

14 March 2017 “Pi Day” Blizzard

Joe Cebulko (3/30/2017)

1. Introduction

The Pi Day blizzard was a significant coastal storm that dumped a widespread two to three feet of snow over the Northeast United States (US) on 14 March 2017. There were major impacts to travel throughout the day on the 14th and into the 15th. Schools were closed for 2 days in many regions and daily routines were significantly altered. Model guidance was quite good for this event many days in advance. This short summary will focus on the dynamical aspects associated with the coastal storm.

2. Dynamical Understanding

The origin of this historic winter storm was as a positive potential vorticity (PV) anomaly over the West Pacific on 7 March 2017 (Fig.1), a week before the impacts were felt in the Northeast US. This PV anomaly combined with positive meridional wind anomalies resulted a “ping” of the wave guide and triggered a downstream Rossby Wave train amplification. As the amplified flow progressed over the US, other dynamics began to come into play. The 200-300 hPa averaged irrotational winds associated with the developing low-pressure system resulted negative PV advection to the North and South of the low beginning at 0000 UTC 14 March 2017 (Fig.2). The negative PV advection increased the respective upper tropospheric PV gradients and PV frontogenesis commenced. PV frontogenesis is associated with jet-o-genesis, therefore two separately enhanced jet streaks developed within the amplified flow between 0000 and 1200 UTC 14 March 2017 (Fig.2). This coupled jet allowed for the Northern and Southern energies to phase and provide a vast pool of energy available for cyclogenesis.

The surface low pressure center was located beneath the left-exit region of the equatorward jet and beneath the right-entrance region of the poleward jet, maximizing the upper-tropospheric divergence available for cyclogenesis (Fig.3). With the low tracking along the outskirts of the NE coast, 1000-500 hPa thickness values remained below 540 dam (Fig.3) keeping the precipitation type as all snow for the ALY CWA. The 500-hPa height and wind fields displayed somewhat of a split flow pattern with two separate regions of energy (Fig.4). These two separate pieces of energy phased together between 1200 and 1800 UTC 14 March 2017 and resulted a cut-off low at 500-hPa (Fig.4). During this same time period there was significant absolute vorticity (AVOR) advection over the state of New York (NY) which provided forcing for upward vertical motion (UVM) (assuming positive differential vorticity advection) (Fig.4). In addition to positive AVOR advection there was a 500-hPa relative vorticity maximum collocated with UVM over the state of NY providing further dynamics favorable for cyclogenesis during the same time frame (Fig.5). Additional UVM was observed at 600-hPa (Fig.8) and 700-hPa (Fig.9) as well with maxima located over the western portion of the ALY CWA at 1200 and 1800 UTC 14 March 2017.

700-hPa Q-Vectors are analyzed in order to diagnose regions of Q-Vector convergence (QCONV). QCONV was observed beneath the coupled 250-hPa jet streaks further enhancing forcing for UVM and upper tropospheric divergence (Fig.6). Precipitable water (PWAT) anomalies are looked at in order to get a climatological perspective and were on the order of 2-3 standard deviations at the peak of the storm, meaning there was plenty of moisture available for this system to take advantage of (Fig.7). Moving down to 850-hPa there was strong warm air advection (WAA) between 0600 and 1800 UTC 14 March 2017 over the ALY CWA providing additional lift and enhanced precipitation.

The resulting MSLP field exhibits ~984mb low situated just off the east coast with surface wind gusts well over 25mph at its peak intensity (Fig.11). The system is impressive on its own but the most noteworthy aspect of this storm was the large band of extremely heavy snow (2-4in/hr) that remained quasi-stationary for a good portion of the storm. There was even a report of 11 inches of snow in 2 hours in Herkimer county! The following section will explore this band of heavy snow a bit more in depth.

3. *Quasi-Stationary Snow Band Analysis*

Strong middle tropospheric forcing was responsible for the heavy band of snow that dramatically enhanced snowfall totals over the NW portion of the ALY CWA. There was a linearly oriented region of 600-hPa (Fig.12) and 700-hPa (Fig.13) frontogenesis that allowed a mesoscale frontal boundary to be embedded within the synoptic scale precipitation field (Fig.14). This frontogenetic forcing was occurring in a very moist column of air as seen from the KALB soundings from the event (Fig.15). Note how saturated the atmosphere is at 1200 UTC 14 March 2017. Cross section analyses across the snow band (along the red line indicated in Figure 14) give some insight into why this impressive band developed. For the sake of time I will discuss only the 1200 and 1800 UTC 14 March 2017 cross sections (Figs. 18, 19 respectively).

The 1200 UTC cross section analysis displays a mid-level frontal feature illustrated by the potential temperature contours between ~700-hPa and 500-hPa (Fig.18). This is also a region of lower static stability and enhanced lapse rates. A region of frontogenesis is located above the frontal feature between 300-hPa and 450-hPa acting to enhance the potential temperature gradient (Fig.18). There is also a quite glaring UVM(red)/DVM(blue) couplet illustrated at 1200 UTC. The DVM is likely a result of downsloping off the Taconics while the UVM is associated with previously mentioned dynamics and the frontal boundary that is evident on the cross

section. Note that the mid-level UVM maximum is located within the dendritic growth zone (DGZ) indicated by the black dashed lines. Interestingly, there is also a low-level positive PV anomaly as a result of the diabatic heat release from the intense precipitation that likely had a positive feedback response by decreasing the half wavelength of the upper tropospheric trough resulting QG-“pop” (more efficient dynamics). Also, precipitation is often located downstream of a low level PV anomaly as was the case here. Finally, note the approximate location of the band of heavy snow is denoted by the star.

At 1800 UTC 14 March 2017 QG-“pop” has been initiated and there is very robust forcing present. The potential temperature gradient associated with the frontal boundary is stronger and this is a region of very low static stability. There are steep lapse rates and convective precipitation occurring at this point. Note that the aforementioned region is collocated with robust frontogenesis values and robust UVM. A good amount of the favorable dynamics are located within the DGZ as well. Imagine the snow totals if the DGZ was ~100mb lower! I wasn't able to figure out how to calculate saturated geostrophic equivalent potential vorticity in NCL but I would be willing to bet there are some very negative values collocated with the region of frontogenesis releasing the potential instability. Finally, note the concentrated positive low-level PV anomaly that resulted from the diabatic heat releases! It is definitely believable that there were 5+ in/hr snowfall rates within this band of heavy snow!

4. Outcome of the event

So what did all of this lead to? A LOT of snow! Figures 21 and 22 display the GAZPACHO snowfall analyses. It is quite evident where the band setup for a few hours! This pesky band of snow resulted in an “underforecast” of >12in (Fig.23) (60-80% error (Fig.24)) under the region of banded snowfall. See the QA for this event for more information

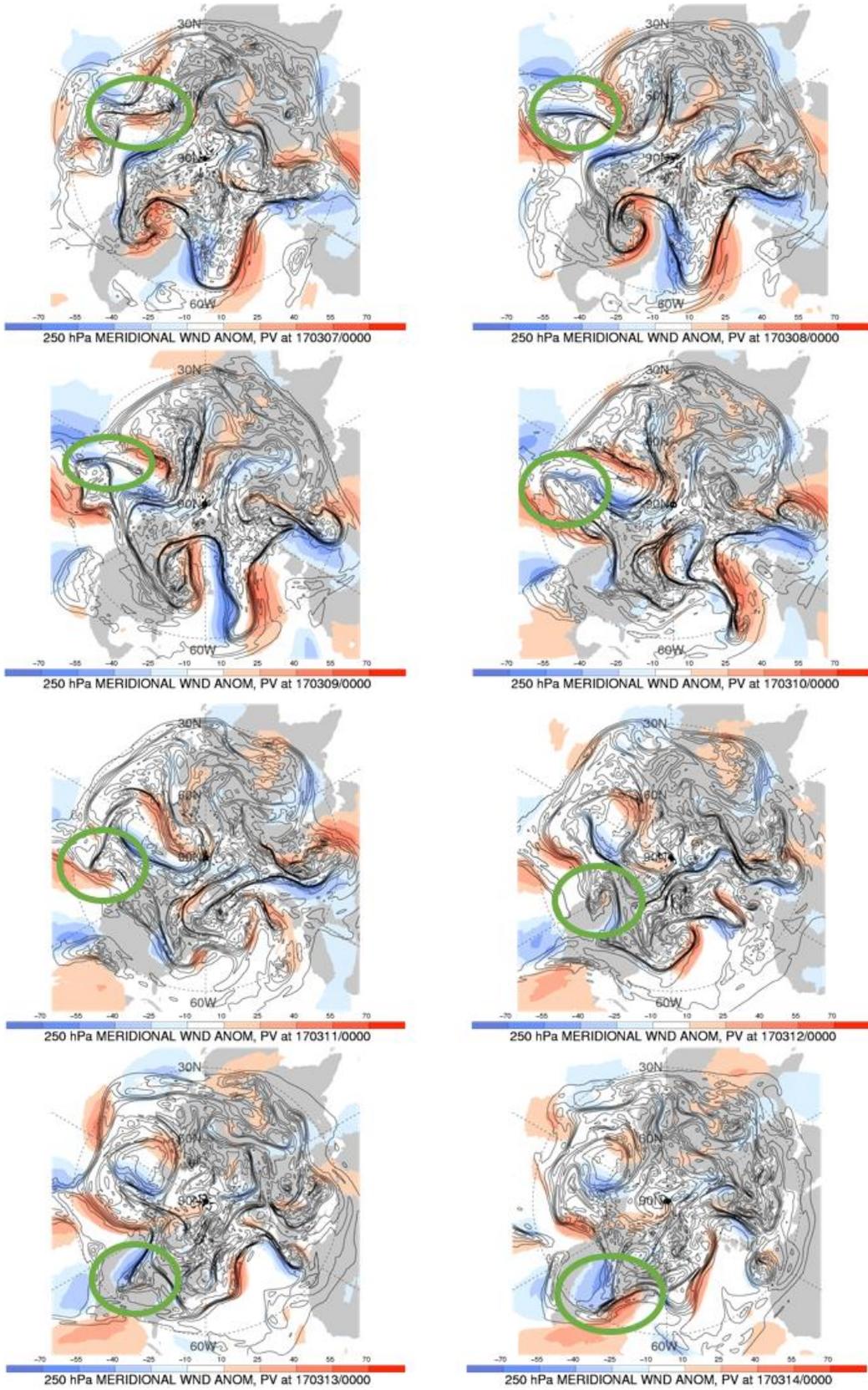


Figure 1. 250-hPa Meridional wind anomaly, PV (Source: Heather Archambault)

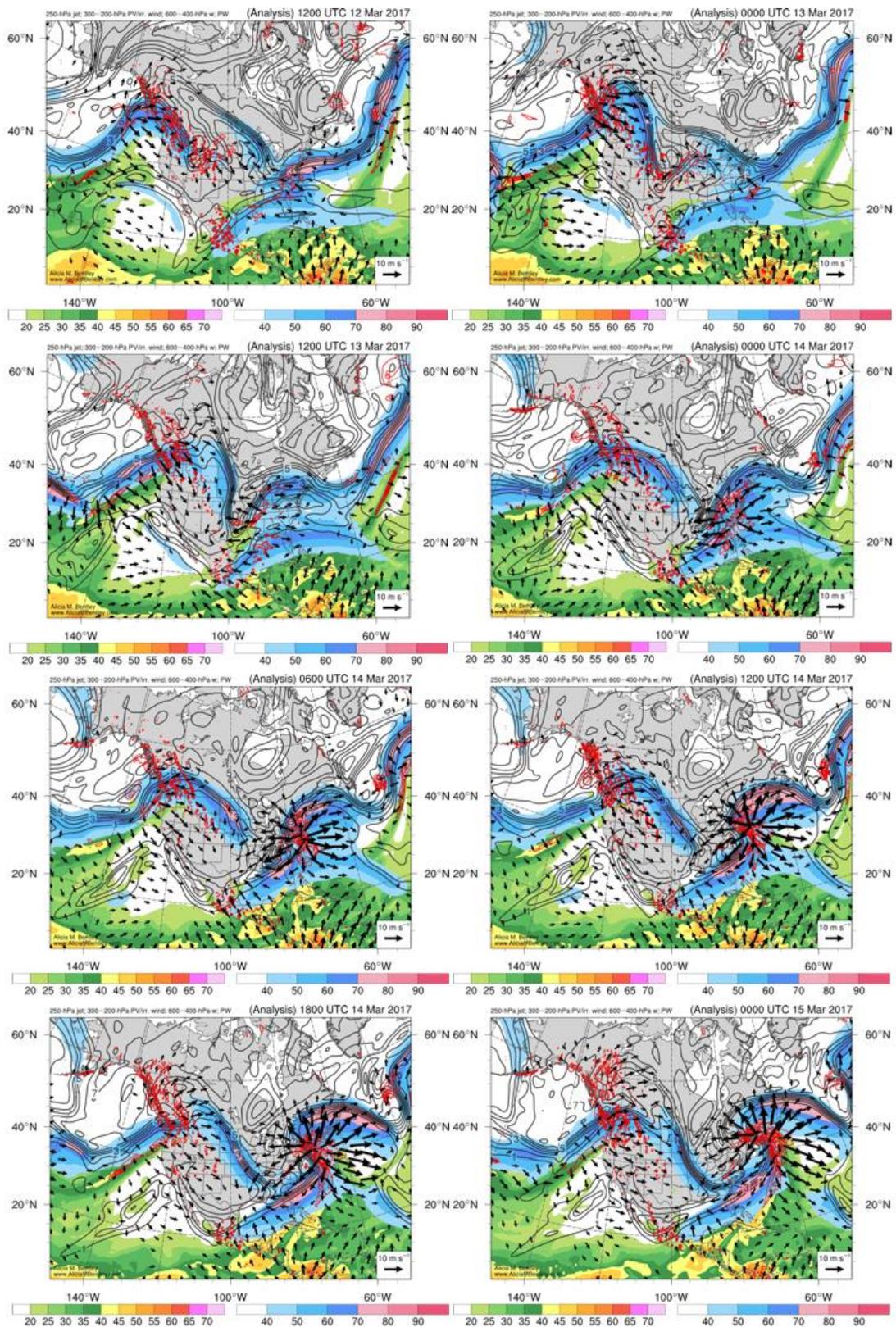


Figure 2. 250-hPa jet, 300-200hPa PV and irrotational winds, 600-400hPa w, PW
(Source: Alicia Bentley)

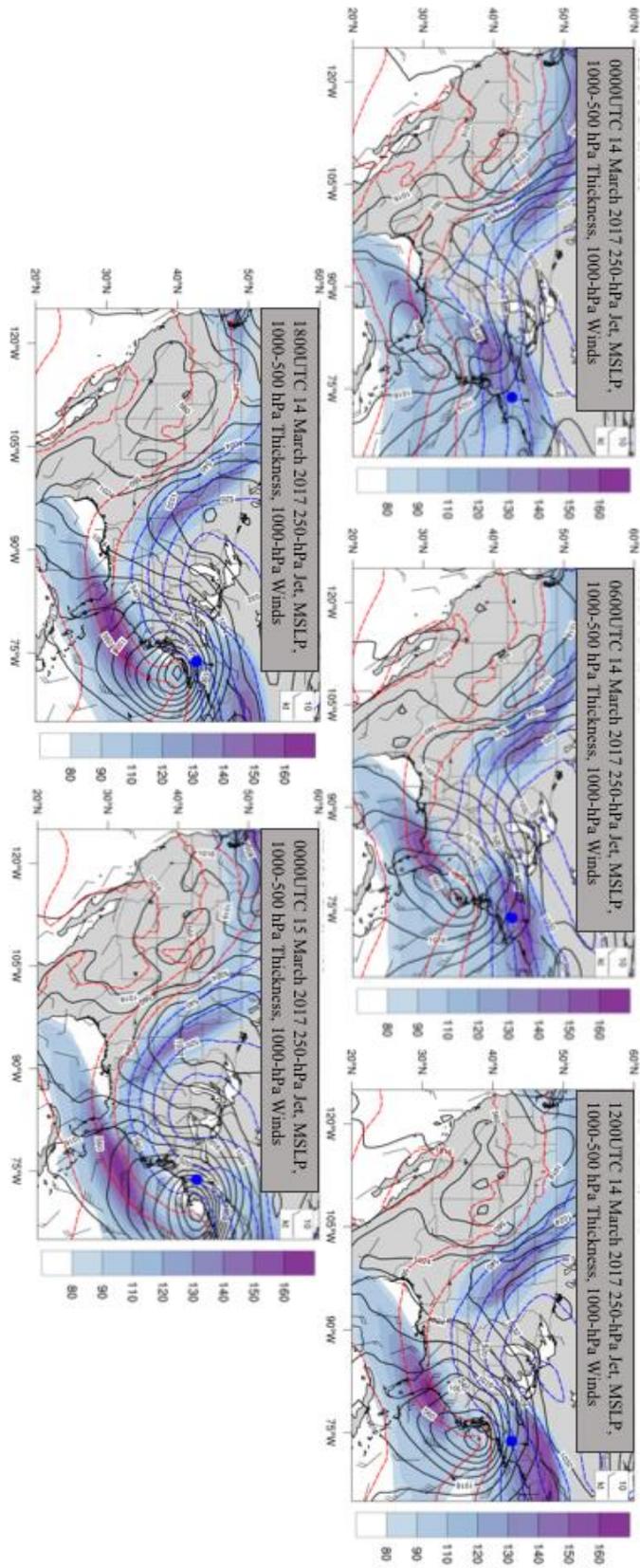


Figure 3. See image captions

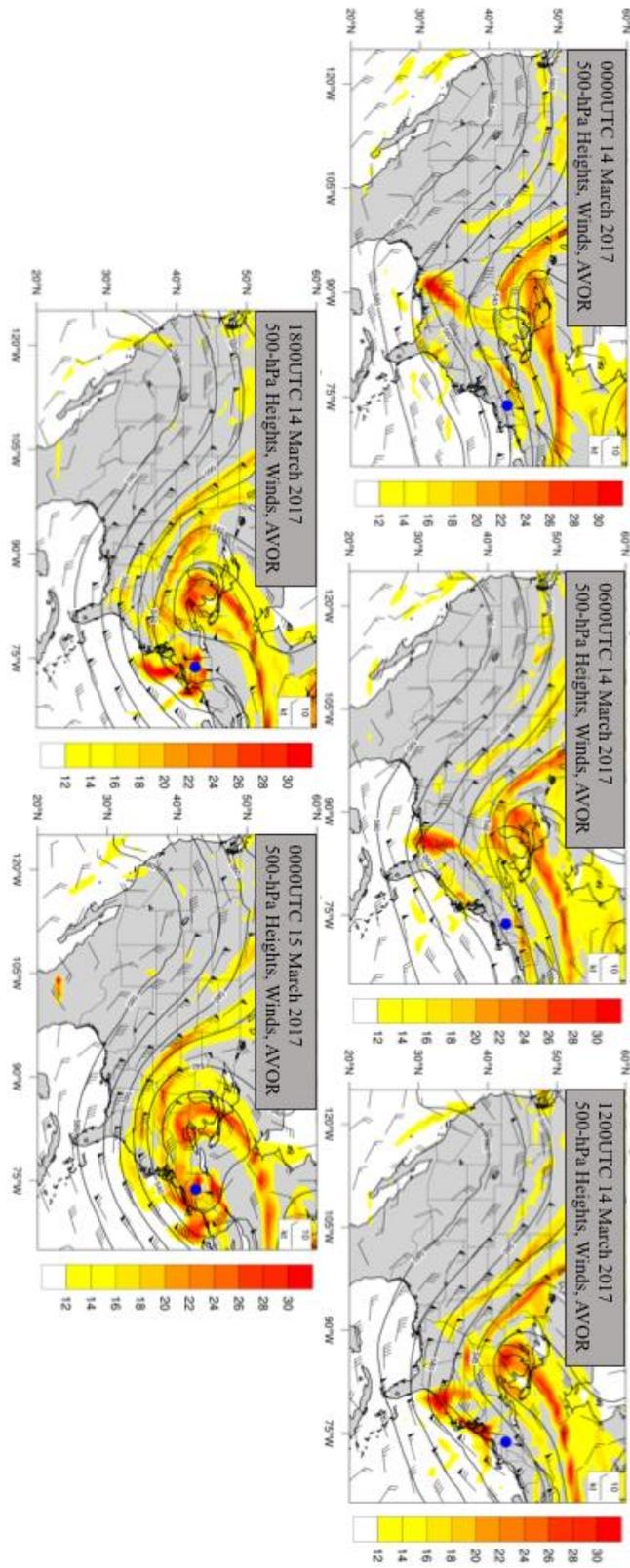


Figure 4. See image captions

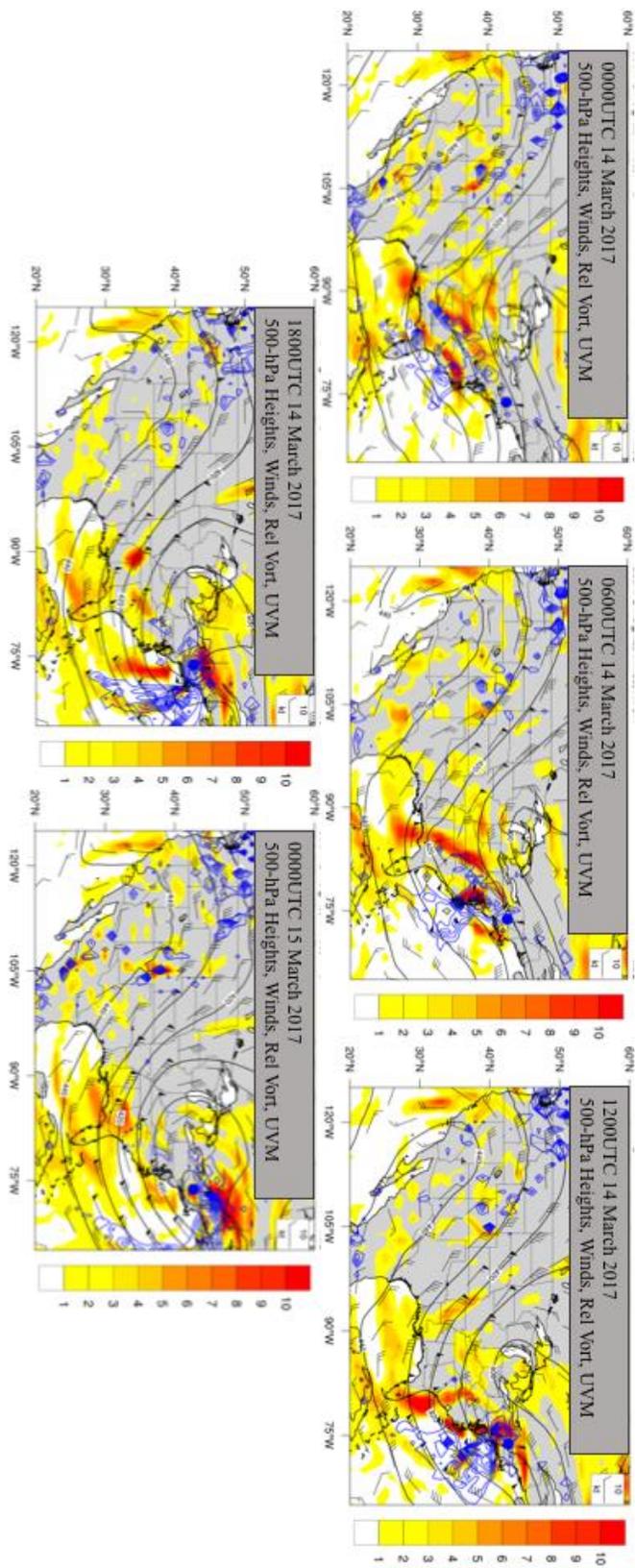


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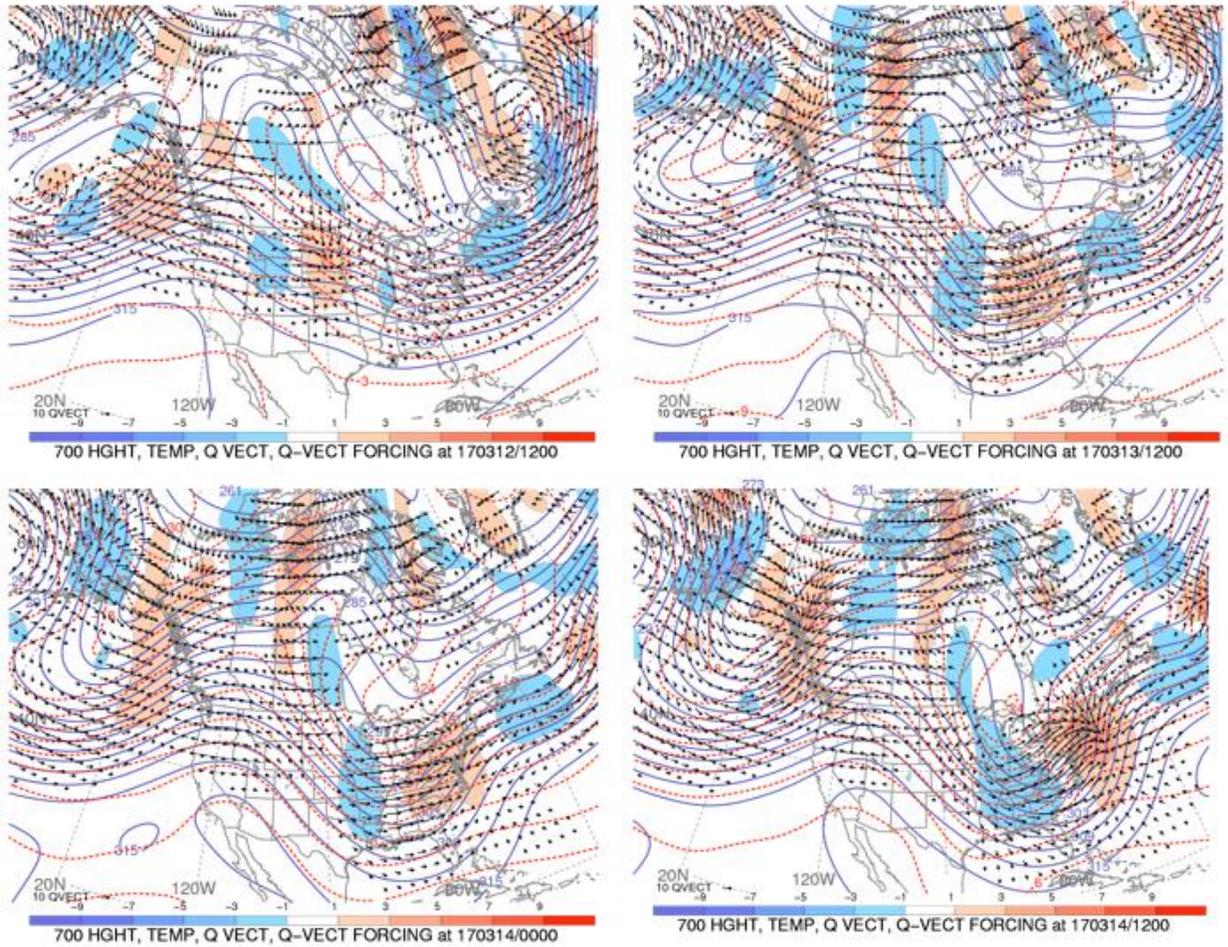


Figure 6. 700-hPa heights, temps, Q-Vectors, Q-Vector convergence/divergence.
 (Source: Heather Archambault)

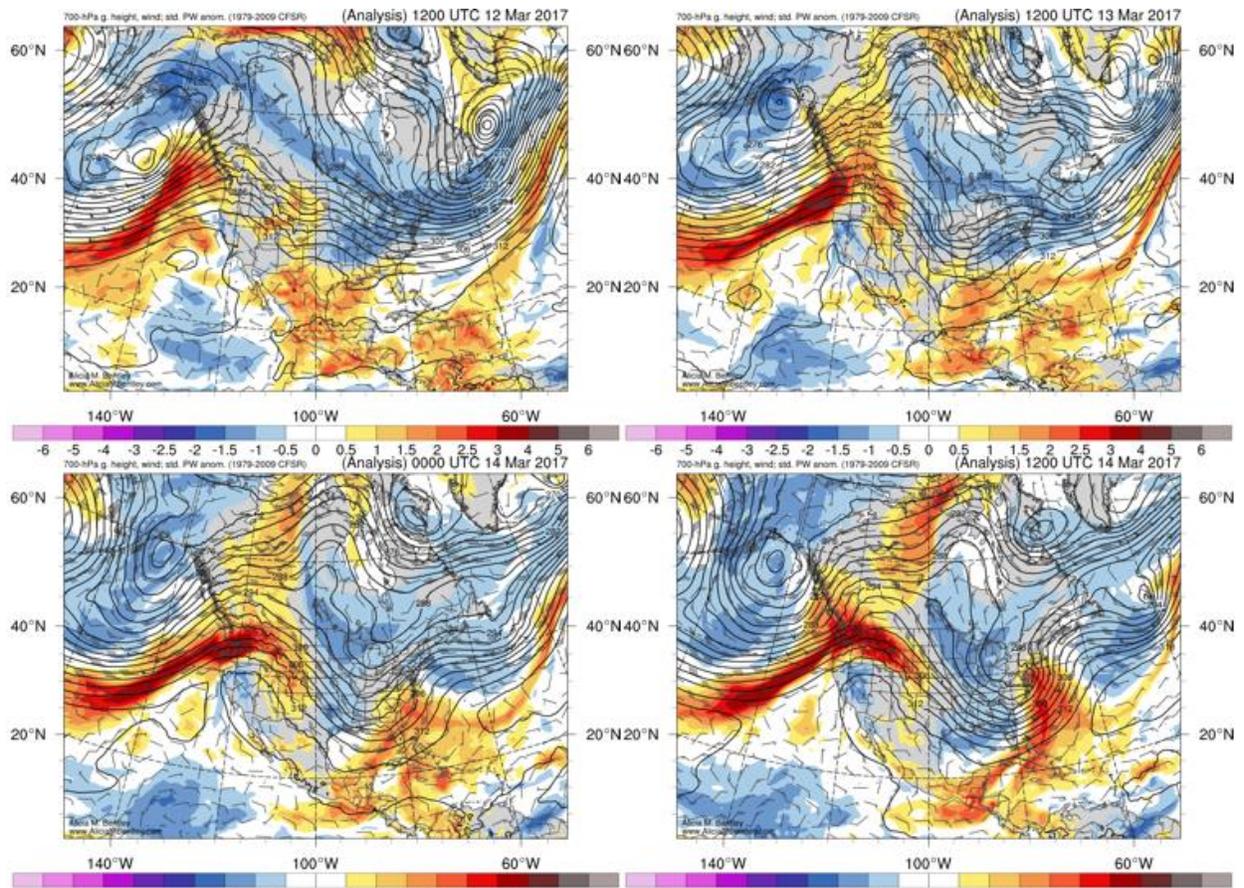


Figure 7. 700-hPa heights, wind, std. PW anomaly (Source: Alicia Bentley)

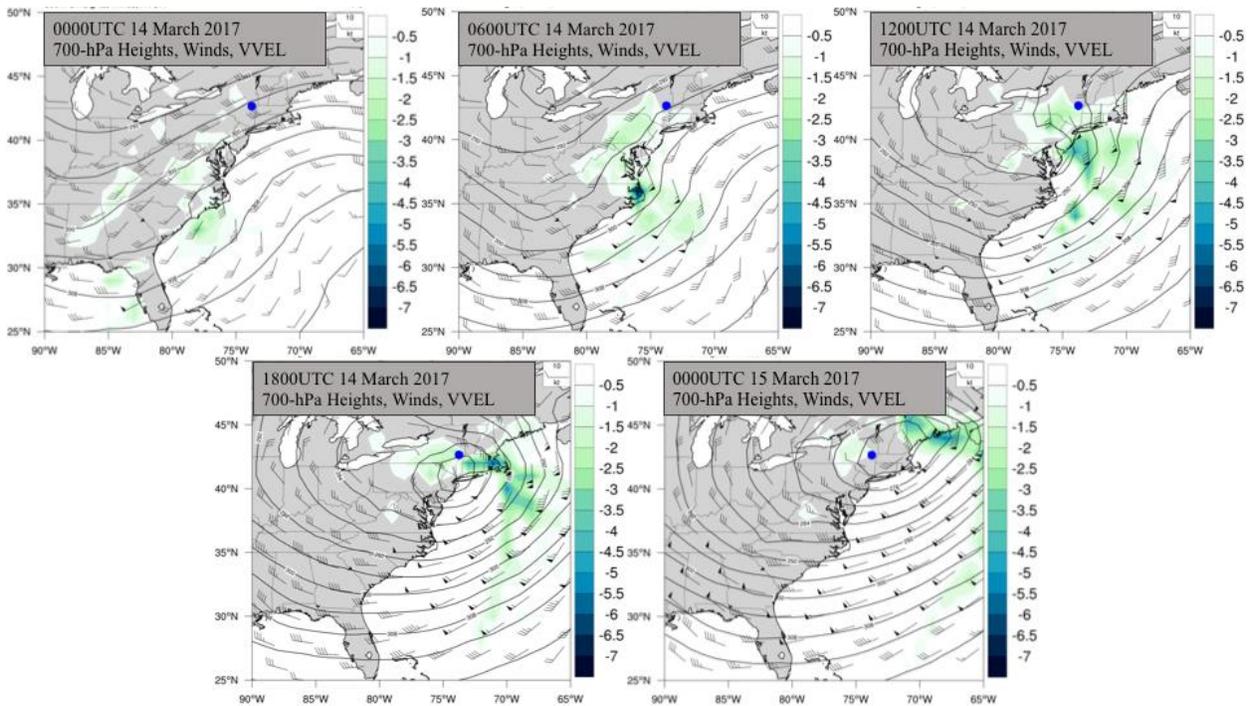


Figure 8. See image captions

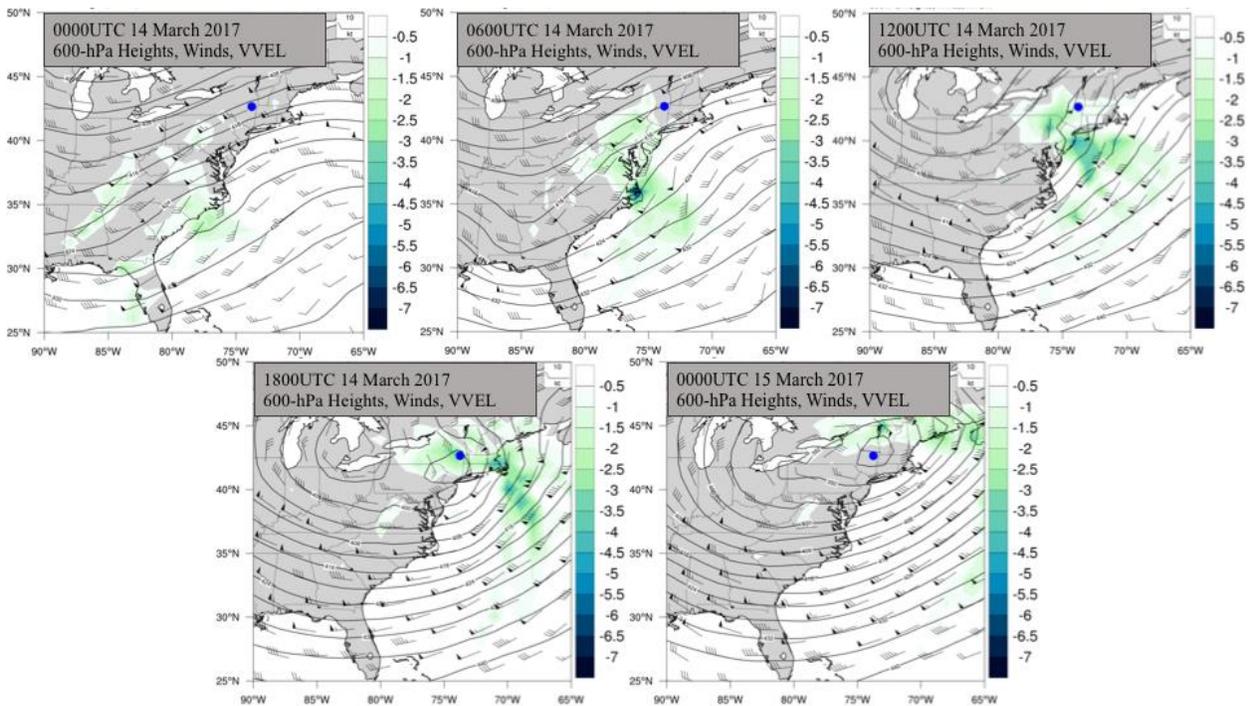


Figure 9. See image captions

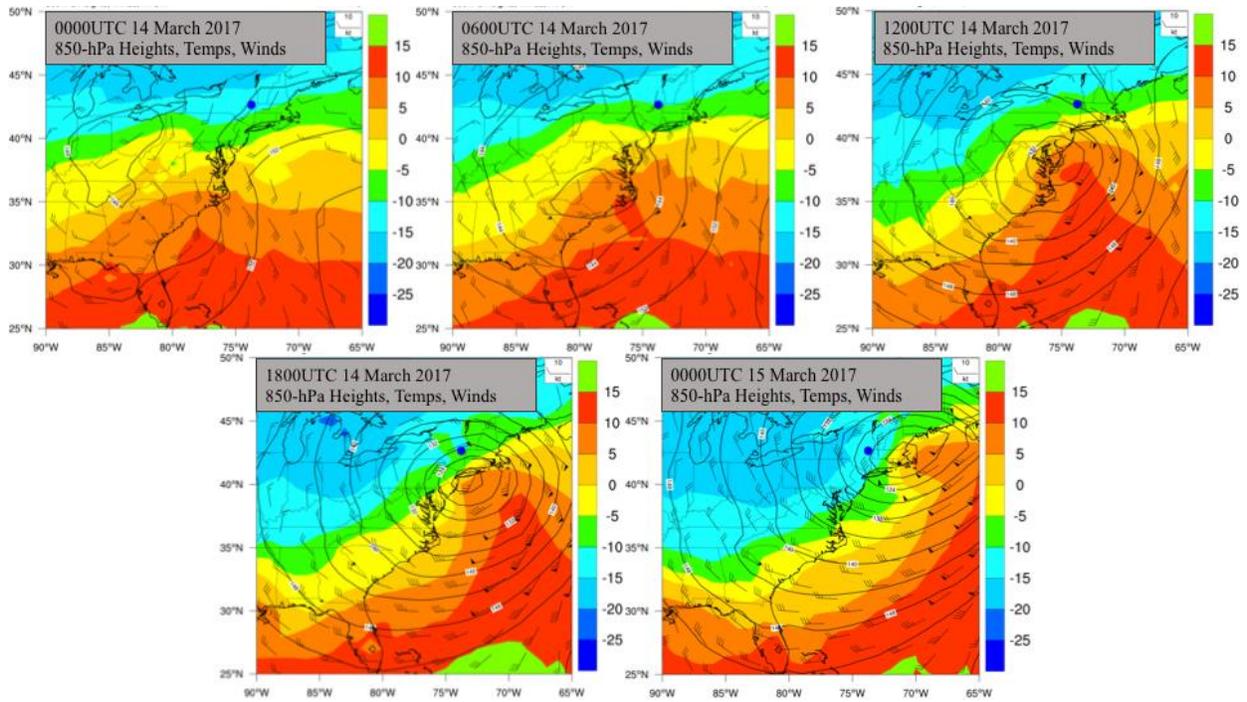


Figure 10. See image captions

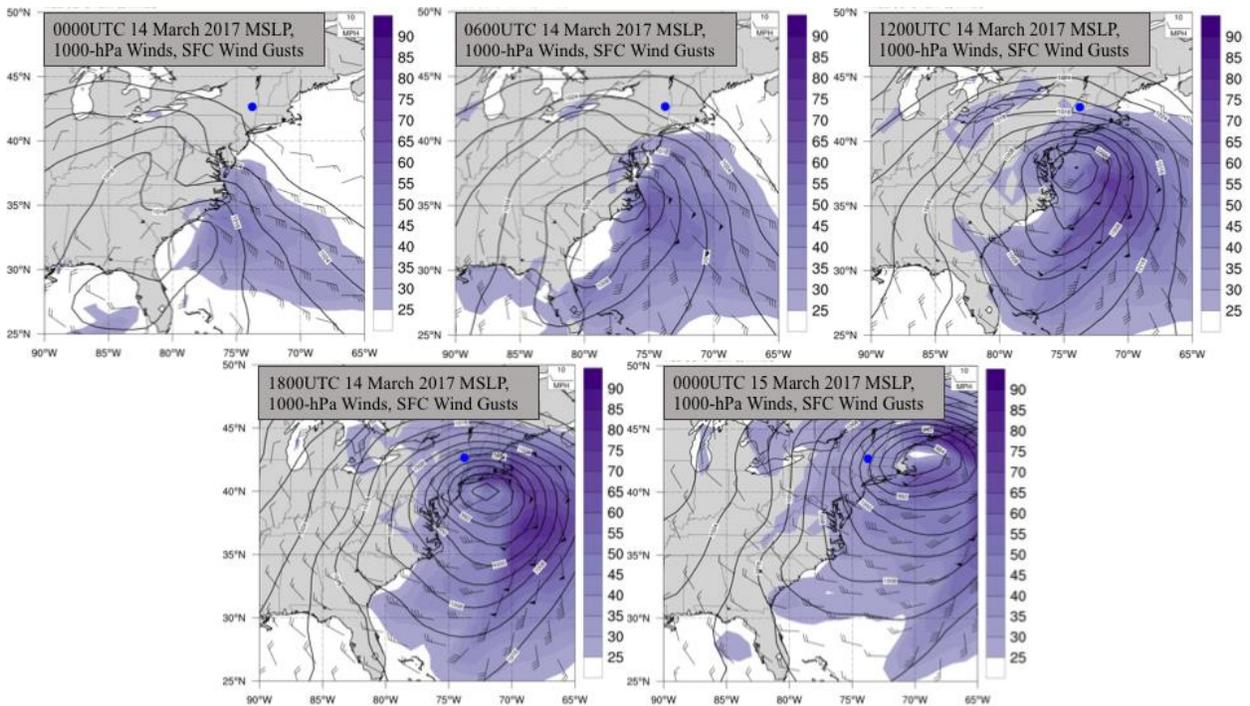


Figure 11. See image captions

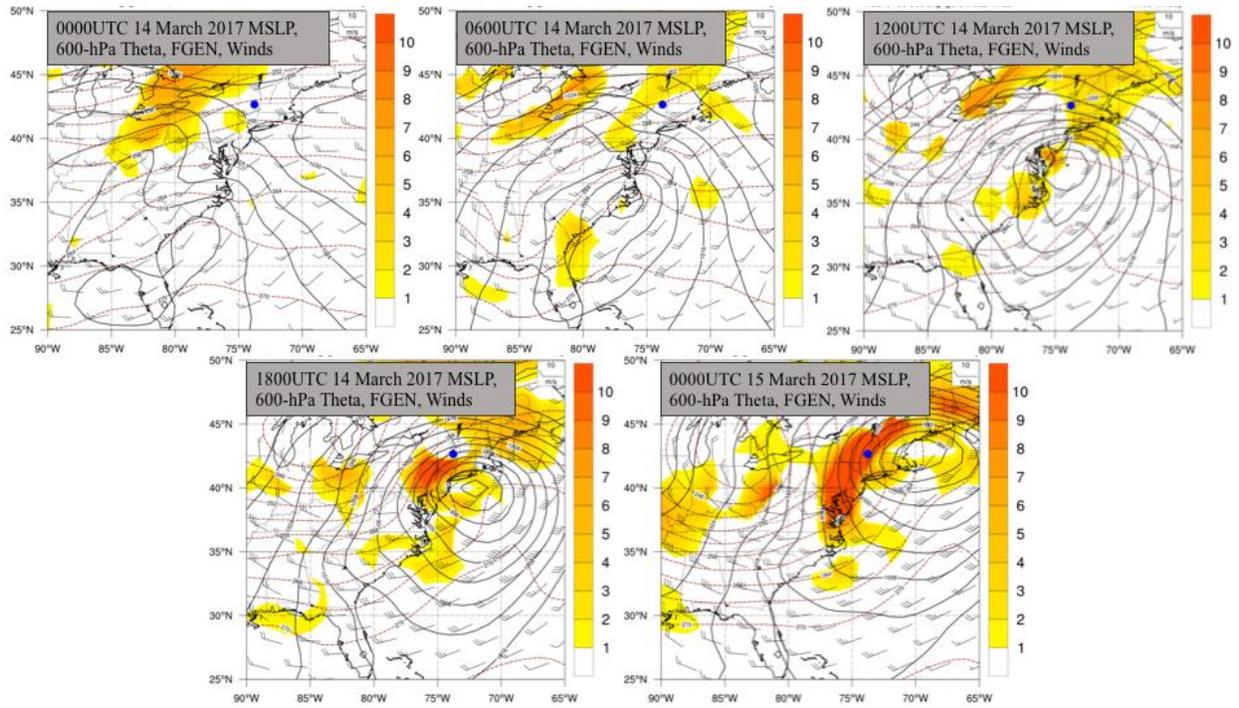


Figure 12. See image captions

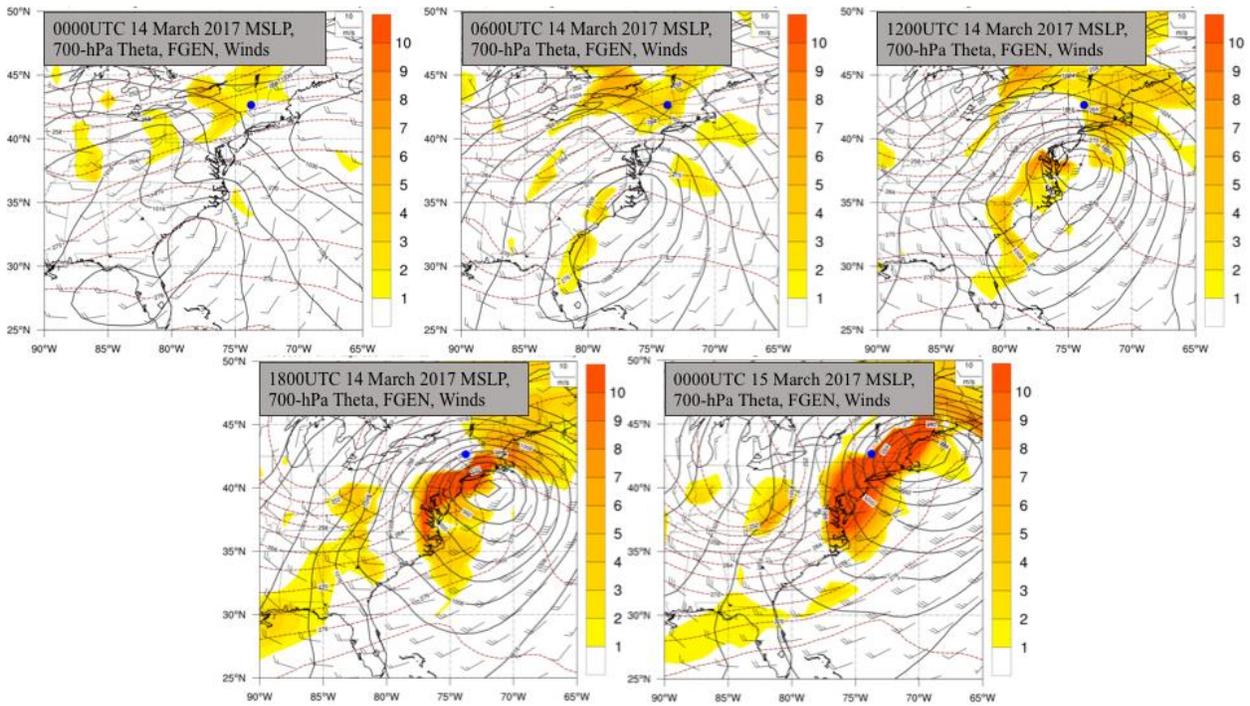


Figure 13. See image captions

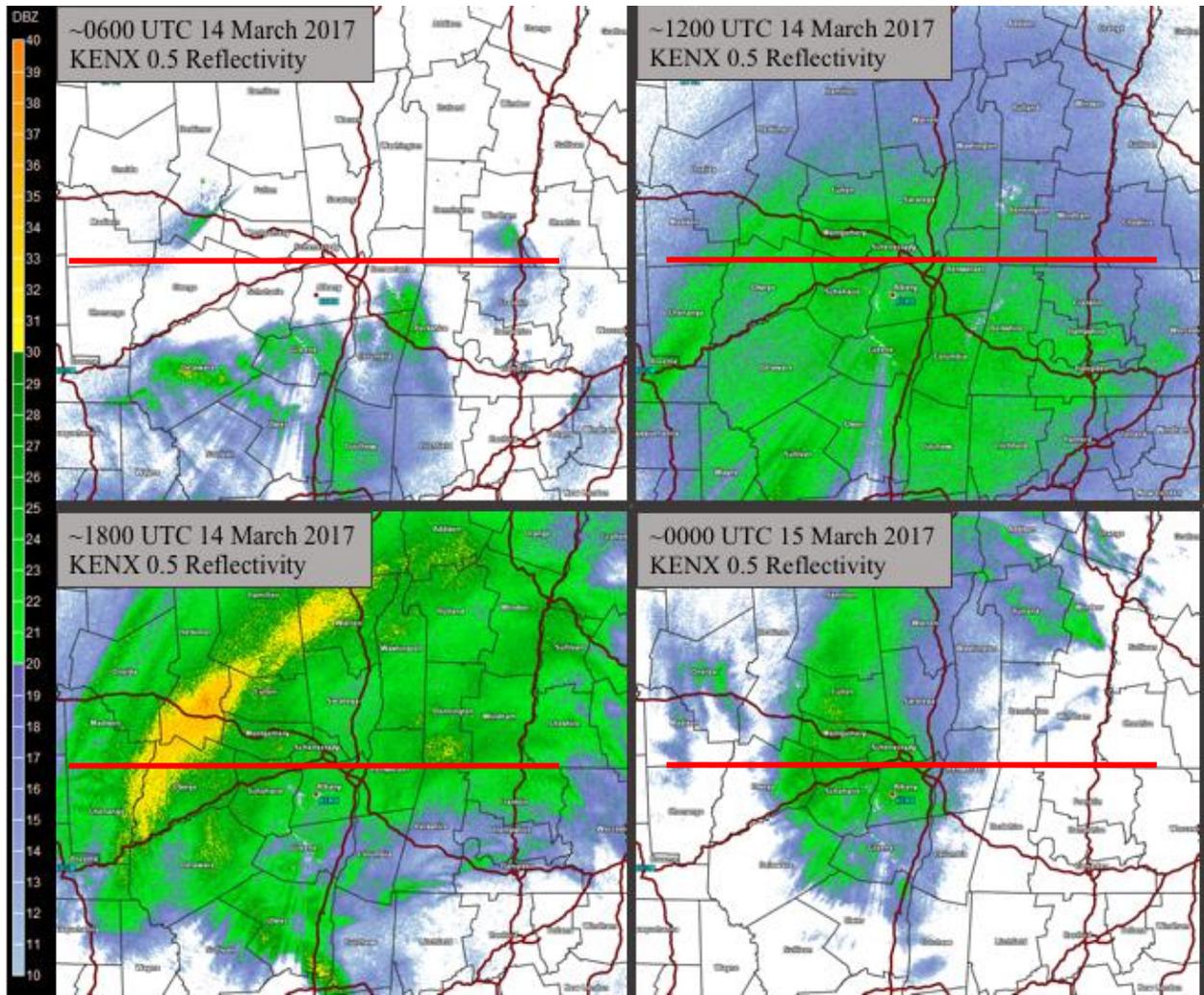


Figure 14. See image captions

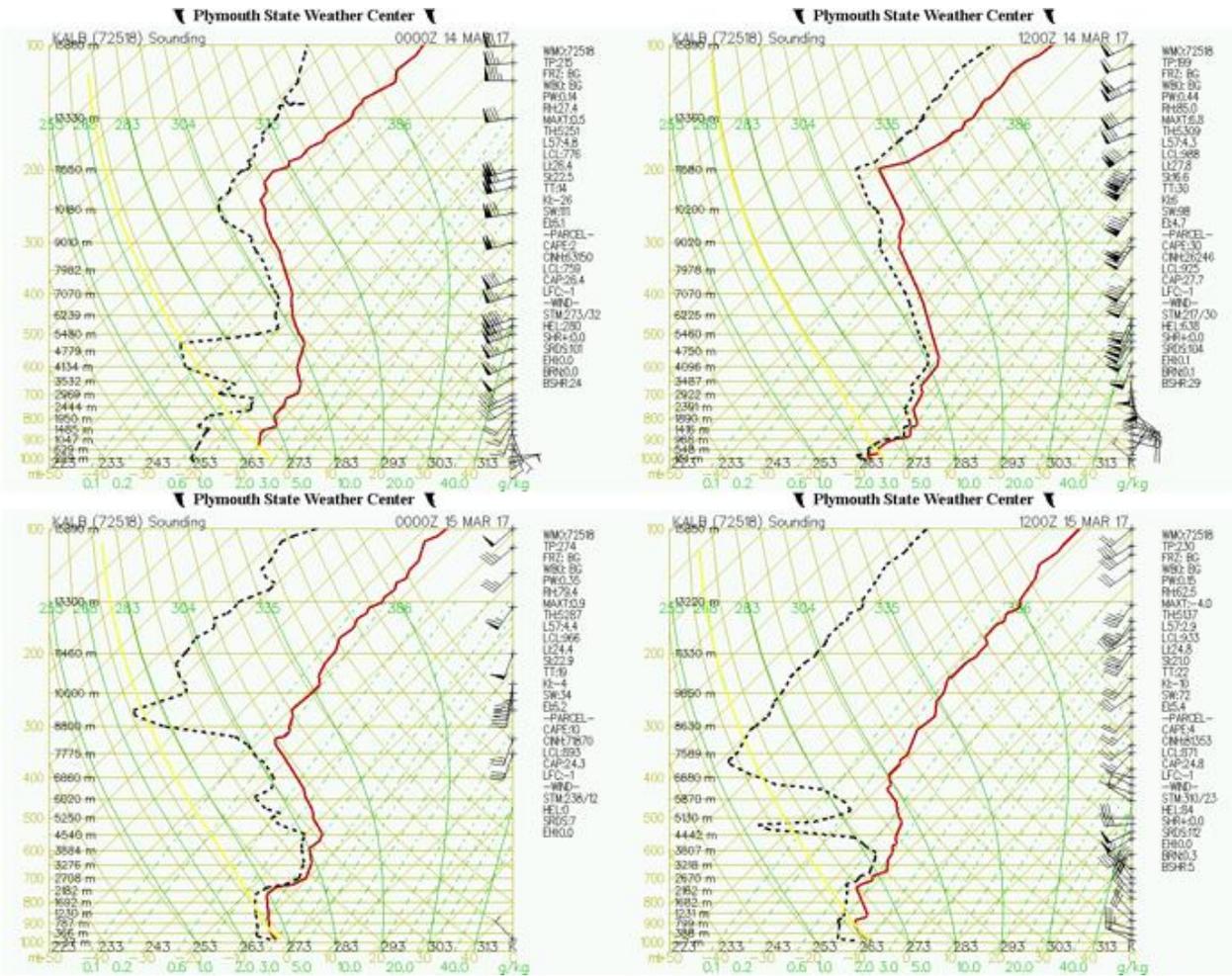


Figure 15. (Source: Plymouth State University)

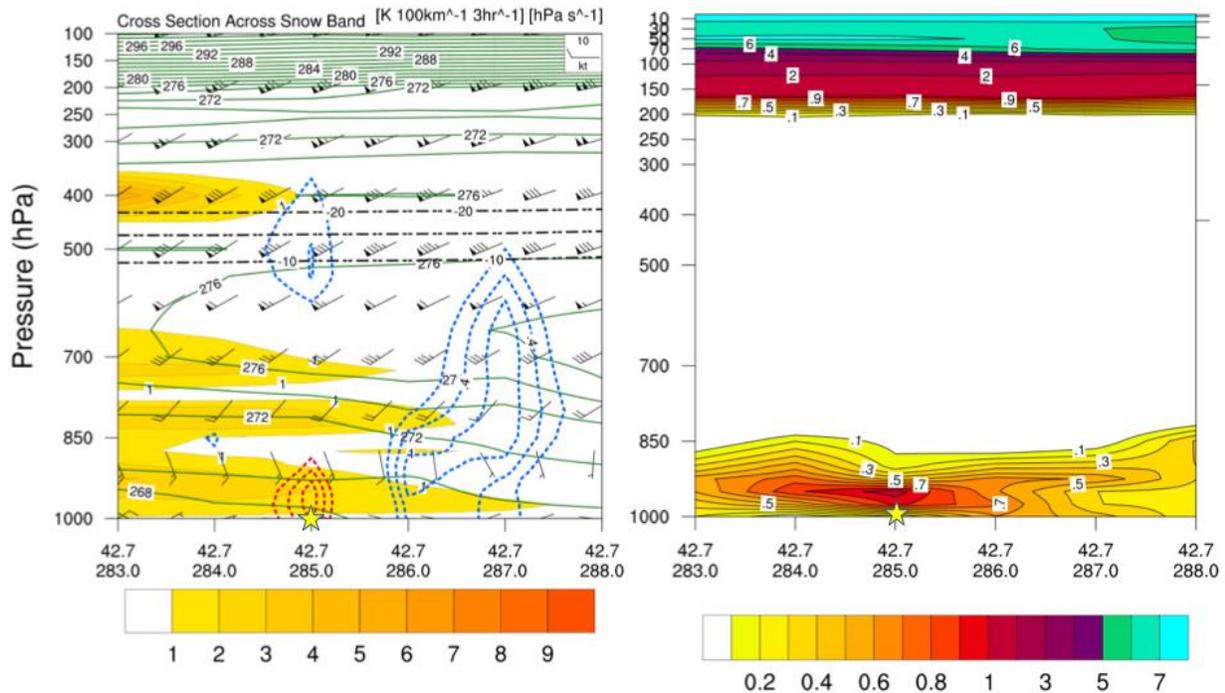


Figure 16. **LEFT:** Cross section across heavy snow band (along the red line indicated in Fig.14) at 0000 UTC 14 March 2017. Potential Temperature (green contours), frontogenesis (shaded to scale), winds (wind barbs), UVM (red dashed contours), DVM (blue dashed contours), and DGZ (black dashed contours). **RIGHT:** PV

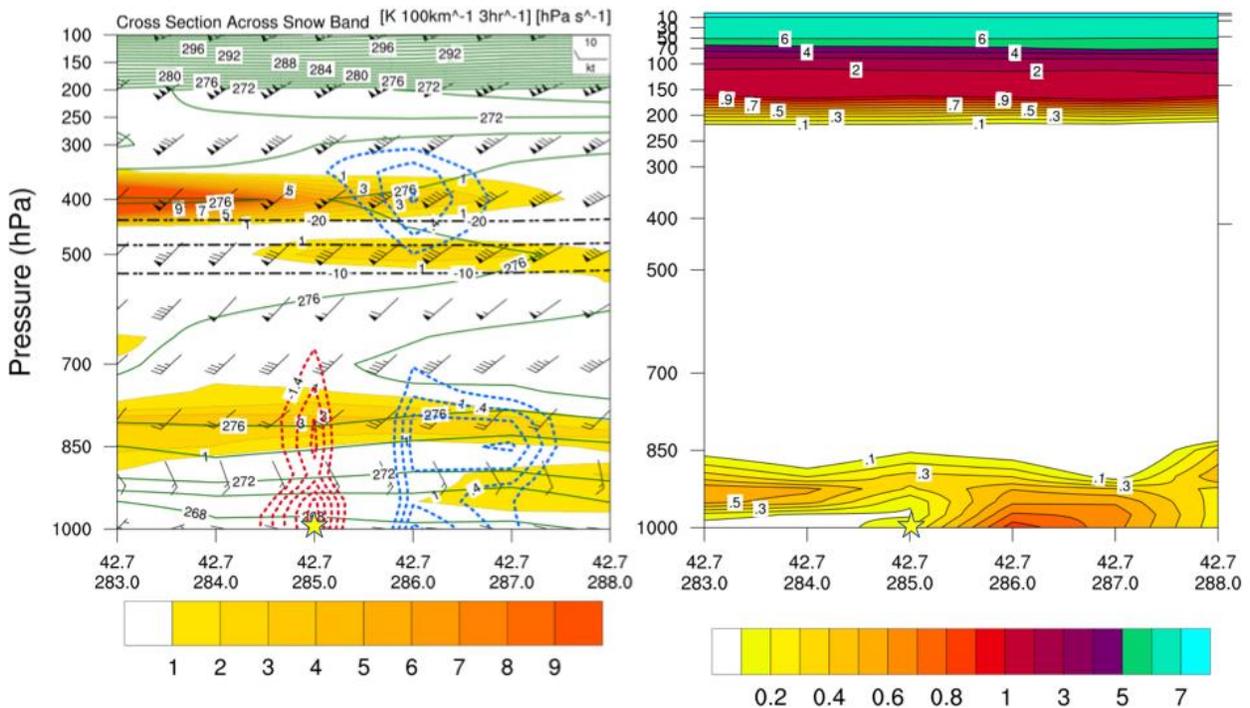


Figure 17. As in Figure 16 except at 0600 UTC 14 March 2017

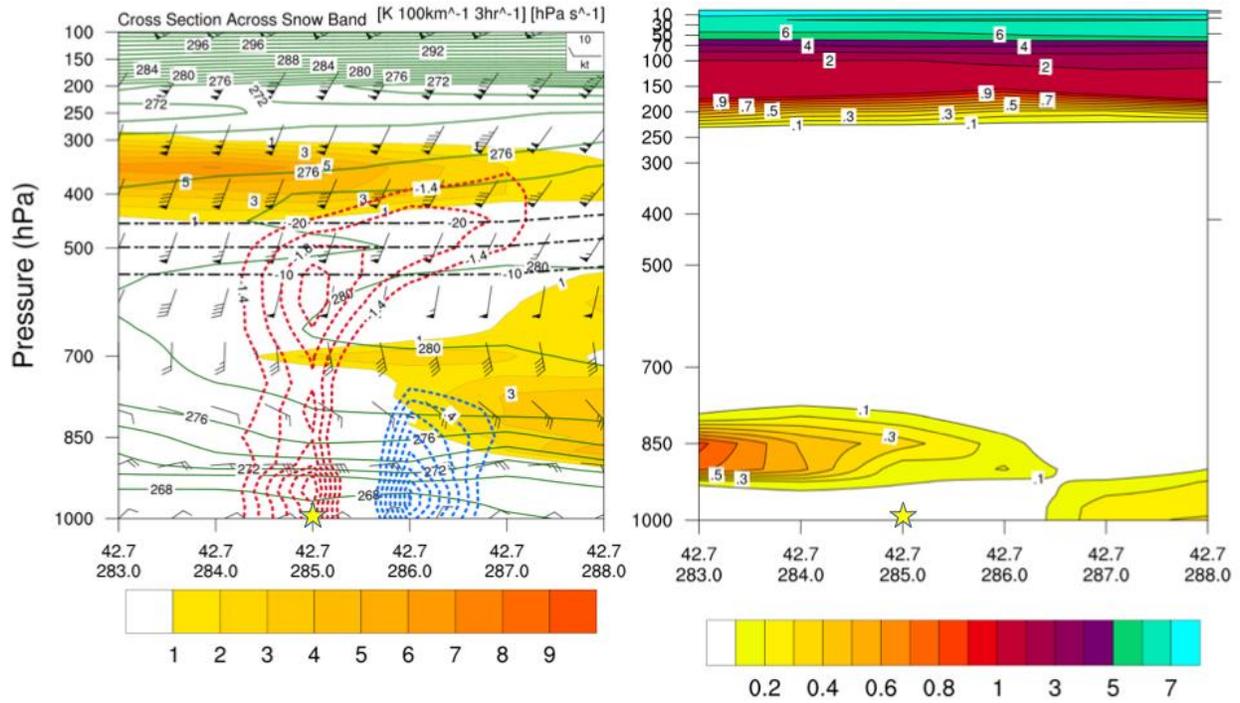


Figure 18. As in Figure 16 except at 1200 UTC 14 March 2017

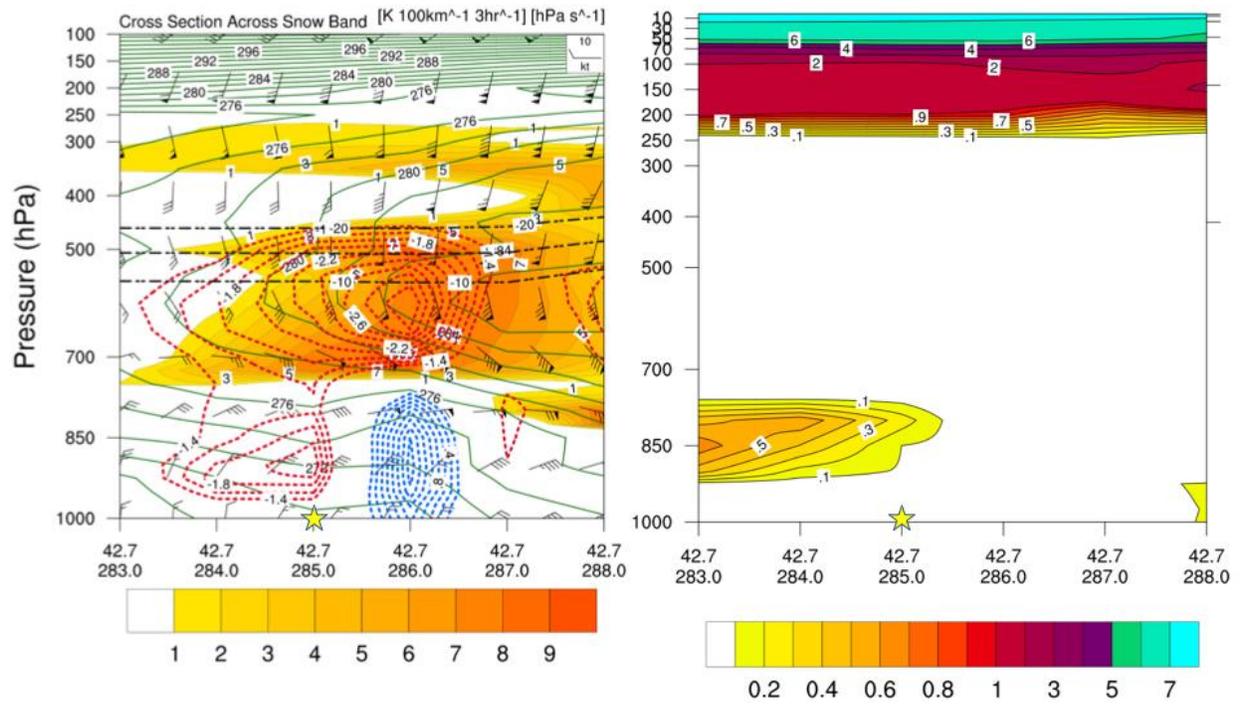


Figure 19. As in Figure 16 except at 1800 UTC 14 March 2017

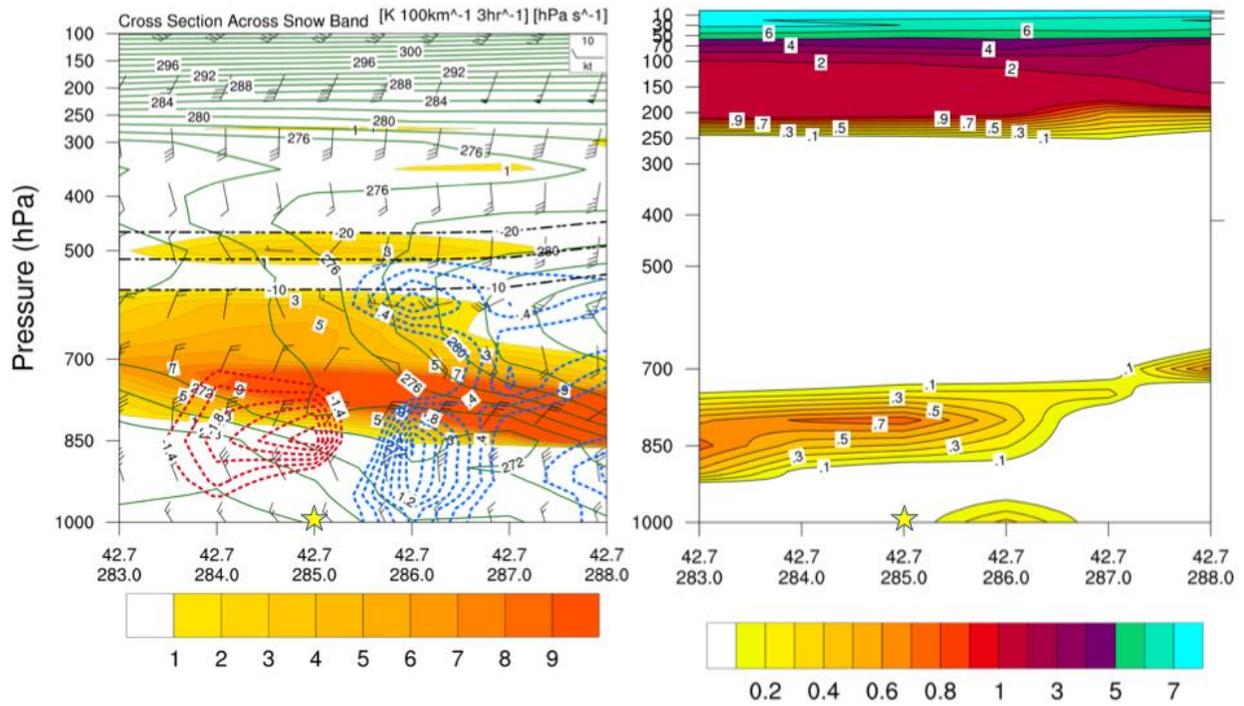


Figure 20. As in Figure 16 except at 0000 UTC 15 March 2017

National Weather Service Albany March 14th, 2017 Nor'easter

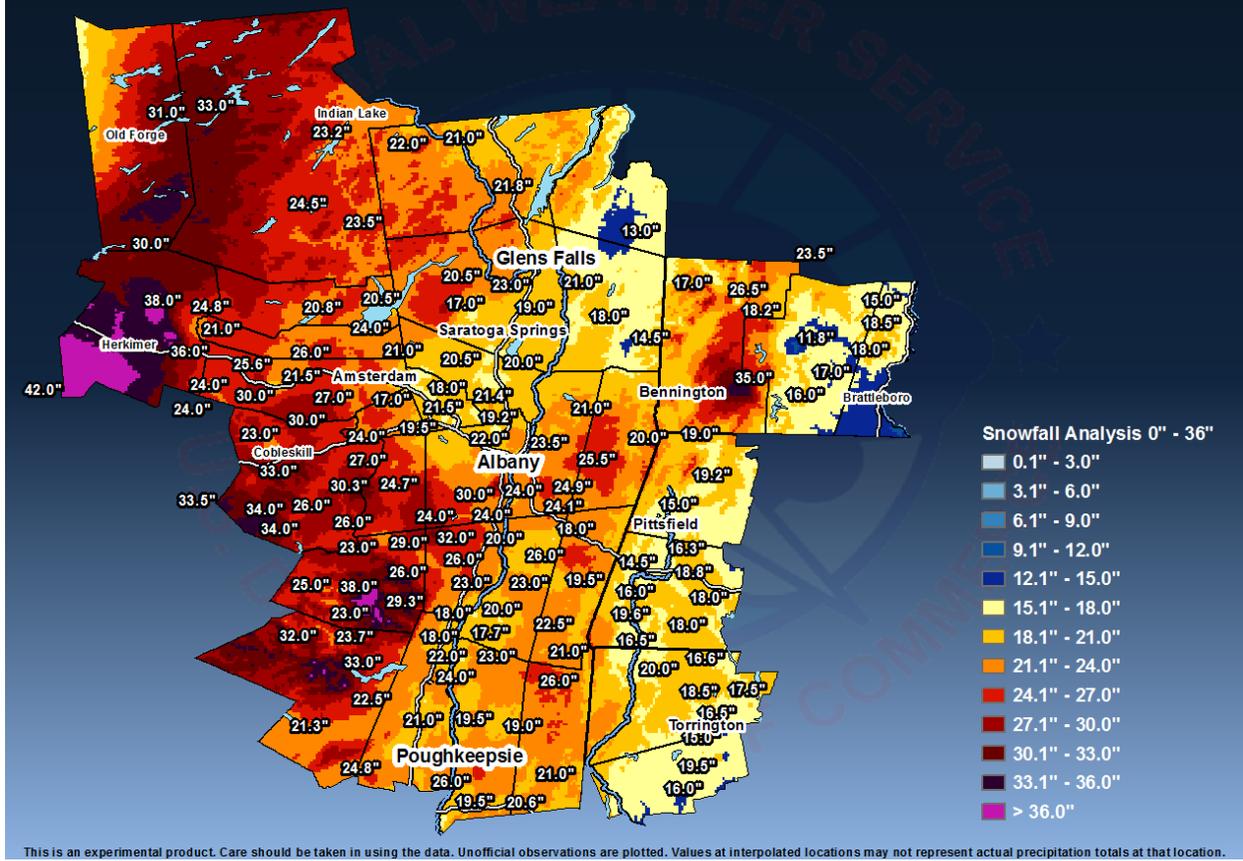
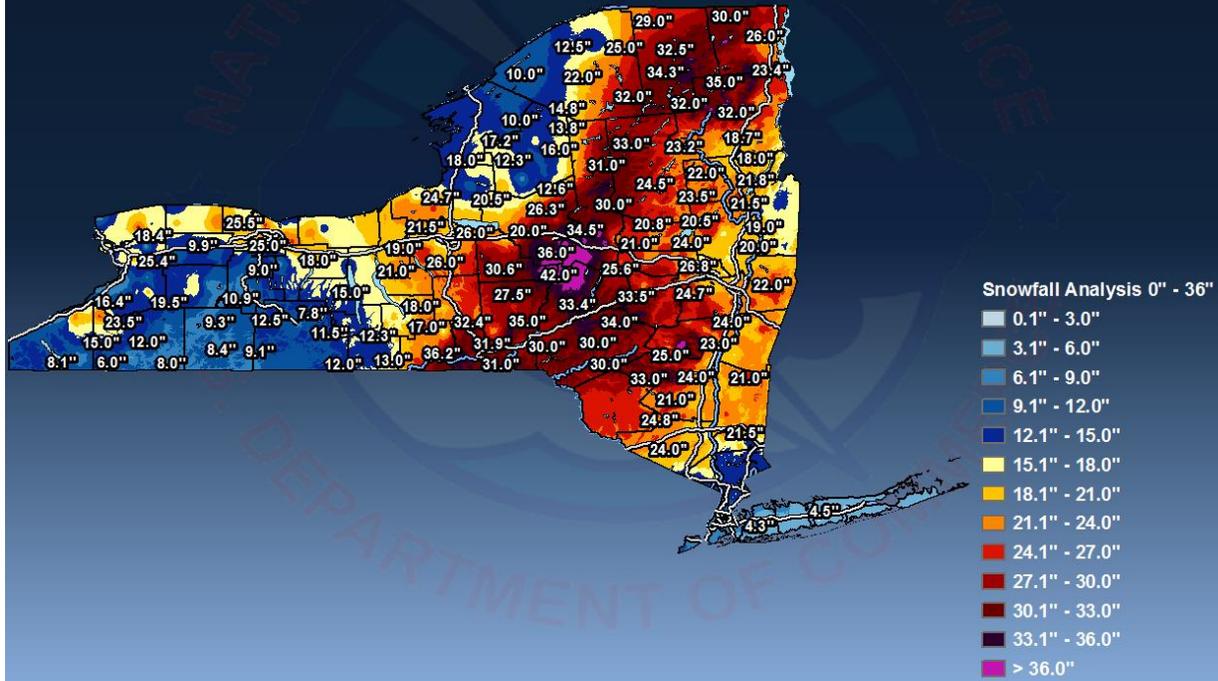


Figure 21. GAZPACHO output

New York State March 14th, 2017 Nor'easter (Unofficial Observations)



This is an experimental product. Care should be taken in using the data. Unofficial observations are plotted. Values at interpolated locations may not represent actual precipitation totals at that location.

Figure 22. GAZPACHO output

National Weather Service Albany March 14th, 2017 Nor'easter

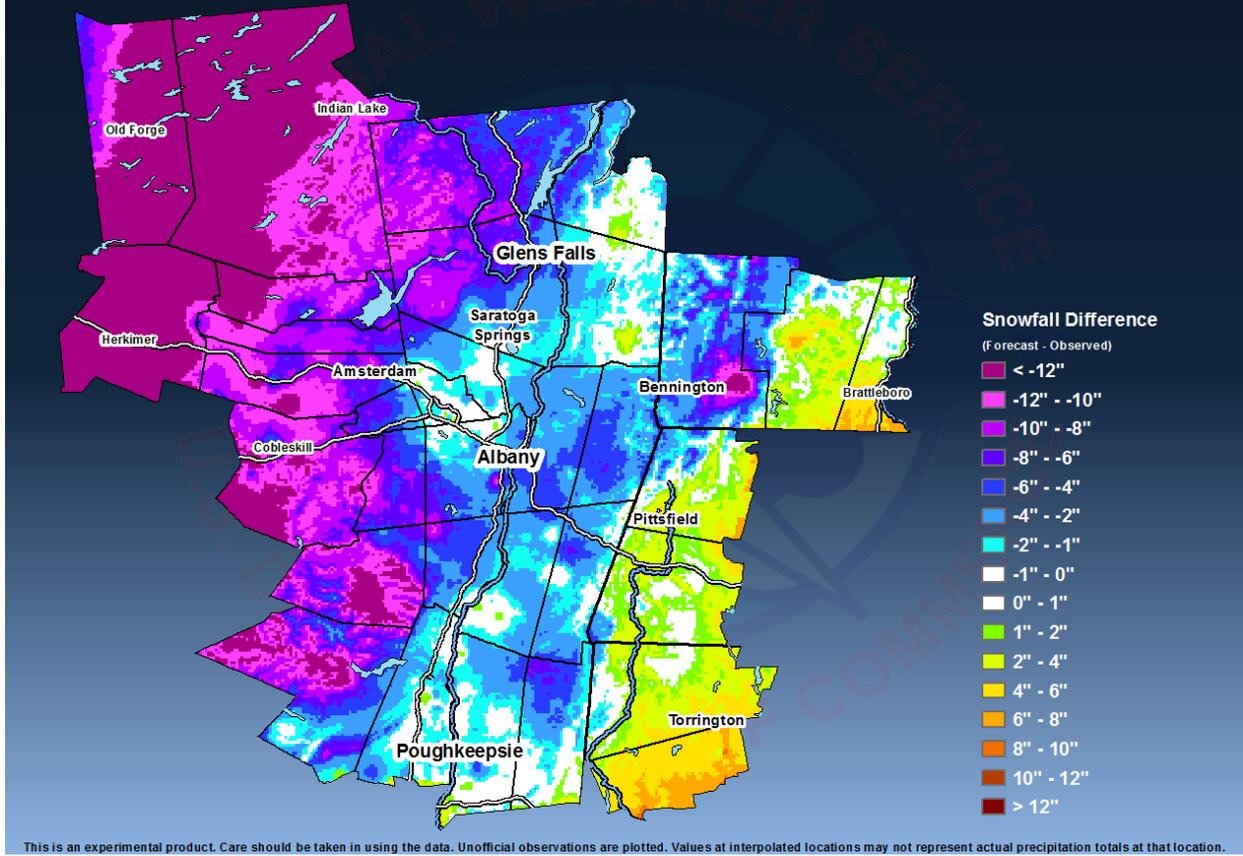


Figure 23. GAZPACHO output

National Weather Service Albany March 14th, 2017 Nor'easter

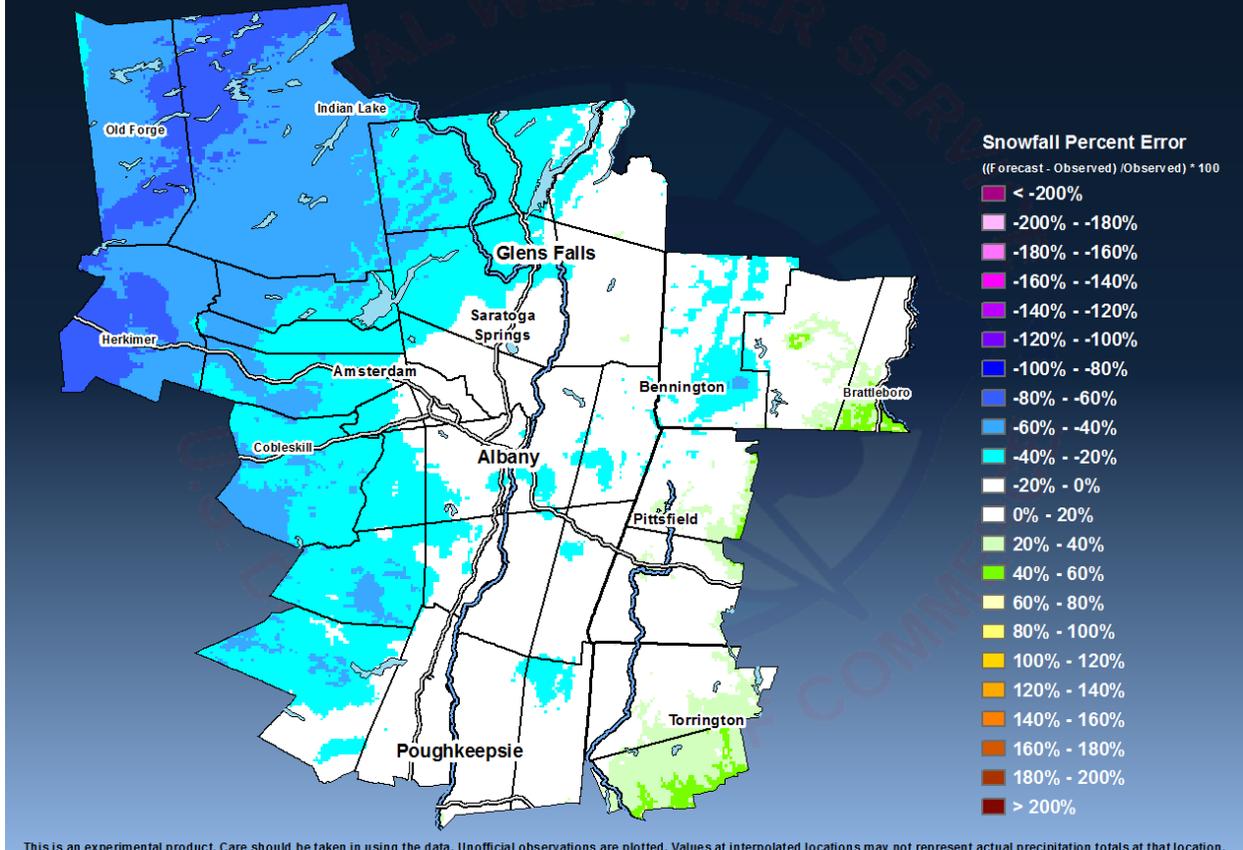
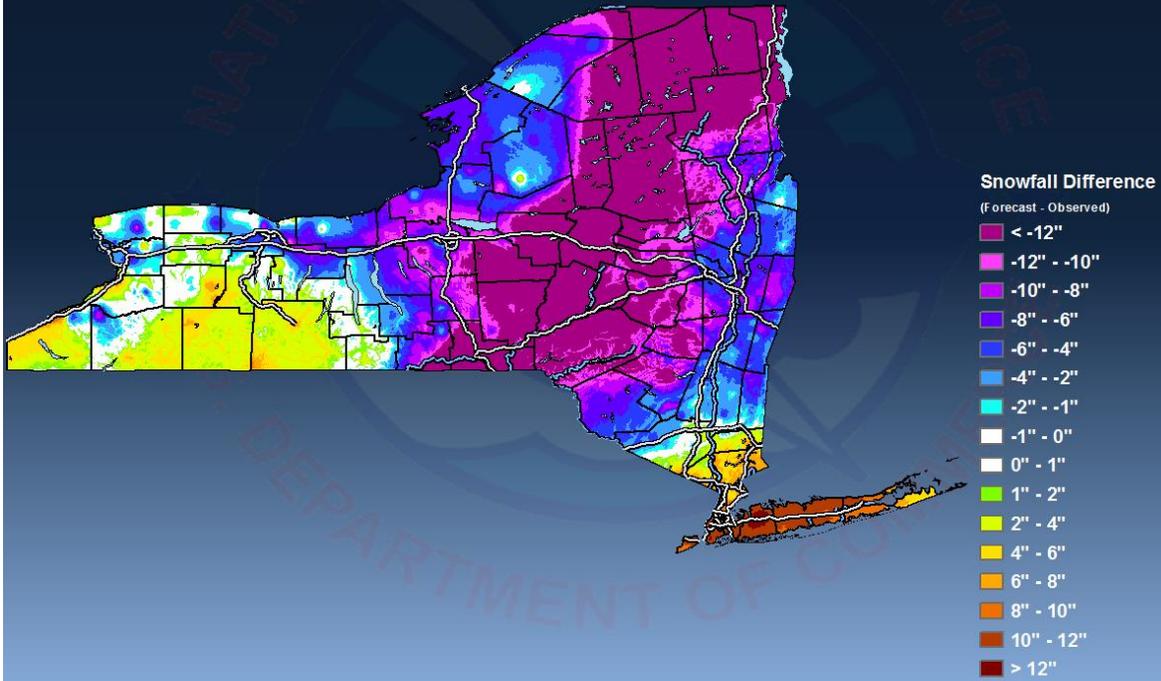


Figure 24. GAZPACHO output

New York State

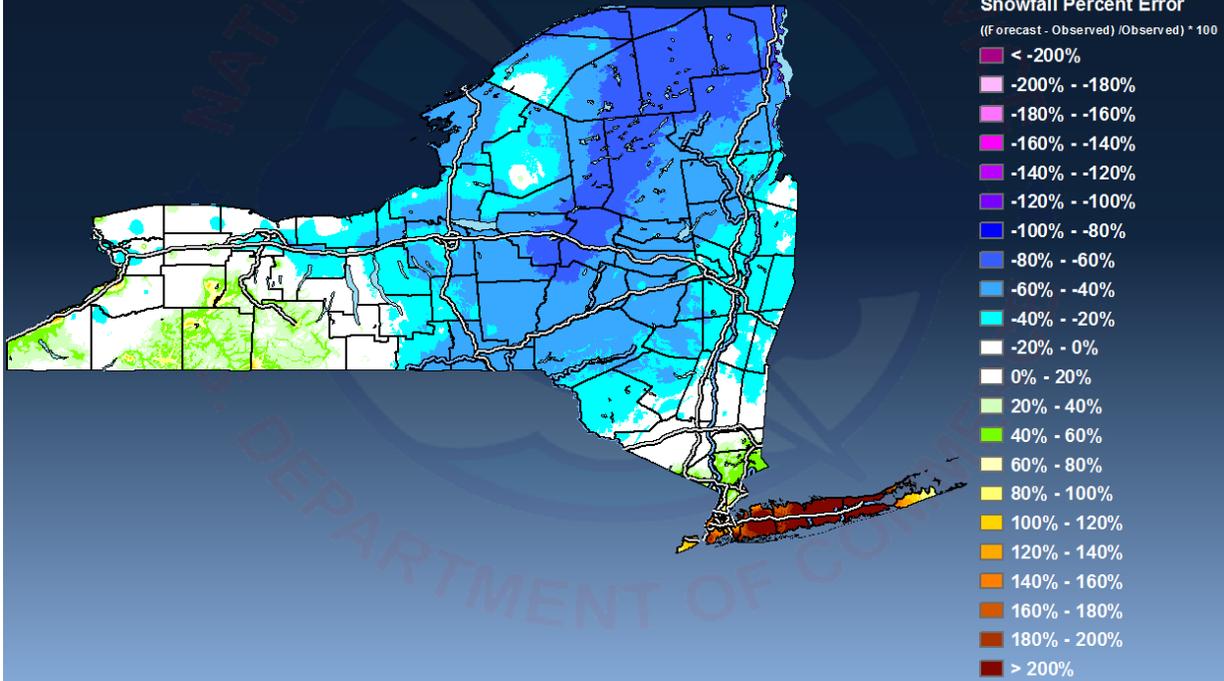
March 14th, 2017 Nor'easter (Unofficial Observations)



This is an experimental product. Care should be taken in using the data. Unofficial observations are plotted. Values at interpolated locations may not represent actual precipitation totals at that location.

Figure 25. GAZPACHO output

New York State March 14th, 2017 Nor'easter (Unofficial Observations)



This is an experimental product. Care should be taken in using the data. Unofficial observations are plotted. Values at interpolated locations may not represent actual precipitation totals at that location.

Figure 26. GAZPACHO output