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A CASE STUDY OF A SEVERE WEATHER EVENT IN NORTHEASTERN PENNSYLVANIA ON JULY 15, 1992

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1. INTRODUCTION

On July 15, 1992, an outbreak of severe thunderstorms and tornadoes occurred over sections of Pennsylvania and northern New Jersey. Based on conventional radar data and local storm reports from SKYWARN weather spotters and county Emergency Management Agency (EMA) officials, thunderstorm cells were tracked from their initial development during the midday hours until the activity began to diminish in intensity early in the evening.

This paper will present the synoptic features that triggered the outbreak through an analysis of upper-air and surface conditions. Also, upper-air soundings are included in order to assess atmospheric stability and vertical wind shear. Specific emphasis was placed on severe convection that occurred in northeastern Pennsylvania.

2. OVERVIEW

On July 15, 1992, the combination of moist, unstable air at lower levels, strong mid-level positive vorticity advection (PVA), and favorable positioning of upper-level jets most likely contributed to the production of several severe downburst events and two destructive tornadoes across northeastern Pennsylvania. One tornado struck the small town of Kelayres in northern Schuylkill county, causing extensive structural damage throughout the town. Several homes and buildings were nearly leveled. Another tornado touched down in southeastern Columbia county along the Susquehanna River. This tornado tore several mobile homes off their anchors and uprooted many large trees, causing sporadic damage. Also, large hail (up to 2 inches in diameter) associated with this same cell inflicted crop damage and smashed windows. Across the southern half of Luzerne county, there were numerous occurrences of wind damage due to downburst activity.

3. SYNOPTIC AND REGIONAL INITIAL CONDITIONS

For several days preceding the severe weather outbreak, a nearly stationary frontal system extended from the Central Plains states eastward into the lower Ohio Valley and then northeastward into the northern mid-Atlantic states and southern New England. During the morning of July 15, the frontal system remained in place (Fig. 1). This front separated warm, tropical air to the south from a cooler, marine-type environment over much of

New York and New England. Of note were the dew point temperatures of 70°F and higher in eastern Pennsylvania and New Jersey. Two weak low pressure areas were evident along the frontal boundary, one system centered over southeastern New York, while a more important feature developed over northern Ohio.

At 1200 UTC, the Limited-area Fine Mesh model (LFM), the Nested Grid Model (NGM), and the Aviation model (AVN) were all in agreement in initializing a short wave at 500 mb extending from lower Michigan southward through the lower Ohio Valley, with a vorticity maximum in the Ohio Valley region. The LFM depiction is displayed in Fig. 2. This short wave trough was coupled with the surface low pressure system over Ohio.

The 1200 UTC, 300 mb chart (Fig. 3) indicated that an upper-level jet streak was located from the lower Great Lakes region across the St. Lawrence Valley and into the interior of New England, while another speed maximum was located from the western Carolinas into Virginia. The rear of the northern speed maximum, associated with the polar jet stream, moved from northern Ohio toward New England during the day. Meanwhile, the southern speed maximum, associated with the subtropical jet stream, lifted slowly northward and became more pronounced. The positioning of the jet streaks placed northeastern Pennsylvania within the right entrance region of the polar jet streak, and the left exit region of the subtropical jet streak, during the afternoon. The resultant upper-level divergence enhanced the vertical lift over this area. It has been shown that when favorable low-level conditions exist, areas located between the polar and subtropical jet streams and near speed maxima are preferred regions for strong convective development (Whitney 1977). The upper-level jets over Pennsylvania were in a similar position to that noted by Whitney.

The upper-air soundings for 1200 UTC from Pittsburgh, PA (PIT), and Atlantic City, NJ (ACY), were also plotted and analyzed (Figs. 4 and 5). The data generated by the Skew-T Hodograph Analysis and Research Program (SHARP; Hart and Korotky 1991) showed a marginally unstable air mass at PIT (Table 1) and a potentially very unstable air mass at ACY (Table 2). A notable feature associated with the Atlantic City sounding is the very large positive area extending well up into the troposphere (about 43,000 feet). This represented substantial positive buoyant energy, as indicated by a Convective Available Potential Energy (CAPE) value of 2385 J/kg (Table 2). CAPE values of this magnitude often denote the potential for considerable thunderstorm activity (Mogil et al. 1991).

One inhibiting factor for severe development was a lack of directional shear. Both sounding plots showed a uniform west to southwest flow from the surface up through 300 mb. As a result of weak low-level shear, Energy/Helicity indices (EHI) were unimpressive. EHI values above 1 seem to indicate the potential for strong tornadoes when additional severe weather indicators are present (Hart and Korotky 1991; LaPenta 1991). However, some speed shear was evident, especially at ACY. This may have been a factor in producing severe downburst winds.

Despite the weak directional shear, a thunderstorm rapidly became severe over central Pennsylvania around 1830 UTC as it moved to the right of the environmental wind flow. The deviant track of this cell substantially increased its helicity, and associated EHI.

4. THE FORMATION OF SEVERE CONVECTION

Radar data from the National Weather Service office in Binghamton, NY was used to follow the development of thunderstorms in central and eastern Pennsylvania on the afternoon of July 15. Simulations of the radar coverage of precipitation echoes and echo intensity are presented in Figures 6a-i.

By early afternoon, thunderstorms began to form over western Pennsylvania. The Binghamton radar first began to observe this activity just after 1600 UTC (Fig. 6a). For the next several hours, thunderstorms increased in both intensity and coverage over central and northeastern Pennsylvania.

Radar depiction and storm reports revealed that the majority of severe weather in northeastern Pennsylvania originated from one persistent thunderstorm cell between 1800 and 2100 UTC (Fig. 7). It appeared that both dynamic forcing and low-level convergence peaked during this time period.

Strong PVA was over Pennsylvania during the afternoon hours, based on the 1200 UTC position of the short wave (Fig. 2) and the 0000 UTC position (not shown). Also, the 2100 UTC surface analysis (Fig. 8) revealed two important synoptic-scale features. A stationary frontal boundary was positioned over extreme northern Pennsylvania and extended into northern New Jersey, while a pre-frontal trough developed ahead of a cold front that advanced through western Pennsylvania. The trough stretched from north-central Pennsylvania to just west of Philadelphia (PHL), and then further south toward the Washington, DC area. Both the stationary front and pre-frontal trough provided low-level convergence. During the afternoon of July 15, most of northeastern Pennsylvania was between these two features. As a result, moisture convergence was maximized and additional lift was provided. The moisture convergence resulted in an area of high surface dew points across east-central and northeastern Pennsylvania (Fig. 8).

An important characteristic of the severe cell was its turn to the right, which started around 1800 UTC. By shortly after 1830 UTC, the storm began to produce hail and damaging winds. Initial movement of the thunderstorm was toward the northeast, which paralleled the prevailing low-level flow. However, the thunderstorm cell later turned toward the east and then southeast. This abrupt turn to the right dramatically increased the cell's helicity.

Using extrapolation of data from the 1200 UTC PIT wind profile, local surface winds at 1800 UTC, and the modification capabilities of the SHARP Workstation, two hodograph charts were constructed for Wilkes-Barre Scranton, PA (AVP) at 1800 UTC. This was done to illustrate the marked difference in severe potential of the right-turning thunderstorm cell. In Fig. 9a, a storm motion from about 280

degrees was calculated by use of the SHARP program to simulate a right-turning cell. For Fig. 9b, the storm motion was updated to simulate the actual amount of turning to the right by the severe cell. The storm-relative helicity value (0-2 km) for this cell was 114 m^2/s^2. Thus, the cell's movement of nearly 60 degrees to the right of the environmental wind flow, combined with its rapid forward motion, created a much more favorable shear profile for severe development.

Temperature and dew point data from PIT, Huntington, WV (HTS), and Dulles Airport, VA (IAD) at 1200 UTC, and surface temperatures from AVP at 1800 UTC, were used to create a modified sounding. The reconstructed sounding (Fig. 10) showed an unstable air mass over northeastern Pennsylvania (CAPE of 2651 J/kg and a lifted index of -6). A large positive area extended upward to around 200 mb. This indicated the potential for significant buoyancy among any given air parcel, with the capability to be lifted to at least 40,000 ft.

5. CONCLUSIONS

The development of severe thunderstorms across northeastern Pennsylvania on July 15, 1992 was most likely the result of favorable positioning of upper-level winds over an unstable environment, combined with strong PVA. Convergence boundaries at the surface helped to focus this convection. The SHARP program was helpful in pinpointing the important contribution of positive buoyancy and also the magnitude of potential instability. It was also shown that detailed hand analysis of upper-air and surface charts allowed for a more precise view of the atmosphere by enabling the analyst to identify the more subtle features associated with the severe weather.

Much of the damage caused by severe weather on this day was inflicted by a single cell that turned to the right and maintained itself for several hours. The enhanced shearing on the storm's outer fringes caused by its movement away from the prevailing flow appeared to be a major factor in the formation of severe convection. The SHARP program was instrumental in showing how this cell's deviation from the mean flow most likely was a catalyst for the initiation of rotation and subsequent tornadic development.

ACKNOWLEDGMENTS

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A special thanks goes to my wife, Teresa, for her help in proof-reading this document.

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Whitney, L. F., Jr., 1977: Relationship of the subtropical jet stream to severe local storms. *Mon. Wea. Rev.*, **105**, 398-412.

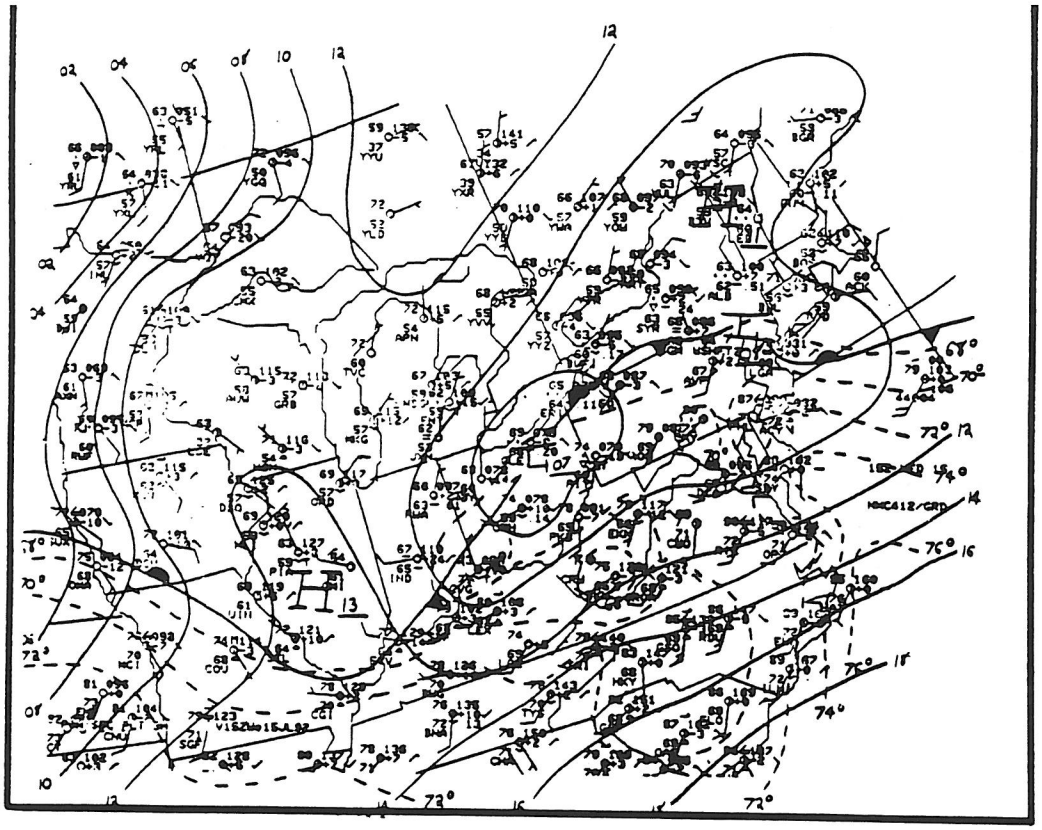


Figure 1. Surface analysis at 1500 UTC on 15 July 1992, showing isobars (mb, solid) and isodrosotherms (°F, dashed). Conventional symbols used for fronts and pressure centers.

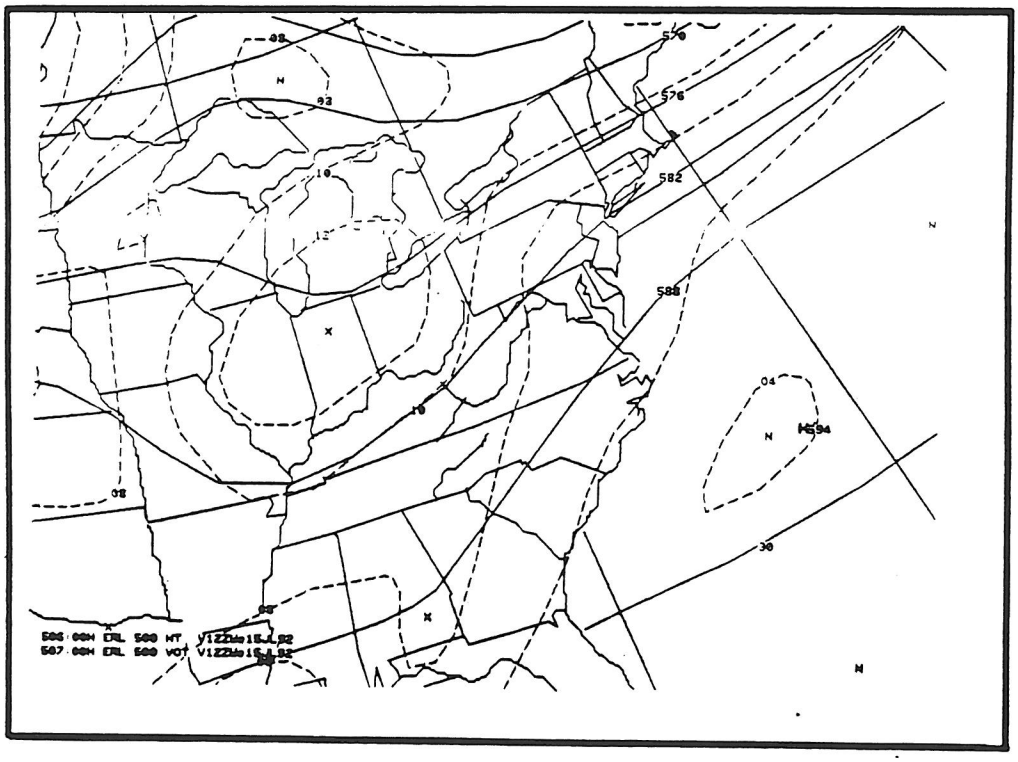


Figure 2. LFM analysis of 500 mb height (dm, solid) and vorticity (s^{-1}, dashed) at 1200 UTC on 15 July 1992.

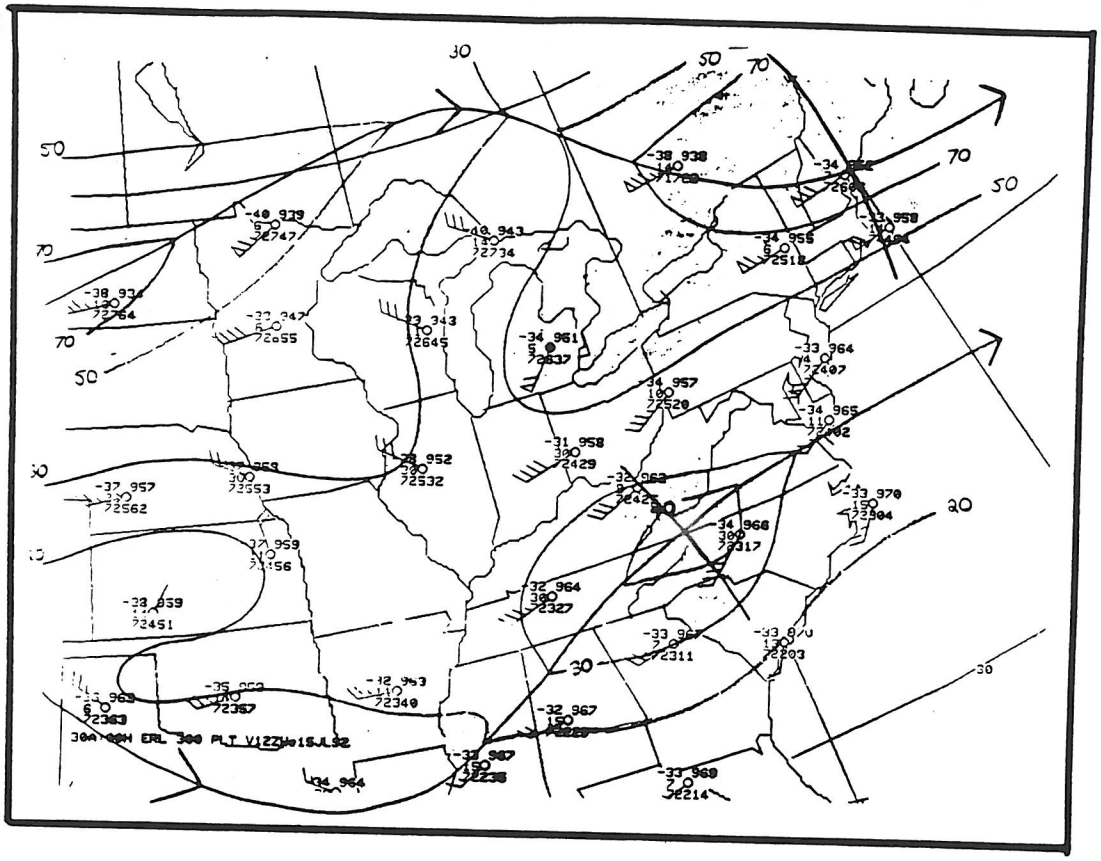


Figure 3. LFM 300 mb isotach (kt, solid) analysis at 1200 UTC on 15 July 1992. Solid arrows denote jet stream axes.

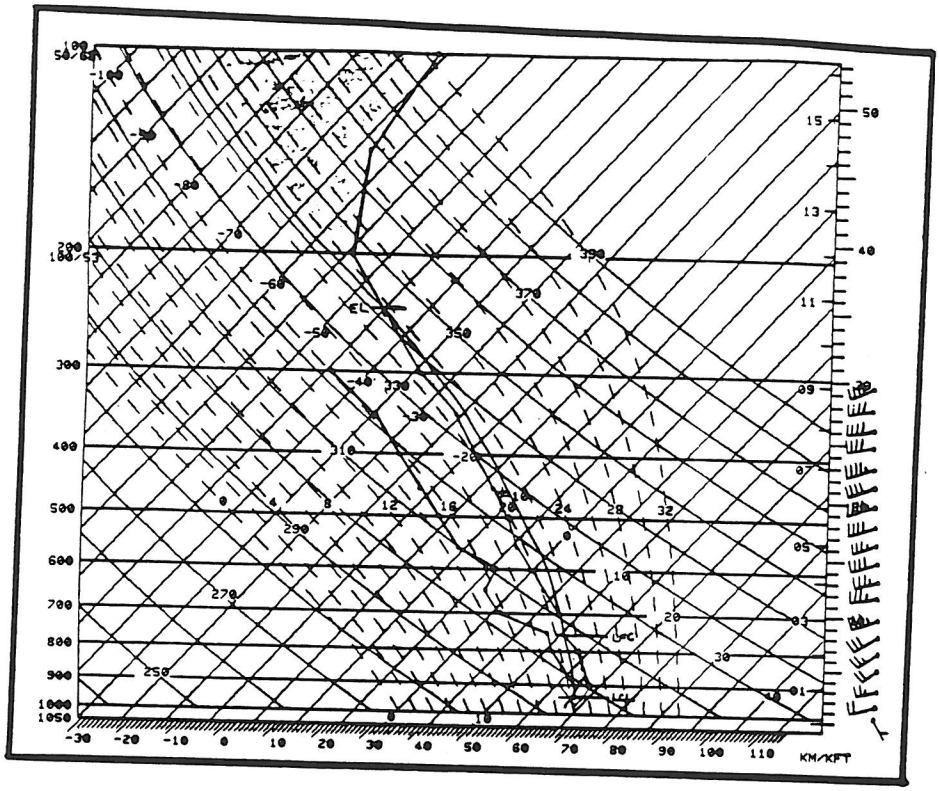


Figure 4. Environmental sounding for Pittsburgh (PIT) at 1200 UTC on 15 July 1992.

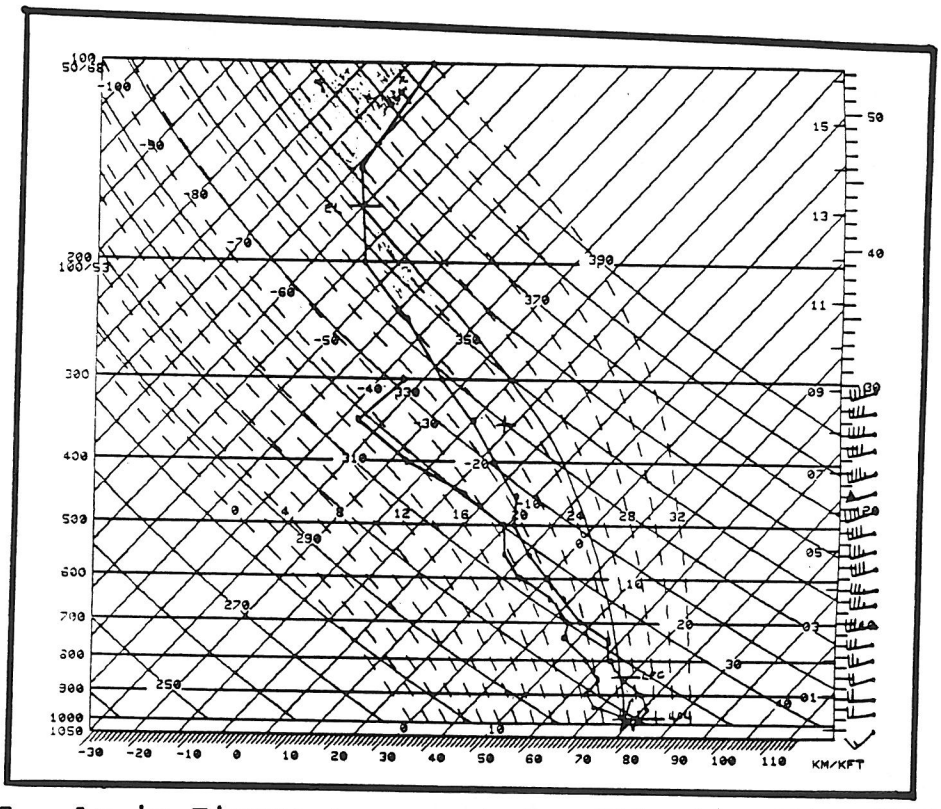


Figure 5. As in Figure 4, except for Atlantic City (ACY).

Table 1. Convective indices generated by the SHARP Workstation, for the environmental sounding for Pittsburgh displayed in Figure 4.

Single-Station RAOB data for: PIT
Date: 07/15/92 Time: 12 UTC

**********CONVECTIVE INDICES**********

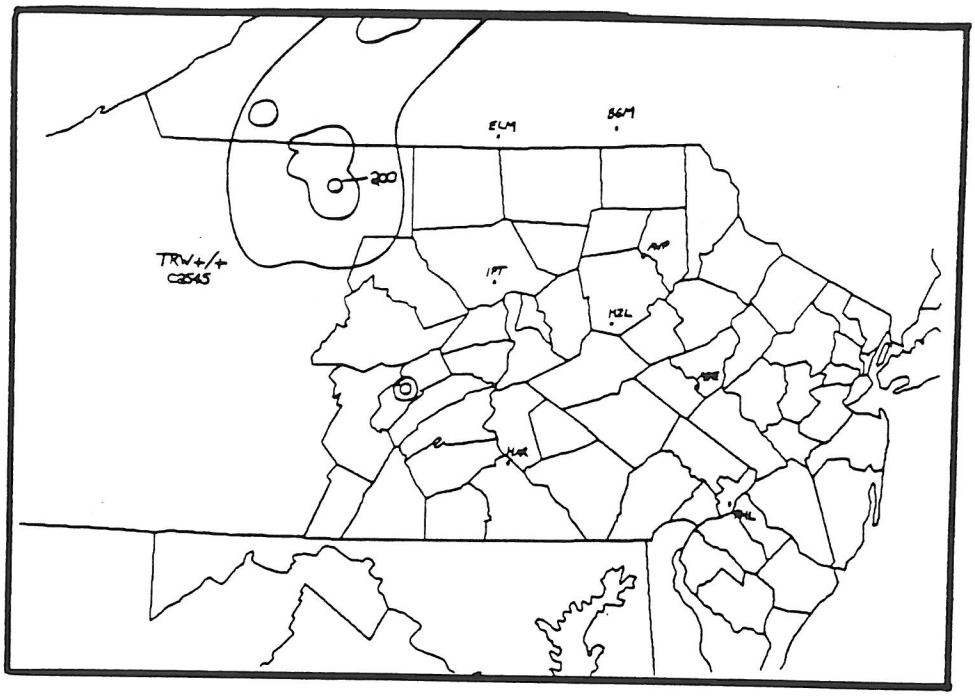
Lifted Index @ 500mb...	-3	Cross Totals (CT).....	23
@ 300mb...	-2	Vertical Totals (VT)....	25
		Total Totals.....	48
Showalter Index.....	-2		
Sweat Index.....	254	B+.....	840 J/kg
TEI.....	14.2	B-.....	1 J/kg
		Max UVV.....	41 m/s
K Index.....	33		
Precipitable Water.....	1.68 in		
		BRN.....	11
700-500mb Lapse Rate...	6.1 C/km	Energy/Helicity Index..	0.49

Table 2. Convective indices generated by the SHARP Workstation, for the environmental sounding for Atlantic City displayed in Figure 5.

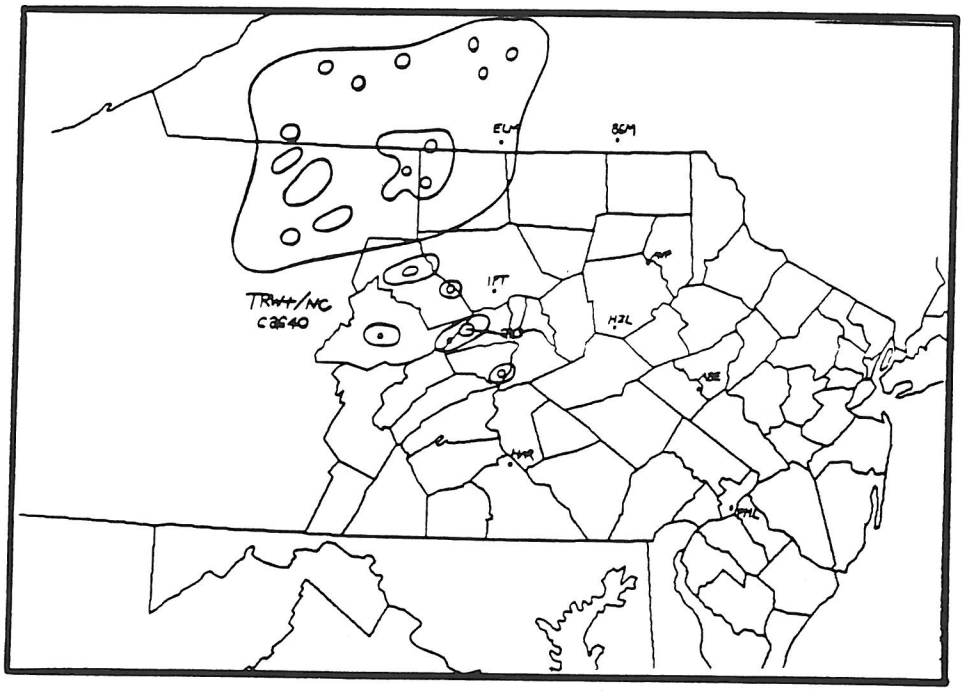
Single-Station RAOB data for: ACY
Date: 07/15/92 Time: 12 UTC

**********CONVECTIVE INDICES**********

Lifted Index @ 500mb...	-7	Cross Totals (CT).....	25
@ 300mb...	-7	Vertical Totals (VT)....	28
		Total Totals.....	53
Showalter Index.....	-6		
Sweat Index.....	402	B+.....	2385 J/kg
TEI.....	10.7	B-.....	12 J/kg
		Max UVV.....	69 m/s
K Index.....	43		
Precipitable Water.....	2.23 in		
		BRN.....	89
700-500mb Lapse Rate...	6.3 C/km	Energy/Helicity Index..	0.51

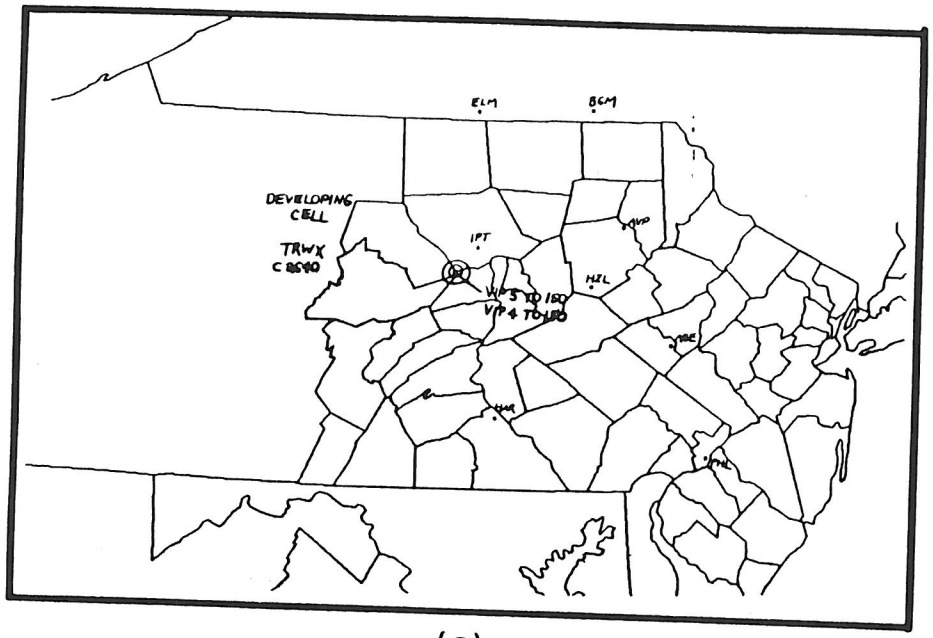


(a)

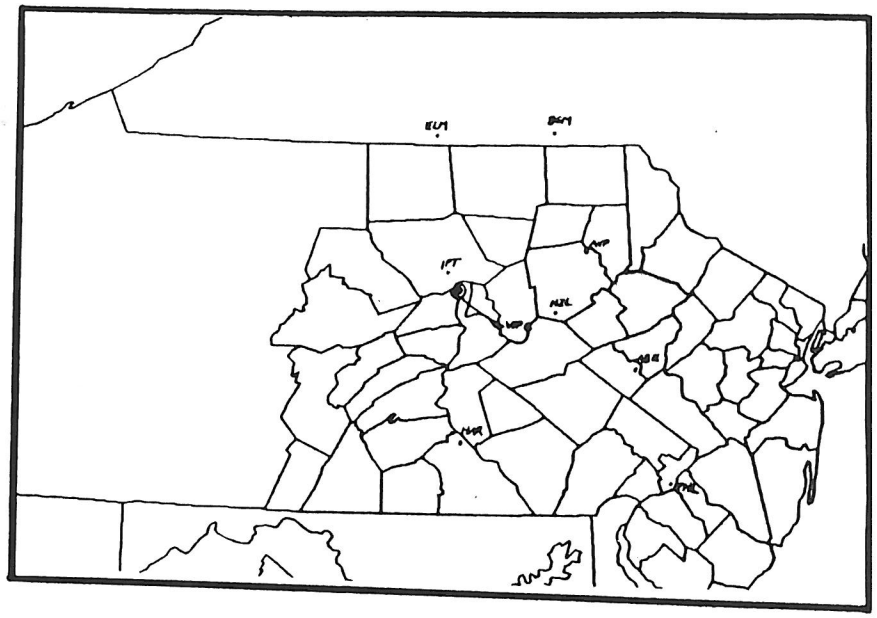


(b)

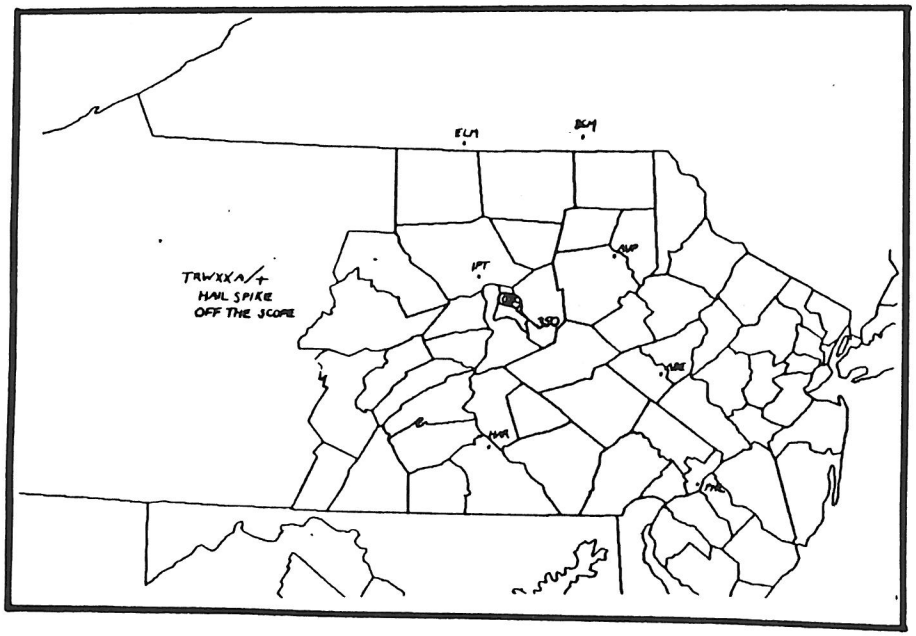
Figure 6. Radar images from the Binghamton (BGM) radar on 15 July 1992 at (a) 1630 UTC, (b) 1725 UTC, (c) 1750 UTC, (d) 1831 UTC, (e) 1845 UTC, (f) 1852 UTC, (g) 1930 UTC, (h) 1953 UTC, and (i) 2030 UTC.


ELM
BGM
DEVELOPING CELL
TRWX
C 8590
IPT
HZL
VIP 5 TO 150
VIP 4 TO 150
MUE
HAR
PHL

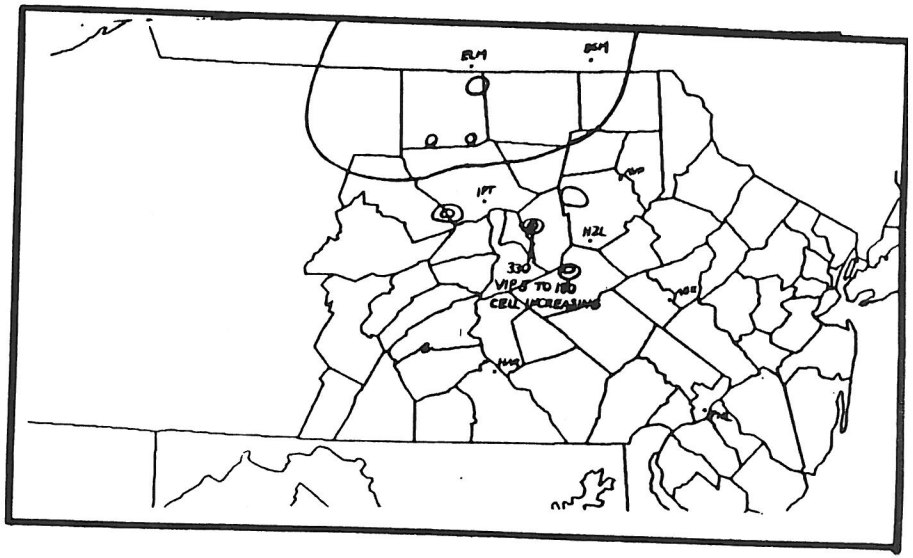
(c)


ELM
BGM
IPT
HZL
MUE
HAR
PHL

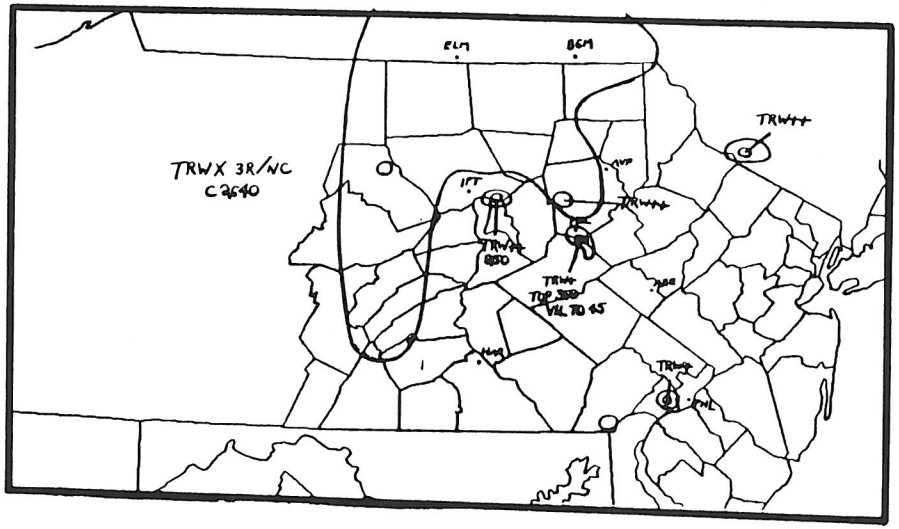
(d)


ELM
BGM
TRWXX A/+
HAIL SPIKE
OFF THE SCOPE
IPT
330
MUE
HAR
PHL

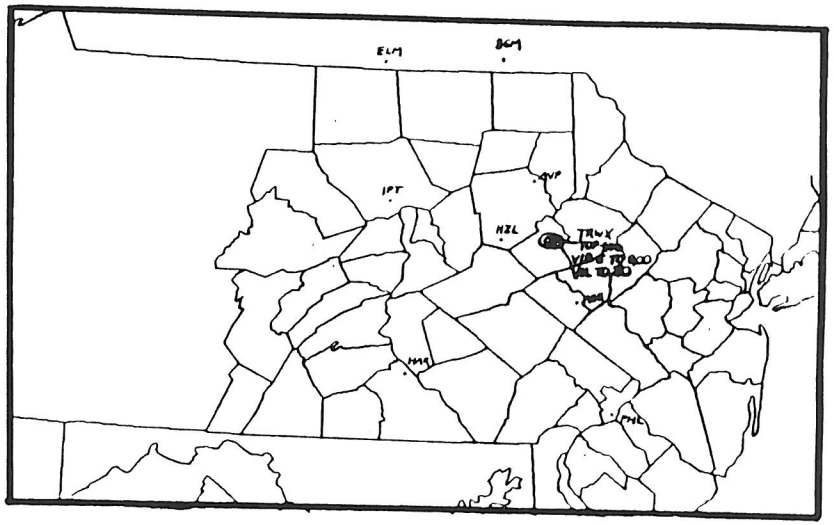
(e)


ELM
BGM
IPT
HZL
330
VIP 5 TO 150
CELL INCREASING
MUE
HAR
PHL

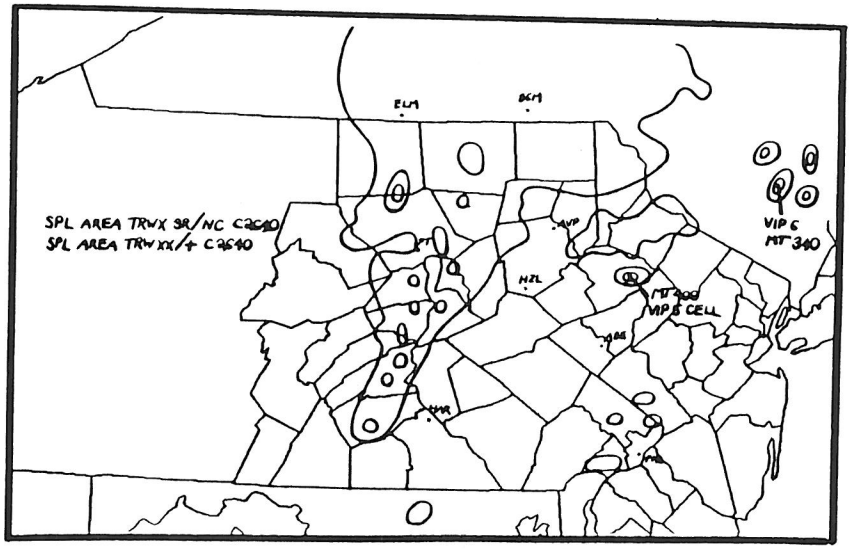
(f)


ELM
BGM
TRWX 3R/NC
C2640
IPT
AVP
TRWX
TRWX
TRWX
TOP 350
VIL TO 45
ABE
HAR
PHL

(g)


ELM
BGM
IPT
AVP
HZL
TRWX
ABE
HAR
PHL

(h)


ELM
BGM
SPL AREA TRWX 3R/NC C2640
SPL AREA TRWXX/+ C2640
IPT
AVP
HZL
VIP 6
MT 340
MT 300
VIP 5 CELL
ABE
HAR
PHL

(i)

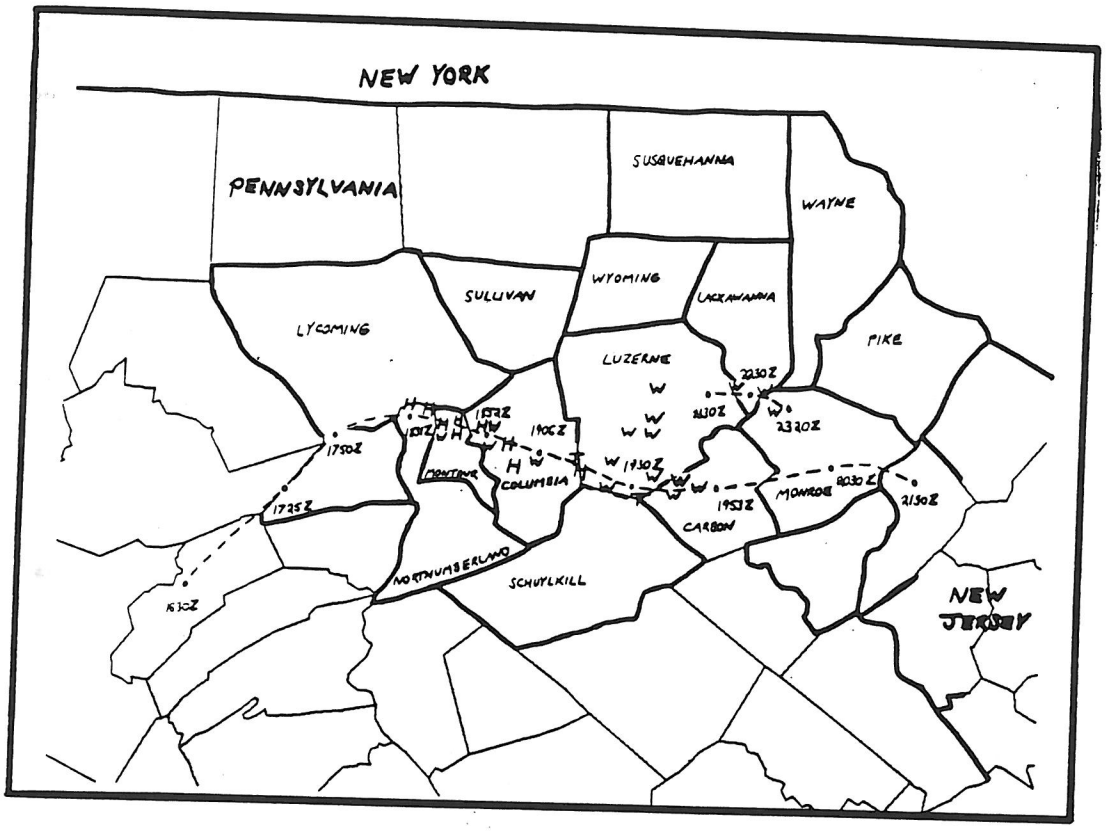


Figure 7. County map of northeastern Pennsylvania and northwestern New Jersey, with dashed lines representing the approximate paths of severe cells. Also indicated are locations of reported wind damage (W), confirmed tornado touchdowns (T), and large hail (H).

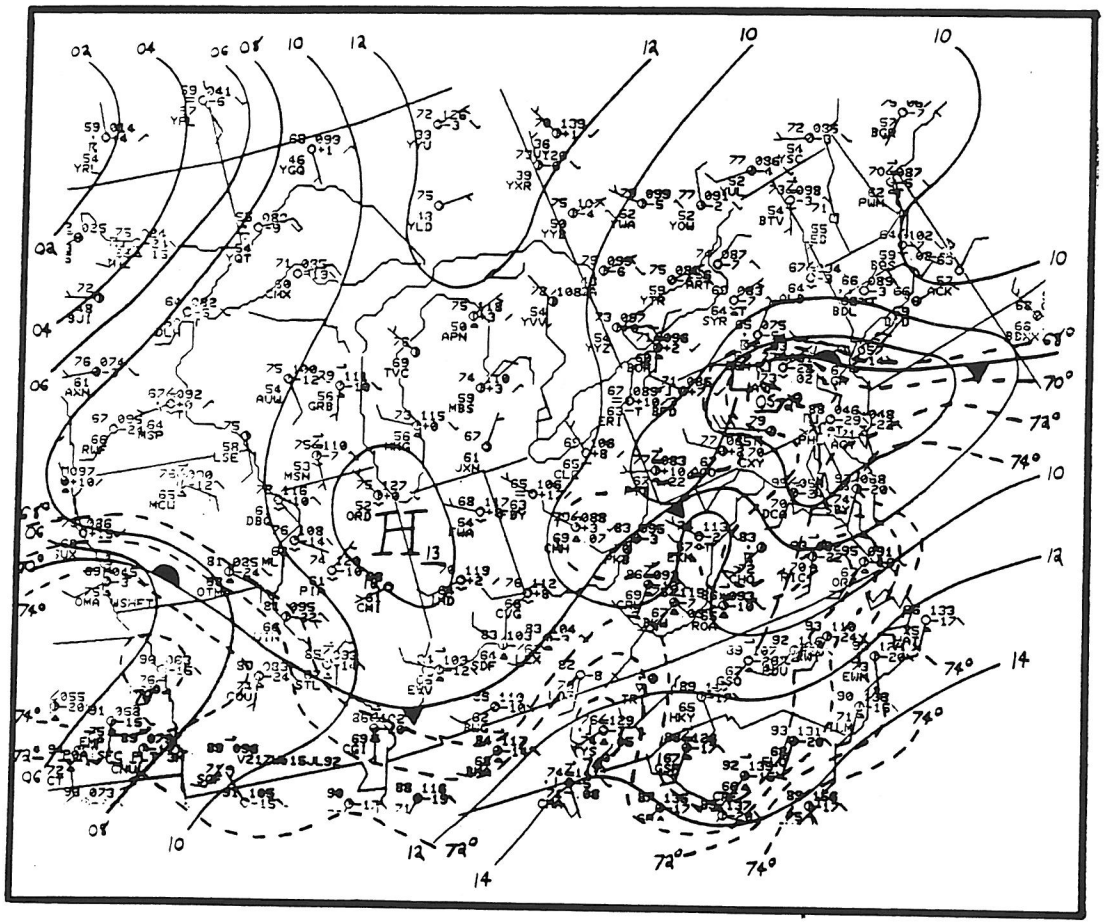
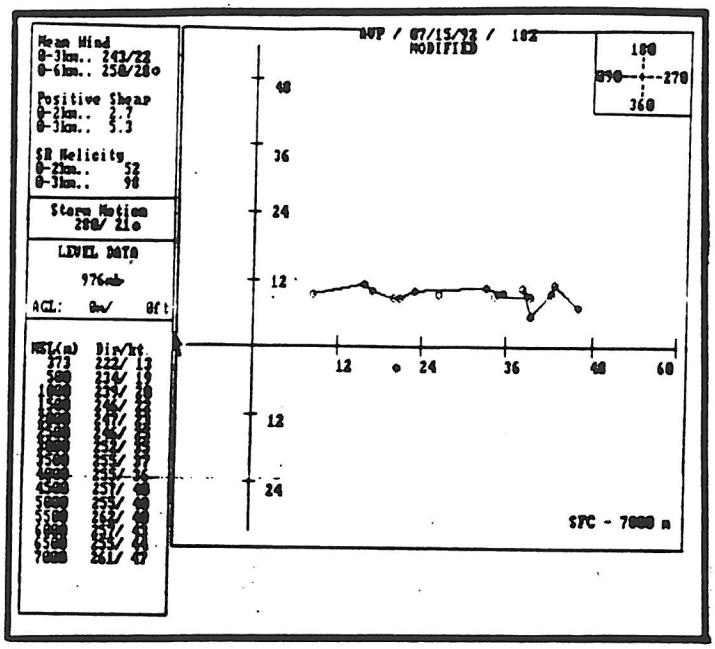
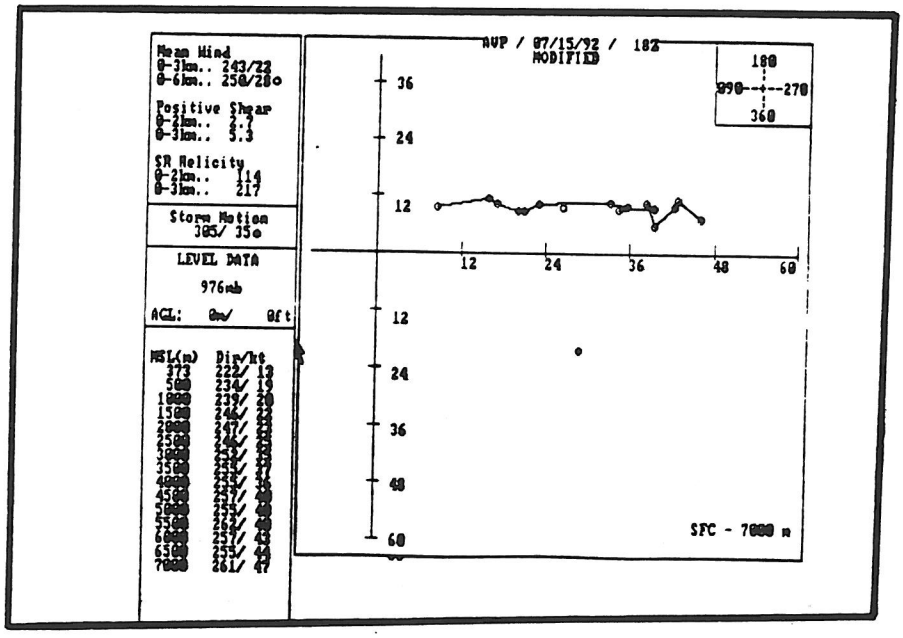


Figure 8. As in Figure 1, except at 2100 UTC.

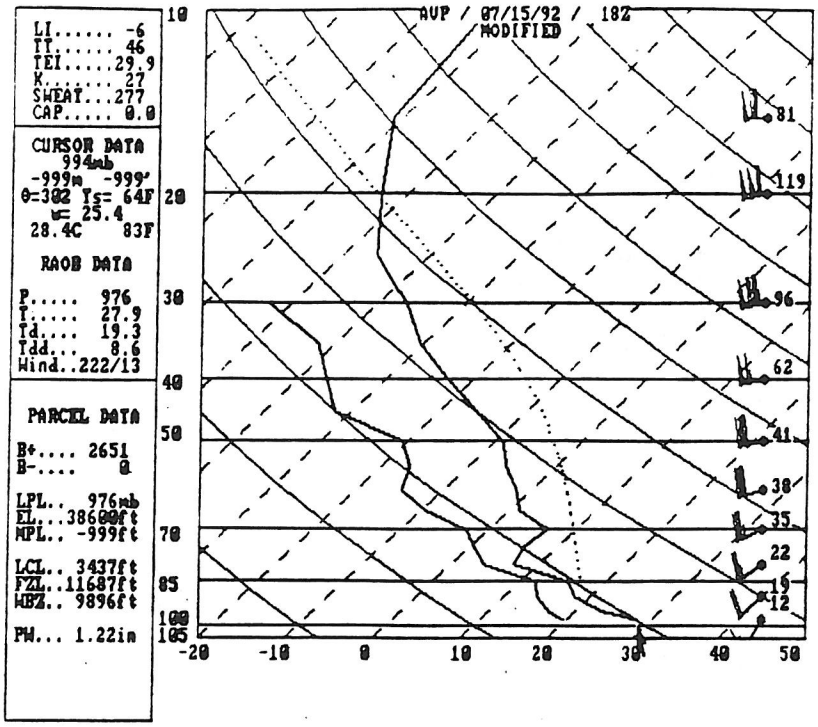


(a)



(b)

Figure 9. Hodograph analysis for Wilkes-Barre Scranton (AVP) at 1800 UTC on 15 July 1992, using (a) SHARP-calculated storm motion and (b) actual storm motion of the severe cell.



Single-Station RAOB data for: AVP
Date: 07/15/92 Time: 18 UTC

**********CONVECTIVE INDICES**********

Lifted Index @ 500mb... -6
@ 300mb... -8

Showalter Index..... 0
Sweat Index..... 277
TEI..... 29.9

K Index..... 27
Precipitable Water..... 1.22 in

700-500mb Lapse Rate... 6.1 C/km

Cross Totals (CT)..... 21
Vertical Totals (VT).... 25
Total Totals..... 46

B+..... 2651 J/kg
B-..... 0 J/kg
Max UVV..... 73 m/s

BRN..... 98
Energy/Helicity Index.. 1.89

Figure 10. SHARP-generated environmental sounding and convective indices for AVP at 1800 UTC on 15 July 1992. See text for details on how the sounding was created.