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NWS Use of FAA Radar Data – Status and Operational Considerations

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1. INTRODUCTION

In the late 1990s, the National Weather Service (NWS) began a joint venture with the Federal Aviation Administration (FAA) to explore the feasibility of using weather radar information from several types of operational FAA radars (Saffle, 2000).

Benefits to the NWS by using FAA weather radar data to complement Weather Surveillance Radar – 1988 Doppler (WSR-88D) data were identified as follows and plans were formed (Saffle, 2001):

- Backup data during WSR-88D outages,
- Low-altitude information at longer ranges of the WSR-88D,
- Improved coverage in the WSR-88D cone of silence,
- Data in areas of incomplete WSR-88D coverage (e.g., where there is beam blockage or ground clutter),
- Different viewing perspectives on storms to better sample radial velocity maxima and storm morphology,
- Improved quality control of WSR-88D data for such problems as anomalous propagation,
- Potential mitigation of obscuration of storms due to range folded echos,
- Improved "best information" mosaics,
- Improved precipitation estimates,
- Facilitate multiple Doppler analyses to provide rectilinear wind fields.

The NWS continues to collaborate with the FAA on projects to ingest data from several FAA radars: Terminal Doppler Weather Radar (TDWR), Air Route Surveillance Radar – Model 4 (ARSR-4) and Airport Surveillance Radar – Model 11 (ASR-11). The characteristics of each of these FAA radar systems are described by Stern (2003).

Since 1997, the NWS Office of Science and Technology (OST) has conducted proof-of-concept demonstration projects (DiVecchio, 2003) using World-Wide Web server systems to provided products from these radars to selected Weather Forecast Offices (WFOs). The NWS has demonstrated that weather data from FAA radars could complement the WSR-88D network.

Recent progress using data from these systems varies by radar: during the winter of 2004-2005 the NWS evaluated the FAA's ARSR-4 changes aimed at improving the detection of low altitude winter weather; in November 2004 the Cleveland, OH WFO started evaluating ASR-11 products on a NWS developed Web server display system and in July 2005 the FAA commissioned the Erie, PA ASR-11; the NWS Linux-based TDWR Web server continued to be used at five WFOs, and most significantly, the NWS began national deployment of the TDWR Supplemental Product Generator (SPG) which allows data from TDWR to be displayed and fully integrated along with WSR-88D and other weather data on the Advanced Weather Interactive Processing System (AWIPS

This paper will provide an overview, status, future plans, and some operational considerations involved in the use of data from these FAA radars.

2. TDWR

The FAA operates 45 TDWRs near many of the largest U.S. airports (see Figure 1). These C-band Doppler weather radars provide data similar to the WSR-88D, but at higher spatial and temporal resolution and with different antenna scan strategies. The TDWR automatically changes between two main scan modes, Monitor mode and Hazardous mode, when TDWR algorithms detect a potential hazard near its associated airport. In both modes the scan pattern begins with a long-range (248 nautical mile--nmi), low pulse repetition frequency (PRF), reflectivity-only scan which is used by TDWR algorithms to flag multiple trip echoes. The remaining scans provide reflectivity and

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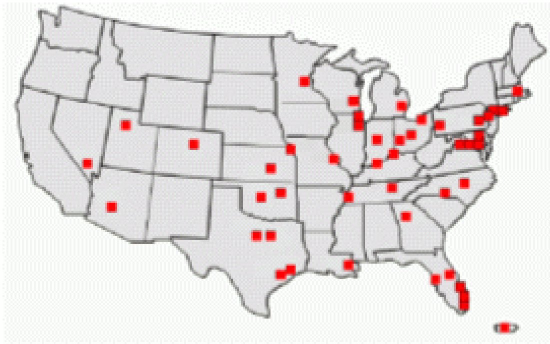

Figure 1 TDWR Site Locations

Doppler data to the normal (short) range (48 nmi) of the TDWR. In Monitor mode, after the initial three low level scans, the elevation angle consistently increases up to a maximum angle of 60 degrees. However, in the Hazardous mode the TDWR makes a low elevation scan (less than one degree) once per minute and repeats a sequence of aloft scans every three minutes. Figure 2 shows the Hazardous mode scan pattern for the Baltimore-Washington International airport (BWI) TDWR.

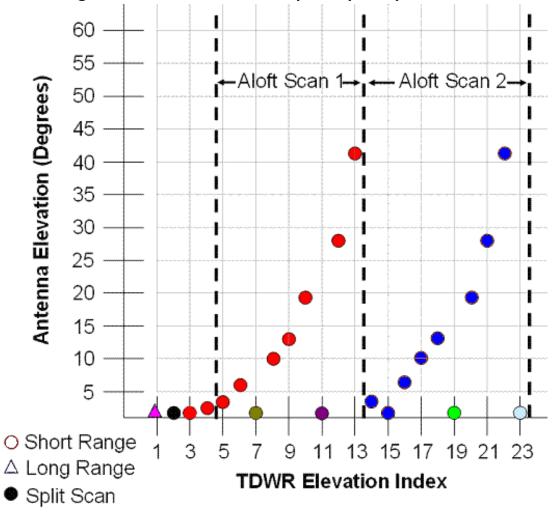

Figure 2 TDWR Hazardous Mode Scan

The TDWR provides reflectivity and Doppler base data at a resolution of one degree azimuth by 150 meters in range. However, the range resolution at the long range, low PRF scan, changes to 300 meters beyond 135 km.

2.1 TDWR Web Server

To demonstrate the utility of TDWR data at WFOs, a NWS OST-developed Web server (Stern, 2004) ingests TDWR base data and generates product image files which are viewable from a Web browser (see figure 3). It provides reflectivity and velocity base data images for several elevation angles, looping, zoom, cursor readout, and 31-day archive of image files. The user interface is available directly at the Web server and also from the AWIPS Netscape browser, if the Web server is located within the AWIPS network. This Web server was used at the Sterling, VA, Salt Lake City, UT, Phoenix, AZ, Las Vegas, NV, and Greenville-Spartanburg, SC WFOs.

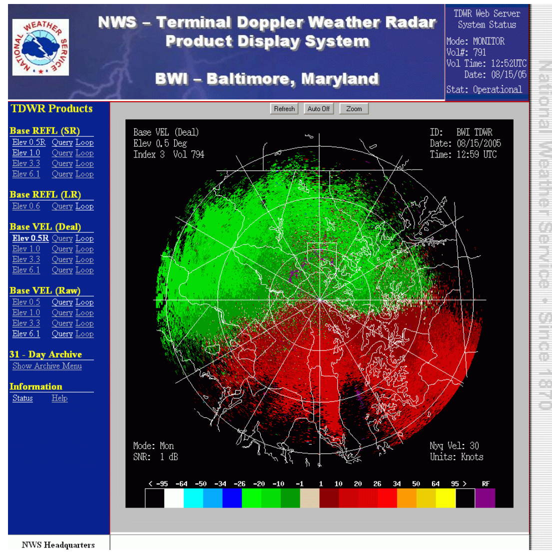

Figure 3 NWS-developed TDWR Web Server

2.2 TDWR Supplemental Product Generator

The NWS established a requirement to generate products from TDWR data and to provide them into AWIPS for display and integration with other weather data. The TDWR SPG (Istok, 2004) ingests TDWR base data and generates products following WSR-88D Interface Control Document (ICD) formats. Using the Common Operations and Development Environment (CODE) (Ganger, 2005), WSR-88D Open Radar Products Generator (ORPG) software was used to develop the SPG. Since the SPG provides products to AWIPS in the same method and format as products are currently provided from the WSR-88D, many of the capabilities available in AWIPS D2D for WSR-88D products will be available for TDWR SPG products. Initially, the SPG will just provide TDWR base products. However, additional algorithms and products will be incorporated in subsequent SPG software builds. Additional engineering details on the SPG are provided by Stern (2005).

In August 2005, the NWS OST began deploying TDWR SPG systems to WFOs. AWIPS software changes required to request and display TDWR SPG are included in AWIPS Operational Build 5 (OB5). SPG deployment may continue into 2007. After deployment is completed, Operations and Maintenance (O&M) of SPG systems will be transferred to the Radar Operations Center (ROC), a tri-agency (NWS, FAA, and Department of Defense--DoD) organization with support costs provided by NWS.

2.2.1 SPG System Architecture

The SPG system consists of ORPG software that is tailored to characteristics of the TDWR, a little-endian PC processor, the Linux operating system, and T1 ingest communications equipment. The SPG system will be on the AWIPS Local Area Network (LAN). The SPG was developed using Linux CODE which was based on the official source code release of WSR-88D RPG Build 6. The SPG will be installed in a standalone cabinet, using an AWIPS equipment rack. The rack space became available as a byproduct of the AWIPS DX server upgrade.

2.2.2 TDWR and WFO Sites

SPGs will be deployed to WFOs which have TDWR radars within their County Warning Area (CWA). The 45 operational TDWRs will be provided to 34 WFOs. Multiple TDWR SPG systems will be provided to WFOs where the CWA includes more than one TDWR (e.g., Washington D.C., Miami, New York City, Chicago, and others). Initially, SPG products will only be available to the associated WFO. However, it is expected that requirements will be established to provide products to remote users. The SPG supports product access to users in the same manner as is available from WSR-88D radars (e.g., multiple dedicated connections, non-associated one-time requests, and central collection).

2.2.3 Products and Capabilities

The SPG provides base reflectivity, velocity, and spectrum width products in both standard (4-bit) and full resolution (8-bit) format. The spatial and temporal resolution of the TDWR data is preserved in the SPG products. That is, the shorter range scans contain a resolution of 150 meters per gate while the long range reflectivity-only scan has a resolution of 300 meters. To take advantage of the 80 meter/second velocity threshold of the TDWR, SPG-generated velocity products will use a one meter/second resolution.

Within the six-minute hazardous mode scan pattern, time stamps of the base data products will distinguish between the repeating scans at the same elevation angle. In figure 2, this is represented by the color of the dots which represent the hazardous mode elevation scans. Products from scans that are the same color will have the same time stamp and time will increase by one-minute for each new color. This time-stamp scheme supports product time and elevation sequence stepping by the AWIPS All-Tilts function.

The AWIPS capabilities for SPG TDWR products are consistent with those provided for WSR-88D products. The capabilities include routine and one-time product request, zoom, data sampling, image combine/fade, looping in time and elevation, TDWR and WSR-88D mosaic, storm relative velocity, VR shear, and local AWIPS archive. Figures 4-6 are AWIPS displays of TDWR SPG products.

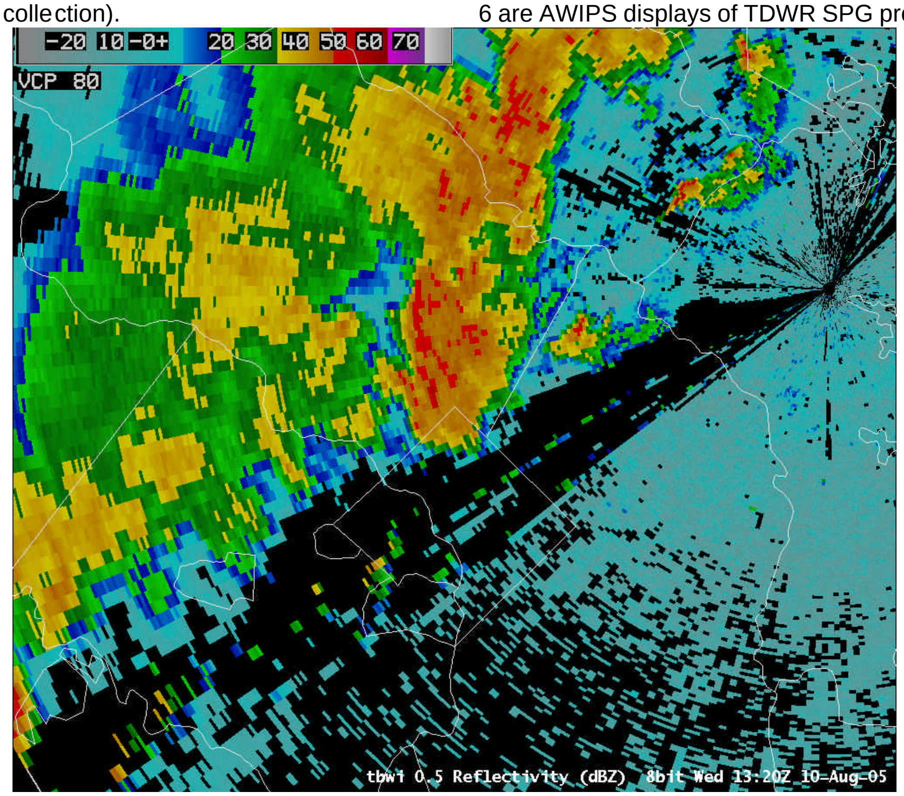

Figure 4 AWIPS D2D display of the TDWR 256 level (8-bit) One-Minute Reflectivity Product from the Baltimore-Washington International Airport on July 27, 2005 at 2220Z

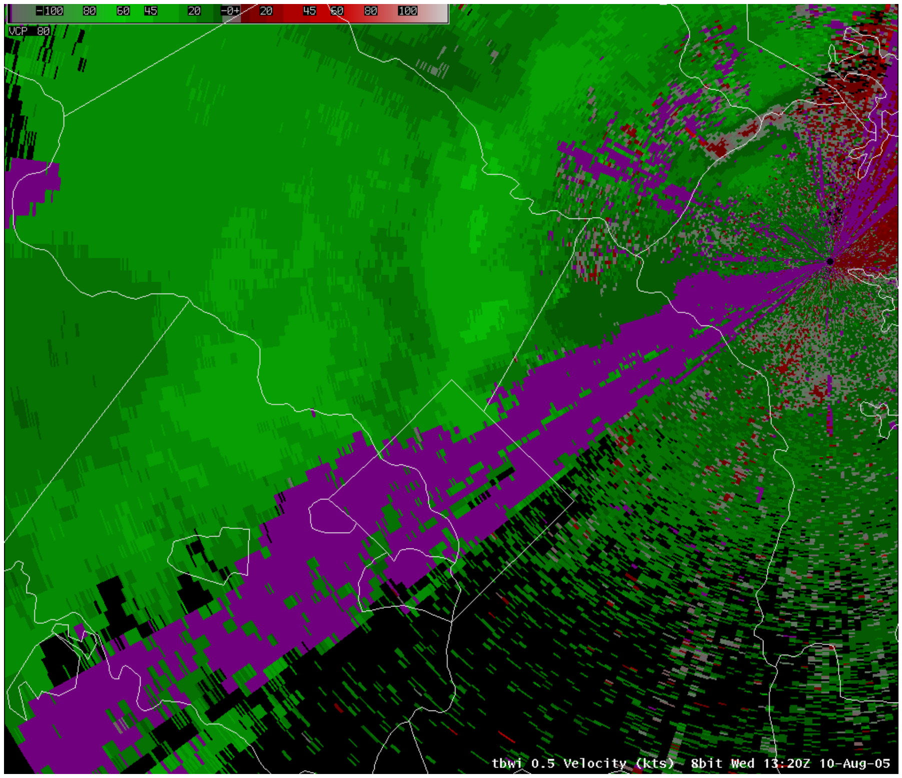

Figure 5 AWIPS D2D display of 8-bit TDWR Short-Range One-Minute Base Velocity

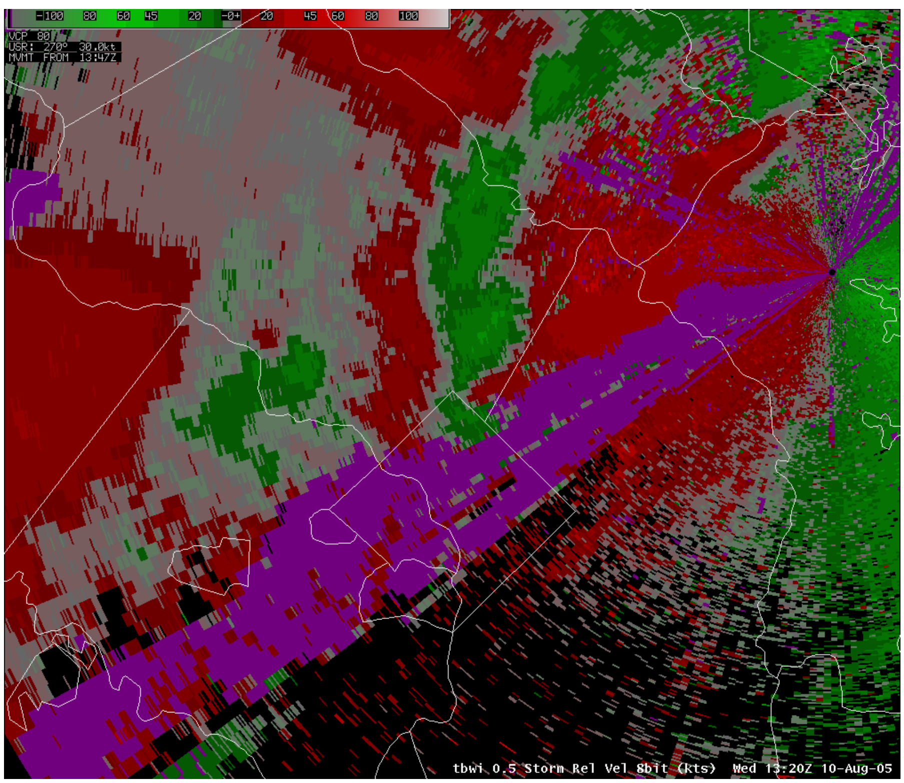

Figure 6 AWIPS D2D display of 8-bit TDWR Short-Range One-Minute Storm Relative Radial Velocity (data from 27 July 2005 2220Z)

2.2.4 Future Plans

The capabilities described above provide a foundation for future growth. Algorithm and products which may be easily adapted to TDWR data include composite reflectivity, VIL and VAD algorithms. Due to the more frequent and interlaced scanning in elevation, and the increased resolution in range and elevation but the use of non-contiguous elevation angles, areas that require more significant effort to tailor the NEXRAD algorithms to the TDWR data include: storm cell identification and tracking, mesocyclone and tornadic vortex detection, and rainfall accumulation. Additional possible enhancements include: adapting AWIPS SCAN to TDWR products, central collection of products and/or base data, and multiple Doppler radar algorithms.

2.3 TDWR Operational Considerations

Although the TDWR and WSR-88D radars are similar there are some important differences that should be kept in mind when using TDWR data. Signal attenuation is much more severe at times and results in storms appearing less intense when there is heavy rainfall closer in toward the radar. The Doppler dilemma is worse for C-band radars and leads to more range folding and a more challenging velocity dealiasing problem. The TDWR uses a single PRF on most elevations and consequently range folding will exist in the reflectivity, as well as the velocity, channel. TDWR addresses range folding by collecting a low-PRF low elevation scan every 6 minutes and then flagging data that might be contaminated from range folding on all other elevation scans below 15 degrees. Aggressive clutter filtering is employed which results in reduced reflectivity along the zero isodop area. On the other hand, site specific elevation angles and the increased resolution in time (one and three minute surface and aloft scans in hazardous mode) and space (150 meter range and ½ degree beamwidth in the vertical) often provide views of weather that are not available elsewhere.

3. ARSR-4

The ARSR-4 is a long-range surveillance radar system, capable of detecting aircraft at a range up to 250 nmi. There are 43 ARSR-4 units deployed around the periphery of the continental United States as well as Hawaii and other U.S. territories (Figure 7).

The ARSR-4 utilizes a 60-foot diameter, L-Band, phased-array antenna, that generates 10 beams which are divided into the upper or "high stack" and the lower or "low stack". The lowstack array contains a weather channel which provides a six-level reflectivity map based on the NWS DVIP (Digital Video Integrator and Processor) standard (US DOC, 1981).

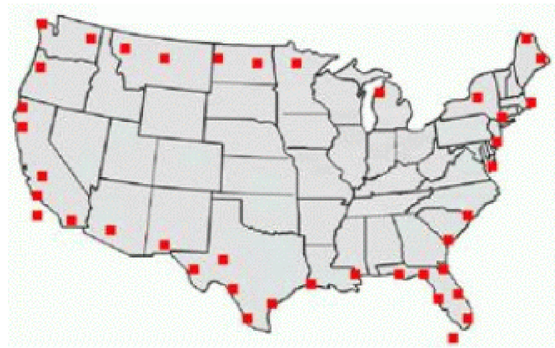

Figure 7 ARSR-4 Site Locations

The ARSR-4 reflectivity map is similar to the WSR-88D hybrid scan reflectivity product. That is, at near-in ranges, the highest beam (in the low stack) is used, followed by the next lower beams at middle ranges, until finally the lowest beam is used at longest ranges. An example of this scheme can be seen in Figure 8.

The beam width of the ARSR-4 is 1.41 degrees in the horizontal and 2.2 degrees in the vertical. The range resolution is 0.25nmi out to a range of 250 nmi. The reflectivity information is updated every 36 seconds.

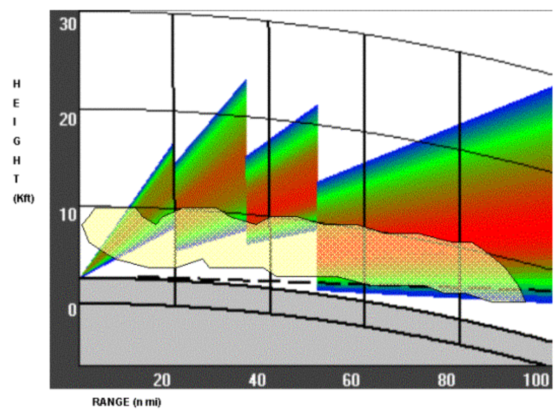

Figure 8 Switch Range Setting Before 2004

3.1 Products and Capabilities

The ARSR-4 Web server display system generates reflectivity image files from ARSR-4 base data and provides user access to the images from a browser. Reflectivity data is provided out to a range of 125 nmi and at a resolution of one-quarter nmi in range and 1.41 degrees in azimuth. Images are updated every minute. Time looping of reflectivity images is provided along with data sampling, 14 day archive of image files, system status, and a user manual. The home page of the ARSR-4 Web server is shown in figure 9. The Web Server is installed at the Bismarck, ND WFO. ARSR-4 radar images are also available from the Bismarck WFO home page.

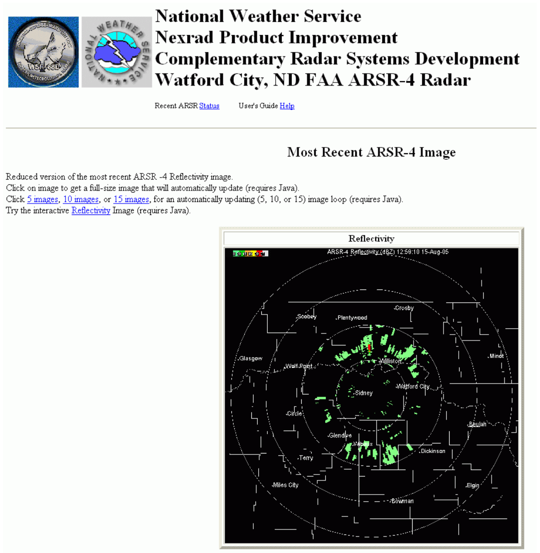

Figure 9 NWS-developed ARSR-4 Web Server

3.2 ARSR-4 Operational Considerations

A proof-of-concept demonstration to evaluate NWS use of the ARSR-4 radar has been underway in North Dakota since 1999 (Saffle, 2001). The objective of this demonstration is to evaluate the utility of ARSR-4 data in NWS winter weather operations in the Williston area, particularly for heavy snow events occurring with low altitude storm tops.

In 2001, the FAA completed modifications to the Watford City, ND ARSR-4 to provide six-level NWS DVIP output. Using an NWS OST developed Web server. ARSR-4 data was assessed at the Bismarck, ND WFO during the winter of 2001-2002. Evaluation concluded that the range thresholds used by the ARSR-4 to switch beams were not optimal for low altitude precipitation detection. Example data from the ARSR-4 web server are provided by Saffle (2001), Stern (2002), and Stern (2003).

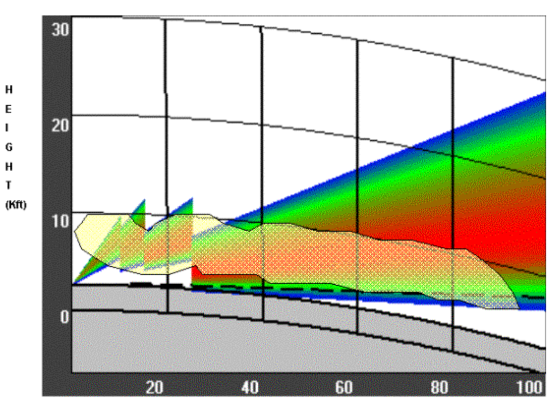

Figure 10 New ARSR-4 Switch Range Setting

In 2004, the FAA completed NWS-requested modifications to the ARSR-4 to provide a new set of thresholds (see Figure 10). Comparing Figures 8 and 10, notice that the red-colored center of each beam used to create reflectivity products now intersects the layers of snow (depicted as yellow hatching) that typically occur between 5,000 and 10,000 feet. The NWS evaluated the ARSR-4 with this new "Switch Range" setting during the 2004-2005 winter season and the report is undergoing formal coordination.

Although snow detection was the motivation for the Williston demonstration, ARSR-4 data is useful to NWS operations for a variety of other types of weather. For example, the ARSR-4 reflectivity product in figure 11 provides a good depiction of a convective event. This figure also shows an effect of the six-level NWS DVIP output scheme, which reports levels 1-5 at short ranges and levels 2-6 at longer ranges. Notice the absence of level 6 within the first two range rings and absence of level 1 beyond that same range. The switch range scheme can cause data ring artifacts since at set ranges a change is made to using lower elevation beams. An example of this is evident in figure 11 within the inner range ring.

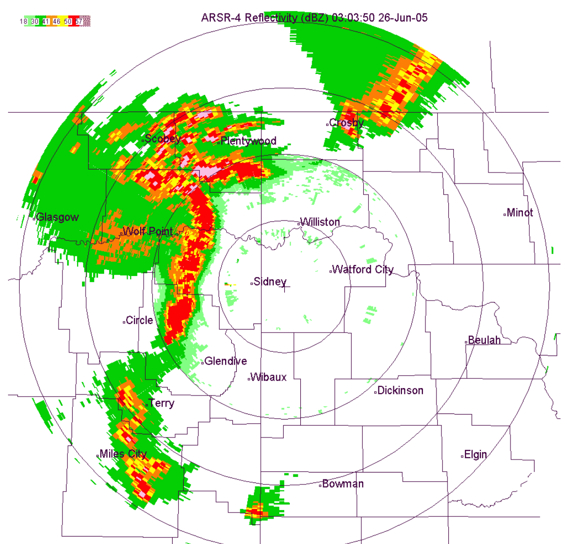

Figure 11 ARSR-4 Reflectivity Product from Watford City, ND on June 26, 2005 at 303Z

3.3 Future Plans

Similar to the SPG approach being followed for TDWR data, the NWS plans to develop the capability to generate radar products from ARSR-4 data in a form which can be displayed in AWIPS D2D and integrated with WSR-88D radar data and other types of weather data. A six-level reflectivity product could be generated as often as every 36 seconds at a spatial resolution of one-quarter nmi in range by 1.41 degrees in azimuth extending out as far as 250 nmi.

After testing the new switch range setting in North Dakota, the FAA will deploy the new ARSR-4 software, containing the NWS 6-level output and the new switch range scheme, to all radars, which will then allow the NWS to use ARSR-4 data from other sites. Immediate benefits could be gained from radars in locations such as Washington State, to complement WSR-88D coverage west of the Cascades.

Another approach that could be pursued is to modify the ARSR-4 to add an external NWS signal processor in order to obtain higher resolution reflectivity data from several elevations and Doppler data which could then be used as input to more sophisticated algorithms and products.

4. ASR-11

The ASR-11 is a solid-state, S-Band, terminal area air traffic control radar. The FAA and the DoD are currently deploying the ASR-11 at over 200 airports (Figure 12) serving smaller metropolitan areas and military airfields (Raytheon, 2002).

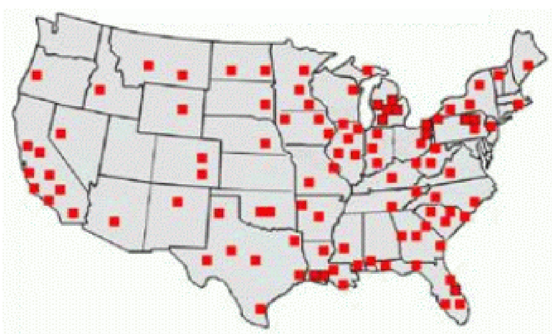

Figure 12 ASR-11 Site Locations

The ASR-11 employs a fan beam antenna with the following dimensions: 1.41 degrees in the horizontal by 4.8 degrees in the vertical. The antenna rotates at 12 RPM and generates a six-level reflectivity map based on the NWS DVIP standard every 30 seconds. The coverage range extends to 60 nmi at a resolution of one-half nmi.

4.1 Products and Capabilities

The ASR-11 Web server display system is modeled after the ARSR-4 Web server. Reflectivity images are provided at one-minute updates which extend out to 60 nmi. The reflectivity data is based on the six-level NWS DVIP standard. The Web server includes looping, data sampling, 14 day archive of image files, system status, and a user manual. The home page of the ARSR-4 Web server is shown in figure 13.

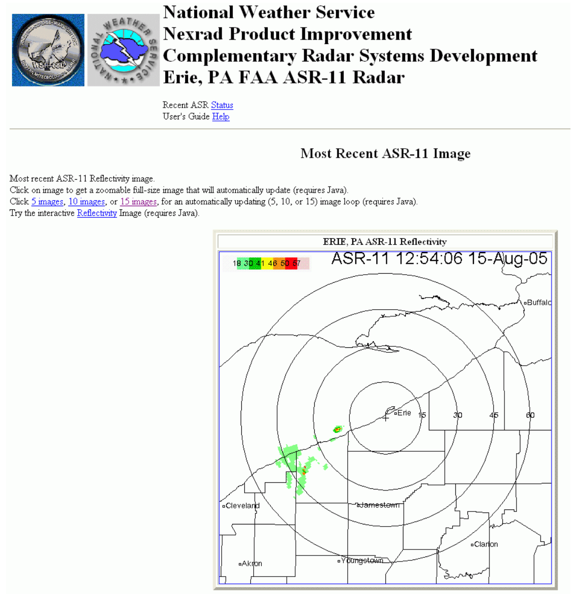

Figure 13 NWS-developed ASR-11 Web Server

4.2 ASR-11 Operational Considerations

The ASR-11 Web server is installed at the Cleveland, OH WFO and receiving data from the ASR-11 in Erie, PA. The objectives of the Erie demonstration are to evaluate the utility of ASR-11 data in NWS lake-effect snow operations in the Erie area, and to determine if the ASR-11 data can replace the Erie WSR-74C data for lake-effect snow. The FAA accepted this new radar during the summer of 2004 and it was commissioned in July 2005. The Cleveland WFO began evaluating ASR-11 data in November 2004, but radar data quality problems caused the demonstration to be delayed until fall of 2005.

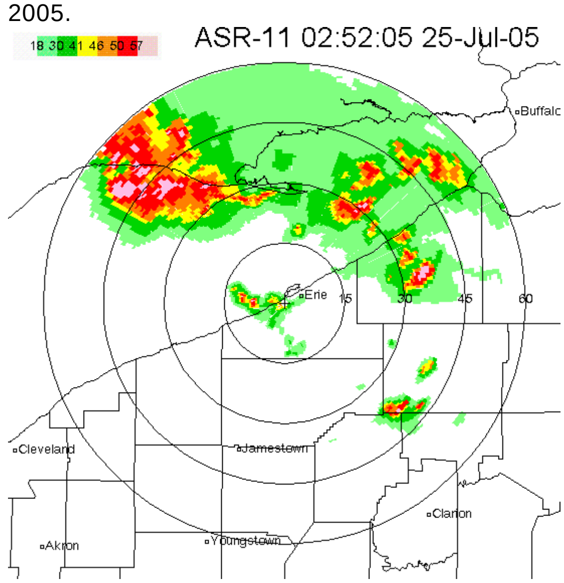

Figure 14 ASR-11 Reflectivity Product from Erie, PA July 25, 2005 at 252Z

Like the ARSR-4, winter weather is the initial motivation for the ASR-11 demonstration. However, as shown by the Web server reflectivity image in figure 14 convective weather is well represented in the ASR-11 data.

4.2 Future Plans

As described for the ARSR-4 and TDWR, the NWS plans to develop the capability to generate radar products from ASR-11 data in a form that can be displayed in AWIPS D2D and integrated with WSR-88D radar data and other types of weather data. A six-level reflectivity product would be generated as frequently as every 30 seconds at a spatial resolution of one-half nmi by 1.4 degrees in azimuth with a maximum range of 60 nmi.

Since processing requirements for ARSR-4 and ASR-11 products are modest, it is likely that the SPG could generate them along with the TDWR products for sites with access to multiple types of radar

5. SUMMARY

The NWS continues to make progress on incorporating FAA radar data into NWS operations. The three radar systems discussed provide frequent data updates and are located in areas which can provide complementary information to WSR-88D data. Radar data assessment projects are in progress for the ARSR-4 at the Bismarck, ND WFO and for the ASR-11 at the Cleveland, OH WFO. In 2005, the NWS began deploying the SPG system, which will provide to NWS forecasters TDWR data which is fully integrated with other weather data and the full suite of AWIPS user capabilities.

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