3.20 ANALYSIS OF THE INTEGRATED TERMINAL WEATHER SYSTEM (ITWS) 5-NM PRODUCT SUITE *

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1. INTRODUCTION

Currently, the prototype Integrated Terminal Weather System (ITWS) displays six-level precipitation data generated from the Airport Surveillance Radar (ASR-9) and the Next Generation Weather Radar (NEXRAD). The ASR-9 data are updated every 30 seconds and provide a 0.5 nm spatial resolution to a distance of 60 nm (Weber, 1986). Since the ASR-9 is a fan beam radar, the data represent the average precipitation within the vertical column. As reported by Isaminger, et al., (1999), this sensor can significantly underestimate the precipitation intensity and areal coverage due to precipitation processing limitations and hardware failures. In particular, storms located near the sensor can be underestimated or missed entirely (Crowe, et al., 1999). The NEXRAD data are updated every 5-6 minutes with a spatial resolution of 0.5 nm (2.2 nm) and a coverage region of 100 nm (200 nm). The maximum reflectivity value in the vertical column at each grid point is used to create the product. This sensor can overestimate the precipitation intensity near the surface due to bright band contamination and the composite technique (Crowe and Miller, 1999). The update rate can also become an issue if the storms are moving rapidly or developing quickly.

In order to confront these issues, the specified ITWS product suite will include six-level precipitation derived from the Terminal Doppler Weather Radar (TDWR). The data from this sensor will be depicted in a high-resolution window (5-nm) around the airport. The TDWR one-minute update rate will provide timely information on rapidly moving or developing storm cells. In many regards, the data will be complimentary to that provided by the ASR-9 and NEXRAD. In others, the weather levels could vary significantly. This report will focus on a discussion of the 5-nm product capabilities and limitations based on an analysis of data collected in Memphis (MEM) and New York City (NYC). A discussion of key product enhancements will serve to illustrate the modifications required to improve this product suite. Finally, a list of recommendations will be presented to assist in product development.

2. ANALYSIS

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For this analysis, the 5-nm products (precipitation, storm motion/extrapolated position, and storm cell information) were compared to those produced from the ASR-9 and NEXRAD data for ten MEM and NYC cases. All of the statistical results were based on the TDWR and ASR-9 products, which have similar update rates. The database was composed of isolated (slow moving) and organized (fast moving) storms in order to provide a comprehensive evaluation.

2.1. Precipitation

The 5-nm precipitation field showed the most persistent differences when compared to the ASR-9 and NEXRAD products. As shown in Figure 1, the TDWR cell intensity was generally higher than the ASR-9 by 1-2 weather levels. This was expected based on the different horizontal and spatial coverage and resolution of the two radars (Crowe, et al., 1999). The relatively few cases where the TDWR underreported the cell intensity were caused by attenuation. Most of the large discrepancies were due to the ASR-9 either missing, or only partially detecting, a cell within the "cone of silence." As shown in Figure 2, there is a large cell located to the southwest of the runways (rectangles). An examination of the 5-nm image shows a small level 3-4 cell has formed over the airport (black box). This echo is missed entirely by the ASR-9 and is only shown as level 1 by the NEXRAD due to latency. Also, the TDWR and NEXRAD report the larger cell as one weather level higher than the ASR-9. This is an excellent example of the advantages of incorporating the TDWR precipitation data into ITWS.

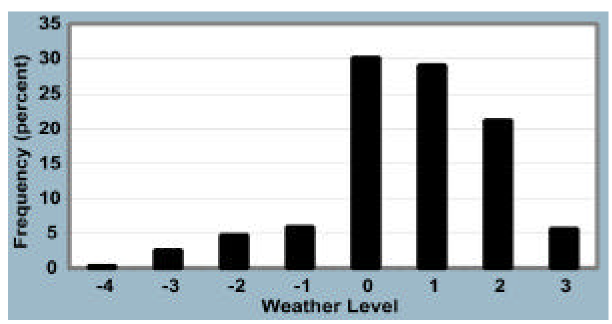

Figure 1. Comparison of TDWR and ASR-9 Weather Levels.

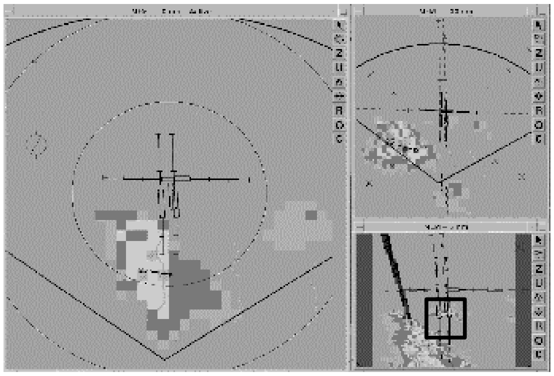

Figure 2. Graphic of 5-nm precipitation product. For this and subsequent three-panel images; the ASR data is in the upper left, the NEXRAD in the upper right and the TDWR in the lower right.

Another advantage of using the TDWR surface data is shown in Figure 3. In this example, there is a complex of cells located to the northeast, west, and southwest. Both the ASR-9 and NEXRAD show a solid area of level 3 and greater echoes to the west. By contrast, the 5-nm product shows a gap (black box), with one cell located west and another to the southwest. This is due to the fact the TDWR-based product is able to better localize the precipitation and does not detect the precipitation aloft.

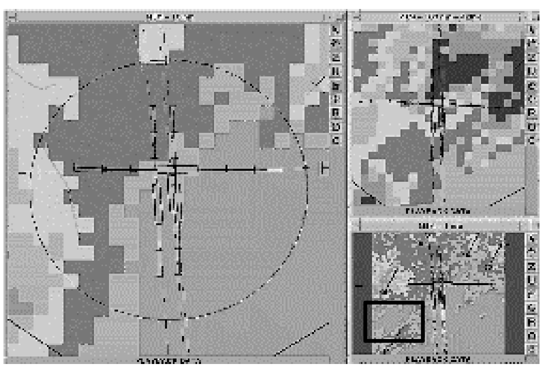

Figure 3. Graphic from MEM showing a gap between cells in the 5-nm precipitation product.

The most significant limitations of the 5-nm precipitation product are caused by uncorrected path-length and radome attenuation. When path-length attenuation occurs, the data can be degraded by as much as 9 dB before flagging is invoked. An example of attenuation flagging is shown in Figure 4. In this case, there is heavy precipitation (levels 5 and 6) stretching across the Areas Noted for Attention (ARENAs), which are depicted by the polygons. The white radials on the backside of the strongest returns indicate attenuation flagging. Overall, the TDWR product did a good job of representing the actual cell intensity for this case even with the attenuation flagging/degradation.

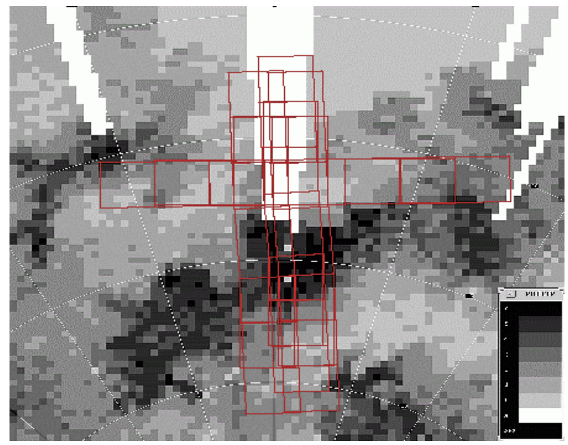

Figure 4. Graphic of the 5-nm precipitation product with attenuation flagging.

Radome attenuation can account for a significant underestimation of the cell intensity as well. As shown in Figure 5, there is a line of heavy precipitation located just west of the ARENAs. The TDWR product also shows a level 3-5 echo located over the airport (black box), which the ASR underestimates at this time. There is already attenuation evident to the southwest since the TDWR data are lower than the ASR-9 in this region. Some of the precipitation differences can be attributed to the strong returns aloft, which are not detected on the TDWR surface scan. As the heavy precipitation impacts the radar (Figure 6), the product is significantly degraded. The ASR-9 shows a solid area of level 5 extending across the airport, while the TDWR product peaks at level 3. In this example, the degradation persists for 25-30 minutes.

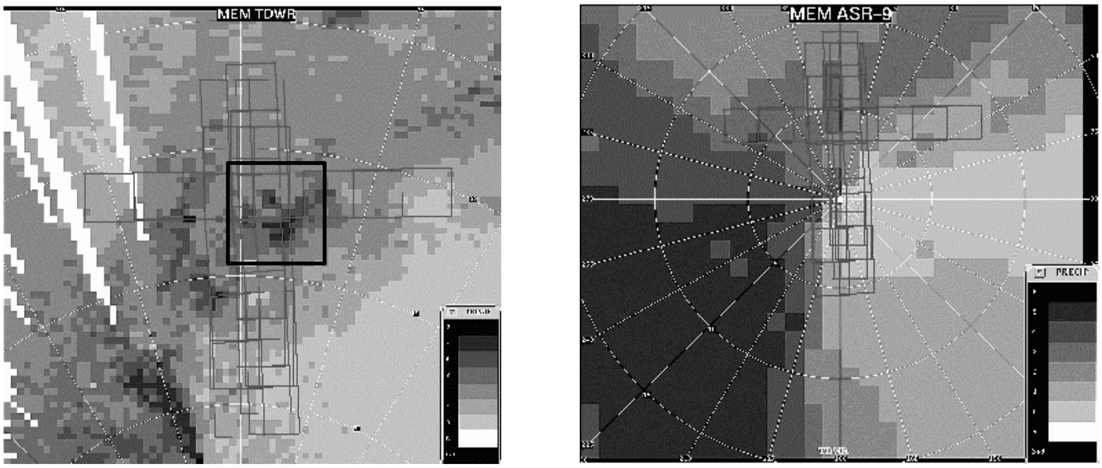

Figure 5. Example of the 5-nm precipitation product prior to radome attenuation.

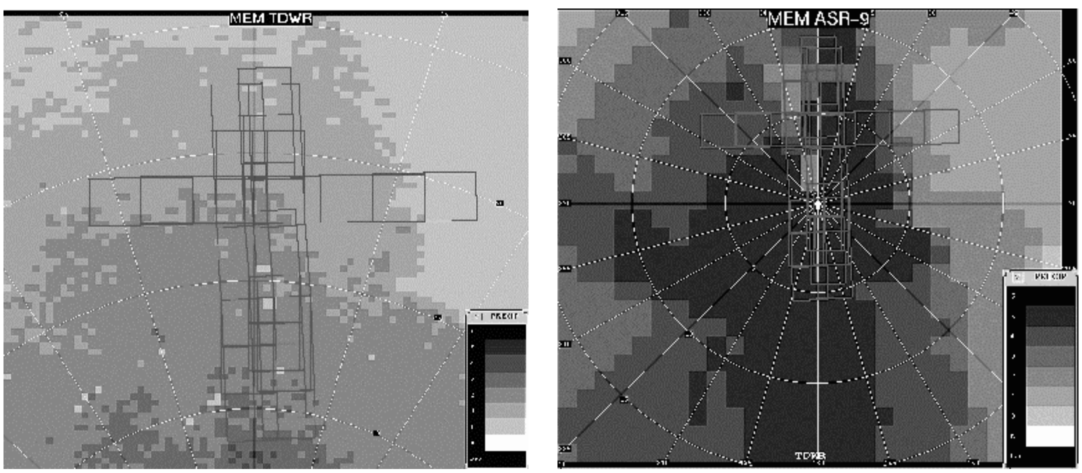

Figure 6. Example of the 5-nm precipitation product experiencing radome attenuation.

2.2. Storm Motion/Extrapolated Position

In terms of motion, there was good agreement among the products. For this evaluation, the average cell motion for each image was used to generate the statistics. As shown in Figure 7, the vast majority of the 5-nm motion vectors were within 5 knots and 5 degrees of their ASR-9 counterparts. Most of the outliers were related to either attenuation of the precipitation product or rapid cell growth. Fast-moving cells produced the greatest variability in the motion products. An example of the product from this type of case is shown in Figure 8. For this event, the TDWR-based storm speeds are underestimated by 10-15 knots when compared to the other products, primarily due to attenuation flagging over this time period. As shown here, the direction of motion varied only slightly due to the flagging.

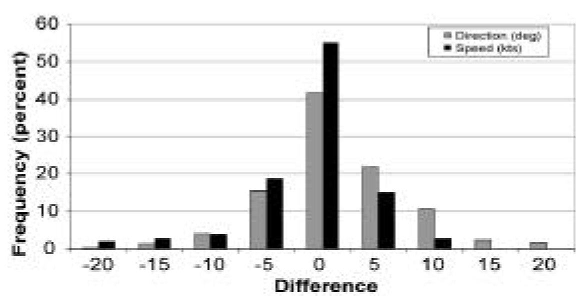

Figure 7. Comparison of TDWR and ASR-9 Storm Motion Products.

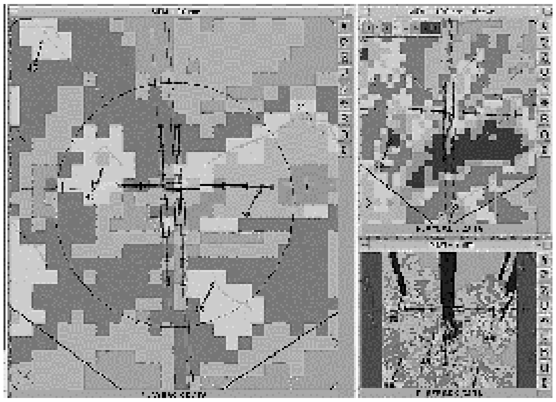

Figure 8. Graphic from MEM showing the 5-nm storm motion product.

We were not able to analyze the storm extrapolated position (SEP) contours since this product was not generated for any of the cases. The primary reason for the lack of SEP contours is that they are not displayed if any portion of the detection or forecast falls outside the coverage domain, which applies to all fast-moving storms. In addition, cells that move slower than 7.5 knots are not assigned any contours.

2.3. Storm Cell Information

As shown in Table 1, the TDWR and ASR-9 storm cell information products were also in agreement most of the time. The echo tops and severe weather attributes were the same 80 and 91 percent of the time, respectively. Most of the differences occurred in cells that extended outside the 5-nm coverage region. If the cell was entirely within the 5-nm domain, the storm cell information was generally the same for these two products. The different update rates, resolution, and coverage could explain the different severe weather attributes for the same cell. These differences would not be considered significant, since the information was virtually identical for cells that impacted the ARENAs.

Table 1. Comparison of TDWR and ASR-9 Storm Cell Information Products

Echo Tops		Severe Wx Attributes	
Same	Different	Same	Different
80.3%	19.7%	91.2%	8.8%

3. PRODUCT ENHANCEMENTS

In order to improve the utility of the 5-nm products, three modifications to the algorithm should be evaluated. They are to correct for the estimated path-length attenuation, identify/flag radome attenuation, and modify the SEP module so the entire contour must be outside the coverage region to suppress the display of the product. In terms of the path-length issue, the estimated loss values could be added back into the reported reflectivity value at each range gate. This modification would require careful evaluation since it is well known that radar attenuation corrections may introduce errors as large as they attempt to correct.

There are three different approaches being evaluated for the wet radome detector, i.e., single sensor/single image, single sensor/multiple images, or multiple sensors. The simplest technique would be to define a small window around the radar and search for a site-adaptable number of pixels above a site-adaptable reflectivity threshold. If these thresholds were exceeded, than a wet radome flag would be set. A discussion of the multiple image approach can be found in Crowe, et al., (1999). The multiple sensor technique would determine product degradation by comparing the TDWR image to that of the ASR-9 or NEXRAD. This would be the most complicated method since a heuristic rule-set would be required to determine when to ignore the data from the other sensors. Once radome attenuation has been identified, the algorithm could either partially compensate for the losses or nullify the product.

4. RECOMMENDATIONS

Based on this analysis, we recommend the following course of action:

1. The 5-nm products should be operationally evaluated in 2000 at the ITWS prototype sites.
2. Evaluate the efficacy of correcting for path-length attenuation.
3. Change the ITWS specification so that the entire SEP contour must be outside the coverage region to suppress the display of the product.
4. Develop an algorithm that can detect and warn for radome attenuation.

5. REFERENCES

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