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A DOWNSLOPE WINDSTORM IN NEW JERSEY? AN ANALYSIS OF THE 4 JANUARY 2009 HIGH-WIND EVENT

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1. INTRODUCTION

During the early morning hours of 4 Jan 2009, an unanticipated strong wind event occurred in northern New Jersey. Despite an NWS zone forecast calling for winds less than 8 kt (10 mph), winds up to 46 kt were reported around High Point. Because the event occurred in what is by New Jersey standards mountainous terrain, the goal of this paper is to examine the extent to which that terrain may have led to this poorly forecast event. Note that knots are used for the primary unit of wind speed in this paper to match the units in which the majority of observations were taken.

2. SYNOPTIC OVERVIEW

The wind event occurred in northwesterly flow to the southwest of a deep, vertically stacked cyclone positioned over the Canadian Maritimes (Fig. 1). At 850 hPa (Fig. 1a), winds in excess of 20 kt were present over New Jersey, and noted warming can be seen in the lee of the Appalachian Mountains from New Jersey up to Maine. Large-scale subsidence was present over the region (Fig. 1b), being located upstream from the primary trough axis off the coast. Winds at upper levels (Figs. 1c,d) were also from the northwest, implying unidirectional shear over the region.

Given this synoptic pattern, the NWS zone forecast for Sussex County (the northernmost part of New Jersey) was routine:

NJZ001-041100-
SUSSEX NJ-
845 PM EST SAT JAN 3 2009

.OVERNIGHT...MOSTLY CLEAR. LOWS AROUND 15. NORTHWEST WINDS 5 TO 10 MPH.

A look at the 0900 UTC 4 Jan 2009 observations from the standard surface network (valid about seven hours after that forecast was issued) shows that the forecast appeared to be on track (Fig. 2). However, a closer look reveals another story. Although station FWN reported calm winds at this time, the station at High Point, 14 km to the north, reported 46-kt wind gusts at 0800 UTC and 1000 UTC. These winds were nearly double what other stations in the area experienced. For instance, Mount Pocono, PA (MPO) reported a gust to 24 kt at 0500 UTC, the highest winds in the standard network near High Point. Further to the northeast (and closer to the cyclone), gusts did reach 32 kt at North Adams, MA (AQW).

The Albany, NY sounding taken at 1200 UTC 4 Jan 2009 reveals features that may be favorable for mountain wave activity (Fig. 3). One can imagine dividing the troposphere into three layers based on that sounding. Layer 1, closest to the surface, is close to isentropic and extends to 934 hPa. Layer 2 extends to about 800 hPa, is very stable, and can be thought of as representing a discontinuity in the potential temperature field. Layer 3 covers the rest of the troposphere and is characterized by a relatively uniform lapse rate close to moist neutrality. The stratosphere (not shown) could be thought of as a fourth layer. Although there is no critical level in this sounding, the presence of a low-level jet within the inversion implies that the shear vector reverses direction, which has been proposed to act like a critical level (Durran 1996). The

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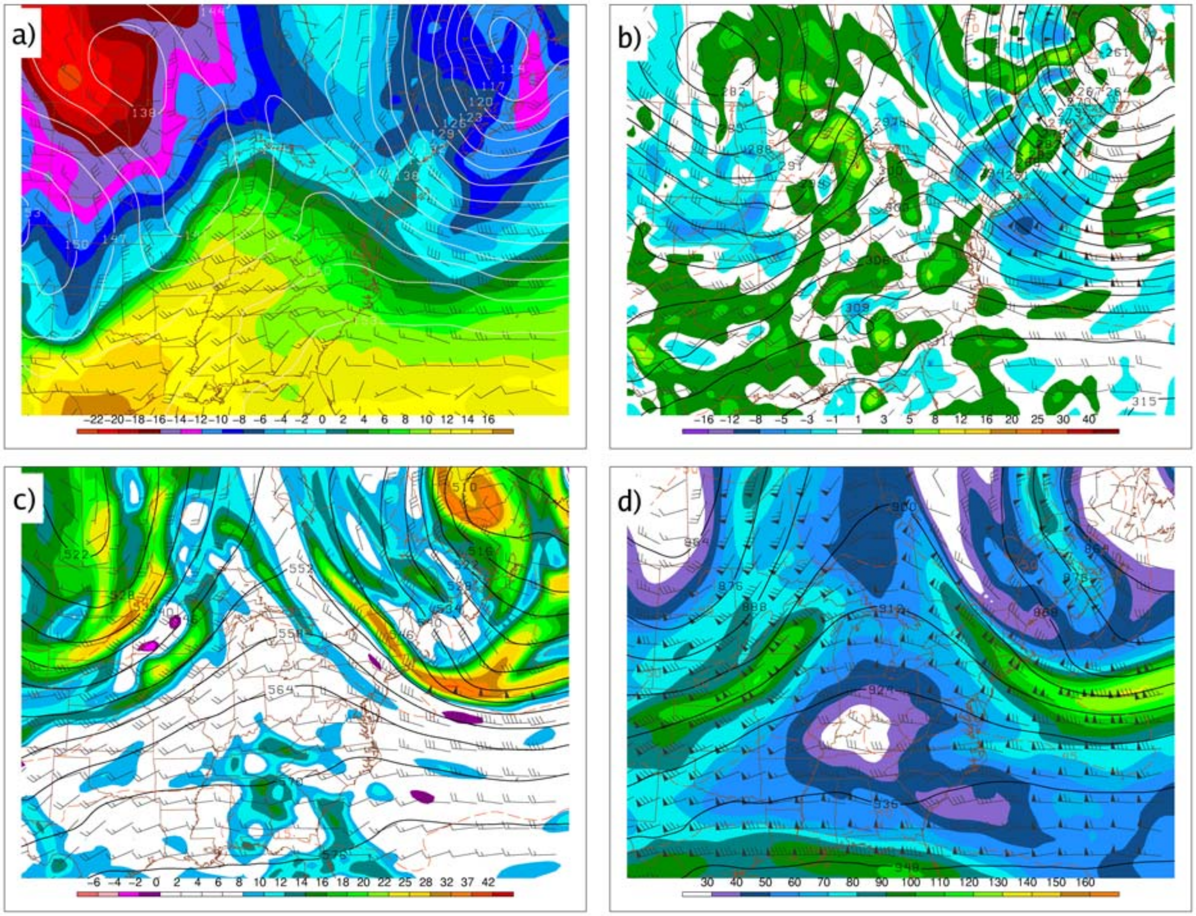

FIG. 1. Upper-level conditions at the time of the event. (a) 850-hPa winds (barbs, standard convention), temperature (filled contours every 2°C), and geopotential height (contoured every 3 dam). (b) 700-hPa winds, vertical motion (filled contours in cm s^{-1} according to scale), and geopotential height (contoured every 3 dam). (c) 500-hPa winds, absolute vorticity (filled contours $\times 10^{-5}$ s^{-1} according to scale), and geopotential height (contoured every 6 dam). (d) 300-hPa winds, wind speed (filled contours every 10 kt), and geopotential height (contoured every 12 dam).

layered structure to the potential temperature field is also favorable for mountain wave activity (Klemp and Lilly 1975).

3. GEOGRAPHY OF HIGH POINT

High Point is the highest point in New Jersey, with an elevation of 550 m. It is not an isolated mountain, but rather part of a quasi-two-dimensional ridge extending from Pennsylvania into New York. This ridge is known as Blue Mountain in Pennsylvania, Kittatinny Mountain in New Jersey, and the Shawangunk Mountains in New York. To the west of this ridge lay the Pocono Mountains of Pennsylvania and Catskill Mountains of New York. Figure 4 displays the topography of the region. Although the topography associated with this ridge has been suggested to influence tornadic circulations (Bosart et al. 2006), it has not been shown to influence wind speeds in relatively quiescent conditions such as was the case with this event. Note that northwesterly flow is perpendicular to the ridge.

Assuming the Albany sounding is representative, it suggests that the base of the temperature inversion was about 130 m above the summit of High Point. The low-level jet in the Albany sounding had its core about 400 m above the summit, but the observed winds (shown below) were 6 kt stronger than this jet maximum. Therefore, any perturbations to the flow induced by the mountain ridge would not need to be inordinately large.

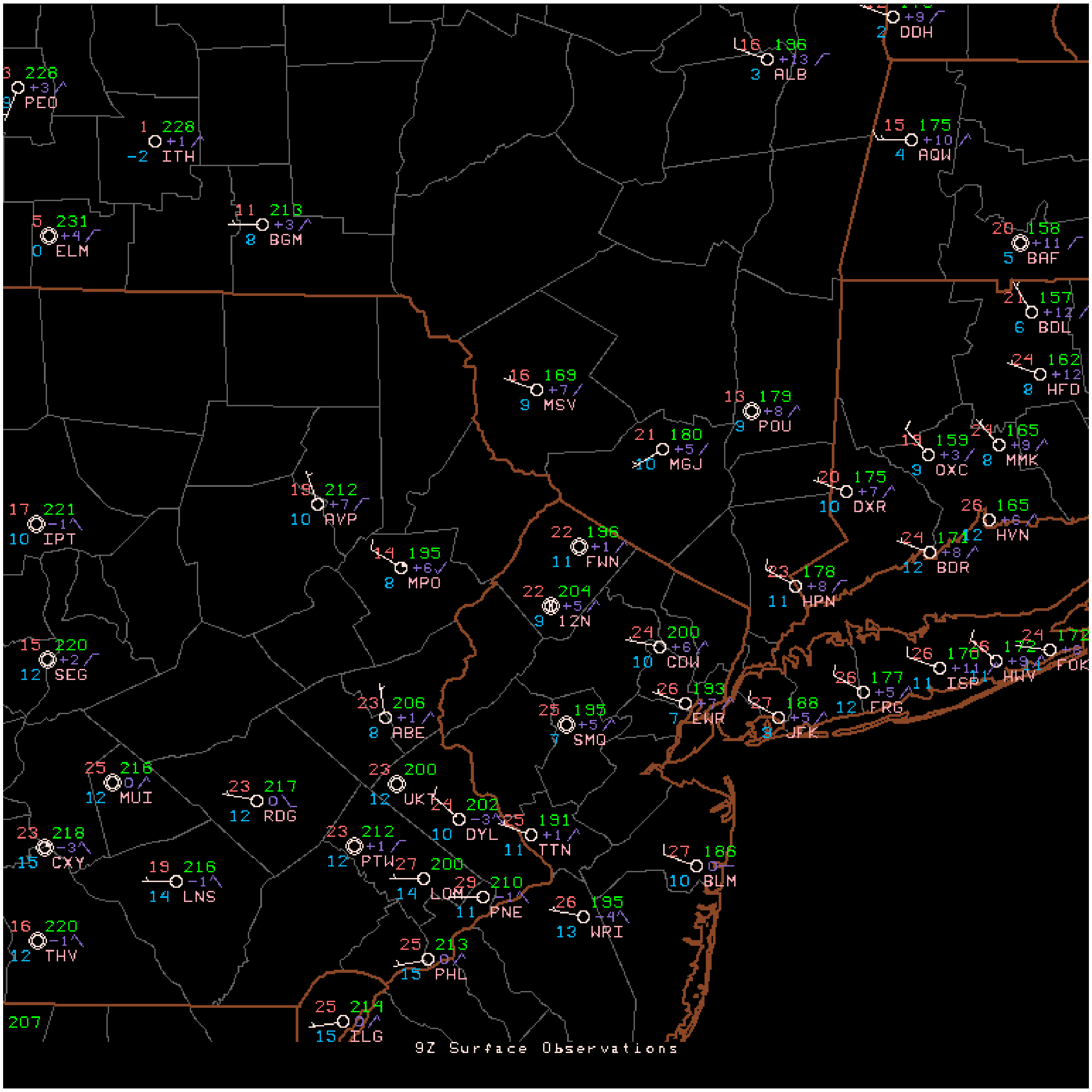

FIG. 2. Surface observations at 0900 UTC 4 Jan 2009.

Three stations contained within the New Jersey Climate and Weather Network are located near High Point. The High Point Monument station (HPM) is located near the summit. The High Point station (HPT) is located to the south at the High Point State Park ranger station. To the east is the Wantage station (WNT). Based on the observations, WNT was nearly directly in the lee of the High Point summit. Figure 5 maps these station locations.

4. HIGH POINT OBSERVATIONS

Figure 6 shows the observations from the stations near High Point, as well as the ASOS station 14 km distant at Sussex (FWM). Note that at all locations except HPM, both the sustained wind and wind gusts were reported at the top of each hour. The HPM station reported the instantaneous wind every 15 minutes. The observations indicate that this high-wind event was highly localized. HPM and WNT were quite gusty, but a station as close as HPT recorded wind gusts only half as strong, and, as we saw

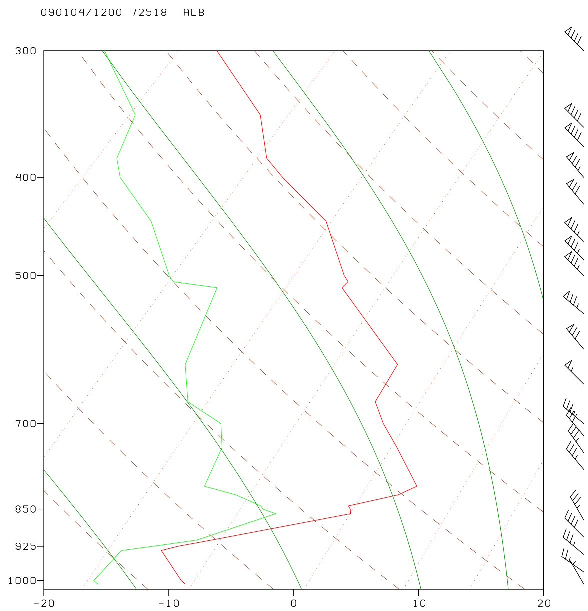

FIG. 3. Albany sounding valid 1200 UTC 4 Jan 2009.

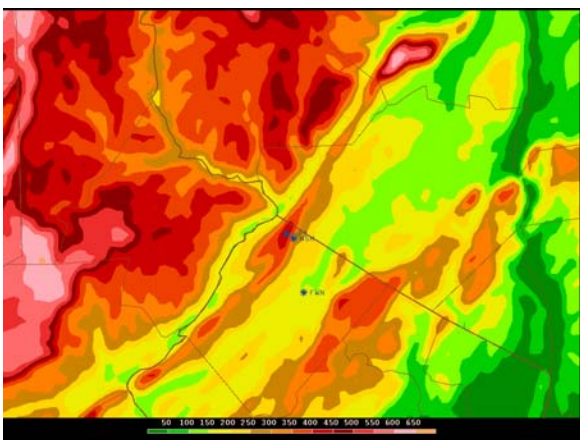

FIG. 4. Surface terrain height (shaded, m).

before, FWM was calm during the height of the event. A comparison of the temperatures at each station revealed that the lapse rate at these levels was dry adiabatic (not shown).

5. MODEL SIMULATION

The Weather Research and Forecasting (WRF) Model was used to further examine the role the topography played in this event. Five domains were employed, ranging from 36 km to 4/9 km. 60 vertical levels were used on the outer three domains, with an increase to 117 levels on the inner domains. The model was initialized from North American Regional Reanalysis data valid at 00 UTC 4 January 2009, or 6–12 hours

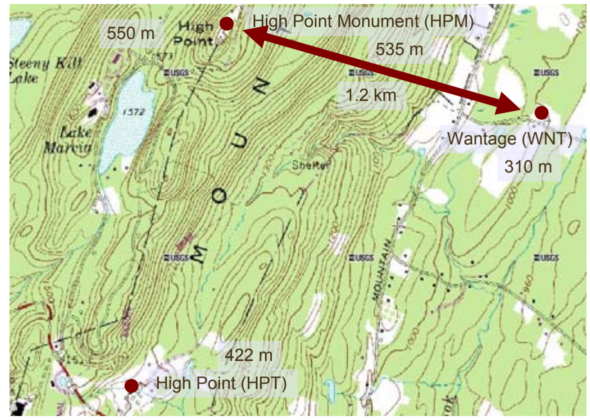

FIG. 5. Topographical map of High Point region.

before the event. Figure 7 shows the 10-m wind speed and the gust diagnostic as determined by the WRFPOST algorithm, while Figure 8 shows a cross section of the model solution oriented parallel to the flow and perpendicular to the ridge. Both figures depict nine-hour forecasts.

The wind gust diagnostic (Fig. 7) captures the high gusts at the HPM and WNT stations quite well, with a slightly underestimated prediction in the 35–40 kt range. However, the gusts are vastly overestimated at HPT and FWN. In contrast, the sustained winds are quite good at HPT and FWN, and again underestimated somewhat at HPM and WNT.

The cross section (Fig. 8) shows that High Point did indeed excite mountain waves in its lee, something that the upstream Poconos and Catskills apparently failed to do. The relationship between the vertical motion and potential temperature fields suggests that the isentropes are acting as streamlines of the flow to a good approximation. The WRF Model simulation is able to capture the enhancement of the wind at and in the immediate lee of High Point as well. We hypothesize that the height and bell-shaped nature of High Point were just right to excite mountain waves under the conditions of 4 Jan 2009.

6. Conclusions

A very localized high-wind event occurred in northern New Jersey during the early morning hours of 4 Jan 2009; this event was not anticipated. Observations and model results suggest that this event was akin to the downslope windstorms that occasionally wreak havoc in the lee of the Rocky Mountains. In fact, the amplification of the winds necessary in this

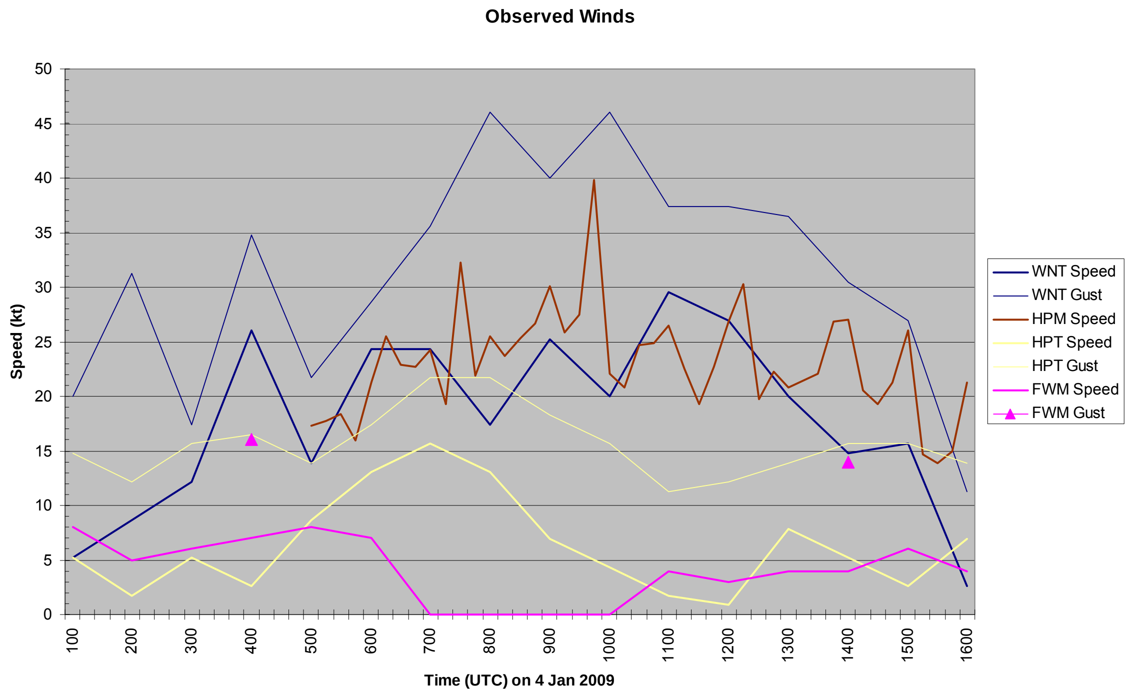

FIG. 6. Time series of winds and wind gusts observed at Wantage (WNT), High Point Monument (HPM), High Point (HPT), and Sussex (FWM) stations.

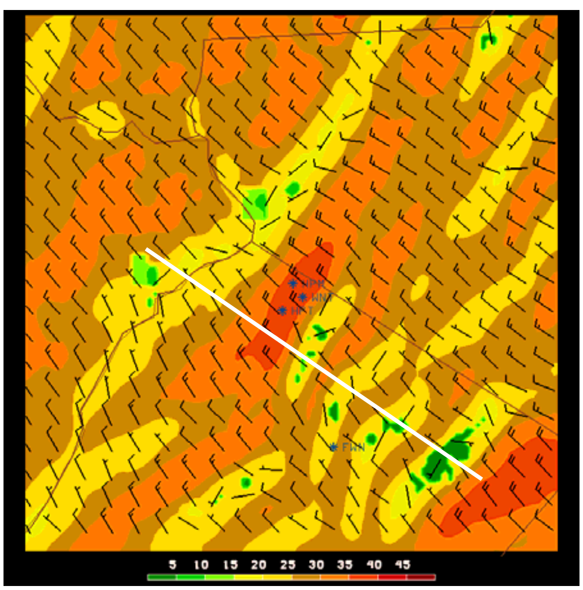

FIG. 7. WRF forecast of 10-m wind speed (barbs, standard convection) and wind gusts (shaded every 5 kt). The white line indicates the location of the cross section in Figure 8

case (about 6 kt) is a reasonable amount to expect for High Point under the same dynamics as a Colorado downslope windstorm given that the Front Range is three times wider and six times higher. On the other hand, there is no clear sign of wave breaking (i.e., nearly vertical isentropes) in the WRF solution, so the phrase “downslope windstorm” would be inappropriate to use in this case if wave breaking is considered a necessary condition for a windstorm. However, it is reasonable to conclude that mountain waves were involved in producing the strong, gusty winds that were observed.

It is unclear whether this event was localized to High Point, since other summits up and down the Kittatinny Ridge are not monitored on a routine basis. It is also unclear how frequently these events occur. It may be that the inversion height must be in a very narrow range to produce the wind enhancement that was observed, thus leading to the rarity of this type of event. The development of a climatology of High Point windstorms is a matter for future research.

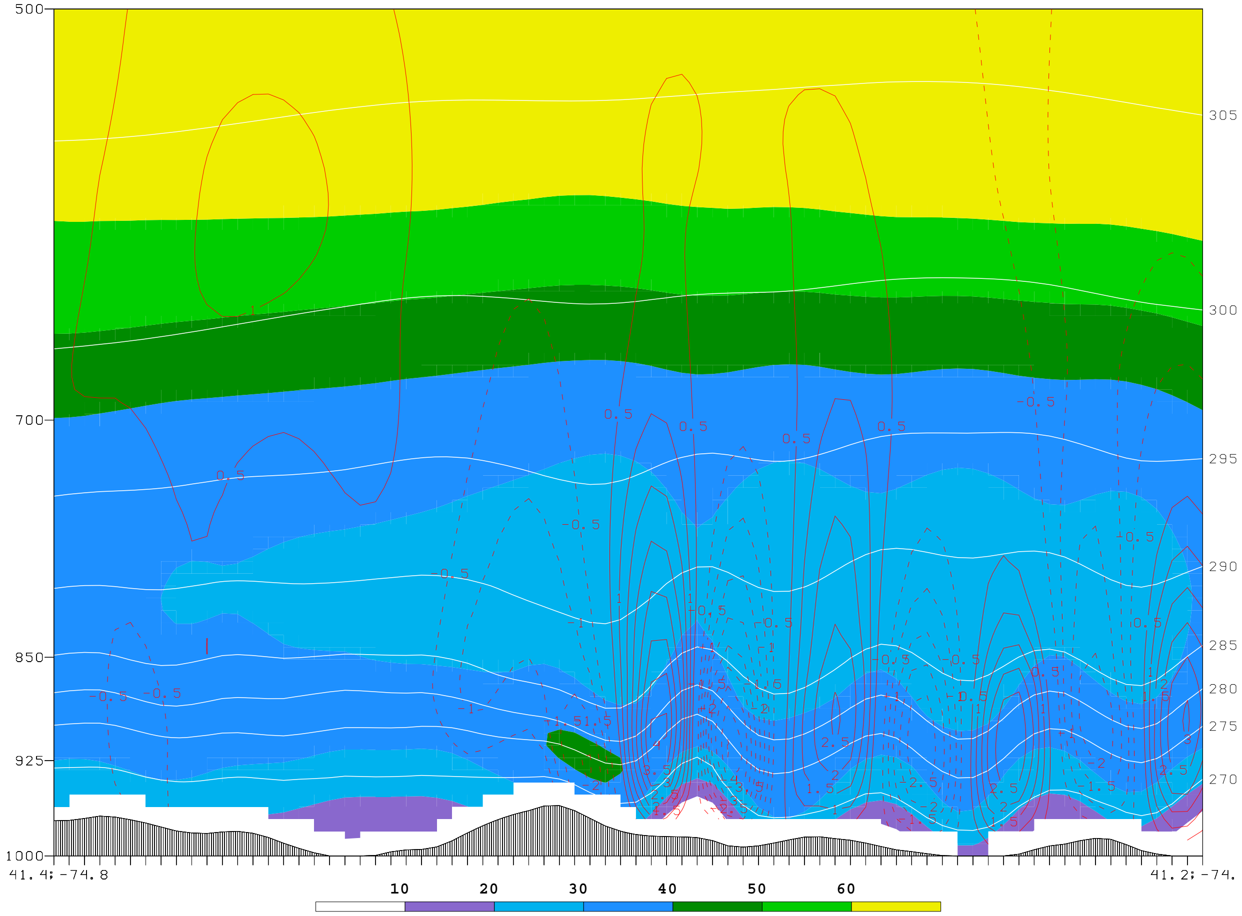

FIG. 8. Cross section parallel to the flow passing through High Point containing potential temperature (contoured every 5 K, solid white), vertical motion [contoured every 0.5 m s^{-1}, red, positive (negative) values solid (dashed)], and wind speed (shaded every 10 kt).

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