Central and Eastern U.S. Heavy Precipitation Event – February 24-25, 2011
By: Sean Ryan, HPC Meteorologist

Overview: On 24-25 February 2011, a strong surface low and associated frontal system developed across the lower Mississippi River Valley and moved northeastward through the eastern Ohio River Valley and off the coast of New England. The storm affected most of the eastern U.S. with everything from severe weather to heavy rain and snow. Figure 1 shows the total snowfall accumulations that resulted from this storm system across the Midwest and Northeast.

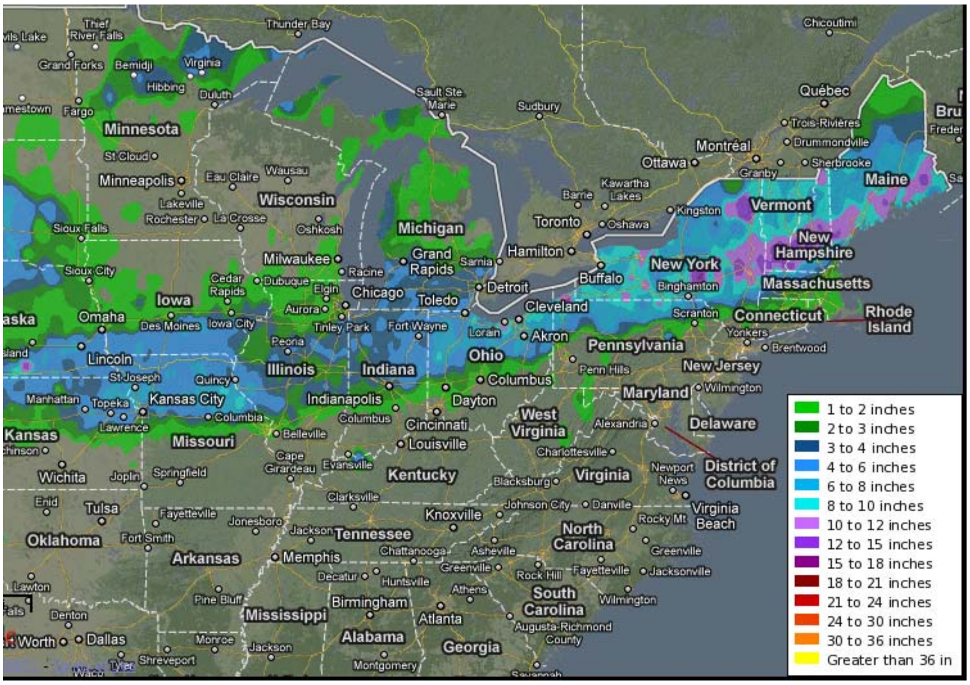

Figure 1: Snowfall accumulations across the north central and northeast U.S. on 24-25 February, 2011.

Snowfall amounts of 4 to 8 inches were common, while many areas of the Northeast received heavier snows of 10 to 15 inches. Across the south central and southeast U.S. rainfall amounts of 2 to 4 inches were widespread, with locally higher amounts. The highest rainfall total reported was just over 6 inches in College City, AR. These heavy rainfall amounts were primarily associated with convection, as strong to severe thunderstorms affected much of the region (fig. 2).

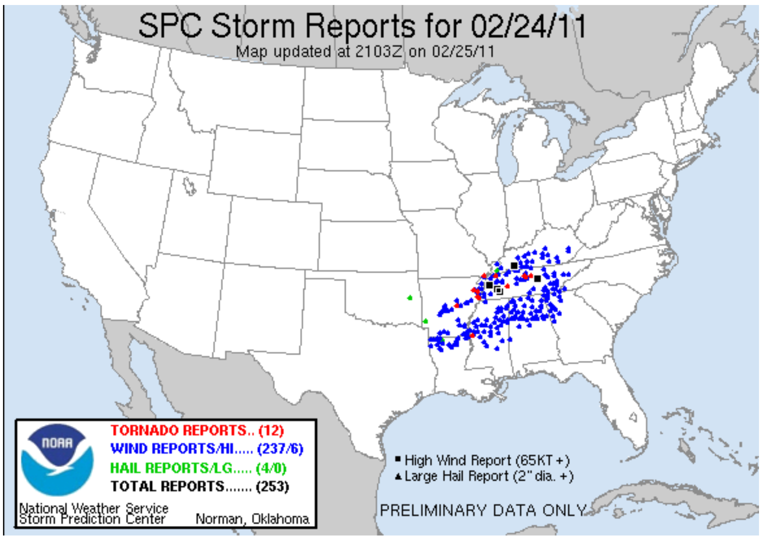

Figure 2: Tornado, damaging wind, and hail reports from 24 February, 2011 (SPC).

Synoptic Pattern: The upper-level pattern present during this event was a split-flow pattern, with both polar and subtropical jets evident at 300 hPa (Fig. 3). Note the trough over the Western U.S. at this time; this was the primary upper-level feature respnsible for the development of the surface cyclone.

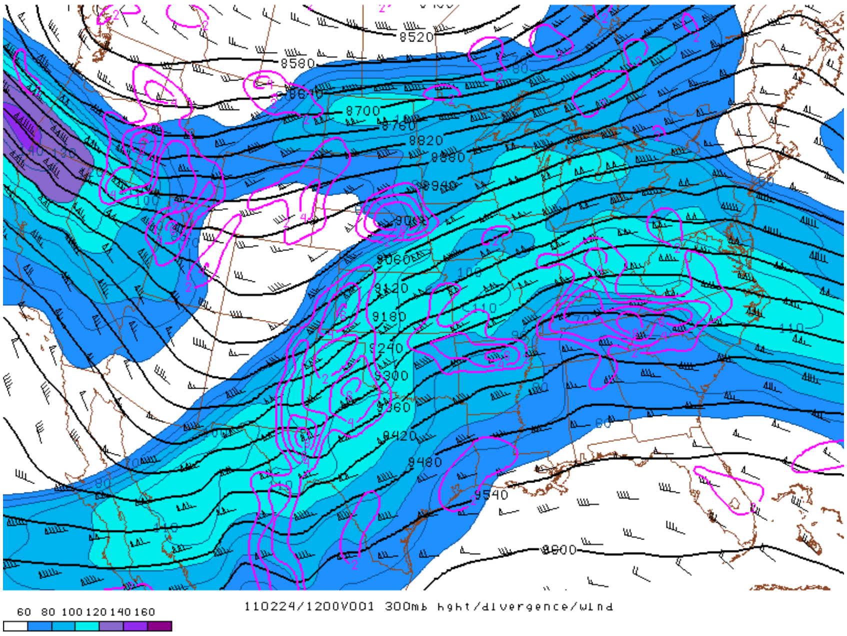

Figure 3: 300 hPa height (black contours, m), wind barbs, isotachs (shaded, kt), and divergence (pink contours, s^{-1}) from 12 UTC on 24 February, 2011.

The majority of the severe thunderstorms associated with this event occurred on 24 February. Intense upper-level divergence (Fig. 3) indicated that substantial ascent was occurring at this time. Low-level warm advection contributed to an increase in the instability and forcing for ascent across the same regions (Fig. 4). As the upper-level trough moved eastward and the surface cyclone strengthened, differential vorticity advection also played a role as a forcing mechanism (Fig. 5).

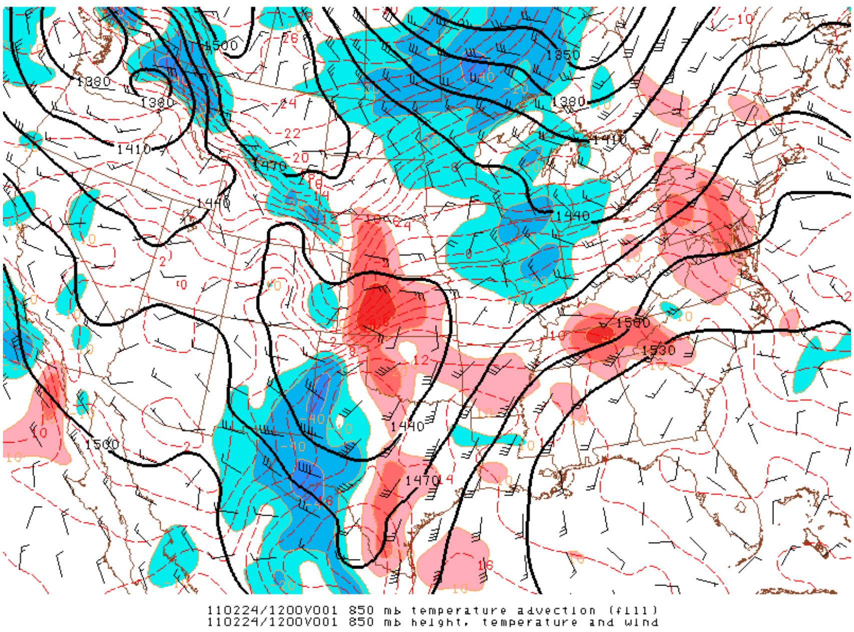

Figure 4: 850 hPa height (m), wind barbs, and temperature advection at 12 UTC on 24 February, 2011. Warm colors represent positive thermal advection and cool colors represent negative thermal advection.

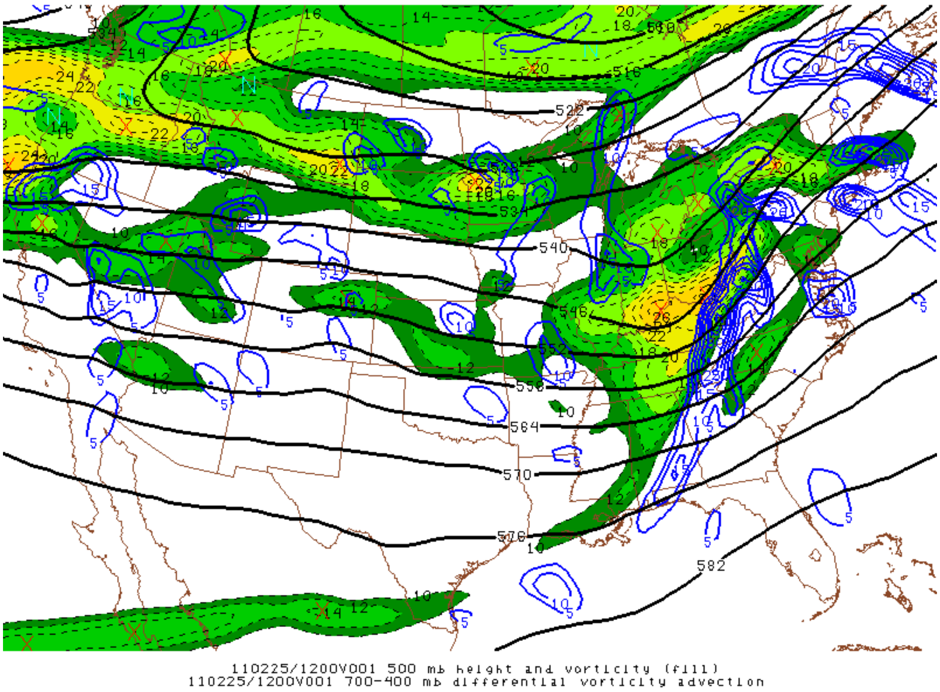

Figure 5: 500 hPa height and vorticity (shaded) and 700-400 hPa differential vorticity advection (contours) for 12 UTC on 25 February, 2011.

A surface analysis from 12 UTC on 24 February (Fig. 6) shows a stationary frontal boundary draped from the Ohio River Valley southward into the southern plains and then north up the eastern slopes of the Rockies. A relatively strong thermal gradient existed in association with the front, with a broad 30 degree (F) temperature gradient noted across the boundary. The presence of this frontal boundary, combined with support from aloft, resulted in ascent, producing showers and thunderstorms, with heavy rainfall.

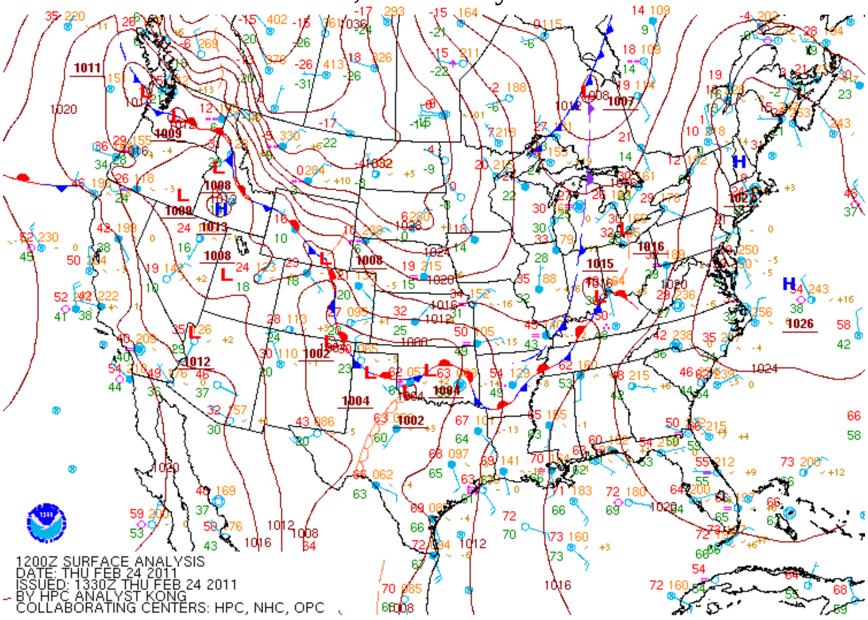

Figure 6: Surface analysis from 12 UTC on 24 February, 2011. (HPC)

As the surface low over the southern plains deepened by 00 UTC on 25 February (Fig. 7) and the precipitation shield north of the front became more organized, widespread moderate to heavy snow broke out across areas from the central plains into the Ohio River Valley and Great Lakes.

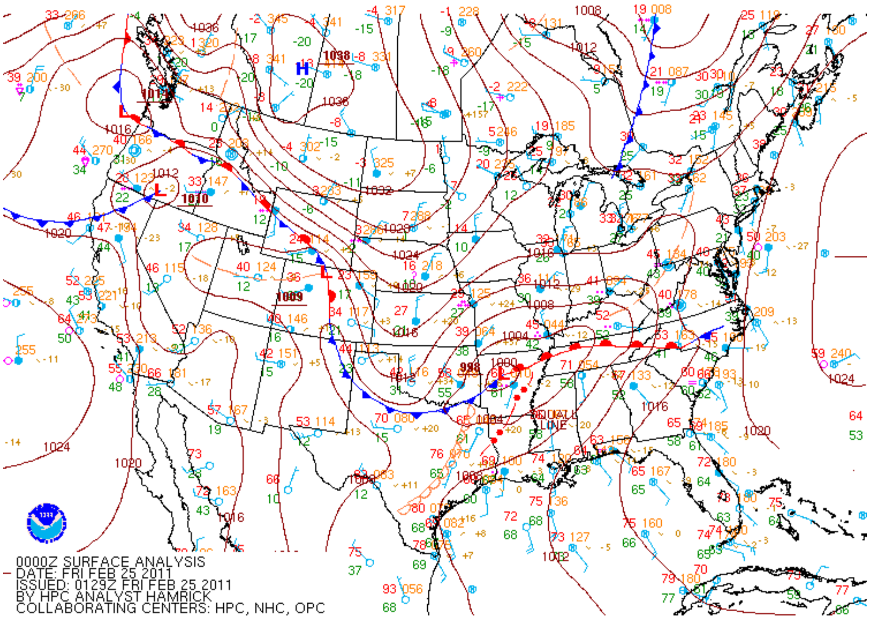

Figure 7: Surface analysis from 00 UTC on 25 February, 2011. (HPC)

Radar imagery from approximately the same time (Fig. 8) shows the large shield of precipitation along and north of the frontal boundary, as well as the squall line that developed in the warm sector across the lower Mississippi River Valley.

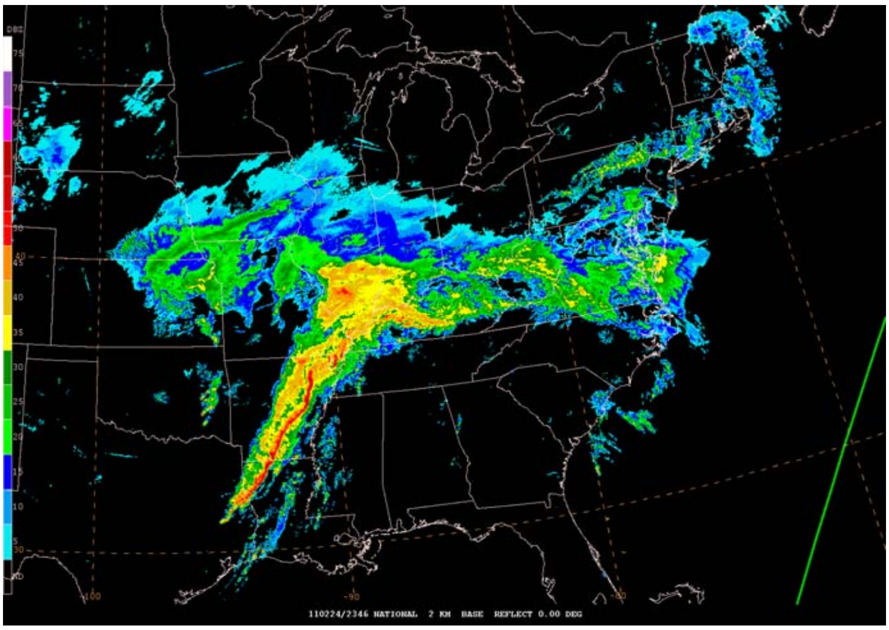

Figure 8: Mosaic reflectivity image from 2346 UTC on 24 February, 2011.

By 12 UTC on 25 February (not shown), the surface low had moved to near the Ohio/West Virginia border and had deepened to 993 hPa. By this time, moderate to heavy snow was spreading into much of the northeastern U.S. By 00 UTC on 26 February (not shown) the surface low had moved offshore of the coast of Maine and deepened to 985 hPa. A mosaic radar image from approximately 18 UTC on 25 February (Fig. 9) shows snowfall across New England as the surface low approaches the U.S. east coast. Snowfall across Maine persisted into early on 26 February before coming to an end.

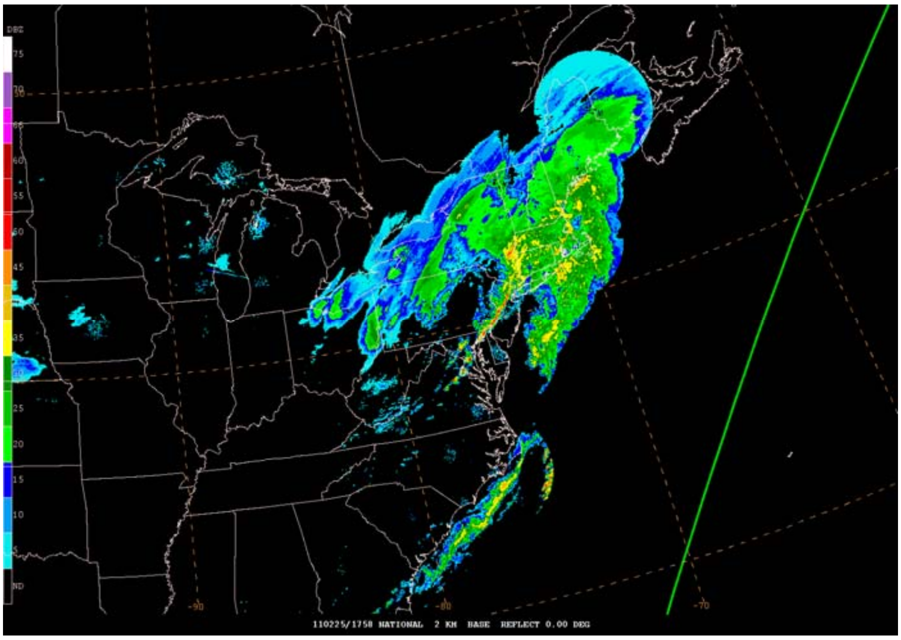

Figure 9: Mosaic reflectivity image from 1758 UTC on 25 February, 2011.

<u>Mesoscale Pattern:</u> Mesoscale features such as frontogenetical forcing can play a significant role in the placement of heavy precipitation bands in mid-latitude cyclones (Schultz and Schumacher, 1999), particularly in the precipitation areas north of the warm front and surface low. An analysis of 850-700 hPa frontogenesis (Fig. 10) from 25 February at 00 UTC (same time as the surface analysis in Fig. 7) shows a large area of intense frontogenesis northeast of the surface low and north of the surface warm front. The radar image from the same time (Fig. 8) shows a large area of moderate to heavy precipitaiton colocated with the intense 850-700 hPa frontogenetical forcing. The strong frontogenetical forcing was colocated with a plume of moisture moving northward from the Gulf of Mexico, as is shown by the 850 hPa dewpoint analysis from the same time (Fig. 11). A plume of moisture is evident by the area of dewpoints greater than 14 deg C being advected northward from the Texas Gulf Coast into the lower Mississippi River Valley.

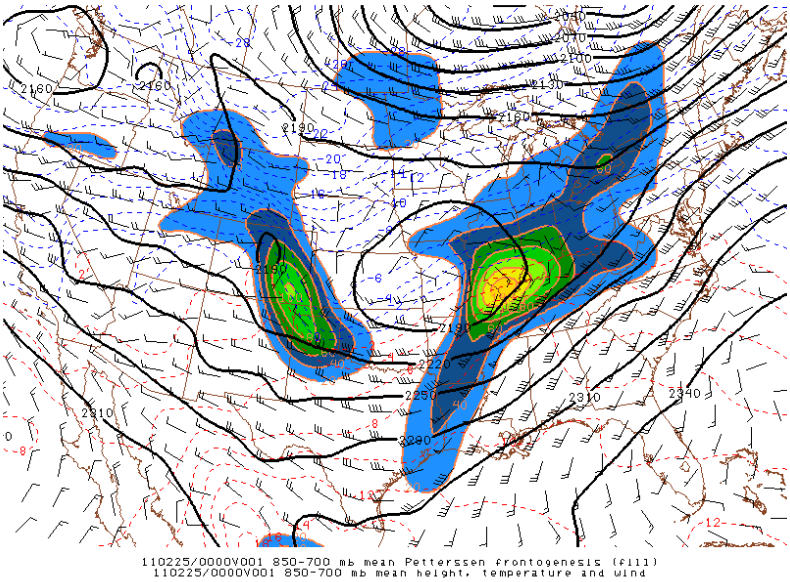

Figure 10: Analysis of 850-700 hPa mean Pettersen frontogenesis (shaded), 850-700 hPa mean height (black contours), mean temperature (red and blue dashed contours), and mean wind barbs from 00 UTC on 25 February, 2011. (SPC)

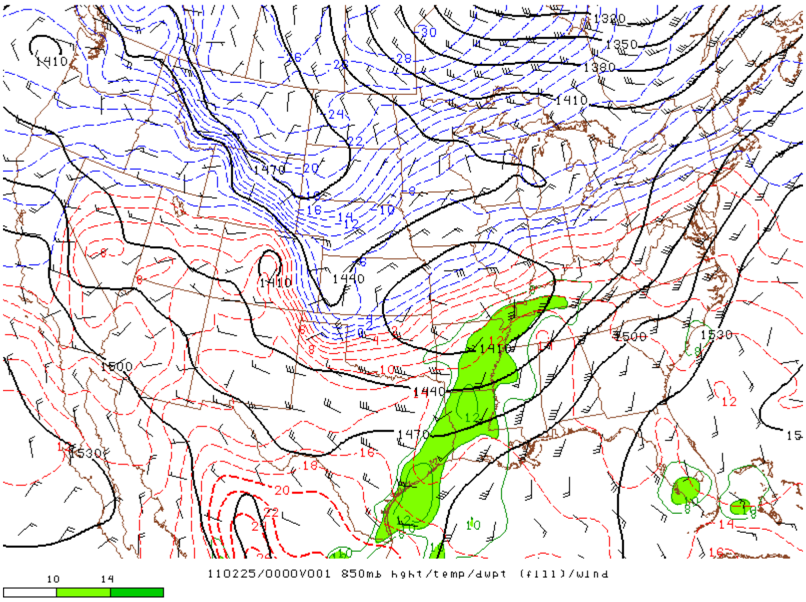

Figure 11: Analysis of 850 hPa height (black contours), temperature (red and blue dashed contours), wind barbs, and dewpoint (shaded) from 00 UTC on 25 February, 2011. (SPC)

By the time of the radar image in figure 8 (18 UTC on 25 February), a plume of Atlantic moisture is evident streaming northward into southern New England (Fig. 12). Frontogenesis at this time was also strongest across New England (Fig. 13).

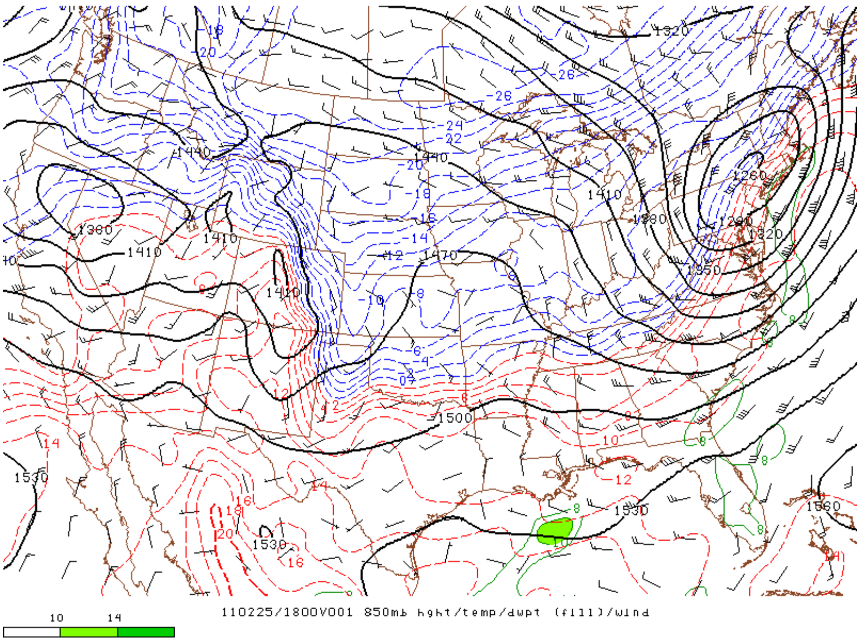

Figure 12: Analysis of 850 hPa height (black contours), temperature (red and blue dashed contours), wind barbs, and dewpoint (shaded) from 18 UTC on 25 February, 2011. (SPC)

A surface analysis from 18 UTC on 25 February (Fig. 14) shows an additional cold front approaching the system from the northwest. The air mass behind this cold front was colder than that behind the more southern cold front connected with the winter storm. The result of this second cold front approaching from the north may have been enhanced frontogenesis as the thermal gradient along the boundaries tightened even more that it had been previously.

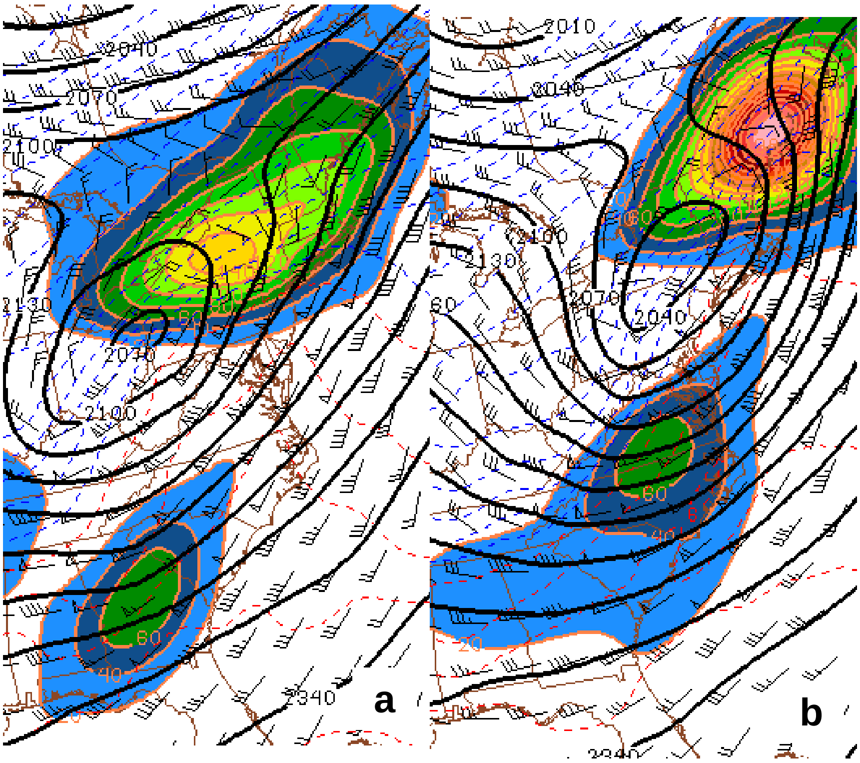

Figure 13: 850-700 hPa mean Petterson frontogenesis (shaded), mean geopotential height (black contours), mean temperature (red and blue dashed contours), and mean wind barbs for (a) 12 UTC on 25 February, 2011 and (b) 18 UTC on 25 February, 2011.

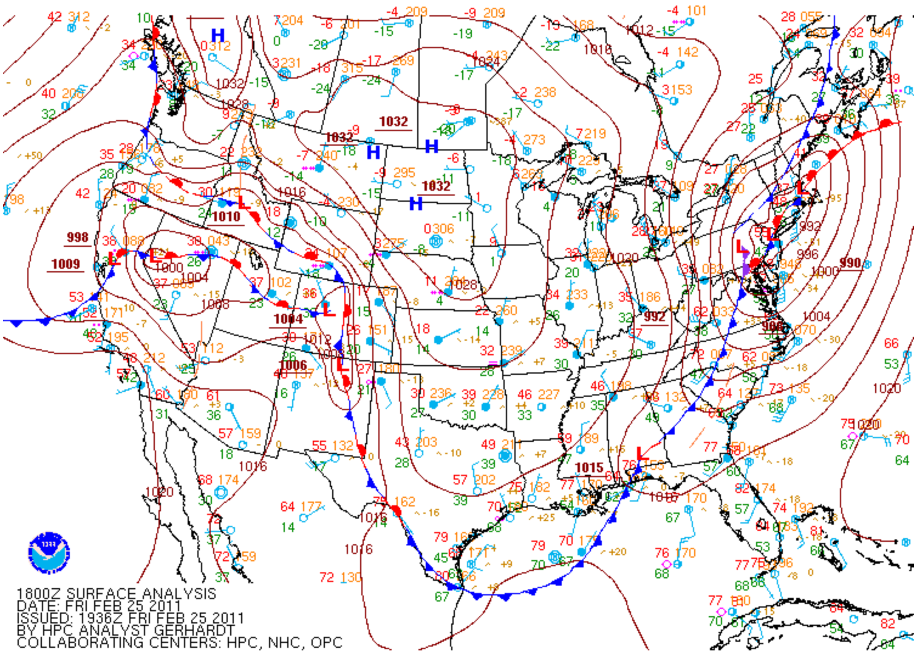

Figure 14: Surface analysis from 18 UTC on 25 February, 2011. (HPC)

An analysis of 850-700 hPa frontogenesis (Fig. 13) shows that frontogenesis did indeed strengthen between 12 UTC and 18 UTC on 25 February, as the surface low lifted northeastward and gradually off the east coast. Strong convergence at 850 hPa is eivdent across New England in Figure 13b with a 70 knot low-level jet entering the region from the south, while the flow beind the northern frontal boundary was northwesterly.

The band of most intense frontogenesis in the 850-700 hPa layer strengthened rapidly as it moved from central New York state northeastward to the coast of east central Maine. This band of strengthening frontogenesis was also positioned in the divergent right rear quadrant of the upper-level jet streak (not shown). Upon examination of the storm total snowfall amounts (Fig. 1), it becomes evident that these are the same areas where the heaviest snowfall (10-15 inches) fell.

Conclusion:

A storm system with wide ranging effects from heavy rain and severe thunderstorms to heavy snow affected the central and eastern U.S. on 24-25 February, 2011. A surface low developed along an initially stationary frontal boundary across the southern plains, and then lifted northeastwards across the Ohio Valley and off the coast of the Northeast. Thunderstorms occurred in the warm sector while heavy rain and snow occurred north of the low and warm front, initially as a result of intense warm advection and frontal lifting across the stationary frontal boundary, and later as a result of intense frontogenetical forcing. As the system moved into the Northeast, a second cold front approaching the region from the north enhanced the thermal gradient and low-level convergence across the region, resulting in increased frontogenesis and an increase in the snowfall intensity. The heaviest snowfall occurred in a band extending from east central New York northeastward to downeast Maine, where as much as 15 inches of snow fell during the storm.

Reference:

Schultz, D.M., P.N. Schumacher, 1999: The use and misuse of conditional symmetric instability. *Mon. Wea. Rev.*, **127**, 2709-2732.