ANALYSIS OF RARE CONSECUTIVE NORTHEAST FLOW CONVECTIVE EVENTS OVER CENTRAL NEW YORK AND NORTHEAST PENNSYLVANIA

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Abstract

Two convective events were examined that occurred over the county warning area of the National Weather Service Office in Binghamton, New York on consecutive days in June, 2007. These events were unique because they both occurred under deep northeasterly flow, a highly anomalous flow configuration for the northeastern United States, and a flow direction not typically associated with severe weather. The event on 12 June 2007 led to numerous severe hail and wind reports. The increasing organization of convection during the afternoon and early evening is examined and found to be strongly tied to interactions between existing convection and low-level boundaries. On the following day, under very similar synoptic conditions, the late morning convective environment appeared primed for a repeat episode of severe weather. By early afternoon, however, a substantial decrease in surface moisture and concurrently, surface-based convective instability, led to the development of only isolated, sub-severe convection over the Binghamton, New York County Warning Area. A comparison of the two events reveals that subtle differences in the low-level kinematic and thermodynamic fields, as well as differences in the larger-scale forcing for ascent, played a significant role in limiting the convective potential on this day.

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1. Introduction

Severe convection is a well-known occurrence over the northeastern United States (US), particularly during the warm season (June-August; Kelly et al. 1985; Storm Prediction Center [SPC] 2009). With prevailing westerly flow aloft in the midlatitudes, convective cells typically possess an eastward component of motion. A subset of these storms, those occurring under northwest flow aloft, have been responsible for some of the most notable severe weather events over the northeastern US (e.g., Johns 1982, 1984; Bosart et al. 1998; Cannon et al. 1998).

Northeasterly flow aloft is a much less common flow direction over the northeast US. Constructing a ten year (1998-2007) climatology using the National Oceanic and Atmospheric Administration/Earth System Research Laboratory (NOAA/ERSL) radiosonde database of 0000 UTC soundings at Albany, New York (KALY) during the warm season, a flow direction between 0 and 90 degrees at 500 hPa was found to occur only 4.2 percent of the time (approximately 4 days per warm season). Typically, deep northeasterly flow over the northeastern US is only established when a cutoff cyclone resides over the northwest Atlantic. The climatology of cutoff cyclones has been well established (e.g., Hawes and Colucci 1986; Bell and Bosart 1989; Parker et al. 1989; Smith et al. 2002) and their connection with warm season heavy precipitation has been more recently addressed (e.g., Novak et al. 2002; Najuch et al. 2004). While severe convection has been well researched in the northeastern US (e.g. Riley and Bosart 1987; Wasula et al. 2002; Bosart et al. 2006) the connection between cutoff lows and severe convection has seen less attention (e.g., Najuch et al. 2004). To the author's knowledge, no studies have focused directly on the unusual challenges associated with forecasting severe convection under deep northeasterly flow associated with a cutoff cyclone.

In this study, the full suite of available observational and numerical model data was used to compare and contrast convective events occurring under deep northeasterly flow on consecutive days in June 2007 over the National Weather Service (NWS) Binghamton, New York (BGM) Weather Forecast Office (WFO) County Warning Area (CWA). The 12 June 2007 event featured twenty eight reports of severe weather (¾ in [19 mm] diameter hail and/or wind gusts of 58 mph [50 knots] or greater) over the BGM CWA in an environment that initially appeared only marginal for supporting severe weather. The following day, 13 June 2007, brought late-morning conditions very similar to those on the previous day. By early afternoon, however, a dramatic decrease in low-level moisture and, therefore, instability greatly reduced the threat of severe convection, with only isolated non-severe storms developing on this day. In addition to providing a detailed analysis of both events, the differences that led to the second day being a null event for severe weather were examined.

The data used in this study are discussed in section 2, and the 12 and 13 June 2007 events are described in sections 3 and 4, respectively. Section 5 presents the unique operational forecast challenges of 12-13 June 2007. Section 6 includes a summary of and conclusions from this study.

2. Data

The primary dataset for this study is archived meteorological data for the 12-13 June 2007 events operationally available to NWS forecasters on the Advanced Weather Interactive Processing System (AWIPS). These data include remote and in situ observations, as well as numerical model guidance from the suite of National Center for Environmental Prediction (NCEP) operational models. The NOAA/ESRL Physical Sciences Division provided all archived upper-air plots (using the NCEP/NCAR reanalysis dataset; Kalnay et al. 1996) used in this study.

3. 12 June 2007

a. Synoptic analysis

The upper-air pattern at 1200 UTC 12 June 2007 featured a strong ridge over central North America with an anomalous (deviations from climatology >10 dm at 500-hPa; not shown) cutoff low centered off the New England Coast. These features were vertically stacked through the tropospheric column as shown in Fig. 1, with the implication being that the geostrophic flow direction over the northeastern US was northeasterly through the troposphere. A time sequence of 500-hPa plots for the days leading to 12 June 2007 (Fig. 2) indicated that this cutoff low had slowly retrograded over the Northwest Atlantic, with day-to-day changes in the flow pattern aloft over the northeastern US being very gradual.

The surface pattern at 1600 UTC (1200 pm EDT; Fig. 3) mimicked that aloft with high pressure centered over northern Michigan and low pressure southeast of the New England Coast. Cyclonic isobaric flow was occurring between these features, with a weak inverted trough over western New England, coincident with a region of elevated moisture. To the west of this trough, winds over central New York and northeast Pennsylvania were northerly, in line with the pressure gradient. Observations at this time indicated that the region was far enough from the cooling effects of the moist maritime air and associated cloudiness

Fig. 1(a).

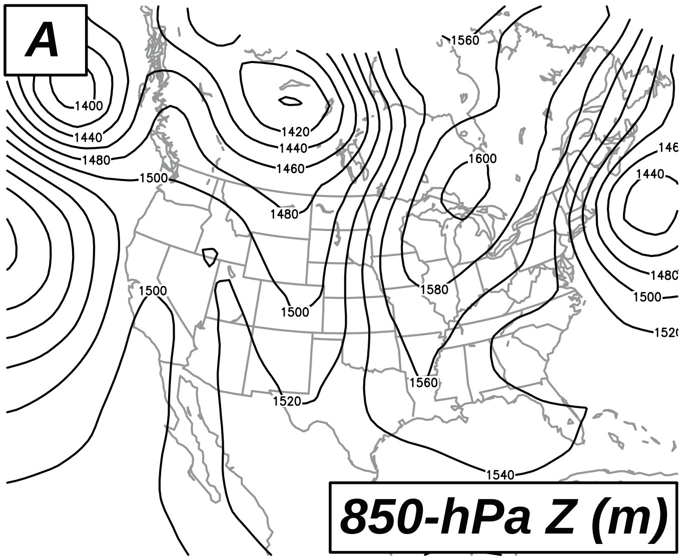

Fig. 1(b).

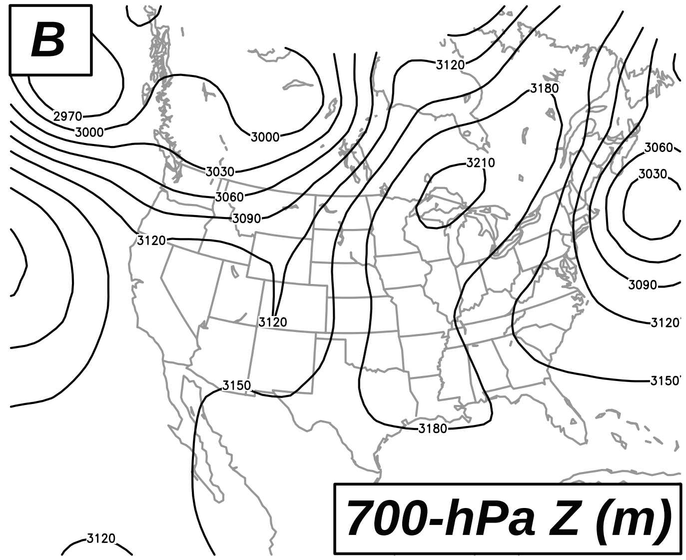

Fig. 1(c).

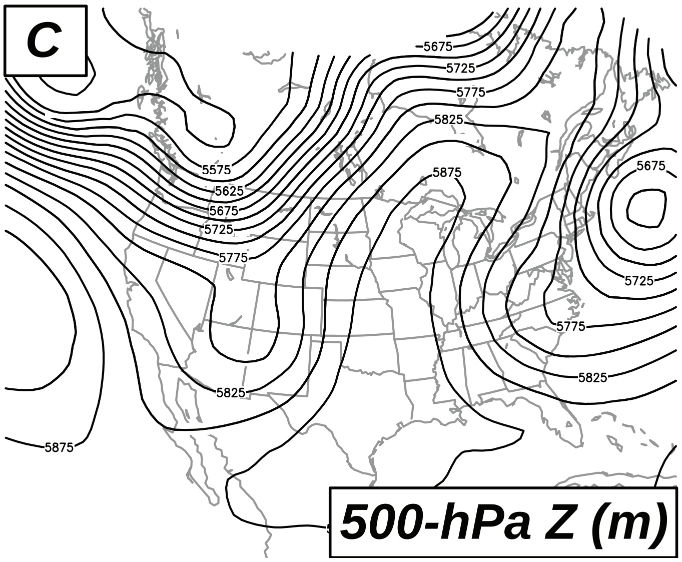

Fig. 1(d).

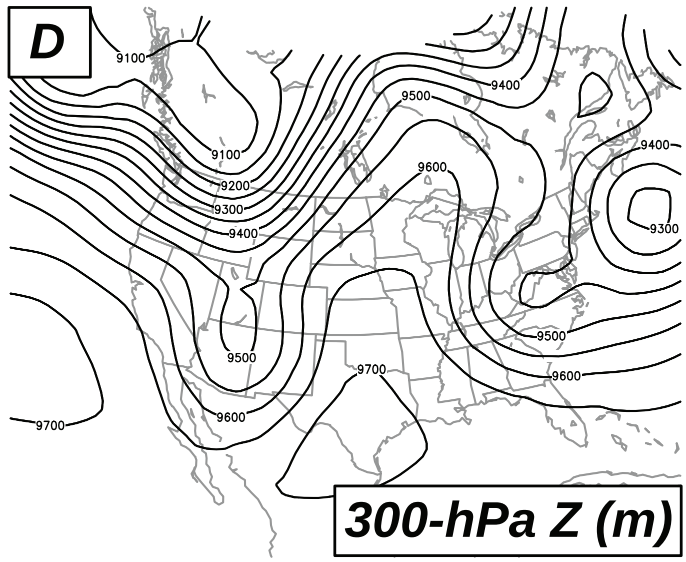

Fig. 1. Plots of height (m) at 1200 UTC 12 June 2007 at (a) 850-hPa, (b) 700-hPa, (c) 500-hPa and (d) 300-hPa.

along the New England Coast to see temperatures rising into the lower 80s F (upper 20s C). Dewpoints were also relatively high in this region, in the vicinity of the inverted trough.

b. Convective potential

A series of factors modulated the potential for convection on 12 June 2007. While surface observations at 1600 UTC did not indicate any synoptic fronts (Fig. 3), cyclonic flow around the low off the New England Coast implied weak synoptic-scale convergence over the BGM CWA, which was likely locally enhanced by the inverted trough over western New England. At mid levels, a Geostationary Operational Environmental Satellite (GOES)-12 water vapor satellite image from 1215 UTC (Fig. 4) revealed a short wave disturbance centered over New England that was migrating southwest with time. The arrival of this disturbance over eastern New York around the time of convection initiation early in the afternoon could be expected to provide large-scale support for ascent in the form of differential cyclonic vorticity advection, and an increase in deep layer shear due to increasing mid-level flow.

Substantial instability was in place by 1600 UTC (1200 pm EDT) across the BGM CWA (Fig. 5). Mean-layer (1000m layer) convective available potential energy (MLCAPE) reached over 1000 J kg^{-1} throughout significant portions of the BGM CWA, with values of 500-1000 J kg^{-1} elsewhere. With insignificant amounts of mean layer convective inhibition (not shown), the environment could be expected to sustain robust convective growth.

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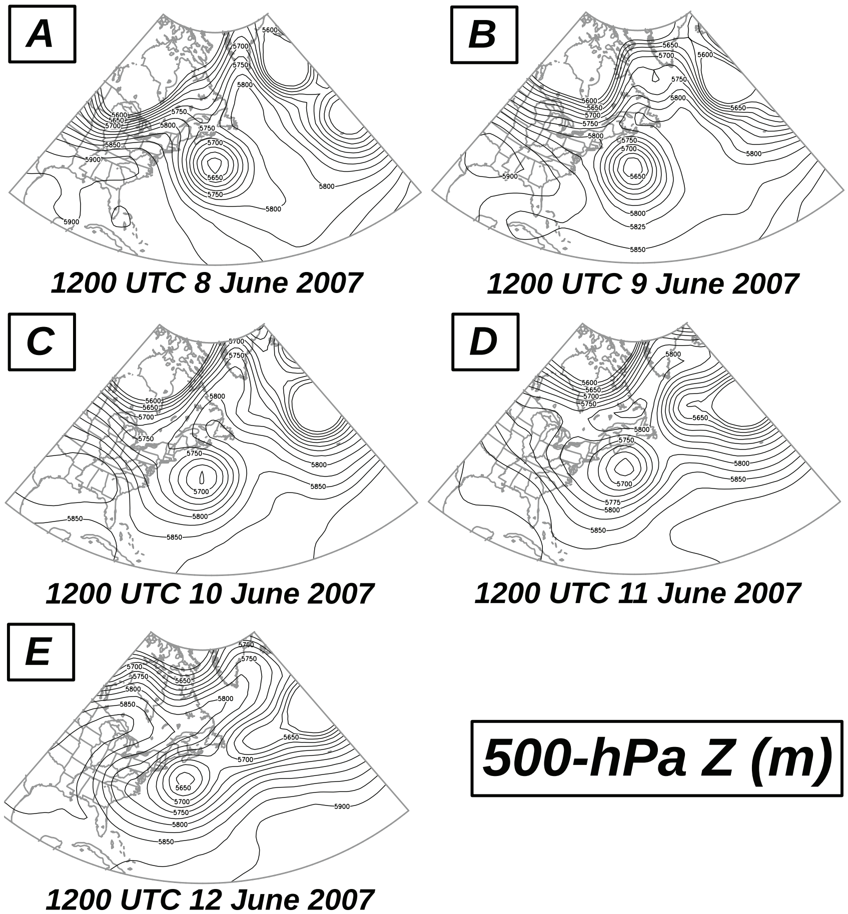


Fig. 2, Time sequence of 500-hPa heights (m) for 8-12 June 2007 at 1200 UTC each day.

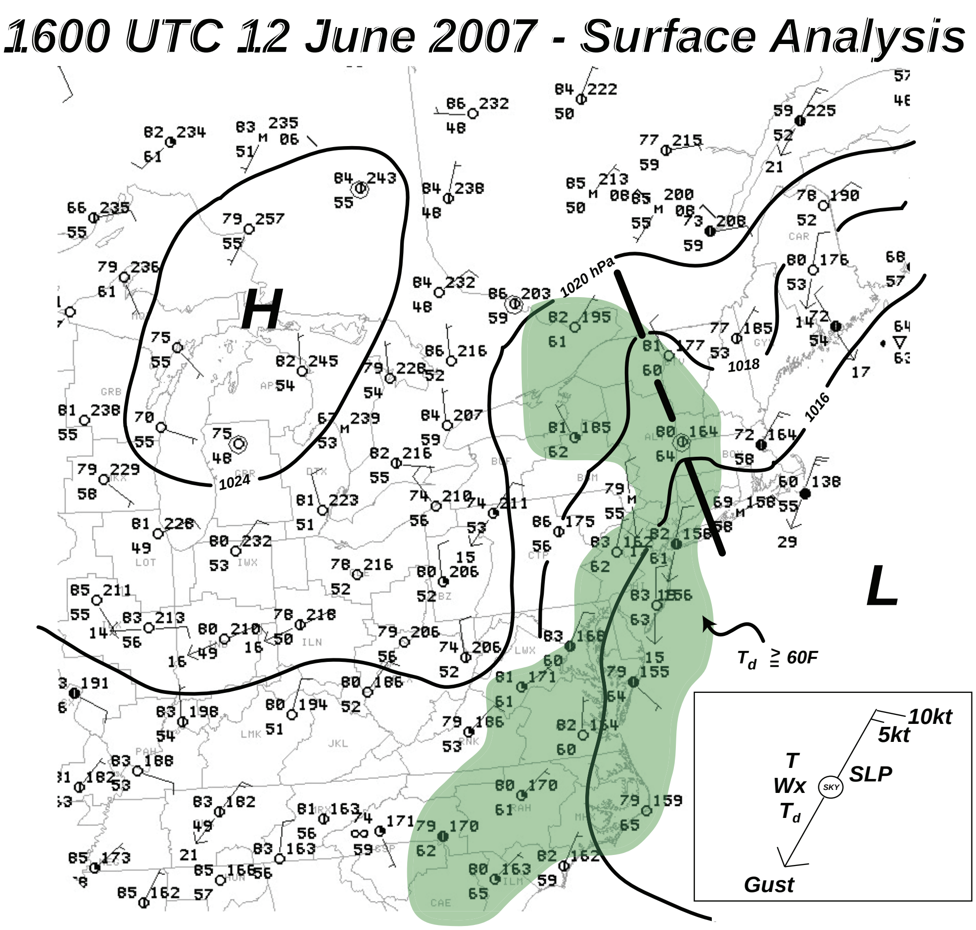


Fig. 3. Conventional surface analysis at 1600 UTC on 12 June 2007. Area of dewpoint temperatures greater than 60 F (15 C) shaded.

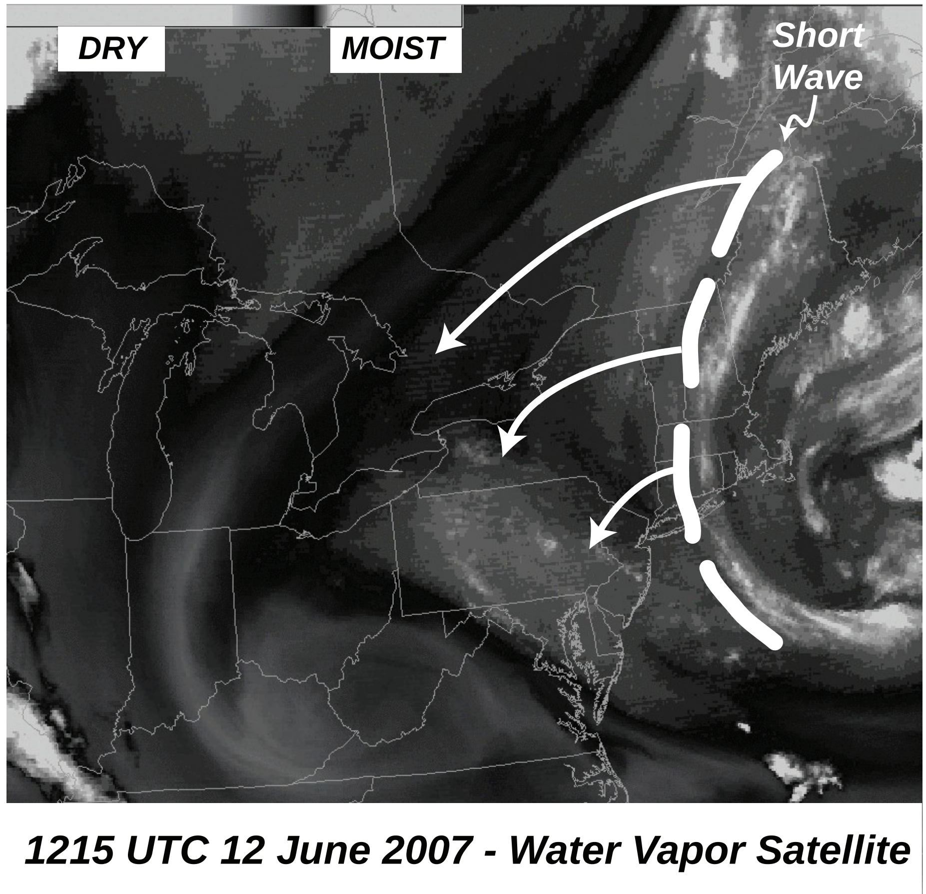


Fig. 4. GOES water vapor image from 1215 UTC 12 June 2007 with short wave of note and its motion annotated.

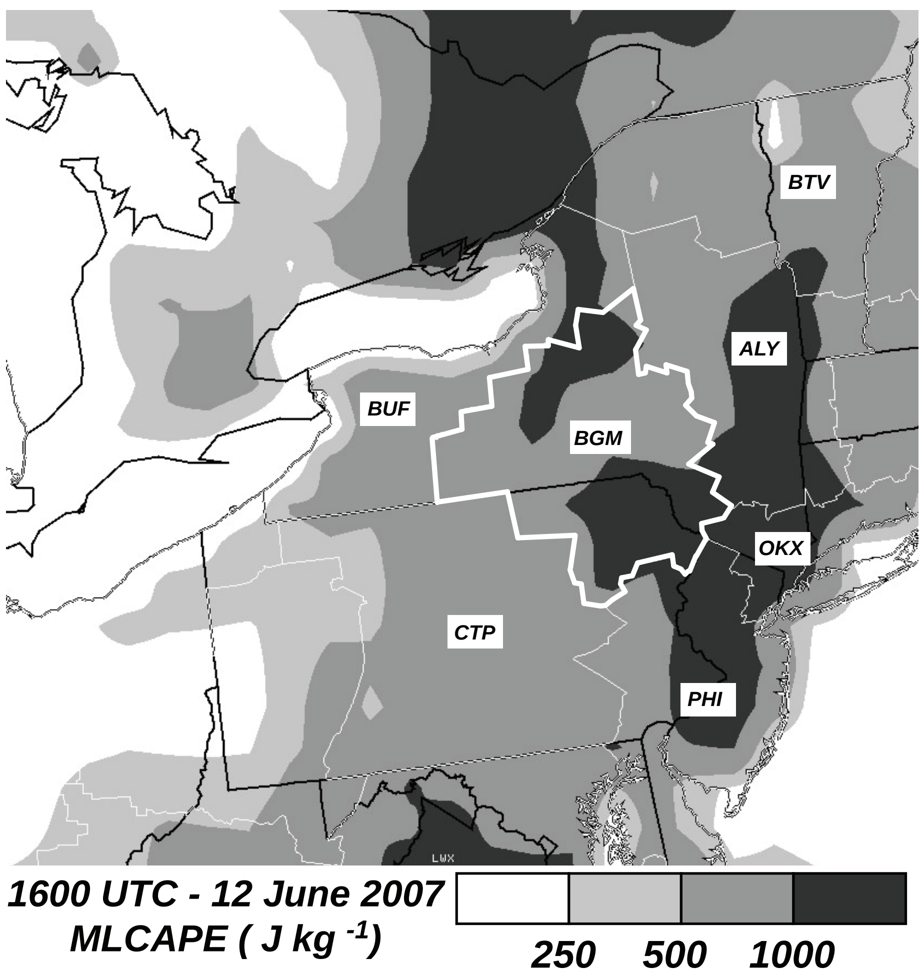


Fig. 5. RUC analysis of MLCAPE at 1600 UTC on 12 June 2007. BGM CWA outlined with surrounding CWAs labeled.

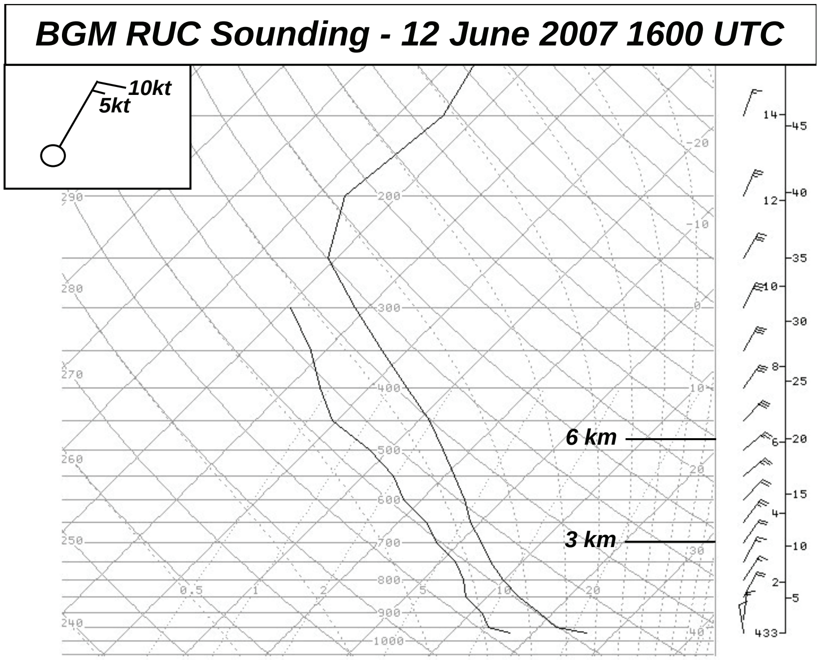


Fig. 6. RUC analysis sounding at BGM at 1600 UTC, 12 June 2007.

Fig. 7(a).

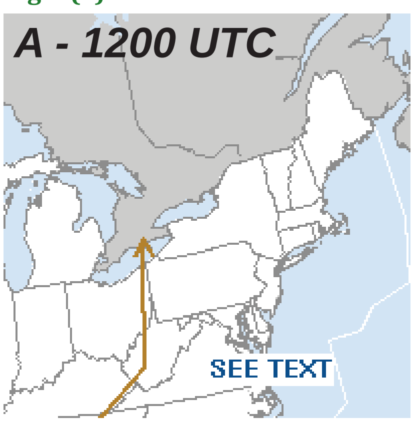


Fig. 7(b).

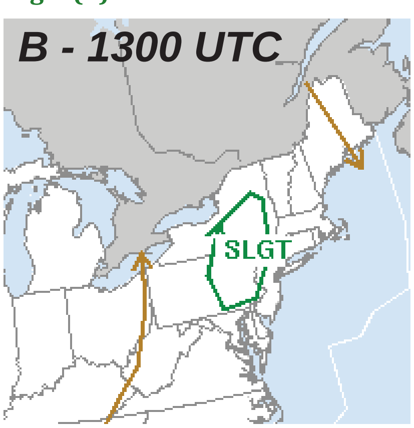


Fig. 7(c).

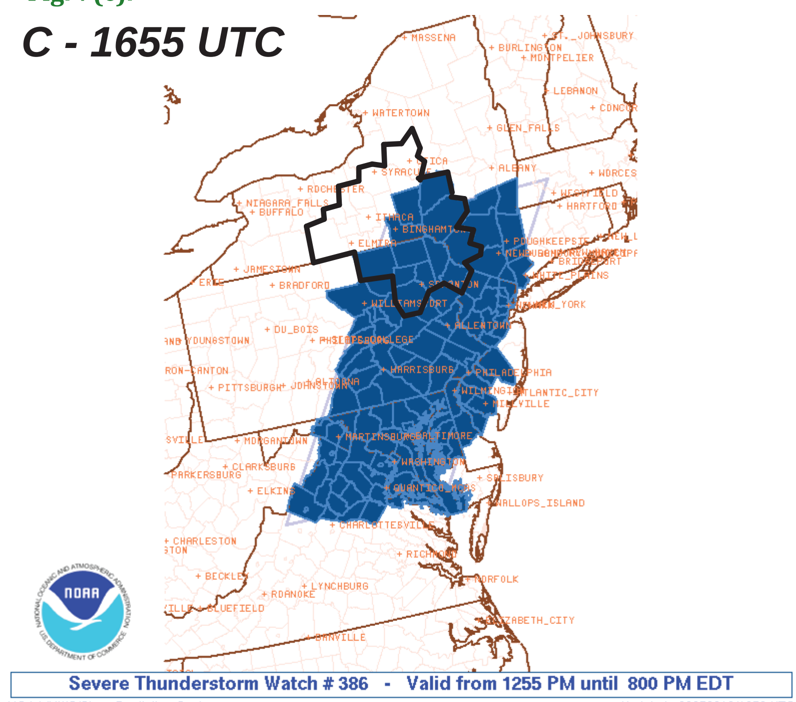


Fig. 7. Products issued by SPC on 12 June 2007. (a) 1200 UTC Day 1 Convective Outlook. (b) 1300 UTC Day 1 Convective Outlook. (c) Severe Thunderstorm Watch #386 (shaded) issued at 1655 UTC; BGM CWA is outlined.

A 1600 UTC RUC analysis sounding at BGM (Fig. 6) indicated deep shear (0-6 km) of 20 kts (11 m s^{-1}), which was fairly evenly distributed in the vertical, given 0-3-km shear values of 10 kts (6 m s^{-1}). These shear values would be expected to support some convective organization (e.g. Weisman and Klemp 1982), with unorganized "pulse" cells also possible.

The SPC Day 1 Convective Outlook at 1200 UTC on 12 June 2007 indicated no enhanced risk of severe thunderstorms over the BGM CWA (Fig. 7a). This was updated to a "slight risk" at 1300 UTC (Fig. 7b) with a severe thunderstorm watch being issued at 1655 UTC (through 0000 UTC 13 June 2007; Fig. 7c) over portions of central New York and northeast Pennsylvania.

c. Convective evolution

Composite reflectivity from the KBGM WSR-88D (Weather Surveillance Radar 88) at 1700 UTC indicated convection over, or immediately downwind (given a steering layer flow from northeast to southwest) of higher terrain areas over northeastern Pennsylvania, eastern New York and western New England (Fig. 8). Higher terrain is frequently the location for convection initiation (e.g., Hallenbeck 1922; Klitch et al. 1985; Tucker and Crook 2005), due to local mountain-valley circulations generated by differential heating.

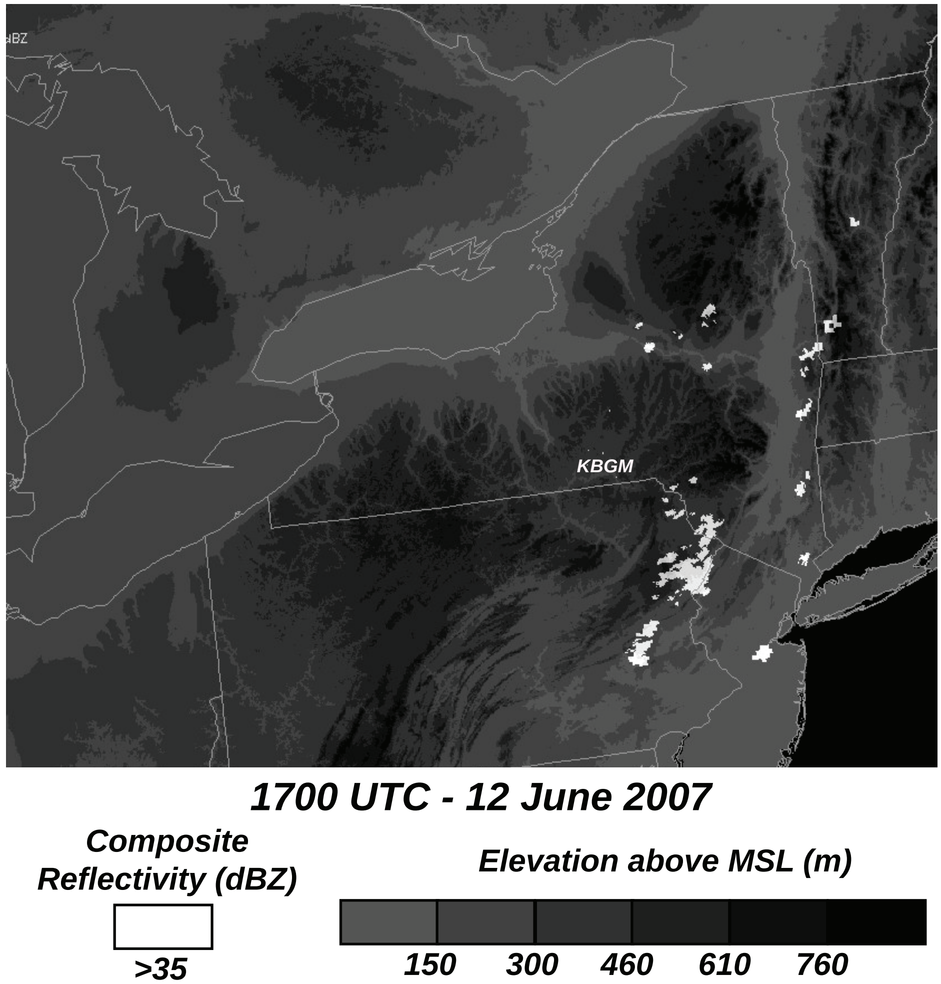


Fig. 8. Topographic map of the BGM CWA (elevation above MSL in meters and shaded) along with areas of composite reflectivity returns >35 dBZ (in white) from the KBGM WSR-88D at 1700 UTC 12 June 2007.

A series of KBGM WSR-88D base reflectivity images is shown in Fig. 9a-e to document the convective evolution during the remainder of the afternoon of 12 June 2007. Within three hours of convection initiation over the higher terrain (see Fig. 8), pulse convection developed throughout much of central New York by 2000 UTC (Fig. 9a). While the character of this pulse convection was quite similar at 2100 UTC (Fig. 9b), a dominant cell had developed over southeast Madison County. By 2200 UTC (Fig. 9c), while much of the pulse convection was weakening, the cell over Madison County maintained its strength and moved southwest into northern Chenango County. Numerous severe weather reports, including hail and wind damage, were received from Madison and Chenango Counties as this cell passed (National Climatic Data Center 2007). In addition, an outflow boundary can be seen as a fine line to the southwest of this convection, intersecting the primary convective cell. By 2300 UTC (Fig. 9d) this cell continued to move southwest, along the aforementioned outflow boundary, and into eastern Cortland County. Notice how convection throughout the remainder of the BGM CWA had diminished rapidly in intensity as daytime heating waned. At 0000 UTC (Fig. 9e), the primary area of convection was itself beginning to weaken and no additional severe weather reports occurred during the remainder of the evening. A total of 28 severe weather reports (15 hail, 13 high wind) were received on 12 June 2007 (National Climatic Data Center 2007, Fig. 10) with a large portion of these reports occurring along the track of the primary convective cell described above.

d. Surface boundary interactions

Surface boundaries and their importance in spawning and strengthening convection have been studied extensively in the literature (e.g., Byers and Braham 1949; Matthews 1981; Wilson and Schreiber 1986; Weckwerth

Fig. 9(a).

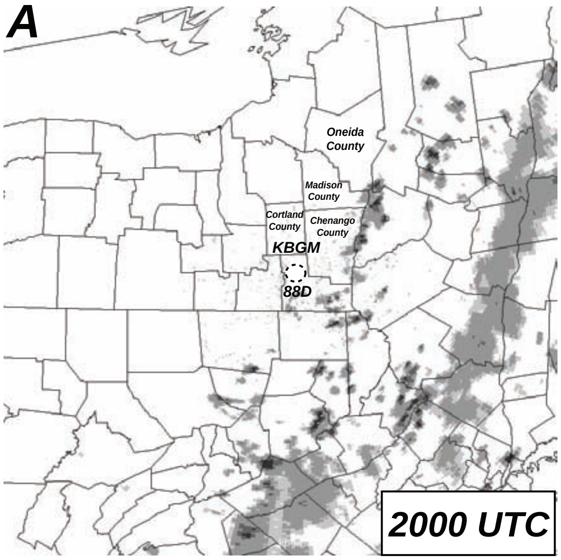


Fig. 9(b).

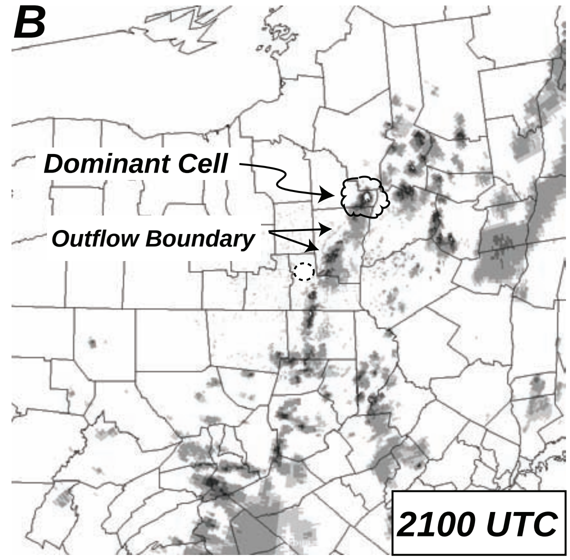


Fig. 9(c).

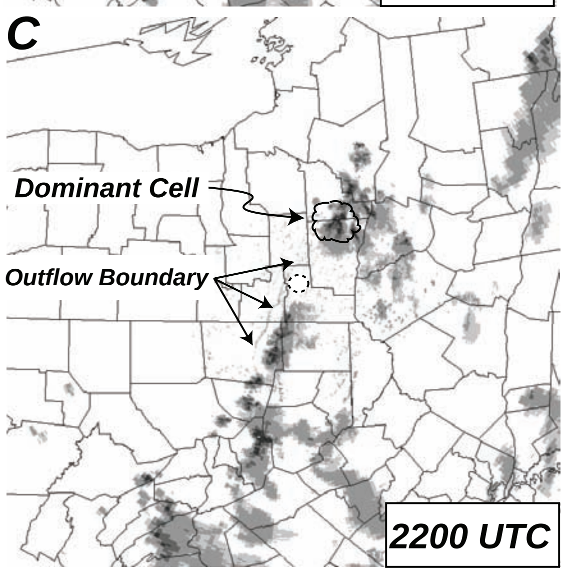


Fig. 9(d).

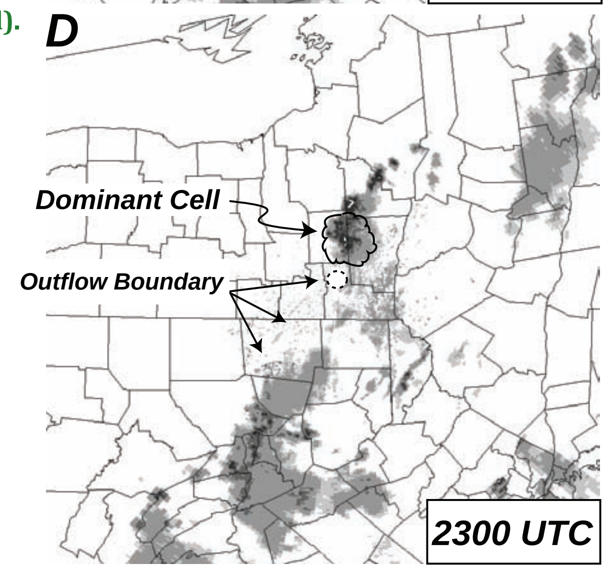
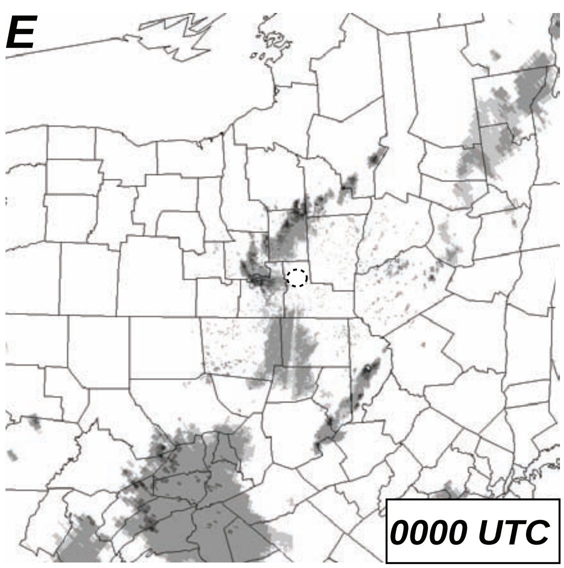


Fig. 9(e).



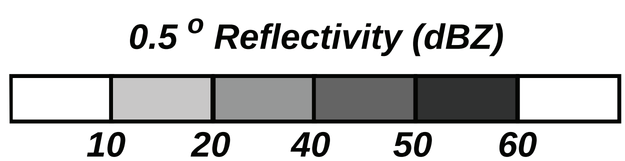


Fig. 9. Time sequence of 0.5° reflectivity data from the KBGM WSR-88D (dashed circle) for 2000 UTC 12 June 2007 through 0000 UTC 13 June 2007. Location of relevant counties, outflow boundary and dominant convective cell discussed in the text are highlighted.

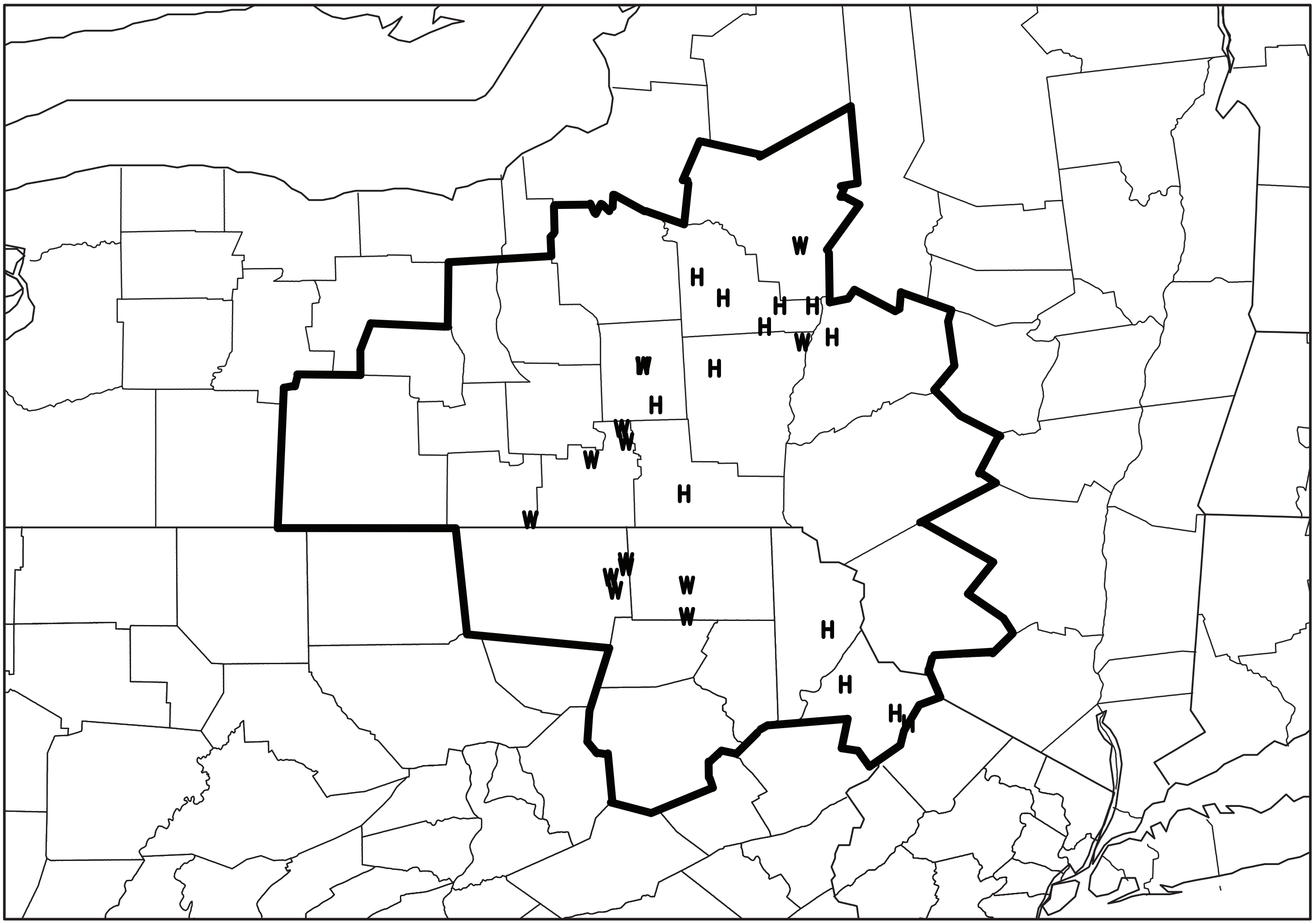


Fig. 10. Severe wind (marked by "W") and hail (marked by "H") reports in the BGM CWA on 12 June 2007 (from NCDC 2007).

et al. 2008). Analysis in the previous section suggests that the primary area of convection moved southwest along a northeast-to-southwest oriented outflow boundary. It is reasonable to assume that enhanced convergence along this boundary would have provided an added source of low-level ascent that could have fueled the updraft associated with the primary area of convection. Figure 11 shows the outflow boundary in greater detail. It is apparent that this boundary only made slow northwestward progress through 2100 UTC (Figs. 11a-b), and was nearly stationary afterwards (Fig. 11c). This slow northwesterly motion allowed for an extended period of interaction between this boundary and the convection riding southwestward along it.

The reasons for the outflow boundary's slow movement are now examined. Surface observations from 2200 UTC (Fig. 12) for Ithaca (KITH), Penn Yan (KPEO) and Syracuse, New York (KSYR) indicated north-northwesterly flow around 10 kts (~5 m s^{-1}) ahead (i.e., northwest) of an inverted trough axis and the slowly advancing outflow boundary. As evidenced by the KBGM VAD vertical wind profile (not shown) and surface observations (Fig. 12), the outflow boundary had moved west into the BGM CWA. Given that the north-northwesterly flow was nearly orthogonal to the approaching outflow boundary, it is reasonable to hypothesize that it slowed the expanding outflow boundary between 2100-2200 UTC. A quick calculation confirms the initial motion of the gust front, as estimated from 2100-2130 UTC, was ~15 kts (8 m s^{-1}).

Using the equation for the speed of density current propagation, the motion of the outflow boundary may be estimated (Seitter 1983; Mahoney 1988):

$$V = \mathrm{k}\left(\frac{\Delta p}{\mathrm{r}}\right)^{\frac{1}{2}} \qquad \textbf{(1)}$$

where κ is the non-dimensional Froude number, Δp is the surface hydrostatic pressure difference between the density current head and the environment, and ρ is the density of the environmental air. Using the following values of κ (1.3;

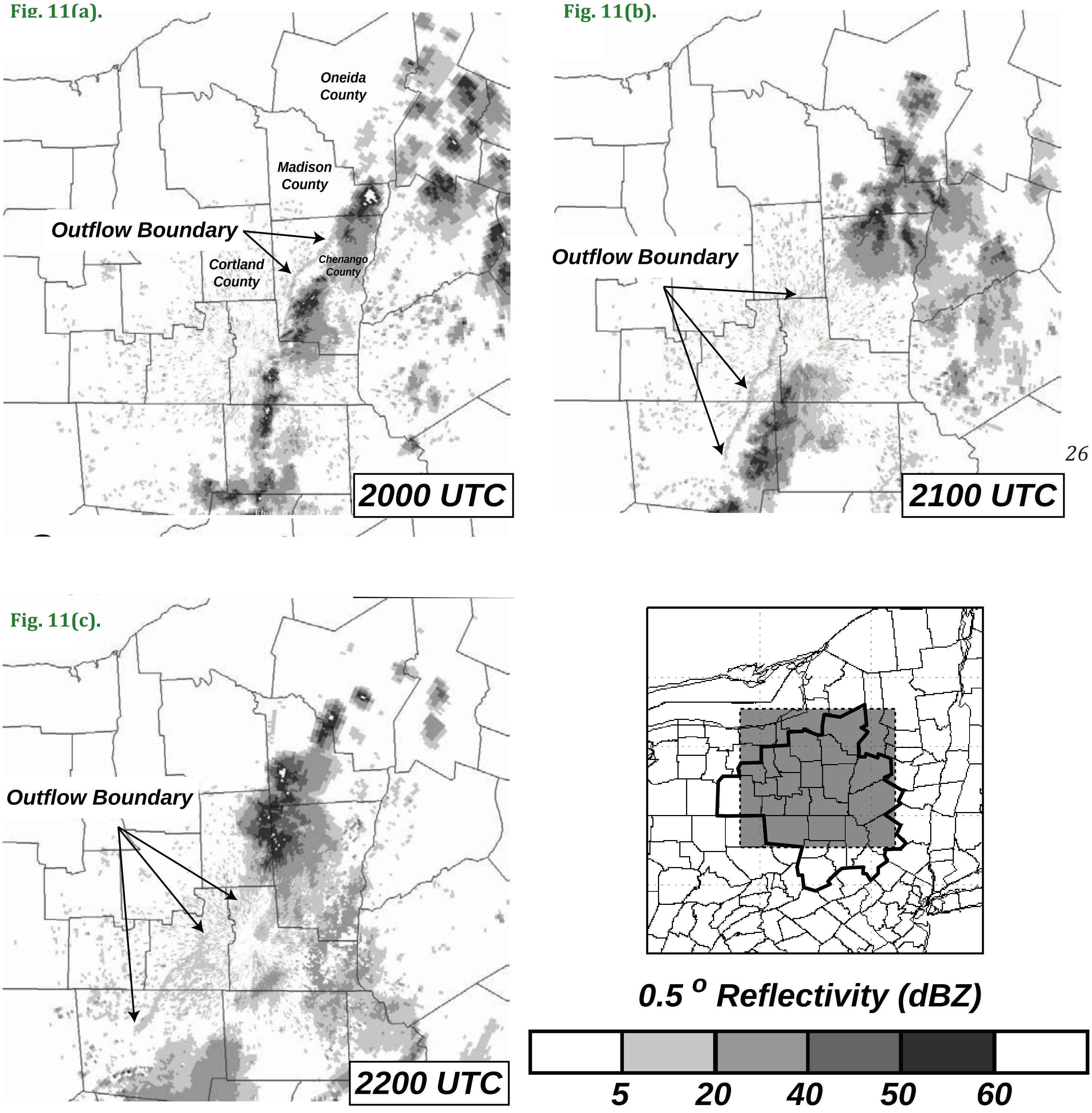


Fig. 11. Time sequence of 0.5° reflectivity data (dBZ) from the KBGM WSR-88D for 2000-2200 UTC 12 June 2007 with location of outflow boundary annotated. Map insert shows the larger area of interest (shaded) with counties and the BGM CWA denoted.

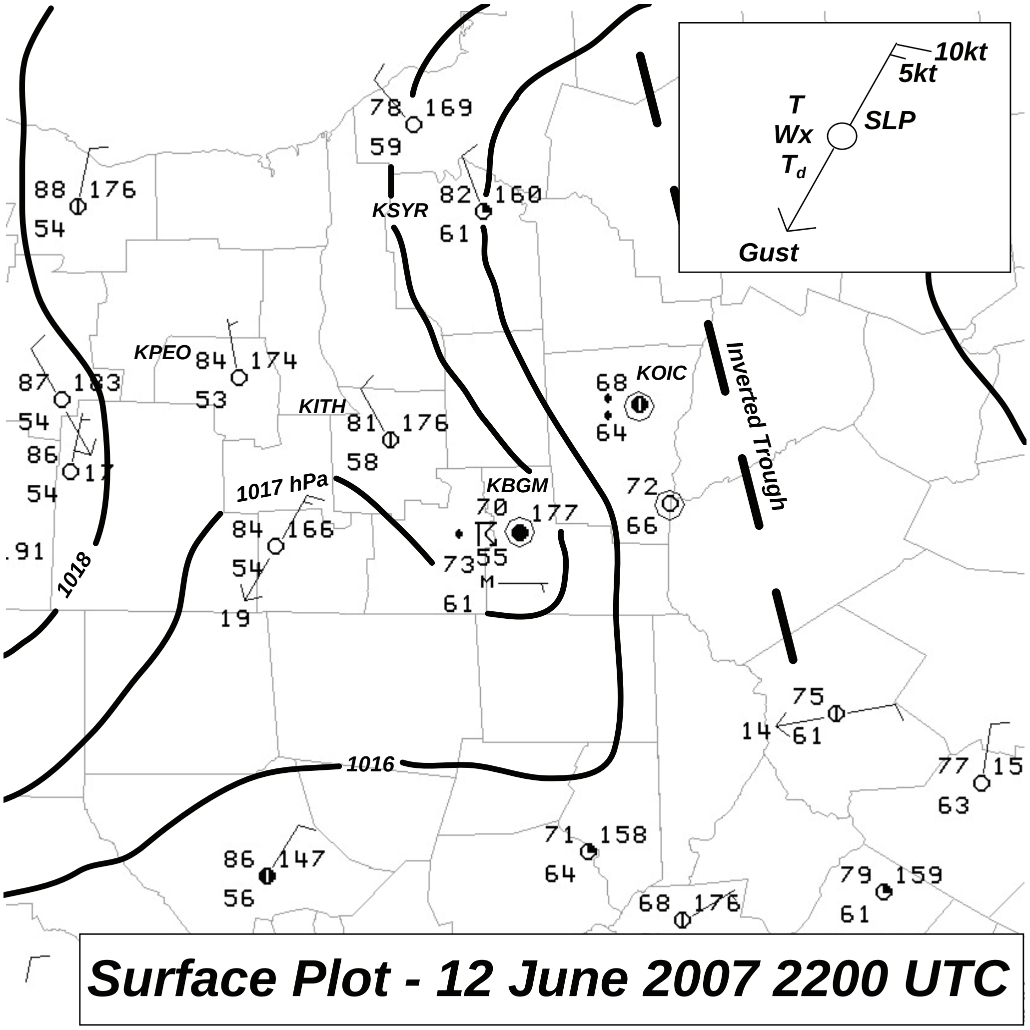


Fig. 12. Plot of surface observations at 2200 UTC on 12 June 2007 with key locations identified.

Mahoney 1988), Δp (1.4 hPa; using the KBGM observation just before and just after outflow boundary passage) and ρ (1.18 kg m^{-3} ; using an environmental p and T of 1017 hPa and 300 K respectively), a rough estimate of V~14 m s^{-1} is obtained. The difference between this and the observed outflow boundary motion of 8 m s^{-1} is 6 m s^{-1} (12 kts), and is close to the strength of the flow opposing the outflow boundary to the northwest. Later in the evolution of the outflow boundary, convection associated with the initial boundary weakened. Given a lack of further cold air to work with, the outflow boundary likely stalled in response to opposing flow to the northwest, and the warming of the airmass behind it.

In summary, it appears that deep northeasterly flow allowed for storm motion to the southwest, and the preferential location of southwest-northeast oriented outflow boundaries that moved orthogonal to this orientation. The position of the inverted trough, over the BGM CWA by 2200 UTC, maintained northwesterly winds west of the strengthening convection, with these winds directly impeding the movement of the outflow boundary west of this convection. Without the influence of the stalled outflow boundary, one would hypothesize that convection would likely have been weaker, shorter-lived and less likely to produce widespread severe weather versus what was observed on 12 June 2007.

In addition to the outflow boundary described above, two other boundaries played key roles in focusing robust convection over southern Madison County on 12 June 2007. These boundaries are depicted in Figs. 13 and 14. In Fig. 13 a lake breeze boundary can be seen from the perspective of the Montague, New York (KTYX) WSR-88D. At 1900 UTC, this boundary manifested itself as a fine line in the base reflectivity data (Fig. 13a). A clear distinction between lake-modified air at KSYR, Fulton, New York (KFZY), Kingston, Ontario (CYGK), and inland air at Fort Drum (KGTB) and Watertown, New York (KART) is apparent, with temperatures about 10 F (5-6 C) warmer

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Fig. 13(a).

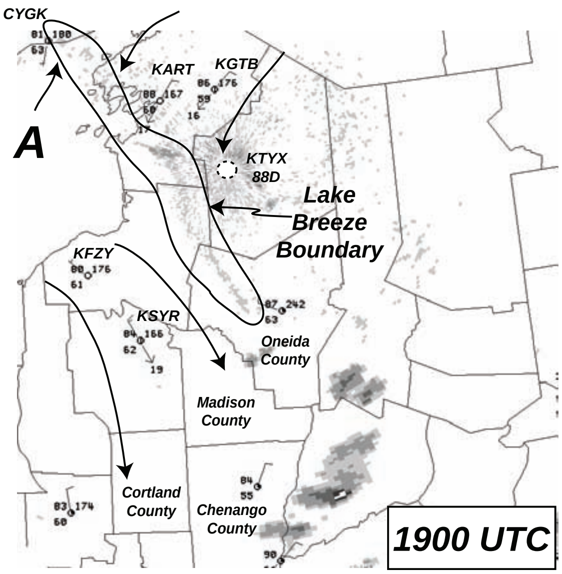


Fig. 13(b).

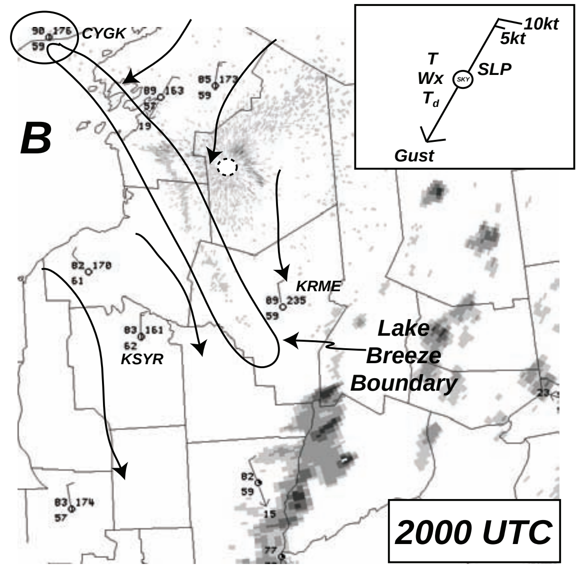


Fig. 13(c).

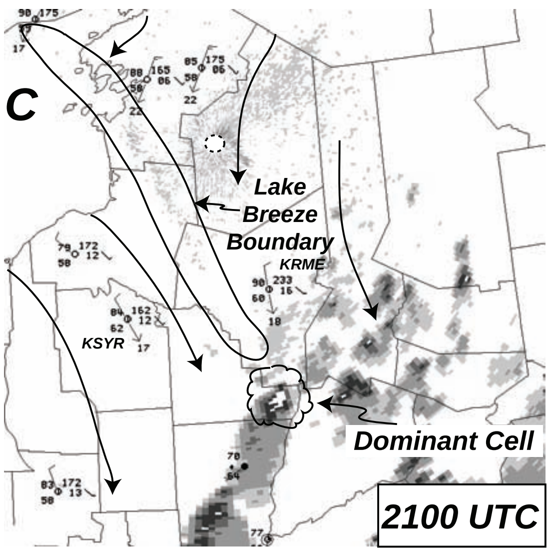


Fig. 13(d).

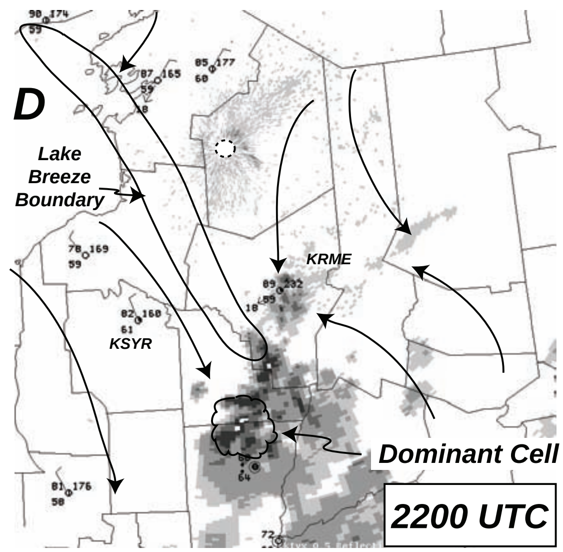
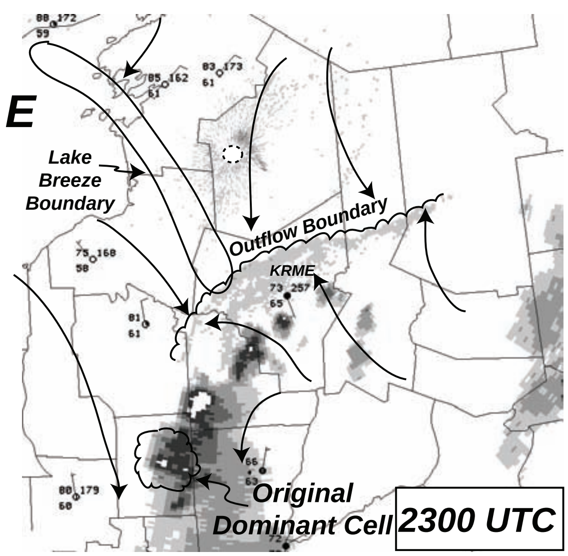


Fig. 13(e).



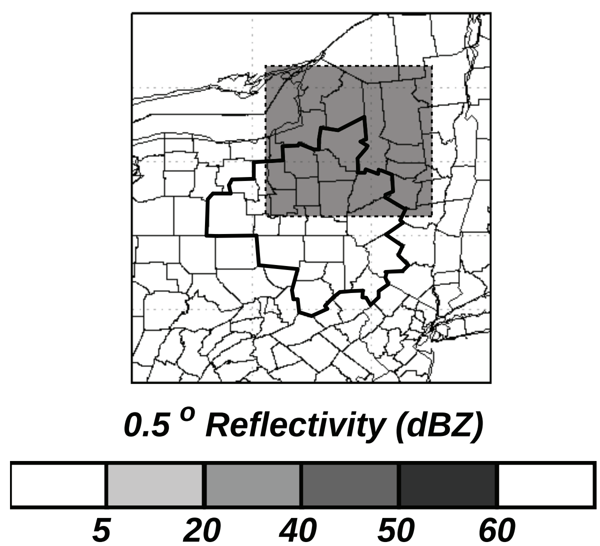


Fig. 13. Time sequence of 0.5° reflectivity data (dBZ) from the KTYX WSR-88D (dashed circle) for 1900-2300 UTC 12 June 2007 along with regional surface observations. Location of lake breeze boundary, outflow boundary, dominant convective cell, and surface wind pattern discussed in the text are highlighted. Map insert, same as in Fig. 11.

Fig. 14(a). Fig. 14(b). Fig. 14(c). Fig. 14(d). Fig. 14(e).

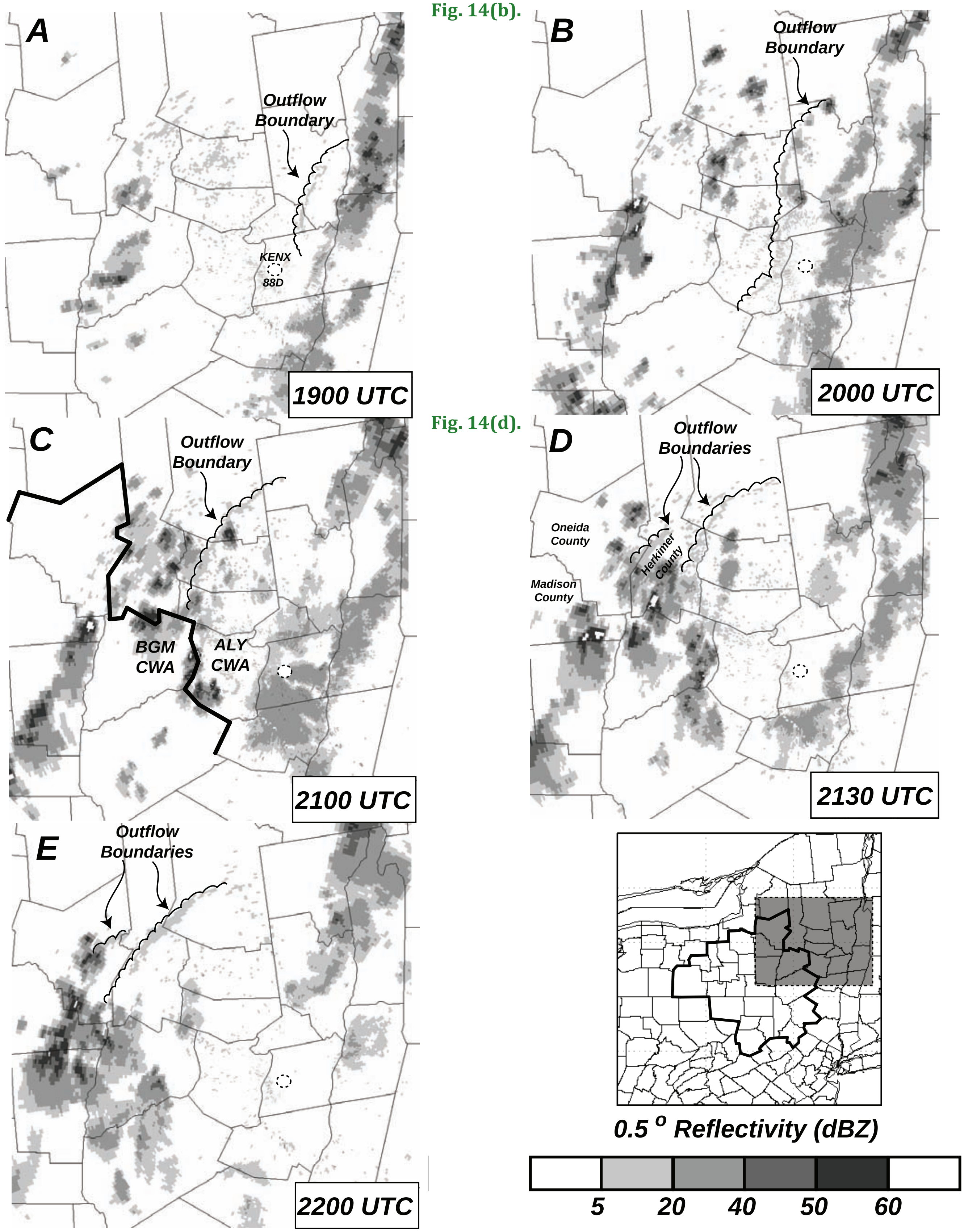


Fig. 14. Time sequence of 0.5o reflectivity data (dBZ) from the KENX WSR-88D (dashed circle in each image) for 1900-2200 UTC 12 June 2007. Location of relevant counties, outflow boundaries, and BGM/ALY CWA boundary discussed in the text are highlighted. Map insert, same as in Fig. 11.

east of the boundary with a sharp wind shift along the boundary. By 2000 UTC (Fig. 13b), this boundary had edged southwest with temperatures (dewpoints) rising (falling) at CYGK along with a 140 degree wind shift. During the 2100-2200 UTC period (Figs. 13c-d), while the thin line became less well-defined, observations continued to suggest a clear boundary between KSYR and Rome, New York (KRME), with implied convergence along this boundary strengthening as the winds at KRME veered to a more northeasterly direction by 2200 UTC, likely in response to the westward moving inverted trough (Fig. 12). An extrapolation south and east of these locations (beyond the range where KTYX would be able to see the shallow lake breeze boundary) would place the lake/land airmass boundary very near the location of cell development/strengthening over Madison County between 2100 and 2300 UTC. By 2300 UTC, an outflow boundary (described below) passed through KRME with pronounced cooling along with a wind shift to southeasterly.

Another important low-level boundary was provided by convection over eastern New York, described in Fig. 14. By 1900 UTC (Fig. 14a), a north-south oriented line of convection, which had developed over the higher terrain of western New England (not shown) had spawned an outflow boundary that moved westward across eastern New York. This boundary was better defined, while spawning new convective cells at 2000 UTC (Fig. 14b). By 2100 UTC (Fig. 14c), the boundary, while somewhat harder to pick out amongst the convective cells it encountered, was continuing to move westward, just about to enter the BGM CWA. During the 2130-2200 UTC period (Figs. 14d-e) the primary boundary, although harder to define (as it was increasing in distance from the Albany, New York WSR-88D [KENX]), was joined by a second boundary from convection that developed over Herkimer County, New York. These two boundaries, by 2200 UTC, likely extended into Oneida and Madison counties, encountering ongoing convection, as well as the lake breeze boundary previously described.

A summary of the important boundaries and their respective roles in the convective evolution on 12 June 2007 is shown in Fig. 15. Pulse convection initially developed over the higher terrain of east-central New York and western New England given ample mean layer instability, weak synoptic-scale forcing for ascent, and ascent aided by the terrain (Fig. 15a). At the same time, a lake breeze boundary had developed northwest of this initial convection. Over time the linearly oriented convection (Fig. 15b) in western New England (due to the orientation of the orography in this region and the collocation of an inverted surface trough) generated a convective outflow boundary that moved westward across eastern New York, spawning new convection that continually pushed this boundary westward. Later, this boundary intersected the lake breeze boundary (Fig. 15c) at a location just south of KRME. Constructive interference between the two boundaries spawned the most robust convective cell of the day. Finally, convection southwest of this primary cell laid out an additional outflow boundary that was both slow-moving (due to the impeding flow to its northwest) and parallel to the motion of the primary convective cell. While all other convective cells diminished in intensity with the loss of day-time boundary layer heating in the evening, the primary cell persisted far longer due to its favorable interaction with the source of low-level convergence provided by the outflow boundary.

4. 3 June 2007

a. Synoptic analysis

The upper-air pattern at 1200 UTC on 13 June 2007 greatly resembled that of the previous day (cf. Figs. 16 and 1). While strengthening westerly flow impinged on the ridge over the central US, the position of the ridge axis had moved very little. The most notable difference was with the strength of the northwestern Atlantic cutoff, which had weakened from the previous day. Although this would imply weaker geostrophic flow aloft, given little change in the ridge strength to the west, an investigation of the height gradient at 500-hPa suggests that much of this flow weakening occurred over and off the coast of New England with little change aloft over the BGM CWA.

More noticeable differences between 12 and 13 June 2007 are apparent in the surface analyses (cf. Figs. 17a, 3). Of primary note is the location of the inverted trough, which had shifted west and was located over central New York at 1600 UTC on 13 June. While this would imply increased low-level convergence over the BGM CWA at 1600 UTC, this trough was continuing to move southwest, with the enhanced convergence moving out of the BGM CWA during the afternoon. Also of importance is an expanded area of low cloudiness over New England and eastern New York at 1600 UTC (Fig. 17b). As a result of this cloudiness, temperatures across New England and eastern New York were much cooler than on the previous day (cf. Figs. 17a and 3), in some cases by as much as 15-20 F (8-11 C). Finally, a surface ridge of high pressure had built southwestward from Atlantic Canada into northern New England, with cooler and drier air accompanying this ridge. The net result of the cloudiness and approaching high pressure was to effectively shut off the convective potential over New England and eastern New York (see section 4b). An investigation over central New York,

Continued page 32

Fig. 15(a).

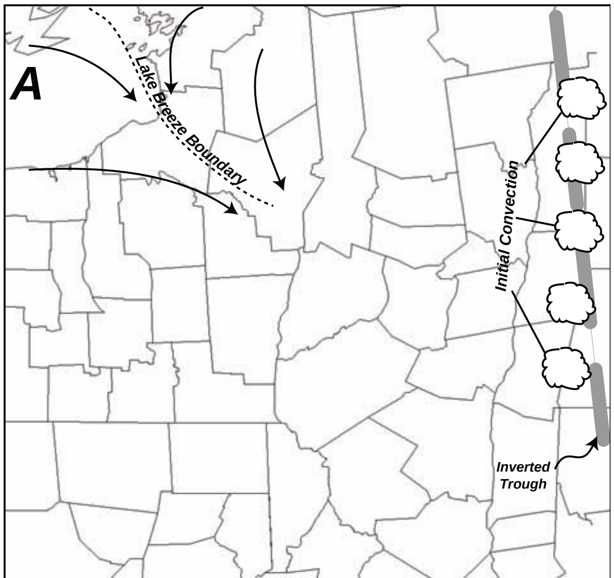


Fig. 15 (b).

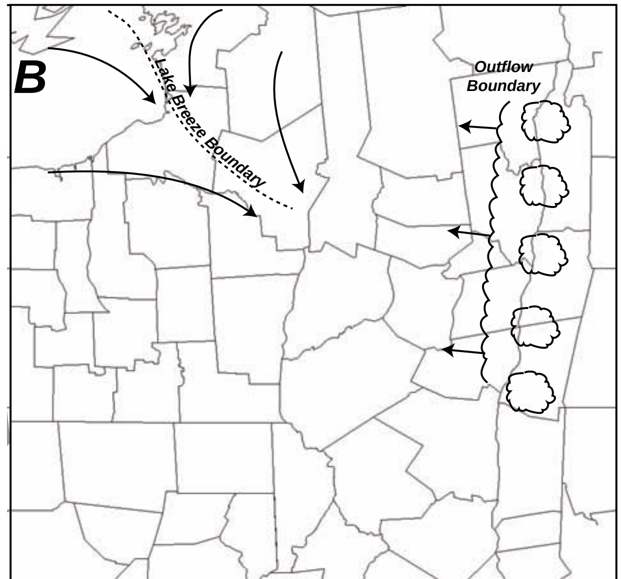


Fig. 15(c).

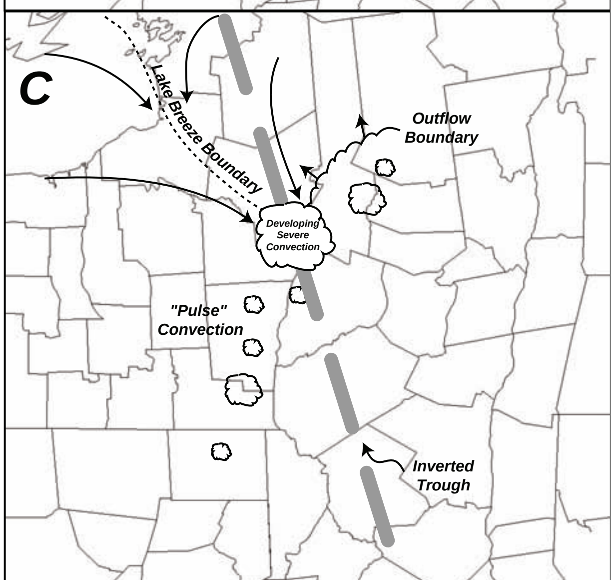


Fig. 15 (d).

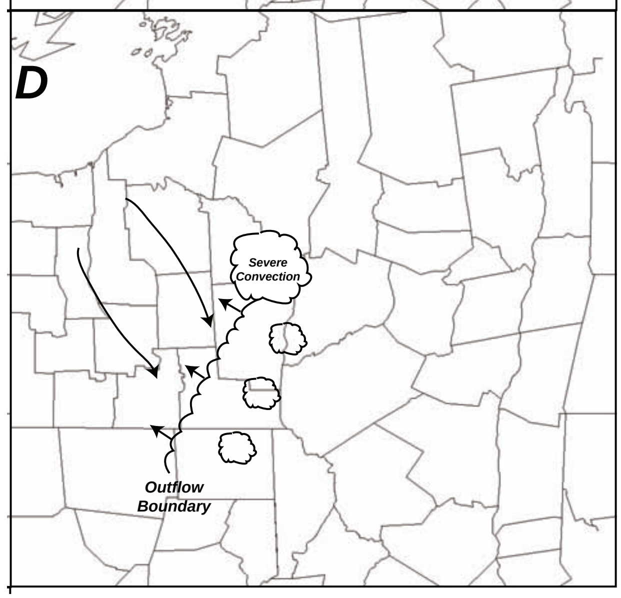


Fig. 15(e).

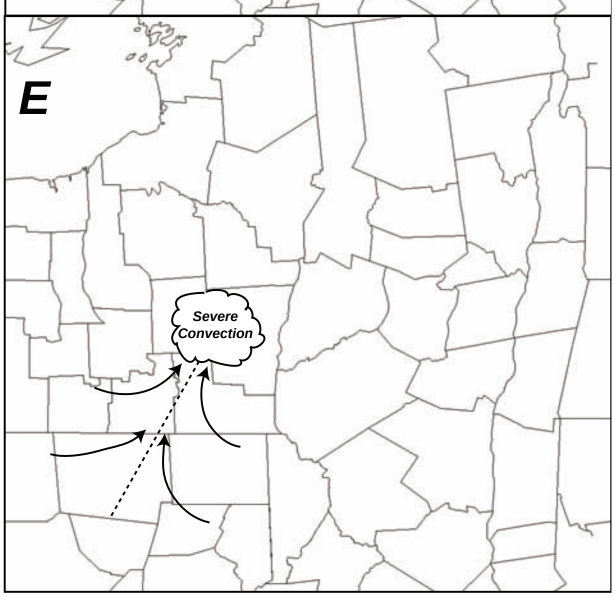


Fig. 15. Summary of important factors governing convection evolution on 12 June 2007.

however, suggests relatively little change from the previous day at 1600 UTC with surface temperatures around 80 F (27 C) and surface dewpoints a few degrees higher than on the previous day, possibly due to the location of the inverted trough (Fig. 17a) and moistening effects of the previous day's convection.

Quite interestingly, dramatic changes in the surface conditions occurred during the early afternoon hours of 13 June 2007. Surface observations over the BGM CWA at 1700 UTC (Fig. 18) indicated that northeasterly winds had strengthened at the surface, and in tandem with this, surface dewpoints fell as much as 15 F (8 C). Of particular note is the observation at KRME where the surface flow varied between northeast and southeast during the early afternoon hours (Fig. 19). While the winds were southeasterly, dewpoints in the lower 60s F (15-20 C) were observed. When the flow became northeasterly, however, the dewpoint dropped into the upper 40s F (5-10 C).

b. Convective potential

Cyclonic low-level flow was less focused on 13 June 2007 than 12 June 2007 (Figs. 17a and 3) with the surface high intruding over northern New England altering the low-level wind patterns. This suggested less large-scale cyclonic convergence over the area. At mid-levels, a GOES water vapor satellite image from 1215 UTC (Fig. 20), revealed another short wave disturbance; this time centered over central and eastern New York, migrating south and west. The implied forcing for ascent in advance

Continued page 35

Fig. 16(a).

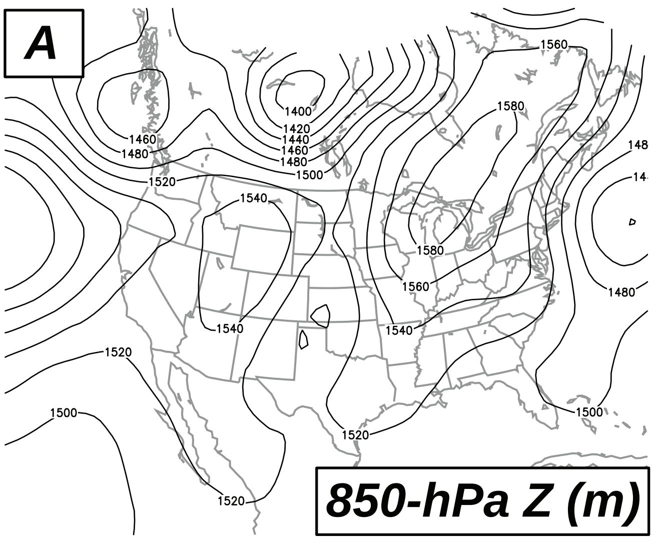


Fig. 16(b).

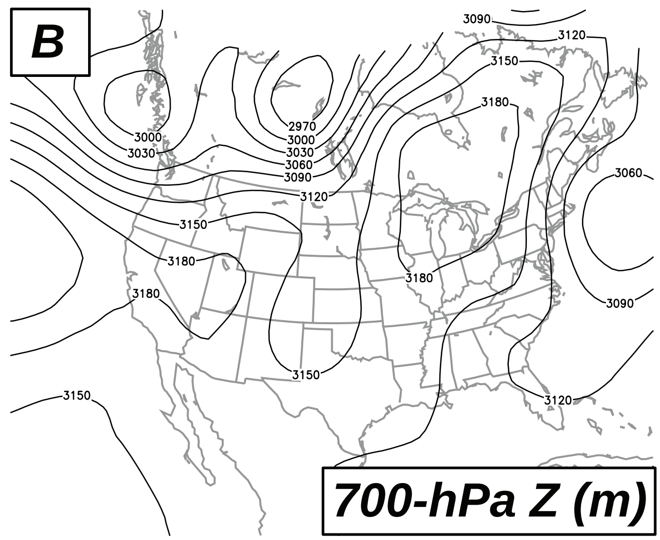


Fig. 16(c).

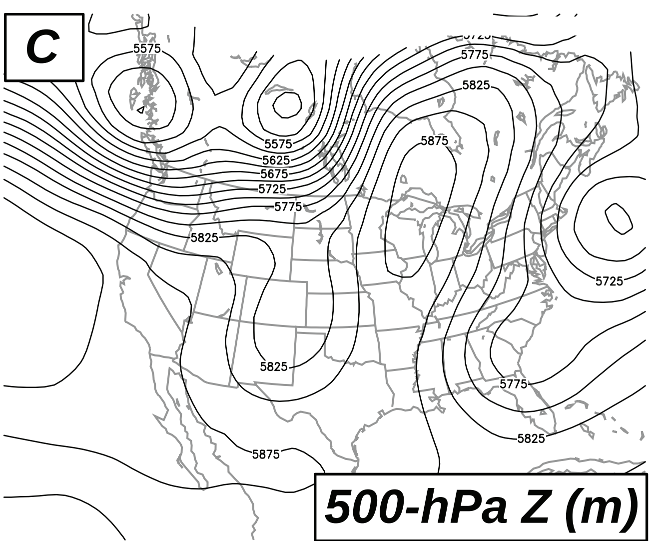


Fig. 16(d).

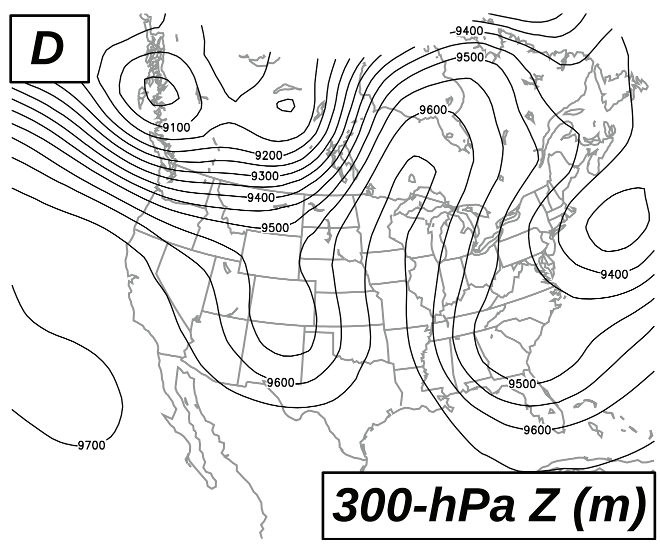


Fig. 16. Plots of height (m) at 1200 UTC 13 June 2007 at *a) 850-hPa, (b) 700-hPa, (c) 500-hPa, and (d) 300-hPa.

Fig. 17(a).

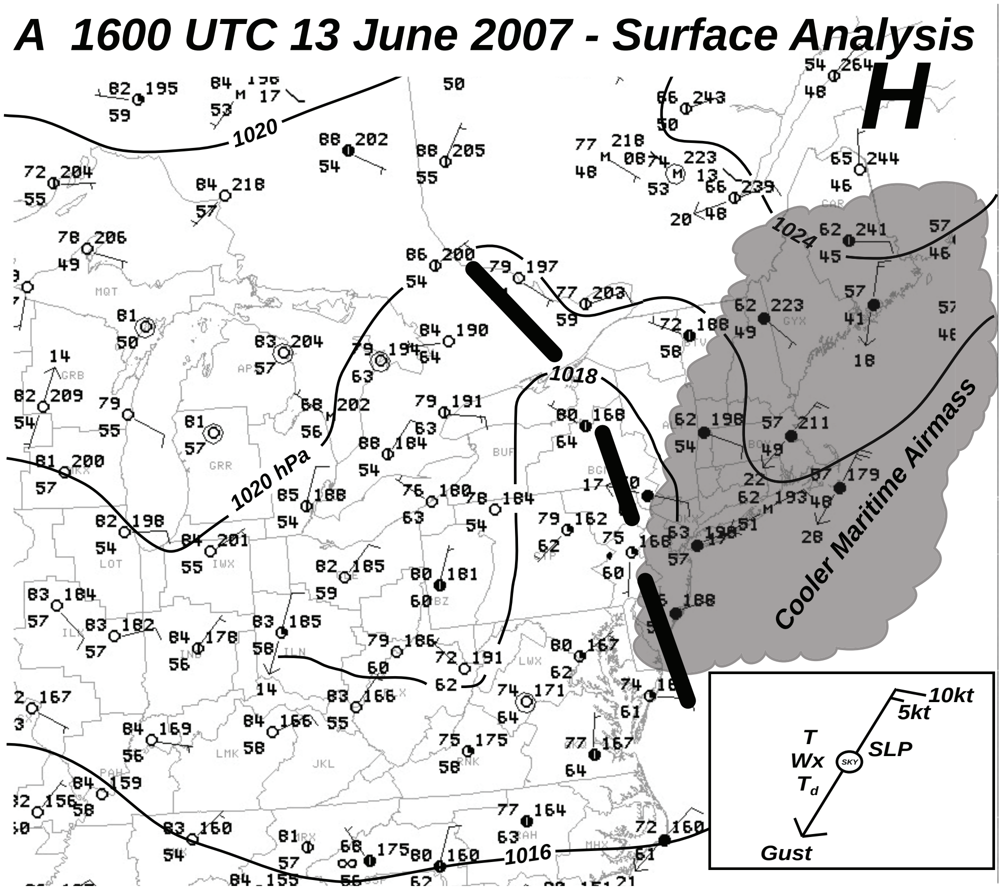


Fig. 17(b).

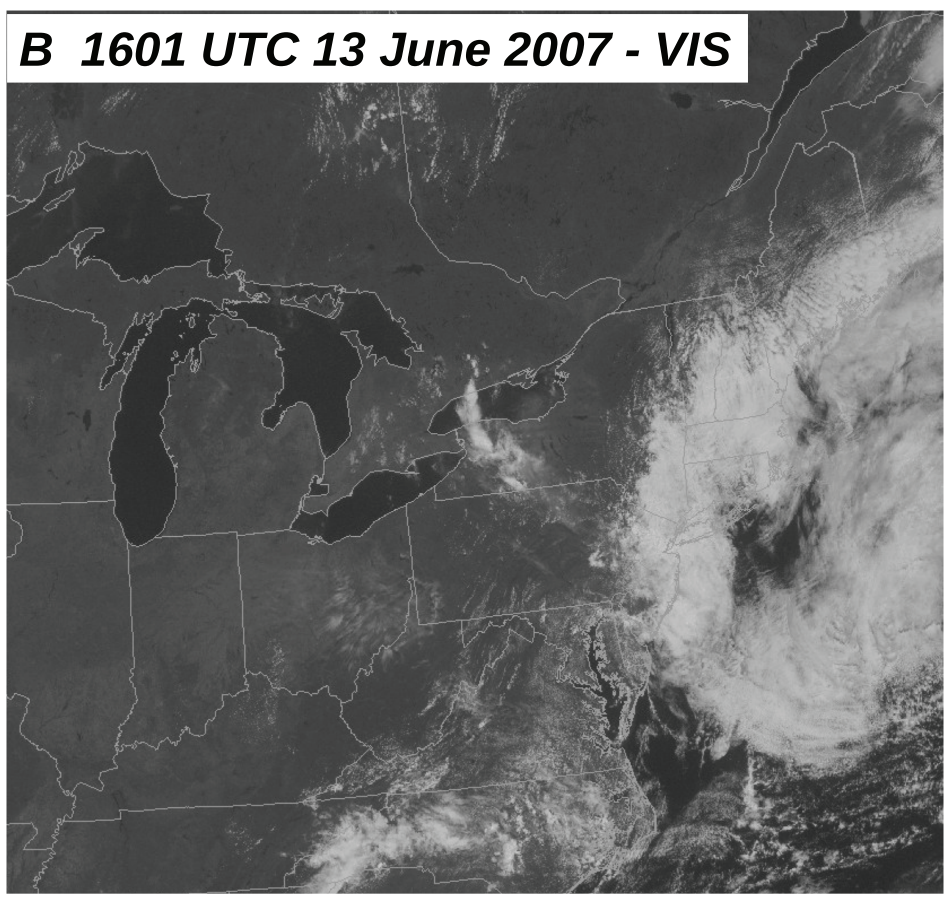


Fig. 17. (a) Conventional surface analysis at 1600 UTC on 13 June 2007. (b) GOES visible satellite image of the northeastern US at 1601 UTC on 13 June 2007.

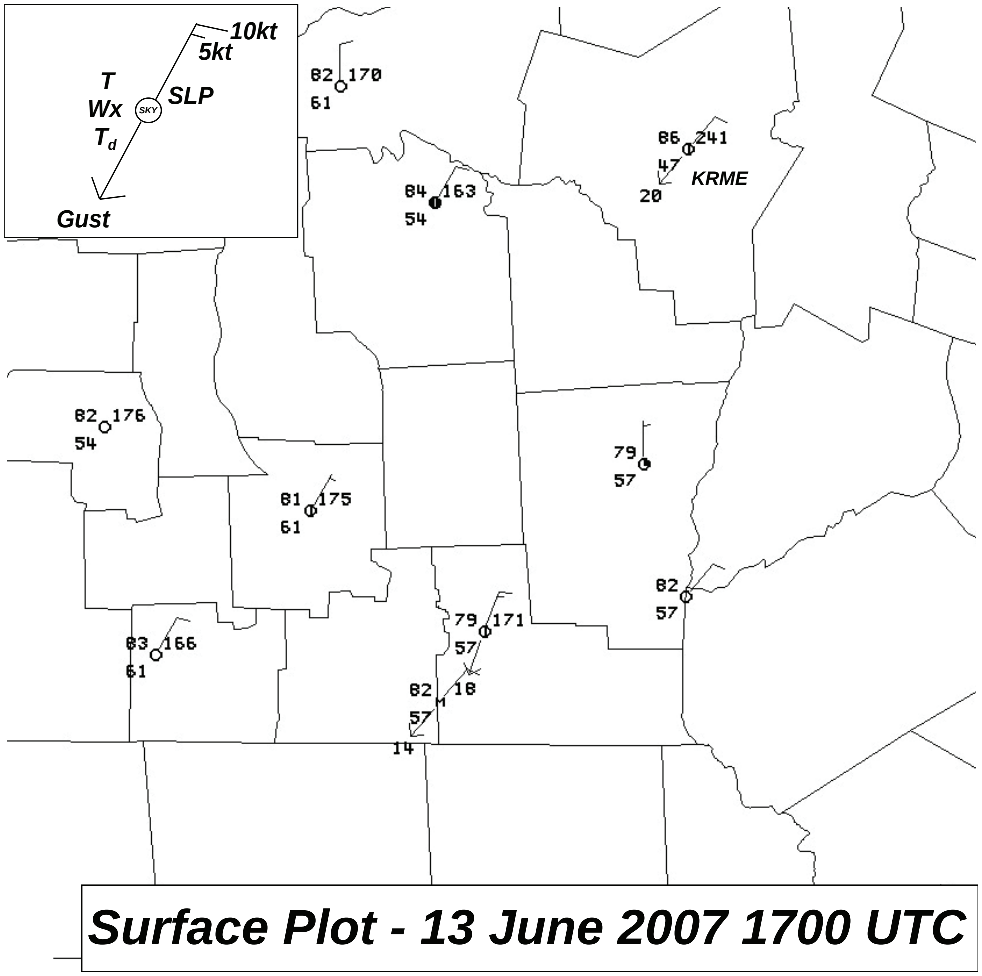


Fig. 18. Plot of surface observations at 1700 UTC on 13 June 2007 with the location of KRME annotated.

KRME Observations 13 June 2007 1500-2200 UTC

Fig. 19(a).

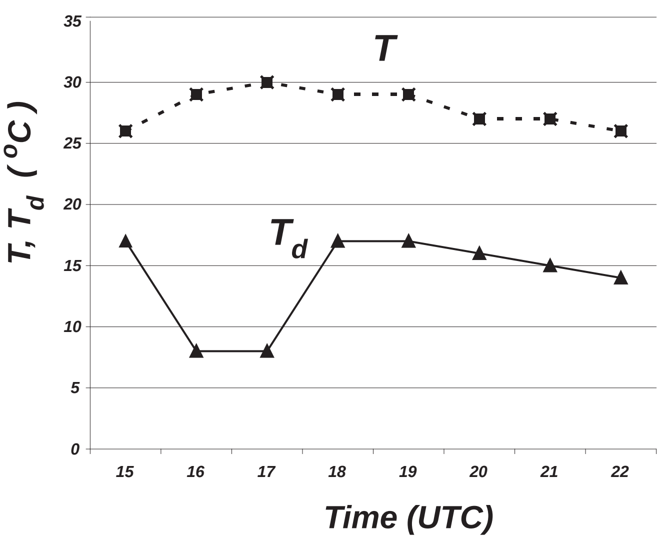


Fig. 19(b).

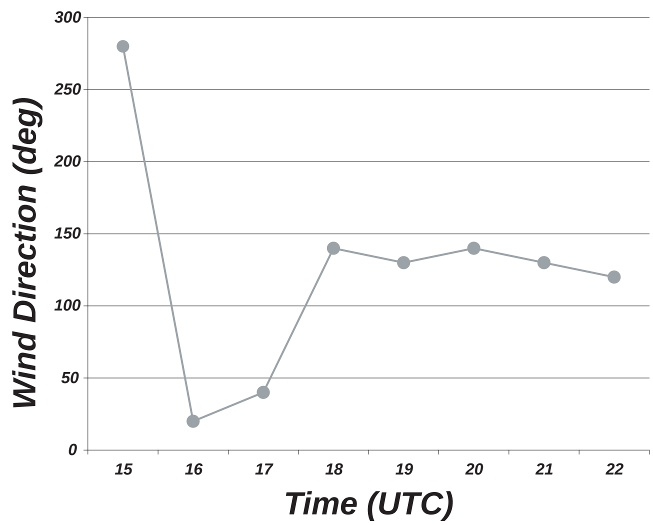


Fig. 19. (a) Plot of temperature and dewpoint at KRME for the period 1500-2200 UTC on 13 June 2007. (b) Same as in (a) except showing wind direction.

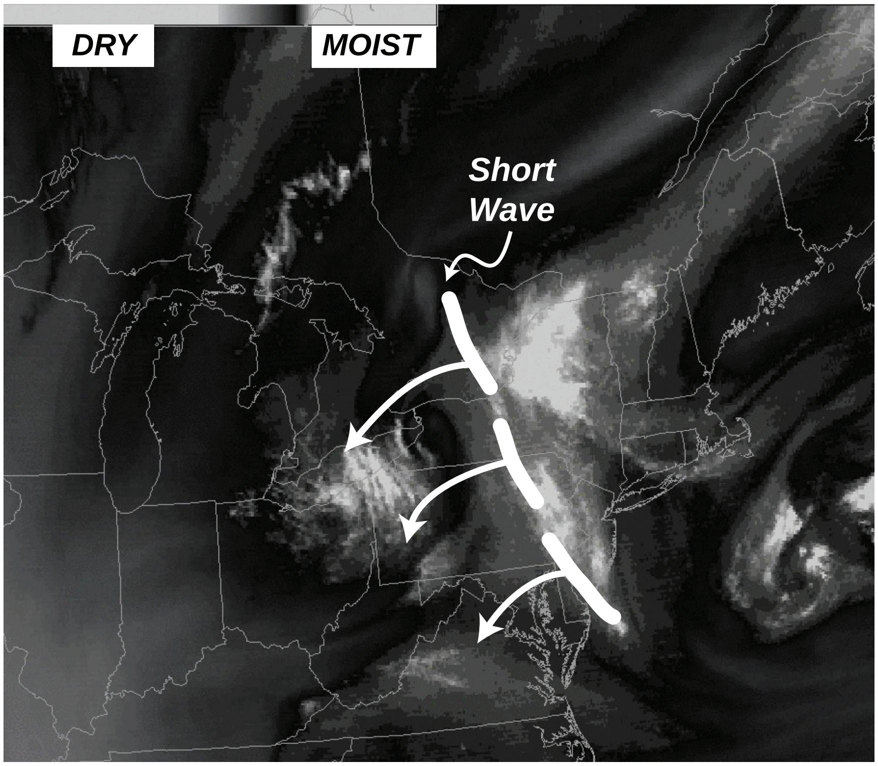


Fig. 20. GOES water vapor image from 1215 UTC 13 June 2007 with short wave of note and its motion annotated.

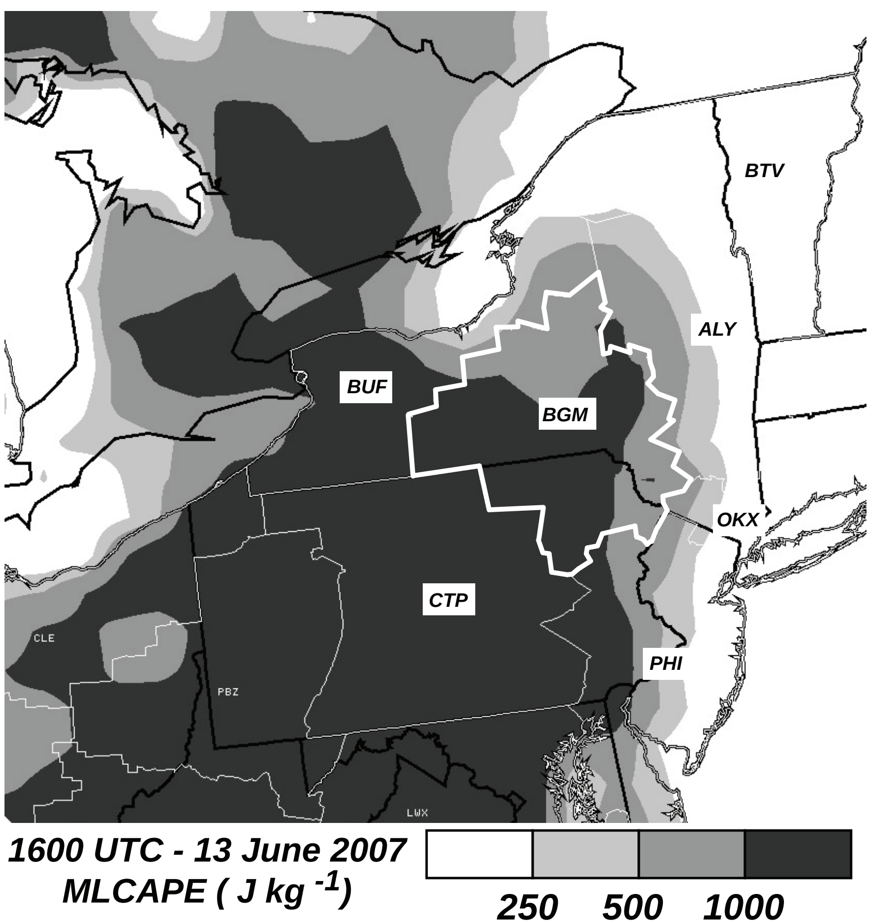


Fig. 21. RUC analysis of MLCAPE at 1600 UTC on 13 June 2007. BGM CWA outlined with surrounding CWAs labeled.

of this short wave would appear to be over the BGM CWA at this time, with any assistance from the wave in forcing convection later in the day, likely moving south and west out of the BGM CWA.

The cooler low-level airmass over New England and eastern New York associated with the advancing marine layer had eliminated convective instability from this part of the region (cf. Figs. 21 and 5) as of 1600 UTC. Also of note is the much more expansive area of MLCAPE values > 1000 J kg^{-1} from the BGM CWA south and west, with somewhat higher peak instability values than on the previous day. Overall, just before the time of convection initiation, the atmosphere again appeared "primed" for convective development in the BGM CWA. By stark contrast, MLCAPE values analyzed by the RUC just one hour later (Fig. 22) at 1700 UTC had dropped markedly. This decrease continued into the mid afternoon hours with values below 500 J kg^{-1} at 2000 UTC (not shown). It is clear that the reduction in instability resulted from the dramatic decrease in low-level moisture, apparent from the surface analysis in Fig. 18. In summary, although the late morning pattern appeared at least as unstable as the previous day, a rapid evolution in the low-level moisture field suggested a greatly reduced convective threat just 1-2 hours later.

Deep shear values on 13 June 2007 were quite similar to those on the previous day, reaching 20 kts (11 m s^{-1}) in the 0-6-km layer (Fig. 23) with similar values in the 0-3-km layer. As on 12 June 2007, these values were indicative of an environment that would support some convective organization with multicellular structures and "pulse" cells.

The 1200 UTC SPC severe weather outlook indicated a "slight risk" for severe convection south and west of the BGM CWA (Fig. 24a). A severe thunderstorm watch was issued at 1725 UTC (Fig. 24b), not including any of the BGM CWA, but rather anticipating severe convection farther south and west. It is not surprising that the BGM CWA was left out of the watch, given that substantial low-level drying had occurred by 1700 UTC.

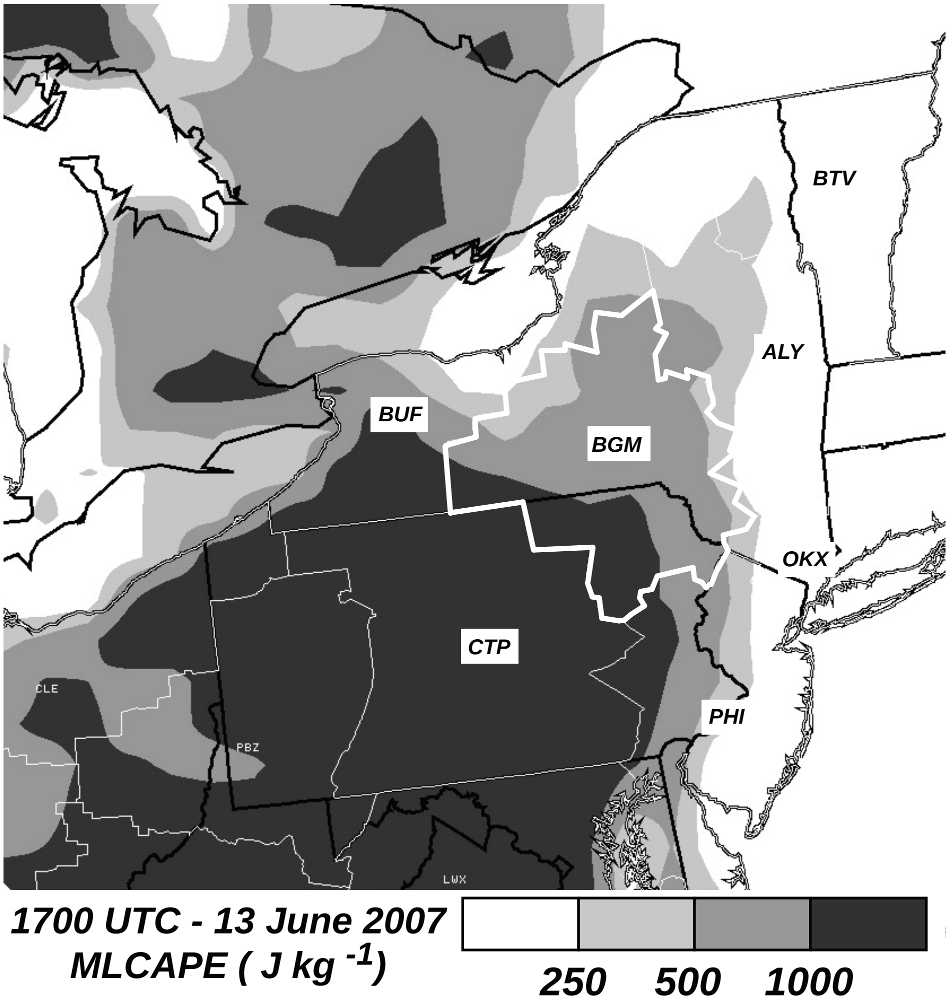


Fig. 22. RUC analysis of MLCAPE at 1700 UTC on 13 June 2007. BGM CWA outlined with surrounding CWAs labeled.

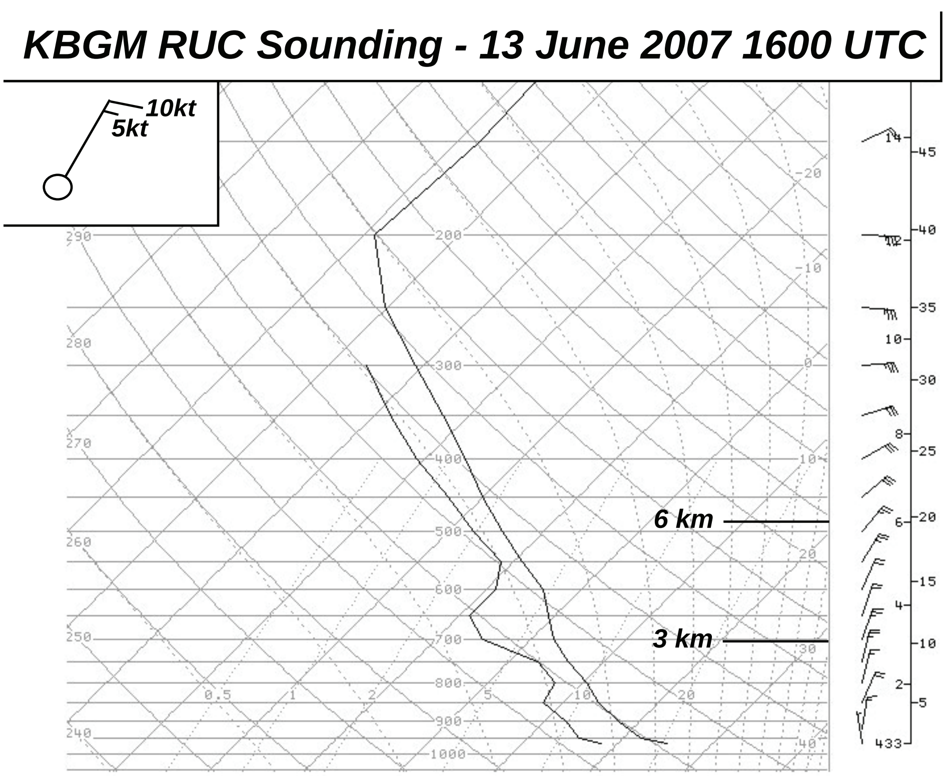


Fig. 23. RUC analysis sounding at BGM at 1600 UTC, 13 June 2007.

Fig. 24(a).

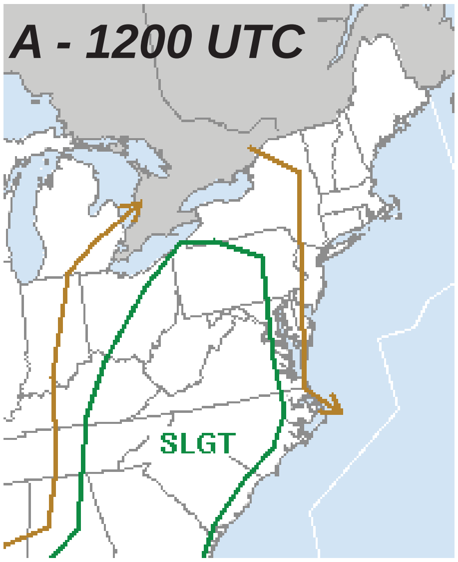


Fig. 24(b).

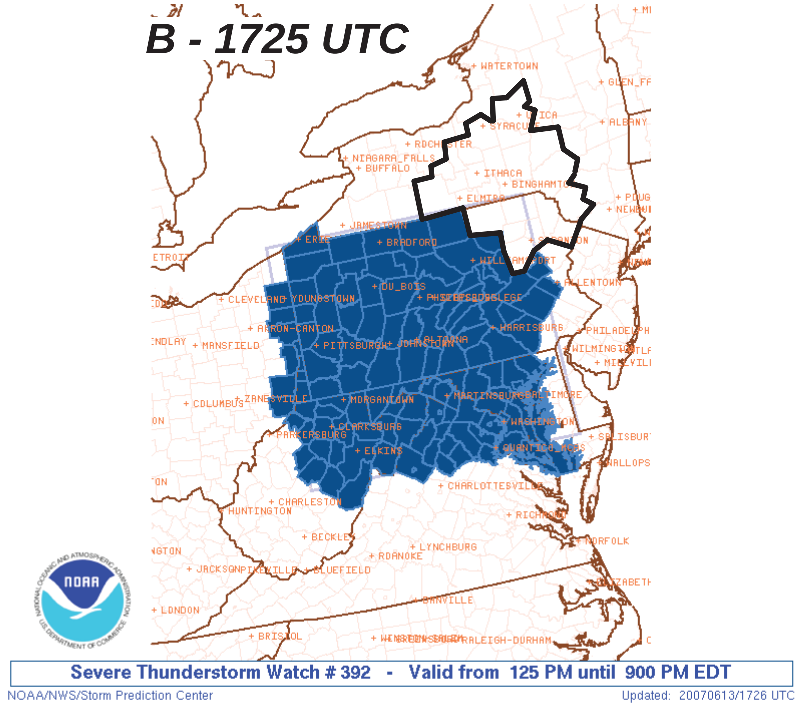


Fig. 24. Products issued by SPC on 13 June 2007. (a) 1200 UTC Day One Convective Outlook. (b) Severe Thunderstorm Watch #392 (shaded) issued at 1725 UTC. BGM CWA is outlined.

c. Convective evolution

Despite the low-level stabilization, some convection did develop over the southern and southwestern fringes of the BGM CWA between 1600 and 1700 UTC on 13 June 2007 (Fig. 25). This convective development occurred in the area of the CWA where the greatest instability remained (in the vicinity of the inverted trough) and the greatest differential cyclonic vorticity advection occurred aloft, with its implied support for synoptic-scale ascent (Fig. 20). Consistent with the deep northeasterly flow, this convection moved south and west with time, exiting the BGM CWA by about 2000 UTC (1600 EDT) with no reports of severe weather occurring with this convection in the BGM CWA.

d. Explanation for low-level drying

The dramatic difference in convective evolution between 12 and 13 June 2007 appears directly related to the rapid low-level drying that occurred during the early afternoon of 13 June 2007, which greatly reduced both the convective potential across the BGM CWA and the subsequent convective strength. The causes for this drying are now examined. In Fig. 26, the daytime evolution of the thermodynamic and kinematic environment in the lowest 2.5 km AGL shows the growth of the daytime boundary layer coinciding with substantial drying above 1.5 km AGL behind the departing mid-level short wave, while the low-level flow gradually veered northeasterly east of the inverted trough axis. Given that the growing boundary layer reached some of the drying aloft, it appears that downward mixing of dry air accounted for at least some of the observed drying in the early afternoon. The fact that the drying is most prominent below 1 km, however, suggests that additional factors were also at work.

It is hypothesized that the flow *direction* was also key in the low-level drying. Northeasterly flow is known as a very "dry" wind direction for the BGM CWA by WFO forecasters, because it is a downslope wind direction off of the Adirondack Mountains north and east of the BGM CWA. This orographic explanation is also consistent with the time-height diagram in Fig. 26. The most prominent loss of boundary layer moisture seen in the figure occurs at

Fig. 25(a).

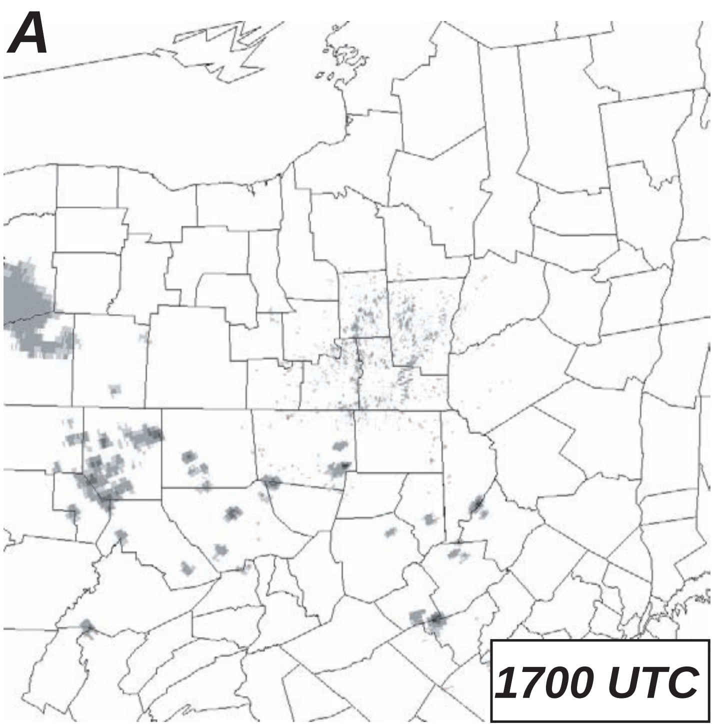


Fig. 25(b).

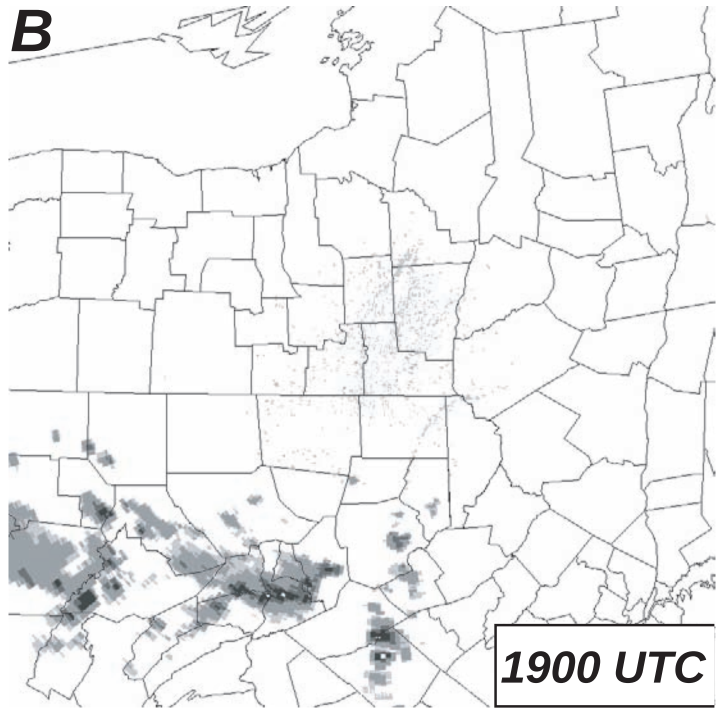
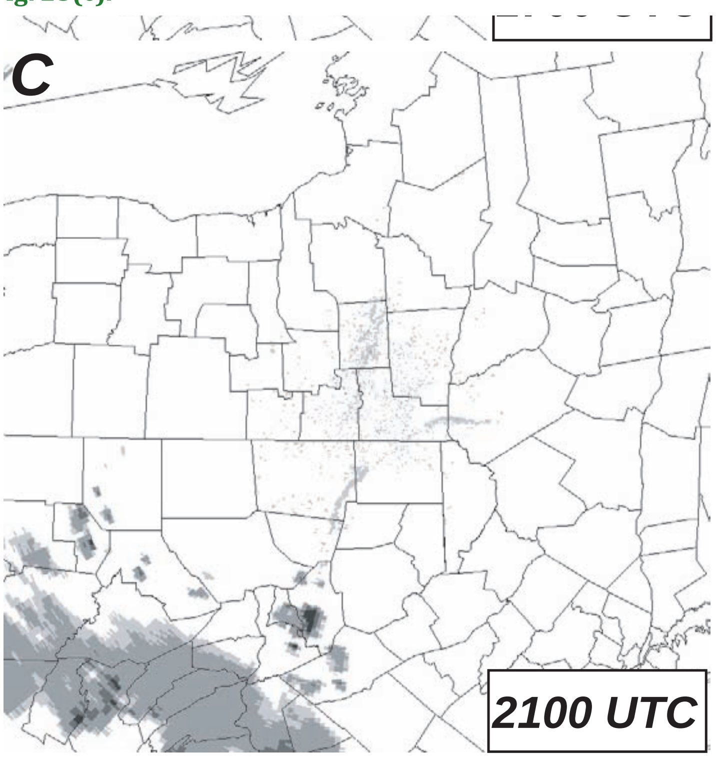


Fig. 25(c).



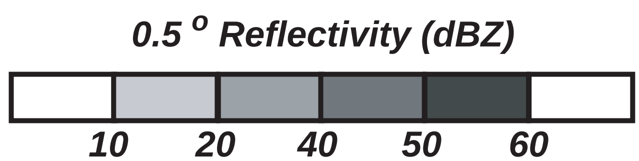


Fig. 25. Time sequence of 0.5o reflectivity data (dBZ) from the KBGM WSR-88D for 1700-2100 UTC 13 June 2007.

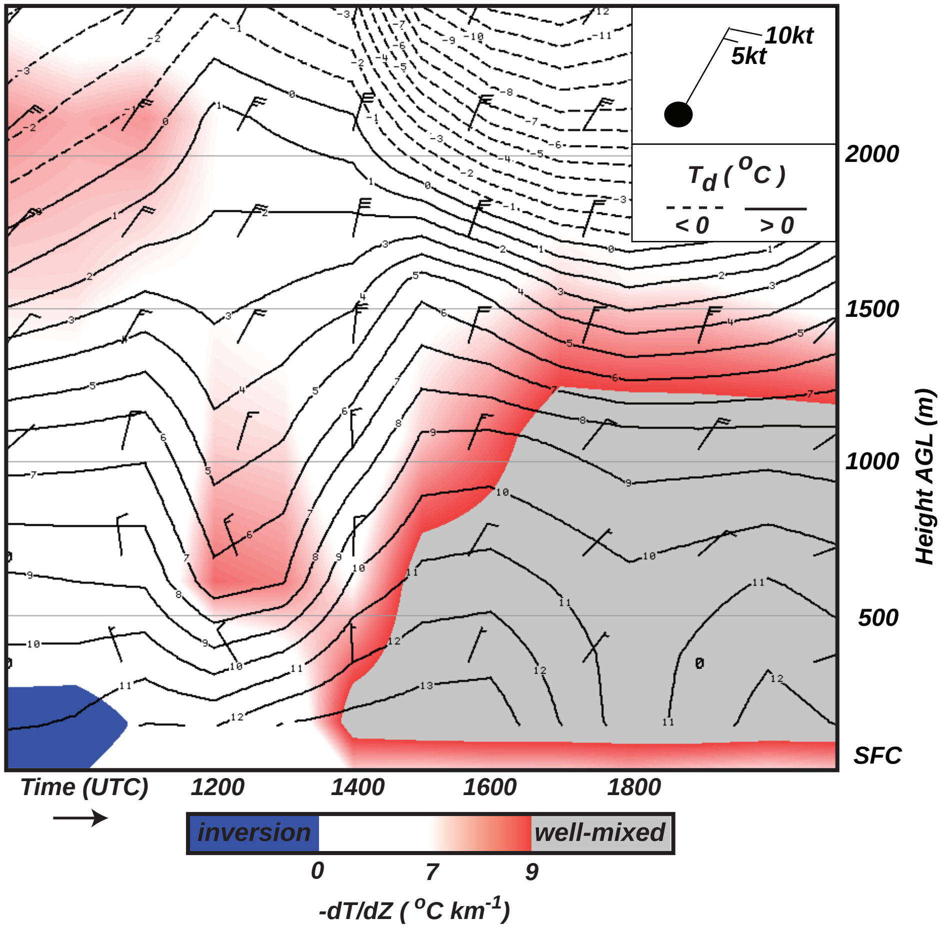


Fig. 26. Time-height diagram of dewpoint (oC, contour, dashed for negative values), temperature lapse rate (oC km-1 , shaded), and winds (kts; black barb) for 0900-2100 UTC 13 June 2007, based on LAPS analyses for a point in Madison County, New York (see Fig. 9 for county location).

elevations below ~600 m AGL (~900 m MSL). The highest peaks of the Adirondack Mountains are between 900-1200 m MSL. Consequently, one would expect a downslope drying effect downwind of these mountains to occur below this level. One more piece of evidence implicating northeasterly downslope flow as an additional culprit for the low-level drying, is to examine the mixing ratio of a parcel near the top of the mountains, which, according to a RUC sounding near KBGM at 1600 UTC (e.g. Fig. 23) was 9-10 g kg^{-1}. Assuming dry adiabatic descent, this same mixing ratio at ground level would have indicated a surface dewpoint (at a "typical" elevation around 1200 ft, 365 m MSL) in the 53-57 F (12-14 C) range, generally consistent with surface moisture observations during the afternoon.

5. Forecast Challenges

The severe convective event on 12 June 2007 was particularly challenging for operational forecasters, having occurred under a highly anomalous flow configuration which did not fit typical conceptual models for severe weather in the northeastern US. To demonstrate the rarity of this case, a database was created from 2007-2008 severe weather reports using the NWS Stats-on-Demand interface (NWS 2007). This database revealed 70 days of severe hail, thunderstorm wind, or tornado reports in the BGM CWA. Using the NOAA/ESRL radiosonde database at KALY, a flow direction between 0 and 90 degrees at 500 hPa was observed only twice (June 12 being one of these two events), or 2.9 percent of events with 12 June 2007 being the only case to feature *multiple* severe weather reports. This indicates that northeast flow severe weather in the BGM CWA is quite uncommon and occurs with similar regularity to warm season northeast flow aloft (4.2 percent of days).

Another important forecast challenge on 12 June 2007 was the influence of low-level boundaries on convection evolution. A combination of a lake breeze boundary and outflow boundaries, originating over central New York and western New England, locally enhanced convective potential with relatively little severe weather noted outside of where this constructive combination occurred. Low-level boundary interaction is likely a key reason why 13 of 28 severe weather reports occurred just northwest of the severe thunderstorm watch that was issued by SPC (cf. Figs. 7 and 10), and suggests that these fine-scale processes were of great importance in pinpointing where severe weather would occur. This case also highlights the importance of operational forecasters using real-time mesoanalysis to help anticipate where enhanced convection with potentially severe storms is more likely to develop.

The "null" event of 13 June 2007 was as challenging as the previous day given that very similar conditions observed at 1600 UTC on both days produced drastically different results. The low-level drying that occurred during the early afternoon hours suggests that forecasters not only must keep watch on upstream thermodynamic changes, but also be aware of local and regional orography and its potential mesoscale impacts. Finally, the arrival of stable maritime air over eastern New York and New England on 13 June 2007 squelched chances for convection in this area, resulting in no potentially beneficial outflow boundaries moving into the BGM CWA in the afternoon.

6. Summary and Conclusions

A rare series of convective events occurred over the BGM CWA during 12-13 June 2007. What made these events unusual is that they occurred under deep northeasterly flow, a rare flow direction for the northeastern US, and a flow direction quite uncommon, and not well-researched for severe weather.

An analysis of 12 June 2007 revealed many of the features typical of strong to severe convective events including substantial instability, broad forcing for ascent (albeit weak) and weak to moderate vertical wind shear. While multiple convective cells that developed on the afternoon of 12 June 2007 became severe, the interaction between convection, lake breeze and outflow boundaries, and a collocated inverted trough allowed one particular cell to persist which led to numerous severe weather reports.

Analysis of conditions during the morning of 13 June 2007 suggested that a repeat episode of severe convection was possible across the BGM CWA. Instability and shear were similar to the day before and while the surface and upper-level environment appeared somewhat less favorable for convection, it did not appear to be a strong inhibiting factor and, in fact, numerical model guidance suggested convection would develop. By early afternoon, however, vertical mixing of increasingly dry air aloft behind a departing short wave, along with downslope drying off of the Adirondack mountains led to drastically reduced instability which, when coupled with weaker forcing for ascent aloft, was unable to generate severe convection over the BGM CWA.

This series of events underlines that severe storms can and do form under deep northeasterly flow across the northeastern US, but as is often the case with any convective event, very subtle changes in the thermodynamic and kinematic fields and in outflow boundary development, location and movement can have substantial impacts on the eventual convective evolution, including the propensity for convection to become severe.

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