An Overview of the December 11-12th, 2008 Winter Storm

A winter storm brought moderate snow accumulation across much of Northern New York as well as Central Vermont and significant ice accumulation across Southern Vermont from 11th through 12th of December 2008. The surface low tracked from the Gulf Coast across the Mid-Atlantic northward through southern New England and into Northern Maine. Impacts included widespread power outages in Southern Vermont due to freezing rain and hazardous travel conditions throughout Northern New York and Central Vermont due to the combination of high water content snow and freezing drizzle. Moderate icing occurred across Southern Rutland and Windsor Counties, with the greatest ice accumulation and most damage, being observed across Bennington and Windham Counties in Vermont.

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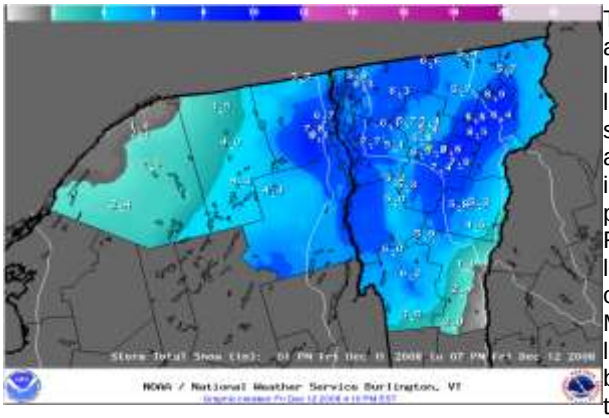

Total snowfall amounts (Fig. 1) ranged from 1-9 inches across the North Country with the heaviest snow located from Eastern NY through Central VT were a large swath of 5-9 inches of snow fell. The highest snowfall totals were reported from Lyndonville, VT (9") and Randolph, VT (8.5"). Lesser amounts of snow fell in the Saint Lawrence Valley (1-3") as the heaviest precipitation was east and south of this area. Southern Rutland and Windsor Counties in VT also received less snow (1-3") due to the snow quickly transitioning over to freezing rain on the evening of Dec 11th. Moderate ice accumulations occurred in these locations with .25 - .50 inches of ice accumulation with both Rutland and Springfield receiving 0.50" of ice on top of the snow. There was also a brief period of freezing rain and drizzle across Central VT on the morning of the Dec 12th with only a thin coat of ice reported across the region.

Surface Analysis

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On the evening of Dec 10th a wave of low pressure was developing in the Gulf States on a stalled out cold front (Fig 2 right). Meanwhile an area of high pressure was located over southern Ontario, Canada establishing a cold continental polar air mass over the area. This surface area of high pressure was responsible for keeping sub freezing air locked in across the region at the surface over the next 2 days.

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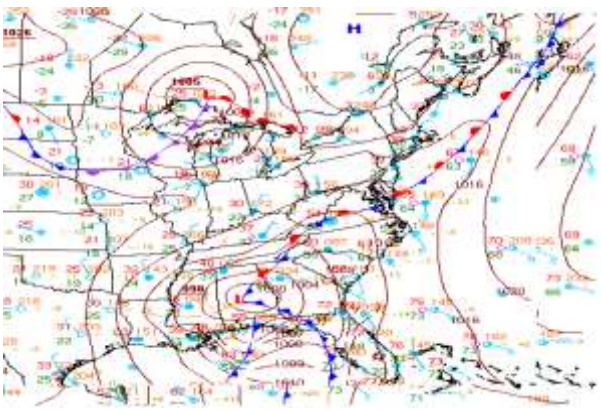
At 12UTC (Universal Time Coordinate) (7 AM) on 11 December 2008, surface low pressure began to strengthen across a stalled frontal boundary draped over the southeast United States (Fig 3 right). Meanwhile, high pressure was located over Quebec Province in Canada, with a cold front across Southern New England. This created a strong temperature contrast across the region, with cold northeast winds converging with warm moist southerly winds. This battle of air masses, along with abundant low level moisture, helped to enhance precipitation across the region, well ahead of the developing area of low pressure in Alabama.



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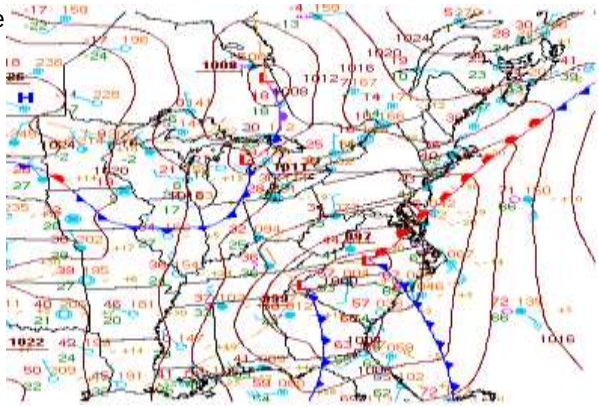
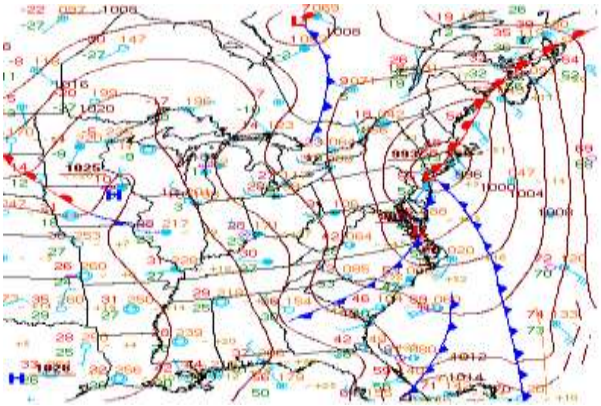
By 00 UTC (7 PM) 2008 11 Dec 2008 the primary surface low tracked to Northern Georgia, before it weakened and transferred energy to a secondary area of low pressure, which developed on the eastern side of the Appalachian Mountains. This was analyzed by the Hydrological Prediction Center (HPC) surface analysis Dec 12th 00 UTC (Fig 4 right). The stationary front located south of New England began to move back north as a warm front, as strong southerly flow developed in the warm sector of the developing Mid-Atlantic surface low.



By 12 UTC (7 AM) 12 Dec 2008, the Mid-Atlantic low tracked off Atlantic Seaboard and strengthen to a 993mb area of low pressure located over Long Island. (See Fig 5 below) The associated surface warm front pushed inland through coastal New England, but the front was unable to push through interior New England were a cold polar airmass was firmly entrenched. A northeast surface analysis on 12 Dec 2008 at 12 UTC (Fig 6 below) shows a strong temperature gradient across New England with temperatures in the mid 50s across Cape Cod and only in the mid to upper 20s across Central and Northern VT.



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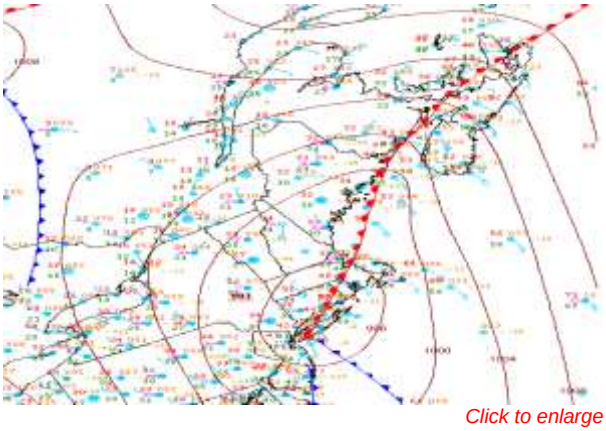

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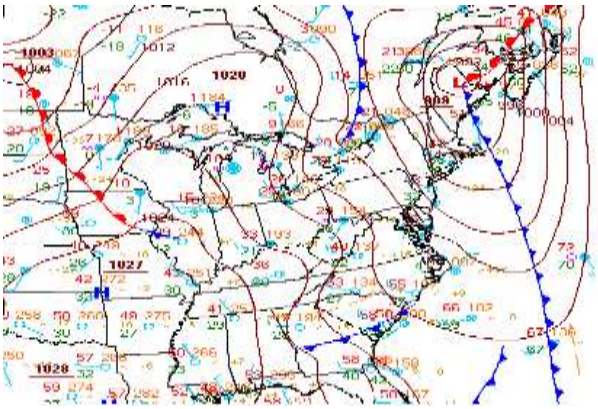
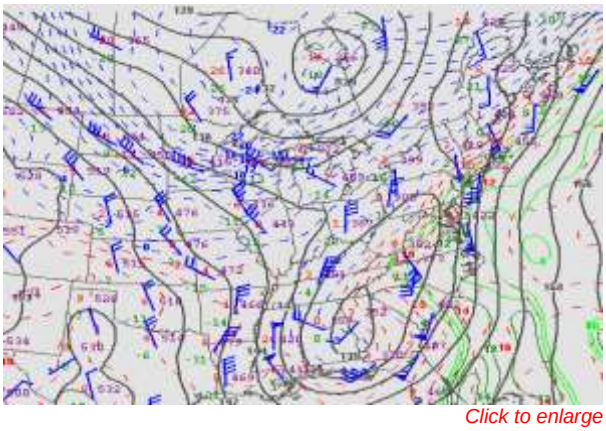
By 00 UTC (7 PM EST) on 12 Dec 2008, surface low began to pull away from the area and moved into Northern Maine (Fig 7 right) bringing the steadier precipitation to an end. Some light wrap around snow showers lingered in the mountains of Vermont and New Hampshire. Overall, the surface low deepened while moving up the Atlantic Seaboard but rapid cyclogenesis was not observed.



Upper Air Analysis

a. 850mb Analysis

Moderate 850mb warm air advection accompanied this system with a tight baroclinic zone located across southern New England on Dec 12th at 00 UTC. The 850mb baroclinic zone strengthened and slowly moved north from Dec 12th 00 UTC through 12 UTC as the southerly flow increased from 15kts at 00UTC to near 50kts by 12 UTC on Dec 12th. The 850mb upper air analysis shows this increase in wind speed on Dec 12th (Fig 8 & 9). During the evening of Dec 11th the 850mb freezing line slowly moved north allowing the precipitation type to change from snow to a sleet and freezing rain mix across the Mid Atlantic States. The Dec 12th 12UTC upper air analysis shows the 850mb 0C isotherm located across Central Vermont. The 850mb low center tracked just south of Vermont on the morning of Dec 12th with the upper level flow becoming westerly advecting cold air back into the area.



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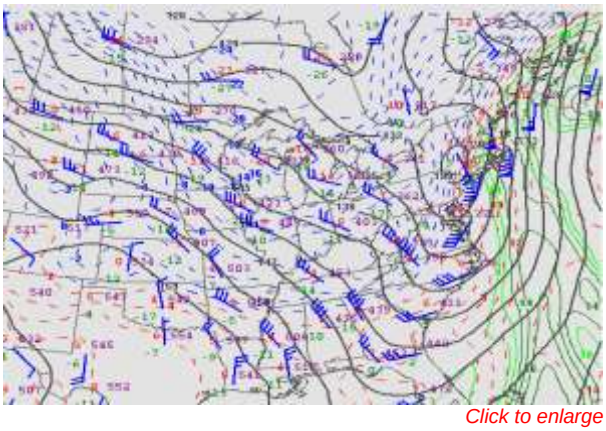

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b. 700mb Analysis

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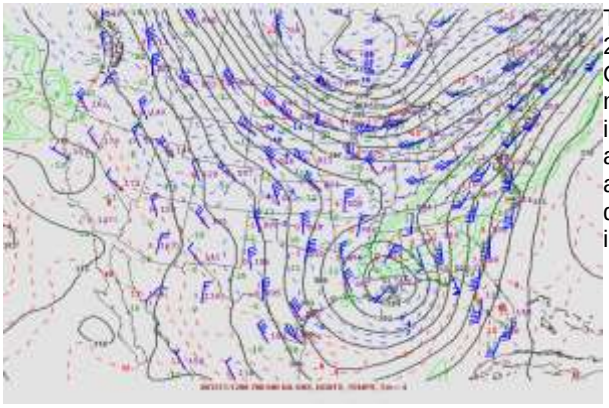

The 700mb analysis at 12 UTC (7 AM LST) on 11 Dec 2008 (Fig 10 left) showed a strong closed low over New Orleans with an additional 700mb trough and associated northern stream energy across central Ontario province in Canada. An increasing southwest flow aloft, helped to advect warm moist air into the Northeast United States, ahead of this developing full latitude 700mb trough. Small dewpoint depressions across southern New England indicate the deep moisture fetch this system had.

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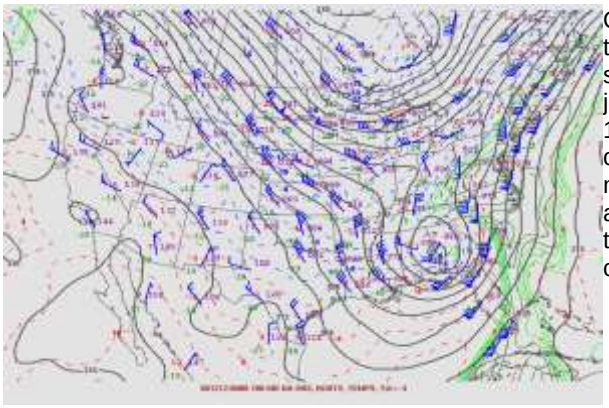

On the evening of Dec 11th the closed 700mb low began to lift out of the south as the 700mb jet began to strengthen over the Atlantic Seaboard. Note the 80 knot jet over South Carolina on 12 Dec 2008 at 00 UTC (Fig 10 left). Flow over the Northeast became even more confluent on the evening of Dec 11th as winds turned more southerly across southern New England. The approaching 700mb trough axis across Ontario continued to approach the Northeast further enhancing the confluent flow.

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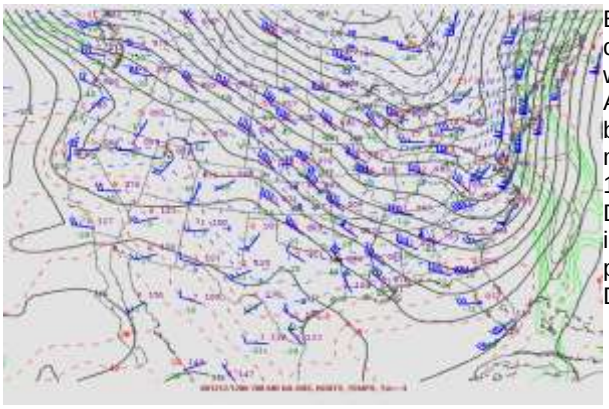

By the morning of Dec 12th (Fig 12 left) the 700mb closed low over the Gulf Coast States became an open wave and rapidly progressed north, toward the Mid Atlantic States. The 700mb trough across Canadian began to merge with the southern stream trough as they moved through the Northeast during the day on Dec 12th. Mid-level flow became westerly by midday on the Dec 12th as the trough moved through the area ushering in colder and drier air aloft. This changed any remaining precipitation back over to snow during the afternoon on Dec 12th.

c. Frontogenesis

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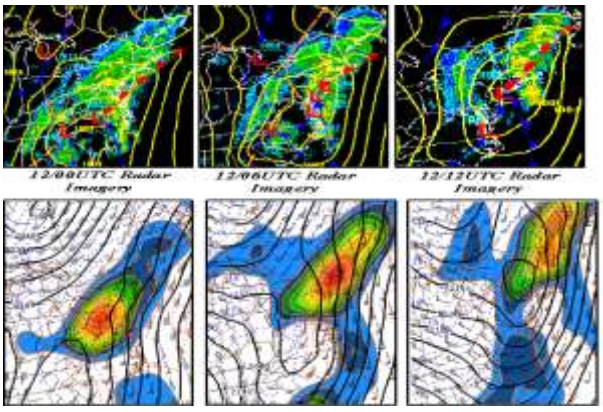

This system exhibited strong 850-700mb horizontal frontogenesis during the night of Dec 12th, when the heaviest snowfall and freezing rain occurred. Areas of strong frontogenesis help forecasters identify regions of heavy rain or snow potential. The previous 850mb and 700mb analysis showed strong convergence resulting in a tightening temperature gradient from Dec 12th 00 UTC through 12 UTC over the Mid-Atlantic state into the Northeast. Fig 13 shows the 850-700mb frontogenesis image from 12/00 UTC through 12/12 UTC in 6hr increments. Fig 13 depicts radar imagery concurrent with the frontogenesis images. Notice how the precipitation shield enhancement lines up quite well with the strongest frontogenetic forcing from 00UTC -12UTC. By Dec 12/12 UTC the frontogenetic forcing moved east of Vermont into New Hampshire and Maine. This explained why precipitation rates decreased rapidly by 12 UTC on 12 Dec 2008. In addition, dry air moving in aloft further helped to decrease the areal coverage and intensity of the precipitation across the forecast area. Another forcing mechanism which occurred occurring besides frontogenesis was isentropic lift. There was strong overrunning (warm moist air overriding cold dry air at the surface) especially across Southern Vermont, which also enhanced lift across the region. The combination of the two forcing mechanisms led to the heaviest snowfall and rainfall rates during this 12 hour period.

d. 500mb Analysis

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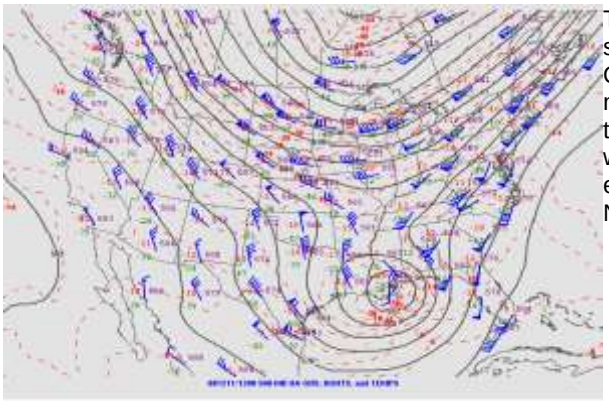

The 500mb analysis on Dec 11th 12 UTC (Fig 14 left) showed an anomalous cold core low located over New Orleans with a -24C 500mb temperature. Across the north central U.S. and Central Canada a broad 500mb trough dominated the mid-level tropospheric flow. There was strong confluence over the Ohio River Valley into the equatorial entrance region of a jet streak over the Northeast U.S.

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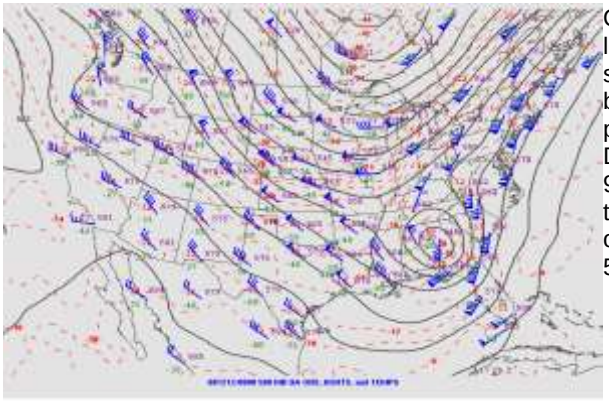

On Dec 12th at 00 UTC (Fig 15 left) the closed 500mb low over the Deep South began to lift north and east as a strong 95 knot jet rounded the base of the trough. The broad 500mb trough over the northern U.S. slowly progressed east with a 85 knot jet streak across the Dakotas entering the base of the trough, while a strong 95 knot jet streak was located downstream of the base of the trough over Maine. Strong confluent flow continued over the Ohio River Valley at the entrance region of a 500mb jet over the Northeast.

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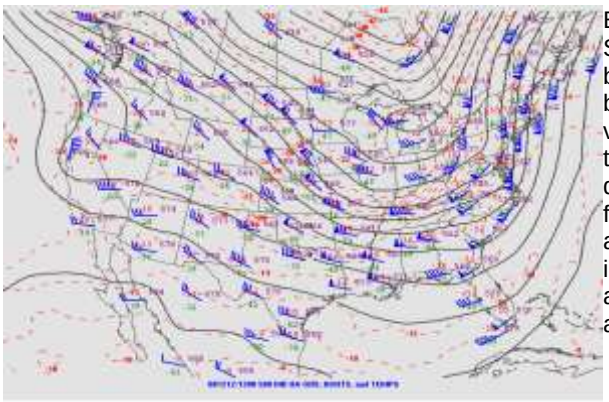

By Dec 12th at 12 UTC the closed 500mb low over the South began to weaken and rapidly lift north (Fig 16 below). In addition, this feature began to merge with the broad 500mb trough located over the northern U.S. A very strong 110 knot jet was located over New Jersey on the morning of Dec12th. This strong jet on the downstream side of the 500 mb trough was responsible for the rapid progression of the 500mb low pressure across the Deep South. As the northern stream trough interacted with the southern stream 500mb low pressure, a negatively tilted mid/upper level trough developed across the Eastern United States.

e. 300mb Analysis

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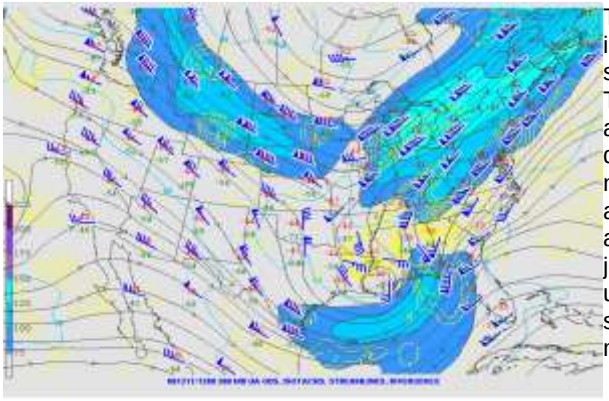

The 300mb analysis on Dec 11th at 12 UTC (fig 17 left) indicates polar jet energy across the northern U.S. with a strong 140 knot jet streak located over the Northeast. This strong jet helped to enhance upper level divergence across the region. Furthermore, a 110 knot jet max was digging into the upper level trough over Montana. The northwest to southeast orientation of the 300mb jet across Montana helped to deep the full latitude trough across the Eastern United States. In addition to the polar jet energy, a subtropical jet of 95 knots was rounding the upper level trough base over Louisiana. The analysis shows very strong upper level diffluence over Georgia moving toward the Mid Atlantic States.

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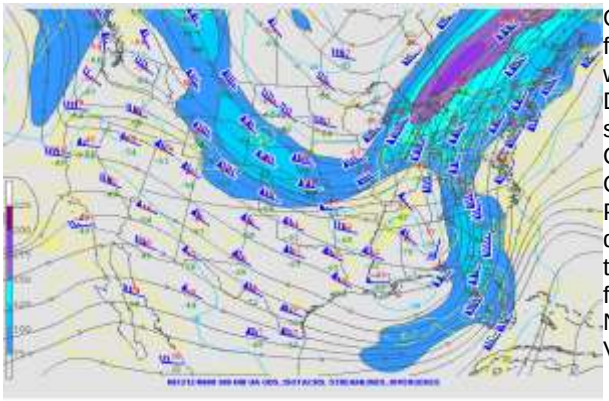

On the evening of Dec 11th the upper-level tropospheric flow had the sub-tropical jet energy beginning to merge with the polar-jet energy over the Eastern Seaboard. The Dec 12th at 00 UTC analysis (Fig 18 left) shows a very strong jet streak of 160 knots located over southern Ontario province. The entrance region (Right Rear Quadrant) of this jet streak was located over Pennsylvania, which is a favorable region for upper level diffluence that induces lift in lower levels of the troposphere. As this jet streak lifted northeast, the favorable region of upper level divergence moved Northern New York as well as Central and Northern Vermont.

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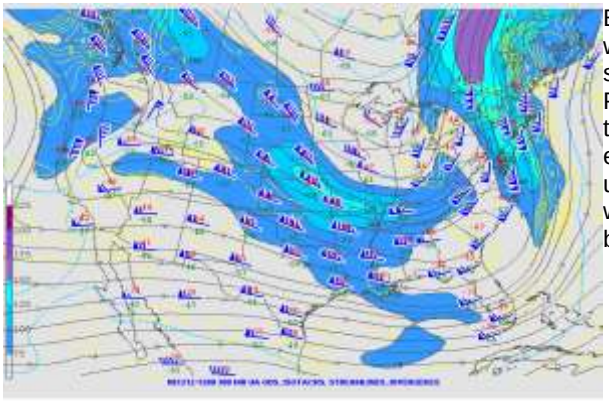
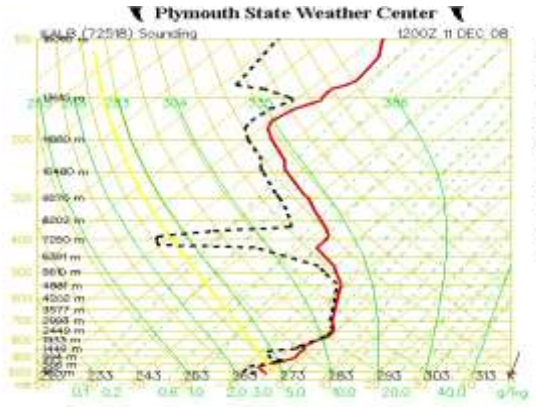


By Dec 12th 12 UTC (fig 19 left) the upper level trough was negatively tilted across the Eastern U.S. with a strong upper level jet streak located over Quebec Province. The strongest upper level diffluence transitioned to Maine and was co-located with the equatorial entrance region of another jet streak. The upper level trough continued to lift out during the day, with the upper level trough axis moving east of the area by Dec 13th 00 UTC.

Mesoscale Analysis

The biggest challenge with this system was predicting how far north the freezing rain would move and the timing of the snow to freezing rain/sleet change over. Both of these forecast challenges had large implications of the overall ice accumulation and impacts this storm would have. The surface low tracked well to our south, which placed our southern zones in a favorable region for the heaviest precipitation. The strongest 850-700mb warm air advection and frontogenesis would be over this region.

The observed ROAB sounding from Albany, NY (KALB) was representative of the vertical temperature profile across Rutland and Winsor counties, VT during this event. The 11 Dec 12 UTC, KALB sounding (Fig 20) shows a deep saturated layer from the surface to 500mb with moisture still in the favorable dendritic growth zone (-12C to -18C) were ice crystals form in the cloud layer (needed for snowflake formation). The sounding shows the whole column below 0C line, but southwest flow of warm aloft has developed, with 750mb temperatures just below 0C. Light snow began on the morning of Dec 11th across southern Vermont; Fig 21 shows observations at Springfield, VT from 8:00 am through 11:00 am EST (13 UTC - 16 UTC) on Dec 11th.



8:32 AM	28.4°F	21.2°F	79%	30.12 in	10.0 miles	Calm	Calm	-	NA	Overcast
8:54 AM	28.0°F	21.0°F	79%	30.16 in	10.0 miles	NE	3.5 mph	-	NA	Overcast
9:54 AM	28.0°F	21.0°F	79%	30.17 in	6.0 miles	Variable	3.5 mph	-	0.00 in	Snow	Light Snow
10:21 AM	28.4°F	21.2°F	79%	30.13 in	2.5 miles	NE	3.5 mph	-	0.00 in	Snow	Light Snow
10:37 AM	28.4°F	23.0°F	83%	30.12 in	3.0 miles	NNE	4.6 mph	-	0.00 in	Snow	Light Snow
10:54 AM	28.0°F	21.9°F	78%	30.15 in	6.0 miles	NNE	3.5 mph	-	0.00 in	Snow	Light Snow

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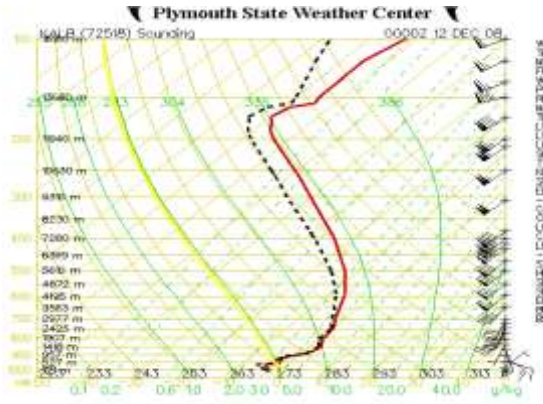
During the afternoon of Dec 11th warm air advection in the mid-troposphere continued out of the southwest, which produced a deep warm layer of air above 0C from 900 to 750mb. By early evening on Dec 12th at 00 UTC, KALB sounding (Fig 22 below) indicated the warm layer with a sufficient thickness (~ 3000ft) to melt any frozen precipitation. The max temp in the warm layer was +3C at 850mb. (Fig 22 below) Notice the below freezing layer from the surface to 900mb which wasn't quite deep enough to refreeze the rain drops before they hit the surface to create sleet. This represents a classic freezing rain sounding, which was observed across southern Vermont, greater Albany area, and southern New Hampshire. Fig 23 shows meter observations from Springfield, VT indicating below freezing surface temps and freezing rain.



7:03 PM	30.2°F	28.4°F	93%	29.99 in	4.0 miles	Calm	Calm	-	NA	Rain	Light Freezing Rain
8:07 PM	30.2°F	28.4°F	93%	29.95 in	4.0 miles	North	4.6 mph	-	NA	Rain	Light Freezing Rain
8:54 PM	30.9°F	28.9°F	92%	29.96 in	6.0 miles	Calm	Calm	-	NA	Rain	Light Freezing Rain
9:04 PM	30.2°F	28.4°F	93%	29.94 in	7.0 miles	NNW	3.5 mph	-	NA		Overcast
9:54 PM	30.0°F	27.0°F	88%	29.94 in	5.0 miles	Variable	5.8 mph	-	NA		Overcast
10:54 PM	30.0°F	28.0°F	92%	29.91 in	5.0 miles	Calm	Calm	-	NA	Rain	Light Freezing Rain
11:10 PM	30.2°F	28.4°F	93%	29.85 in	5.0 miles	NNE	3.5 mph	-	NA	Rain	Light Freezing Rain
11:32 PM	30.2°F	28.4°F	93%	29.83 in	5.0 miles	NNE	3.5 mph	-	NA	Rain	Light Freezing Rain
11:54 PM	30.9°F	28.0°F	88%	29.82 in	5.0 miles	North	4.6 mph	-	NA	Rain	Light Freezing Rain

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Further north across the Northern Adirondacks and Central Vermont the warm tongue of above freezing air was still moving toward this region. The NAM forecast sounding at Dec 12th 00 UTC (fig 24) indicated below freezing temperatures throughout the column. It is also interesting to note that the snow was just beginning to fall around this time across the greater Burlington area.

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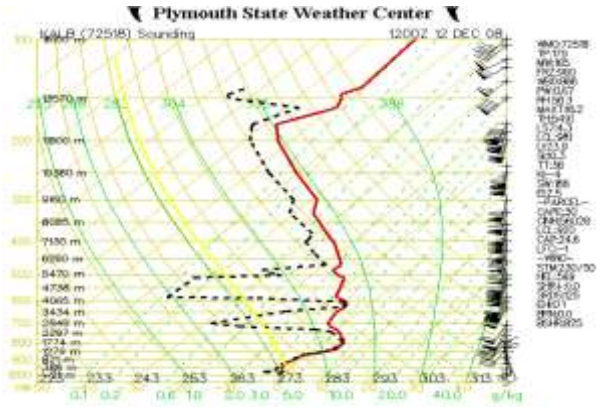

By the morning of Dec 12th the majority of the precipitation for the system had already fallen and the strongest forcing began to shift to the east. Throughout the evening of Dec 11th strong warm air advection continued in the mid-troposphere with the KALB Dec 12th 12 UTC sounding (Fig 25) indicating 800mb temperatures warming to +5C. Surface temperatures across the region were still below freezing, except for extreme southern Windsor County Vermont. Another interesting feature which occurred on the KALB 12 Dec 12 UTC (Fig 25 below) sounding was a large dry slot in the 750 to 500mb layer. This feature had large implications on the sensible weather during the morning of Dec 12th across the entire area. This dry slot was collocated with the dendritic snow growth region of the troposphere. Without any ice crystal formation or moisture in the cloud layer, essential stopped the accumulation snow throughout Central and Northern VT during the morning of Dec 12th.

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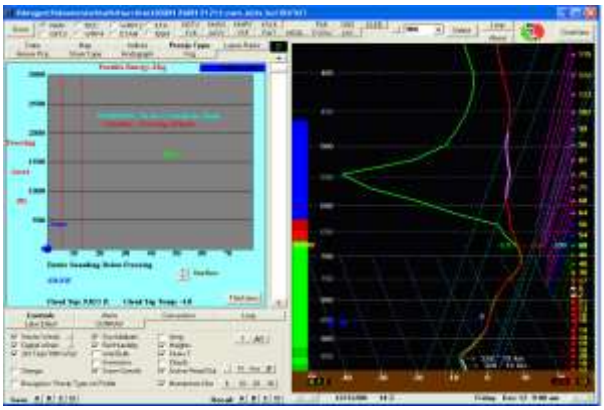
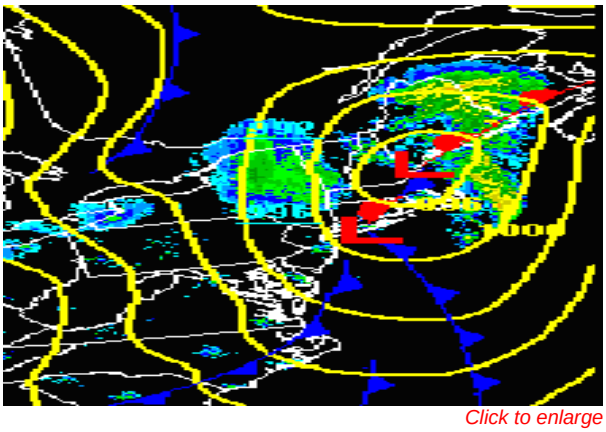


The NAM 12 UTC run on Dec 12th picked up on this feature, but previous runs were not aggressive enough with the amount of dry air in the mid-troposphere advecting into our region. Notice the dry slot in figure 26 from 600 to 500mb layer, aligned perfectly with the -12C to -18C snow growth region. This feature caused a prolonged period of light freezing rain throughout the region. However, as the flow aloft became westerly and colder air ushered backed in the area the light freezing rain turned back to snow during the afternoon of Dec 12th.

Additional snow occurred on the backside of the departing low pressure system due to a weak deformation zone as flow turned westerly with the passage of the mid-level trough axis. (Fig 27 below) The mosaic reflectivity imagery shows the weak backside deformation snow across the area. This deformation zone was strongest over NY were an additional 2 to 3 inches of snow fell. The 24 hour liquid water equivalent (snow, ice and rain) was greatest across southern and eastern Vermont (Fig 28 below) were over 1 inch on average fell. Amounts were less across central Vermont and Essex County NY, were 1 inch on average fell. The Saint Lawrence Valley had the least amount of precipitation with less than 1/2 of an inch.



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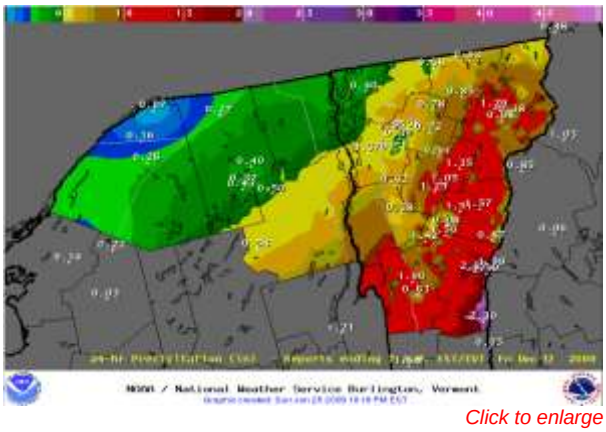

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Conclusions

This system produced a significant precipitation gradient from northwest to southeast across our forecast area. (See figure 28 above) This precipitation gradient combined with a complex thermal profile, made for an extremely difficult winter precipitation forecast for WFO BTV county warning area. The heaviest snowfall totals (5 to 9 inches) occurred just north and west of the mixed precipitation change over line, from northern New York into central and northern Vermont. Meanwhile, the heaviest precipitation amounts (0.75 to 2.00 inches) occurred across central and southern Vermont, but a warm layer aloft resulted in more mixed precipitation and less snowfall. In addition, below freezing surface temperatures resulted in a moderate ice accumulation (0.25 to 0.50 inches) across Rutland, Windsor, and Orange Counties in WFO BTV forecast area.