# P4.2 MESOSCALE ANALYSIS OF THE CAVENDISH, VT BOW-ECHO TORNADO ON 21 JULY 2003

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## 1. INTRODUCTION

The occurrence of tornadic producing thunderstorms across Vermont and northern New England is not a common occurrence. Storm Data from the National Climatic Data Center indicates that 37 tornadoes have been reported in Vermont since 1950 and only 3 in the last 10 years. It is possible that the tornado frequency is higher since the population density within Vermont is relatively low and therefore many events may not be verified. Storm data also shows that most events occurred in southern Vermont with many of the tornadoes rated F0-F1. The development and evolution of tornadic producing thunderstorms across this region is not well understood due to the limited number of studies of such events.

Additionally, radar detection of these events is extremely difficult given the mountainous terrain and positioning of radars across the area. This makes the warning decision making process very difficult and leads to very low probability of detection (POD) and below average lead times when compared to the national averages. From 1986 to July 2004, the average northen New England (national) lead time, POD, and false alarm rate was 6.2 (8.8) minutes, 0.44 (0.55), and 0.76 (0.76), respectively for tornadic events.

On 21 July 2003 a squall line with an embedded bow echo produced a series of tornadoes from eastern New York into southern Vermont. This study will examine WSR-88D radar data, mesoscale surface analysis, and upper air data to better understand the mesoscale environment associated with this type of tornadic evolution in northern New England.

## 2. MESOSCALE ENVIRONMENT

The upper-level pattern on 21 July 2003 featured a strong mid- and upper- level trough across the central Great Lakes with an embedded convectively induced vorticity maximum approaching northern New England by 0000 UTC. This well-defined mesoscale convective vortex (MCV) was produced by a decaying mesoscale convective system (MCS) that moved across the Central Plains the previous evening. A line of severe thunderstorms developed across western New York and Pennsylvania and tracked into southern Vermont by 0300 UTC on 22 July.

A detailed surface analysis at 0000 UTC on 22 July shows surface low pressure near Syracuse, New York, with an east-west orientated boundary extending from southern Vermont into eastern New York (Fig. 1). This trough line was enhanced by outflow from earlier convection that moved across the region. In addition, a pre-frontal trough was analyzed extending from low pressure near Syracuse southeastward into northeast Pennsylvania. The air mass ahead of this boundary featured temperatures in the 70s with surface dew points well into the 60s advecting into the Hudson and Connecticut River valleys. Also, noted was a distinct wind shift associated with the east-west boundary across southern Vermont and eastern New York with surface observations showing easterly flow north of the boundary and southeast winds south of the boundary with some temperature and dew point discontinuity. These boundaries helped to enhance the low-level shear across the region.

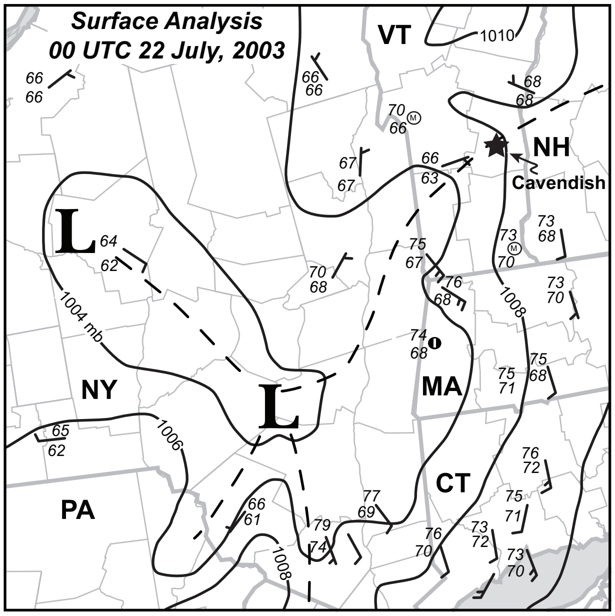

*Figure 1. Surface analysis at 00 UTC on 22 July, 2003. Surface temperature and dewpoints are shown in degrees F. The location of Cavendish, VT (star) is also shown.*

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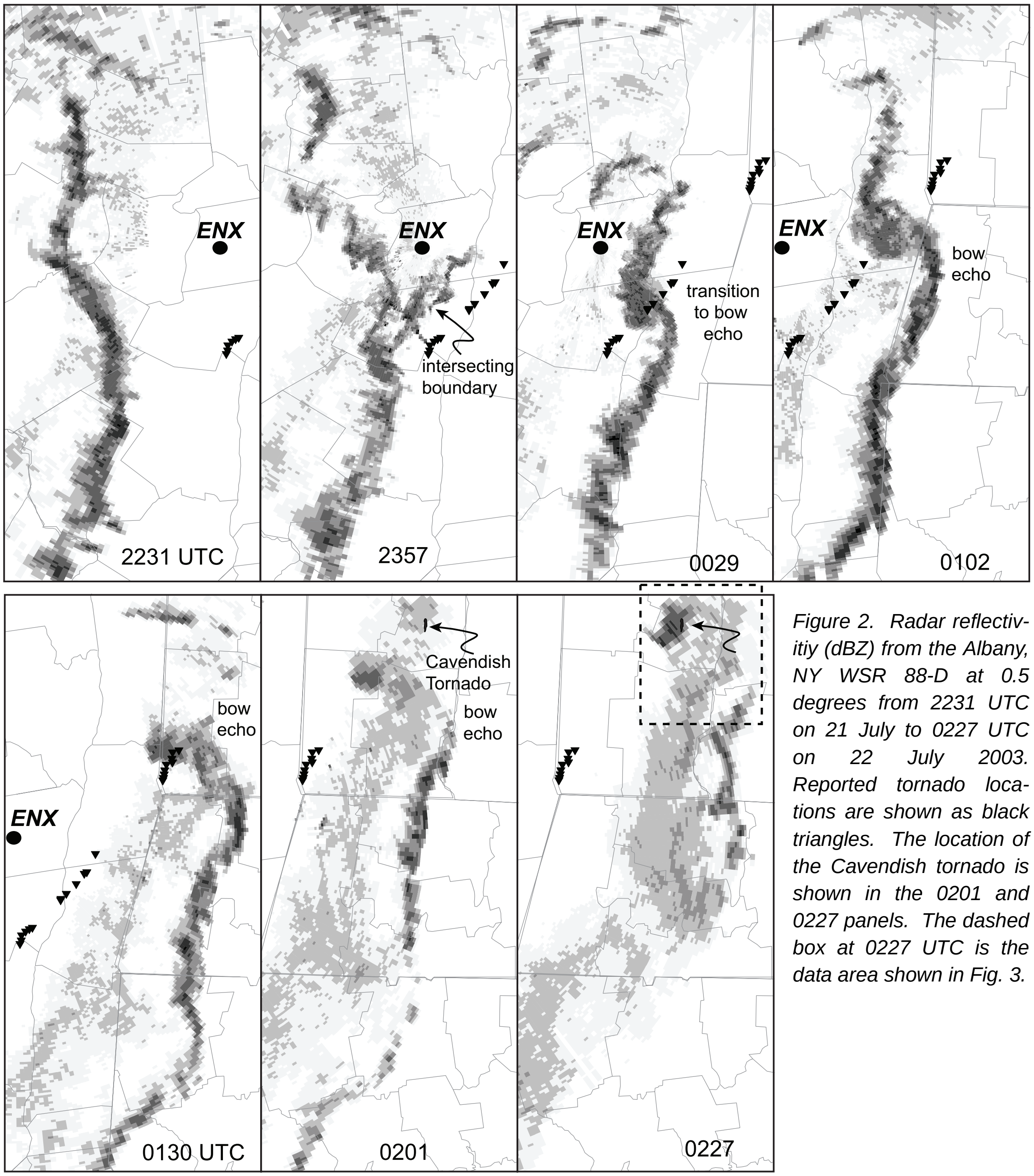

*Figure 2. Radar reflectivitiy (dBZ) from the Albany, NY WSR 88-D at 0.5 degrees from 2231 UTC on 21 July to 0227 UTC on 22 July 2003. Reported tornado locations are shown as black triangles. The location of the Cavendish tornado is shown in the 0201 and 0227 panels. The dashed box at 0227 UTC is the data area shown in Fig. 3.*

The 0000 UTC Albany, New York sounding (not shown) on 22 July 2003 indicated a very unstable layer aloft with elevated Convective Available Potential Energy (CAPE) values of 2700 Jkg$^{-1}$ and minimal amounts of Convective Inhibition (CIN). In addition, a strong southerly low-level jet of 50 knots at 850 hPa helped to produce helicity values near 300 m$^2$s$^{-2}$.

## 3. RADAR ANALYSIS

Figure 2 shows a time series of reflectivity images from the Albany radar (KENX) as the MCS tracked across eastern New York into southern Vermont. An important feature in Fig. 2 is the intersecting boundary that is visible at 2357 UTC. Near the intersection point, a bow echo with prominent rotating comma head structure formed after 2351 UTC within the convective system and subsequently moved in to southwestern Vermont. Tornado damage was reported from eastern New York into

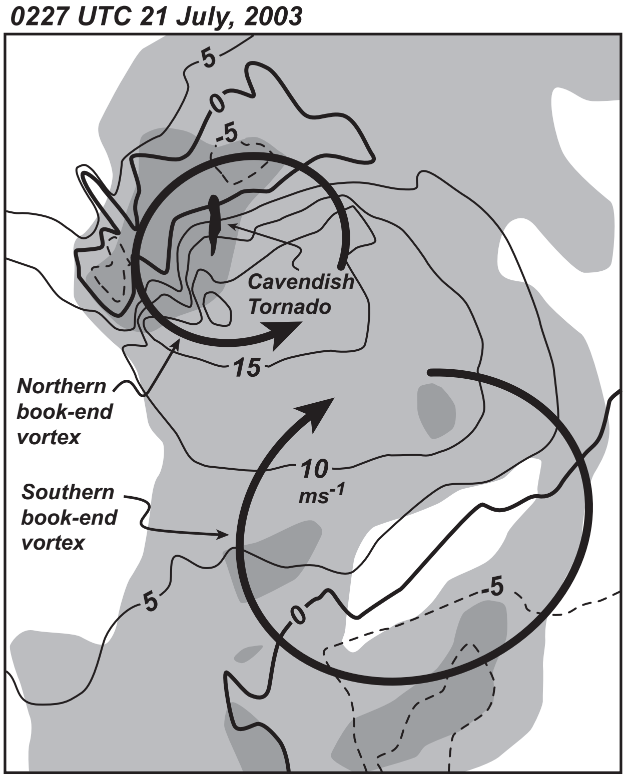
0227 UTC 21 July, 2003

*Figure 3. Radar reflectivity (gray) and storm-relative radial velocities (black solid and dashed contours indicate flow away and toward the radar, respectively) from the Albany, NY 88-D at 0227 UTC on 22 July, 2003. The location of the cavendish tornado damage track is also plotted in black.*

southern Vermont and appeared to be produced in association with the northern bookend vortex produced by this bow echo. Bow echoes are often observed to form at the intersection point of a convective system and preexisting boundary (Klimowski et al. 2000).

The bow echo and associated comma-head echo continued to propagate northeastward along the low level thermal boundary and produced several tornadoes from just south of Albany at 2330 UTC to Cavendish, Vermont around 0230 UTC. The location of the Cavendish tornado track is shown in the last two panels in Fig. 2.

A more detailed view of storm structure at the time that the Cavendish tornado was on the ground is shown in Fig. 3. Evident are the northern cyclonic and southern anticyclonic bookend vortices. Clearly, the Cavendish tornado formed in close association with the northern bookend vortex. While most bow echo tornadoes tend to form at or north of the bow echo apex, previous studies have shown that they sometimes form within the northern book-end vortex circulation (e.g., Pfost and Gerard 1997). The bow echo reflectivity structure is not well-defined, however, the bow echo was approximately 140 km from the ENX radar over mountainous terrain at the time in Fig. 3.

The KCXX radar located in Burlington, Vermont provided marginal radar coverage of this bow echo. This was a result of beam blockage from the Green Mountains and the large distance to the storm. This makes the warning decision making process across southern Vermont extremely challenging for forecasters at WFO Burlington.

## 4. DAMAGE ANALYSIS OF THE CAVENDISH TORNADO

The tornadic bow echo produced significant damage as it tracked from eastern New York into Burlington's county warning area near Cavendish. A detailed ground and aerial survey of the Cavendish tornado revealed extensive tree damage with some structural damage to several homesteads (Fig. 4). From the surveys it was concluded the tornado touched down just southwest of Cavendish and traveled northward for approximately 3.5 miles. The damage survey clearly showed cyclonic circulation to the tree debris field (Fig. 4a), with several trees splintered into many pieces. The F2 damage areas were characterized by all trees snapped or blown over.

## 5. CONCLUSIONS

There are limited studies on the convective modes that produce tornadoes across northern New England. The event presented herein is, however, consistent with previous observational studies over the Central and High Plains that have shown the intersection point of a primary convective system and a preexisting boundary is a preferred location for tornadogenesis (Przybylinski et al. 2000) and that the cells at the intersection point can evolve into a bow echo structure (Klimowski et al. 2000). Furthermore, radar and damage survey data suggest that the F2 Cavendish tornado formed within the northern book-end vortex associated with a bow echo.

Due to the mountainous terrain and radar locations, the best radar coverage of the Cavendish event was from the Albany radar, even when the tornadic storm was in the BTV CWA. The distances from the radars to the bow echo were about 140 km away when the bow echo was producing tornadic damage. Notably, the Albany radar had much less beam blockage due to the Green Mountains, which extend up to 1.2 km across southern Vermont. Moreover, storm motion was parallel (perpendicular) to the KENX (KCXX) radial viewing angle.

The pre-storm environment indicated an east west orientated boundary, that the tornadic bow echo

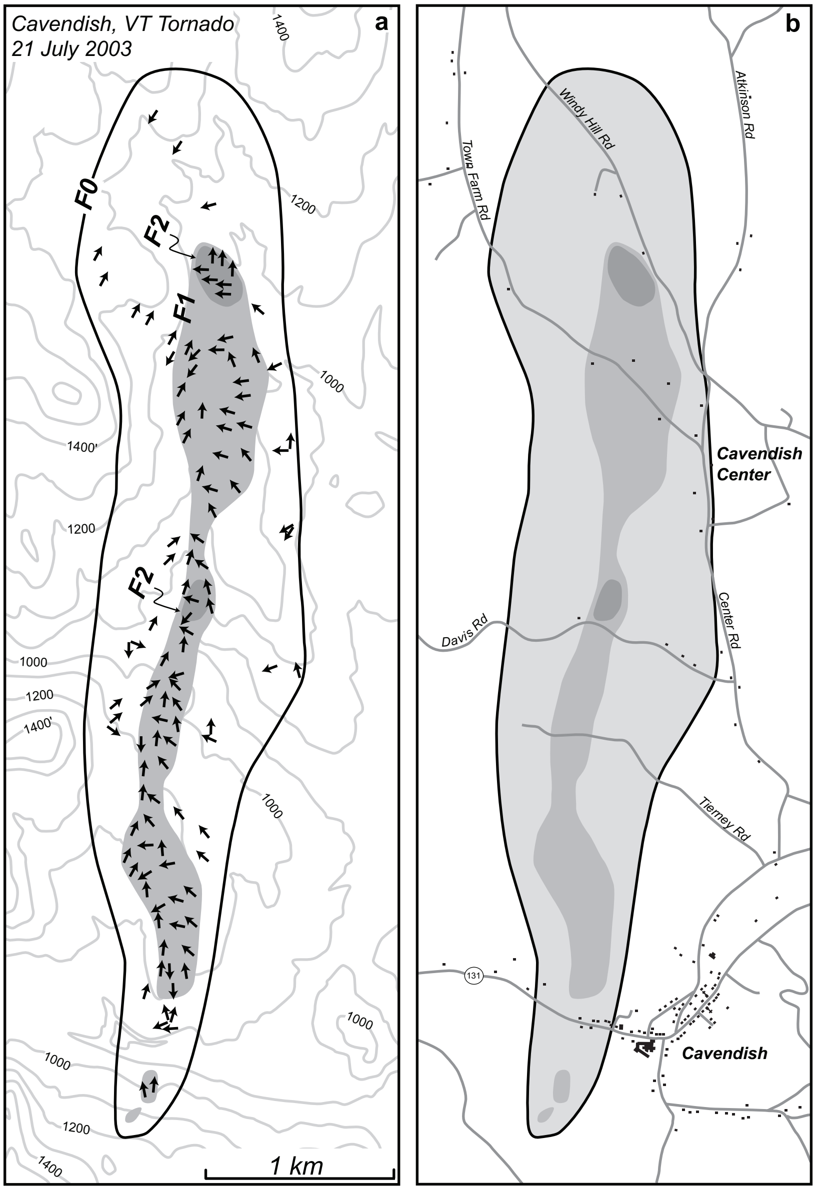

*Figure 4. Damage survey analysis of the Cavendish tornado. (a) Damage vectors are shown in black while terrain is contoured in gray. The F0 damage contoured is shown in black while F1 and F2 are shaded in gray. (b) F-scale analysis is shown in gray with roads (gray) and building locations shown in black.*

traveled along. The identification of these low-level boundaries and storm intersection points is extremely important in helping forecasters better detect the occurrence of tornadic storms across northern New England. This will increase lead time and probability of detection (POD) in the warning decision making process across the BTV CWA, where issuing tornado warnings is not a common occurrence.

*Acknowledgements:* The research results presented herein were supported by the National Science Foundation under Grant ATM-0233178.

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