THE NEW WSR-88D HIGH RESOLUTION PRODUCTS AND THEIR USE IN DIAGNOSING SEVERE CONVECTION ON MAY 10, 2003

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1. INTRODUCTION

The availability of eight-bit high resolution WSR-88D products at National Weather Service (NWS) Weather Forecast Offices (WFO) has given warning decision makers several important new tools in the effort to further the mission of the NWS - to protect life and property, and enhance the nation's economy (NWS, 1999). The inclusion of these additional products has enabled NWS offices to more quickly determine the intensity and scale of rotation associated with potentially severe thunderstorms.

The description of these products as eight-bit refers to the amount of information available for display per data bin. Standard sixteen-level products use four bits to project the information they contain. This increase in resolution allows the user to see additional levels of detail in the data fields. Although eight-bit products were previously available through WSR-88D Archive Level II data, they were unaccessible in real-time for contribution into the warning decision process (Bookbinder and Andra, 2003).

Three new products make up the current suite of eight-bit high-resolution products. These are Base Reflectivity (DZ), Base Velocity (DV), and Storm Relative Mean Radial Velocity Map (SRM8).

2. NEW PRODUCT CHARACTERISTICS

Four-bit products have been used for the diagnosis of severe weather since the national implementation of the WSR-88D system, as part of the NWS Modernization and Restructuring effort during the 1990's. Originally, the data was displayable at local NWS offices through the WSR-88D Principal User Processor, and then later through the Advanced Weather Interactive Processing System (AWIPS).

With the deployment of WSR-88D Open Radar Product Generator software build 1.2 and AWIPS software build 5.2.2, the communication interfaces, as well as, the AWIPS display software, Display in Two Dimensions (D2D), were upgraded to allow access to the first set of high-resolution reflectivity and velocity products (Scientific Services Division NWS Eastern Region, 2003). With the fielding of AWIPS software build Operational Build 1, the eight-bit SRM product became available to NWS forecasters. An additional high-resolution Vertically Integrated Liquid (HRVIL) product will become usable with the installation of AWIPS Operational Build 3 scheduled for Spring 2004 (Ramer, 2003).

2.1 *Reflectivity - Compare and Contrast*

The display levels of 16-level reflectivity (Z) products are dependent on the Volume Coverage Pattern (VCP) that is in use at the time. During VCP 31 and 32 (clear-air mode), the data levels available for display on AWIPS range from -28 dBZ to +28 dBZ, while in VCP 11 and 21 (precipitation mode), the levels displayable are 5 dBZ to 75 dBZ. This disparity in ranges can often cause display limitations when significant precipitation is occurring in one portion of the display area while weaker, but important returns, are located elsewhere. These scenarios can occur when there are phase changes across the area, when bright-banding may be impacting the signal return, or when an important dry, but potentially convection triggering, boundary is located over the display area. In addition, when switching between non-precipitation and precipitation modes, a temporal discontinuity is often evident in the displayed levels decreasing the usefulness of looping images during the early stages of a precipitation event (Bookbinder and Andra, 2003).

In contrast, the DZ product is mode invariant enabling a range of -30 dBZ to 90 dBZ independent of VCP being used (Warning Decision Training Branch (WDTB), 2003a). This property allows radar data analysts to view phenomena that are producing high signal return over a section of the display while

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simultaneously monitoring features that would normally be undetectable in precipitation mode.

Although the data is sampled at a resolution of .25 km x 1 degree beam width, the Z product has a displayable resolution of 1 km x 1 degree to a range of 230 km. The four .25 km bins are averaged and the resultant power is displayed in the appropriate 1 km pixel. From 230 km to 460 km range, the best range resolution displayable decreases to 2 km. The DZ product retains a resolution of 1 km x 1 degree beam width through the full 460 km range of the radar (WDTB, 2003c).

One significant limitation of the DZ product is that the increased data and range resolution produce a data file that is up to five times larger than the equivalent file for the 16-level product. This increased size decreases available bandwidth and limits its usefulness to systems outside of the radar's local dedicated AWIPS (Bookbinder and Andra, 2003).

Another limitation that may be evident near the radar is the effect of higher azimuthal resolution and the increase in non-meteorological noise near the antenna. The increase in data levels combined with increased resolution may lead to difficulties in identifying important signatures at low elevation angles that may be more easily detected with the standard Z products. This limitation can be partially offset through the use of an appropriate color curve on the displayed product.

2.2 *Velocity - Compare and Contrast*

The derivation algorithm of the 16-level base velocity product (V) processes the individual .25 km range bins and converts them to various resolutions depending on the range from the radar site. Between the site and 60 km, every .25 km bin is displayed. From 60 km to 115 km, every other range bin is displayed resulting in an effective range resolution of .5 km. At a 115 km to 230 km range, every fourth sampled range bin is used leading to an effective resolution of 1 km (WDTB, 2003c). Base velocity data is not displayable beyond 230 km. No averaging or priority is given when converting the higher sampling resolution to the lower display resolution. This resolution transformation may lead to difficulty in identifying small-scale signatures. Although, a higher resolution velocity product, Severe Weather Velocity (SWV), is displayable at the .25 km bin size, it analyzes only a 50 km x 50 km box centered on a requested point (WDTB, 2003d).

The DV product displays every .25 km bin out to the full 230 km velocity-detectable range of the WSR-88D. This effectively eliminates the need for the SWV product by displaying the sampling resolution over the entire display. In addition, the DZ increases the displayable velocity data value range and resolution (WDTB, 2003c).

The DV suffers from the same limitations as the DZ product with file sizes as large as ten times that of the equivalent display from a 16-level product (Bookbinder and Andra, 2003). The problems of noise near the site are also evident at times.

2.3 *SRM - Compare and Contrast*

The SRM product combines the use of base velocity data and storm motion to produce a product which enables more rapid identification of storm-relative severe weather signatures such as mesocyclones, tornado vortex signatures, and storm-top divergence. The algorithm takes the individual velocity bins and subtracts the average storm motion vector of all storms identified by the WSR-88D Storm Cell Identification and Tracking (SCIT) algorithm during the previous scan. Unlike the base velocity data, when converting to lower resolution (1 km), the SRM uses the maximum value of the applicable .25 km range bins, rather than the first in the series (WDTB, 2003d).

The use of the SCIT algorithm to compute the storm motion vector for subtraction can lead to the masking of features if the storm track information is unrepresentative of the individual storm being interrogated. In addition, changes in the average storm vector may change the display leading to a perception of increasing or decreasing signature intensity when actually the trend is a residual effect of a change in the vector being used. The user has the ability to override the default storm motion by sending a request to the Radar Product Generator (RPG).

The SRM8 is created differently than the other high resolution products discussed. It is derived at each individual display workstation rather than at a central processor (RPG). Similar to the 16-level SRM, the SRM8 is composed by subtracting a storm vector from the individual .25 km range bins. The difference though, is how the algorithm determines the vector to use. In AWIPS Operational Build 1, the vector last determined in composing a severe weather warning or statement, or last computed through the distance/speed tracking tool is used. Since these vectors will vary across workstations, the display of the SRM8 will also differ. This can be both a strength and a limitation of the product. Beginning with AWIPS Operational Build 2 (OB2), the user will have the ability to use the SCIT computed average storm vector or a user input vector in the algorithm's computations (WDTB, 2003d).

The strengths in using the SRM8 include the ability to display the individual .25 km range bin values through the full velocity-range of the WSR-88D, and the ability to display higher speeds using the display sampling tool than is available in the 16-level SRM product.

Another potential strength is the ability to use multiple SRM8 products at different workstations with diverse storm motion vectors as input. This allows separate users to interrogate different storms with divergent motions without impacting other warning decision makers. However, this characteristic also makes it difficult to use the same workstation to analyze multiple storms in diverse flow environments. There can also be difficulty making comparisons of products between workstations in an operational environment that maintains a high level of coordination between users. Reviewing products used to base warning decisions is difficult since there is no indication of the storm vector used in archived data.

An additional limitation includes potential high levels of signal noise near the antenna as is the case with the DV product which is the algorithm's primary input.

3. FUTURE CAPABILITIES

3.1 *Radar Display Control*

The inclusion of the AWIPS build OB2 option to use the SCIT computed vector, or a vector input by the user, should improve the limitations associated with continuity and collaboration. This data is input through the Radar Display Control unique to each workstation (Figure 1).

3.2 *High-Resolution Vertically Integrated Liquid*

An additional high-resolution product, the high-resolution Vertically Integrated Liquid (HRVIL) will be made available with the introduction of AWIPS Operational Build 3 (Ramer, 2003). This product is sponsored by the Federal Aviation Administration (FAA) and designed to be used with the FAA Integrated Terminal Weather System. Its usefulness in operations outside aviation forecasting is still unknown (WDTB, 2003a).

3.3 *File Size*

Due to the file size of these new products and the available bandwidth, it is unknown as to when the increased resolution will be available to those users outside the local WSR-88D's AWIPS system.

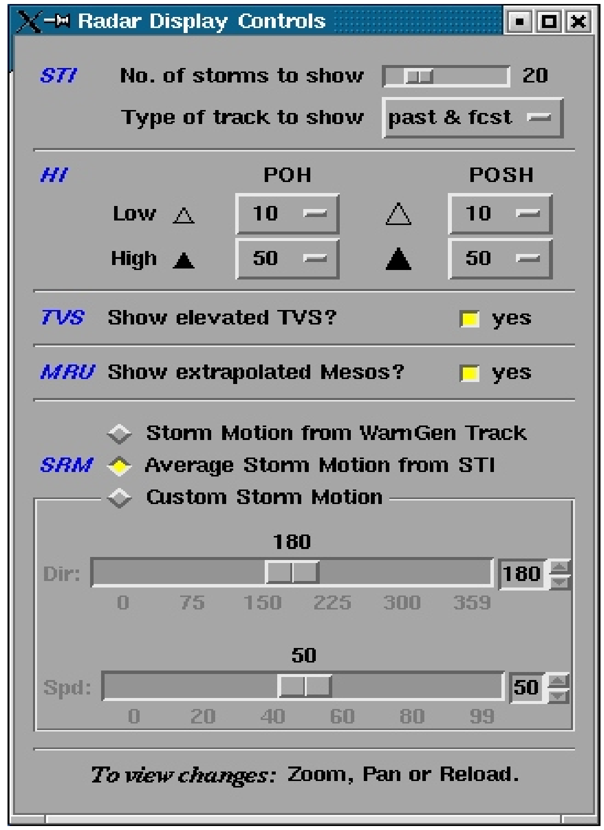

Figure 1. AWIPS Radar Display Control Graphical User Interface (GUI).

4. *SUMMARY OF THE 10 MAY 2003 TORNADO EVENT*

Tornadic thunderstorms rapidly erupted during the early evening hours of 10 May 2003 across northeast Missouri and southeast Iowa. A high shear, high instability environment was supportive for supercells throughout the evening into central Illinois. The Lincoln, IL (KILX) sounding at 0000 UTC 11 May 2003 (not shown) indicated Convectively Available Potential Energy of nearly 3600 J kg^{-1}, a Lifted Index of -11 °C, 0 to 3 km Storm Relative Helicity of 290 $m^2 s^{-2}$, and 70 degrees of directional shear with 25 m s^{-1} speed shear in the 0 to 6 km layer.

The supercells produced 11 tornadoes, which affected five central Illinois counties between 0110 UTC and 0335 UTC on 11 May 2003. The tornadoes traveled a total of 103 km near densely populated communities, produced tens of millions of dollars in damage, and resulted in 37 injuries. Most importantly

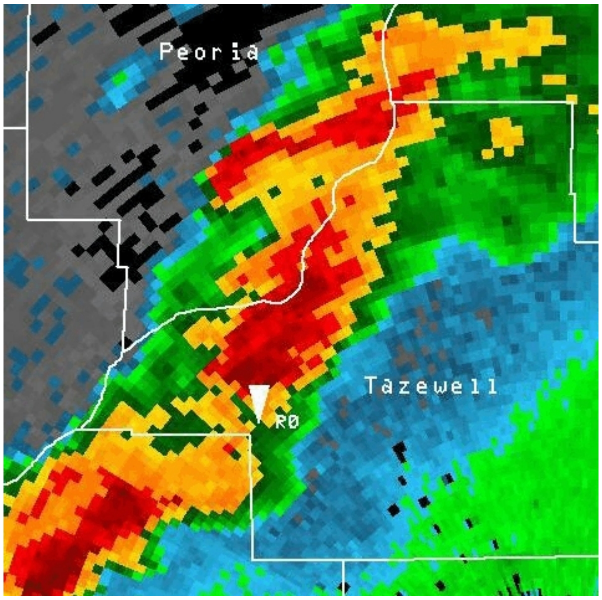

Figure 2. The 0.5 degree elevation eight-bit Reflectivity image from the Lincoln IL (KILX) Doppler radar at 0242 UTC 11 May 03. The inverted white triangle is the location of a radar defined TVS. Note the lower reflectivity inflow notch to the left of the TVS.

there was no loss of life. (U.S. DOC, 2003)

The average tornado warning lead time of the 11 tornadoes was 22.1 minutes, with a probability of detection of 100 %. The tornadic storms, however, were hybrids of classic supercells, making identification of features in reflectivity images difficult. The SRM8, DV, and DZ products were extremely valuable in the warning process, and in directing storm spotters in the field.

4.1 *Comparison of Reflectivity images*

The tornadic supercells of the evening of 10 May 2003 were hybrids of classic supercells with few identifiable reflectivity features. However, due to the increased resolution of eight-bit reflectivity products, subtle features were more easily interpreted.

An inflow notch associated with gate-to-gate shear and a Tornadic Vortex Signature is very apparent in the DZ product at 0242 UTC in southwest Tazewell County, Illinois (Figure 2). The associated 16-level reflectivity product (Figure 3) does not show this feature as clearly as the DZ image.

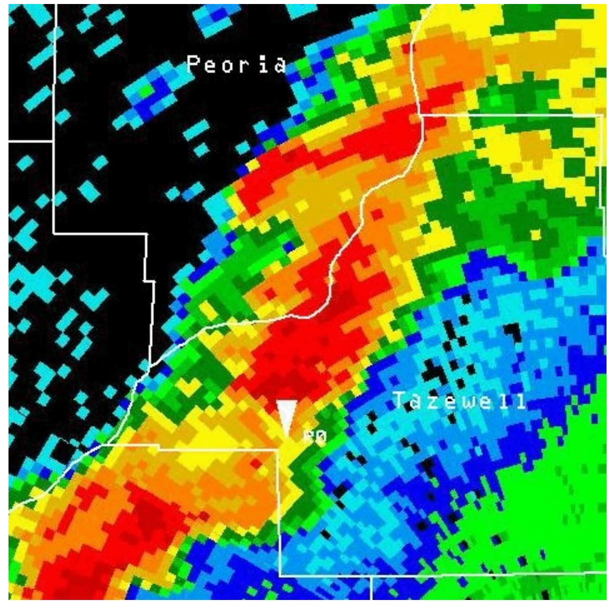

Figure 3. Same as Figure 2, except for the 16 data level reflectivity product. Note the difference between Figures 2 and 3 in the resolution of the inflow notch to the left of the inverted white TVS triangle.

4.2 *Comparison of Base Velocity images*

SRM products are typically employed for analyzing and interpreting storms that exhibit rotation. However, a check of the base velocity images indicated some significant differences between the eight-bit and 16-level products.

A tornadic thunderstorm was approaching the town of Astoria, Illinois at 0142 UTC. The DV image at 0142 UTC clearly indicated a mesocyclone 4.8 km southwest of Astoria, at a distance of 77 km from the radar (Figure 4). Note the .25 km data bins in Figure 4, which are at least 100 km from the radar, on the far left part of the image. In contrast, the 16-level base velocity at 0142 UTC indicated a broader circulation 4.8 km southwest of Astoria, with very little detail (Figure 5). This is mainly due to the lower resolution of 16-level base velocity products at distances greater than 60 km from the radar. Notice the higher resolution pixels on the far right side of Figure 5, which are within 60 km of the KILX radar. The presence of this mesocyclone, as depicted by the high-resolution velocity images, was communicated to spotters in the field. Five minutes later, at 0147 UTC an F1 tornado was reported 1 km south of Astoria.

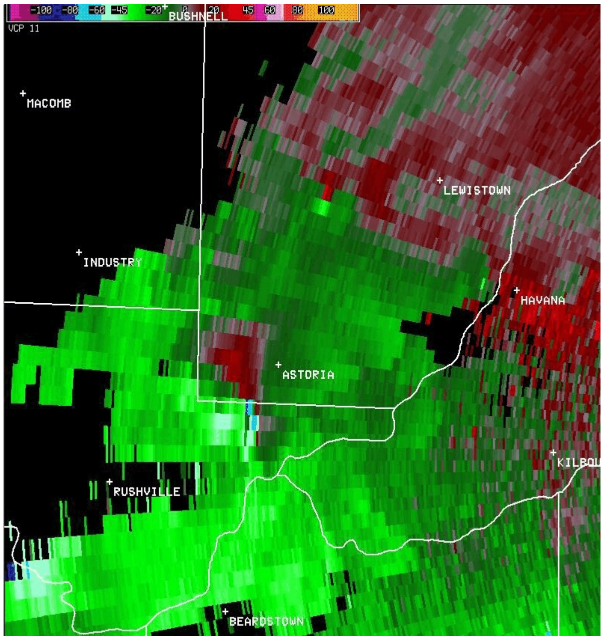

Figure 4. The 0.5 degree elevation eight-bit DV image from KILX for 0142 UTC 11 May 2003. Red shades indicate wind moving away from the radar, with green/blue shades indicating wind moving toward the radar.The KILX radar is outside the picture, and to the right.

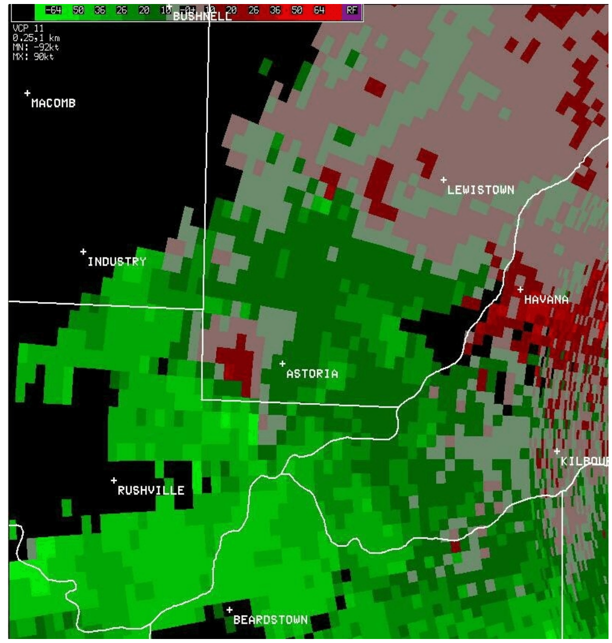

Figure 5. The same as in Figure 4, except for the 16 level base velocity product. Note the finer resolution of the velocity bins on the far right side of the image, only within 60 km of the KILX radar.

4.3 *Comparison of Storm Relative Velocity (SRM) Images*

The ability of SRM8 products to readjust the storm motion it uses for its calculations as often as the radar operator adjusts the cell movement makes it a valuable tool for rotational velocity interpretation, as compared to the 16-level SRM product. This feature proved extremely valuable to warning forecasters during the evening of 10 May 2003.

A tornado, which eventually produced F3 damage, was approaching the town of South Pekin at 0245 UTC. Both the SRM8 (Figure 6) and 16-level SRM (Figure 7) images at 0247 UTC 11 May 2003 indicated a strong mesocyclone with gate-to-gate shear. However, the eight-bit image provided a more detailed analysis of the storm-relative velocity and shear information. Figure 6 clearly shows gate-to-gate shear 2.4 km south of South Pekin. The V_r shear, also known as the rotational velocity (equal to $[|V_{inbound}| + |V_{outbound}| / 2]$), was 33.3 ms^{-1}, with a very high shear value of .1213 s $^{-1}$. The storm movement utilized in these calculations was 19 ms^{-1} (37 knots) from an azimuth of 237 degrees.

The corresponding 16-level SRM image produced significantly less detail in the storm relative velocity field. The V_r shear was >28 ms^{-1} with a shear of >.1018 s $^{-1}$. The storm motion used in these calculations was 22 ms $^{-1}$ (44 knots) from an azimuth of 229 degrees. It is clear from a comparison of these two images, that the eight-bit

SRM offers much more detail enabling the warning forecaster to narrow down the affected area, which in turn should aid in decreasing false alarms.

The F3 tornado that impacted South Pekin was in contact with the ground for a total of 29 km. Toward the end of the tornado's life cycle, the low level mesocyclone began to occlude. The higher resolution eight-bit SRM at 0256 UTC (Figure 8) indicated this more clearly than the 16-level SRM at the same time (Figure 9). Note the better resolution of the weaker outbound storm relative velocity in Figure 8, which is most likely an indication of the rear flank downdraft.

The occlusion of the main low level mesocyclone is completed by 0306 UTC, as its diameter shrinks and decreases in intensity. A new mesocyclone formed near the triple point of the rear flank downdraft and the front flank downdraft, about 3.2 km southeast of Morton, Illinois. The SRM8 (Figure 10) clearly indicated this process. This new mesocyclone would eventually lead to the development of an F2 tornado 12 minutes later 14 km northeast of Morton.

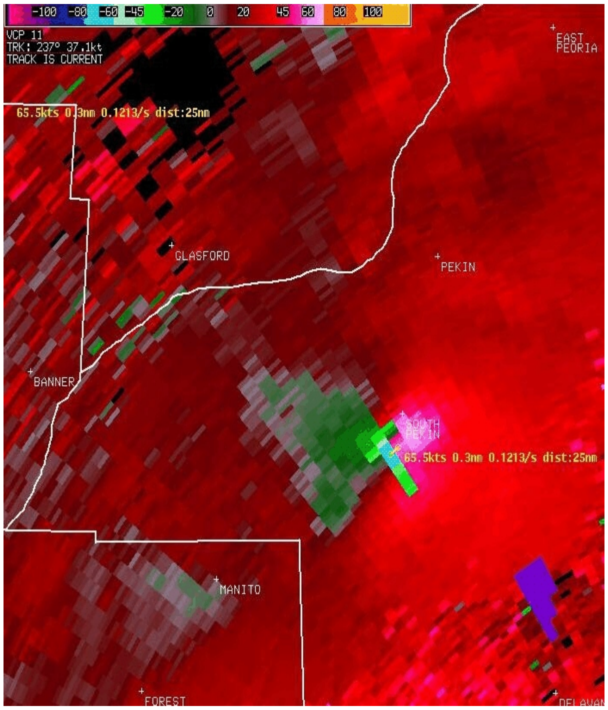

Figure 6. The 0.5 degree elevation eight-bit SRM from the KILX radar at 0247 UTC 11 May 2003.

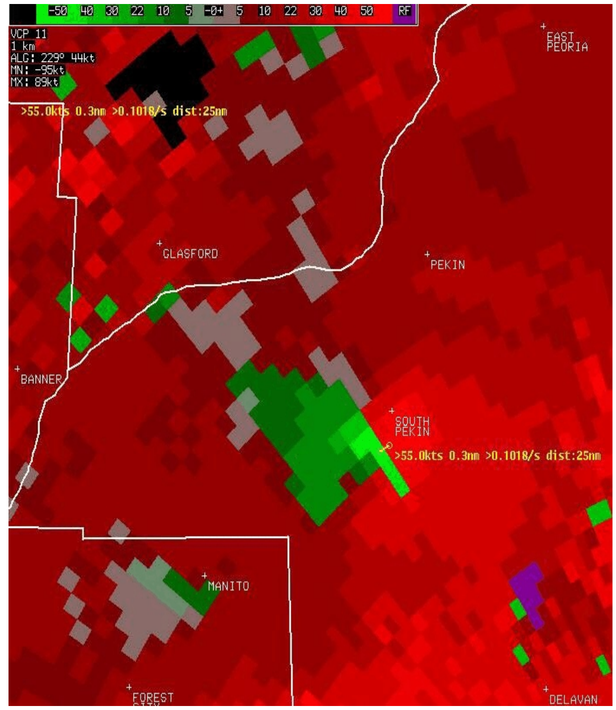

Figure 7. The same as Figure 6, except for the 16-level SRM.

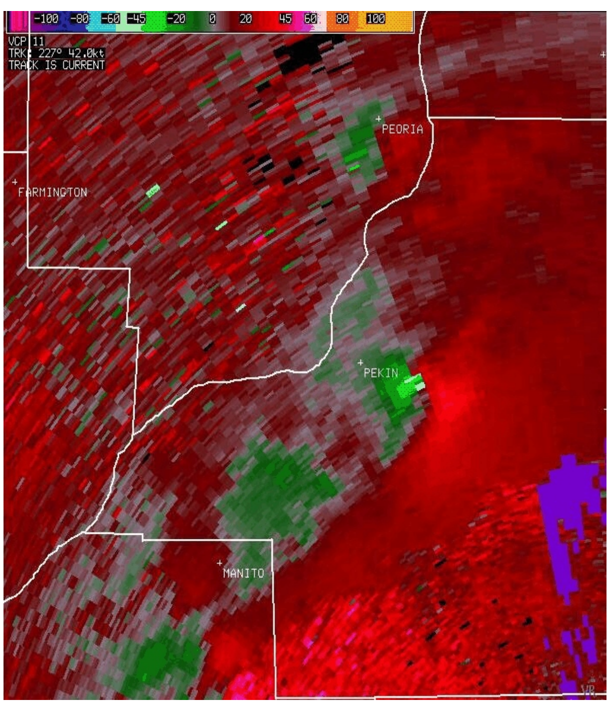

Figure 8. The 0.5 degree elevation SRM8 from KILX at 0256 UTC 11 May 2003.

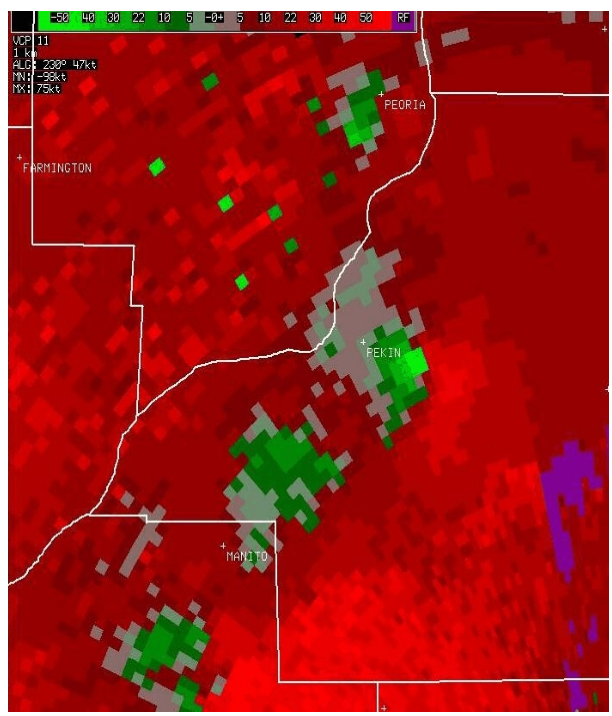

Figure 9. The same as Figure 8, except for the 16-level SRM.

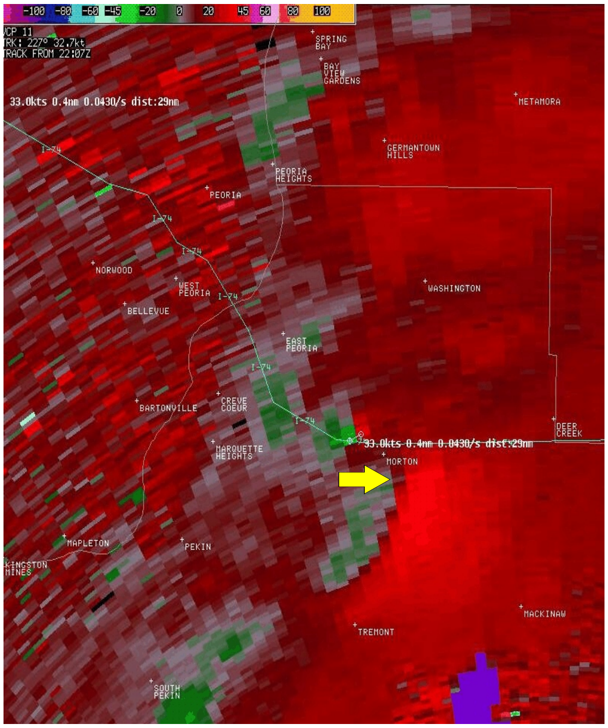

Figure 10. The 0.5 degree elevation SRM8 from KILX at 0306 UTC 11 May 2003. Arrow indicates developing mesocyclone.

5. SUMMARY

The introduction of the WSR-88D eight-bit high resolution radar products into the NWS WFO warning decision process has proven to be an important step in improving the diagnoses of severe convection. The products, made available at most WFOs this past winter season, include reflectivity, velocity, and storm relative velocity map displays. A brief comparison of the high resolution suite of tools with the more familiar 16-level versions was presented with a focus on the warning process associated with the tornadic storms that moved through central Illinois on May 10, 2003. The average lead-time of more than twenty minutes was partially due to the increased resolution available to warning decision makers through these products.

6. ACKNOWLEDGMENT

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