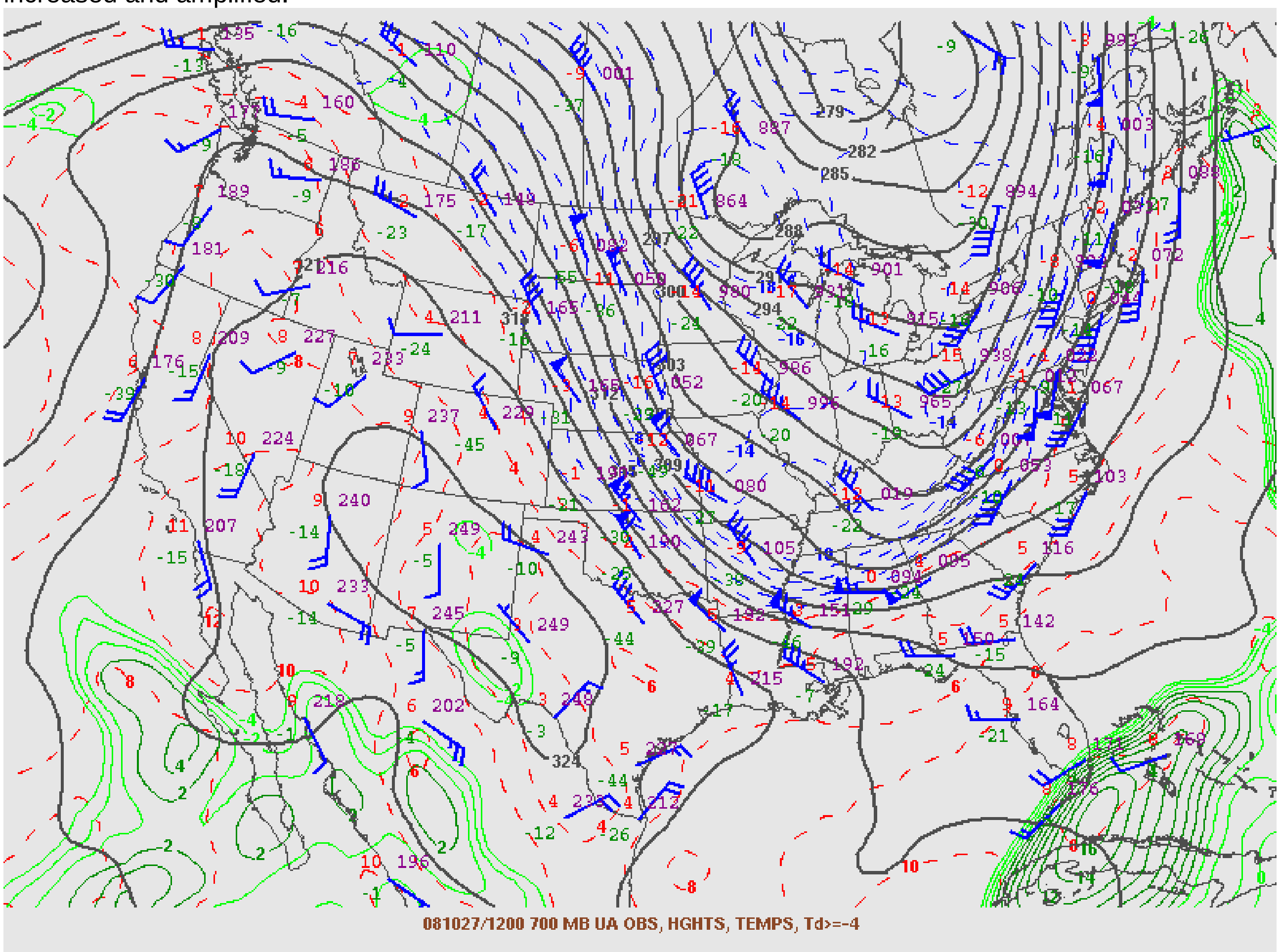


Fig 16. As in Fig. 14, except at 12z October 27. Click on image to enlarge.

At 28/00z, the 700mb trough axis had reached the Carolina Piedmont (Fig. 17), and was beginning to acquire a slight negative tilt. The jet axis was rounding the base of the trough from Jacksonville, FL to Morehead City, NC and the flow exhibited strong curvature off the Southeast Coast. The strong vorticity advection emerging off the Carolina Coast would contribute strongly to the explosive deepening phase of the surface cyclone shown in the surface section.

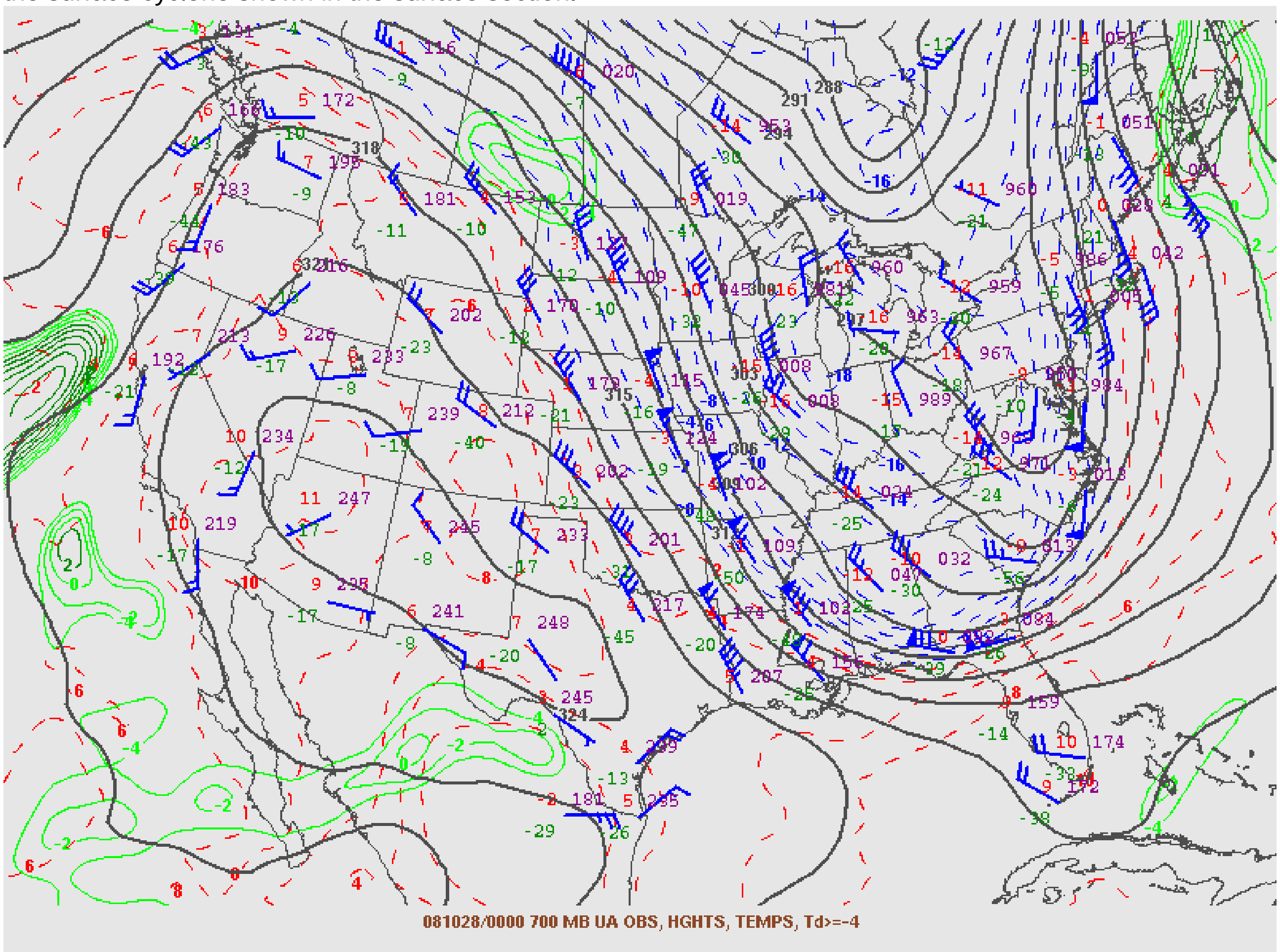
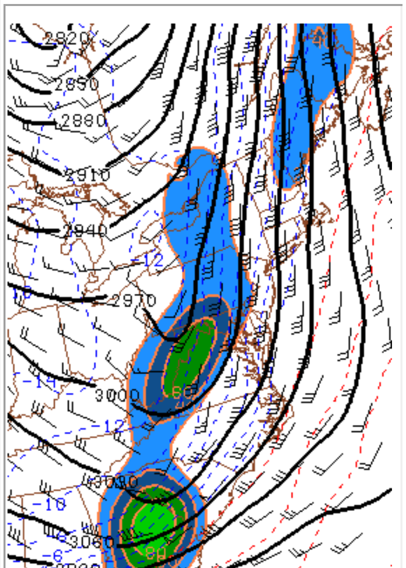
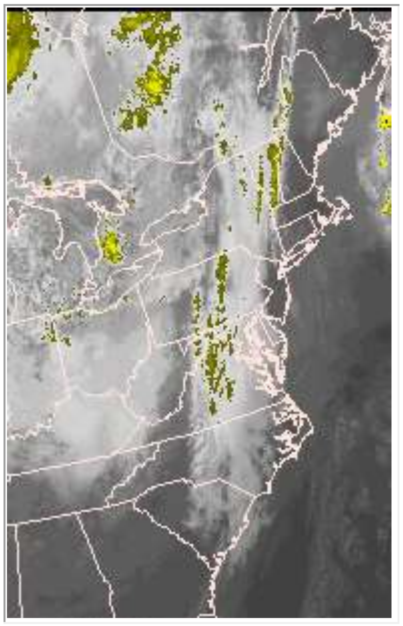


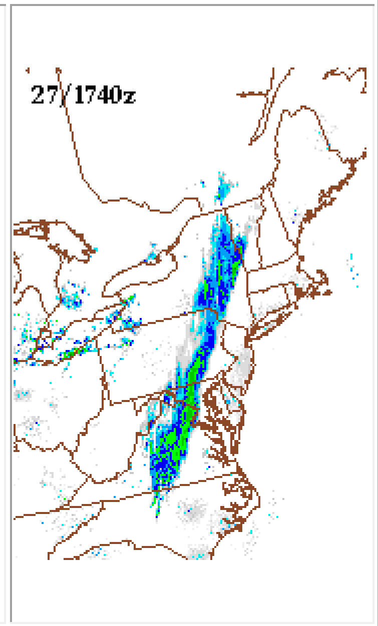
Fig 17. As in Fig. 14, except at 00z October 28. Click on image to enlarge.

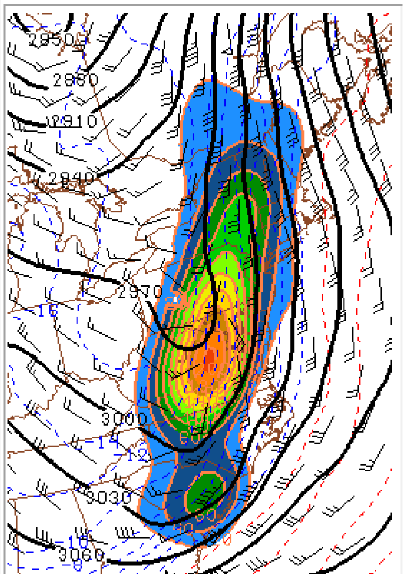
There is also a coincident increase in 700mb horizontal frontogenesis from the mid-atlantic states northward beginning around 27/21z, which contributes to strong cloud top cooling and a baroclinic leaf structure in the IR imagery). This sequence in 700mb horizontal frontogenesis, cloud top cooling on IR, and expansion of composite reflectivity can be seen in Fig. 18. The northward expansion and increase in radar reflectivity occurs across the Chesapeake Bay, eastern Pennsylvania, and eastern New York occurs between 27/18z and 28/03z.



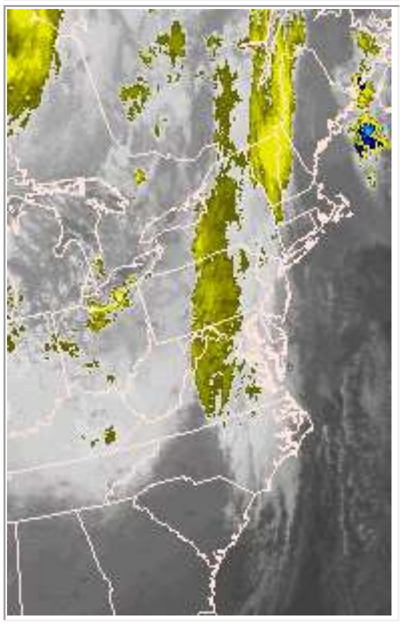
(a)700mb Frontogenesis 27/18z

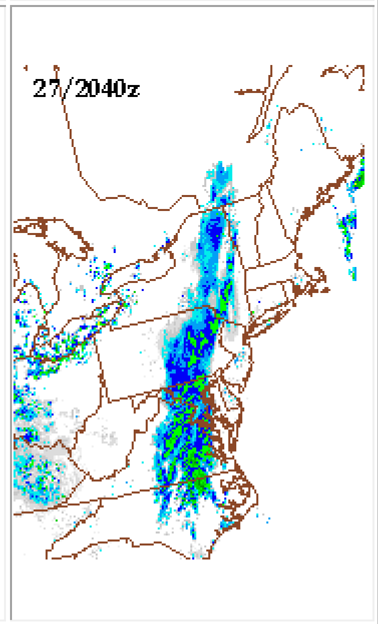






(b)700mb Frontogenesis 27/21z





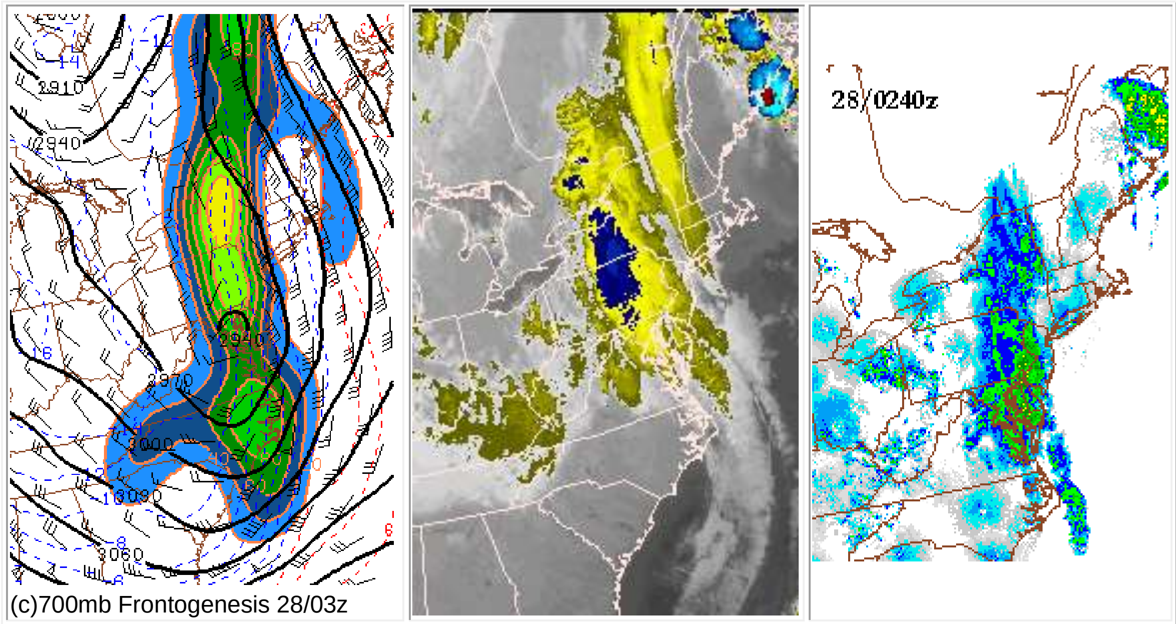


Fig 18. RUC based 700mb horizontal frontogenesis (positive values shaded) at (a) 18z October 27, (b) 21z October 27, and (c) 03z October 28. 700mb geopotential height (solid black lines, 30m interval) and isotherms (dashed red, 2C interval) and wind barbs also shown. Corresponding IR imagery and mosaic NWS 88-D composite reflectivity shown to the right. Time of IR images are (a) 27/1815z, (b) 27/2132z, and (c) 28/0332z. Click on 700mb RUC-analysis images to enlarge.

- Click here for loop of 700mb height, temperature, wind, and 2-D frontogenesis from 27/00z through 30/00z.
- Click here for long-loop of IR imagery from 27/1215z through 30/0015z.

The rapid deepening of the low pressure system at low-levels resulted in a closed 700mb low after 28/06z and a decrease in frontogenetic forcing across central and northern New York. Much of the forcing during the daylight hours on the 28th and into the 29th was related to isentropic ascent and warm advection rather than frontogenetic forcing. The 700mb analysis at 28/12z is shown in Fig. 19.

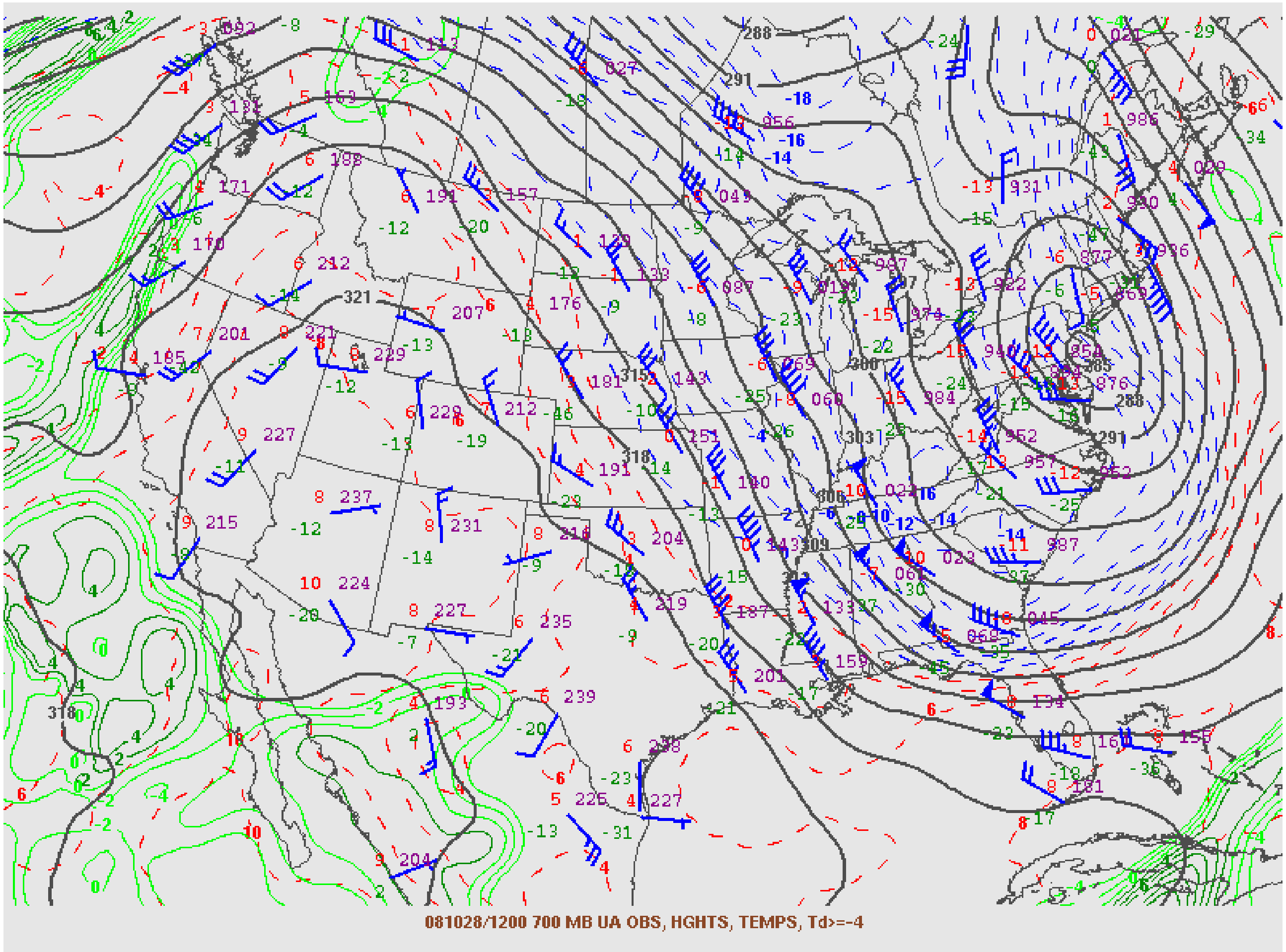


Fig 19. As in Fig. 14, except at 12z October 28. Click on image to enlarge.

III. Upper Air Analysis

(c) 500mb analysis

The 500mb analysis at 26/00z (Fig. 20) shows northwesterly winds of 75-100 kt across the Dakotas and Montana with broadly diffluent flow downstream across the mid and upper Mississippi River Valley. The cyclonic shear side of the 500mb jet streak was associated with a very cold temperature minima of -40C across east-central Alberta, with the thermal trough extending southeastward into North Dakota.

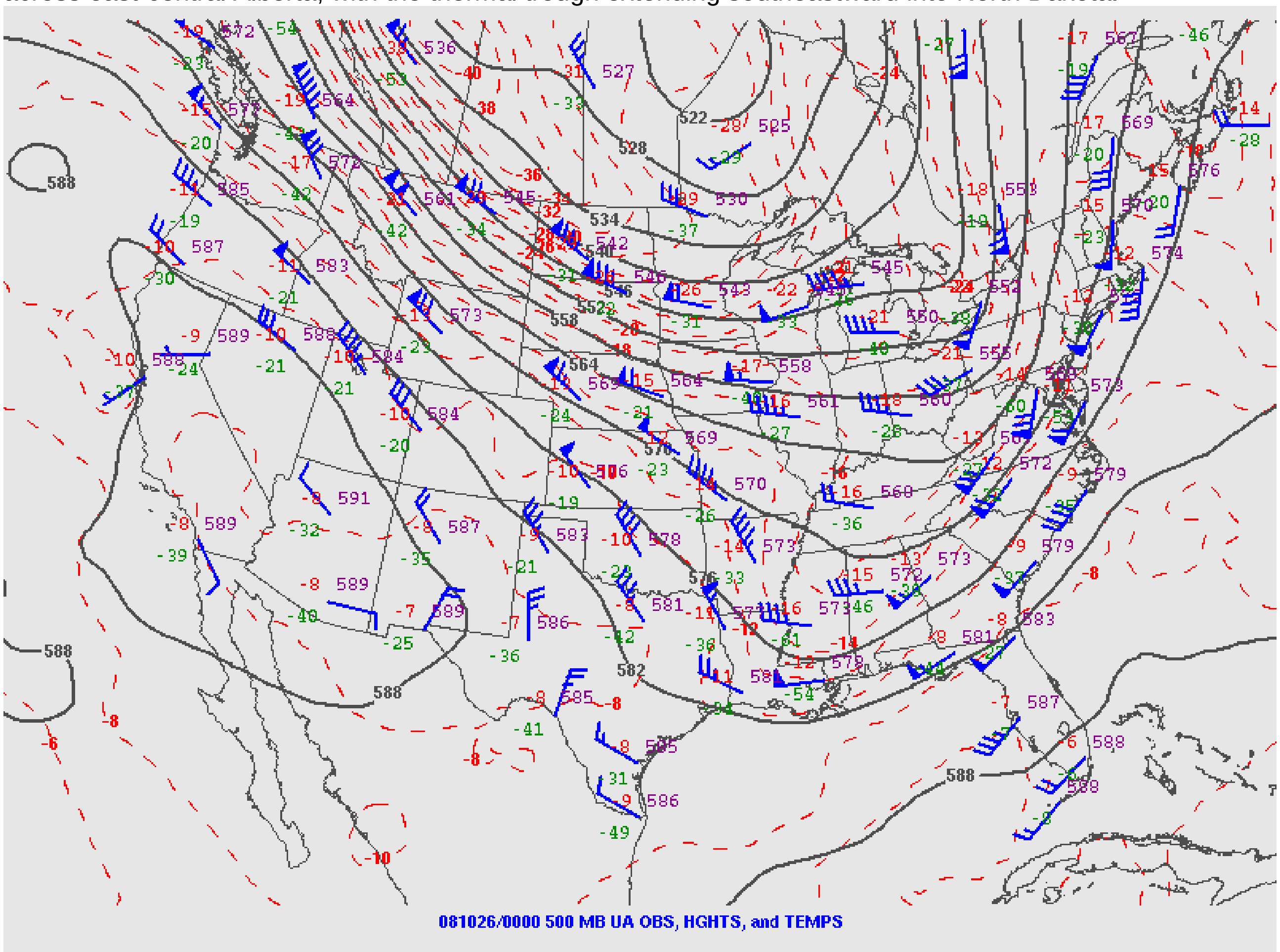
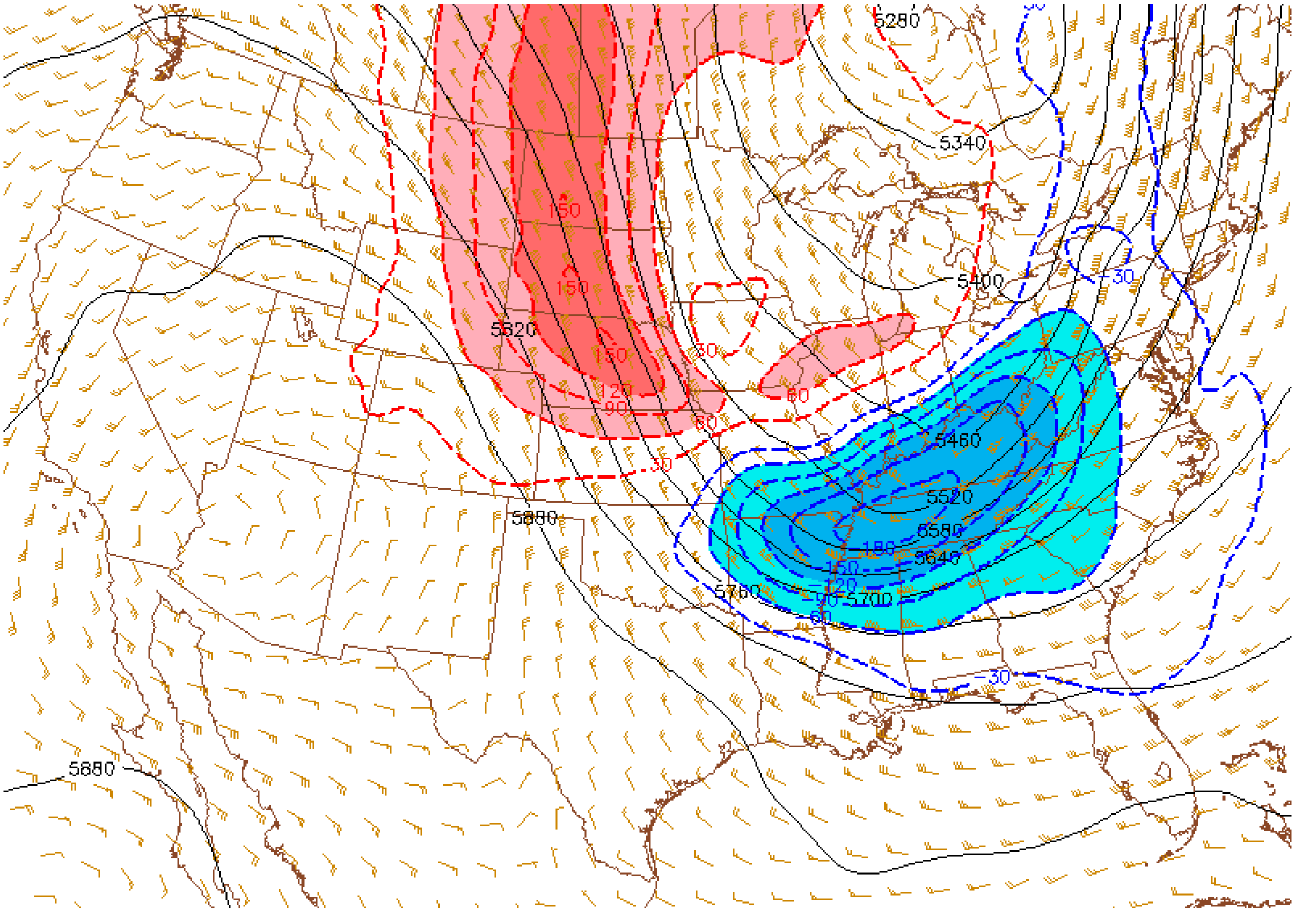


Fig 20. 500mb analysis at 00z October 26th. Geopotential height (solid lines, every 60m), isotherms (red dashed lines, every 2C), and wind barbs at rawinsonde stations in knots. Standard upper air station model is shown. Click on image to enlarge.

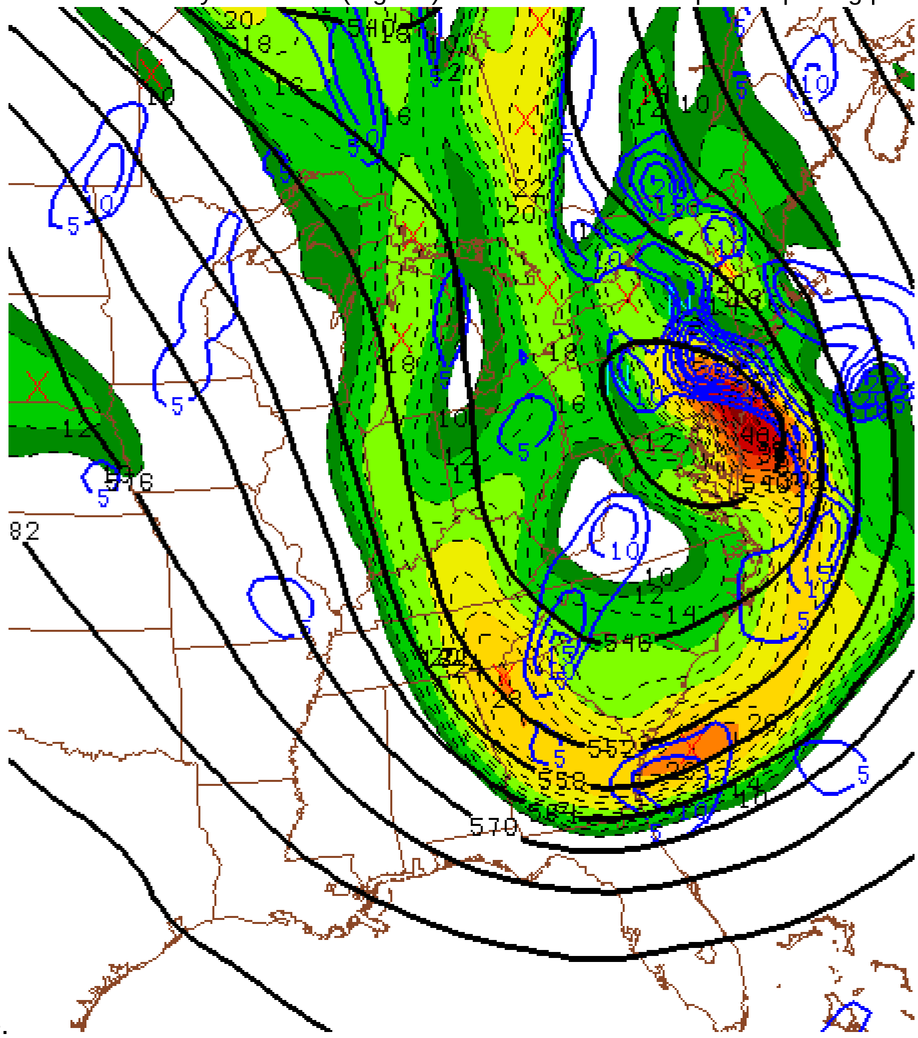
By 27/00z, the 500mb trough dug strongly across the central Plains, and was associated with winds up to 115kt at Topeka, KS. The 12-hrly height falls also increased during the period 27/00z through 28/00z as the shortwave trough intensified (Fig. 21).



081027/1100 : 081027/0000 12hr 500mb height change and current hght, temp, and wind

Fig 21. RUC based 500mb geopotential height (black solid lines, 60m contour interval), 12-hr height change (color filled, 30m interval), and wind barbs (kt) at 12z October 27. Click on image to enlarge.

The trough axis emerged off the southeastern U.S. coast between 28/00z and 28/12z contributing to strong differential vorticity advection (Fig. 22) and the coincident rapid deepening phase of the surface



cyclone.

Fig 22. RUC based 500mb geopotential height (black solid lines, 60m contour interval), absolute vorticity (color filled, 10^{-5} s^{-1}), and 700-400mb differential vorticity advection (blue solid lines, 10^{-5} s^{-1}) at 12z October 28. Click on image to enlarge.

The system would become vertically stacked by 29/00z (Fig. 23), with the 500mb low passing across central New England. THe 500mb low was closed, and the broader 500mb trough exhibited a negative tilt from western Hudson Bay into New York and New England. The low then tracked northward into southern Quebec by 29/12z, with the North Country remaining within the broad circulation of the upper low and westerly to northwesterly mid-tropospheric winds through 30/00z.

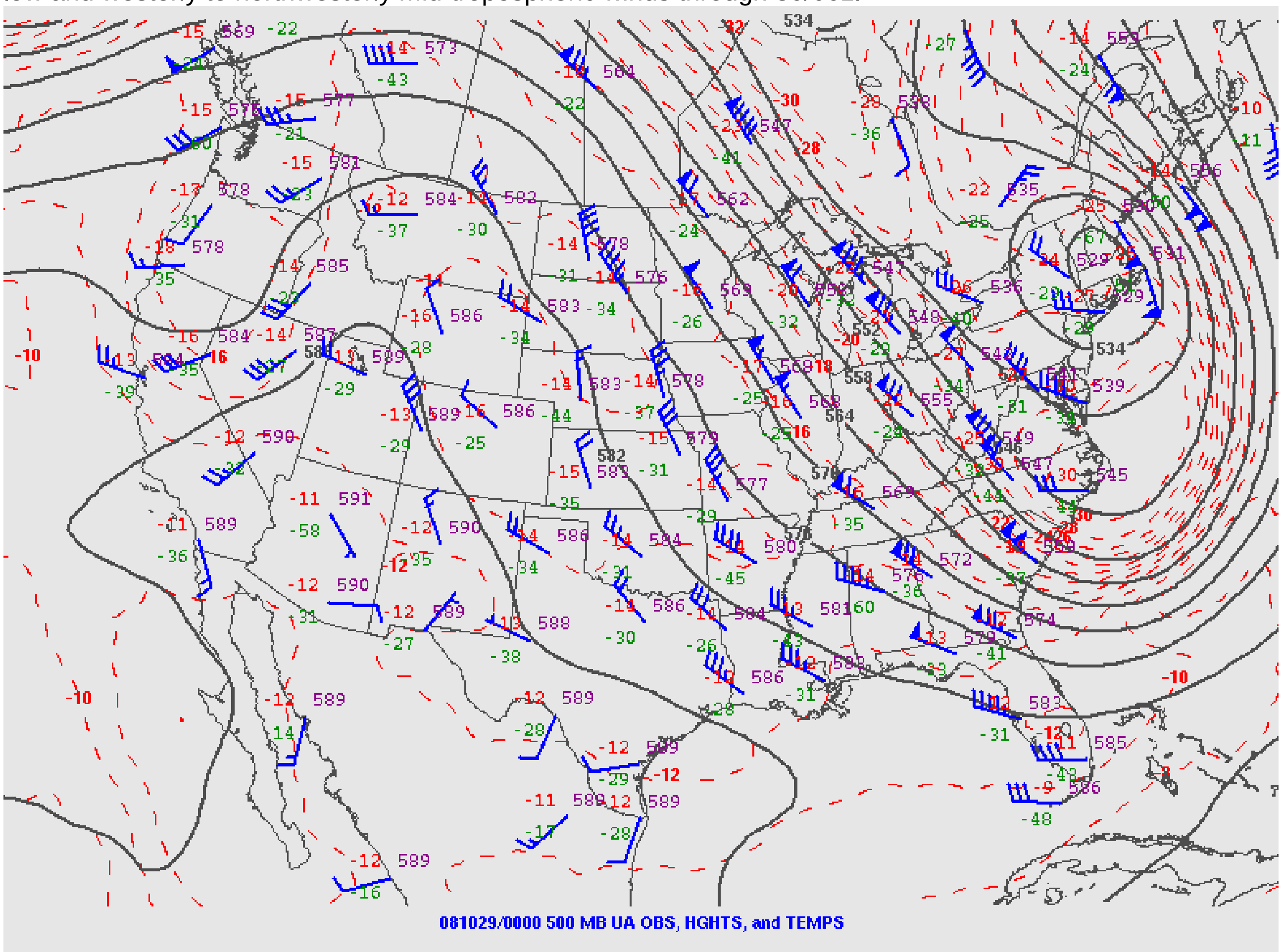


Fig 23. As in Fig. 20, except for 00z October 29th. Click on image to enlarge.

- Click here for loop of 500mb geopotential height (60m interval), absolute vorticity, and 700-400mb differential vorticity advection from 26/00z through 30/00z.
- Click here for loop of 500mb geopotential height (solid lines, 60m interval), 12hr height change (color fill, 30m interval), and wind barbs from 26/12z through 30/00z.

(d) 300mb analysis

The 300mb analyses indicate a strong upper tropospheric jet in excess of 150kt across the Dakotas and northeastern Montana at 26/00z (Fig. 24).

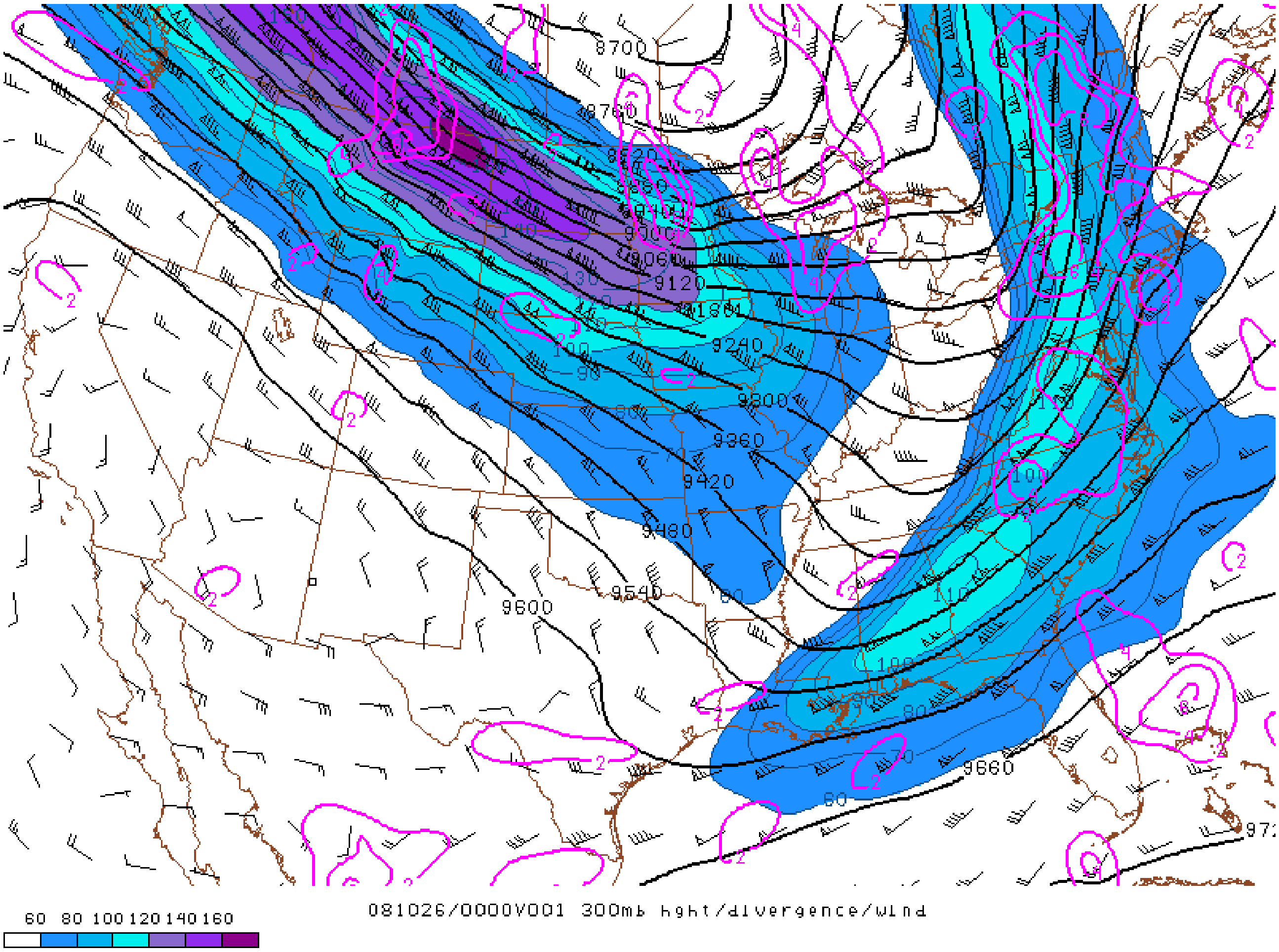


Fig 24. RUC based 300mb analysis of geopotential height (solid black lines, every 60m), divergence (solid magenta contours, every $2x10^{-5}s^{-1}$, and isotachs (color filled every 10kt above 60kt) at 00z October 26th. Click on image to enlarge.

This jet streak would result in significant amplification of the upper trough from 26/00z through 28/00z (see loop below). Thereafter, the strongest winds are located downstream of the trough axis along the east coast of the United States. This contributed to strong upper level divergence across the mid-Atlantic region beginning around 28/00z, and then northward across New York and New England from 28/15z through 29/06z (Fig. 25).

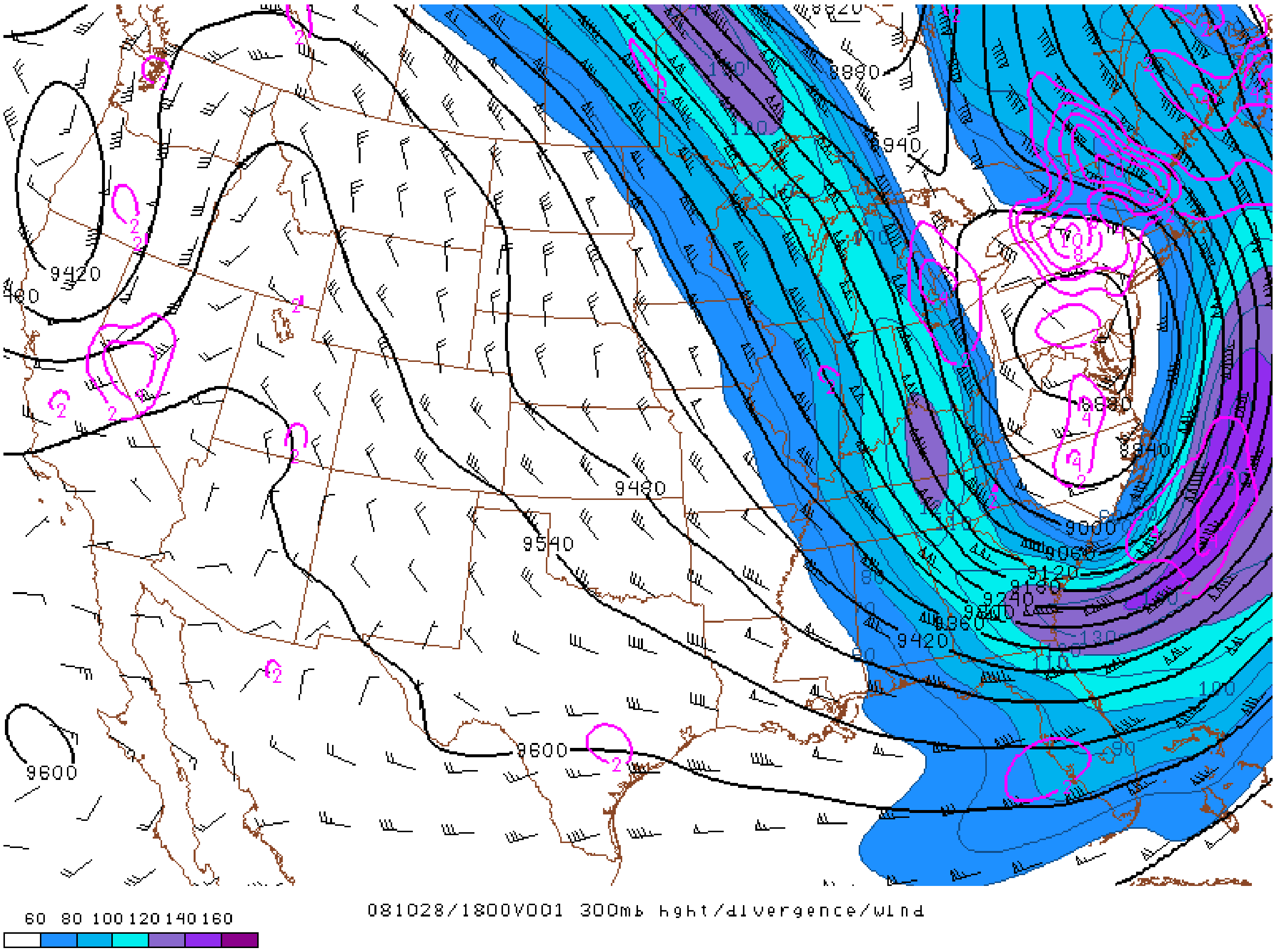


Fig 25. As in Fig. 24, except for 18z October 28th. Click on image to enlarge.

- Click here for loop of 300mb geopotential height (60m interval), wind barbs and isotachs (20kt contour interval above 60kt), and 300mb divergence (solid magenta lines, 10^{-5} s^{-1}) from 26/00z through 30/00z.

IV. Mesoscale Analysis

Boundary layer temperatures represented the primary forecast challenge associated with this early season storm. Where and when temperatures would be cold enough to support snowfall during the event largely depended on the track of the low pressure system, which ultimately followed the Connecticut River Valley northward across New England. This particular track favored the western portion of the WFO Burlington forecast area, owing to the strong 850-700mb warm advection taking place to the east until the surface low center reached northeastern VT late in the afternoon on October 28th.

The observed sounding at Albany, NY (ALB) from 28/12z (Fig. 26) was representative of the above freezing near-surface conditions across much of the North Country early in the event. The ALB sounding at 12z also features a deep saturated layer with in cloud temperatures in the favorable dendritic growth zone (-12C to -18C). The wet-bulb zero level at ALB was around 4200', but around 1100' at Maniwaki, Quebec (Fig. 27).

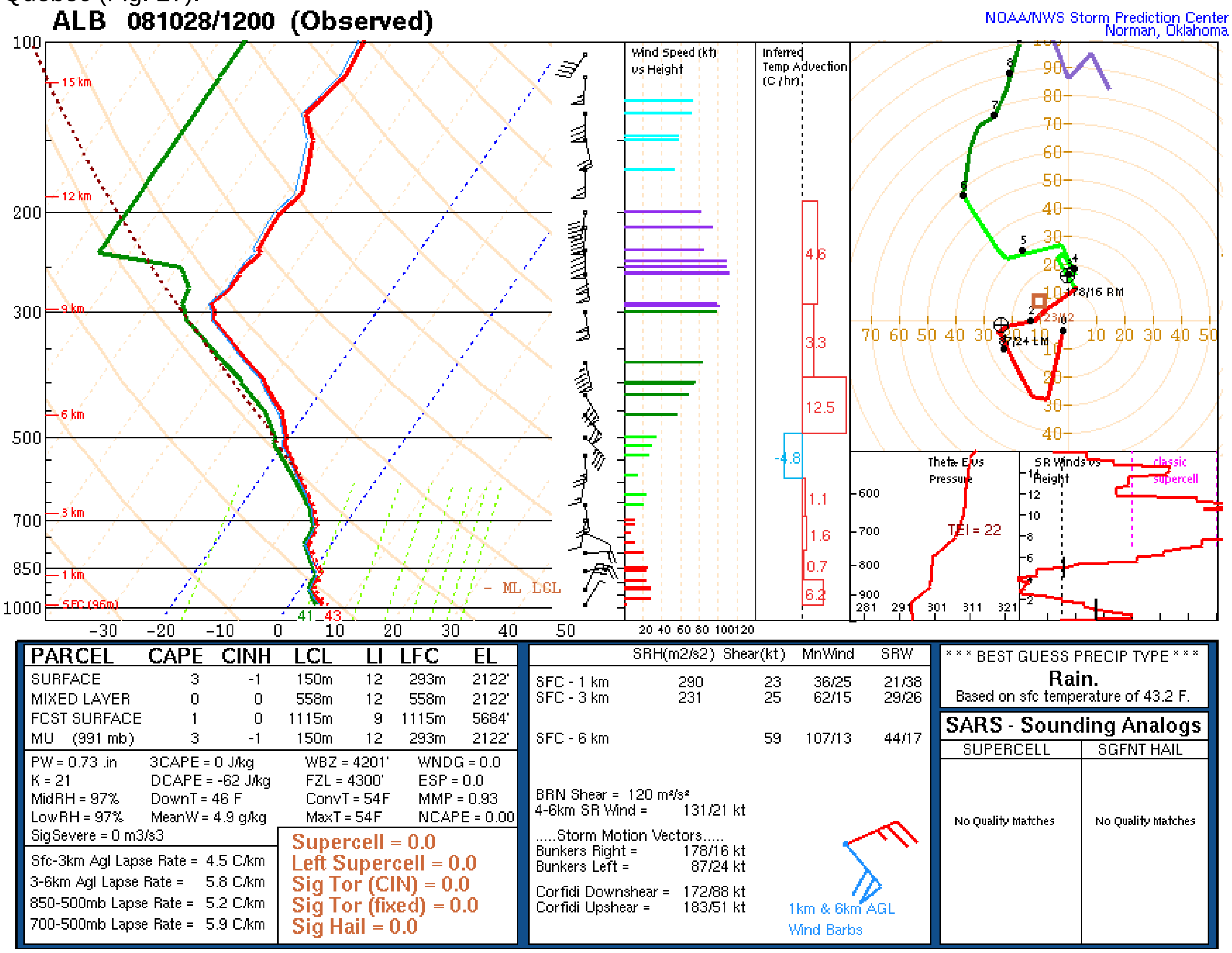


Fig 26. Albany, NY sounding (ALB) at 12z October 28th. Click on image to enlarge.

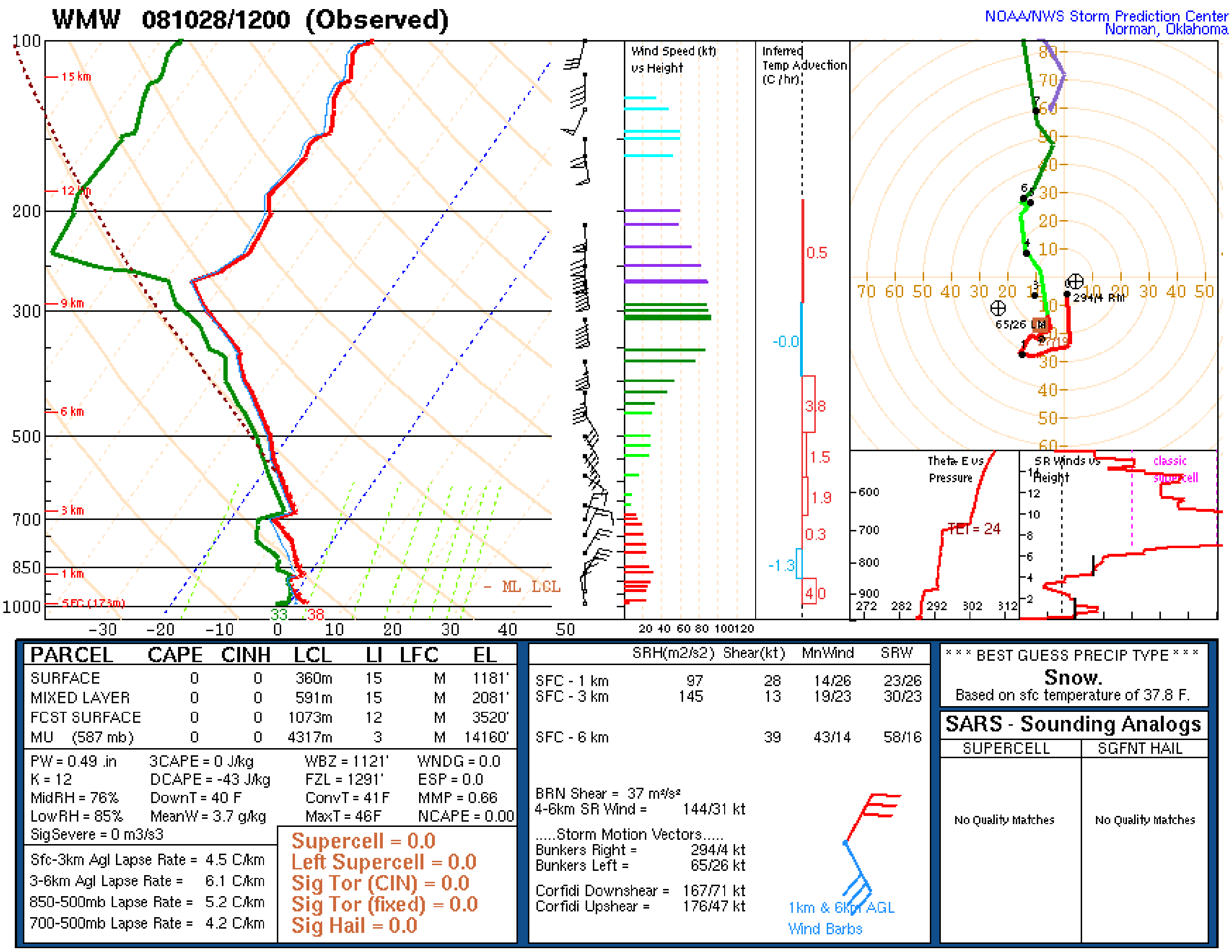


Fig 27. Maniwaki, Quebec (WMW) sounding at 12z October 28th. Click on image to enlarge.

During the morning hours on October 28th, snow levels across the North Country fluctuated between 1500' and 2000'. The meteogram at Saranac Lake (KSLK) is representative of the above freezing surface temperatures represent across much of the area through most of the daylight hours on 28 October (Fig. 28). Temperatures began falling appreciably after 2pm EDT.

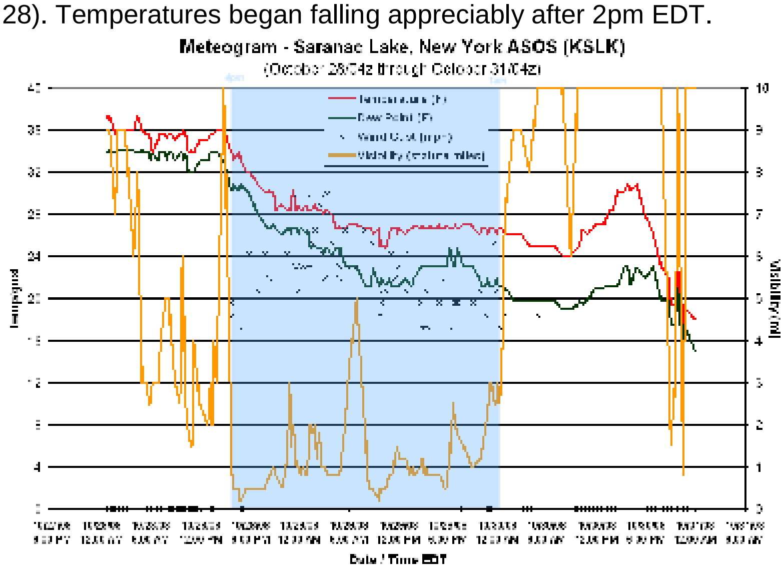


Fig 28. Meteogram (time series analysis) for Saranac Lake, NY ASOS. Shaded region shows period of prolonged snowfall and reduced surface visibility. Click on image to enlarge.

Conditions began to change during the mid to late afternoon hours on October 28th. At 28/21z, mosaic composite radar reflectivity imagery (Fig. 29) had become much more widespread across northern New York, while also being affected by "bright banding" due to melting snow aloft in vicinity of the Champlain Valley. At this time, the surface low had reached the upper Connecticut river valley. At 28/21z, surface temperatures fell to 33F at KSLK and that marked the beginning of prolonged accumulating snow at that location. Visibility during the next 30 hours was generally below 3 miles in snow, and briefly down to 1/4 mile. The accumulating snow ended during the early morning hours on October 30th. Wind gusts had also increased and were near 30 mph at times between 29/04z and 29/06z (Fig. 28). Although falling mostly as rain, precipitation reached its heaviest at KBTV between 28/18z and 29/00z with a 6-hrly accumulation of 0.70".

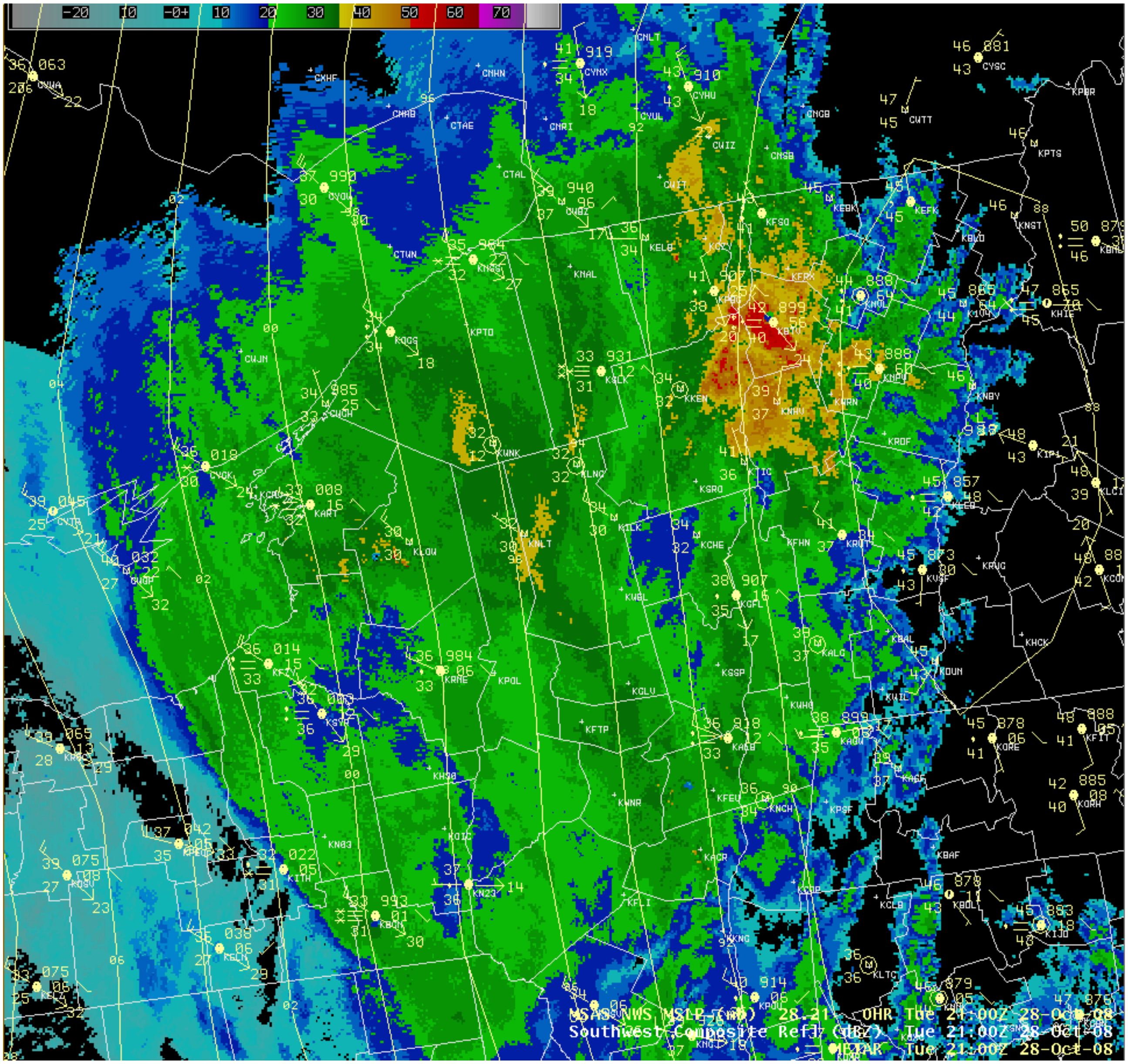
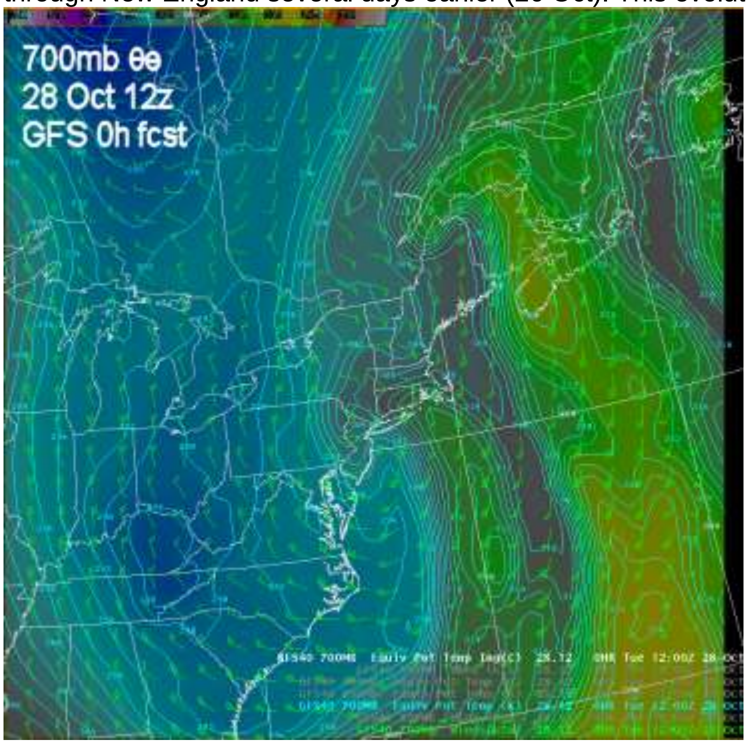
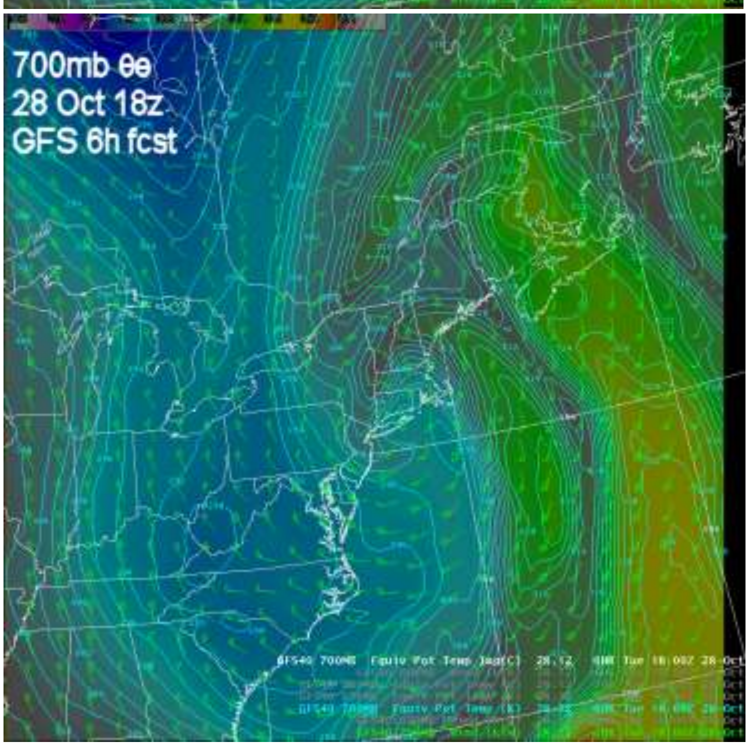


Fig 29. Mosaic radar imagery at 21z October 28th. Also shown are surface observations and sea-level pressure (2mb contour interval). Click on image to enlarge.

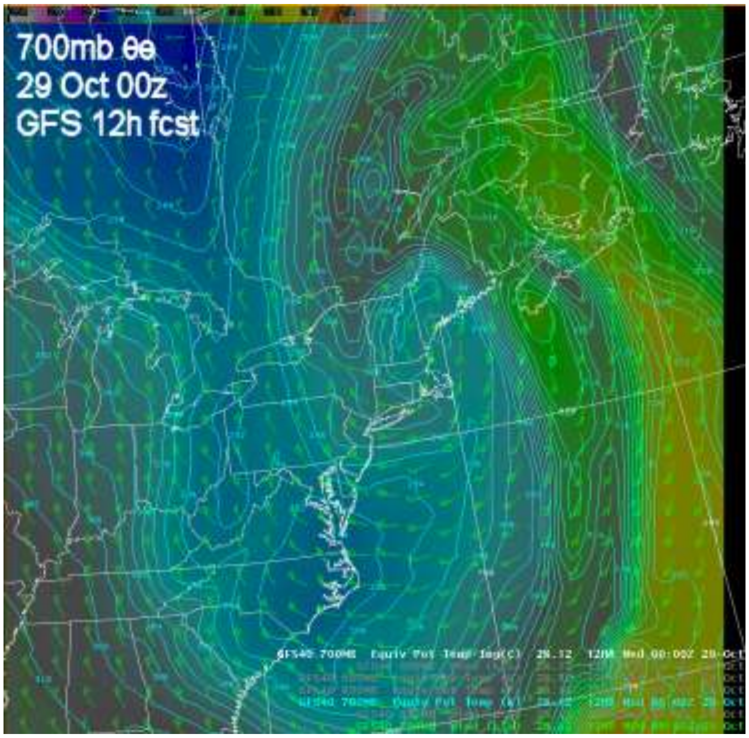
Consistent with the 850mb warm advection (Fig. 12) and trajectory analysis (Fig. 13) shown earlier, a trough of warm-air aloft (or TROWAL) airstream evolved across northern New York late on October 28th and was coincident with the period of heaviest precipitation across the area, including heavy snow at the higher elevations of New York. The 28/12z run of the GFS shows the migration and eventual merger of two 700mb theta-e ridges associated with the warm conveyor belt on the western periphery of the low track by 29/00z (12h forecast). This formed the organized TROWAL during the afternoon and evening on 28 Oct. It appears that the easternmost theta-e axis was left from the stalled frontal boundary that past through New England several days earlier (26 Oct). This evolution is shown in Fig. 30 a-c.



(a)



(b)



(c)

Fig 30. The operational 28/12z GFS 700mb equivalent potential temperature (theta-e, K) and wind (kts) at (a) 28/12z (00h forecast), (b) 28/18z (06h forecast) and (c) 29/00z (12h forecast). A pronounced TROWAL extends north to south across far Northeastern New York at 29/00z.

A GFS model vertical cross-section at 29/00z (Fig. 31) shows a strong upward vertical motion signature (absolute magnitude greater than 20 microbars/s) within the TROWAL, likely a combination of large-scale warm advection and frontogenetic forcing mechanisms. The strong vertical motion also occurred through the dendrite growth layer (ambient temperatures of -12C to -18C) as shown in Fig. 31. The "folding" of the theta-e contours above the UVV max is indicative of conditional instability present in the 450-350mb layer over the northern Adirondacks.

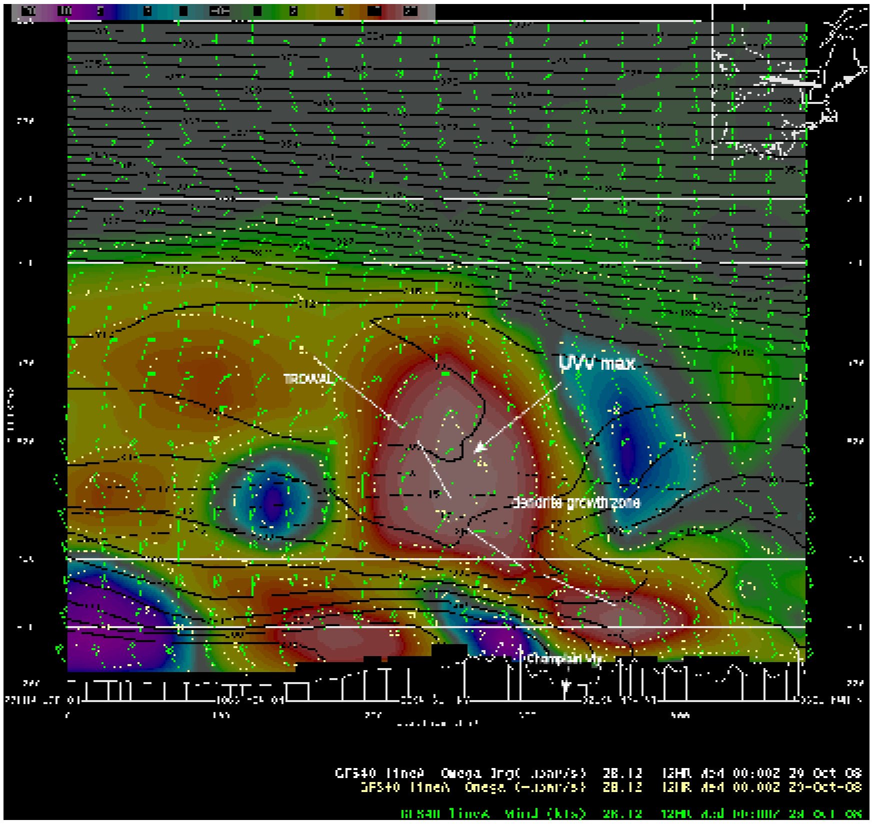


Fig 31. The 12z GFS model vertical cross-section valid at 29/00z (12 hr forecast). Black solid lines are contours of equivalent potential temperature (theta-e). Dotted lines indicate negative omega, with warm (cold) color-filled areas corresponding to areas of ascent (descent). The -12C, -15C and -18C isotherms are shown as dashed black lines. This region is favorable for dendritic snow growth. The intersection of the plane of the cross-section with the ground is shown in the upper right. Click on image to enlarge.

An 88-D KCXX radar reflectivity cross-section taken from the Northern Adirondacks east-northeastward into north-central Vermont (Fig. 32) at 28/2053z shows the well-defined bright banding associated with melting snow aloft (maximized in the 950-900mb layer) across the Champlain Valley and along the western slopes of the Green Mountains. The RUC-derived freezing level at 28/21z slopes downward from near 800mb over north-central Vermont, to near 925mb (near ground level) across the Northern Adirondacks.

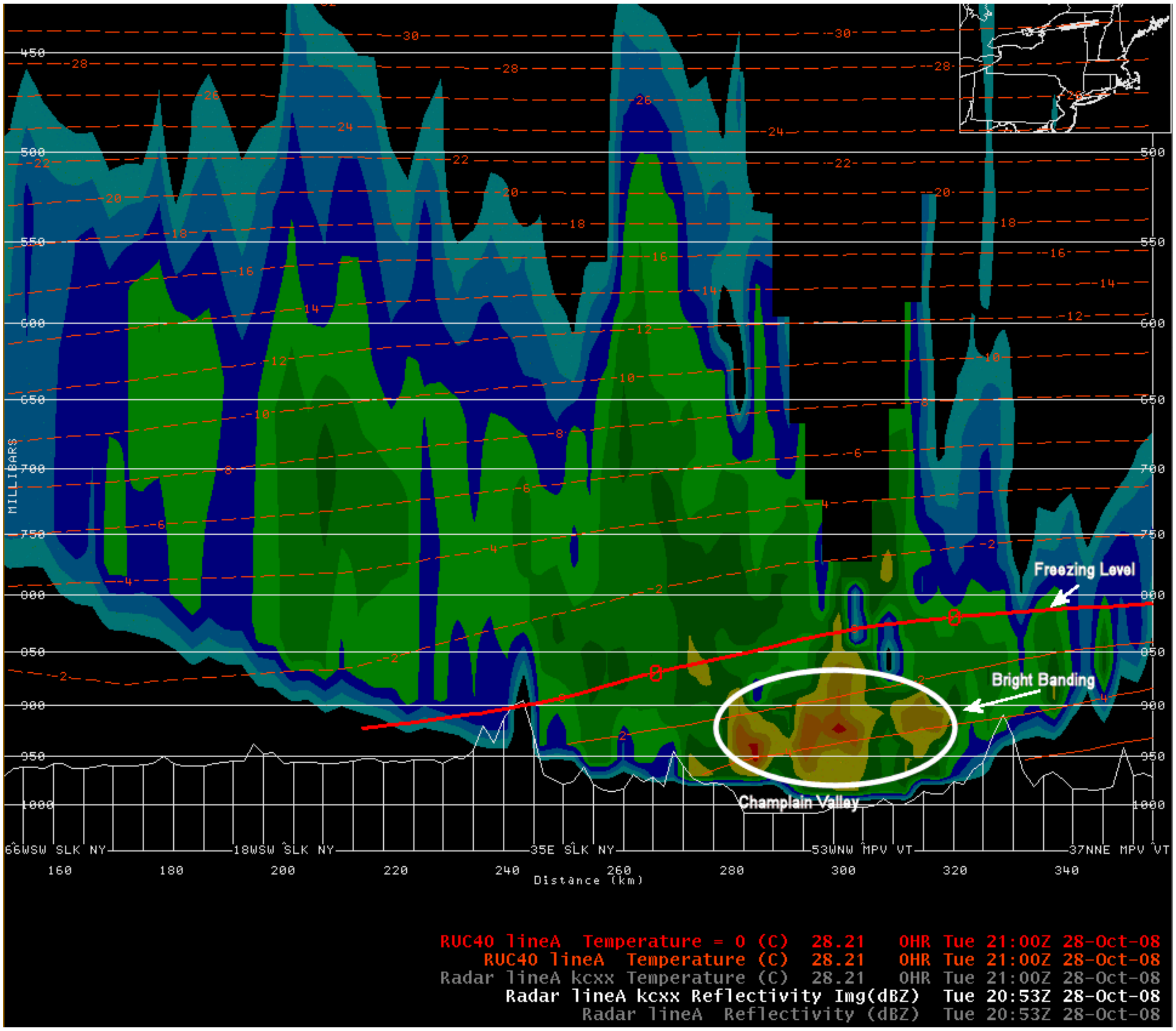


Fig 32. KCXX radar reflectivity (dBz) cross-section at 28/2053z, juxtaposed with 0h RUC model temperatures at 28/21z. The intersection of the plane of the cross-section with the ground is shown in the upper right. Click on image to enlarge.

The displacement of the bright banding feature downward toward the ground in and near the Champlain Valley is evident in this loop of radar reflectivity from 2058z through 2350z, as rain changed to wet snow with cooling temperatures aloft during this time period. Light snow accumulations would occur across the Champlain Valley during the late evening hours on 28 October into the early morning hours on 29 October as the surface low tracked northward into Quebec. Accumulating snow would also continue in the heavy snow accumulation area of Northern New York through the 29th with wraparound moisture and orographic ascent into the Adirondack Mountains. Additional snow would also occur along and downstream of the Green Mountains in Vermont with 850mb northwesterly winds of 35-40 kts through much of October 29th, before ending during the evening hours.