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GENERAL PURPOSE WEATHER SURVEILLANCE WITH THE AIRPORT SURVEILLANCE RADAR 11 (ASR-11) * †

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1. INTRODUCTION *

The United States (US) government recently completed the installation of a network of 141 WSR-88D Doppler weather radars across the continental US (CONUS) dedicated exclusively to weather surveillance. This network provides nearly continuous single-Doppler radar coverage of weather reflectivity over the country and is credited with improving the severe weather warnings (Bieringer and Ray, 1996). While this new network is a significant improvement over the radar network that it replaced, it still falls short of providing homogeneous low altitude coverage across the entire country.

The US government through the Federal Aviation Administration (FAA) and Department of Defense (DOD) also operates a national radar network consisting of over 400 C to L band radars. There is growing interest in using these FAA and DOD radars to supplement data provided by the WSR-88D network (Weber, 2000). Among the radars in the FAA/DOD network is the next generation in airport surveillance radars, the ASR-11. This paper examines the possibility of using data from the ASR-11 to supplement data available from the WSR-88D network.

Section 2 discusses the difficulties associated with detecting low altitude weather phenomena at longer ranges with the WSR-88D radar network. In this section we illustrate an example of where the ASR-11 can be used to supplement the WSR-88D radar network. This extends the work of (Weber, 2001) by focusing on some of the operational weather surveillance deficiencies in the WSR-88D network that could be improved by using reflectivity products currently provided by the ASR-11. Section 3 discusses ASR-11 weather reflectivity data and provides an example of its utility. Section 4 describes potential for adding a Doppler signal processing capability to the ASR-11 that is similar to the ASR-9 weather systems processor (WSP) (Weber, 1992). This is followed by a brief summary and conclusions.

2. BACKGROUND

Shallow and low altitude weather phenomena are difficult for the WSR-88D radars to detect on the periphery of their coverage regions. This problem arises from the fact that under normal electromagnetic (EM) propagation conditions the height of the pencil beam from a weather radar increases with range from the radar. For example, the 0.5° elevation beam of the WSR-88D will normally sample only the atmosphere above 2600 m at ranges beyond 150 km. This tends to not be a significant issue when using weather reflectivity returns to identify, track and determine the intensity of deep convection; however, it can be a significant problem if the weather phenomena are more shallow in nature.

An example of one such atmospheric phenomenon that has a serious economic and public safety impact is lake effect snowfall. Lake effect snow-bands are typically very shallow in nature with depths extending to a maximum height of 2500 – 3000 meters. (Pease and Sykes, 1966) In order to effectively sample a lake effect snow-band, a weather radar typically needs to sample the storm at elevations below 2500 meters. Under normal EM propagation conditions this would require the snow-band to be within 145 km of the radar to detect it and even closer in order to provide more accurate estimation of its intensity. The same argument holds for other shallow phenomena such as developing convection and some forms of stratiform precipitation.

Within the WSR-88D network there are numerous regions where the radars do not provide adequate low altitude coverage. In these regions, the closest WSR-88D is typically not capable of detecting, or will underestimate the intensity of, the low altitude phenomena. For this reason it is desirable to explore the possibility of utilizing data from the numerous ASR-11 radars around the country.

Data from the ASR-11 radars are of particular interest for a number of reasons. They are numerous: over 110 ASR-11s are scheduled for deployment around the US. These ASR-11s are slated to be installed in the nation's second tier airports which are often located near less populous cities. WSR-88D radars are often sited near larger metropolitan areas. As a result, some of the ASR-11 radars are located in regions where the WSR-88D network has poor low altitude coverage. Finally, the ASR-11 has a rapid update rate. It produces a new weather reflectivity image every 30 seconds versus approximately five to six minutes (depending on the VCP) for a complete volume scan from the WSR-88D.

Figure 1 illustrates a portion of the WSR-88D radar network in the great lakes region. The solid gray circles depict WSR-88D coverage out to a range of 100 km. At a range of 100 km the center of the WSR-88D beam samples the atmosphere at an elevation of approximately 2000 meters and is used in this paper to represent the point at which low altitude radar coverage becomes degraded. Overlaid on this same map are the ASR-11 locations and dashed circles denoting their coverage out to a range of 112 km. Although the fan-beam ASR-11 may likewise have problems accurately measuring reflectivity from shallow precipitation echoes over its entire coverage area, the figure does indicate that additional low altitude weather surveillance can be

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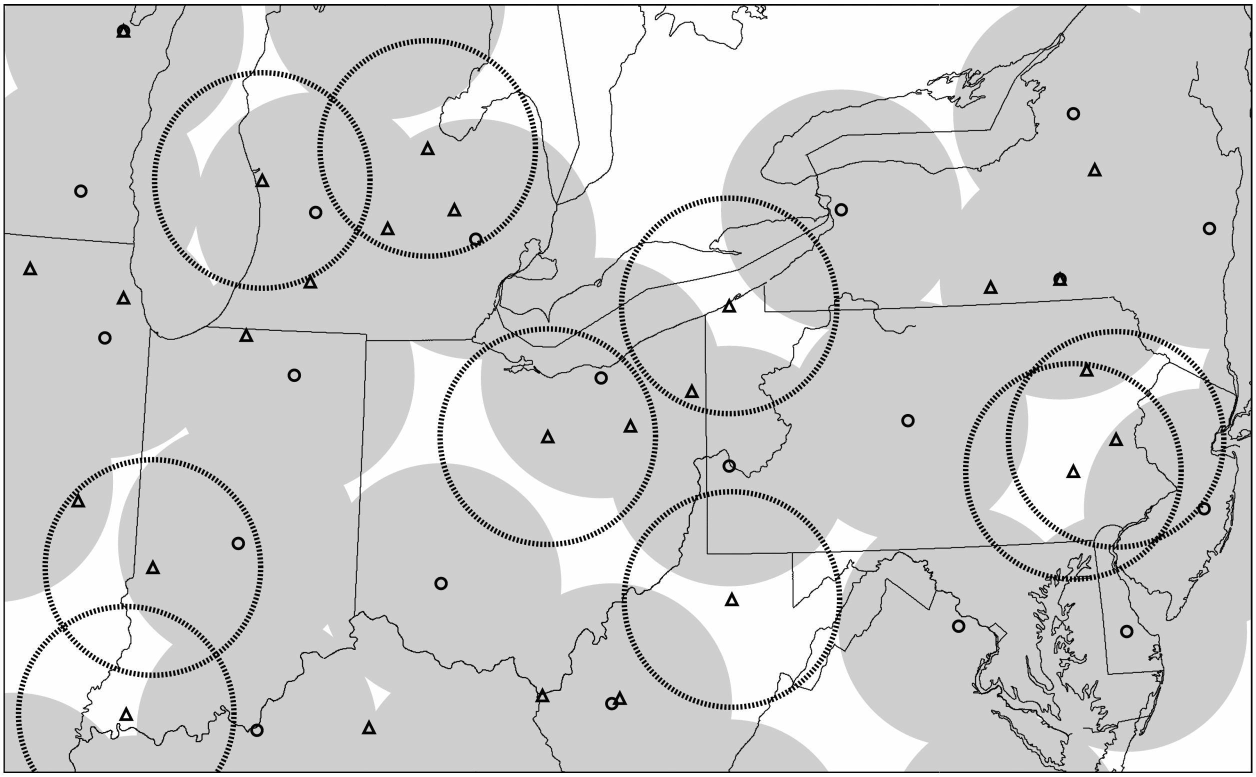

Figure 1. WSR-88D and ASR-11 radar networks. Circles are used to represent the WSR-88D locations and triangles are used to represent ASR-11 locations. WSR-88D radar coverage out to a range of 100 km is illustrated by the gray circles. ASR-11 locations which can provide supplemental low altitude coverage are illustrated by the dashed circles.

provided in the regions between the WSR-88D's. Figure 1 illustrates that the ASR-11 could supplement the WSR-88D low altitude weather radar coverage in eastern Pennsylvania, West Virginia, portions of central Ohio, and near Erie, PA.

3. ASR-11 WEATHER REFLECTIVITY DATA

Airport surveillance radars, as the name suggests, are designed to detect and track aircraft in the terminal airspace surrounding an airport. The terminal airspace typically covers a 50-60 nm radius centered on the airport. To support their primary mission of tracking aircraft, these radars use rapid antenna scan rates, fan shaped beams, pulse repetition frequency (PRF), and radio frequency (RF) diversity. Newer ASRs like the ASR-9 and ASR-11 also have a weather surveillance capability. Due to restrictions imposed by the target channel, some features of the radar signal processing and hardware differ from those used by conventional weather radars. Although the ASR-11 is not designed strictly to be a weather surveillance radar, it is still capable of providing an accurate representation of precipitation intensity and storm structure.

One important feature in which airport surveillance and weather radars differ is in the shape of the radar beam. ASR radars use antennas which produce a fan shaped beam pattern while weather radars use a pencil shaped beam. The fan shaped beam supports the requirement that the radar detect aircraft from the surface to 40 kft. This is advantageous for rapid detection and tracking of aircraft across a large volume of sky but also allows this class of radar to scan a large volume of the atmosphere for weather echoes very quickly. The returns from this radar are in essence an integration of reflectivity through a vertical column. A single scan from an ASR radar can, in a simplified sense, be equated to series of vertically integrated scans from different elevation tilts of a weather radar. This is an important consideration when making comparisons between weather reflectivity data from ASR and weather radars.

Figure 2 provides a sample of six level video integrated precipitation (VIP) weather reflectivity data from the Eglin, AFB (VPS) ASR-11 at 19:07 on January 19th 2001. The six weather levels correspond to weather reflectivity ranges in dBZ units given in table 1. A corresponding WSR-88D vertically integrated liquid water (VIL) image is shown in Figure 3. As one would expect, the images do not match exactly; however, the ASR-11 display does capture the general structure of the precipitation detected by the WSR-88D. These images illustrate that the ASR-11 can provide an accurate depiction of precipitation intensity that would be useful when WSR-88D returns are degraded or unavailable.

Level	1	2	3	4	5	6
dBZ	18-29	30-40	41-45	46-49	50-56	57+

Table 1. Six level VIP weather and the corresponding weather reflectivity ranges.

4. ASR-11 AS A DOPPLER WEATHER RADAR

Shallow and low altitude Doppler velocity signatures are also difficult and sometimes impossible to detect at longer ranges from the radar. The development of the ASR-9 WSP has demonstrated that operationally useful Doppler velocity measurements can be made with an air-traffic control radar. These radar measurements are of sufficient quality that it is possible in many cases to discern gust fronts, microburst outflows, and thunderstorm mesocyclonic signatures in the velocity returns. Automated algorithms have also been designed and tuned to detect gust fronts and microbursts (Weber, 1995). The ASR-11 currently provides only six level weather reflectivity information; however, it is technically possible to develop a Doppler weather processor akin to the WSP for this radar (Weber, 1999). Although no significant efforts have been made thus far to develop these capabilities for the ASR-11, simulations have been performed, and ASR-11 time series data are being examined to demonstrate feasibility.

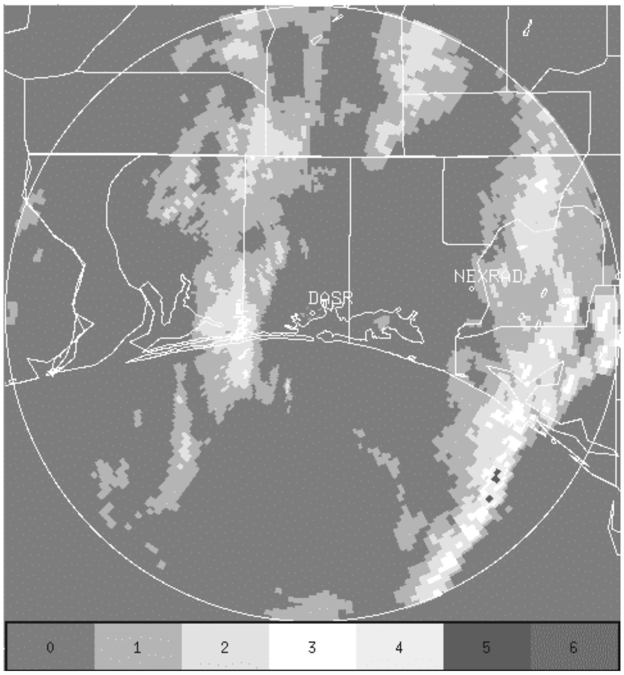

Figure 2. Six VIP level reflectivity image from the Eglin AFB, FL ASR-11. This image depicts stratiform precipitation detected by the ASR-11 following a strong cold frontal passage.

A more detailed discussion of this topic can be found in Weber (1999). This paper discusses the technical challenges associated with developing a WSP enhancement for the ASR-11 and provides an example of weather reflectivity and Doppler velocity data that could be derived from this radar. His study suggests that recognizable Doppler velocity signatures can be detected by an ASR-11 radar.

5. CONCLUSIONS

The current network of WSR-88D radars is a significant advancement towards improving the nation's weather forecasting and warning accuracy; however, it still does not provide sufficient coverage for low altitude weather phenomena. Since it is not economically feasible to deploy additional WSR-88D radars, one must look elsewhere for a solution. The weather capable radars operated by the FAA/DOD, including the ASR-11, are well suited to compliment the WSR-88D radar network. This paper has briefly touched on the utility of using six level ASR-11 weather reflectivity data in regions with poor low altitude WSR-88D coverage. Furthermore, with additional technical development the ASR-11 could also provide improved weather reflectivity and Doppler velocity data in regions with poor coverage.

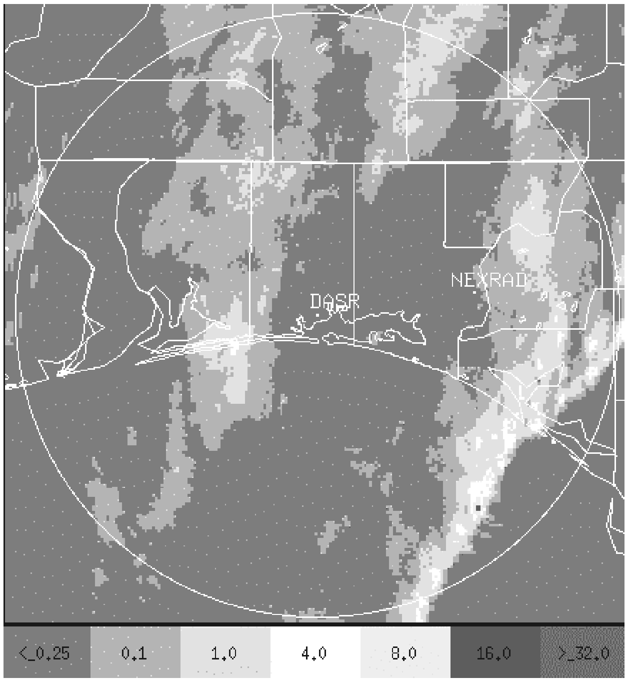

Figure 3. An image of vertically integrated liquid water (VIL), in units of kg/m^2 from the Red Bay, FL WSR-88D. This figure is for the same situation as that shown in Figure 2.

6. REFERENCES

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