6B.2 IMPORTANT CONSIDERATIONS TOWARD DEVELOPING SITE-SPECIFIC SCANNING STRATEGIES FOR WSR-88Ds

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1. INTRODUCTION

Full scale deployment of Weather Surveillance Radar – 1988 Doppler (WSR-88D) radars began in the early 1990s to consolidate, replace, upgrade, and expand aging radar networks in the U. S. (Whiton et al. 1998 a, b); radar coverage greatly improved. Four operational scanning strategies, or volume coverage patterns (VCPs), were installed into each WSR-88D as the common solution to radar surveillance. This initial suite consisted of two clear air VCPs and two precipitation VCPs; each begins scanning with a minimum elevation angle of 0.5 deg (Klazura and Imy 1993). For sites positioned near complex terrain the minimum elevation angle overshoots low-altitude weather hazards that impact surrounding communities, especially in valleys.

Simulations show potential benefits of elevation angles below 0.5 deg. As an illustration, low-altitude radar coverage at or below one kilometer for the Medford, OR WSR-88D (KMAX) from a lowest elevation angle of 0.5 deg, is depicted as a hatched red area in Fig. 1. If elevation angles below 0.5 deg were used coverage would increase as shown by the yellow region. Quantitatively, the red area covers 3,727 sq. km whereas the yellow area covers 51,851 sq. km. For a height of 1 kilometer above ground a 1,291 percent increase in coverage occurs! This desktop analysis of radar coverage improvements uses high resolution terrain data and considers the geometry of the half-power beam surface while assuming standard propagation. This simulation process is but one of several tools used to explore new VCPs for the WSR-88D network.

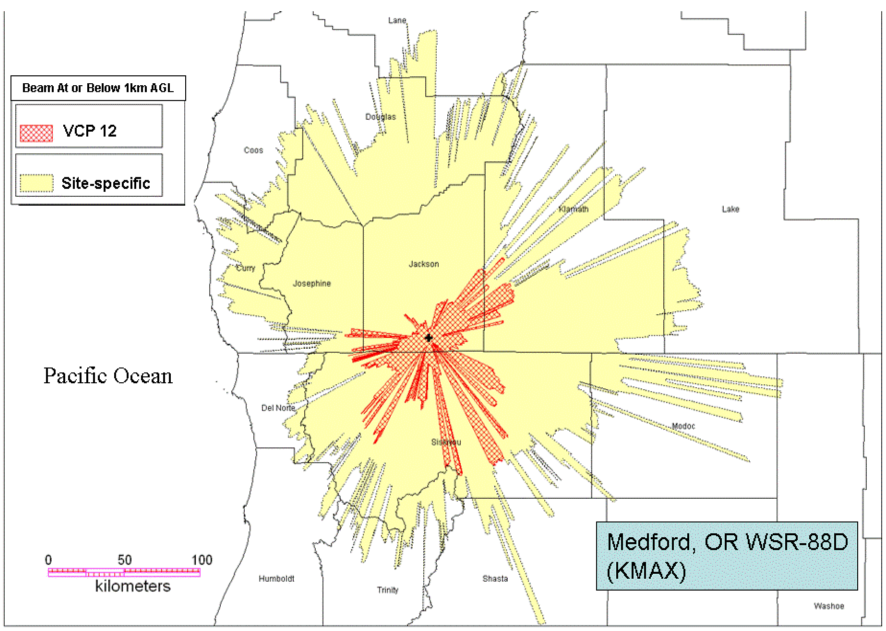

Figure 1 - Potential increase in low-altitude radar coverage is depicted for Medford, OR. Red hatched area shows the current coverage by taking into account the radar beam between half-power points at or below 1 km above ground level using VCP 12. Yellow region shows the possible increase in coverage for the same height above ground using a site-specific scan strategy having elevation angles as low as -0.8 degrees.

This paper describes important considerations to develop site-specific scanning strategies for some WSR-88D sites. A brief background and the benefits of this effort are discussed, as well as some of the requirements involved in the development of site-specific scanning strategies.

To confirm benefits of lower elevation angles, the WSR-88D Radar Operations Center (ROC)—in partnership with scientists and meteorologists at affected National Weather Service (NWS) Weather Forecast Offices (WFOs), the National Severe Storms Laboratory (NSSL), the Federal Aviation Administration (FAA), the Department of Defense (DoD), the Warning Decision Training Branch (WDTB) and the South Dakota School of Mines and Technology (SDSMT)—propose a field test for six WSR-88Ds, three located on mountain tops and three on relatively flat terrain. The field test plan, as discussed below, represents a major step to reach the ultimate goal of improving radar detection capabilities at sites where beam overshoot is a critically restrictive problem.

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2. BACKGROUND

As WSR-88D radar sites were being chosen according to numerous selection criteria (Leone et al. 1989), all WSR-88D radar sites were deployed with the lowest elevation angle set at 0.5 deg. In 2005 a National Research Council committee report (NRC 2005) determined the WSR-88D lowest scan angle as a constraint and stated, "This problem is of special concern for radars at high-altitude sites in mountainous areas," continuing with, "similar difficulties arise in areas subject to intense precipitation from shallow cloud systems, such as places in the lee of the Great Lakes affected by lake-effect snowstorms."

The committee summarized, "It is obvious that use of a lower antenna elevation angle from an elevated radar site would provide greater low-level coverage in directions not obscured by intervening terrain." With more experience from a proposed field test, benefits from site-specific scanning strategies as described in this paper might be realized.

Funds for testing or implementation have not been identified. Environmental studies, WSR-88D software changes, and potential impacts on user display systems involve additional costs that precede testing.

3. BENEFITS OF SITE-SPECIFIC SCANNING

In Canada, the network of operational Doppler radars effectively use negative elevation angles at some mountaintop sites and have recently applied lower elevation angles in winter months for flatland radars that need to detect shallow snowstorms caused by cold air advection over warm water (Donaldson et al. 2003).

Brown et al. (2002) show that by using negative elevation angles with the Missoula, MT WSR-88D (KMSX), forecasters at the local NWS office would be able to detect, among other things, the onset of arctic blizzards in the surrounding valleys and the presence of shallow warm-season severe storms triggered by the flow of cold air over a large lake 100 km from the radar. Scanning at an elevation angle of -0.8 deg, the radar would detect conditions within 1 km of the lake's surface. In addition, sensing at these lower elevation angles would greatly improve the accuracy of quantitative precipitation estimates throughout the radar coverage area.

Wood et al. (2003) discuss the three mountaintop WSR-88Ds that cover Utah and western Colorado: Salt Lake City, UT (KMTX), Cedar City, UT (KICX) and Grand Junction, CO (KGJX). The Salt Lake City radar is located on the south end of the Promontory Mountains that extend into Great Salt Lake about 75 km northwest of Salt Lake City. Being elevated, the radar does not sample the lower portions of shallow snowstorms and low-topped supercell storms and therefore does not provide the type of crucial information near the surface that negative elevation angles would provide. Neither the Cedar City nor Grand Junction mountaintop radars are sensing close enough to the surface in southern and southeastern Utah to realistically estimate how much precipitation is reaching the surface. The resulting absence of information is especially crucial during the warm season when hikers and tourists in the national parks and recreation areas in the region have the potential of encountering flash flooding. For the Cedar City radar the terrain drops off so rapidly to the southwest that the lowest elevation angle is 3–4 km above the surface at 100 km range and 6–7 km above the surface at 200 km. If the beam were lowered to –0.8 deg, it would be within 1–2 km of the surface out to ranges of 230 km from the radar and would be able to detect shallow cool season rainstorms that produce flooding by raining onto snow surfaces.

Brown et al. (2007) discuss one of the few WSR–88Ds in the northeastern U.S. that qualifies as a mountaintop radar, even though it is not as high above the surrounding terrain as those in the western states. The Fort Drum WSR–88D (KTYX) is located in eastern New York State on top of the Tughill Plateau about 50 km east of Lake Ontario and 0.52 km above the lake's surface. Lake-effect snowstorms typically are only 2 km deep, so using the current WSR–88D lowest elevation angle of 0.5 deg, these shallow snowstorms are detected only over the eastern quarter of the lake and surrounding terrain. However, if a lowest elevation angle of -0.4 deg were used, characteristics of the snowstorms could be monitored over the eastern two-thirds of the lake and surrounding terrain.

Brown et al. (2007) also show that by lowering flatland radars from 0.5 deg to 0.2 deg, the coverage area for shallow lake-effect snowstorms would increase by about 60%. Earlier theoretical considerations (Smith 1998) indicate that some flatland WSR-88D radars would be more effective using a lowest elevation angle of 0.2 to 0.3 deg.

These examples point to the potential benefit of implementing site-specific scanning at certain sites where limitations of the current VCPs hamper detection of weather near the earth's surface. Several of the WSR-88D sites listed in these studies have been included in the field test plan.

4. SIMULATIONS

Simulations, as mentioned, demonstrate that areal coverage will dramatically improve at some locations; and, other radar networks serve as successful real-world examples. Geographic Information System (GIS) tools have become indispensible as a way to quantify the operational performance of site-specific scanning strategies. Modeling techniques of a hypothetical radar beam as it scans about a specific topography are evolving. Each evaluation of weather radar beam blockages appears more realistic as model complexity increases although useful results are obtained from low resolution topographic information (Kucera et al. 2004).

Studies of specific interaction between radar beam and terrain have treated the beam geometry with varying degrees of sophistication. Howard et al. (2007) developed a basic line-of-radar-sight model that is useful for validating other models. Shipley et al. (2008) has explored beam coverage on Virtual Globe (VG) platforms such as Google Earth and NASA WorldWind. A VG representation of elevation scans above the earth's surface provides a convenient user interface and a surprisingly versatile and robust way to investigate beam occultation.

The GIS models used at the ROC employ sophisticated beam geometry and 1 arc-second terrain data from the Shuttle Radar Topography Mission (SRTM). If more than half of the beam is blocked, the beam is considered blocked. Computations are based upon azimuthal and vertical sampling in increments of one-tenth of a degree instead of typical one degree sampling.

Whether simulations are simple or complex, they can not replace the actual field test. Concurrent with operations, testing at a few carefully selected sites will help us identify potential problems and validate simulations.

5. CONSIDERATIONS

In terms of this project's goals, evaluating the meteorological benefits of site-specific scanning strategies is a central concern. Several opposing factors such as the relative project cost, systems limitations, and ground clutter impacts can be compared to benefits. The authors and many others believe fruition of this project offers a huge operational gain.

Proposals to improve the WSR-88D network need to clearly recommend 'how' and 'where' changes should be made. We must reasonably identify sites according to level-of-need for scanning adjustments and show a cost-benefit analysis. Because of earth's curvature, beam overshoot with increasing range is a known limitation of weather radar. Consequently, a method will be required to choose which sites might obtain the greatest benefit from lower elevation angles. Approximations of potential operational gain and increased public service are, in turn, closely linked to eventual costs.

System limitations related to product delivery need to be analyzed. Products originating from the WSR-88D are, in general, either elevation-based or volume-based. When additional elevation angles are assigned to a VCP, new elevation products, as well as more 'components' in existing volume products, are derived from the additional data. Product file structures and the number of volume-based products will not change. However, completely new elevation products will be available. Depending upon design, systems dependent upon the WSR-88D data may or may not require software changes. Increased bandwidth requirements will, in general, be inconsequential.

Another concern with lowering elevation angles is the expected increase in ground clutter. Again, a field test appears to be the only confident way to assess potential difficulties related to ground and sea clutter returns. Canadian radars using lower elevation angles do encounter increased ground clutter, so the general problem is recognized (Brown et al. 2007); however, recent clutter mitigation enhancements specific to the WSR-88D appear promising.

6. FIELD TEST PLAN

With a final objective to improve network radar operations, a field test plan identifies six test sites chosen to confirm existing theoretical studies that support use of specific scanning strategies. Results of the proposed field test will consist of qualitative evaluations of meteorological benefits and quantitative analyses of system limitations and ground clutter contamination. The test is designed to have little impact on existing operations of the WSR-88D network and external systems while providing new data to the local WFO staff and researchers.

The test plan specifies adding at least one lower elevation angle to the present VCPs at WSR-88D test sites where lower scans will provide the greatest benefit. New VCPs will not affect the normal distribution of products as generated from elevation angles of the current VCPs. Below is a list of the six proposed NWS test sites and the augmenting elevation angles for each:

Test Site	Added Angle(s)
• Missoula, MT (KMSX)	-0.8°,-0.4°,0.0°
• Salt Lake City, UT (KMTX)	-0.4°,0.0°
• Amarillo, TX (KAMA)	+0.2°
• North Webster, IN (KIWX)	+0.2°
• Medford, OR (KMAX)	-0.8°,-0.4°,0.0°
• Albuquerque, NM (KABX)	+0.2°

The improved coverages using these additional elevation angles are shown in Fig. 2.

A field test of lower elevation angles is competing for resources with other projects including newly engineered dual-polarization capabilities. Dual-polarization will be a major upgrade to the nation's WSR-88D network that represents a valuable new capability. Once the upgrade is complete, operational WSR-88Ds are expected to provide improved quantitative precipitation estimates, hydrometeor classifications, and the potential for other detection benefits. In fact, with dual-polarization capabilities, the WSR-88D might be less hampered from inevitable instances when the beam is partially blocked at lower elevation angles. However, beam overshoot will remain problematic even with dual polarization. The field test of lower angles can be performed with or without dual polarization capabilities.

7. SUMMARY

Lower scanning angles at some WSR-88D locations would provide additional crucial data that would result in improved performance of forecasts and local warnings, particularly at WFOs where radars are at high elevations. A two-year test is proposed to capture seasonal variation.

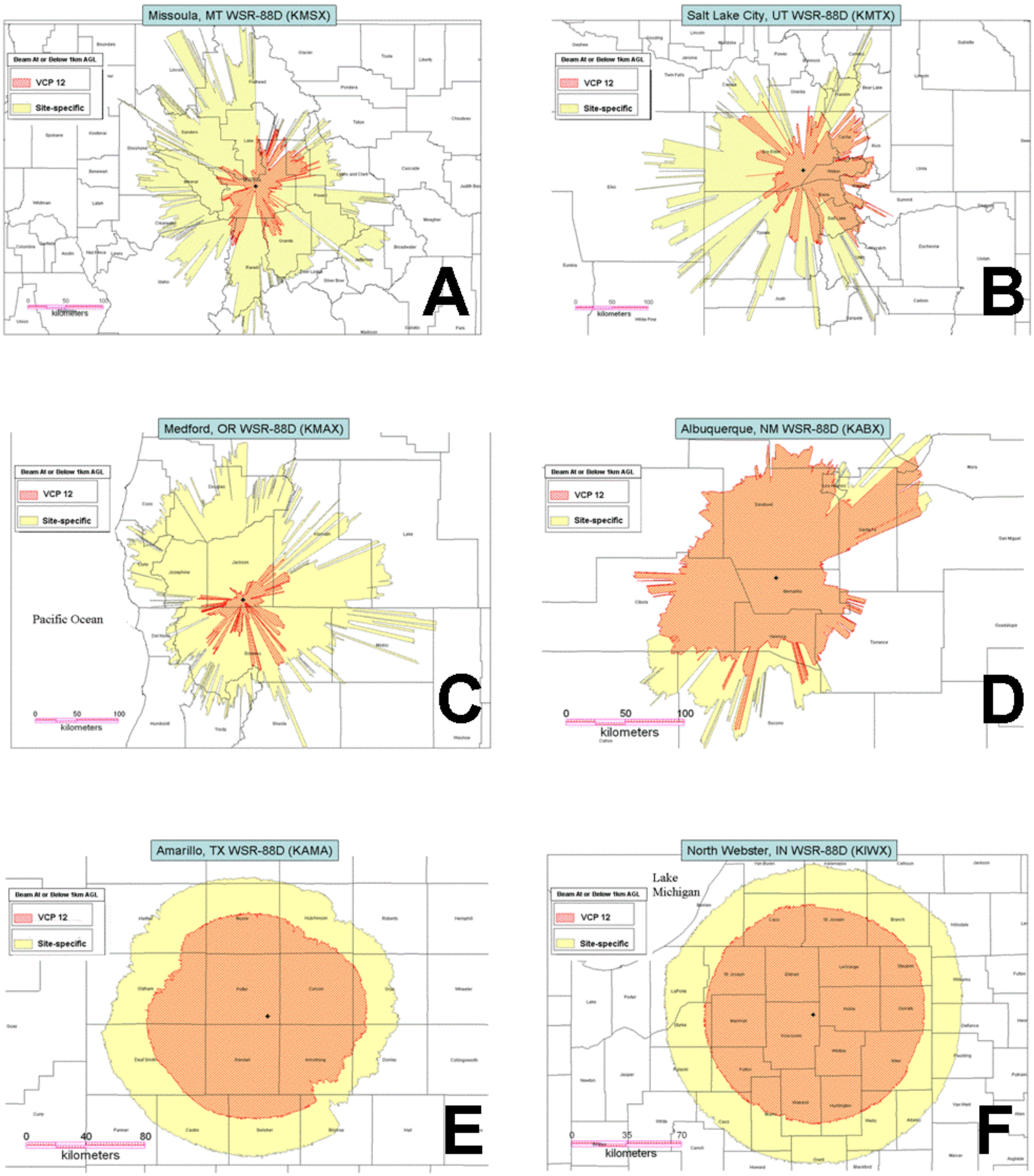

Figure 2 – As in figure 1, the potential increase in low-altitude radar coverage is depicted. Red hatched areas show the current coverage of the radar beam at or below 1 km above ground level. Yellow regions show the possible increase in coverage for the same height above ground using the additional elevation angles listed in the table on the previous page. The radar sites shown in these drawings (with percent coverage increase) are A. Missoula, MT (803%), B. Salt Lake City, UT (247%), C. Medford, OR (1291%), D. Albuquerque, NM (31%), E. Amarillo, TX (84%), and F. North Webster, IN (86%).

Expected benefits from simulations of lower elevation angles have been well documented. Simulations have become more realistic; however, a field test will allow us to learn more about WSR-88D software and interfacing systems changes, as well as costs. Meteorological advantages and unknown factors such as clutter returns can be documented.

The test is designed to provide verification data needed for eventual deployment at some sites. The results of the field test will be used to weigh costs and impacts during a final implementation decision process.

8. ACKNOWLEDGMENTS

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