P10.6 THE MAY 11, 2003 SEVERE WEATHER NULL CASE ACROSS THE NORTHEASTERN AND MID-ATLANTIC STATES

Michael L. Jurewicz, Sr.*, Michael Evans, and Michael Cempa
National Weather Service, Binghamton, New York

Steven J. Rogowski
National Weather Service, Sterling, Virginia

1. INTRODUCTION

An outbreak of severe thunderstorms and tornadoes was expected across portions of the Northeastern United States and Mid-Atlantic region from New York State to Virginia during the afternoon and early evening of May 11, 2003. The approach of a vigorous surface cold front into an unstable and highly sheared environment was supposed to be the primary catalyst for such an event. In fact, the initial Tornado Watch issuance by the National Weather Service (NWS) Storm Prediction Center (SPC) described the situation as "particularly dangerous" due to an unusually potent combination of instability, strong low-level shear, and forcing. However, despite expectations, severe weather was limited to portions of Pennsylvania and New York State, while individual reports were isolated in nature.

There was a significant history of severe thunderstorms and tornadoes across the central United States for several days prior to May 11 (May 7-10). In section 2 of this paper, synoptic settings across the Midwest on May 10 are examined, along with those over the eastern states on May 11, to identify notable similarities and differences. In section 3, radar data over New York State and Pennsylvania is investigated. A discussion of the mesoscale environment and how it related to storm-scale structure and development is also given. Lastly, a summary is presented in section 4.

*Corresponding author address: Michael L. Jurewicz, Sr., National Weather Service, 32 Dawes Drive, Johnson City, NY 13790; e-mail: Michael.Jurewicz@noaa.gov.

2. SYNOPTIC OVERVIEW

During the period from the early evening of May 10 until the early morning of May 11 (0000 UTC to 1000 UTC), severe weather was widespread over the Midwestern United States. Within this broad region, two concentrated areas of severe weather development occurred. The first area encompassed parts of Illinois, Wisconsin, Iowa, and Missouri, where numerous tornadoes touched down during the early evening between 0000 UTC and 0400 UTC. The second area included much of Kentucky and Tennessee, where an intense squall line produced extensive wind damage from late at night into the early morning between 0400 UTC and 1000 UTC.

Severe weather developed over the Midwest on the 10^{th} as mid-tropospheric height falls and cooling, associated with the approach of a closed 500 hPa cyclone, overspread a warm, moist, and potentially very unstable environment. As this occurred, an existing mid-tropospheric capping inversion near 750 hPa was sufficiently eroded and any regions of convective inhibition (CIN) were eliminated. Meanwhile, a deep layer of large-scale lift developed in response to a well developed vertical coupling between upper-tropospheric divergence and lower tropospheric convergence. The data in Fig. 1 indicates an Eta-forecast, pronounced area of 250 hPa divergence at 0000 UTC centered over central and northern Illinois, which was likely associated with the right entrance region of a 100+ kt jet streak. Later that night, the same jet streak propagated towards the northeast across the Lower Great Lakes region, with the associated area of 250 hPa divergence shifting eastward into the Ohio and Tennessee Valleys by around 0600 UTC. The upper-tropospheric divergence was coupled with lower-tropospheric synoptic-scale convergence along an approaching surface cold front. A deep layer of upward vertical motion is indicated between the upper-tropospheric divergence and the lower-tropospheric convergence.

Throughout the Midwest, adequate wind shear was present in the lowest 3 km above ground level (AGL) to support organized convective systems late on the 10th. However, there is evidence that differences in some of the characteristics of the shear resulted in a different mode of convection over the area where the tornadic storms developed, vs. the area where the squall line occurred. A deep layer of both directional and speed shear was evident over Illinois between 0000 UTC and 0300 UTC, within an environment that favored the development of tornadic supercells. Later that evening between 0300 UTC and 0600 UTC over the Lower Ohio and Tennessee Valleys, pronounced speed shear was evident in the lowest 1.5 to 2 km AGL. However, there was little speed shear above 2 km and the flow was unidirectional. The environment across this area favored squall line and bow-echo development. Numerous prior studies confirm that environments featuring deeper layers of shear in the lowest 3 to 6 km tend to favor supercellular development, while environments featuring a shallower layer of speed shear in the lowest 1 to 3 km tend to favor linear convective development (DeWald and Funk 2000; Evans and Doswell III 2001; Moller et al. 1999; Weisman and Rotunno 2000; Weisman and Trapp 2003; Wicker 1996).

In contrast to the mid-tropospheric cooling observed over the Midwest on the 10th, mid-tropospheric warming occurred over the Northeast and Mid-Atlantic states during the afternoon and evening on the 11th, in response to significant mid-level subsidence. The same 500 hPa cyclone described earlier remained nearly stationary over the Upper Midwest during the day on 11th, while very little in the way of mid-tropospheric height falls or cooling translated eastward. Additionally, the nose of a strong middle to upper-tropospheric jet streak rotated northeastward, reaching Ohio and western Pennsylvania between 1800 UTC, May 11 and 0000 UTC, May 12 (Fig. 2). The position of this speed maximum placed much of the area from Pennsylvania southward to Virginia underneath its right-exit region, a quadrant that typically favors large-scale sinking motion (Bluestein 1993; Uccellini and Johnson 1979). The data in the cross-section shown in Fig. 3, drawn from Ohio to southern New England at 2100 UTC on May 11, confirmed the presence of strong mid-tropospheric subsidence over northern Pennsylvania, with upward motion confined to the lower-troposphere. It is thus theorized by the authors that mid-tropospheric downward motion was induced from unfavorable jet dynamics and resulted in compressional warming of the 700 to 500 hPa layer. The presence of the mid-tropospheric warm layer may help explain both the lack of widespread convection on the 11th, as well as the shallow nature of the thunderstorms that did develop. Several observed and ACARS soundings (not shown) between 1800 UTC and 2100 UTC indeed showed a substantial thermal inversion around 600 hPa; which helped limit the instability in the warm sector. More detailed descriptions of surface frontal positions and evolutions of boundary layer environments are given in section 3.

The degree of 0-3 km environmental shear across the Northeastern and Mid-Atlantic states on May 11 was similar to that observed over portions of the Midwest the evening of May 10, where tornadic supercells were prevalent. This implies that shear profiles over the eastern states would have been supportive of supercell development, had enough instability and lift been in place to sustain more vigorous and deeper updrafts (McCaul and Weisman 2001; Nair et al. 2002; Weisman and Klemp 1982).

3. RADAR AND MESOSCALE ANALYSIS

Despite the inhibiting effect of the mid-tropospheric cap, scattered thunderstorms managed to develop over northern Pennsylvania and upstate New York during the mid to late afternoon on May 11. Some of these storms developed significant low-level rotation, with two storms producing short-lived, weak tornadoes. However, the majority of the storms occurred with no tornadoes and no wind damage reports of any kind (although several funnel cloud sightings were reported).

One storm that did produce a weak, short-lived tornado developed over north-central Pennsylvania around 2010 UTC. The storm attained significant low-level rotation quickly after it developed, with the tornado touchdown occurring shortly thereafter. The storm continued to exhibit significant rotation as it moved eastward towards northeastern Pennsylvania. However, no further reports of tornadoes or wind damage were received. Figure 4 shows a 4-panel of WSR-88D 0.5 degree reflectivity and storm relative velocity (SRM) data around the time of tornado touchdown (a and b), and about 2.5 hours later (c and d), after reports of wind damage had ceased. Other storms that developed significant rotation, but were not accompanied by any wind damage reports, also occurred across central New York.

One factor that likely led to the failure of these storms to produce wind damage was their interaction with an air mass that had stabilized at low levels. Figure 5 shows a surface meso-analysis across Pennsylvania and upstate New York at a) 2000 UTC and b) 2300 UTC. At 2000 UTC, a dry line extended from central New York southward across central Pennsylvania, with a very narrow warm sector just to the east. The storms initially appeared to develop either in the warm sector or very close to surface boundaries between 2000 UTC and 2100 UTC. However, by 2300 UTC, the tornadic storm that originally developed over central Pennsylvania had moved east of the warm sector into a more stable atmosphere across northeastern Pennsylvania. Meanwhile, the warm sector over central New York appeared to become occluded by 2300 UTC, as a surface meso-low developed southward from central New York towards northern Pennsylvania. Consequently, the storms over central New York that initially developed in an environment characterized by low-level instability, quickly became decoupled from the boundary layer as cooler, more stable air at low-levels was drawn southward towards the developing meso-low.

4. SUMMARY

An outbreak of severe thunderstorms and tornadoes was expected across sections of the Northeastern United States during the afternoon and evening of May 11, 2003 due to the combined effects of substantial instability, upward motion, and low-level wind shear. Despite the anticipated occurrence of severe weather, very little developed.

Synoptic settings over the eastern states on May 11 were compared and contrasted with those across the Midwest on May 10, where significant severe weather did take place. Mid-tropospheric height falls and cooling accompanied strong lower-tropospheric instability across portions of Illinois, Kentucky, and Tennessee during the evening of May 10, which helped trigger explosive convective development. Mid-tropospheric subsidence and warming accompanied marginal lower-tropospheric instability over the Mid-Atlantic and Northeastern states during the afternoon of May 11, which helped limit convective development both spatially and vertically.

The Eta model indicated that a deep layer of lift was in place across much of the Mississippi, Ohio, and Tennessee Valley regions the evening of May 10. The pronounced lift was produced by a favorable coupling of upper-tropospheric divergence, associated with a 250 hPa jet streak just to the north, and lower-tropospheric convergence, associated with a strong surface cold front just to the west. Meanwhile, lift was restricted to a shallow layer in the lower-troposphere across the eastern states during most of the afternoon on the 11th. Pronounced sinking motion in the mid-troposphere was produced from unfavorable positioning with respect to an approaching mid- to upper-tropospheric jet streak in the Ohio Valley. Thus, most of the area from Virginia northward to Pennsylvania was placed underneath its convergent right-front quadrant.

The magnitude of both the directional and speed shear in the lowest 3 km AGL was comparable between the Midwest on the 10th and the Northeast on the 11th. Given this similarity, the authors contend that an environment more conducive to the maintenance of strong updrafts would have supported supercell development across the Northeast on the 11th.

Even with the limiting synoptic-scale factors described above, scattered thunderstorms did develop over New York State and Pennsylvania on the afternoon of the 11th. Although there was isolated occurrences of weak, short-lived tornadoes and large hail, severe weather was largely absent.

Mesoscale analyses and regional WSR-88D imagery showed that several cells formed near a rapidly occluding surface boundary. The development of a meso-low over northern Pennsylvania resulted in cooler, more stable air becoming increasingly prevalent in the lower-tropospheric environment where these storms resided. The authors have theorized that such stabilization of the lower troposphere resulted in a decoupling of storm-scale circulations with their boundary layer environment. As a result, individual thunderstorms became more elevated in nature, with a much lower capacity to translate strong winds down to the surface.

5. REFERENCES

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6. FIGURES

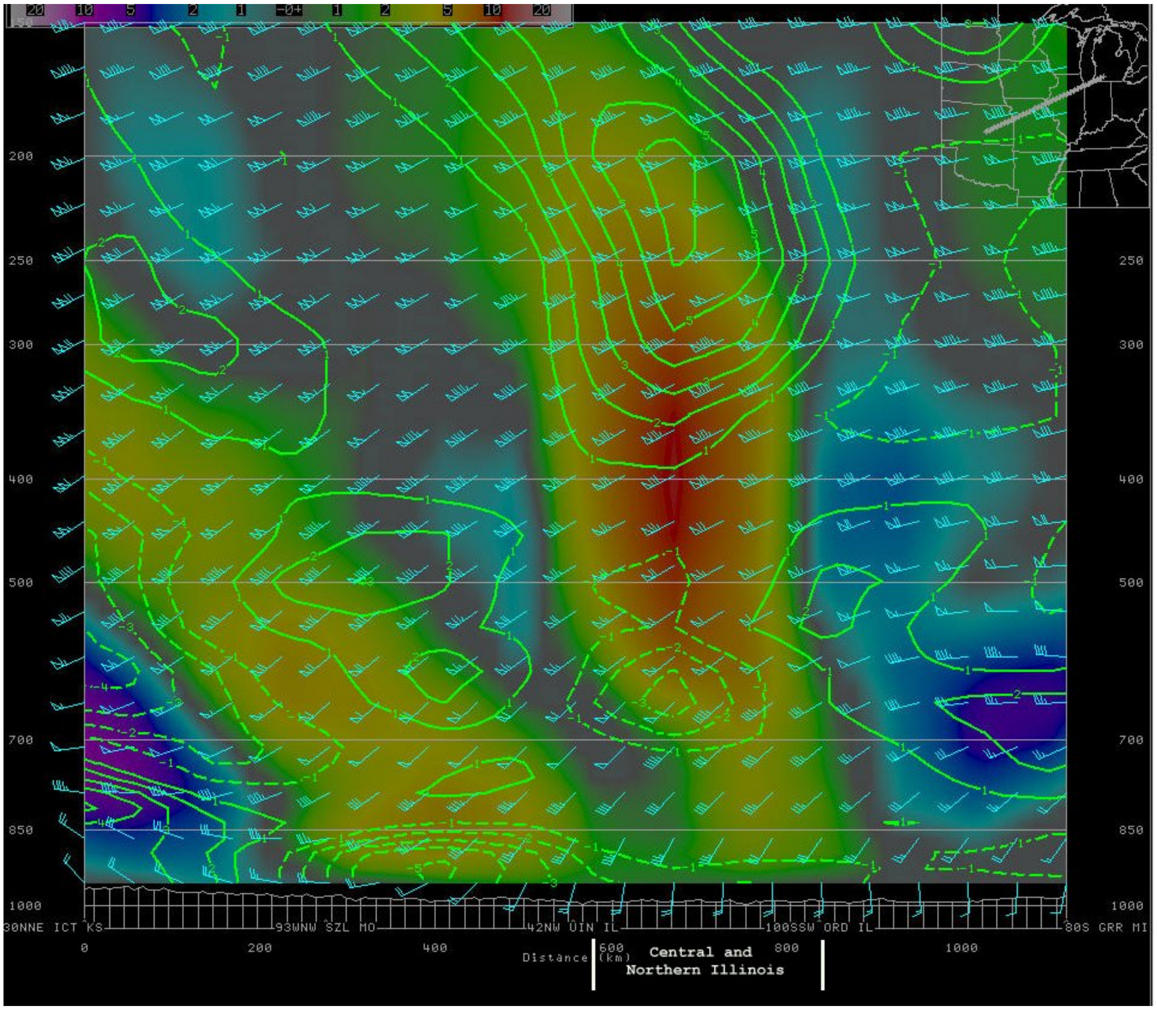

Figure 1. Eta initialized cross-section of convergence ($1x10^{-5}s^{-1}$, dashed lines), divergence ($1x10^{-5}s^{-1}$, solid lines), and omega (μbs^{-1}, upward motion shaded red, downward motion shaded blue), valid at 0000 UTC, 11 May, 2003. The cross-sectional axis extends from eastern Kansas to southern Lower Michigan. The location of central and northern Illinois is highlighted along the x-axis of the cross-section.

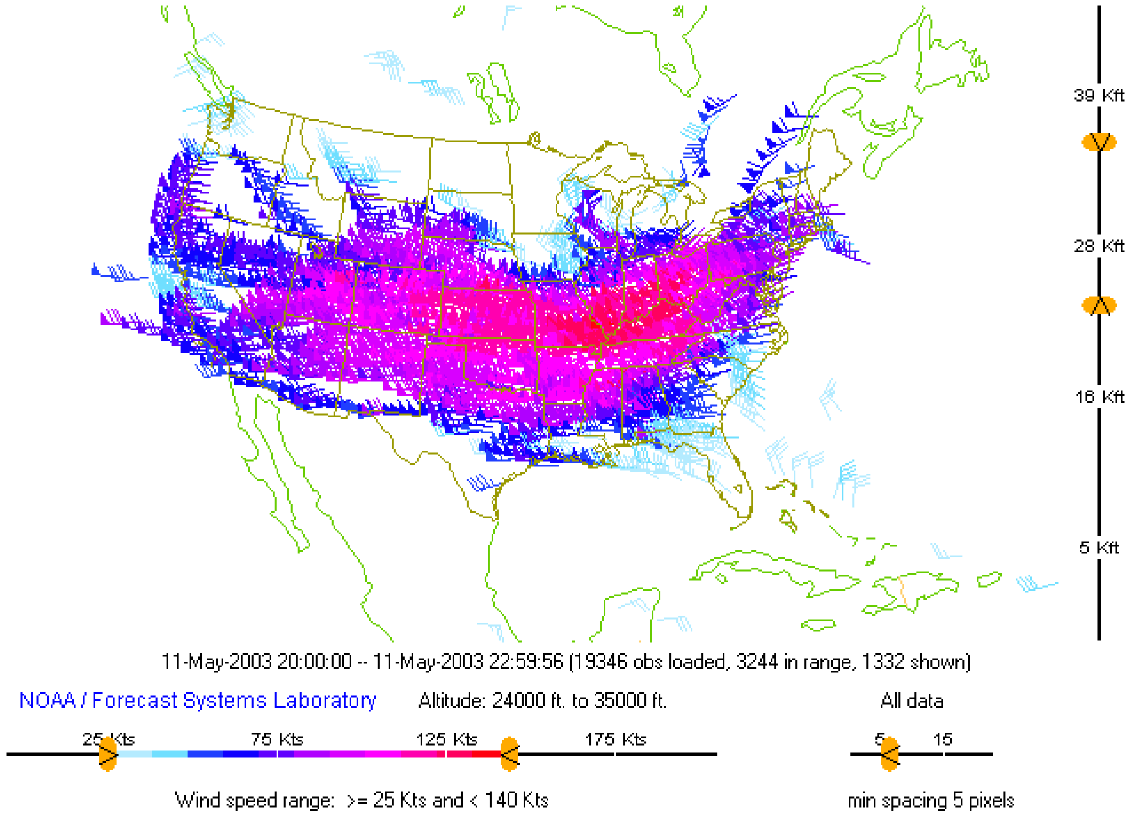

Figure 2. Isotach analysis (kts) in the 250 hPa to 400 hPa layer from ACARS observations. The valid period is 2000 UTC, 11 May, 2003 to 0000 UTC, 12 May, 2003.

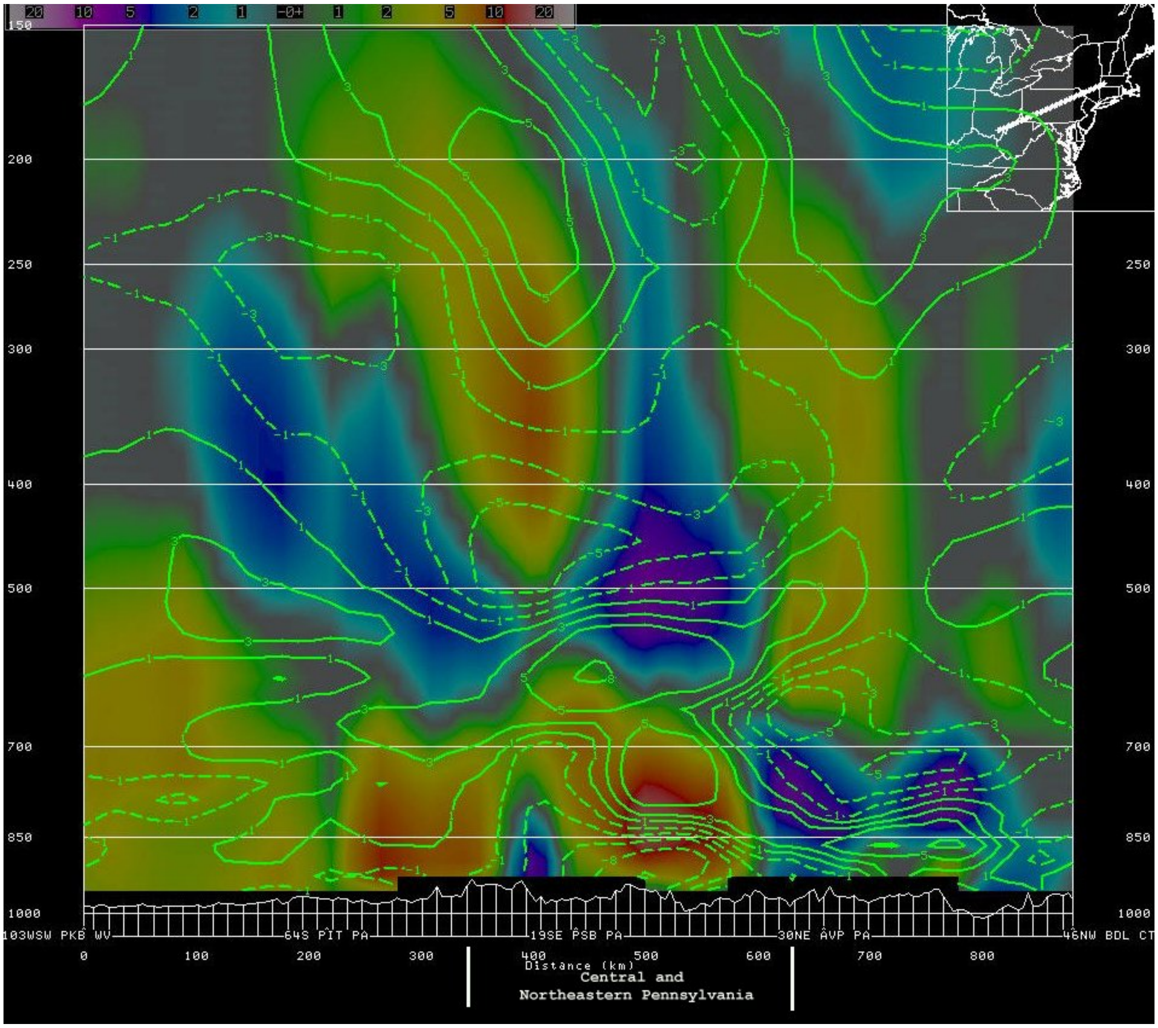

Figure 3. Eta 3-hour forecast cross-section of convergence ($1x10^{-5}$ s^{-1}, dashed lines), divergence ($1x10^{-5}s^{-1}$, solid lines), and omega (μbs^{-1}, upward motion shaded red, downward motion shaded blue), valid at 2100 UTC, 11 May, 2003. The cross-sectional axis extends from southern Ohio to western Massachusetts. Central and northeast Pennsylvania is highlighted along the x-axis of the cross-section.

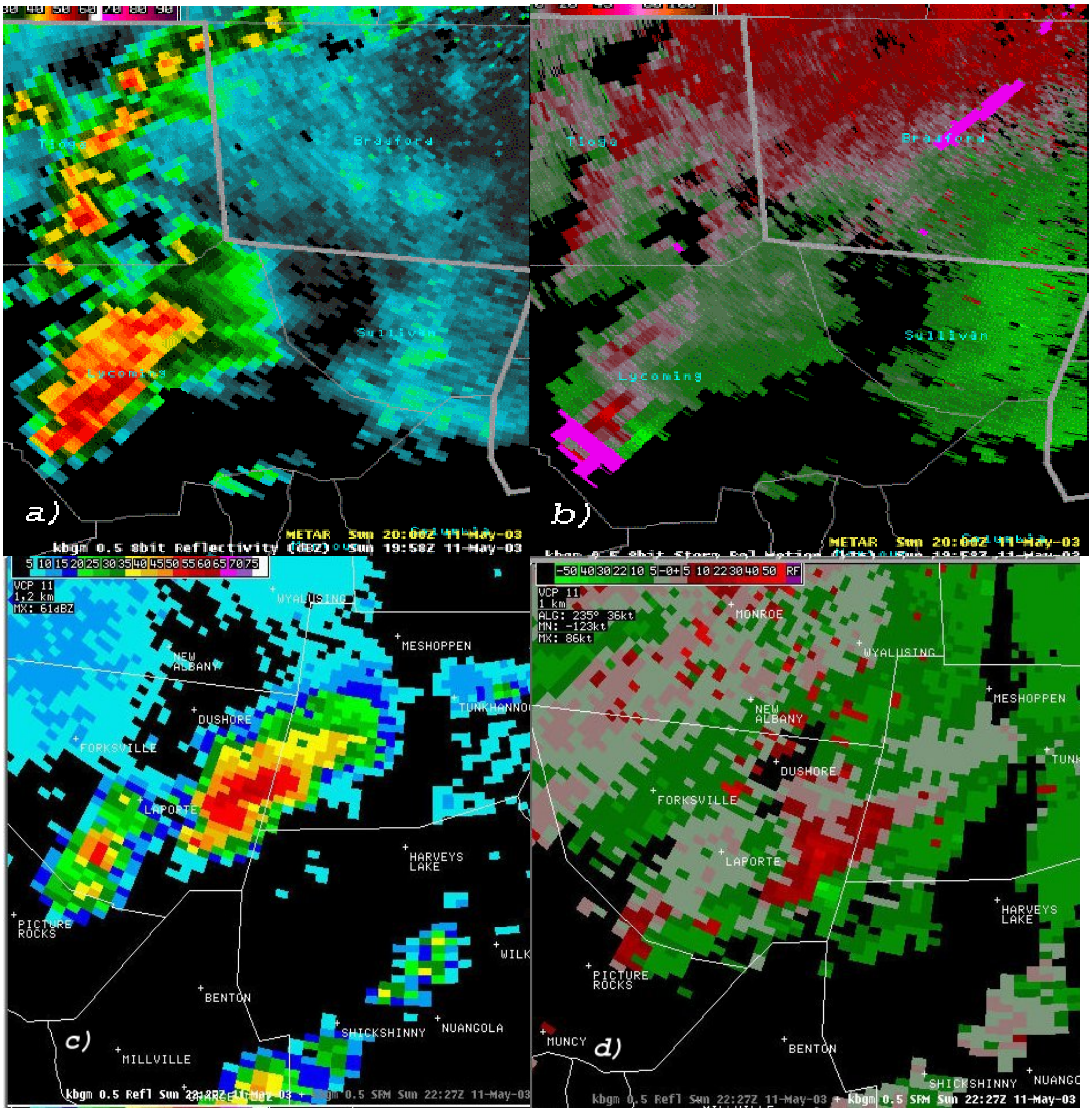

Figure 4: a) 0.5 ° Base reflectivity from the State College WSR-88D at 1958 UTC, 11 May, 2003. b) 0.5 ° Storm relative velocity (SRM) from the State College WSR-88D at 1958 UTC, 11 May, 2003. c) 0.5 ° Base reflectivity from the Binghamton WSR-88D at 2227 UTC, 11 May, 2003. d) 0.5 ° SRM from the Binghamton WSR-88D at 2227 UTC, 11 May, 2003.

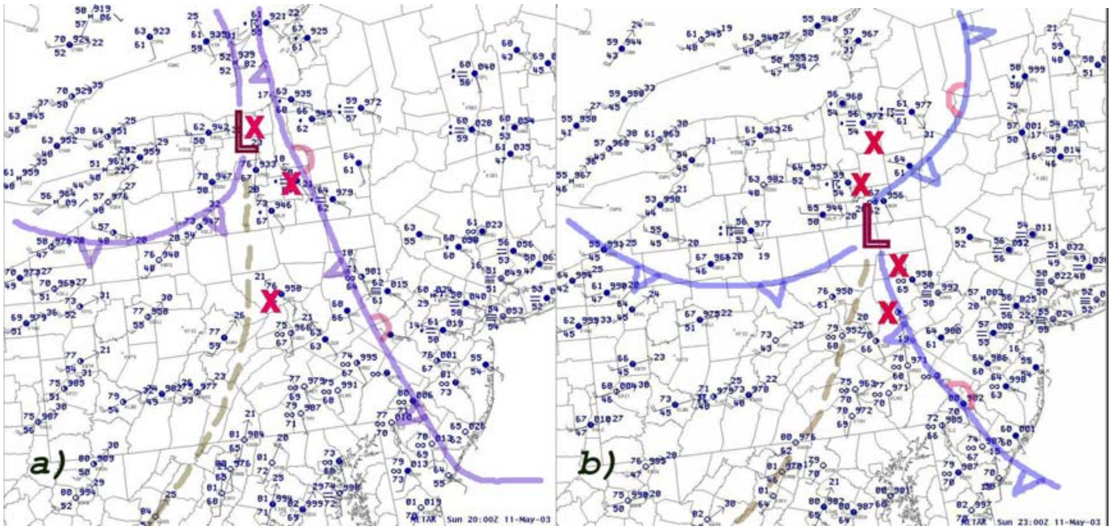

Figure 5: a) A meso-analysis across New York State and Pennsylvania at 2000 UTC, 11 May, 2003. The X's mark the location of significant thunderstorms. b) Same as part a, except at 2300 UTC, 11 May, 2003.