19.5 THE WRENTHAM TORNADO OF 2004:

Evolution of a Tornadic HP Supercell from a Pronounced Splitting Bow Echo in the WFO Taunton, MA County Warning Area

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1. INTRODUCTION

A squall line, forced by an approaching cold front, developed across eastern New York State during the afternoon of 21August 2004. The squall line moved slowly eastward across the Taunton, Massachusetts County Warning Area (CWA) during the mid to late afternoon, producing severe weather in the form of straight line wind damage across the Interstate 84 and Interstate 95 corridors, and a F1 Tornado in Wrentham, MA. This tornado had a track length of 6 miles (NCDC, 2004). This paper will present the radar evolution of this event and will examine how modest changes in the near-storm environment, enhanced by a pronounced split in the squall line, lead to tornadic development.

2. MESOSCALE ENVIRONMENT

The North American Regional Reanalysis (NARR) (Mesinger et. al. 2006) shows a cold front was approaching western New England at 12 UTC 21 August 2004. Ahead of this boundary across southern New England, a tropical air mass was in place with surface dew points of 72 to 74°F (22 to 23°C) (Fig. 1). In addition, southern New England was positioned in the right entrance region of a 115 kt jet maxima at 200 mb (Fig. 2).

By early afternoon, surface temperatures had climbed into the lower 80s and southwest flow at the surface had increased to 15 to 20 kts in advance of the cold front. The combination of ample low level moisture, upper level divergence and increase surface instability, placed southeastern New England in an increasingly favorable environment for severe convection. The Storm Prediction Center (SPC) placed the region in a Severe Thunderstorm Watch at 1734 UTC.

By 1800 UTC a line of thunderstorms had developed in advance of the cold front in western New England. Ahead of this line, surface based Lifted Indices (LI) ranged from – 4 to -7. Point soundings from the Local Analysis and Prediction System (LAPS) (Albers et al. 1996) indicated an increasingly favorable moisture, shear and buoyancy profile was becoming established across eastern New England in the lowest kilometer. At 19 UTC, a well defined axis of high dew points (73-75°F/23-24°C) was positioned just northeast of the bow echo complex (Fig. 3). Based on a point sounding at 1900 UTC in the vicinity of Wrentham, MA, (Fig. 4), the CAPE had exceeded 1000 J/kg and the helicity (0-3km) was above 150 m^2/s^2, much of this focused in the lowest 1 KM. In addition, in response to the increased low level moisture, Lifted Condensation Levels (LCL) of between 250 m and 350 m above ground level (AGL) were now in place. Rasmussen and Blanchard (1998) suggested that tornadic storms tend to be associated with environments with low LCLs, generally 800 meters or less.

3. RADAR DIAGNOSIS

The developing squall line approached Rhode Island and central Massachusetts at 1900 UTC. Within this line, a “seahorse” shaped bow echo evolved across northeast Connecticut and was entering northwest Rhode Island at 1915 UTC (Fig. 5). Several notches of reflectivity minima on the back edge of this bow echo as well as base velocity data as noted in Fig 5 indicated the presence of a Rear Inflow Jet (RIF). The magnitude of this RIJ was about 50 kts, at an elevation of 1800 ft AGL and 60 kts at an elevation of 5500 ft near the Connecticut/Rhode Island border (not shown). While no severe weather was apparently associated with this feature, it should be noted

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that this region of western Rhode Island is quite rural and it is conceivable that some tree damage may have occurred.

The RIJ completely pierces the bow echo at approximately 1928 UTC (not shown), producing a noticeable split in the line of convection. Commensurate with this split, a new mesocyclone develops (Fig. 6) in northern Rhode Island by 1936 UTC. There is also a pronounced tightening of the reflectivity gradient and a sharpening of its north-south orientation near the Massachusetts/Rhode Island border at this time.

This new mesocyclone experiences upscale growth similar to that documented in Trapp and Weisman (2003). By 1945 UTC (Fig. 7), the complex of convection north of the line split had begun to transverse the axis of high dew points and had taken on a “Kidney-bean” shape, common to HP Supercells (Moller, Doswell III, and Przybylinski, 1990). Note also at this time, the development of a curved appendage on the south end of this complex. At 0.9 degrees, storm relative velocities indicated a mesocyclone with 24 kts of rotation and a diameter of 1.7 nm. By 1949 UTC (not shown) this mesocyclone constricts to 0.8 nm and the rotation velocity increases to 28 kts. Based on spotter reports, it is believe that tornado damage commenced between 1945 UTC and 1949 UTC.

At 1953 UTC, a well defined hook echo appears in the 0.5 elevation reflectivity. The 0.5 elevation storm relative velocity data indicates a user defined mesocyclone with 28.5 kts of rotation and a 0.7 nm diameter at an elevation of 542 ft (AGL) (Fig. 8) and a maximum gate-to-gate shear of 54 kts.

Just as quickly as it formed, the HP Supercell weakens significantly by 1959 UTC and evolves into a comma shaped bow echo by 2028 UTC as the system accelerates off to the northeast (not shown).

4. SUMMARY

WFO Taunton experienced its first tornado of summer 2004 during the afternoon of 21 August 2004. This was a weak and brief tornado associated with a HP Supercell, which resulted from the splitting of an earlier seahorse-shaped bow echo complex. Despite the user defined mesocyclone being classified as a minimal mesocyclone, this low level cyclonic rotation was positioned just 542 ft AGL, and had a history of producing straight line wind damage earlier in Woonsocket RI.

A significant feature of this case is that, while the user defined mesocyclone strength and gate-to-gate shears are on the low end of the tornado threshold, its presence in a tropical environment with low LCLs, based at least as low as 1000 ft AGL dramatically increases the likelihood of this circulation realizing itself as a tornado.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

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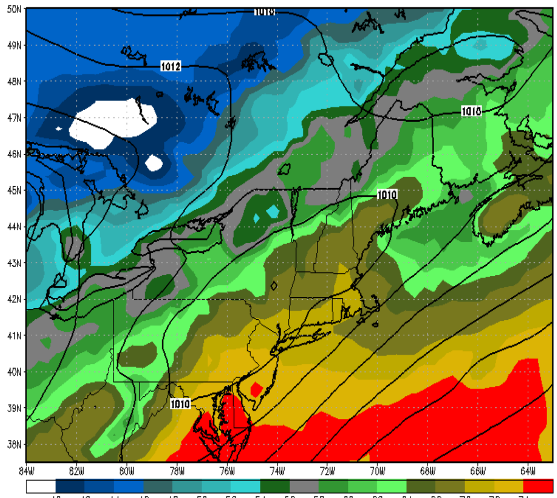

Figure 1. Reanalysis of mean sea level pressure (contoured, mb) and surface dew points (shaded,°F), from the NARR, 1200 UTC, 21 August 2004. Axis of high dew points extends across much of southeastern New England, with the surface front positioned across eastern New York State.

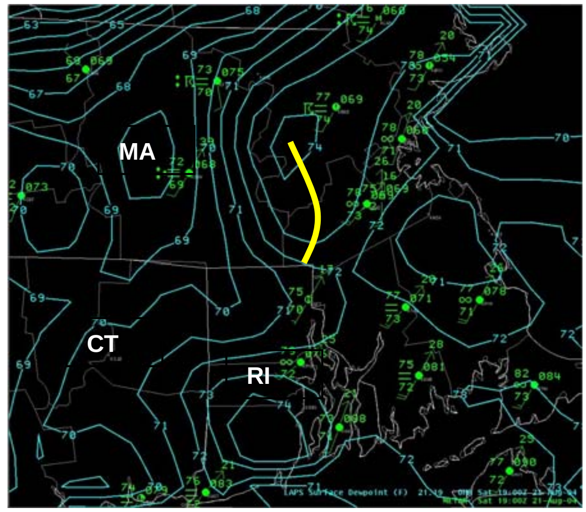

Figure 3. Station observations and LAPS surface dew point analysis (contoured, °F) Valid 1900 UTC 21 August 2004. Note the region of high dew points located from extreme northeast Rhode Island into east central Massachusetts as denoted by the solid yellow line.

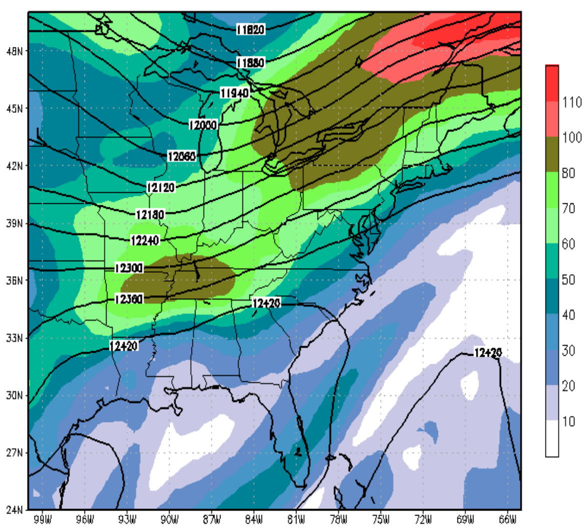

Figure 2. Reanalysis of 200 mb heights (contoured, m) and wind speeds (shaded, kts) from the NARR, 1200 UTC, 21 August 2004. Note the 110-115 kt jet maxima positioned across southern Quebec, placing much of New England in the favorable right entrance region.

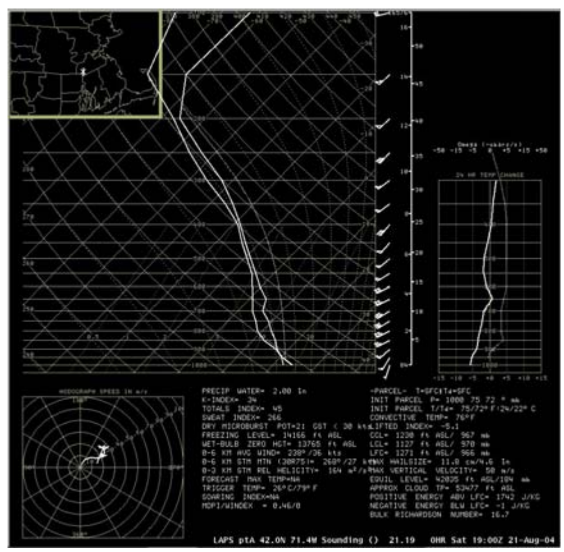

Figure 4. LAPS sounding near Wrentham, MA at 1900 UTC, 21 August 2004. Note the CAPE analyzed at 1742 J/kg, and a low LCL at 1127 ft (339 m), as well as the pronounced curvature in the wind field in the lowest 1 km and a storm relative helicity of 164 m^2/s^2

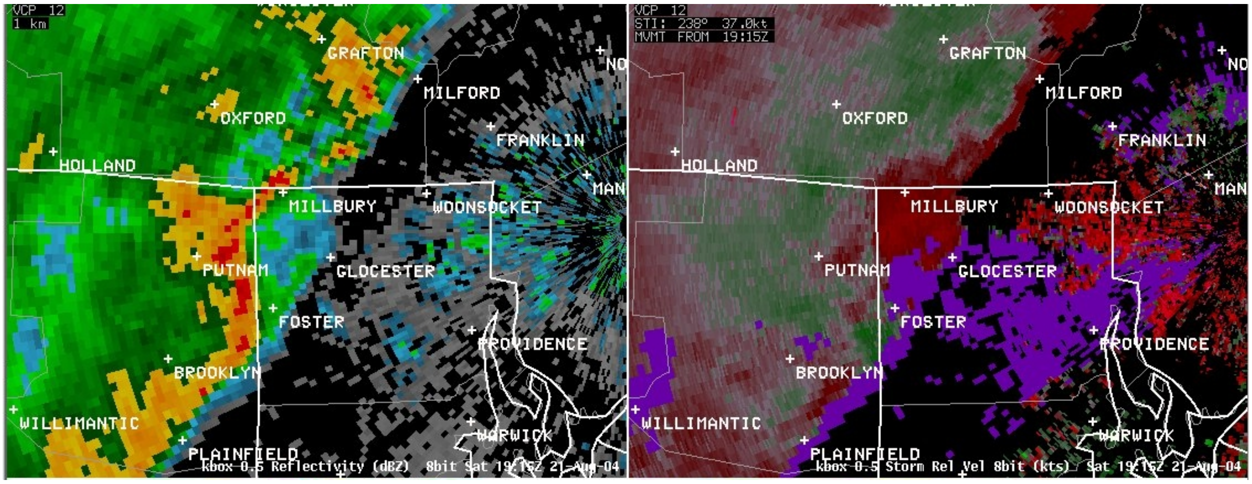

Figure 5. Left panel is base reflectivity at 0.5 degrees and right panel is base velocity at 0.5 degrees both valid at 1915 UTC, 21 August 2004. Note the “seahorse-shaped” bow echo on the Connecticut-Rhode Island border and the presence of several weak echo “notches” on the western flank approach Foster. Note the high velocity region (45-55 kts) just south of Foster, at an elevation of 1800 ft AGL.

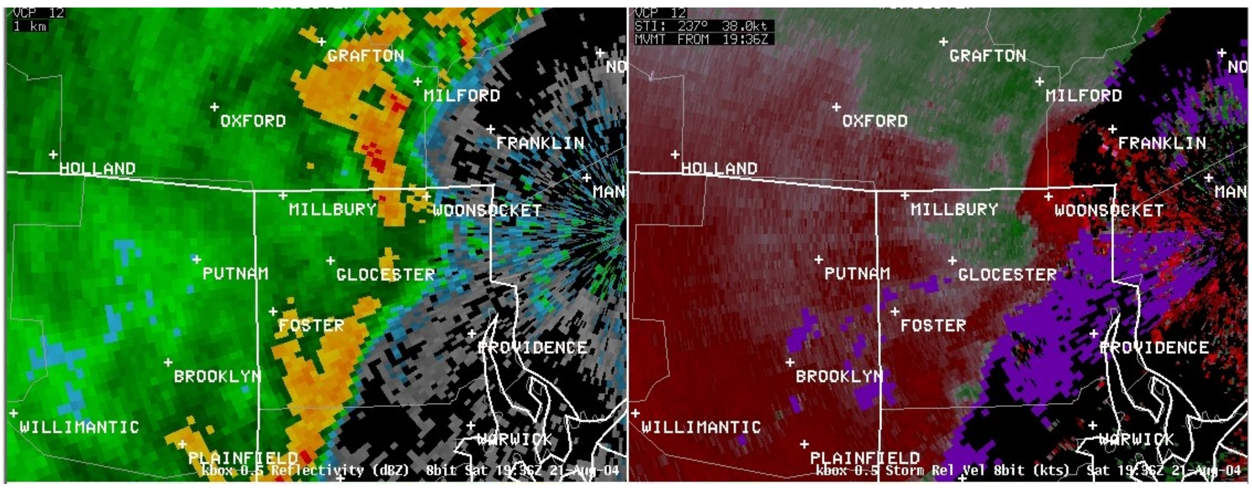

Figure 6. Left panel is base reflectivity at 0.5 degrees and right panel is storm relative velocity at 0.5 degrees both valid at 1936 UTC, 21 August 2004. The bow echo has been split in two. A new small mesocyclone has developed on the southern flank of the northern half of the split near North Smithfield.

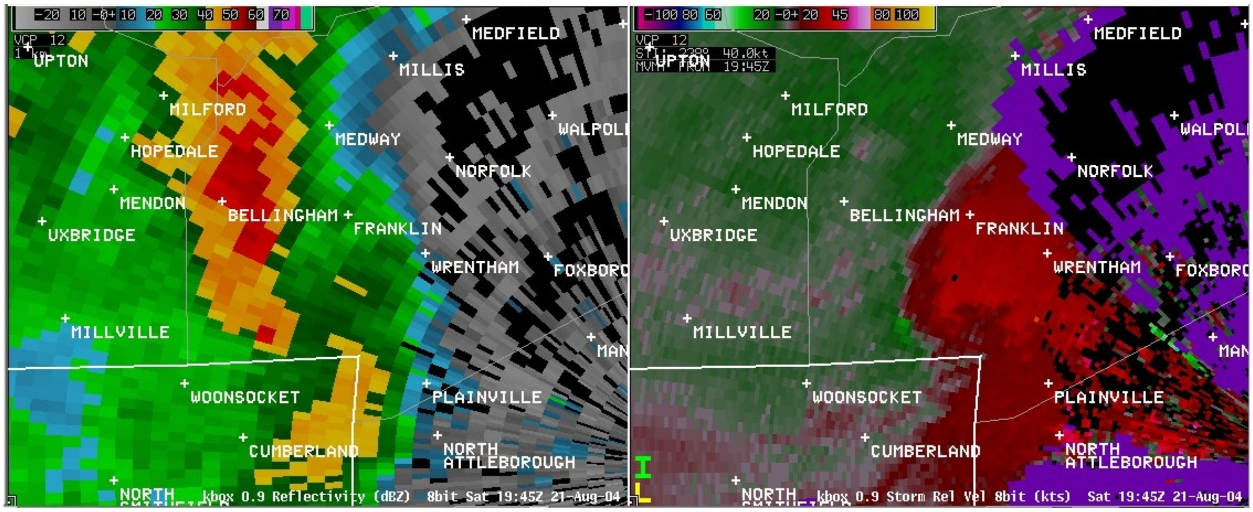

Figure 7. Left panel is base reflectivity at 0.9 degrees and right panel is storm relative velocity at 0.9 degrees both valid at 1945 UTC, 21 August 2004. The complex begins to take on a HP Supercell form as the mesocyclone continues to grow upward as it approaches Wrentham, MA.

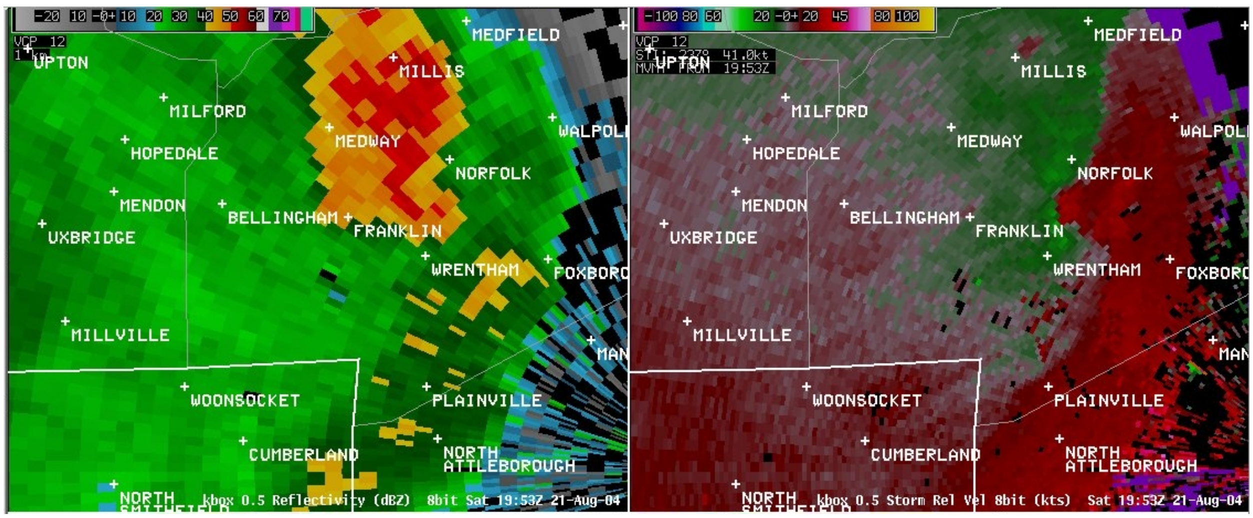

Figure 8. Left panel is base reflectivity at 0.5 degrees and right panel is storm relative velocity at 0.5 degrees both valid at 1953 UTC, 21 August 2004. Note the hook echo just north of Wrentham. The storm was at its strongest point at this time, with a v/r shear at 0.5 degrees of 27 kts.