Eastern United State Severe Weather Outbreak of 28 April 2002
Pennsylvania Perspective

by
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1. Introduction

A large area of the United States, from Missouri to Maryland experienced severe weather from late Saturday, 27 April into the evening hours on Sunday 28 April 2002. The severe weather included lines of rotating supercell thunderstorms, hail storms, bow echoes, and tornadic supercell thunderstorms. Tragically, several tornadoes of F3 to F5 intensity resulted in fatalities in Missouri, Kentucky, and Maryland. This was likely the largest severe weather outbreak over the eastern United States since the 3-4 April 1974 super outbreak. The preliminary Storm Prediction Centers (SPC) plot of severe weather for 28 April is shown in Figure 1.

in Maryland was on 2 June 1998 near Frostburg.

In Pennsylvania, severe weather arrived in the afternoon hours and rapidly moved from west to east across the state. A relatively solid line developed. This line contained a mix of fast moving bow echoes and rotating supercell thunderstorms. As of 29 April, only one confirmed F1tornado was known to have occurred in central Pennsylvania.

There were numerous reports of large hail and damaging straight line winds. Supercells and bow echoes are both capable of producing microbursts and much of the concentrated F1 damage was likely the result of wet microburts.

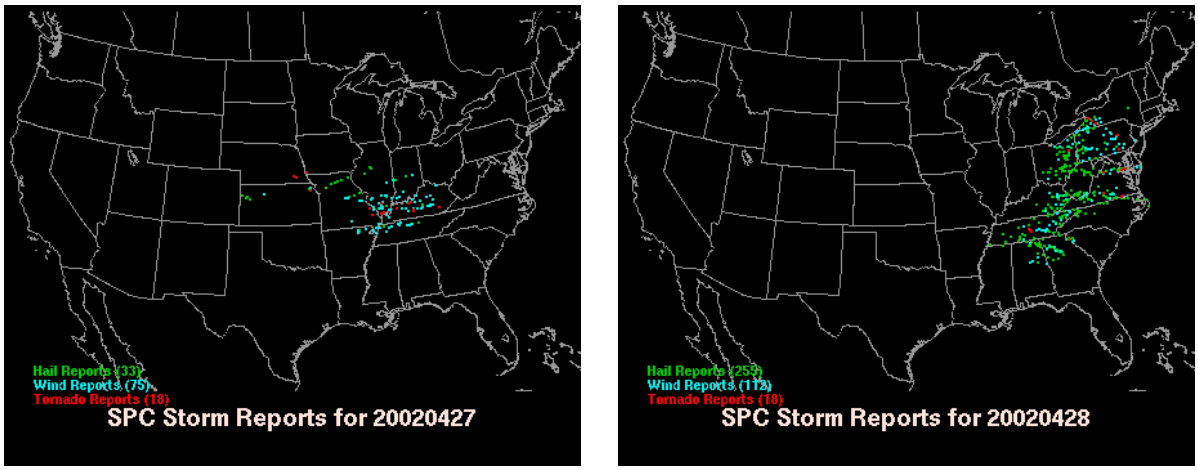

Figure 1. Storm Prediction Center (SPC) plots of severe weather over the eastern United States on a) 27 April and b) 28 April 2002.

The F5 tornado, near La Plata, Maryland, may have been the strongest tornado since 09 November, 1926 when an F5 tornado struck not too far from La Plata which may have resulted in 14 fatalities. The last reported F4 tornado

This paper will examine the forecasts of this event and examine the radar echoes associated with some of the more severe thunderstorms in centeral Pennsylvania.

2. Method

All data were collected and archived in real-time. The Weather Event Simulator (WES) was used to play back the radar, satellite and other observational data. Model imagery was archived locally and displayed using GrADS.

The WES case will be used to train forecasters who did not work the event to build operational experience.

In addition to the WES data sets, some raw archive II radar data was available for this case. At this time, none of that data is shown here.

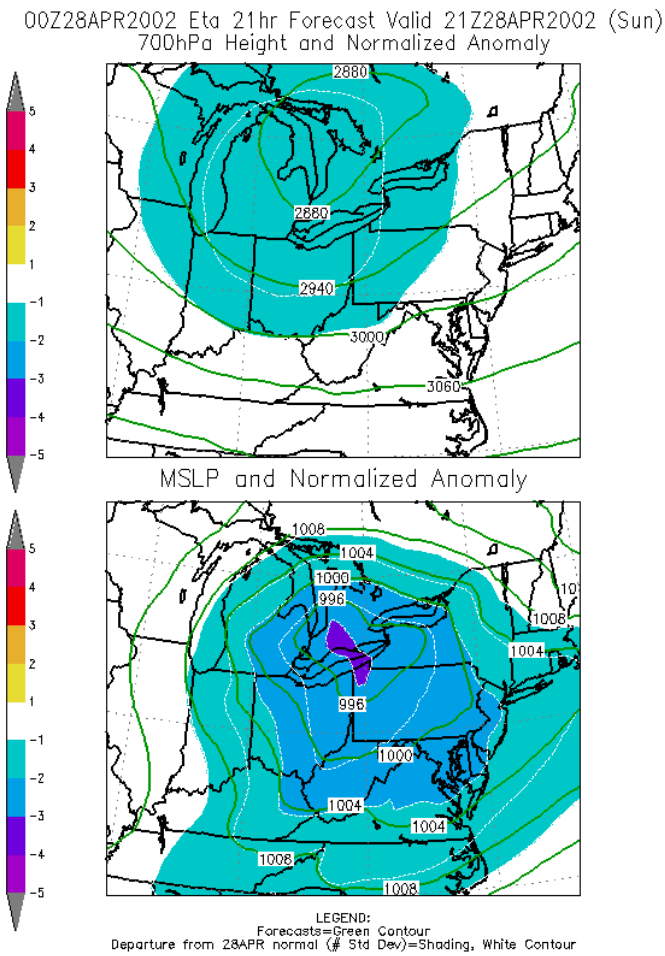

Figure 2 Eta forecast initialized at 0000 UTC 28 April valid at 2100 UTC 28 April 2002. Upper panel shows 700 hPa heights (m) and anomalies (Standard deviations from normal) and lower panel MSLP (hPa).

3. Overview

A deep surface cyclone was forecast to and did move toward the Great Lakes on Sunday afternoon. The Eta forecast of this system is shown in Figure 2. This flow configuration allowed for low-level southwesterly winds to move over the region as more west to west northwest winds were forecast aloft.

The Eta 850 hPa winds (U and V components) and departures from Climatology are shown in Figure 3.

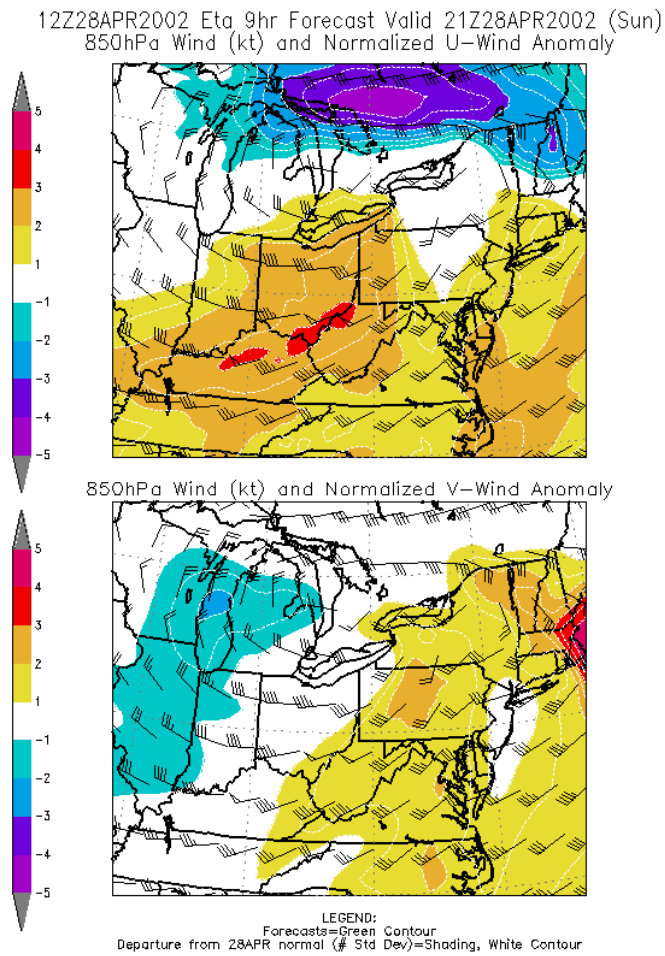

Figure 3. As in Figure 2 except forecasts of 850 hPa winds (U and V) and departures from normal.

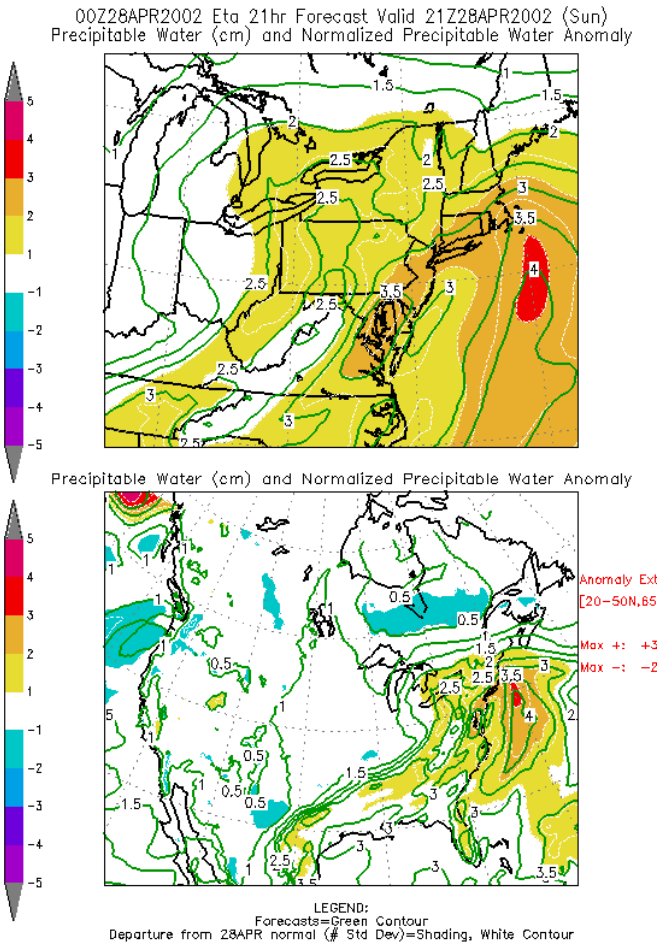

Figure 4. As in Figure 2 except Eta forecasts of precipitable water (cm). Upper panel is zoomed into the eastern United States.

These data show that the Eta forecast anomalous southwesterly winds over the region. The low-level southwesterly jet was forecast to be around +3 Standard deviations above normal In addition to the anomalous southwesterly low-level flow, the Eta forecast a surge of warm moist air ahead of the surface cold front. The precipitable water (PW) anomalies showed this secondary surge of moisture up the Ohio Valley and along the western slopes of the Appalachian Mountains. The larger area of high moisture ahead of the front over southern New England and New York was associated with the larger scale heavy rainfall event that preceded the severe weather event by 6-12 hours.

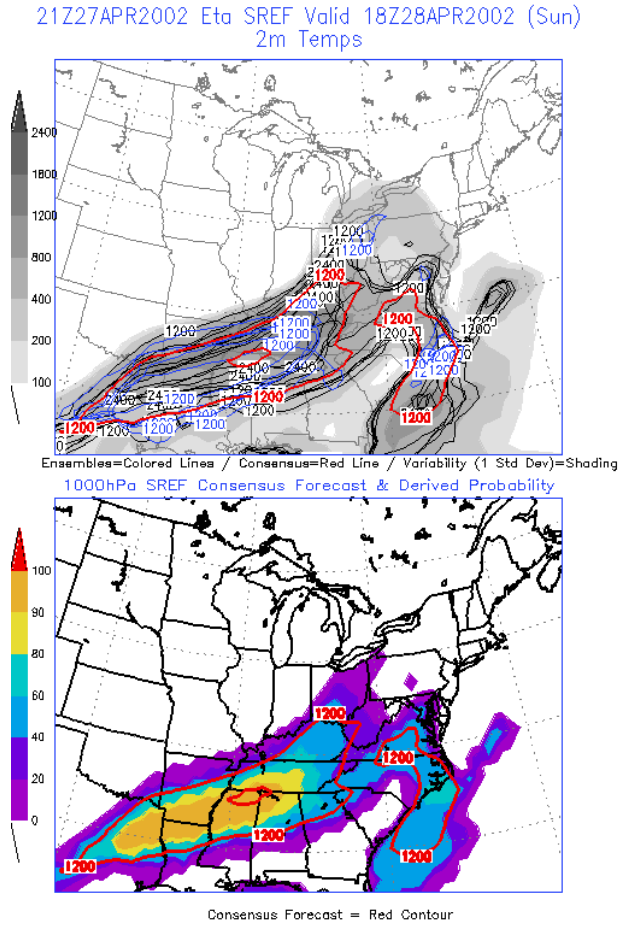

Figure 5 NCEP SREF forecasts of CAPE (Jkg^{-1}). Upper panel shows spaghetti plots and dispersion about the mean. Eta members are black and RSM members are red. Lower panel shows the probability of the CAPE greater than or equal to 1200 Jkg^{-1} and the position of the consensus 1200 and 2400 contours.

The Aviation model, though of coarser resolution, showed similar forecasts and are not shown. NCEP's numerical weather prediction models did an excellent job forecasting the intrusion of dry warm air into the eastern United States after the larger scale rain event. Then, the models did an excellent job forecasting the surge of warm moist air and the low-level southwesterly jet just ahead of the approaching cold front.

In addition to the skill of the NCEP models, the NCEP SREF's did an excellent job with this system. For example, the SREF's forecast the surge of high instability ahead of the surface

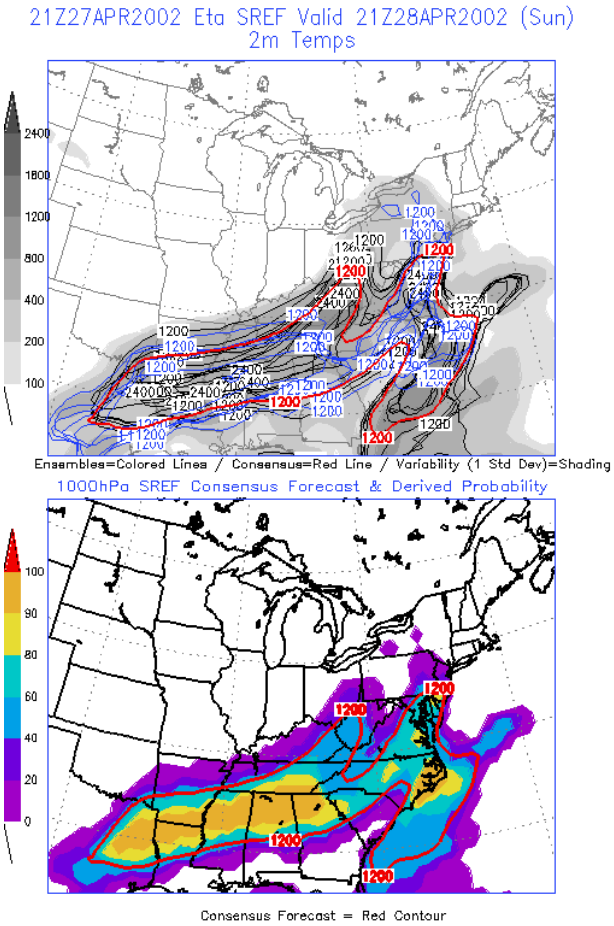

Figure 6. As in Figure 5 except valid at 2100 UTC.

cold front as shown in Figures 5 and 6. The upper panel shows the Convectively available potential energy (CAPE) from each SREF member and the dispersion (Jkg^{-1}) of these forecasts about the mean. The black contours are from Eta members and the red contours are from the RSM members. The lower panel shows the probability of the CAPE equal to our exceeding 1200 Jkg^{-1} with contours of the consensus 1200 Jkg^{-1} and 2400 Jkg^{-1} from all members. These forecasts show that the SREF members were in good agreement in bringing unstable air up the Ohio Valley and along the western slopes of the Appalachian mountains.

The SREF CAPE forecasts valid at 2100 UTC are shown in Figure 6. These data showed the continued surge of instability into the eastern United States. The strongest maximum was forecast to be from southern New Jersey southwestward across Maryland and Virginia at this time. The secondary

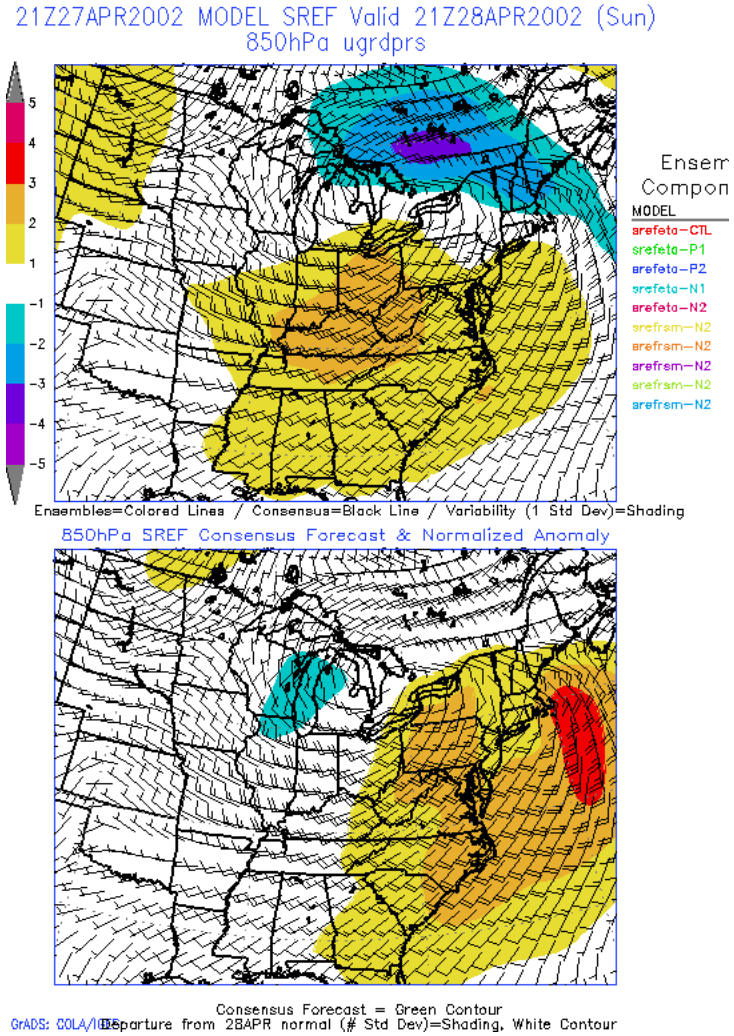

Figure 7. As in Figure 3, except for SREF 850 hPa winds and anomalies valid at 2100 UTC 28 April.

maximum axis was forecast along the western slopes of the Appalachian mountains at this time.

The SFEF 850 hPa wind forecasts, similar to the Eta, showed an

anomalous low-level southwesterly jet over the region.

The combination of low-level instability, the strong southwesterly jet, and the strong jet aloft (not shown) provided ideal conditions for the development of organized convection. In the eastern United States, east of the Appalachian mountains, the southwesterly flow is an important ingredient to get rotating supercell thunderstorms and tornadoes. Easterly winds at low-levels often allow relatively cool and stable Atlantic air into the region reducing the chances of tornadic supercells. On this day, the strong southwesterly winds likely contributed to the ability of the atmosphere to produce persistent mesocyclones and long-lived supercell thunderstorms.

4. Radar Images

Radar showed a series of storms that developed along a general north-south oriented line that extended from southwestern New York to West Virginia. This line then moved rapidly eastward across Pennsylvania producing a wide range of severe weather, including hail, damaging straight-line winds, and several F0/F1 tornadoes.

A severe thunderstorm crossed Huntingdon County between 2025 and 2100 UTC. This storm produced large hail, and uprooted trees as it crossed the County. The reflectivity associated with this storm is shown in Fig. 8.

A line of thunderstorms moved across Centre and Clinton Counties between

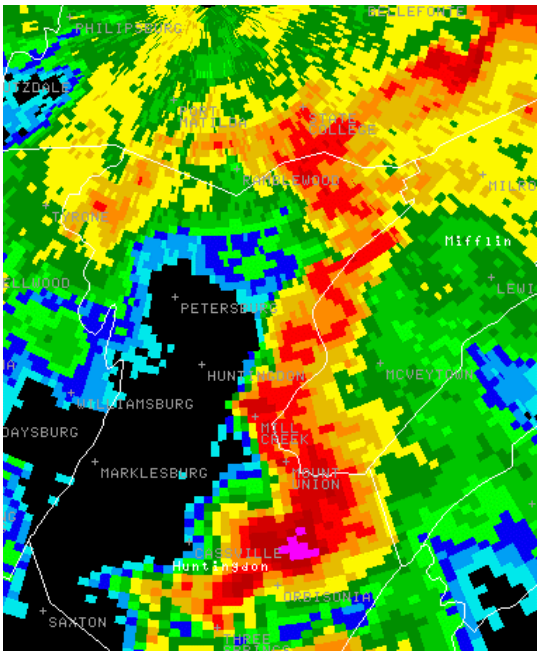

Figure 8. KCCX reflectivity at 2357 UTC over Huntingdon County supercell.

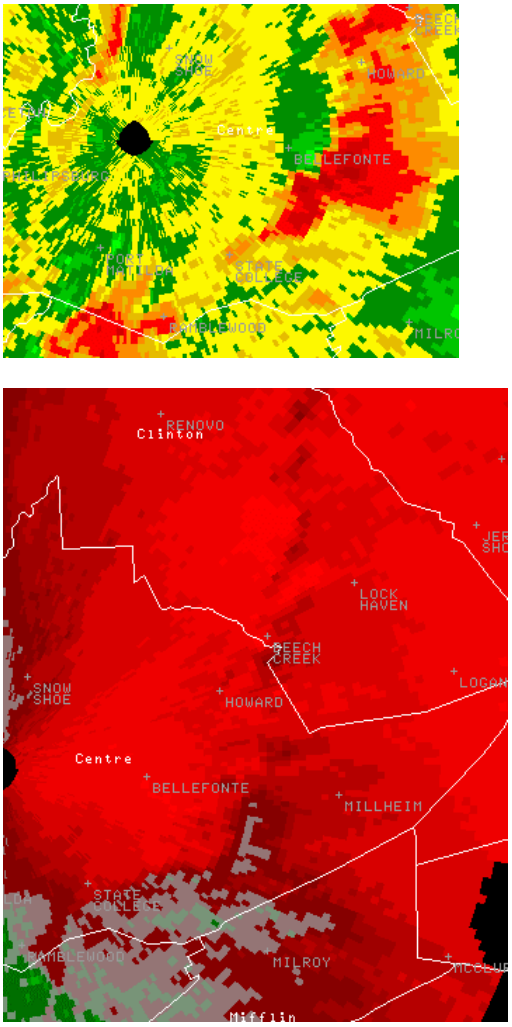

Figure 9. 2107 UTC data showing Top: reflectivity over Centre County. Below, base velocity over Centre and Clinton Counties

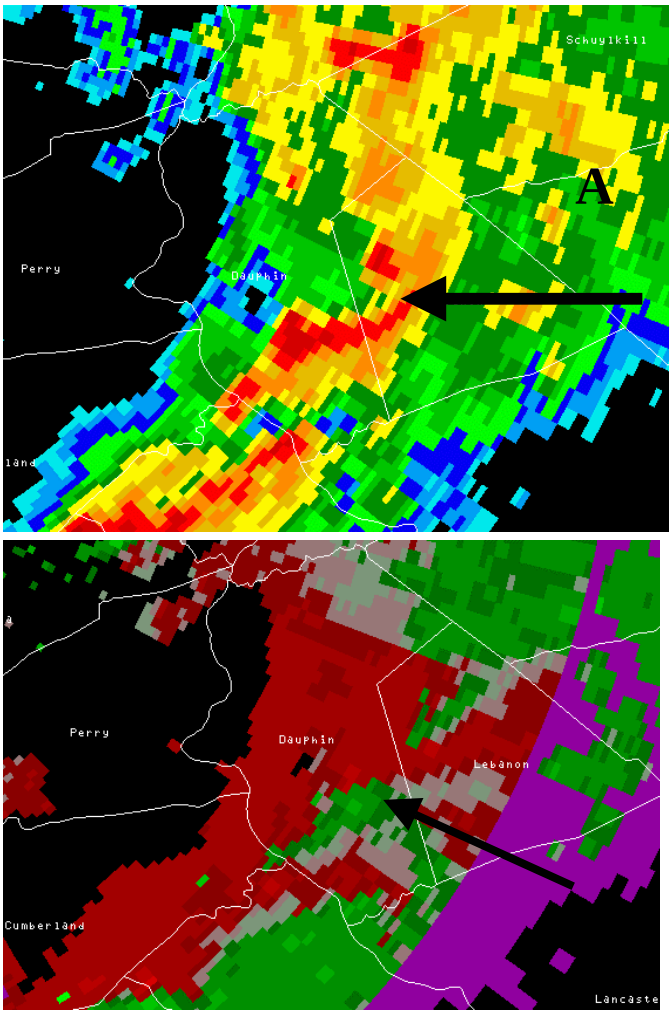

Figure 10. Reflectivity and SRM valid at 2207 UTC showing the structure of the thunderstorm which produced a tornado in Lebanon County. The A denotes initial thunderstorm and the arrows refer to points noted in the text.

2010 and 2115 UTC. The reflectivity of storms (over Centre County) the base velocity is shown in Fig. 9. The only clue of a severe thunderstorm over Clinton County was that the red (outbounds) in the base velocity product were in excess of 64 KTS. The southern storm, in Centre County, produced a wet microburst across the street from the University Park airport and downed trees and power lines west of the airport along Fillmore road.

The tornado in Lebanon County appeared to be associated with a bow-echo like storm. This storm most likely intersected the low-level boundary laid out by convection ahead of the main line. It appeared that a weaker thunderstorm moved southwest to northeast across Lebanon County about

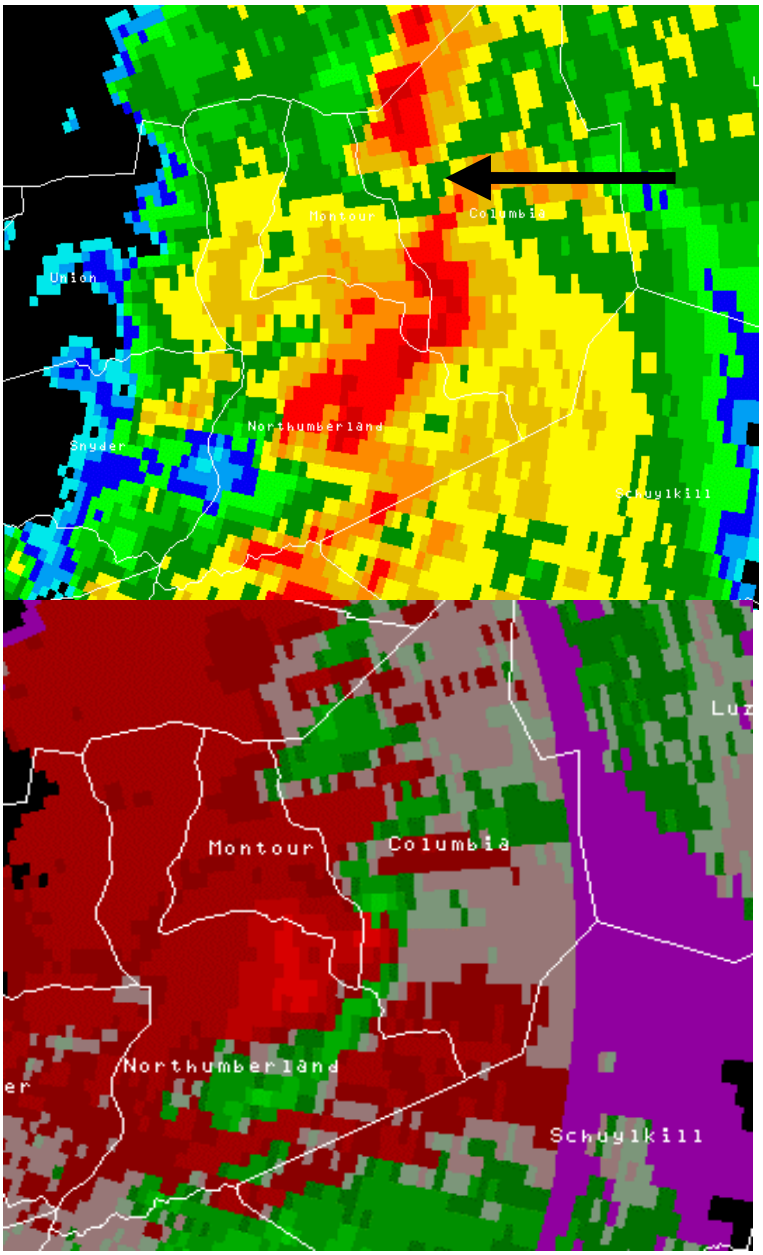

Figure 11. Reflectivity and SRM at UTC of the Columbia county storms. The arrow points to the notch which is close to the area of the tornado.

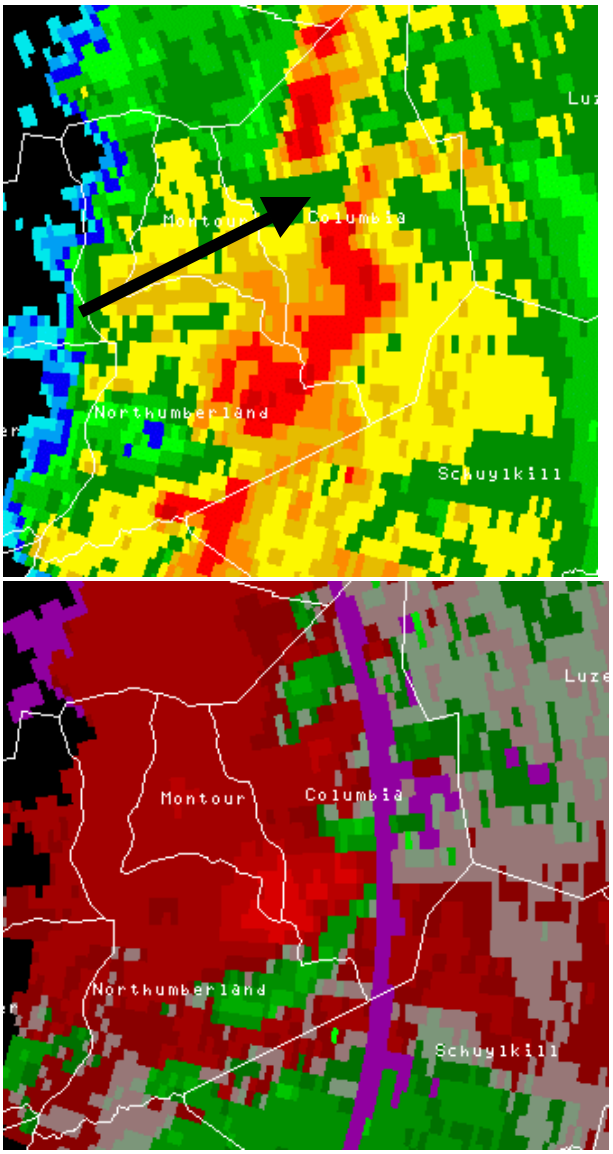

Figure 12. As in Fig 11 except at 2202 UTC.

10-15 minutes before the bow echo entered the County. The remains of the earlier storm are near point A in the upper panel of Figure 10. The arrow points to the notch in the line. In the SRM data (lower panel) the arrow points to the stronger, non-tornadic, anticyclonic circulation over Dauphin County. One might speculate the that the outbounds that punched through the line over central Lebanan County may have been able to tilt the vortex tubes left behind by the earlier convection resulting in the tornado.

The Columbia County storm appeared to form on the north end of a bookend vortex (Figs 11 and 12). There was no discernible convection ahead of this system, therefore there was not clear reason to see how this storm could tap a good source of low-level vortex tubes to generate a tornado.

It did appear that the interaction with the upstream terrain caused a difference in speed between the northern and southern cells along the line (not shown). This resulted in a split in the reflectivity between the main line and the northern part of the line (see the arrows in Figs. 11 and 12). From a radar perspective, reflectivity and SRM data, the southern part of the storm looked more impressive than the tornadic northern cell. However, the rear flank downdraft of the northern cell was clearly punching through the line, right in the area of the weakness. The same thing is happening to the southern part of Columbia County, and it did not result in a tornado.

5. Conclusions

The thunderstorms that developed over the eastern United States on 28 April produced a wide range of severe weather including large hail, damaging straight line winds and deadly tornadoes. These storms developed in a narrow line ahead of a strong surface cold front. Ahead of this front, there was a surge of anomalously strong low-level southwesterly winds, high PW, and high CAPE. The shear and instability associated with the front helped dictate the mode of convection, which favored rotating supercell storms.

As with many known large scale severe weather events over the Mid-Atlantic regions, this event had an anomalous surface cyclone tracking toward the Great Lakes and northeast, the low-level southwesterly winds (critical to keep stable Atlantic air to the east), and more westerly winds aloft. The shear from the surface to 500 hPa was on the order of 40 KTS from the west.

Over Pennsylvania, the storms appeared to develop along a line. The line appeared to be comprised of bow echoes, however these bow echoes may have been the result of the influence of both the terrain and the interaction of the outflow of numerous mini-supercellular thunderstorms. Fortunately, no storms in Pennsylvania reached the intensity or severity of the La Plata, Maryland storm (Fig. 13). This long track storm had a hook or pendant echo along its track across a large portion of Virginia and Maryland. It is not clear what caused the velocity inbound/outbound couplet in the generally cloud free area southwest of the hook echo.

It appeared that most of the severe weather was associated with distinct echoes. Furthermore, higher probability low-level boundaries ahead of the line in Lebanon County may have facilitated tornadogenesis. Quite possibly, the weak thunderstorm that moved across the county 10 minutes prior to the line may have increased the chances of a tornado.

The Columbia County tornado occurred in the distinct fracture in the line. A feature often associated with a strong descending rear flank downdraft.

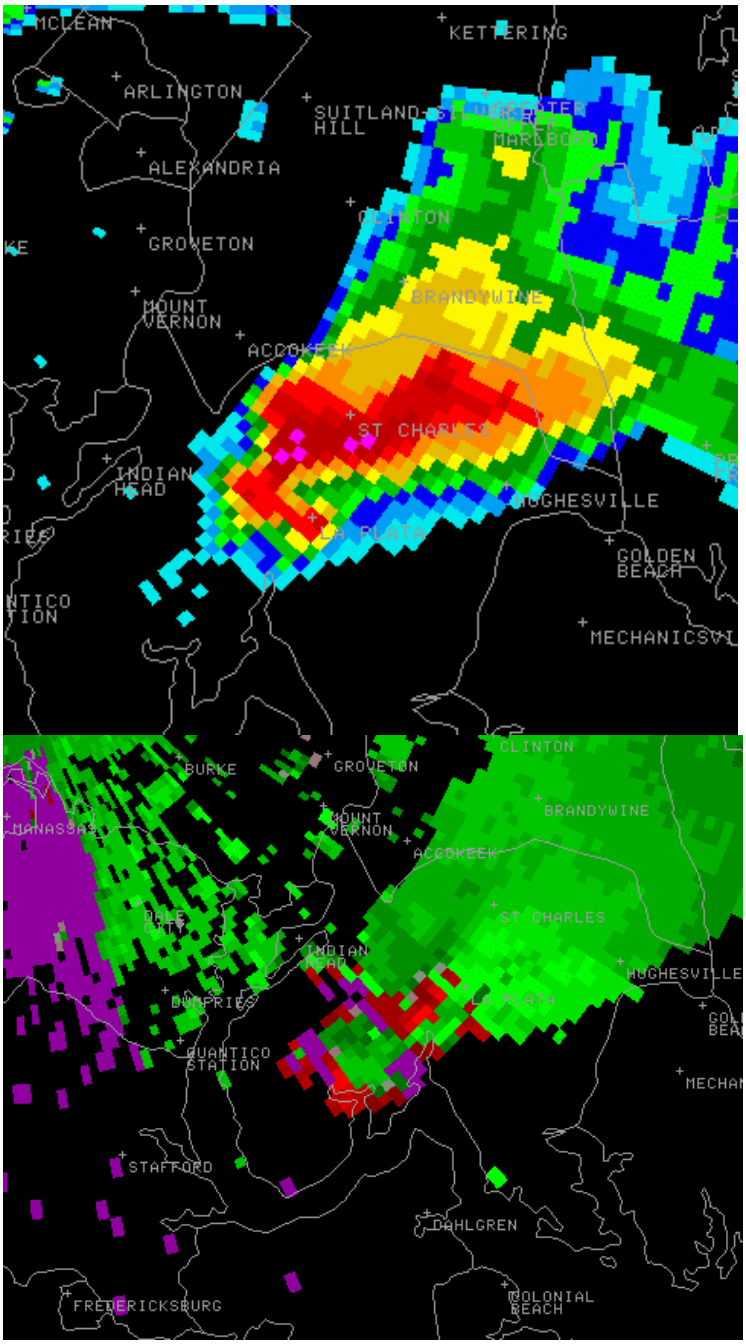

Figure 13. Reflectivity and SRM data from KLWX radar around 2357 UTC 28 April 2002.

NWUS51 KCTP 290313
LSRCTP
PRELIMINARY LOCAL STORM REPORT
NATIONAL WEATHER SERVICE STATE COLLEGE, PA
1111 PM EST SUN APR 28 2002

TIME(EDT)	.....CITY LOCATION..... ....COUNTY LOCATION....	STATE	...EVENT/REMARKS...
229 PM 04/28/02	CLARENDON WARREN	PA	.75 INCH HAIL
340 PM 04/28/02	WARREN WARREN	PA	WIND DAMAGE TREES DOWN IN WARREN AND GLADE TOWNSHIP.
325 PM 04/28/02	DUKE CENTER MCKEAN	PA	1.75 INCH HAIL
335 PM 04/28/02	ELDRED MCKEAN	PA	1.00 INCH HAIL
407 PM 04/28/02	WESTMONT CAMBRIA	PA	WIND DAMAGE TREES AND WIRES DOWN.
432 PM 04/28/02	BEEGLETOWN BEDFORD	PA	WIND DAMAGE SEVERAL TELEPHONE POLES AND WIRES DOWN.
435 PM 04/28/02	CARROLTOWN CAMBRIA	PA	WIND DAMAGE STRUCTURAL DAMAGE TO BUILDING.
445 PM 04/28/02	STATE COLLEGE CENTRE	PA	1.00 INCH HAIL REPORTED AT NITTANY MALL.
448 PM 04/28/02	STATE COLLEGE CENTRE	PA	2.75 INCH HAIL AT UNIVERSITY PARK AIRPORT.
450 PM 04/28/02	3S WELLSBORO TIOGA	PA	WIND DAMAGE MOBLE HOME FLIPPED AND ROLLED OVER SEVERAL TIMES.
455 PM 04/28/02	MEYERSDALE SOMERSET	PA	.75 INCH HAIL
500 PM 04/28/02	ORBISONIA HUNTINGDON	PA	1.00 INCH HAIL
500 PM 04/28/02	RENOVO CLINTON	PA	WIND DAMAGE 70 TREES DOWN.
515 PM 04/28/02	CAMPBELL LYCOMING	PA	WIND DAMAGE TREES DOWN.
520 PM 04/28/02	LEWISTOWN MIFFLIN	PA	WIND DAMAGE TREES DOWN.
540 PM 04/28/02	WILLIAMSPORT LYCOMING	PA	WIND DAMAGE NUMEROUS TREES DOWN.
540 PM 04/28/02	MONTGOMERY LYCOMING	PA	WIND DAMAGE ROOF OFF BUILDING.
540 PM 04/28/02	2E MIFFLINBURG UNION	PA	WIND DAMAGE TREES DOWN.
547 PM 04/28/02	KRATZERVILLE SNYDER	PA	WIND DAMAGE TREES DOWN ON WIRES AND ROADS.
551 PM 04/28/02	SUNBURY NORTHUMBERLAND	PA	WIND DAMAGE TREES AND WIRES DOWN.
600 PM 04/28/02	1N BLOOMSBURG COLUMBIA	PA	TORNADO PUBLIC REPORT.