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THE EASTERN NEW YORK AND WESTERN NEW ENGLAND FLOODS OF 14-17 JULY 2000

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ABSTRACT

Forecasting and warning for flood and flash flood producing rainfall is a great challenge for operational meteorologists. Reviewing flood events is an important step in improving our ability to evaluate flood potential. This case illustrates the complexities involved in diagnosing flood potential. Depending on atmospheric moisture, stability and wind characteristics, warm season closed 500 hPa lows can produce a wide variety of weather. A slow moving closed upper-level low spawned scattered flooding and severe weather as it crossed the northeastern United States during 14-16 July 2000. While this by itself was not an unusual pattern, this was an especially interesting case for two reasons. First, copious amounts of rain fell (three-day rainfall as high as 30 cm [12 in]) in parts of eastern New York and western New England. Second, with the passage of the upper low, distinctly different mechanisms combined to generate flooding rains on each of three days. Using available synoptic and mesoscale data, we will examine how subtle changes within this large scale upper low resulted in substantial changes in sensible weather.

1. INTRODUCTION

Flooding is the number one weather-related killer in the United States (US) with an average of 127 deaths per year during the period 1972-2001 (NOAA 1972-2001). Flooding can be caused by a wide variety of meteorological phenomena including tropical systems, large-scale extra-tropical storms, and convective storms (Maddox et al. 1979; Chappell 1986). The severity of a flood depends on many factors including the quantity and intensity of rain, antecedent soil conditions, extent of vegetation, river channel base flow and ice content, and topography (LaPenta et al. 1995).

A slow moving closed upper-level low spawned scattered flooding[1] and severe weather across the northeastern US during 14-16 July 2000. This by itself was not an unusual event. What makes this case

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[1] In this paper the term *flash flood* will be used to describe flooding that occurs within approximately six hours of a heavy rain event. If the flooding occurs from a longer duration rain, the event will be described simply as a *flood*. Also the term *flood* will be used to generically refer to any flooding, without regard to time factors.

especially interesting is the very large amount of rain that fell with the upper low's passage, and the distinctly different mechanisms that combined to generate flooding rains on each day. Three-day rainfall totals were as high as 30 cm (12 in) in parts of eastern New York (ENY) and western New England (WNE) with flood damage exceeding ten million dollars (see Fig. 1 for geographical references in ENY and WNE). Depending on atmospheric moisture, stability and wind characteristics, warm season closed upper level lows can produce a wide variety of weather[2]. In this event the large scale upper level pattern evolved slowly. However, subtle changes within this large scale system resulted in substantial changes in sensible weather. The hydrometeorological situation that produced flooding on different scales, over 3 consecutive days will be examined. It is hoped that this analysis will give the reader an understanding of the variability in the conditions that produced flash flooding conditions over a fairly large area resulting from different physical mechanisms associated with the 500 hPa closed low.

2. DATA AND METHODOLOGY

The data used in the synoptic and mesoscale analysis of the 14-17 July 2000 floods and severe weather include: Daily Weather Map series surface maps, surface data, upper air data, 80 km Eta model initialized grids and archive IV Albany radar (KENX) data. SHARP software (Hart and Korotky 1991) was used to analyze and modify soundings at Albany during the active period. The Eta model grids from 1200 UTC 14 July to 1200 UTC 17 July 2000 were used in GEMPAK software to create the pertinent plots. The archive IV radar data from KENX included storm total precipitation and 0.5° base reflectivity data. Also, data was used from Storm Data (NOAA 1972-2001) to verify warnings and to plot the severe weather events that occurred during this time frame.

3. STORM EVOLUTION

During the first week of July 2000 a 500 hPa long wave trough persisted across western Canada and the western United States. On 9 July, a closed 500 hPa low was centered over southern British Columbia (Fig. 2). Over the next 4 days the low moved east and weakened with an open wave reaching northwest Ontario on 13 July. The 500 hPa low again closed off as it drifted southeast to Lake Huron by 1200 UTC 14 July. The low meandered across the Northeast, again opening up as it crossed New England on 17 July. At the surface, a cold front moved through the Northeast on 10 July (not shown) and in its wake a cool, dry air mass settled in as high pressure built east across Canada and the Great Lakes. The cold front moved to the southeastern states and stalled. The dry air mass dominated the weather in the Northeast into the morning of 14 July. Surface low pressure associated with the upper trough crossing Canada was north of Lake Winnipeg at 1200 UTC on 12 July. It moved to northwest Ontario on 13 July and then turned southeast and was just north of Lake Huron at 1200 UTC 14 July (Fig. 3a).

a. 14 July 2000

At 1200 UTC 14 July the closed 500 hPa low was between James Bay and Lake Huron and moving southeastward (Fig. 4a). At that time it began to draw substantial

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[2] For further information, a climatology of closed lows in the Northeast is presented in Novak et al. (2002).

moisture from the Gulf of Mexico and the western Atlantic Ocean into the Northeast. The associated surface low was just north of Lake Huron with a warm-frontal trough moving through western New York (WNY), as shown in Fig 3a. A trailing cold front extended from the surface low back through the Midwest and into the Central Plains. Ahead of the surface trough in ENY and WNE surface dewpoints were generally between 13-15°C (56-59°F), while from WNY to the Ohio Valley they were 16-21°C (61-70°F). There was large scale upward vertical motion (not shown) from James Bay to extreme WNY. At 850 hPa (Fig. 5a), the flow was cyclonically curved and light at about 5 to 10 m s^{-1}.

The Albany, NY (KALY) 1200 UTC sounding (Fig. 6a) was modified [using the SHARP Workstation (Hart and Korotky 1991)] for the maximum temperature and dewpoint observed at the Albany International Airport (KALB) that afternoon (see map in Fig. 1). The modified sounding was used to approximate atmospheric conditions during the afternoon of 14 July, and was quite unstable with a CAPE of 2288 J kg^{-1} and Lifted Index of -7. The precipitable water was 3.3 cm (1.3 in). Winds veered from south at the surface to northwest above 400 hPa. The flow was light, less than 10 m s^{-1} below 400 hPa with maximum winds about 15 m s^{-1} above 400 hPa.

Convection developed at midday due to the instability coupled with diurnal heating, and the large scale ascent ahead of the upper low to the west. It gradually increased during the afternoon, but remained fairly scattered across ENY and WNE through the evening as shown in the 2139 UTC KENX radar base reflectivity image (Fig. 7a). A few storms became severe in NY and New England producing large hail (greater than 1.9 cm [0.75 in]) and wind damage (downed trees and power lines). There were three areas of very heavy rainfall (greater than 5 cm [2 in]) through ENY and WNE; one large area in central NY with two very localized areas, one in northern Ulster County, NY and one in southern Vermont (VT), which are depicted in Fig. 7b. Terrain forcing likely played a role in the thunderstorm initiation, as well as the training of the thunderstorms in the two localized areas of very heavy rain. Differential heating between the ground over mountains and the free atmosphere at the same elevation some distance away can produce a convergent upslope flow (Peilke and Segal 1986). This convergence was likely occurring, helping to focus the thunderstorms in Ulster County and in southern VT. Radar data showed that once the thunderstorms formed, they moved slowly off to the northeast in the weak synoptic flow. New development occurred on the southwest flank of these storms resulting in a training of echoes in these two locations. We hypothesize that this training occurred when outflow to the rear (southwest) of these storms combined with the terrain induced convergence to result in favorable locations for the new cell development.

KENX radar estimated rainfall greater than 25 cm (9.8 in) in north central Ulster County in a few hours during the late afternoon and early evening (Fig. 7b) with about 12 cm 4.7 in) estimated to have fallen in one hour (1935 UTC and 2035 UTC). Observed 24 hour rainfall (that included some rainfall on 15 July) included 25.0 cm (9.8 in) at Boiceville and 30.4 cm (12.0 in) at West

Shokan, both in Ulster County, NY (Fig. 1). The hamlet of Sundown suffered the most damage with most roads heavily damaged (NOAA 2000). In VT, radar estimated nearly 25 cm (9.8 cm) of rain in the southwest corner of Windsor County (Fig. 7b). Flash flooding washed out roads in extreme northeast Bennington County.

In summary, convection on day one of the event developed in response to diurnal heating of an unstable atmosphere characterized by synoptic scale upward vertical motion. While the convection was very scattered, training of thunderstorms, possibly caused by the interaction of the convection with terrain, occurred in several locations. This resulted in extremely heavy rainfall and damaging flash floods. Of the 6 flash flooding warnings issued, 4 were verified with an average lead time of 49 minutes (Table 1).

b. 15 July 2000

The 500 hPa closed low moved almost due south overnight (0000 -1200 UTC 15 July) and reached northwest Pennsylvania (PA) at 1200 UTC. The center was elongated to the northwest with a possible second center just east of Lake Huron (Fig. 4b). It then began a slow counter-clockwise loop (Fig. 2) across WNY and Lake Ontario that brought it to southwest Ontario, Canada at 1200 UTC 16 July. At 1200 UTC 15 July, a strong vorticity maximum was located in south-central PA (Fig. 4b). As one surface low moved to north-central PA early on 15 July, a second area of low pressure developed along the front that had been stalled over the southeastern states (Fig. 3b). This development was in response to the approaching vorticity maximum and remained disorganized as it moved northward through the mid Atlantic states as the day progressed.

While the surface system remained weak, rising surface pressures across the Canadian Maritimes helped strengthen the low-level pressure gradient across the Northeast. A strong 850 hPa southeasterly jet (Fig. 5b) developed and strengthened to 25 m s^{-1} by 0000 UTC 16 July from coastal southern New England to northern NY (Fig. 8a). This jet fed abundant Atlantic moisture into the Northeast. It became the focus for a synoptic-scale band of very heavy rain, as it was situated in an axis of high equivalent potential temperature low-level air (Fig. 8a). The jet also helped generate surface to 850 hPa low-level convergence (Fig. 8b) and the resultant upward vertical motion (not shown). The organization of this large-scale band of very heavy rain was in contrast to the scattered convective nature of the precipitation on 14 July.

The 1200 UTC 15 July KALY sounding (Fig. 6b) also highlights the differences in atmospheric conditions on the two days. The atmosphere on 14 July was characterized by large instability (CAPE 2288 J kg^{-1}) through a deep atmospheric layer and light winds. Although the CAPE was only 383 J kg^{-1} on 15 July, the atmosphere was saturated from the surface to almost 600 hPa with the lapse rate in that layer absolutely unstable with respect to the moist adiabatic rate. Lifted parcels which were already saturated would rise unimpeded to the weak inversion just above 600 hPa. There were a number of mechanisms available to provide lift: the upward vertical motion produced by cyclonic vorticity advection associated with the approaching vorticity maxima, the convergence associated with the strengthening low-level jet and orographic lift, as the southeast flow impinged on terrain features of ENY and WNE. The precipitable water increased slightly from 3.3 cm to 3.5 cm (1.3 to 1.4 in). There was no severe weather in the Northeast on 15 July, with only isolated severe events reported from Maryland southward.

After 0000 UTC 15 July, precipitation diminished across ENY and WNE although widely scattered rain continued through the night. After 0900 UTC, the rain began to become more widespread across southeast NY as the Atlantic inflow increased. By 1115 UTC there was an organized band of heavy rain from about KBGM to Long Island, NY. During the morning the band shifted slowly northward. By 1600 UTC it became nearly stationary from western Connecticut to near KALB and westward almost to Lake Ontario. Between 2000-2300 UTC, the band became more intense. This band was evident from KENX WSR-88D base reflectivity image at 0026 UTC 16 July (Fig. 9a). The band shifted slowly northeastward reaching the Adirondacks to western Massachusetts by about 0900 UTC, and weakened considerably. Rainfall from 1200 UTC 15 July to 1200 UTC 16 July exceeded 10 cm (3.9 in) in parts of Rensselaer, Columbia, Berkshire and Litchfield Counties (Fig. 9b) and resulted in flooding with states of emergency declared in several counties.

Markedly different physical mechanisms were responsible for the heavy rain on the second day of the event. Overall instability was significantly less than on the previous day (383 J kg^{-1} versus 2288 J kg^{-1}) and the atmosphere was saturated up to nearly 600 hPa with a lapse rate greater than moist adiabatic. Synoptic-scale forcing was greater, due to convergence associated with a strong low-level jet (25 m s^{-1}) and strong vorticity advection. A well-defined synoptic-scale rain band developed in response to this forcing. Twelve flash flood warnings were issued with six verified and one event occurred outside of a warning (Table 1).

c. 16 July 2000

The 500 hPa closed low was located in extreme WNY at 1200 UTC 16 July (Fig. 4c). A series of short-waves continued to pivot around it. The closed low migrated slowly eastward through NY during the day. As was the case on 14 July, instability played a large role in the production of heavy rain. The 0000 UTC 17 July 2000 KALY sounding modified for the maximum temperature and dew point observed at KALB in the late afternoon indicated a very unstable environment. The CAPE was 2322 J kg^{-1} and Lifted Index -8 (Fig. 6c). The precipitable water from the morning sounding was 3.6 cm (1.4 in), slightly higher than on the previous 2 days. Winds veered from the south to southwest from the surface to 700 hPa with south to southwest winds above that level. The strong 850 hPa 25 m s^{-1} low-level jet shifted north to the Canadian border. Further south, cyclonic flow was still persistent, but the flow had decreased to 5 to 10 m s^{-1} (Fig. 5c). At the surface at 1200 UTC 16 July, disorganized low pressure continued from western NY to the Mid Atlantic States (Fig. 3c). Several associated surface troughs moved from southwest to northeast across the Northeast. The synoptic-scale rain band of 15 July (section 3b) had moved north of NY by 1200 UTC, but scattered precipitation continued through the morning. With the daytime heating of the unstable airmass, convection increased and was most widespread across central NY (not shown).

Through 2230 UTC there was only isolated rainfall in Rensselaer, Bennington and Windham Counties (not shown). At 2300 UTC 16 July, the surface analysis showed a broad area of low pressure across southern NY and northeast PA with a number of associated boundaries (Fig. 10). One boundary extended from the Mohawk Valley southeast across Connecticut. This boundary was especially pronounced across New England. High pressure over the Canadian Maritimes combined with the low pressure trough to produce a moderate east to southeast onshore flow of moist air from in off the Atlantic. Winds turned south behind the trough. Immediately to the northeast of the trough was an axis of high surface dewpoints (19°C [66°F]; Fig. 10). The (low-level) convergence (Fig. 8b) of this moist air in an environment with considerable instability was favorable for thunderstorms with very heavy rain. Thunderstorms continually developed along the trough and moved northward. The very slow movement (compare Fig. 3c and Fig. 10) of the trough resulted in new cells continuously forming and moving over the same areas. While terrain effects may have contributed to the training of cells on 16 July, larger scale processes were primarily responsible for the localized heavy rain.

Although the time of maximum solar heating had passed, convection intensified across southern VT between 2230 UTC 16 July and 0000 UTC 17 July. Cell mergers across Bennington County contributed to a rapid intensification of activity between 2230 UTC16 July and 0000 UTC 17 July (Fig. 11a). Convection there finally lifted north of the area between 0400 and 0500 UTC. A second area of persistent convection was concentrated across Windham County, VT and lasted until almost 0900 UTC. The ground was saturated from rain during the previous two days, and with more heavy rain, flash flooding occurred once more. Across NY, most of the convection had dissipated. The radar estimated three rainfall (Fig. 11b) showed a small swathe of extremely heavy rainfall (greater than 10 cm [3.9 in]) over northeastern Rensselaer and western Bennington Counties, with a second area of very heavy rain in Windham County where 13.1 cm (5.2 in) was observed at West Wardsboro (Table 2). The radar estimated one hour rainfall of 9.5 cm (3.7 in) between 2352 UTC 16 July and 0052 UTC 17 July resulting in flooding that closed or washed out many roads.

Conditions that produced the heavy rain and flash flooding on the final day of the event were similar to the first day. Convection developed in an unstable atmosphere in response to diurnal heating. Unlike on day one when terrain appeared to play an important role in where the heaviest rain fell, low-level convergence associated with a large scale trough helped focus the convection. On this day, 9 flash flood warnings were issued, 5 were verified and there were no missed events (Table 1). The average lead time was 45 minutes.

4. DISCUSSION

Warm season closed 500 hPa lows can produce a variety of conditions that produce flash flooding depending on underlying conditions (moisture, stability, terrain etc.). During 14-16 July 2000, a slow moving upper-level closed low produced several days of flooding across ENY and WNE. While the day to day upper level pattern changes were small during the passage of this system, variable conditions in the lower troposphere and different physical mechanisms combined to generate heavy rainfall each day. Changes in instability, low-level flow and focusing mechanisms produced substantial day to day differences in the intensity and areal extent of heavy rain.

Doswell et al. (1996) reviewed many of the meteorological ingredients for flash flood events and their impacts on operational forecasting. They emphasized that the product of rainfall rate and time duration of the event determines the potential for substantial rainfall. Also, to generate extremely heavy rainfall high precipitation efficiency is needed. Chappell (1992) suggested the following factors are favorable for high precipitation efficiency: moderate CAPE (1500-3000 J kg^{-1}); a vertically elongated distribution of CAPE; a moist environment with high precipitable water and light to moderate vertical wind shear. The soundings in Figures 6a and 6c suggest that on these days the atmosphere was favorable for thunderstorms with high precipitation efficiency. However, on 14 and 16 July the overall closed low pattern did not fit the classic flash flood patterns determined from past work (Maddox et al. 1979; Chappell 1986). The sounding in Figure 6b indicates that on this day the atmosphere was much less favorable for high precipitation efficiency and the heavy rain was more synoptically driven than convectively driven.

Table 2 gives 3-day rainfall totals for a number of locations in ENY and WNE. On 14 July rainfall was convectively driven in an unstable environment (CAPE greater than 2000 J kg^{-1}) with weak low-level flow, and widely scattered in coverage. The radar estimated over 25 cm (9.8 in) of rain on 14 July. Observed 24 hour rainfall (that included some rain from 15 July) exceeded 30 cm (11.8 in). The interaction of the convection with terrain helped localize heavy rain on 14 July. Blaes and LaPenta (1998) documented similar terrain induced convection that produced flash flooding in southern VT in June 1996, which was also associated with a slow moving closed low. On 15 July heavy rain was widespread. Although overall instability was substantially less on that day (CAPE of 383 J kg^{-1}) the atmosphere was saturated up to nearly 600 hPa with a lapse rate greater than moist adiabatic. Synoptic-scale forcing and convergence associated with a strong low-level jet (25 m s^{-1}) produced upward vertical motion (Fig. 8). In addition, the low-level jet helped supply copious amounts of moisture in from off the western Atlantic Ocean. A well-defined synoptic-scale rain band evolved and produced up to 14.5 cm (5.7 in) of rain over ENY and WNE. While rainfall was convective and scattered in nature on 16 July, a large scale surface boundary focused the heavy rain. A surface trough generated low-level convergence in an axis of high moisture with high instability (CAPE greater than 2000 J kg^{-1}) producing an environment favorable for thunderstorms with very heavy rain. Also, a strong southeasterly 850 hPa low-level jet of 10-15 m s^{-1} ahead of the surface low and the 500 hPa shortwave helped advect low-level moisture to fuel the thunderstorm development. Thunderstorms continually developed along the trough and moved slowly northward with up to 13.1 cm (5.2 in) of rain measured.

During the 3 day event, 27 flash flood warnings were issued, 15 flash floods occurred (false alarm ratio 0.44). Of these 15 events, 14 occurred where flash flood warnings were issued (probability of detection 0.94; Table 1). The average warning lead time was 50 minutes, although some warnings had limited lead time with lead time varying from zero minutes to over 3 hours.

5. CONCLUSION

Forecasting and warning for flood and flash flood producing rainfall remains a great challenge for meteorologists. This case illustrates the complexities involved in diagnosing flood and flash flood potential. Recognizing the large scale closed low pattern may direct forecasters in realizing the potential for a severe weather or flash flood event by examining a number of meteorological variables. Examination of current high resolution mesoscale models at 10 kilometers or less (moisture, temperature, wind profiles) may alert forecasters about the potential for quasi-stationary or training thunderstorms capable of producing flooding, since local terrain is better represented. Even if the potential for very heavy rain is recognized, it can be a difficult to pinpoint where the flood danger is greatest. This is exemplified in the isolated nature of heavy rain on the first (July 14) and third (July 16) days of the event. Reviewing flood events (and non-events) is critical in improving our ability to evaluate flood potential. However, since this study only examined a single case, we can not derive specific forecast guidelines that are applicable in an operational environment. Forecasters can utilize pattern recognition from previous research (Maddox et al. 1979; Chappell 1986) and high resolution models to help analyze future warm season closed low events. This study does identify a number of factors (stability, moisture, strength of flow at various levels, synoptic pattern, and terrain) that are likely important in determining flood potential. Future research will have to examine a large number of cases in order to develop a flood forecast methodology.

6. ACKNOWLEDGMENTS

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REFERENCES

Blaes, J. L. and K. D. LaPenta, 1998: The Grafton, Vermont, flood 12-13 June 1996, Eastern Region Technical Attachment, No. 98-10, 22 pp. [Available at: http://www.erh.noaa.gov/er/hq/ssd/erps/ta/ta98-10.pdf]

Chappell, C. F., 1986: Quasi-stationary convective events. *Mesoscale Meteorology and Forecasting*, P. S. Ray., Ed., Amer. Meteor. Soc., 289-310.

______, 1992: Dissecting the flash flood forecast problem. *NOAA Technical Memorandum NWS ER-87*, National Oceanic and Atmospheric Administration, U.S. Department of Commerce, 293-297.

Doswell, C.A. III, H. E. Brooks, and R. A. Maddox, 1996: Flash flood forecasting: An ingredients-based methodology. *Wea. Forecasting*, **11**, 560-581.

Hart, J. A. and W. Korotky, 1991: The SHARP workstation v1.5 users guide. National Weather Service, NOAA, U.S. Department of Commerce, 30 pp. [Available from NWS Eastern Region

Headquarters, Scientific Services Division, 630 Johnson Ave., Bohemia, NY 11716.]

LaPenta, K. D., B. J. McNaught, S. J. Capriola, L. A. Giordano, C. D. Little, S. D. Hrebenach, G. M. Carter, M. D. Valverde, D. S. Frey, 1995: The challenge of forecasting heavy rain and flooding throughout the Eastern Region of the National Weather Service. Part I: characteristics and events. *Wea. Forecasting*, **10**, 78-90.

Maddox, R. A., C. F. Chappell, and L. R. Hoxit, 1979: Synoptic and meso--scale aspects of flash flood event. *Bull. Amer. Meteor. Soc.*, **60,** 115-123.

NOAA, 1972-2001. *Storm Data.* Vols. 14-43. National Climatic Data Center. [Available from National Climatic Data Center, Federal Building, 151 Patton Ave., Asheville, NC 28801.]

Novak, M. J., L.F. Bosart, D. Keyser, T. A. Wasula, and K. D. LaPenta, 2002: Climatology of warm season 500 hPa cutoff cyclones and a case study diagnosis of 14-17 July 2000. *Preprints, 19th Conference on Weather Analysis and Forecasting*, American Meteorological Society, 12-16 August 2002, San Antonio, TX, pp 68-71.

Pielke, R. A., and M. Segal, 1986: Mesoscale circulations forced by differential terrain heating. *Mesoscale Meteorology and Forecasting*, P. S. Ray. Ed., Amer. Meteor. Soc., 516-548.

U.S. Department of Commerce, 2000: Daily Weather Maps Weekly Series [Available from the National Climatic Data Center, Federal Building, Room 120, 151 Patton Ave., Asheville, NC 28801-5001.]

Table 1. Warning Verification from 14 July to 17 July 2000.

	Flash Flood Warnings	Flash Flood Warnings Verified	Flash Flood Events	Flash Flood Missed Events	Probability of Detection	False Alarm Ratio	Average Lead Time
14 July	6	4	4	0	1.00	0.33	49
15 July	12	6	8	1	0.88	0.50	53
16 July	9	5	3	0	1.00	0.44	45
3-Day Total	27	15	15	1	0.94	0.44	50

Table 2. Rainfall Totals from 1200 UTC 14 July 2000 to 1200 UTC 17 July 2000.

County	Location	Rainfall Amount - cm (in)
Albany (NY)	Albany International Airport	8.53 (3.36)
Columbia (NY)	East Chatham	11.51(4.53)
Dutchess (NY)	Poughkeepsie	3.12 (1.23)
Greene (NY)	Platte Clove	12.24 (4.82)
Greene (NY)	Tannersville	12.19 (4.80)
Rensselaer (NY)	Berlin	16.61 (6.54)
Saratoga (NY)	Clifton Park	10.08 (3.97)
Schoharie (NY)	Cobleskill	7.16 (2.82)
Ulster (NY)	Ashokan Reservoir	26.62 (10.48)
Ulster (NY)	Slide Mountain	15.11 (5.95)
Ulster (NY)	West Shokan	30.40 (11.97)
Warren (NY)	Glens Falls	6.65 (2.62)
Warren (NY)	North Creek	6.68 (2.63)
Litchfield (CT)	Bulls Bridge	13.21 (5.20)
Litchfield (CT)	Thomaston Dam	8.81 (3.47)
Berkshire (MA)	Great Barrington	14.76 (5.81)
Berkshire (MA)	North Adams	4.70 (1.85)
Bennington (VT)	Bennington	7.62 (3.00)
Bennington (VT)	Sunderland	8.61 (3.39)
Windham (VT)	Ball Mountain	11.56 (4.55)
Windham (VT)	Townsend	9.60 (3.78)
Windham (VT)	West Wardsboro	13.13 (5.17)

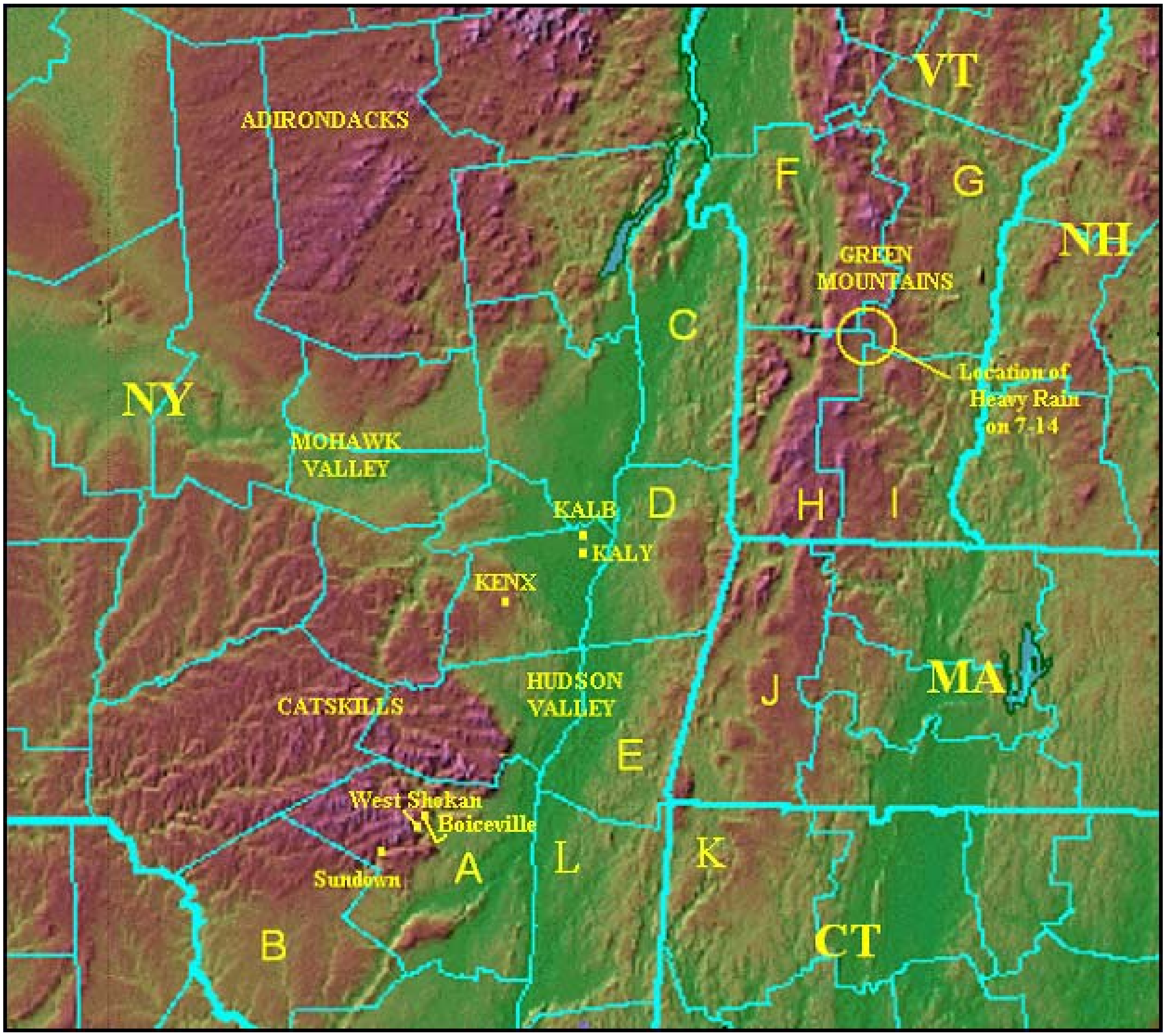

Figure 1. Terrain map of ENY and WNE obtained online from the Color Landform Atlas of the United States, compiled by Ray Sterner of Johns Hopkins University Applied Physics Laboratory (http://fermi.jhuapl.edu/states/states.html). The letters indicate county names as follows: (A) Ulster, (B) Sullivan, (C) Washington, (D) Rensselaer, (E) Columbia, (F) Rutland, (G) Windsor, (H) Bennington, (I) Windham, (J) Berkshire, (K) Litchfield and (L) Dutchess. Location of heavy rain 7-14 July 2000 indicated.

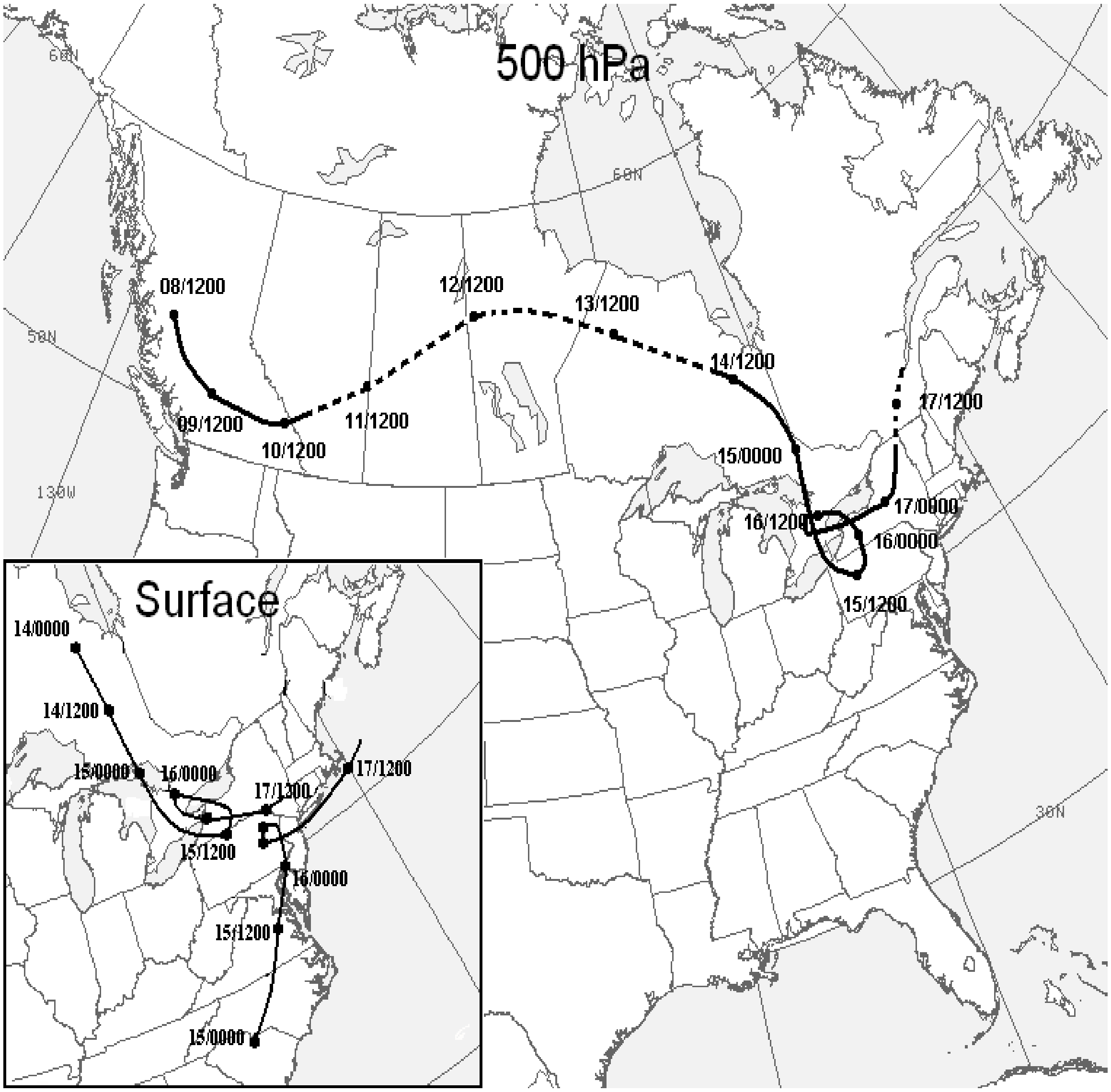

Figure 2. Track of 500 hPa system (large figure) that produced the floods of 14-16 July 2000. The solid lines indicate the portion of the track where the 500 hPa system was closed and the dashed lines indicate where it was open. The inset in the lower left gives the track of surface lows. Locations of the 500 hPa low and surfaces lows are shown with the solid dots with the date/time UTC.

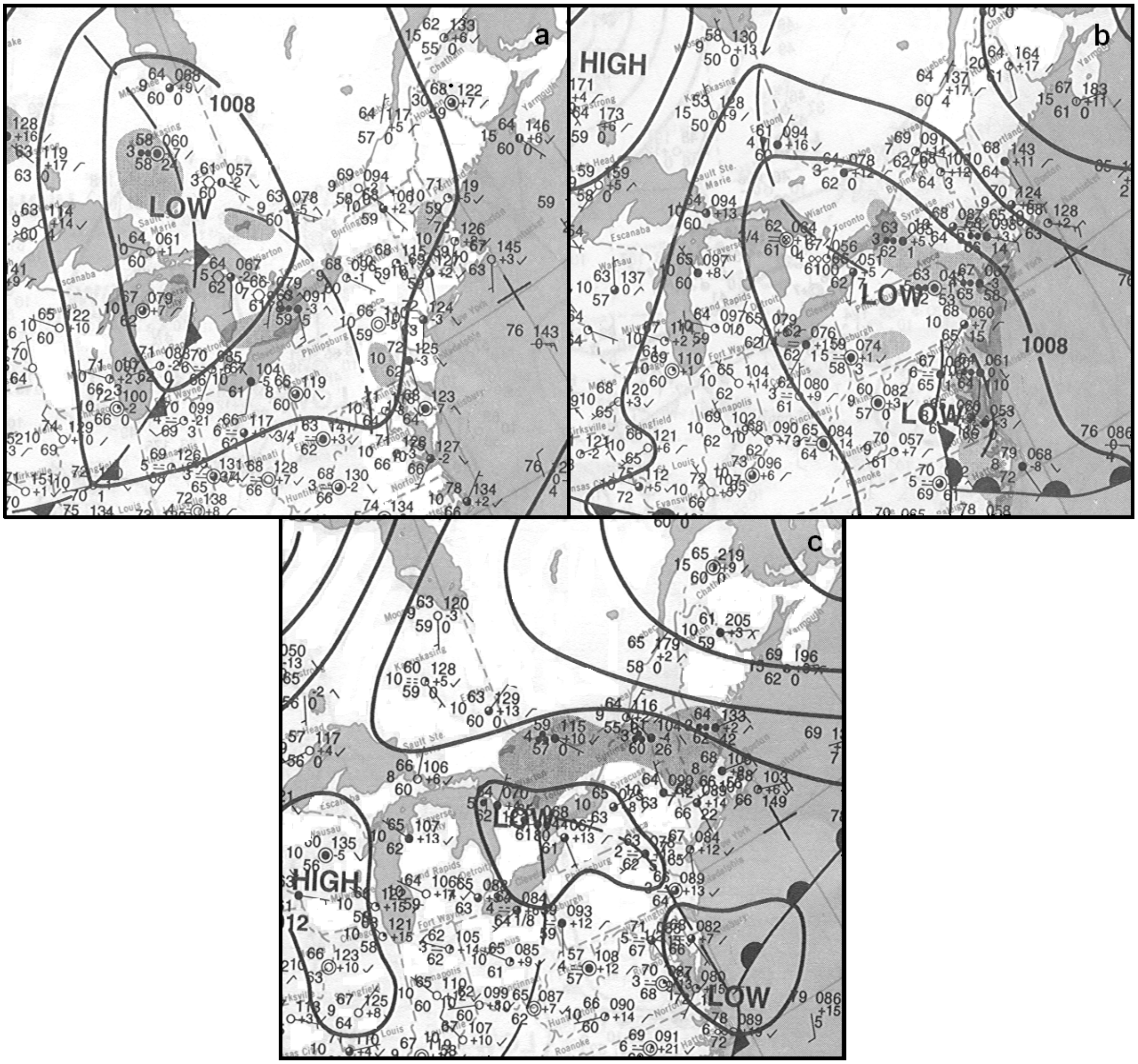

Figure 3. Daily Weather Map Weekly Series surface analyses for (a) 1200 UTC 14 July 2000, (b) 1200 UTC 15 July 2000 and (c) 1200 UTC 16 July 2000. Mean sea level pressure is contoured every 4 hPa, precipitation areas are shaded grey, and data is shown using standard station plots.

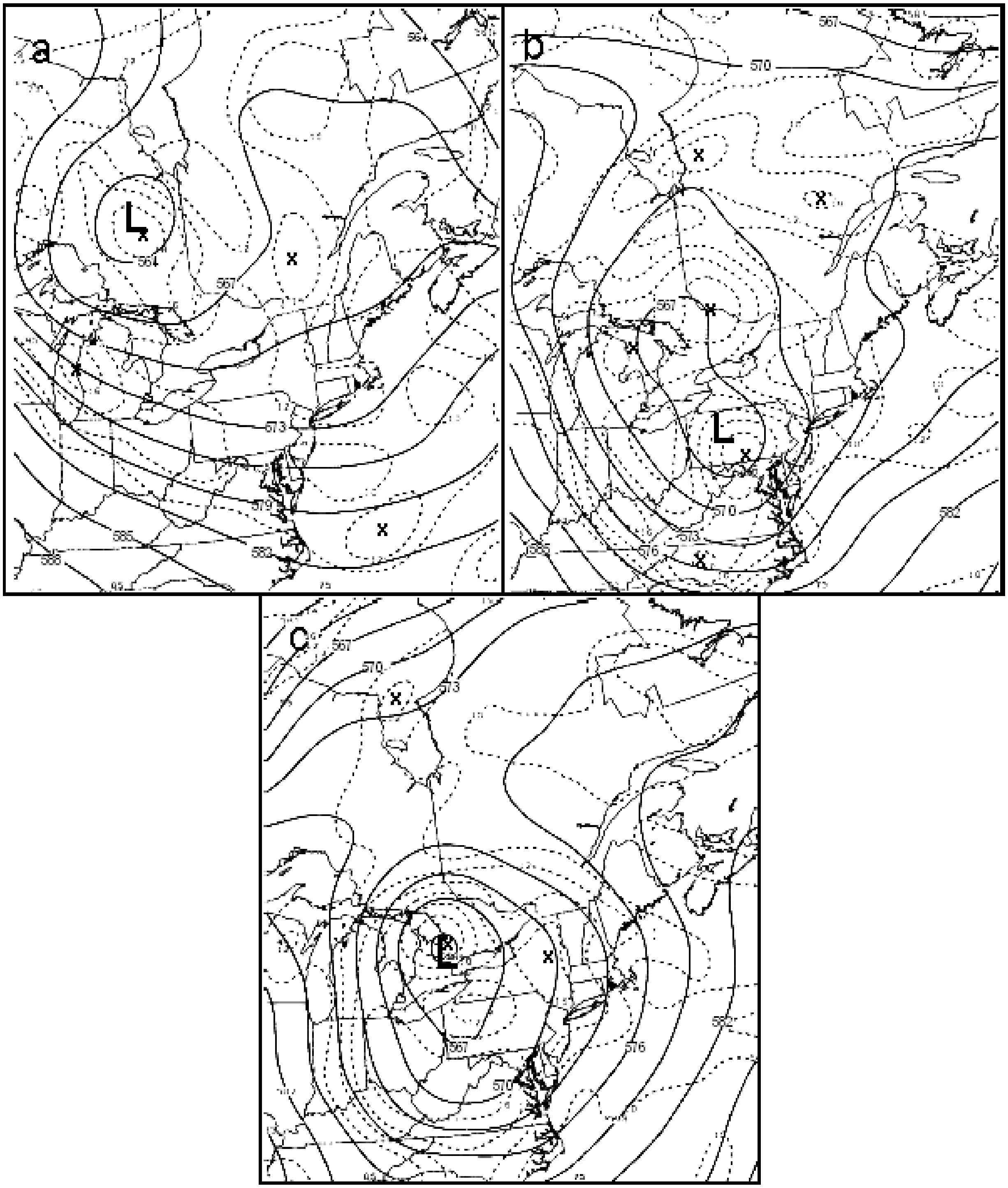

Figure 4. 500 hPa geopotential heights (solid lines, contours every 3 dm) and absolute vorticity (dotted lines, contours every 2 x 10^{-5} s^{-1}) from ETA model forecast initialized grids for (a) 1200 UTC 14 July, (b) 1200 UTC 15 July and (c) 1200 UTC 16 July. The x's denote absolute vorticity maxima.

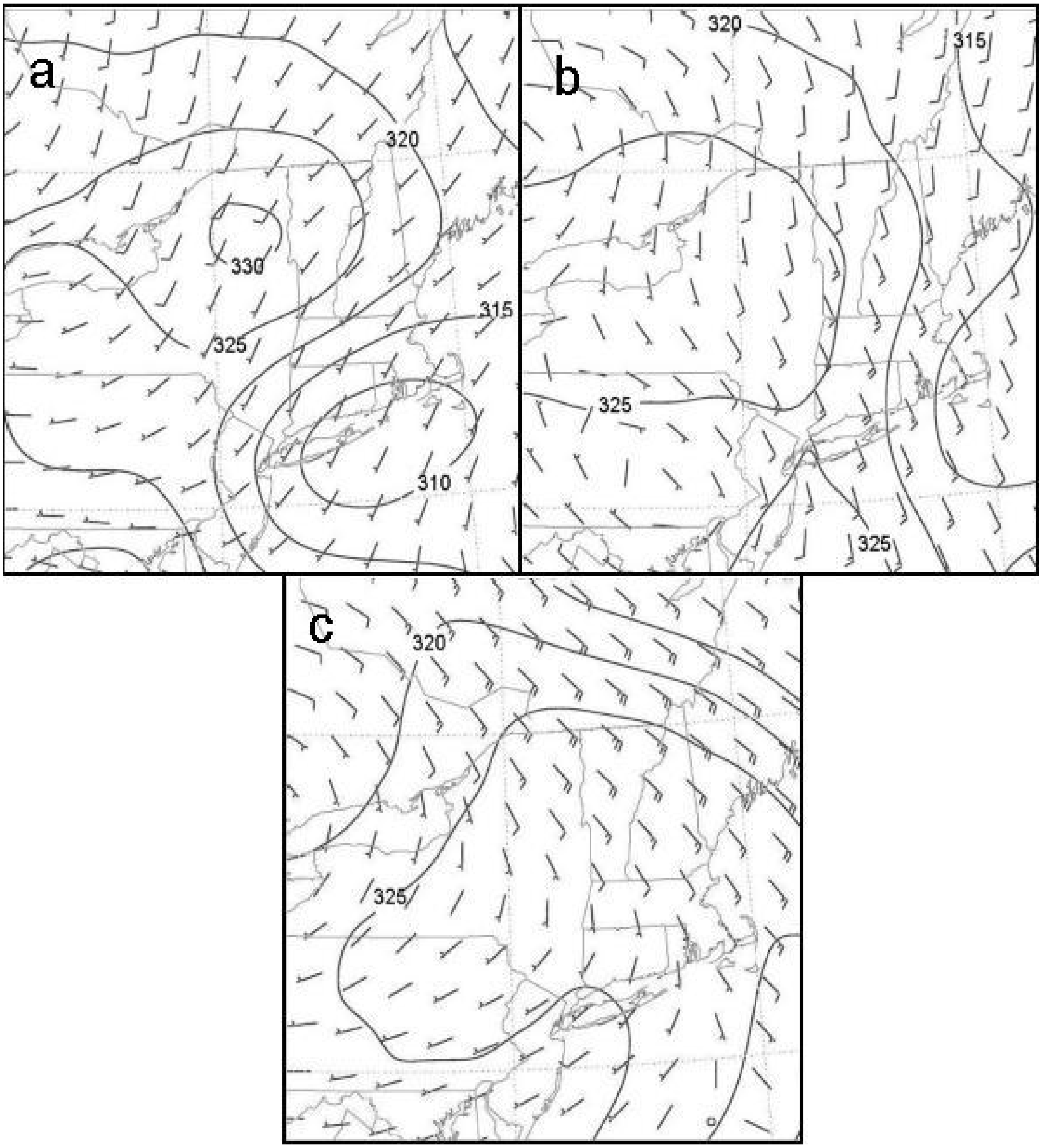

Figure 5. 850 hPa analyses (from ETA model initialized grids) for (a) 1200 UTC 14 July, (b) 1200 UTC 15 July and (c) 1200 UTC 16 July. Solid lines are equivalent potential temperature (K). For winds, full barbs denote 10 m s^{-1} and half barbs 5 m s^{-1}.

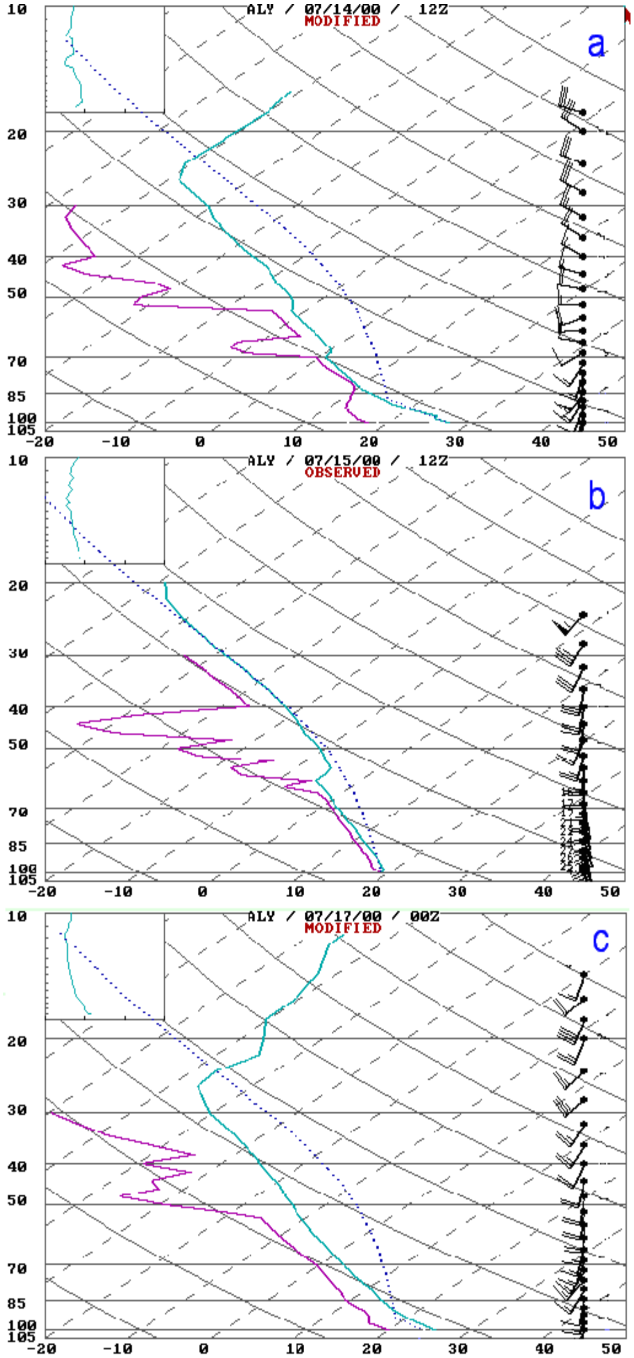

Figure 6. (a) ALY 1200 UTC 14 July 2000 sounding modified for observed surface temperature and dewpoint on that afternoon, (b) 1200 UTC 15 July 2000 observed ALY sounding and (c) ALY 0000 UTC 17 July 2000 sounding modified for observed surface temperature and dewpoint. Aqua line represents temperature, purple line dewpoint and dotted blue line the path of a lifted parcel. Half (full) wind barb = 2.5 (5) m s^{-1}. A wind pennant = 25 m s^{-1}.

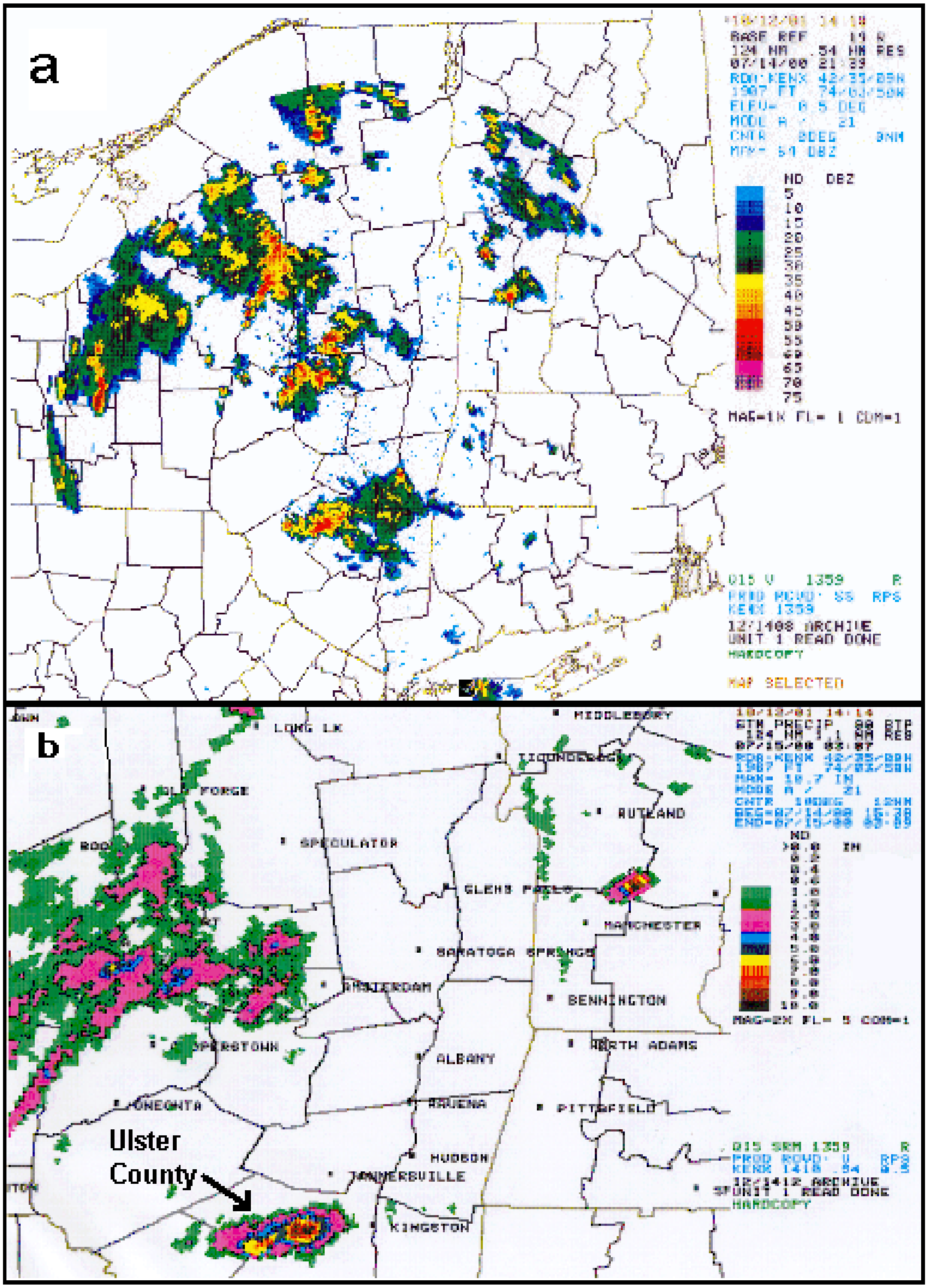

Figure 7. (a) Albany, NY (KENX) radar 0.5° base reflectivity at 2139 UTC 14 July and (b) KENX radar estimated precipitation from 1530 UTC 14 July to 0300 UTC 15 July.

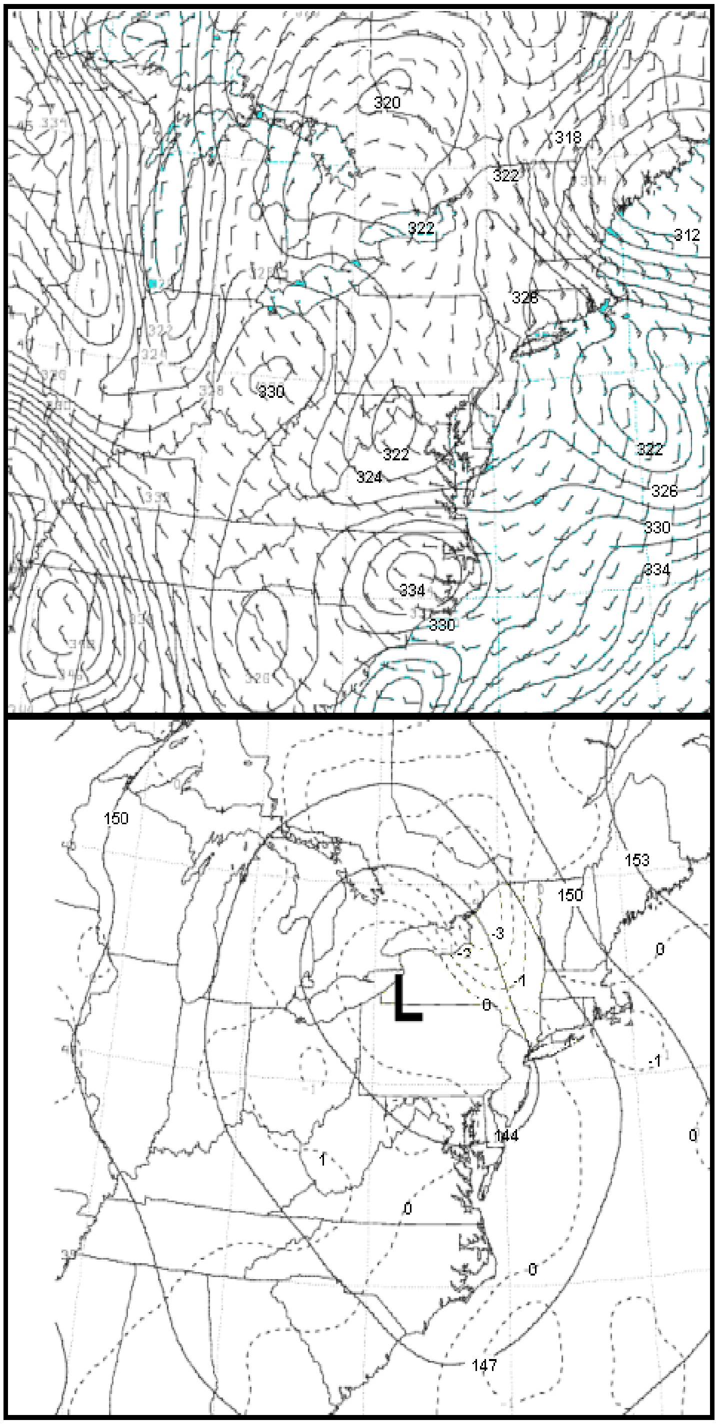

Figure 8. (a) 0000 UTC 16 July 850 hPa analysis of equivalent potential temperature (K) and winds (full barb denotes 10 m s^{-1} and half barb 5 m s^{-1}), and (b) 0000 UTC 16 July 850 hPa analysis of heights (solid line every 3 dm) and convergence (dotted lines, contours every 1 x 10^{-5} s^{-1}; from ETA model forecast initialized grids).

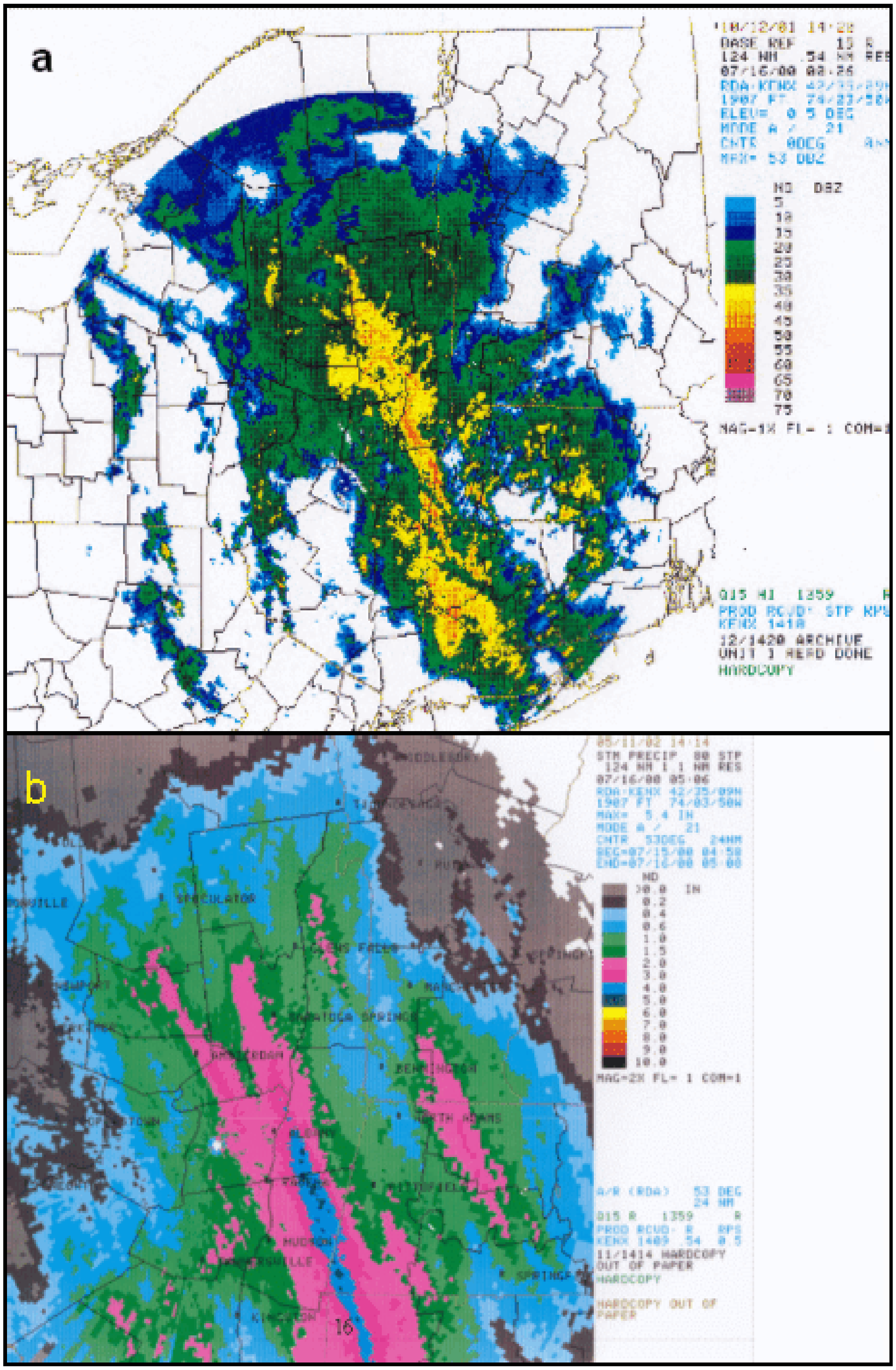

Figure 9. (a) KENX radar 0.5º base reflectivity at 0026 UTC 16 July and (b) KENX radar estimated precipitation from 0458 UTC 15 July to 0508 UTC 16 July.

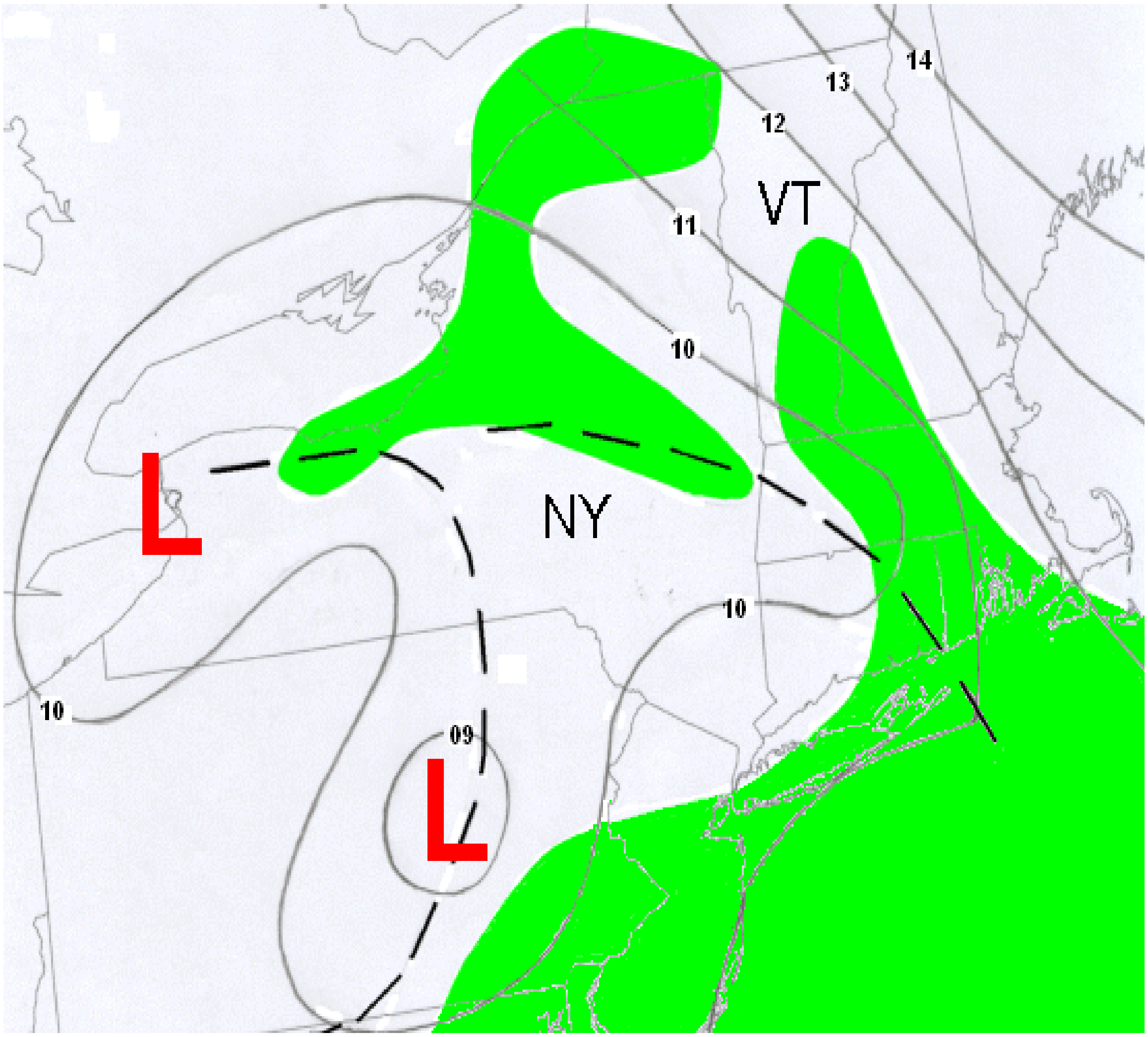

Figure 10. Surface analysis for 2300 UTC 16 July 2000. Solid lines are surface pressure in hPa (plus 1000) every 1 hPa with dashed lines representing surface troughs. Green shaded areas indicate areas with surface dewpoints greater or equal to 19ºC (66ºF).

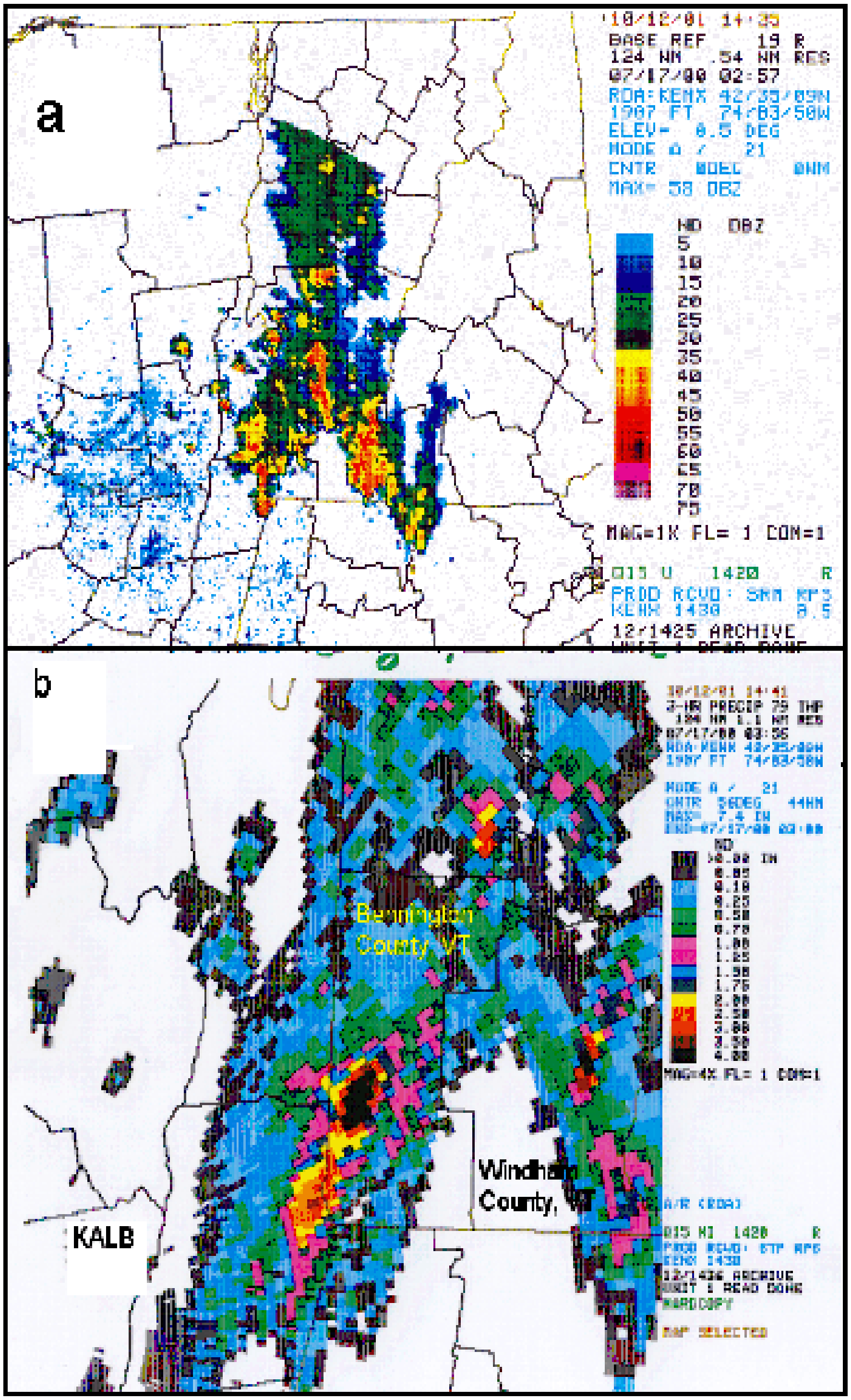

Figure 11. (a) KENX radar 0.5° base reflectivity at 0257 UTC 17 July and (b) KENX radar estimated precipitation from 0000 UTC to 0300 UTC 17 July.