March 2nd, 2009
Why Little Snow for Central and Eastern Vermont???

This post storm analysis will focus on why limited amounts of snowfall occurred across Central and Eastern Vermont as well as parts of Northern New York on March 1st through March 2nd of 2009. This complex and significant late season winter storm produced up to a foot of snow in Arkansas and Tennessee with many locations from Washington DC to Boston receiving 4 to 12 inches. Furthermore, thunder snow with visibilities below one half mile was reported at Atlanta and Columbus Georgia on 1 March 2009, with severe thunderstorms being observed in the warm sector across southern Georgia and northern Florida. Meanwhile, this complex system with plenty of moisture and upper level support produced very little snowfall across the North Country.

We will examine the pre storm environment across the Eastern United States as well as the middle and upper atmospheric conditions, which resulted in very little snowfall across the North Country. This will include reviewing water vapor and satellite imagery, along with investigating upper air data. Furthermore, we will examine surface observations and trends to conclude why this storm had limited impacts on Central and Eastern Vermont, as well as parts of Eastern New York.

Upper Air Analysis

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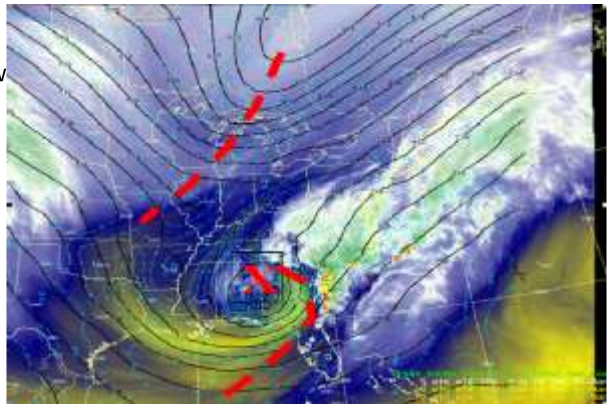

The upper air analysis from 28 February through 2 March 2009 was extremely complicated across the Eastern two thirds of the United States, with a split flow between the northern and southern jet stream. In addition, this complex mid and upper level pattern featured several potent disturbances in the fast jet stream winds aloft, which models struggled to handle correctly. Figure 1 shows a water vapor imagery taken on 1 March 2009 at 15 UTC. Note the very strong disturbance marked with a "red X" in the picture below across southern Georgia, while another disturbance in the northerly jet was located over the Central Great Lakes. Furthermore, plenty of lightning activity was observed in the warm sector over southern Georgia, while abundant mid to upper level moisture was advecting across the Carolinas and Mid Atlantic States, ahead of a deep full latitude trough. Sometimes, the deep vertical development of thunderstorms across the Gulf Stream can block mid level moisture from reaching our region. Otherwise, moisture was associated with strong upper level divergence and good 850 to 700mb frontogenesis.

Upper level divergence is caused by the jet stream winds aloft quickly evacuating the air aloft, which enhances rising motions in the column, and development of surface low pressure. Frontogenesis occurs when warm moist air from the south, collides with cold arctic air to the north, and can produce very heavy precipitation rates in narrow bands, which occurred with this particular storm. Meanwhile, figure 1 shows a well defined dry slot (noted by the darkening on the picture below) across Northern Florida into Eastern Georgia, which eventually played a significant role in limiting snowfall amounts across Eastern Vermont. Finally, note the northern stream energy across the Central Great Lakes is slightly out of phase with southern stream system, which also prevented the surface low pressure from tracking closer to the coast. The red dot lines help to outline the out phased system, with southern stream energy just 3 to 6 hours faster than the northern stream energy across the Great Lakes.

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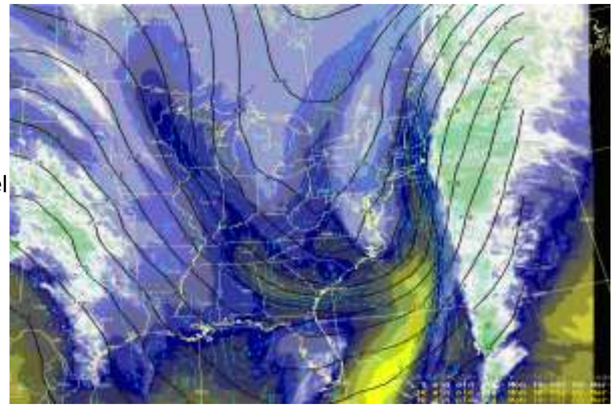

Figure 2 shows the water vapor imagery on 2 March 2009 at 19 UTC. This image below shows a well defined mid and upper level dry slot across Central and Eastern Vermont, which help to limit overall snowfall accumulations. Furthermore, the best deep layer moisture is located along the eastern seaboard and with no phasing or negatively tilted mid/upper level trough this moisture never moved into Central or Northern Vermont, as expected. For this to occur we needed a closed 700mb and 500mb circulation, which is strengthening instead of weakening as it moves across the Eastern United States. Finally, the northern stream energy lagged over the Central Great Lakes, and never interacted with southern stream energy moving along the eastern seaboard, which placed the deep mid/upper level trough axis across the Ohio Valley. We like to see this mid/upper level trough axis across the Mississippi River Valley for significant snow storms across the North Country. These were some of the mid and upper level features, which resulted in limited snowfall across the North Country.

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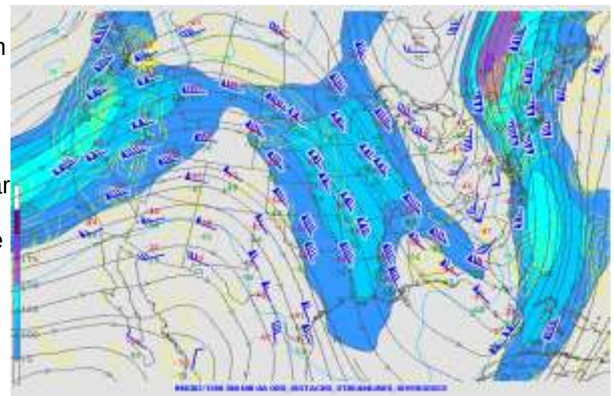

The 300mb upper air analysis at 12 UTC on 2 March 2009 showed a strong dual jet structure off the eastern seaboard with best upper level divergence signature across Eastern New England at 12 UTC. This jet structure implied the best low level convergence caused from strong upper level divergence was located 40 to 50 miles east of Cape Cod. The right rear quad and left front quad of the upper level jet winds are usually a favorable region for surface low pressure development, which was the case for this particular event. However, this favorable region for low pressure development occurred 25 to 30 miles east of Cape Cod, which resulted in limited impacts to our region. Also, the 300mb trough axis was located over the Appalachian Mountains, which is 50 to 75 miles too far east to produce a significant snow for our region.

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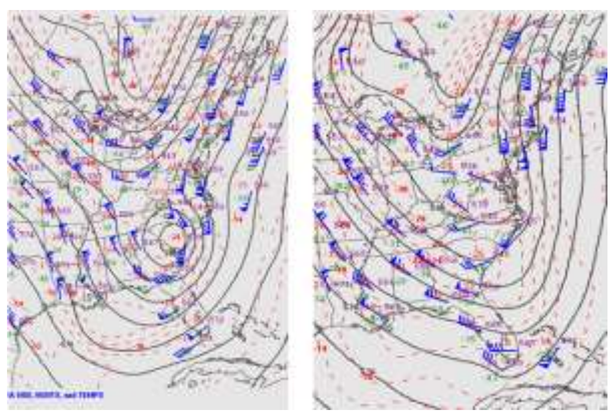

Figure 4 shows the 500mb upper air analysis at 00 UTC (left) and 12 UTC (right) on 2 March 2009. The left image below shows a very deep and well established 500mb circulation across the southeast United States. Meanwhile, the 12 UTC image on the right shows a much weaker 500mb circulation across Eastern Virginia, with south to southwest winds, which prevented deep Atlantic moisture from being pulled back into our region. A closed and negatively tilted 500mb circulation would have advected plenty of deep layer moisture located along the Eastern seaboard, back toward our region. Furthermore, the northern stream trough and associated energy over the great lakes never phased or interacted with the southern stream, which prevent deepening as it tracked toward our region.

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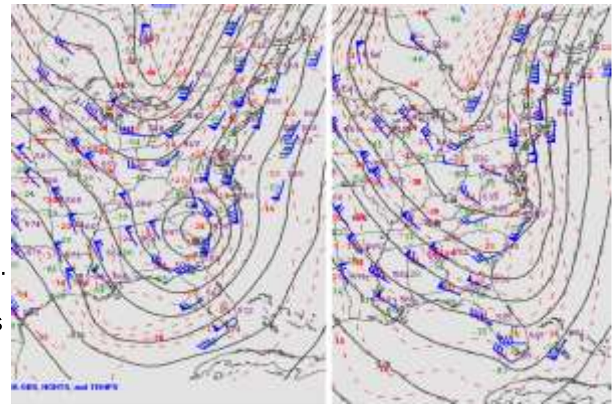

Figure 5 shows the evolution of the 700mb pattern from 00 UTC to 12 UTC on 2 March 2009. Note the well defined closed 700mb circulation across the southeast United States, with a good moisture advection toward the Mid Atlantic. Meanwhile, the image on the right shows a much weaker 700mb circulation at 12 UTC on March 2nd. This weaker circulation was caused by limited phasing of northern stream energy and the fast confluent flow aloft across the northeast United States shearing the system apart. This weakening resulted in limited mid level moisture advection across our forecast area and kept our winds at 10,000 to 20,000 feet above the surface from the southwest, which restricted deep layer moisture from entering our region. Furthermore, the light green lines from the image on the left below, shows the best 700mb moisture across the Eastern Mid-Atlantic States, moving toward Southern New England, with a significant dry slot over South Caroline, near the center of circulation. A very similar pattern was observed at 850mb and 925mb, along with a sharp thermal gradient from the Eastern Mid Atlantic States into Southern New England. The area of low pressure tracked along this low level temperature boundary, which was located from south of Long Island to east of Cape Cod during the event.

Surface Analysis

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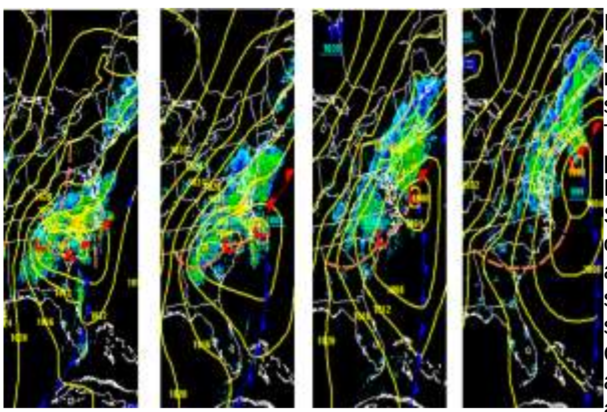
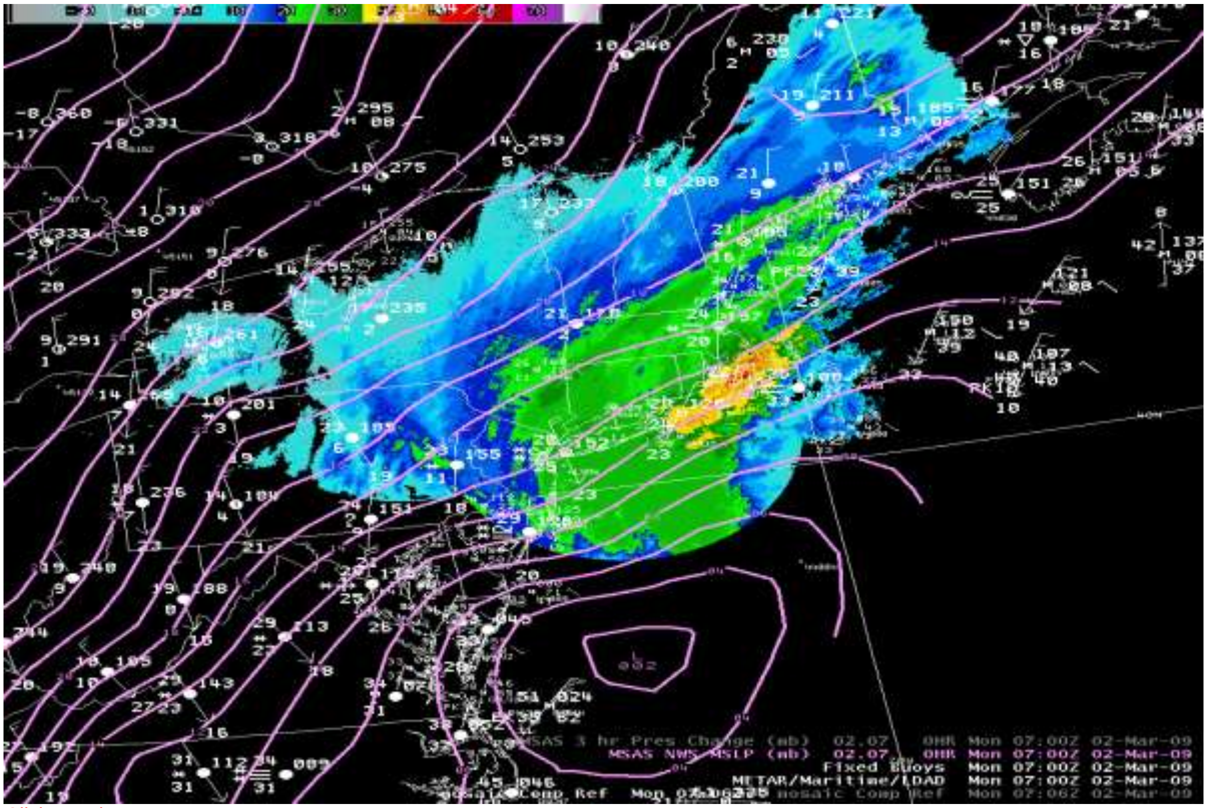


In this section we will examine surface observations and pressure analysis trends during the event, along with radar data. Furthermore, we will investigate why the surface low tracked well south and east of Cape Cod. The first item for discussion will be the surface low pressure evolution from 00 UTC through 18 UTC on 2 March 2009. Note, the surface low tracked from the South Carolina coast at 00 UTC to just south and east of Cape Cod by 18 UTC on March 2nd. This track was along a tight low level thermal boundary, with limited strengthening of the surface low pressure observed. A strong surface high pressure was located over the Central Great Lakes, which provided a very cold and dry air-mass across the North Country on north winds. In addition, the position of the surface high pressure resulted in limited upstream blocking over Eastern Canada, which would have steered the coastal low pressure back toward our region. The prevailing surface flow throughout the event was from the north or northwest, we like to see winds from the northeast to enhance low level moisture and produce significant snowfalls over our region. This track and northerly wind flow prevented the strong/higher reflectivity returns from reaching our region, which is shown in figure 6. Note the strongest returns (brighter colors) are located over the Mid Atlantic and Southern New England region.

Figure 7 below shows a composite reflectivity loop from 07 UTC through 13 UTC on March 2nd. Note the very strong reflectivity returns across Southern New England, which resulted in 8 to 12 inches of snow in about 6 hours. Furthermore, the radar loop shows a very tight southeast to northwest precipitation gradient across the region, with Vermont getting very light returns during the event.



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Moisture, Precipitation, and Forcing Fields

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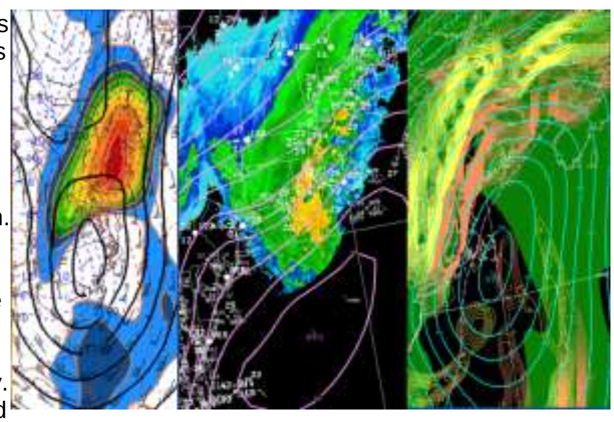

In this section we will discuss the two potential sources for measurable snowfall for this particular event across our Central and Eastern forecast area. Based on the track of the 700mb and 500mb trough and expected movement of the surface low pressure, I thought our first source of measurable snowfall was going to be strong 850 to 700mb frontogenesis forcing and good deep layer moisture advection from the Atlantic Ocean. However, the area of low pressure tracked 25 miles east of the 40N 70W benchmark, which was not handled well by the numerical models. This placed the best forcing and moisture across Southern and Eastern New England, along with the heaviest precipitation, which the radar in figure 8 showed nicely. Meanwhile, figure 8 shows an analysis of the expected 850 to 700mb lift across Southern New England from the RUC and GFS model, along with the radar composite reflectivity display at 12 UTC on 2 March 2009. Furthermore, note the actual position of the surface low pressure in the middle radar picture, compared to the expected position forecasted by the GFS model in the lower right. This variation in the tracked placed the best forcing and heaviest precipitation across Southern New England, with the mid/upper level dry slot impacting Central and Eastern Vermont. The result was much less snowfall, than expected associated with initial band of precipitation.

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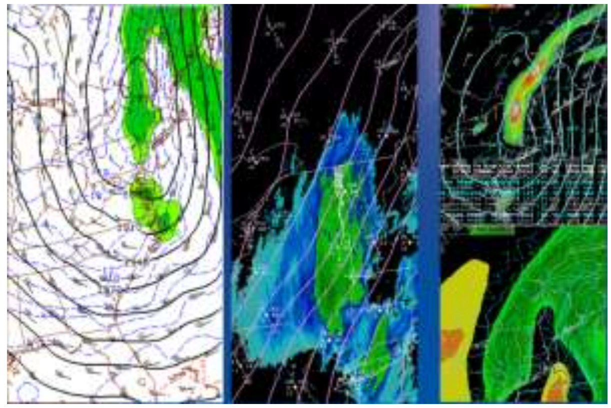

The second band of precipitation was forecast to be associated with the backside wrap around/deformation zone. This precipitation was expected to produce another 3 to 6 inches of snowfall, especially across Central and Eastern Vermont late March 2nd. However, given the track of the mid/upper level dry slot, the best backside moisture axis and associated deformation zone developed across the Champlain Valley and Northern Adirondack Mountains. This area received snowfall amounts between 2 and 5 inches from this second moisture source. Figure 9 below shows the RUC depiction of 12,000 to 20000 above ground level (AGL) moisture on the left, along with the matching radar imagery in the middle, and the GFS analysis of mid level moisture and 700mb lift on the right. Note the composite radar shows the best reflectivity with the heaviest snowfall rates across the Champlain Valley and extreme Eastern Adirondack Mountains. Furthermore, northerly winds down the Champlain Valley, will help to enhance backside moisture in developing. The surface visibilities associated with this backside precipitation ranged from one half to one mile, with one inch per hour snowfall rates occurring at Burlington, Vermont at 21 UTC.

Conclusions

The snowfall map in figure 10 below shows the highest snowfall amounts across the Champlain Valley and parts of the Northern New York. Meanwhile, very light snowfall occurred across Central and Eastern Vermont. From the image below, total snowfall accumulations across Central and Eastern Vermont ranged from a trace to 4 or 5 inches near Walden, while up to 5 inches fell at Burlington, Vermont. Note no snowfall occurred across the Saint Lawrence Valley and only trace amounts to several inches occurred over Windsor County, Vermont on 2 March 2009. This was well below forecast amounts.

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