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A WSR-88D INVESTIGATION OF A NON-CHARACTERISTIC SEVERE THUNDERSTORM OVER SOUTHEAST NORTH CAROLINA

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1. Introduction

A radar operator may encounter a situation in which a storm with a relatively weak radar appearance produces a significant amount of wind damage. One such case occurred during the early evening on 6 September 1999 when a broken line of strong to severe thunderstorms developed in the wake of Hurricane Dennis across western portions of the Warning Forecast Office (WFO) Wilmington North Carolina (ILM) County Warning Area (CWA). The convection began along a sub-synoptic trough during the afternoon, and interacted with outflow boundaries and a sea breeze front. Several warnings were issued during the event, particularly for the thunderstorms that depicted very high vertical integrated liquids (VIL), exhibited atypical storm motion, or attained an organized structure per base reflectivity displays.

From 0020 to 0030 UTC 7 September 1999, a comparatively much weaker thunderstorm moved over Clarkton, North Carolina in southwest Bladen County and produced a swath of wind damage with speeds in excess of 31 m s^{-1} (70 mph) (Fig. 1). This was the only thunderstorm during the event to produce damaging wind gusts; however, WFO ILM did receive several hail reports with some of the other storms. The downburst destroyed or severely damaged several barns, sheds, and dozens of trees. Unfortunately, no warning was issued for Bladen County since this thunderstorm showed little or no trend toward being severe per VIL, base reflectivity, and especially the lower base velocity scans (Fig. 2). One feature the Clarkton thunderstorm did exhibit was strong mid-altitude radial convergence (MARC), that if detected, may have helped the radar operator's warning decision.

The purpose of this paper is to investigate what radar products may have provided the radar operator with a basis to issue a warning for this thunderstorm. In particular, the performance of the Damaging Downburst Prediction and Detection Algorithm (DDPDA) will be assessed in this case study.

2. Synoptic and Mesoscale Discussion

On the morning of 6 September 1999 the remnants of Hurricane Dennis were located across south central Virginia and north central North Carolina with ample tropical moisture in place across the Carolina coastal plain. The flow aloft was generally weak, with a subtropical anticyclone located across much of the Deep South and Gulf of Mexico. A weak 500 mb trough axis extended from the

Ohio Valley into north Georgia (Fig. 3). A lobe of vorticity was expected to sweep across the Carolinas later that day as the upper trough lifted northeast. This lobe of vorticity initially helped to trigger the convection.

At the surface, a weakening cyclonic circulation, formerly Dennis, was situated in Virginia with a trough extending southward along the Appalachian Mountains northern Georgia (Fig. 4). High dewpoints in the 70° to 75° F range were prevalent across the eastern Carolinas. In addition, a sea breeze developed during the late morning hours and penetrated the interior portions of the CWA during the afternoon.

3. Sounding Data

The 1200 UTC 6 September 1999 and 0000 UTC 7 September 1999 soundings from Morehead City, North Carolina (MHX) and Charleston, South Carolina (CHS) were utilized in this case study. Although a weak low-level jet was noted in the soundings, the overall wind profile implied that only minimal shear was present since winds aloft were generally 20 knots or less.

Various convective parameters indicated moderate to strong instability, as well as the potential for strong updrafts. The surfaced based lifted index (LI) initially ranged from -4° to -7° C. The convective available potential energy (CAPE) values were already impressive at 1200 UTC reaching 1500 J kg^{-1}. Strong insolation during the day significantly enhanced these values, especially the CAPE, which reached 5000 J kg^{-1} at CHS by 0000 UTC 7 September 1999. The helicity, which ranged from -24 to 97 m^2 $s^{-2,}$ during the event was weak given the lack of shear, while mid-level lapse rates around 5 C km^{-1} were more reflective of a tropical airmass with little or no cold pooling aloft.

At 1200 UTC 6 September 1999, the precipitable water was 45 mm indicative of the tropical airmass left in the post Hurricane Dennis environment. Even with high precipitable water values, there was evidence of a dry mid-level intrusion in the 1200 UTC 6 September 1999 MHX and CHS temperature and dewpoint profiles (Figs. 5a and 5b). As a result of this dry layer, the wet-bulb potential temperature (θ_w) profiles were somewhat supportive of strong downbursts.

4. Radar Analysis

If a radar operator was to rely solely on the base reflectivity and velocity moments there would have been little if any clue given that the Clarkton storm would produce damaging winds. In fact, the 0.5° base velocity only showed inbound speeds of 5 m s^{-1} or less in the area that was impacted by 31 m s^{-1} wind gusts (Fig. 2). There may be several reasons for such a poor velocity presentation. The downburst may have been nearly orthogonal to the beam, the burst occurred between the scans, or the gust front may have been too shallow for the lowest scan to detect.

The Clarkton storm did not exhibit sustained or significant rotation other than a shallow, broad cyclonic circulation in the lowest scan. The storm also lacked severe characteristics such as a bounded weak echo region (BWER) or weak echo region (WER). The VIL of the day ranged between 62 to 65 kg m^{-2} and at its peak the Clarkton storm attained a VIL of 40 kg m^{-2}. The max reflectivity core never exceeded the wetbulb-zero (WBZ) height.

The overall reflectivity structure of this storm was particularly weak compared to other storms that developed across the ILM CWA that day. However, the Clarkton storm did feature a tight reflectivity gradient on the advancing side of the storm (Fig. 6). This reflectivity gradient coupled with a small inflow notch seen in the lower elevation base reflectivity scans suggested the presence of a somewhat strong updraft. The tight reflectivity gradient is also indicative of strong mid-level convergence. (Schmocker et al. 1996)

Eilts et al. (1996) have found that a rapidly descending reflectivity core is one of the main precursors to a damaging downburst. In this case the Layer Reflectivity Maximum (LRM) mid-level product was very useful in determining when the core of this storm began to fall. This coincided nicely with the time the damage was reported. VIL is primarily a hail detection tool. It has a minimal relationship for the detection of downbursts, but the product was useful determining the collapse of the Clarkton storm (Schmocker et al. 1996).

Even though the LRM and VIL were useful in determining when the storm began to collapse (Fig. 7), these products did not provide the radar operator with a feel for the strength of the observed surface wind gusts. However, in this case, the identification of MARC in the storm relative velocity (SRM) products would have helped the radar operator anticipate a surface wind gust, and provide sufficient lead time. Przybylinski et al. (1995) have found that velocity differentials in the mid levels of storms showed a greater lead time in the detection of downbursts compared to other products and this was the case with the Bladen storm.

5. DDPDA Results

KLTX Archive II base data was processed using WATADS version 10.2 software (WATADS 2000) with variations of the National Severe Storms Laboratory DDPDA. Since the Bladen storm met the convergence layer height criteria, the only parameter adapted for this study was the severe convergence magnitude. Schmocker et al. (1996) determined that MARC velocity differences typically exceeded 22 m s^{-1} for downbursts to produce damaging wind gusts. Additional studies imply 25 m s^{-1} as the threshold needed to produce wind damage (Przybylinski et al. 1995). The operator-defined convergence value for the Bladen storm reached 26 to 27 m s^{-1}, per SRM imagery.

The algorithm was initially run with the default severe convergence value of 25 m s^{-1}. The first run failed to detect severe convergence within the Clarkton storm. In subsequent DDPDA processing, the severe convergence thresholds were gradually lowered until the algorithm finally detected the MARC with a convergence differential of 17 m s^{-1}. This would have yielded 34 m s^{-1} convergence, and could be seen exceeding this threshold via time height plots (Fig. 8). By utilizing lower convergence values in the algorithm an increase in the false alarms should be expected. However, since the algorithm utilizes a 3 by 3 median filter to smooth the data (Smith personal communication), those MARC signatures would reduce the velocity values and escape detection, like the one exhibited by the Clarkton storm, with small maximum convergence inbound and outbound velocities. Likewise, the smoothing will limit the amount of noise, and without this process a higher amount of false alarms can be expected. This problem was encountered when the severe convergence parameter was lowered for this case study.

Previous studies have indicated a high false alarm ratio of downburst algorithms occurs during events with moderate to high shear. As a result the DDPDA was developed by NSSL for those events with strong updrafts and low shear environments (Smith et al. 2000) It is suggested that the only times the severe convergence thresholds should be lowered are during these low shear, high CAPE type of days.

6. Conclusion

A radar operator should always be aware of the storm environment, as well as anticipate changes in the environment to successfully exploit the DDPDA and other radar products. During high CAPE and low shear days, it may be feasible to lower the severe convergence detection thresholds in the DDPDA adaptable parameters in an effort to increase the chances of detecting the smaller scale severe downbursts. This will also allow the radar operator to quickly identify areas of mid-altitude convergence, then focus on those storms with strong, but atypically small severe convergence cores.

References

Eilts, M.D., E.D. Mitchell, R.J. Lynn, P. Spencer, S. Cobb, and T.M. Smith, 1996: Damaging Downburst Prediction and Detection Algorithm for the WSR-88D, *Preprints* 18th *Conf. on Severe Local Storms*, San Francisco CA, Amer. Meteor. Soc., pp. 541-545.

NOAA, NSSL, 2000: WATADS (WSR-88D Algorithm Testing and Display System) Reference Guide for Version 10.2. National Severe Storm Laboratory, Storm Scale Applications Division, Norman, OK.

Przybylinski, R.W., Y. Lin, G.K. Schmocker, and T.J. Shea, 1995: The Use of Real-Time WSR-88D, Profiler, and Conventional Data Sets in Forecasting a Northeastward Moving Derecho Over Eastern Missouri and Central Illinois, *Preprints 14th Conf. on Weather and Forecasting*, Dallas, TX, Amer. Meteor. Soc., pp. 335-341.

Schmocker, G.K., R.W. Przybylinski, and Y. Lin, 1996: Forecasting the Initial Onset of Damaging Downburst Winds Associated with a Mesoscale Convective System (MCS) Using the Mid-Altitude Radial Convergence (MARC) Signature, *Preprints 15th Conf. on Weather and Forecasting*, Norfolk, VA, Amer. Meteor. Soc., pp. 306-311.

Smith, T.M., S. A. Myers, and K. L. Elmore, 2000: An Evaluation Methodology Applied to the Damaging Downburst Prediction and Detection Algorithm, *Preprints 20th Conf. on Severe Local Storms*, Orlando, FL, Amer. Meteor. Soc., pp. 374-377.

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Figures

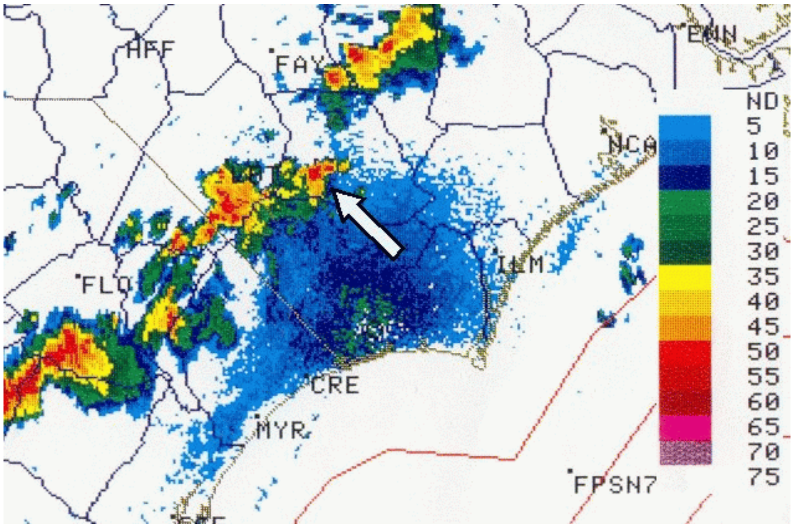

Figure 1. 0025 UTC 7 September 1999 0.5° elevation KLTX base reflectivity image. The arrow denotes the location of the Clarkton, North Carolina, thunderstorm.

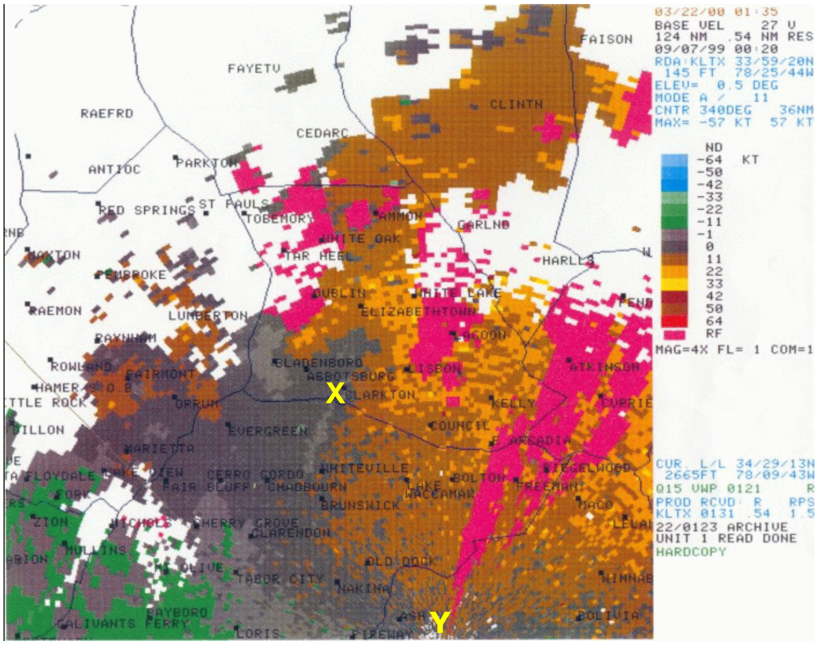

Figure 2. 0020 UTC 7 September 1999 0.5° elevation KLTX base velocity image. The image was observed in the vicinity of the "X", near Clarkton, North Carolina. KLTX radar location at position "Y". On the color scale negative = inbound, while positive = outbound.

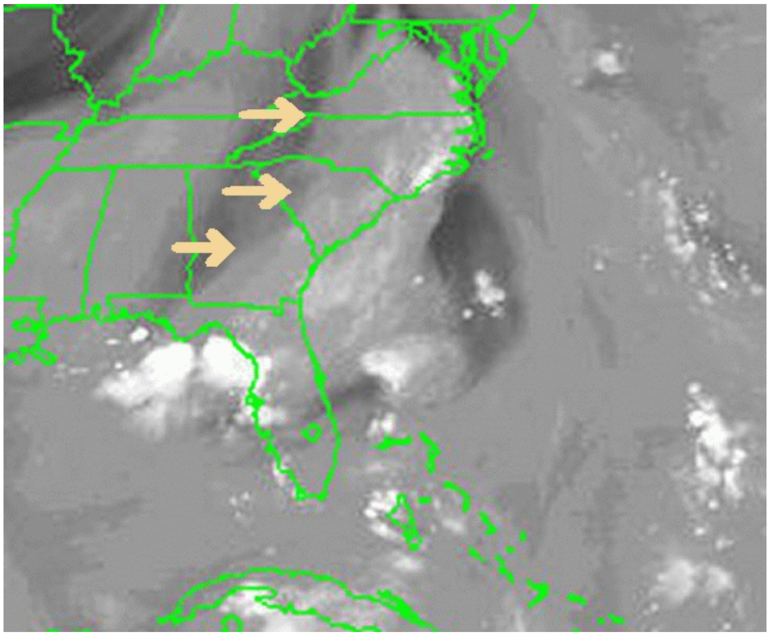

Figure 3. GOES-8 water vapor imagery 1800 UTC 6 September 1999. The arrows denote the upper trough axis that was moving in a northeast direction.

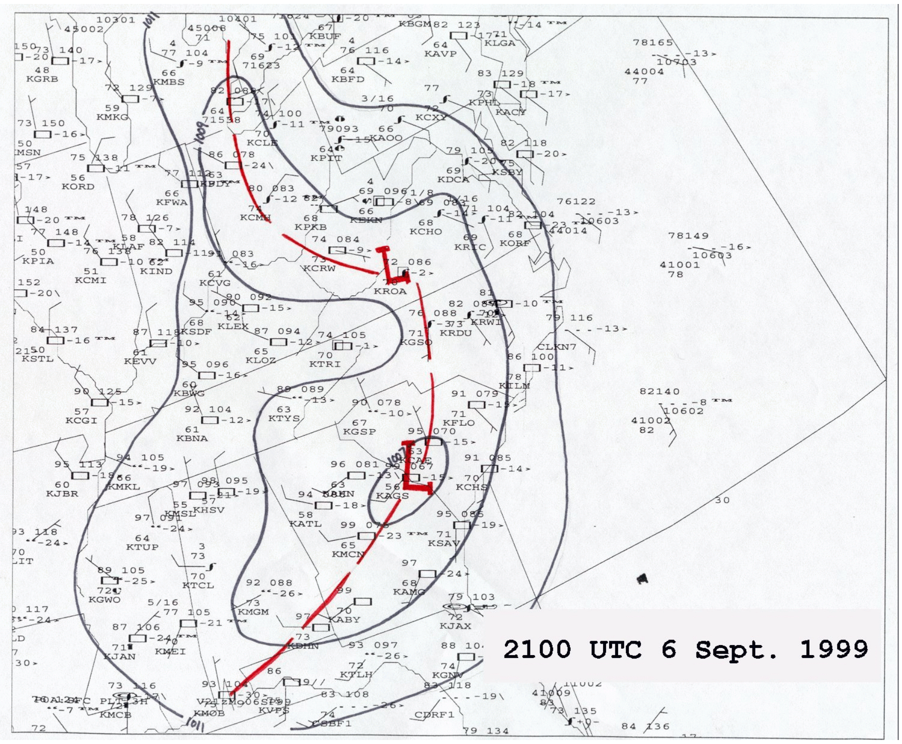

Figure 4. Regional surface analysis for the Carolinas 2100 UTC 6 September 1999 shows the remnants of Hurricane Dennis across Virginia. A pressure trough axis extended south from Virginia into Georgia.

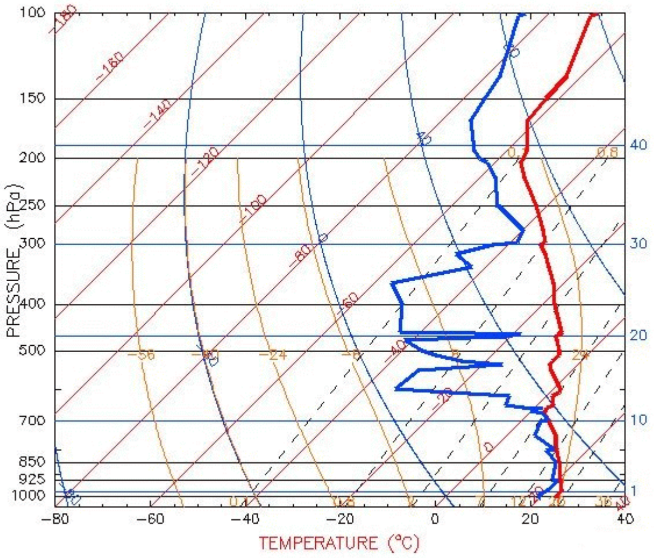

Figure 5a. 1200 UTC MHX upper air sounding.

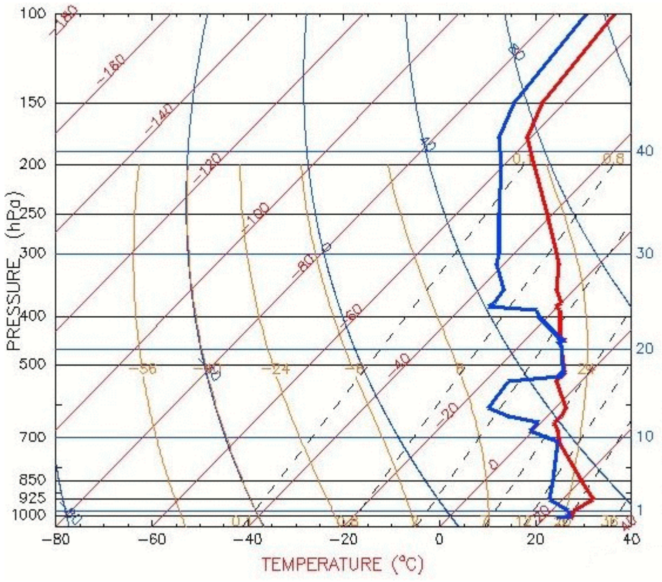

Figure 5b. 1200 UTC CHS upper air sounding.

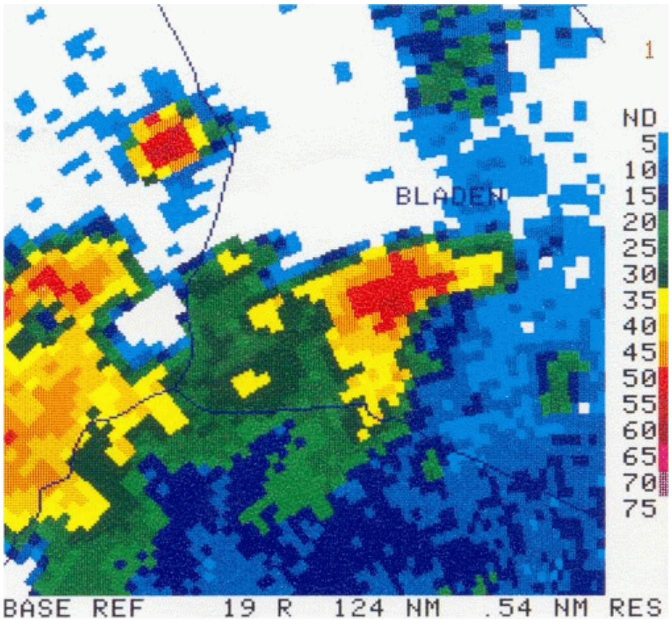

Figure 6. 0030 UTC 7 September 1999 0.5° KLTX Base Reflectivity.

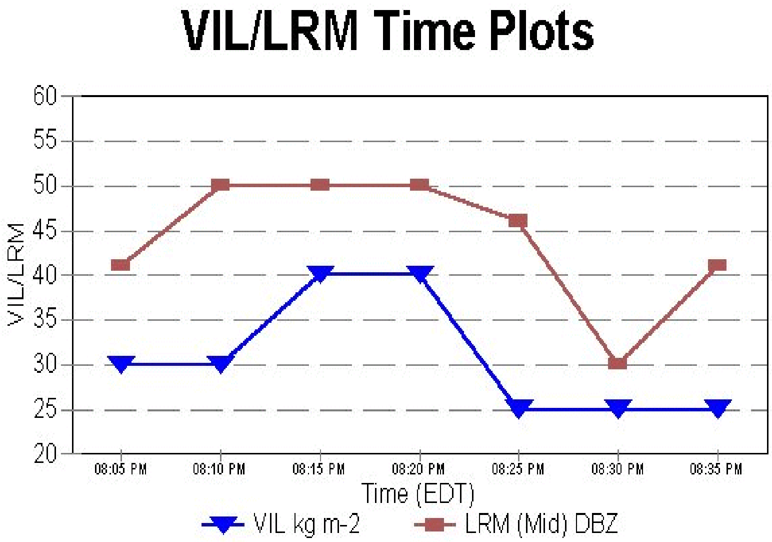

Figure 7. VIL and LRM time plot for the Clarkton storm.

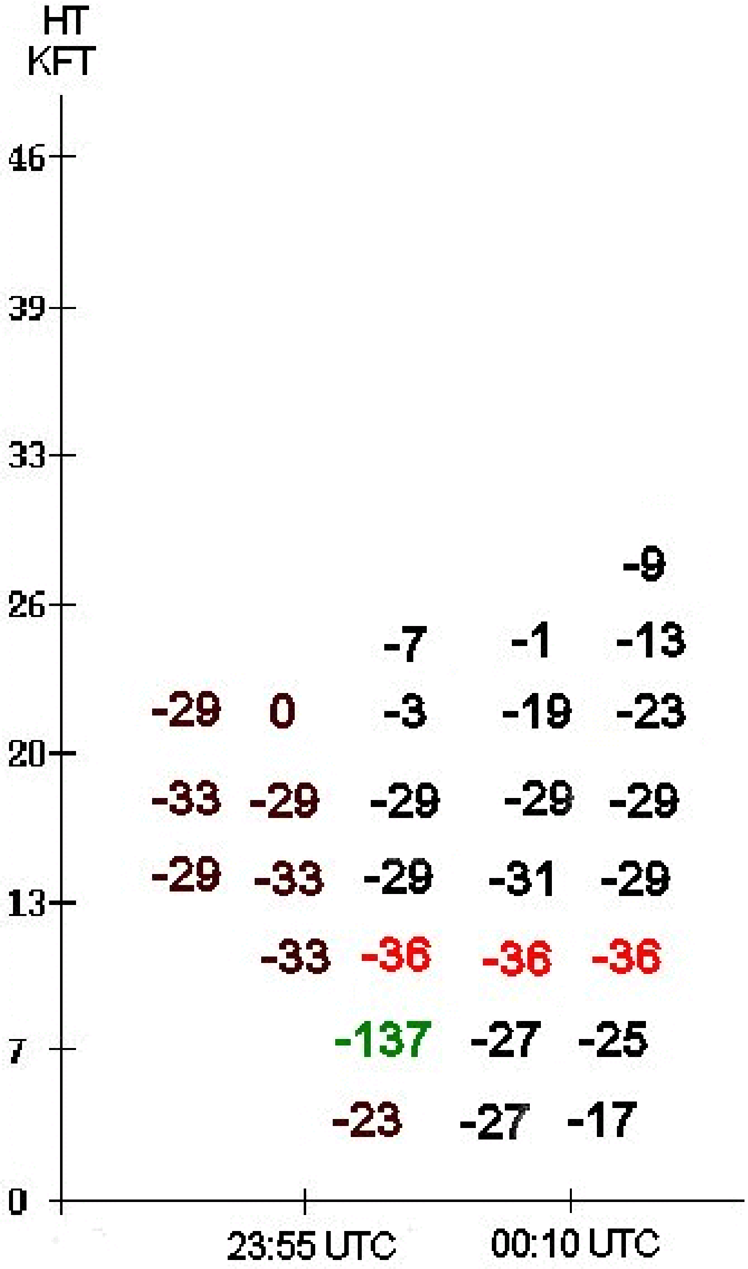

Figure 8. Convergence time-height plot for the Clarkton storm. Note that the -137 m s^{-1} value at the 7 k ft level was a result of dealiasing problems. This value did not trigger the severe convergence alarm.