5.2 NEW WSR-88D OPERATIONAL TECHNIQUES: RESPONDING TO RECENT WEATHER EVENTS

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1. INTRODUCTION

The WSR-88D has been operational for two decades. During that time, hard-coded Volume Coverage Patterns (VCPs) have been the only option for operators when choosing a volumetric scanning strategy. This constraint was due to the hardware limitations of the system. Predefined VCPs meant that VCP characteristics (i.e., elevation angle sequence and update time) were rigid and not editable regardless of changing meteorological conditions.

When evaluating potential enhancements to the WSR-88D hardware and software, the mission requirements of each of the NEXRAD program agencies must be considered and any issues addressed before new capabilities are implemented. For example, software modifications could be made to provide continuous low-level updates at the expense of scanning higher elevations. However, all three agencies require full volumetric products to support their missions. Thus, scanning higher elevations is crucial given operational objectives.

Hardware and software upgrades that have occurred over the past several years along with increases in bandwidth have provided the opportunity for innovative dynamic scanning techniques to be evaluated and implemented by the Radar Operations Center (ROC). The new capabilities discussed in this paper were developed in response to a 2005 National Research Council Committee report and a 2007 field survey where respondents highlighted the need for faster VCP updates (Steadham 2008). Additionally, radar data analyses of recent severe weather events also motivated the implementation of these new changes to operational techniques.

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This paper presents an overview of new techniques developed and implemented as a result of program upgrades and recent weather events.

2. RECENTLY FIELDED TECHNIQUES

2.1 *Automated Volume Scan Evaluation and Termination*

The Automated Volume Scan Evaluation and Termination (AVSET) function (Chrisman 2013a and Chrisman 2009) identifies and evaluates weather returns using strength and coverage thresholds to determine whether the volume scan should continue to the next higher elevation angle. If the thresholds are not met, AVSET terminates the current volume scan. In other words, once the radar's elevation angle overshoots available significant radar returns, the volume scan is terminated because there is no operational benefit for continuing the current volume scan. Therefore, AVSET can shorten the VCP time, providing low-level updates at shorter intervals without impacting the quality of the base data. As operationally significant returns approach the radar, the VCP completion time will approach its full duration. That is, the VCP completion time is dependent on the weather echo displacement from the radar. A comparison table presenting the possible increase in product updates per hour is provided in Table 1.

In order to ensure adequate vertical coverage to support precipitation accumulation processing, the AVSET function only runs on elevation angles higher than 5.0°. A series of reflectivity images shown in Figure 1 illustrate the underlying concept behind AVSET. A time series of volume scan duration is also provided (Figure 1).

2.2 *Enhanced Velocity Azimuth Display Wind Profile*

The Velocity Azimuth Display (VAD) algorithm provides one wind estimate for each required height of the VAD Wind Profile (VWP) product. For each specified height, the elevation angle with a slant range closest to the slant range parameter is used to compute this wind. Thus, the VAD wind estimate for each individual height is based on the data from a single elevation/range pair.

Numerous data cases have demonstrated that the assumption that adequate return exists at a single elevation/range pair for a particular height is not valid. In addition, with the implementation of AVSET, it became possible that some heights would not have an elevation/range pair due to termination of the volume scan prior to sampling valid pairs at those heights.

In order to overcome these limitations, an enhanced version of the VAD elevation/range determination logic was developed to identify all possible elevation/range pairs for each VWP height. The Enhanced VAD Wind Profile (EVWP) (Chrisman and Smith 2009) logic analyzes the wind estimates from multiple elevation/range pairs for each VWP height and determines the "best" wind estimate for that height. Figure 2 illustrates the multiple elevation/range pair possibilities for each VWP height. The EVWP processing is designed such that the additional wind estimates are only used to supplement or improve the availability and accuracy of the VWP product wind estimates. An example of the VWP product from the original output is compared to the EVWP output processing from the same input data stream in Figure 3.

3. CURRENT PROJECTS

3.1 *Supplemental Adaptive Intra-Volume Low-Level Scan*

Rapidly evolving storm systems require more frequent low-level interrogation. Supplemental Adaptive Intra-Volume Low-Level Scan (SAILS) (Chrisman 2013a) inserts an additional low-level (e.g., 0.5°) split cut in the middle of the current volume scan where the middle is determined by the previous volume scan completion time and can vary if AVSET is enabled. The SAILS function is designed for severe weather situations and will only be available with VCPs 12 and 212. Similar to AVSET, SAILS does not impact the quality of the base data estimates since processing techniques are preserved.

Figure 4 illustrates where the additional split cut is inserted into VCP 12 when the termination angle is 19.5°. In this example, the middle of the volume scan is approximately 140 seconds.

The SAILS function significantly reduces the low-level update interval by providing more low-level scans during severe weather operations. The additional split cut will add approximately 34 seconds to the VCP completion time; however, if AVSET is also enabled, VCP completion times can be shortened. Table 2 provides a comparison of the possible product updates per hour when SAILS is enabled. The table also includes a comparison given the scenario that both AVSET and SAILS are enabled.

3.2 *Storm-Based Auto PRF*

Currently, the Auto PRF algorithm selects the Doppler PRF that results in the least amount of range folded data for the entire area within a 230 km radius of the radar. Past data cases demonstrate that severe storms may be range folded, especially around the maximum unambiguous range. The proposed solution was to define an algorithm capable of identifying the most intense storms and assigning the PRF which results in the fewest range-obscured range bins for those storms.

Storm-Based Auto PRF algorithm (Chrisman 2013b) selects the three most intense storms as ranked by cell-based vertically integrated liquid (VIL). Alternatively, the operator may select a single storm of interest. The best PRF is determined each volume scan by calculating the smallest area of range folded echo within the storm's projected position.

The forecast position, as determined by the Storm Cell Components (SCIT) algorithm, is used by Storm-Based Auto PRF to calculate a 20 km radius circle around projected location(s) of the storm(s) of interest. It then calculates the number of obscured bins within the storm circle and selects the PRF that results in the smallest obscured area. If the operator has manually chosen a storm of interest, the algorithm will continue to follow that storm until the storm moves beyond 230 km from the radar, the particular storm is no longer identified by SCIT, or the operator chooses another storm. An example of the expected range obscured bins using PRF 5 as selected by the legacy Auto PRF versus the expected range obscured bins using PRF 8 as selected by Storm-Based Auto PRF is presented in Figure 5. The result of this application is a dynamic PRF selection that tracks a storm, or storms, of interest and continuously assigns the best Doppler PRF for that storm(s).

3.3 *Editable PRFs for SZ-2 VCPs*

Sachidananda-Zrnic (SZ-2) VCPs, specifically VCPs 211, 212, and 221, provide increased availability of velocity data. When first deployed to the field, SZ-2 VCPs had a limitation of a fixed PRF. As of Spring 2014, the PRF for these VCPs became editable (Smith and Chrisman 2013). For the PRF selected, the antenna speed is adjusted so that the required number of pulses is still accomplished. All PRF selection options, except PRF sectors, are now available for the SZ-2 VCPs, including Storm-Based Auto PRF. PRF sectors are not permitted because the WSR-88D does not accommodate variable rotation rates within a single elevation scan, which would be required to maintain the necessary 64 pulses per radial.

4. FUTURE WORK

4.1 *Multiple Elevation Scan Option (MESO)-SAILS*

Building on the premise of SAILS, the Multiple Elevation Scan Option (MESO)-SAILS function would allow the operator up to three additional low-level scans per volume. Like SAILS, these additional scans would be evenly spaced, as close as possible, throughout the volume scan. The new MESO-SAILS option would result in two, three, or four low-level scan updates per volume scan. A comparison of the 0.5° update times for standard operation versus the possible 0.5° update times depending on the number of SAILS cuts for a single volume scan is provided (Table 3). The additional SAILS scans will add to the VCP completion time; however, VCP 12 (or 212) with four low-level scans will complete in about the same time as VCP 21 (6 min.). The deployment decision regarding MESO-SAILS is dependent on appropriate tri-agency members' approval.

5. CONCLUSIONS

The ROC continues to investigate, develop, test, and deploy innovative and operationally significant techniques based on, in part, field- and programmatically-driven requests and recommendations. Actual weather event data analyses also provide a path forward in providing the best technology possible given the collective missions of our tri-agency partners.

7. REFERENCES

Chrisman, J. N., 2013a: Dynamic Scanning. *Radar Operations Center NEXRAD Now,* **22**, 1-3. *[Available at http://www.roc.noaa.gov/WSR88D/PublicDocs/NNOW/NNow22c.pdf].*

Chrisman, J. N., 2013b: Uncovering the Storm. *Radar Operations Center NEXRAD Now,* **22**, 9-11. *[Available at http://www.roc.noaa.gov/WSR88D/PublicDocs/NNOW/NNow22c.pdf].*

Chrisman, J. N., 2009: Automated Volume Scan Evaluation and Termination (AVSET): A Simple Technique to Achieve Faster Volume Scan Updates. *34th Conference on Radar Meteorology, Oct 5-9, Williamsburg, VA*.

Chrisman, J. N. and Smith, S. D., 2009: Enhanced Velocity Azimuth Display Wind Profile (EVWP) Function for the WSR-88D. *34th Conference on Radar Meteorology, Oct 5-9, Williamsburg, VA.*

Smith, S. D and Chrisman, J. N., 2013: PRF Modification Now Available for SZ-2 VCPs. *Radar Operations Center NEXRAD Now,* **22**, 12. *[Available at http://www.roc.noaa.gov/WSR88D/PublicDocs/NNOW/NNow22c.pdf].*

Steadham, R, 2008: 2008 National Weather Service Field Study. Part 1: Volume Coverage Pattern Usage. *Radar Operations Center, Norman, OK, 28 pp. [Available from WSR-88D Radar Operations Center, 120 David. L. Boren Blvd. Norman, OK 73072].*

TABLES

VCP 12	Number of 0.5° Product Updates per Hour	Volumetric Product Updates per Hour
Standard Operation	14	14
AVSET	14 - 19	14 - 19
VCP 212	**Number of 0.5° Product Updates per Hour**	**Volumetric Product Updates per Hour**
Standard Operation	13	13
AVSET	13 - 17	13 - 17

Table 1: The number of 0.5° and volumetric product updates per hour are provided for standard operation and AVSET for VCPs 12 and 212.

VCP 12	Number of 0.5° Product Updates per Hour	Volumetric Product Updates per Hour
Standard Operation	14	14
SAILS	24	12
SAILS and AVSET	24 - 32	12 - 16
VCP 212	**Number of 0.5° Product Updates per Hour**	**Volumetric Product Updates per Hour**
Standard Operation	13	13
SAILS	22	11
SAILS and AVSET	22 - 28	11 - 14

Table 2: The number of 0.5° and volumetric product updates per hour are provided for standard operation and SAILS for VCPs 12 and 212. A comparison of the possible product updates if both SAILS and AVSET are enabled is also included.

VCP 12	Average 0.5° Elevation Update Times	Average 0.5° Elevation Update Times with AVSET Termination Angle = 6.4°
Standard Operation	256 seconds	190 seconds
SAILS x 1	147 seconds	114 seconds
SAILS x 2	108 seconds	84 seconds
SAILS x 3	89 seconds	73 seconds

Table 3: The average 0.5° elevation update times for standard operation versus the possible update times depending on the number of SAILS cuts. An additional comparison is given assuming AVSET is terminating the volume scan at 6.4° (best case scenario).

FIGURES

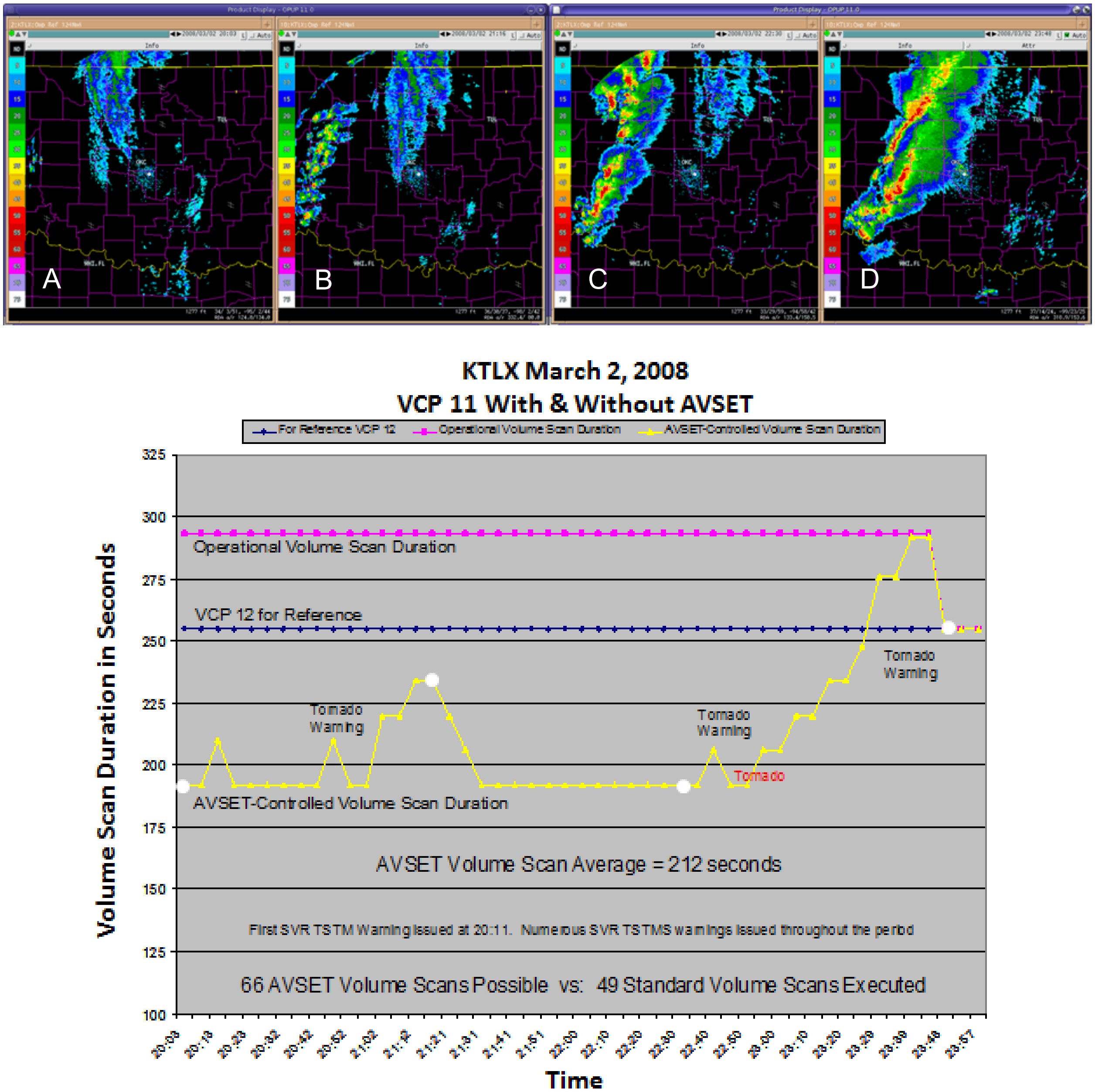

Figure 1: Four reflectivity panels for 02 March 2008 at 20:03 (A), 21:16 (B), 22:30 (C), and 23:48 (D) UTC. The time series chart depicts the duration of the operational volume scan (magenta) versus the AVSET-controlled volume scan (yellow). The four white dots along the AVSET-controlled volume scan correspond to the time of the four reflectivity images. The volume scan duration of VCP 12 (blue) is shown for comparison.

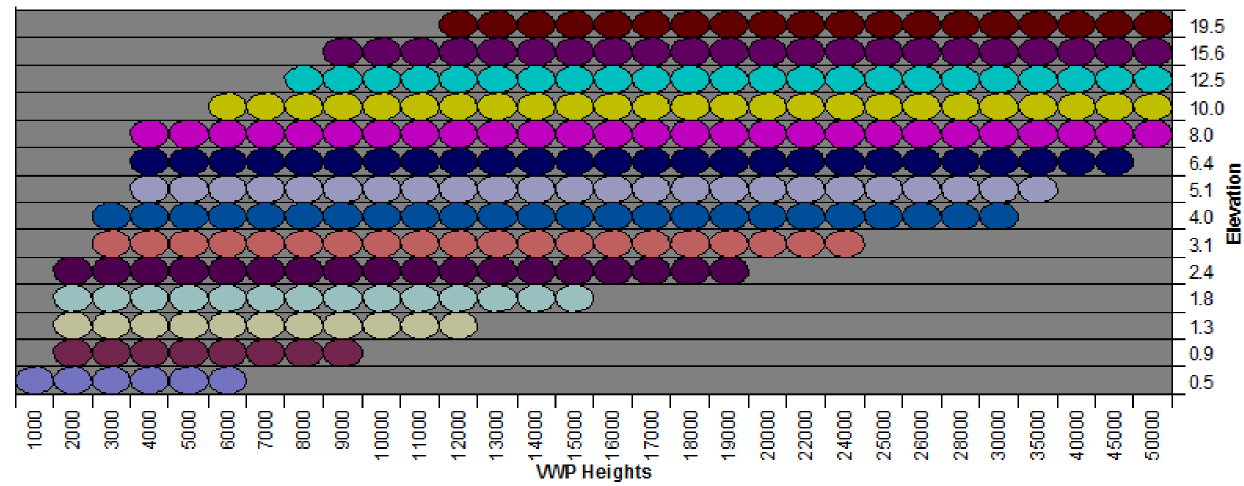

Figure 2: The possible VAD estimates from each elevation angle when restricting the valid slant range to ≥10 km and ≤120 km.

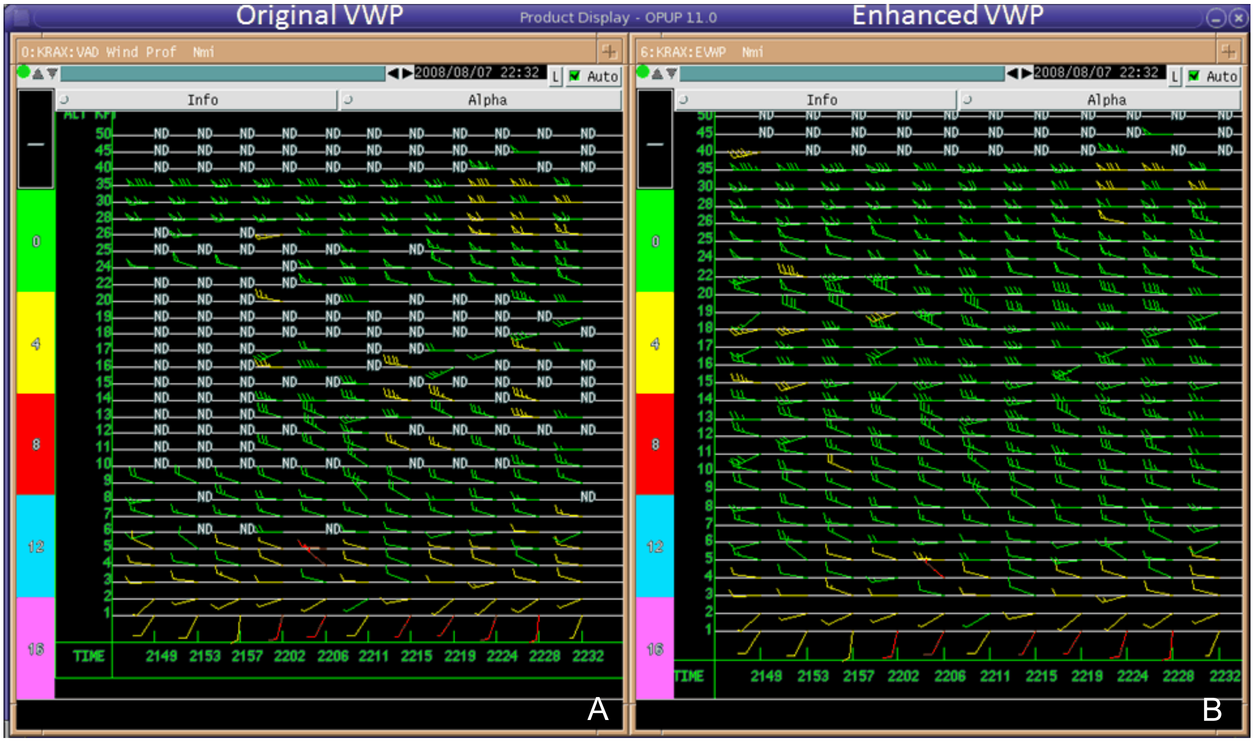

Figure 3: Original VWP wind estimates (A) versus the Enhanced VWP estimates (B).

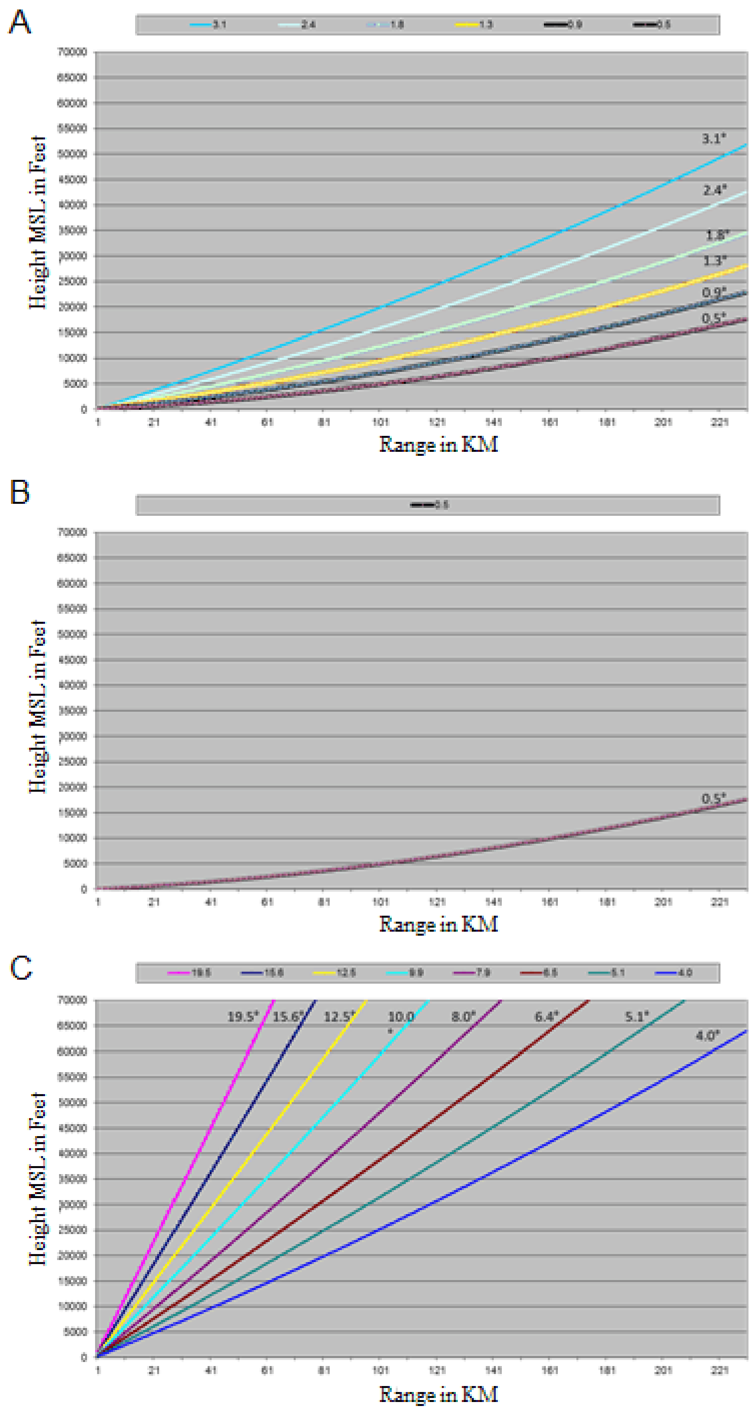

Figure 4: An illustration of a volume scan in which a SAILS cut is inserted into the middle of VCP 12. The radar scans up through the middle of the volume scan to 3.1° (A), transitions down to collect the additional 0.5° split cut (B), then elevates to 4.0° to resume collecting data to complete the volume scan.

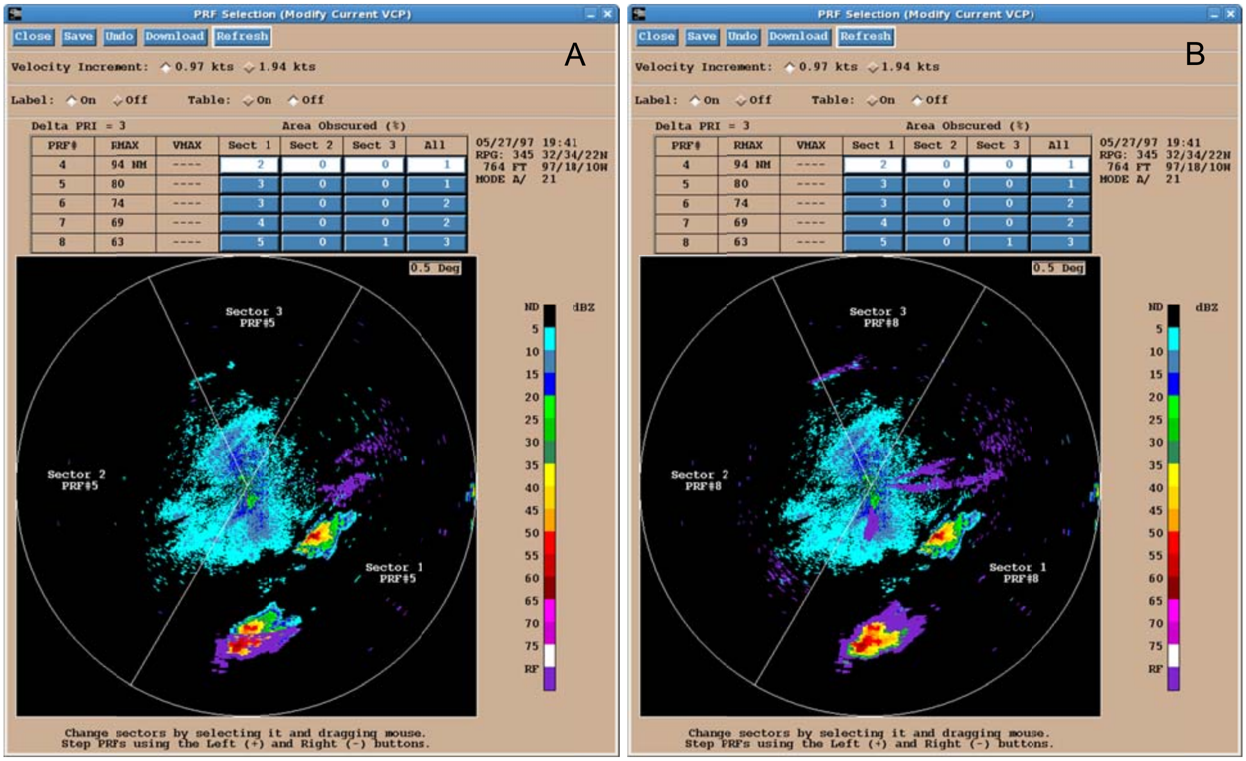

Figure 5: A comparison of the expected range obscured bins using PRF 5 as selected by the baseline Auto PRF algorithm (A) versus the expected range obscured bins using PRF 8 as selected by Storm-Based Auto PRF (B).