Local Report
1996

ON THE USE OF THE WSR-88D DURING SITUATIONS OF RAPIDLY DEVELOPING SEVERE THUNDERSTORMS

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I. INTRODUCTION

During the late-evening and early-morning hours of 20-21 July 1996, a supercell rapidly developed and tracked from northeastern Weston county in northeastern Wyoming to northwestern Todd county in south-central South Dakota (~ 100 mile path). Once developed, the storm maintained a quasi-steady structure (Fig. 1) as it produced a swath of severe hail (¾ to 3 inches in diameter) and damaging outflow winds (~ 60 mph). Considerable damage and a few injuries were reported. For example, 300-500 people were pelted with hail at the Mount Rushmore National Memorial, and one person sustained a concussion. Although the first severe thunderstorm warning provided at least a fifteen minute lead time for Mount Rushmore, people were reluctant to seek shelter. This short note addresses this issue by examining: 1) what indicators from the WSR-88D could have led to a more timely and effective warning, and 2) how signals in the synoptic environment can aid in the warning decision-making process.

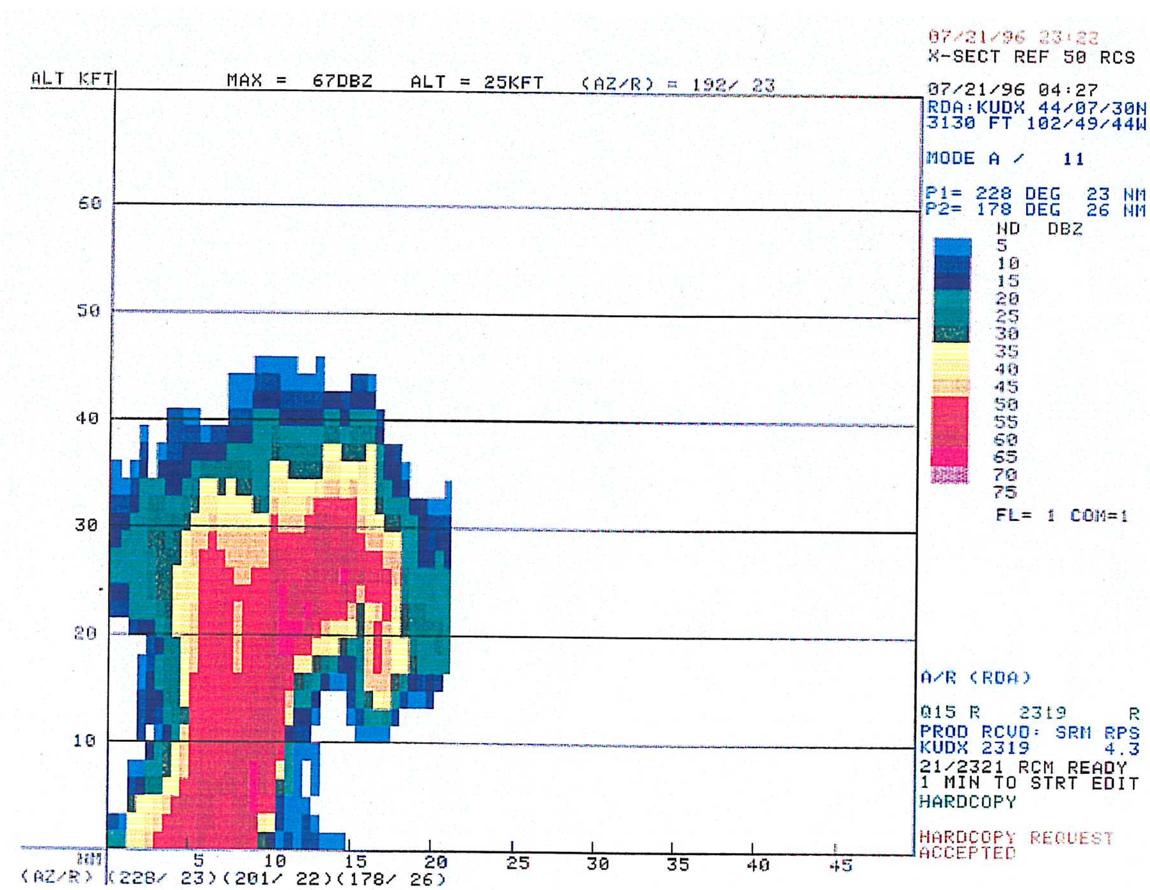

Figure 1. 0427 UTC 21 July 1996 KUDX-88D reflectivity cross-section.

II. DISCUSSION

a) Initial radar signatures

The basis for the first severe thunderstorm warning issued on 20 July 1996 at 917 PM MDT was primarily storm structure (i.e. decent overhang associated with a developing mesocyclone). The day after the above event, archive level IV data were reviewed to determine if there were any signs that may have led to a "better" severe thunderstorm warning. Since the vertically integrated liquid (VIL) is often used as a proxy for severe weather, this was examined first. At the time the warning was issued, the VIL product available to the radar operator was from 45 to 50. It had also achieved this value during the past volume scan. Arguably, this is not an impressive VIL, but when combined with an echo top of 43,300 feet, it crosses over the VIL-density warning threshold (3.5 $g{\cdot}m^{-3}$, Amburn 1996). Nevertheless, it provided some assistance in the decision-making process to issue a warning. Unfortunately, by the time this product was received (~10 minutes after real-time), ping-pong ball size hail had already fallen at Four Corners in Weston county, Wyoming (this report was received the day after the event). If a warning were to have been issued in order to provide a 5 minute lead time for this severe report, a warning would have to have been issued when the VIL was 20 to 25!

Another product that has proven useful is the layer reflectivity maximum (LRM). Starting as soon as 847 PM MDT, the LRM (high) had one pixel of reflectivity greater than 57 dBZ_e. Reflectivity values fell slightly below this value the next volume scan (852 PM MDT) and were somewhat inconsistent. The LRM (mid) had four pixels of reflectivity greater than 57 dBZ_e starting at 847 PM MDT, and remained at or slightly above this level for several volume scans. Based on these products, the decision to warn (or not to warn) was perplexing. The earliest a warning could possibly have been issued using the LRM as guidance was approximately 900 PM MDT, shortly after the 847 PM MDT volume products would have been received. Thus, even this product would have failed to result in an effective severe thunderstorm warning for northeast Weston county in Wyoming.

b) Synoptic setting

The synoptic environment on this evening was characterized by strong vertical wind shear as an upper-level jet streak was propagating into the region. An advancing mid-level short-wave trough and cold air advection were concomitant with low-level warm air advection and a return southeasterly flow of moisture from the central Plains. [These latter processes occurred quite rapidly.] Thus, instability, moisture, and upward vertical motion were present for thunderstorm development (Johns and Doswell 1992). More importantly, the 0000 UTC Rapid City hodograph exhibited sufficient vertical wind shear (Fig. 2; 0-6 km shear = $3.3{\times}10^{-3}{\cdot}s^{-1}$) to promote supercell processes (Weisman 1996; Weisman and Klemp 1986). A uni-directional hodograph favored splitting storms, but a subtle low-level veering of the wind shear vector favored cyclonically-rotating, right-moving storms (Wilhelmson and Klemp 1978). [Note that in Figure 2 the x-axis is scaled as about twice the y-axis. However, the low-level veering of the wind shear vector occurs below 1500 meters AGL, thus the hodograph is primarily uni-directional.]

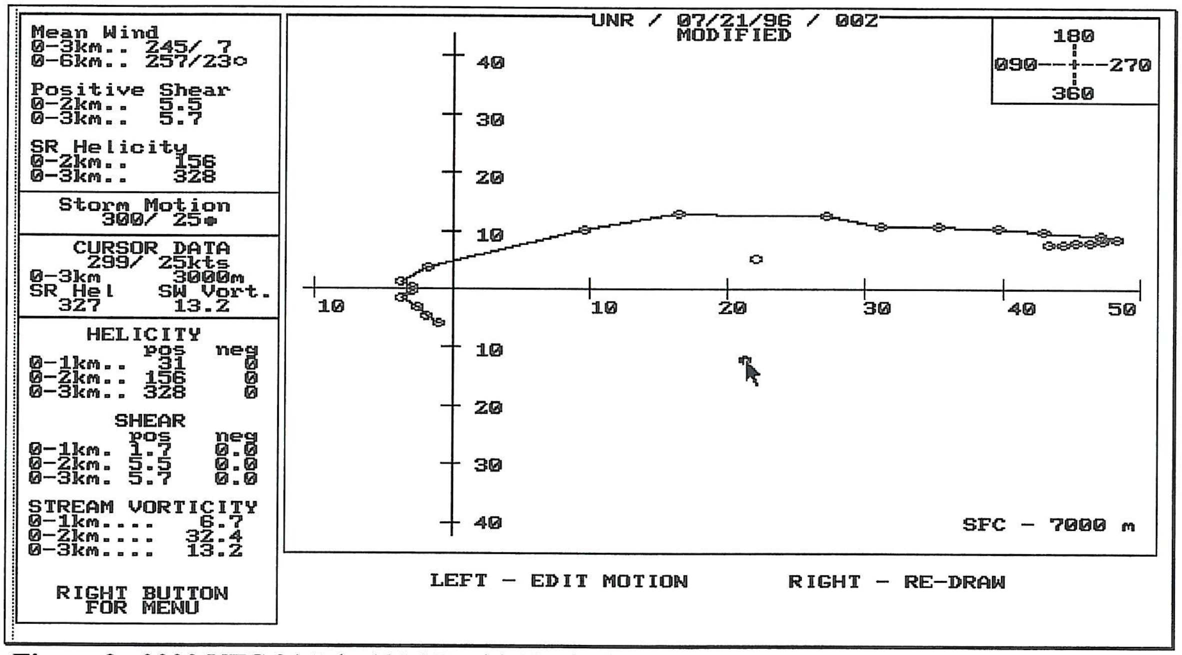

Figure 2. 0000 UTC 21 July 1996 Rapid City hodograph.

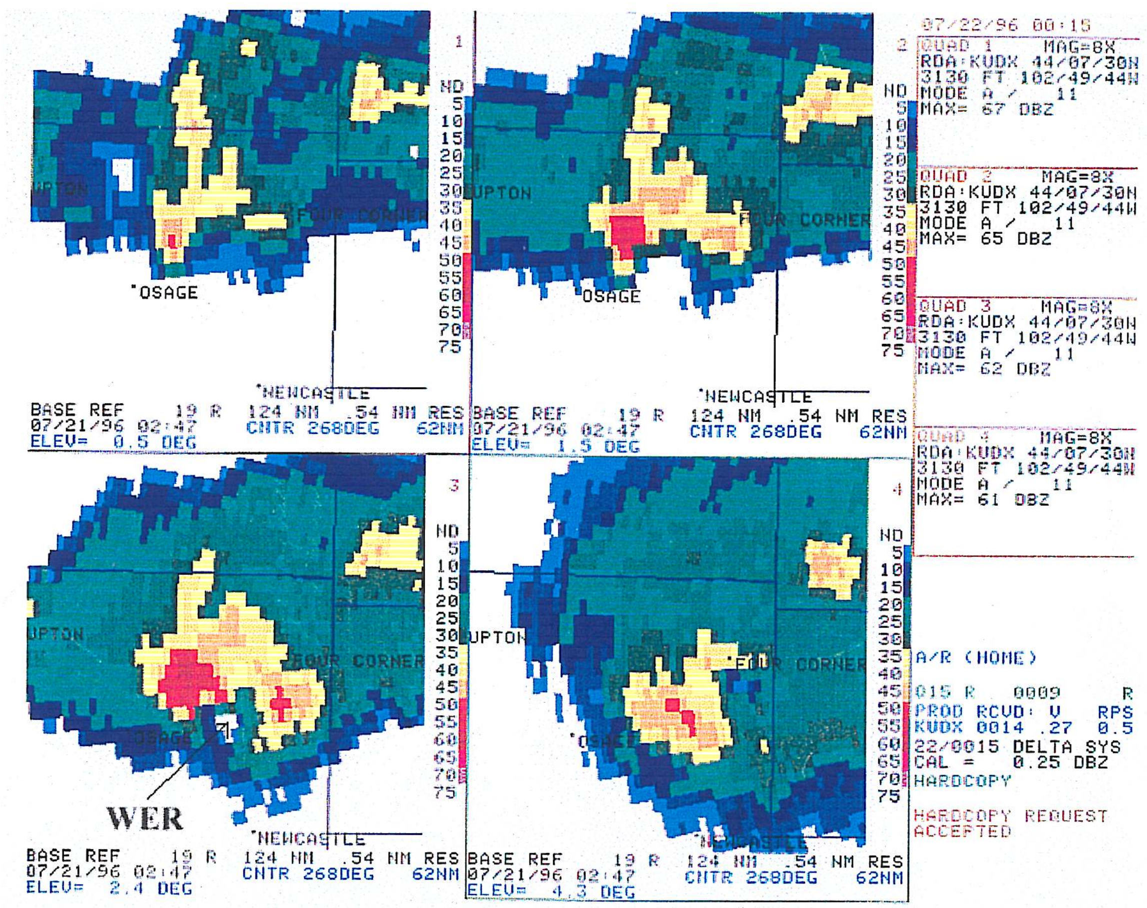

Figure 3. 0247 UTC 21 July 1996 KUDX-88D four-panel reflectivity at 0.5, 1.5, 2.4, and 4.3 degrees elevation. The radar is to the right of the display.

c) *Combined radar and synoptic viewpoint*

With this in mind, the radar operator was anticipating supercell thunderstorms during the evening of 20 July 1996. As mentioned above, the main reason the first warning was issued was due to evidence of a developing mesocyclone. During the first volume scan that a mesocyclone was indicated in the velocity products (842 PM MDT; again this was investigated the day after the event), the four-panel reflectivity was used to determine if any overhang or significant storm structure were present. The structure was very weak with reflectivities generally below 40 dBZ_e. No warnings would conceivably have been issued at that time. By the next volume scan (847 PM MDT), the reflectivity structure was still weak in the lower elevations, however reflectivity values were expanding and growing aloft with a weak echo region (WER) now present (Fig. 3). This was the same time that a corresponding increase in the LRM products occurred. The four-panel storm-relative motion (SRM) product clearly indicated a mesocyclone at 847 PM MDT as the criteria for persistence, depth, and shear had now been satisfied (Fig. 4). This was the soonest time that the storm could be classified as a supercell, according to 'currently accepted' definitions (Doswell 1996). Knowing the environment in which this storm developed (i.e. strong vertical wind shear with moderate instability), combined with an east-southeast movement of 35 miles per hour, science predicts that this storm would likely persist.

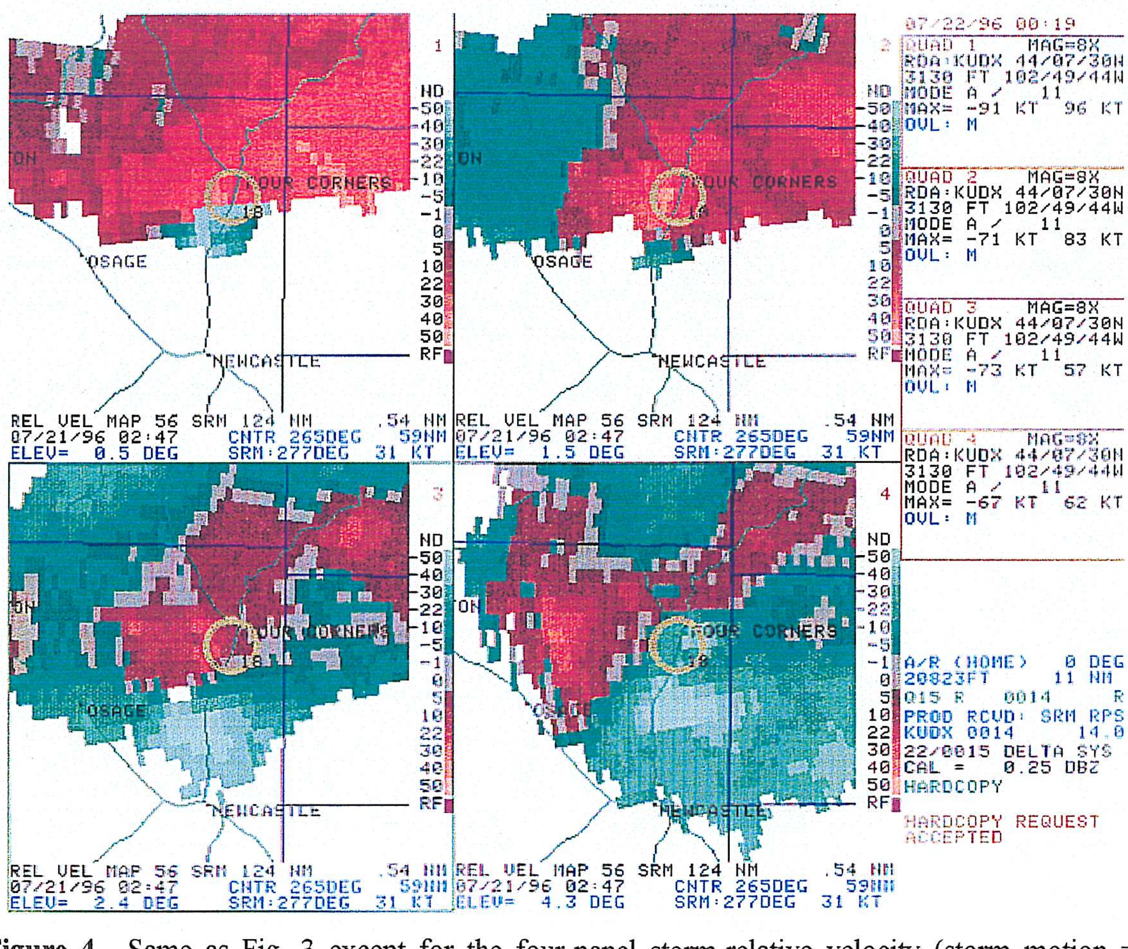

Figure 4. Same as Fig. 3 except for the four-panel storm-relative velocity (storm motion = 277°/31kts).

Taking all of the above products into account, the absolute earliest time that a warning could have been issued was approximately 900 PM MDT. This takes into account the time required for volume products to be processed and delivered to the principal user processor (PUP) workstation (~10 minutes), as well as the time to evaluate the products and type up the warning. Thus, little or no lead time would have been provided for northeast Weston county in Wyoming, but an additional fifteen minutes would have been provided for the visitors at Mount Rushmore. Complicating the matter were the weaker signals coming from the VIL and LRM products. Although the decision to warn fifteen minutes earlier would have been a difficult one, enough data were available to permit such a decision.

III. SUMMARY & CONCLUSIONS

Improvements in the warning process could have been made. If the radar would have been examined more thoroughly, a warning may have been issued for northeastern Weston county around 9 PM MDT. Although it may not have been in time for the first report of severe weather, it would have led to a more active solicitation for spotter reports. When the report of ping-pong ball size hail would have been received (presumably in near real-time), it could have been subsequently included in the warning for western Pennington county. This warning, with the report of large hail, would have amplified the threat of severe weather to those persons at Mount Rushmore, as well as providing nearly a half-hour lead time. Thus, persons may not have been as reluctant to seek shelter.

This case illustrates several important points. First, not all severe events can be warned for. In situations of rapidly developing severe convection, delayed volume products can be the difference between a verified and non-verified warning. Second, products such as the VIL and LRM do not present the whole picture. Although the LRM was showing signs of increasing reflectivity values aloft, the VIL was of little use early on. Thirdly, four-panel presentations of reflectivity and SRM can provide the earliest clues to a severe thunderstorm. These products are received slightly earlier than other volume products, and provide important information on morphology and kinematic structure of potentially severe thunderstorms.

Perhaps most importantly, knowledge of the ambient environment (particularly vertical wind shear), coupled with information from the WSR-88D, can help in situations where thunderstorms are developing rapidly. Often times, the radar operator is faced with the decision of whether to warn or not to warn. If one recognizes the potential for supercell development, the warning process may be made easier, and the decision to warn may be made sooner. In this instance, just limited knowledge of the shear profile via the hodograph provided sufficient information that supercells where possible, contingent on thunderstorm development. Coupled with the radar-observed mesocyclone, a warning could have been issued earlier with reasonable confidence. Therefore, as has been stated numerous times before, the importance of the preconvective environmental vertical wind shear and buoyancy profiles can not be understated in terms of radar operation and the warning process.

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