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ANALYSIS AND PLANS FOR USING FAA RADAR WEATHER DATA IN THE WSR-88D

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1. INTRODUCTION

With the deployment of the Open Systems Radar Product Generator (ORPG), atmospheric scientists and techniques developers will have the full rich data set of the Weather Surveillance Radar, 1988 Doppler (WSR-88D) at their disposal for analysis and new algorithm development. In addition, by exploiting the “open” architecture of the ORPG, it will be possible to integrate weather data from more than one type of radar.

Under the sponsorship of the NEXRAD Product Improvement (NPI) Program, the ability of the ORPG to ingest and process weather data from FAA radars will be utilized. Plans are to include weather data from the Air Route Surveillance Radar, model 4 (ARSR-4), a phased array coastal and border defense and surveillance system; the Airport Surveillance Radars, model 9 and 11 (ASR-9/ASR-11), which are short-range airport radar systems; and the Terminal Doppler Weather Radar (TDWR), which generates high-resolution data at 45 of the nation’s busiest airports.

This paper will update implementation plans for the inclusion of FAA radar weather data within the ORPG and compare aircraft surveillance and meteorological radars for weather imaging.

2. BACKGROUND

Several recent papers have discussed the benefits of incorporating FAA Surveillance radar data into the ORPG as complementary data sets (Saffle, Blanchard, Istok, Pickard, Shema, Holt and Johnson, 2001, Vasiloff, 2001,Saffle, Istok, and Johnson, 2001, Weber, 2000). This paper will focus on work accomplished on bringing ARSR-4 radar weather data into the ORPG and subsequent algorithm development. In addition, implementation plans will be discussed for additional acquisition of FAA radar data sets.

3. ARSR-4

The ARSR-4 is a joint Federal Aviation Administration (FAA) and Department of Defense (DoD) program whose mission is to provide aircraft position information to the FAA, Air Force, Navy and Customs Service. As a secondary function, the ARSR-4 also provides weather information to both the FAA and the National Weather Service (NWS). In mid 2000, the FAA completed deployment of 40 ARSR-4 systems around the periphery of the continental United States.

The ARSR-4 provides several unique capabilities not found in other long-range radars. It can detect a one-square-meter object out to 250 nautical miles (NM). This square-meter target can even be detected through severe weather conditions including heavy ground and sea interference as well as large bird migrations.

The high resolution of the ARSR-4 can be attributed to its radar data acquisition system. Within the huge, 60-foot diameter dome is housed a large L-Band phased-array antenna. Within a phased array system, individual (array) elements can be electronically controlled to manipulate the direction and shape of the beams. With a fixed rotation rate of 5 RPM, the 9 radar “beams” can sample an entire “volume” of the atmosphere every 12 seconds.

Modifications to the ARSR-4 weather processing software on behalf of NWS were recently completed. The “ARSR-4 Extended Weather Software Modification” enhances the weather detection and reporting capabilities of the ARSR-4. The software modification enables the ARSR-4 to simultaneously report both 3 and 5 level weather, as well as detect level 1 weather. In addition, a new “start of picture” message precedes transmission of a complete weather picture, whereas before a picture was built up in multiple scans.

The following sections will provide an overview into both the hardware and software that was required to integrate the ARSR-4 weather data set into the ORPG. Thereafter, a brief discussion comparing WSR-88D data to ARSR-4 weather data is presented.

3.1 Communications between the ARSR-4 and ORPG

The ARSR-4 weather processor transmits weather messages in CD-2 data format through a transmit-only synchronous serial 9600 Baud dedicated Telco connection. The ORPG communications handling consists of synchronous modem, PTI MPS800 Communications Server, and ORPG ARSR Communications Manager daemon. The MPS Server runs PTI Radar Receiver Software, which supports the CD-2 protocol. The PTI receives the weather messages, converts the data from 12 to 16 bits, and transfers messages to the ORPG via LAN connectivity. The ORPG ARSR Communications Manager controls the communications connectivity, interfaces with the PTI Server, receives, formats and time stamps the ARSR weather messages, and sequentially places messages into an ORPG linear buffer for subsequent processing and reflectivity product generation. Figure 1 depicts the ARSR-4 weather data acquisition path.

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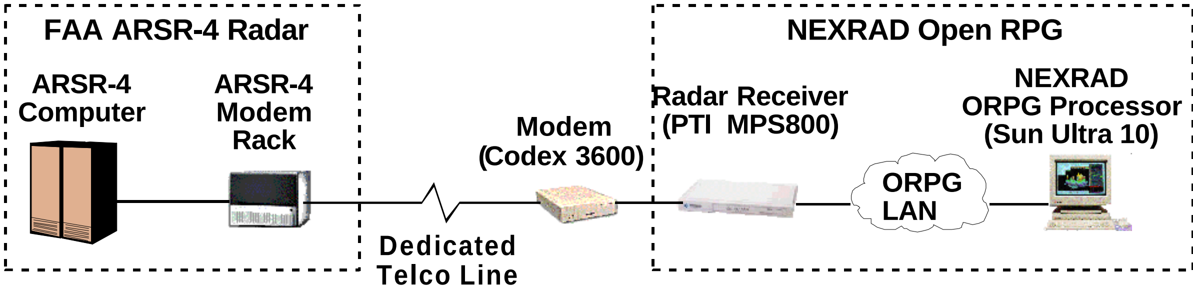

Figure 1. ARSR-4 Weather Data Acquisition Path

3.2 Processing ARSR-4 Data in the ORPG

Two types of records can be processed during ARSR-4 data acquisition. These are the communications status and raw ARSR-4 messages. The former consists of words that indicate the status of the data connection and the results of the most recent ingest processing. Interpreting these messages can indicate if the communications manager is connected or in a terminating condition.

Raw ARSR-4 messages can be of two formats: status or weather level messages. Status messages contain bit fields that reveal the health of the ARSR-4 system, its subsystems, communications and buffers. Weather level messages contain vector information about the reflectivity values in the bins.

Specifically, ARSR-4 reflectivity values are modeled very close to the old NWS MDR (Manually Digitized Radar) values, from level 1 through 6. Each vector contains an azimuth, start range, stop range and weather level value. Only those bins that contain a reflectivity value are transmitted.

To make the usage of ARSR-4 reflectivity data similar to the native WSR-88D data, a new process has been created. The ARSR-4 PServer (short for Product Server) has been developed to read in the raw data records and put them into a common data structure more closely resembling a WSR-88D elevation.

The PServer uses a daemon to constantly read records from the input linear buffer. The process discriminates between communications status messages and radar data messages and continuously checks the status of the data lines. When a “start of picture” message is received, then the system begins to build the radar ‘scan’ or ‘map’ (which is the equivalent analogy to an 88D elevation). Quality control routines are used to monitor the health of the ARSR-4 through interpretation of status messages. In addition, routines are used to ensure that all decoded fields are in proper ranges before placing them in the scan structure. If at any time a quality control flag is set, then additional processing for that map can be aborted, resetting the entire routine for the next scan.

If the map passes all quality control routines, then the output is placed into a linear buffer and an event notification flag is set within the ORPG to alert post-processing algorithms that a new ARSR-4 scan is available.

3.3 ARSR-4 Hybrid Scan Reflectivity Algorithm

Within the ORPG, an event flag has been designated to indicate when a new ARSR-4 scan is ready for processing. The first algorithm to take advantage of this new data set is called the ARSR-4 Hybrid Scan Reflectivity (HSR) Algorithm.

The reason for the use of the term “Hybrid Scan” is because the ARSR-4 only samples for weather in its 4 lowest beams. This results in an approximate CAPPI (Constant Altitude Plan Position Indicator) environment. A “stair stepping” methodology is used in order to sample a portion of each of the lowest beams (Figure 2). Hence, at close in ranges, only weather data from beam 4 is used followed by each succeeding beam until the full range is realized. While the ARSR-4 has a full range of 250 NM, weather sampling will typically be limited to within 100 to 150 NM.

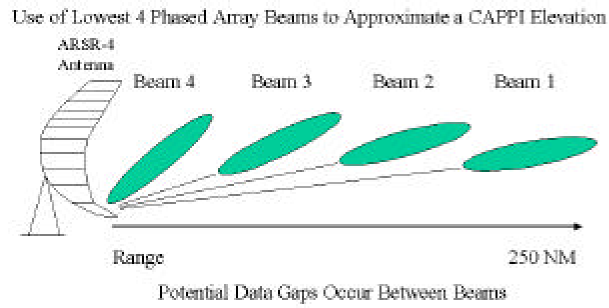

Figure 2. ARSR-4 Beam Structure

In addition, the ARSR-4’s radial has an azimuthal extent of 1.41 degrees, which results in a full scan containing 256 ‘wedges’ (similar to 88D radials). Finally, the reflectivity range resolution is two times that of the WSR-88D at 0.25 NM. The resulting image resembles an 8-level base reflectivity product, which is packaged in a fully compliant format.

Figure 4 compares the images from the Oklahoma City ARSR-4 (left) and the close by Norman, OK WSR-88D (KTLX). The WSR-88D image has more noise from being more sensitive and more colors to show storm structure. The ARSR-4 image accurately shows the most important features and provides valuable data for warnings or backup operations.

3.4 ARSR-4 Data Issues

The previous section described the azimuth and range differences between the ARSR-4 and WSR-88D. However, future developers may find it interesting to note a few other differences:

- For any given range bin, only 5 weather levels are available. For the first (closest in) beam, weather levels 1 through 5 are processed. Beyond the first beam, only levels 2 though 6 are processed. This means that there can be a data discontinuity at the first beam switching range. This feature can be seen in Figure 4 at the second range ring.

- The primary mission of the ARSR-4 is to provide aircraft tracking information. Hydrometeorological targets can hinder this processing. Hence, the ARSR-4 employs a scheme where its polarization fields are switched depending on the amount of weather in individual sectors. In clear air operations (less than 15 percent weather coverage), the ARSR-4 uses linear polarization. However, when the weather in a sector (which consists of 8 wedges) contains bins with 35 percent or more weather returns, then circular polarization is used. Using this scheme, circular depolarization can occur in areas of flat raindrops, which can lead to a loss of precipitation echo, produce underestimates of rainfall and attenuated shadow regions behind high reflectivity cores.

- The ARSR-4 collects 3 full scans before creating an output map for transmission. A temporal smoothing routine is used to reduce echo blossoming.

With these differences known and understood, the full rich data set from the ARSR-4 will add to the capability of the ORPG as a whole.

4. TDWR PLANS AND STATUS

At time of writing of this paper (Oct, 2001), several NWS WFOs (weather forecast offices) were receiving TDWR data for use in operations. The prototype system uses software designed by the Massachusetts Institute of Technology's Lincoln Laboratory for ingest, processing and output of base reflectivity and velocity images. Those NWS offices using TDWR data in operations are listed in the following table.

NWS Office	TDWR Location
WFO Baltimore/Washington, DC	Baltimore/Washington International Airport
WFO Salt Lake City	Salt Lake City Airport
WFO Taunton, MA	Boston Logan Airport
National Severe Storms Laboratory	Will Rogers Airport, Oklahoma City

During the fall of 2001, plans were underway to develop the same type of ingest capability for the TDWR as was created for the ARSR-4. The capability to ingest, and format data for post-processing could be ready in a prototype by the end of calendar year 2001.

Figure 3 shows the Doppler velocity couplet from the Baltimore Airport TDWR as an F3 tornado was striking the University of Maryland Campus on Sept 24, 2001. The hole inside maximum inbound region (center of image) indicates that the radar could not determine the highest velocity. The next outer color represents an inbound velocity of 64 knots.

Figure 5 compares velocity images from the Baltimore Airport TDWR (left) and the Sterling VA WSR-88D (right). The velocity couplet from the University of Maryland tornado is circled in each image. It is clear that the high resolution TDWR imagery can add important information, which can aid the forecasters in the preparation of warnings.

5. FUTURE PLANS FOR ASR RADARS

Current plans are to bring data from ASR-11 data into the ORPG during calendar year, 2002. The ASR-11 is an S-Band radar used for local airport surveillance and has a range of between 60 and 80 NM. Like the ARSR-4, it uses both linear and circular polarization to limit the effects of weather and has a 1.4 degree beamwidth. However, the system uses only two "beams" to sample the atmosphere. These are narrow azimuthally but significant in vertical extent.

ASR-9 data will be similar in structure to the ASR-11 and there are future plans to bring this data set into the ORPG.

6. CONCLUSION

New science and operations will benefit from the introduction of FAA weather radar data sets into the ORPG. In particular, the high resolution and fast refresh rates of the TDWR and ARSR-4 will provide new opportunities for expanding the science of radar meteorology and to enhance current NWS warning operations.

7. REFERENCES

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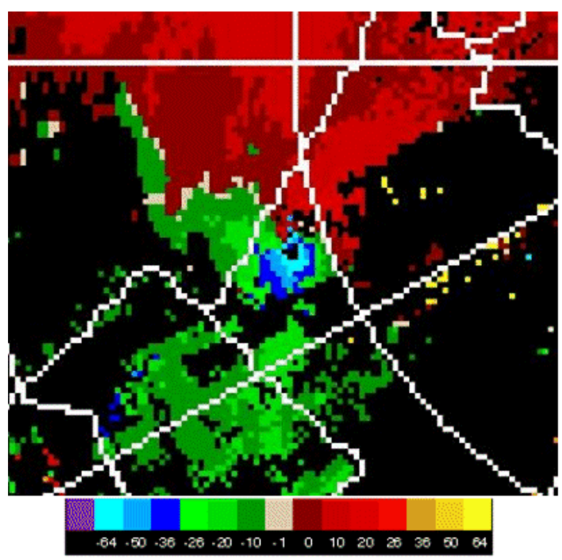

Figure 3. Baltimore TDWR Velocity Image from Sept 24, 2001, 2122 UTC. Tornadic Vortex Signature at center. Distance from the TDWR: 16 NM. Approximate beam elevation: 250 feet AGL

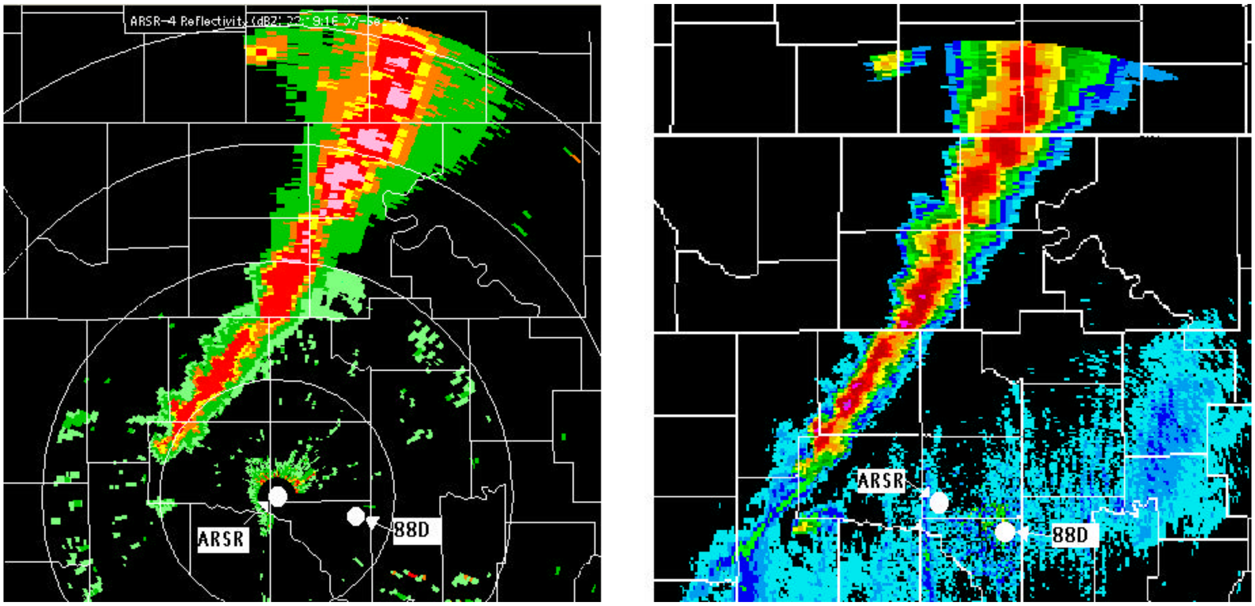

Figure 4. Reflectivity images, both from Sept. 7, 2001 at 2219 UTC. Left image is a Hybrid-Scan Reflectivity Map from the Oklahoma City ARSR-4. Right image is a Base Reflectivity Elevation from the Norman, OK, (KTLX) WSR-88D .Locations of each radar site are shown on each image as white circles.

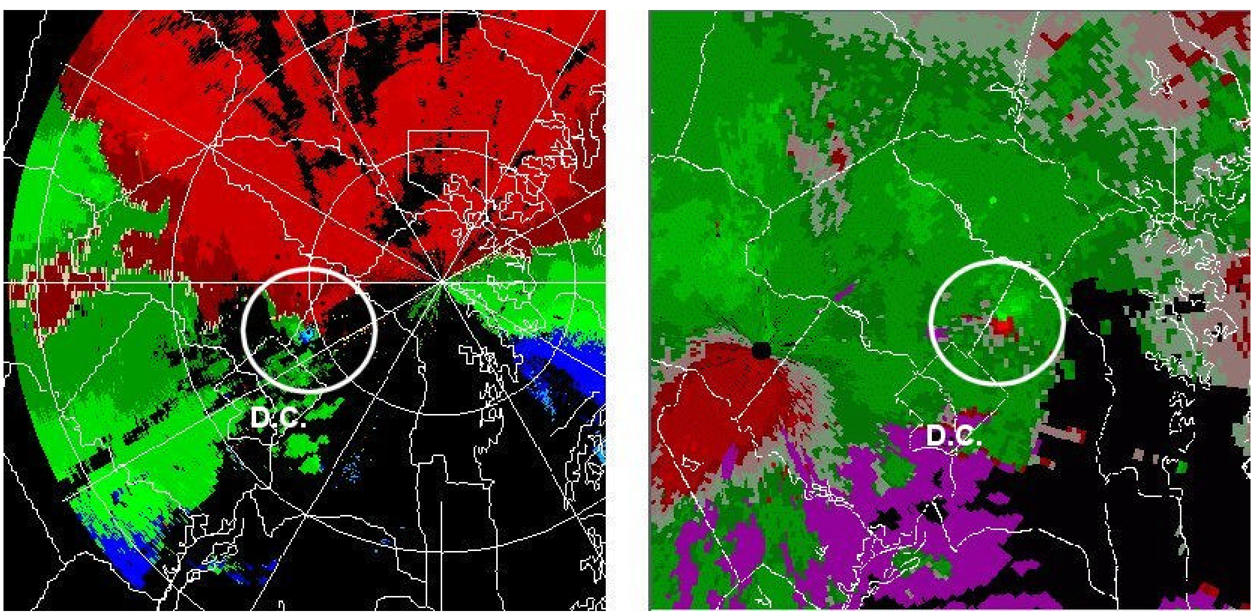

Figure 5. Velocity Images from the F3 College Park, MD Tornado of Sept 24, 2001. Left Image is a Base Velocity Image from the Baltimore TDWR at 2122 UTC. The inbound (blue) couplet exceeds 64 knots and contains a data 'hole' indicating that the radar could not determine the maximum inbound speed. The right image shows a Storm Relative Doppler Velocity Map (SRM) from the Sterling, VA (KLWX) WSR-88D from 2127 UTC. Gate-to-Gate Storm Relative Shear indicates 100+ Knots of rotation.