14.11 ENHANCED WEATHER RADAR DATA REQUIRED TO IMPROVE THE FEDERAL AVIATION ADMINISTRATION'S OPERATIONAL CAPABILITIES.

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1. INTRODUCTION

As any seasoned air traveler knows, weather frequently affects the smooth functioning of commercial aviation within the United States national airspace. To improve the Federal Aviation Administration's (FAA) operational capability in decreasing weather related delays and maintaining airspace capacity during severe weather, the enhancement of the quality of the weather radar data from existing weather radar sensors such as the tri-agency NEXRAD WSR-88D and the FAA's Terminal Doppler Weather Radar (TDWR) is required.

Over the past decade the FAA has prototyped several systems that have successfully demonstrated the value of using highly accurate weather radar data at both terminal and en route environments. These FAA systems are the Integrated Terminal Weather System (ITWS) for airport terminal use, the Weather And Radar Processor (WARP) for en route use, and the Medium Intensity Airport Weather System (MIAWS) (Rappa et al, 2000) for medium sized terminal use. Both the WARP and the ITWS systems are being deployed in the 2002-2004 timeframe to provide better weather data for operational use by the air traffic controller community.

Using input from the WARP system, the Data System Replacement (DSR) display consoles at en route control centers show for the first time color reflectivity levels integrated on the same screen as aircraft positions. This capability will support more efficient traffic management and enhanced aviation safety but can be further improved if higher quality radar data is provided. Although the WSR-88D NEXRAD presently has certain inherent limitations, there are planned improvements to enhance data quality. The advent of the Open Radar Product Generator (ORPG) and the enhanced Open Radar Data Acquisition (ORDA) system will make possible extensive improvements in the quality and timeliness of data delivered to the FAA systems.

The ITWS is used to support terminal traffic management. It ingests radar data from NEXRAD, TDWR, and other FAA radars—all have specific data quality limitations that can be improved.

2. WSR-88D DATA PROBLEMS AND PROPOSED SOLUTIONS

Major issues affecting the FAA's use of WSR-88D are the quality of the base data, quality of the derived products, timeliness of the data, and interruptions of the data flow.

2.1 Quality of Base Data

Base data quality problems: Radar data quality is affected by both internal and external conditions. Within the radar, hardware components can fail, established calibration procedures can be improperly executed, and compo-

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nents can drift out of specifications. Externally, the data quality is frequently contaminated by situations that are beyond the control of the radar—interference from aircraft radars and cell phone transmitters, ground returns from hardened ground targets, and ground returns resulting from beam bending caused by atmospheric conditions, viz. anomalous propagation (AP).

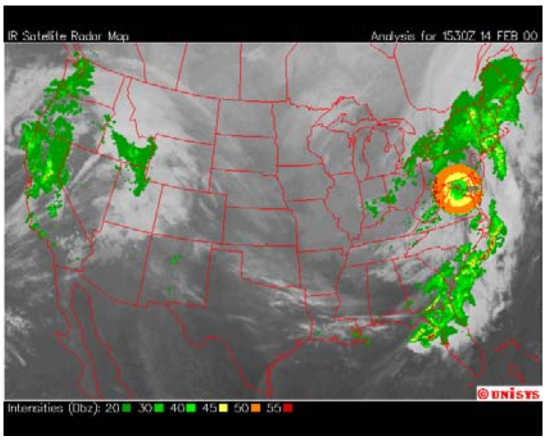

Figure 1. Bull's-eye artifact from calibration procedures

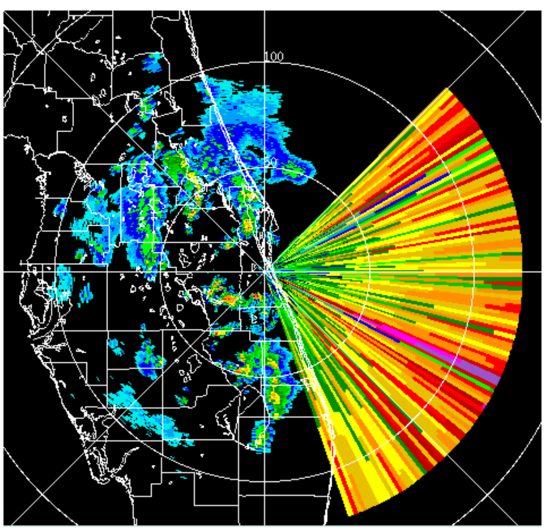

Figure 2. Reflectivity with artifacts Melbourne KMLB 081302:1909Z

Besides these base data issues there are the basic problems with range and velocity folding that affect any pulsed Doppler radar system. The legacy WSR-88D was implemented with adjustable pulse repetition times (PRT) to minimize range folding, and velocity unfolding routines have been developed over the past two decades to handle most velocity folding problems. However, there are still many cases where critical algorithms fail because of range folded data.

Base data improvements: Presently the bull's-eye test pattern, which occasionally finds its way into operational products, can be prevented in several ways—by rigorously following maintenance procedures, by detecting and eliminating the test pattern through software, or by changing the calibration procedure to one that doesn't generate bull's-eye pattern. So far, the FAA has been successful only on one front, viz., the Data Quality Algorithm (DQA) running on the ORPG detects and eliminates the bull's-eye pattern before ingest into specific FAA algorithms (Smalley et al, 2003). For legacy products, the WARP program has implemented an algorithm that detects and eliminates the pattern from products before the mosaicking process begins. However, this procedure has been both expensive to implement and resource intensive to execute.

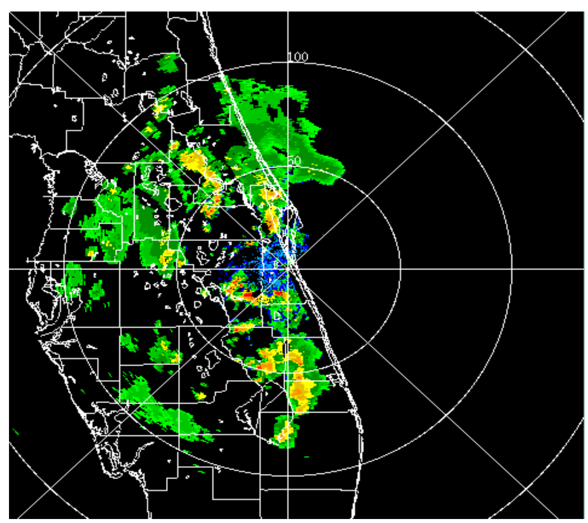

Figure 3. Removal of artifacts using DQA Melbourne KMLB 081302:1909Z

Hardware problems such as automatic gain control component failure can not be reliably detected because of the unpredictability of the failure. The use of a digital receiver in the ORDA will eliminate this particular hardware circuitry but undoubtedly other hardware failures will compromise data quality. More extensive built-in tests should be implemented in the ORDA control software to detect suspicious anomalies and issue alarms to the operator for investigation and necessary repair.

Although National Weather Service forecasters are able to use degraded radar data and products caused by failing or failed hardware, the FAA users require the use of data from a "certified" radar. For the FAA the certification process means that the radar has been calibrated and aligned to some agreed specification that guarantees that "good" data is produced. In order to meet this FAA requirement there must be additional research into generating a WSR-88D "certified" flag that can be interrogated by algorithms in the ORPG and appended to products. This flag would alert FAA display systems that the product was generated by radar data that was not within calibration specifications, allowing specific and unique actions to be taken depending on the display use.

Operational problems caused by ground return and anomalous non-meteorological targets can be mitigated by several means. The DQA not only removes artifacts but uses basic repeatable logic to remove ground targets that have specific characteristics such as near zero velocity and very narrow spectrum widths. Other techniques have been developed for target discrimination and are in various stages of maturity and testing. Implemented in build 2.0 is the Radar Echo Classifier (REC), which was developed by National Center of Atmospheric Research (NCAR) (Kessinger et al, 2001). The National Severe Storms Laboratory (NSSL) has developed a hydrometer discrimination algorithm that uses dual polarization data. Both of these techniques provide probabilities of detection of scatters ranging from hard ground targets to specific types of precipitation (Ryzhkov et al, 2000).

For FAA, use of WSR-88D radar data within the ground clutter region requires better methods of residue removal. The ORDA will provide data at specific 0.5 or 1.0 degree incremental azimuths that will allow the generation of a more accurate and repeatable clutter residue map. This technique has been implemented in the TDWR and is successful in flagging returns that are simple clutter residue.

Several methods are being investigated to lessen the range folding problems. The SZ phase code scheme has been tested by NSSL and NCAR and will be prototyped by NSSL for future inclusion in the ORDA (Frush et al, 2002).

2.2 Quality of Derived Products

Product quality problems: For the WARP system, the composite reflectivity product from multiple WSR-88Ds is used to form a mosaic product that is ultimately displayed on the air traffic controller's (ATC) DSR. Below in Figure 4 is one example of a false echo presentation resulting from extreme AP contamination from the Amarillo WSR-88D. The AP occurred mostly beyond 200 km, at a range where the present signal processor does not provide the velocity and spectral width estimates needed for advanced AP detection and removal techniques.

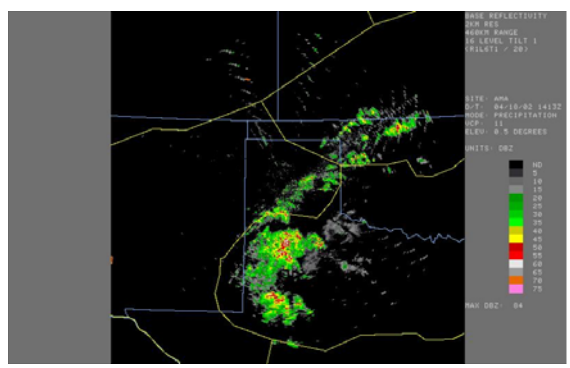

Figure 4. Anomalous propagation example Amarillo KAMA 041002: 1413Z

On the DSR only values at 30 dBZ and above are displayed using 3 color levels for reflectivity. Figure 5 shows a mosaicked composite reflectivity as displayed on DSR with AP break through from the Amarillo radar.

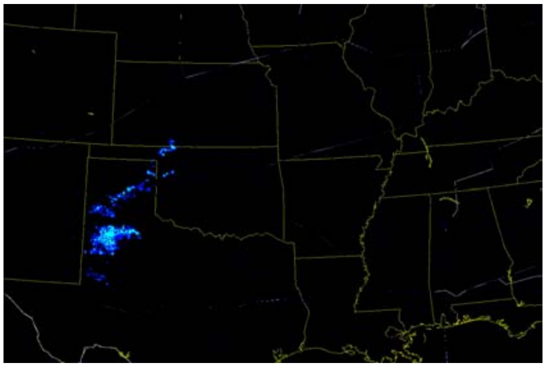

Figure 5. Mosaicked layered composite reflectivity for 041002 as displayed on DSR. Lowest displayed level is 30 dBZ.

Product quality improvements: By the use of improvements listed above in base data, FAA products can be improved. Products currently using the output of the DQA data stream are the high resolution Vertically Integrated Liquid water product and a new enhanced echo tops product in build 4. Other FAA algorithms under development for the ORPG such as Machine Intelligent Gust Front Algorithm (MIGFA) will also use the DQA as input. Lincoln Laboratory will continue to improve the DQA logic and will investigate the use of the REC output to further refine their detection logic.

2.3 Timeliness of Data

Update rate problems: The normal mode of operations of the WSR-88D scanning strategy when only clear air returns are present is VCP 31 (Volume Coverage Pattern), which updates once every 10 minutes. Whenever the precipitation detection function detects more areal reflectivity than an operator preset value, it automatically switches to the precipitation surveillance mode VCP 21, which completes in 6 minutes. Only when severe weather is present and the local WSR-88D operator makes a decision to switch to the convective weather mode does the radar update in 5 minutes.

Update rate improvements: For several years the NSSL and the Radar Operations Center (ROC) have been experimenting with faster VCPs. A formal experiment was conducted in the Spring 2002 to operationally collect data in numerous VCPs and to establish the criteria for switching to those VCPs (Scott et al, 2003). Depending on the outcome of the experiment, proposals will be made to implement a new faster VCP for deployment in the Fall 2003. The new VCP will operate in 4.1 minutes covering 14 unique elevations in a similar fashion to VCP 11. After communication circuit speeds are updated for WARP, this faster VCP will be valuable in providing a more timely mosaicked product for DSR. MIAWS should be able to take immediate advantage of this faster VCP to provide more timely presentations at medium sized airports.

Even faster VCPs would be beneficial for all WSR-88D users but for the FAA there is an additional need to provide controllers rapid depictions of weather comparable to what they now receive from older FAA radars. These radars, such as the ASR-9, can provide radar weather updates in 30 seconds for the terminal area, and the ARSR-4 can provide weather updates in 108 seconds. Unfortunately, these radars have aircraft surveillance as their primary task and weather data collected and processed can be frequently incomplete and inaccurate. Use of a fast scanning, well calibrated WSR-88D can replace and/or mitigate those deficiencies.

In order to scan the WSR-88D much faster than 4.1 minutes, either the accuracy of the velocity and reflectivity estimates must be decreased or other signal processing methods must be found. One of the more promising methods is that of oversampling with whitening, as proposed by NSSL (Torres and Zrnic, 2001). This technique yields multiple independent samples from a single transmitted pulse and requires fewer transmitted pulses, resulting in less dwell time and hence faster scanning. According to calculations made by Dale Sirmans of RSIS (Sirmans, 2002), by using the oversampling technique, the WSR-88D should be able to provide 0.5 degree azimuthal data at 14 unique elevations at 3 minute updates while providing a standard deviation of 0.6 m/s for velocity and 0.5 dBZ for reflectivity. The antenna would not have to exceed its maximum rated rotational speed of 6 rpm to attain this performance factor. When the dual polarization capability is added to the WSR-88D it may be possible to retain the 3 minute update rate but lower the standard deviation back to the original specifications of 1.0 m/s and 1.0 dBZ. Additional experimentation and testing will be required to determine what is possible.

2.4 Interruptions of Data Flow

Interruption problem: When the precipitation detection task in the ORPG automatically instructs the radar to switch VCPs, it is done in an immediate forced mode, not waiting until the completion of the current VCP. Additionally when operators switch from VCP 21 to convective weather mode VCP 11 they typically do an immediate switch. Both situations cause the current stoppage of product generation and an interruption of data flow until the new VCP begins again.

Interruption solutions: The current VCP mode switching needs to be changed so that there is no forced VCP restart. This feature could easily be implemented within the present software but would not provide NWS forecasters the flexibility and rapid mode changes that they require. The use of the more rapid 4.1 minute VCP may avoid the need for forced VCP restarts by eliminating the need for both a surveillance and convective weather mode. Implementing a 3 minute standard VCP would totally eliminate the need for forced switching except when switching from the 10 minute clear air mode scanning strategy.

3. IMPROVEMENTS FOR THE TDWR

Because the TDWR is a C band radar it has the classic problems of severe range and velocity folding. The shortest possible first trip range is 78 km with a Nyquist velocity of 26 m/s; The longest is 141 km with a Nyquist velocity of 14 m/s. Typical scanning strategies currently have a Nyquist range and velocity of around 90 km and 22 m/s respectively. Although the TDWR specifications only require coverage to 60 nm (100 km), there can be range folding occurring from as far as 460 km or the 6th trip in some scanning strategies.

In 2002, the FAA began funding Lincoln Laboratory to start exploration of prototyping a new digital signal processor (DSP) that will have the capabilities of implementing some of the more esoteric wave form processing schemes that have been researched in past years, as well as some that have only been proposed (Elkin et al, 2001). The prototyping platform will allow numerous concepts to be explored and tested—first in a laboratory environment using recorded time series data, then with a prototype interfaced to the Program Support Facility TDWR, and finally, with a demonstration at an operational site. This work was started using a Sigmet RVP7 for its digital receiver and ease of interface. However, a quad Power PC DSP is being used to allow more control over algorithm development and testing. The RVP7 will be replaced with the more powerful RVP8 as soon as it is available. For FY04 the plans are to upgrade one western site for field testing. Possible candidates are Salt Lake City or Las Vegas. If these tests are successful with the anticipated improvement of data quality and greater sensitivity of algorithm performance, all 45 TDWRs will be retrofitted under a Service Life Extensive Program starting possibly as early as FY07.

4. CONCLUSIONS

In order to continue operational improvements related to weather usage, the FAA must continue in its efforts to fund the NEXRAD Product Improvement program and the TDWR prototyping effort that have been started. With new initiative funds for service life extensions, the TDWR's capabilities can be significantly expanded beyond the original specifications to provide a superior terminal Doppler weather radar for generating cleaner base data for algorithms running on the TDWR host computer and on the ITWS system.

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