P 4.4 AUTOMATED VOLUME SCAN EVALUATION AND TERMINATION (AVSET)

A Simple Technique to Achieve *Faster* Volume Scan Updates

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1. INTRODUCTION

Atmospheric volume sampling conducted by the Weather Surveillance Radar -1988 Doppler (WSR-88D) radar is governed by a set of predefined volume coverage patterns (VCPs). Each VCP is defined to automatically and continuously scan predefined elevation angles with a specified scanning time period. This scheme results in each VCP having a particular periodic update cycle that never changes, regardless of the sampled meteorological conditions. The only way to change the update period is to invoke a different VCP and accept its predefined elevation scans and periodic update rate.

Based on a 2007 field survey of National Weather Service Forecast offices, over 62% of the respondents rank faster VCP updates (i.e., more frequent low elevation product updates) as the “Most Important VCP Improvement” that the WSR-88D Radar Operations Center (ROC) could provide (Steadham 2008). However, there are only two ways to achieve faster VCPs: either rotate the antenna faster or sample fewer elevation angles. Both of these options are problematic. If you opt to rotate the antenna faster, data quality (e.g., moment estimate variance, clutter filter performance, etc.,) and hardware maintenance issues, soon overwhelm the benefit. Fast updating VCPs (e.g., VCP12 and VCP121) are already approaching rotational limits imposed by the WSR-88D data quality requirements. On the other hand, if you choose to scan fewer elevations, you have the problem of “which ones to scan, and when”. Defining a multitude of VCPs, each designed to address one of the myriad of meteorological situations expected across the country, becomes a daunting task. Additionally, this option would significantly increase the number of VCPs to manage and maintain.

Given the difficulty of faster VCP design, implementation and management, a novel approach to modify the execution of each individual volume scan is suggested. If each volume scan is treated independently, the number of scanning angles can be dynamically controlled based on the sampled meteorological return. The result of this epiphany is the Automated Volume Scan Evaluation and Termination (AVSET) function.

2. AVSET CONCEPT

The basic premise of AVSET is to terminate the current volume scan after the radar has scanned all of the elevations with operationally important returns. In other words, once the data collection elevation overshoots the significant radar returns, the volume scan is terminated because there is no operational benefit realized by continuing the execution of the current volume scan, and a new volume scan is begun. The net effect of AVSET is to shorten the elapsed time between data collection on low elevation angles during periods when no significant data are available on the higher elevation tilts.

The series of reflectivity images below (Figure 1) illustrate the underlying concept

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Note: The views expressed, herein, are those of the author and do not necessarily represent those of the National Weather Service.

behind AVSET. As shown in Window 0 (upper left window) of this Open System Principal User Processor (OPUP) display, severe storms are located approximately 80nm northeast and 45nm south of the radar. Windows 1-10 (left to right, top to bottom) contain zoomed images of the closest convective storm which is located approximately 45nm south of the radar.

This storm's anvil is last scanned with the 8.0º elevation slice (Window 9). The AVSET thresholds (defined in Section 3, below) are not met on the 10.0º elevation slice (Window 10) and, with AVSET active, the volume scan would be terminated after completion of the 12.5º elevation slice (Window 11). NOTE: Window 11 is the expanded version of the 12.5º Base Reflectivity product.

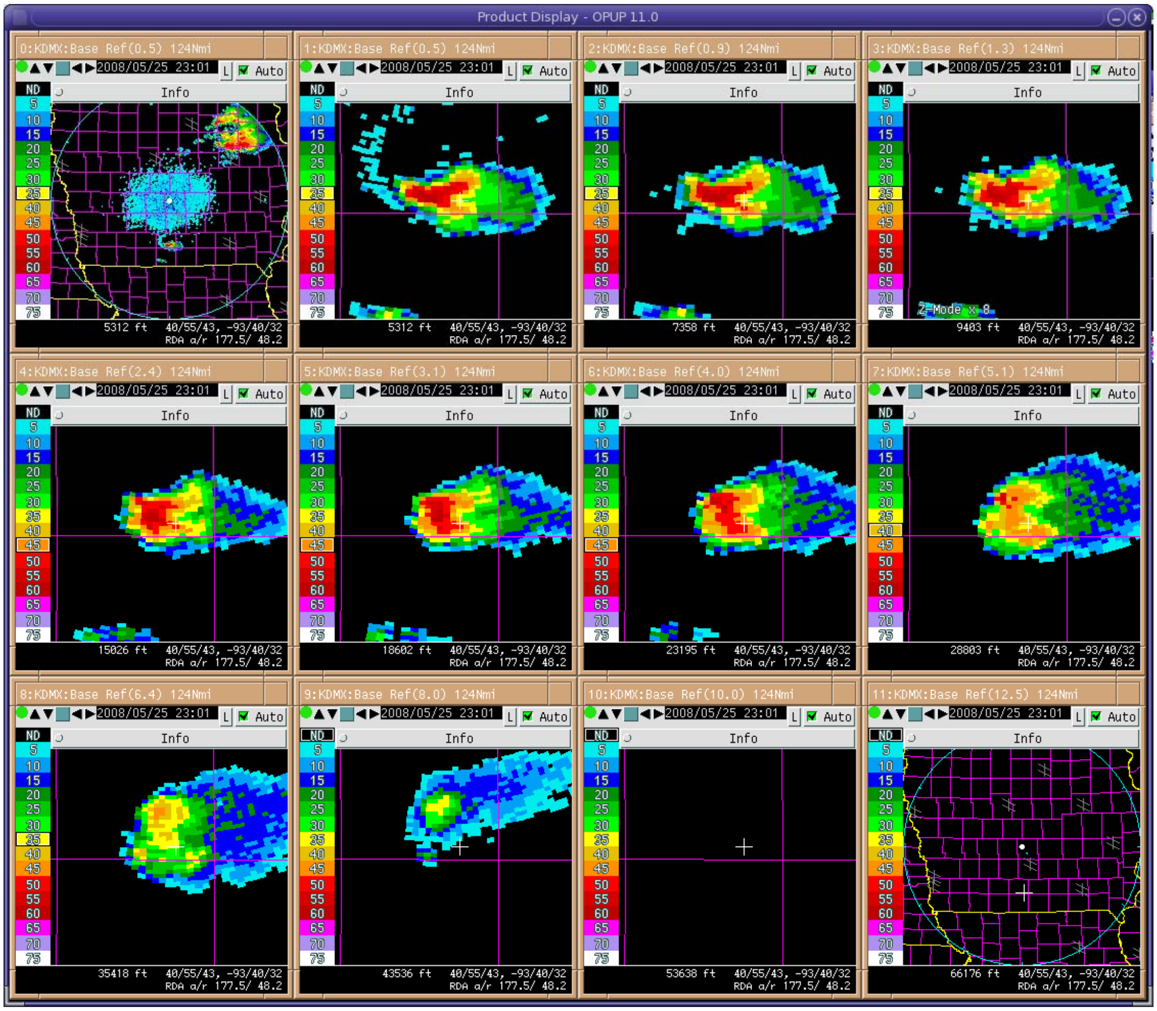

Figure 1: OPUP Reflectivity Display of Multiple Radar Elevation Angles

(OPUP windows are numbered 0-11 starting at the upper left and continuing left to right and top to bottom.)

3. AVSET FUNCTIONAL DESCRIPTION

When enabled by the operator, the AVSET function evaluates the return on each elevation above 5° and calculates the areal coverage of return $\geq$18dBZ and $\geq$30dBZ. If the areal coverage of $\geq$18dBZ is less than 80 km^2 (total over the entire radar coverage area) AND the areal coverage of $\geq$30dBZ is less than 30 km^2 (total over the entire radar coverage area) AND the areal coverage of $\geq$18dBZ has not increased by 12 km^2 or more since the last volume scan, THEN AVSET notifies the RDA control software to terminate the volume scan AFTER completion of the next higher elevation.

AVSET thresholds were selected to "forecast" the likelihood of meaningful meteorological return two elevation angles above the processed elevation (e.g., if the areal coverage is below the threshold on the 6.4º elevation slice, then it is expected that there will not be prominent return present on the 10º elevation slice and above). In the context of height above radar level (ARL), there are significant differences between the elevation slices (see Table 1). For example, at 40 nm the center of the beam for the 6.4º elevation is approximately 27,000ft ARL, while the center of the beam for the 10º elevation is approximately 42,000ft ARL; a difference of ~15,000ft.

Range	VCP 12 Elevation Angles					
	5.1º	6.4º	8.0º	10.0º	12.5º	15.6 º
20nm	11 kft	14 kft	17 kft	21 kft	26 kft	32 kft
40nm	23 kft	27 kft	34 kft	42 kft	52 kft	65 kft
60nm	35 kft	43 kft	53 kft	65 kft	>70 kft	>70 kft

Table 1: Beam Height (ARL) For Elevation Angles at Selected Ranges

When the AVSET thresholds are not exceeded, AVSET sends an end-of-volume flag to the Radar Data Acquisition (RDA) control software. After the completion of the next elevation slice, the RDA control software enters its normal volume scan termination sequence, which prompts the system to begin the transition to a new volume scan (RDA antenna retrace, RPG concludes algorithm processing and product generation, etc.).

4. OPERATIONAL BENEFIT

The amount of volume scan time savings achieved by AVSET depends on the active VCP and the areal and vertical coverage of return. Given the best possible situation, AVSET will terminate the volume scan after completion of the second elevation scan above 5°. Table 2 provides the minimum number of scanning angles, elevation scan times, and shortest VCP durations for four AVSET-controlled VCPs. For reference, Table 3 provides a comparison of AVSET VCP completion times and the average VCP execution times without AVSET for the VCPs listed in Table 2.

AVSET-Controlled Shortest VCP 11		AVSET-Controlled Shortest VCP 12		AVSET-Controlled Shortest VCP 212		AVSET-Controlled Shortest VCP 21	
Elevations	Time (sec)	Elevations	Time (sec)	Elevations	Time (sec)	Elevations	Time (sec)
0.5	19	0.5	17	0.5	17	0.5	32
0.5	19	0.5	14	0.5	21	0.5	32
1.5	18	0.9	17	0.9	17	1.5	32
1.5	19	0.9	14	0.9	21	1.5	32
2.4	22	1.3	17	1.3	17	2.4	32
3.4	20	1.3	14	1.3	21	3.4	32
4.3	20	1.8	15	1.8	15	4.3	32
5.3	21	2.4	14	2.4	14	6.0	32
6.2	21	3.1	14	3.1	14	9.9	25
		4.0	14	4.0	14		
		5.1	14	5.1	14		
		6.4	13	6.4	13		
Scan time	179		177		197		281
Ret/Trans	13		13		13		15
Total Time	**192**		**190**		**210**		**296**

Table 2: AVSET-Controlled VCP Duration in Seconds

NOTE: AVSET will start execution on the first elevation above 5°. With the current design, the AVSET function will always process one elevation cut above the elevation where the AVSET reflectivity thresholds are not exceeded.

	VCP 11	VCP 12	VCP 212	VCP 21
Standard Average VCP Completion Time (Seconds)	293	256	277	346
Fastest AVSET VCP Completion Time (Seconds)	192	190	210	296
Possible VCP Duration Savings with AVSET (Seconds)	101	66	67	50

Table 3: VCP Completion Times Comparison

5. AVSET EXAMPLE CASES

The AVSET algorithm has been installed and available on the ROC test bed radar for over a year. Using this asset, AVSET has undergone several engineering tests and provided multiple data cases for off-line analysis. As important as this asset has been for engineering and developmental testing, meteorological testing requires data sets from various locations across the WSR-88D network. To support the meteorological testing requirement, Steve Smith, ROC Software Engineering Lead, developed an ASVET emulation program that executes on the Radar Product Generator (RPG).

This AVSET emulation program processes Level II data, collected from any WSR-88D, and terminates volume scan processing using the AVSET logic. This capability allows direct product, algorithm performance and VCP duration comparisons using the same input Level II data. Additionally, an RPG tool calculates the AVSET-terminated VCP duration, which supports quantifying the potential benefit of implementing AVSET.

The following three examples were produced using the AVSET emulation program to process Level II data collected by operational WSR-88D locations.

5.1 KTLX March 2, 2008

During this event, severe convective weather moved into central Oklahoma (Figures 2 and 3). During the 4-hour period from 02/2000Z through 03/0000Z, the Norman, OK, National Weather Service Forecast Office (using the Twin Lakes (KTLX) WSR-88D executing VCP 11, then VCP 12) issued three separate tornado warnings and multiple severe thunderstorm warnings. One confirmed tornado occurred at 02/2246Z, approximately 75nm NW of the KTLX radar.

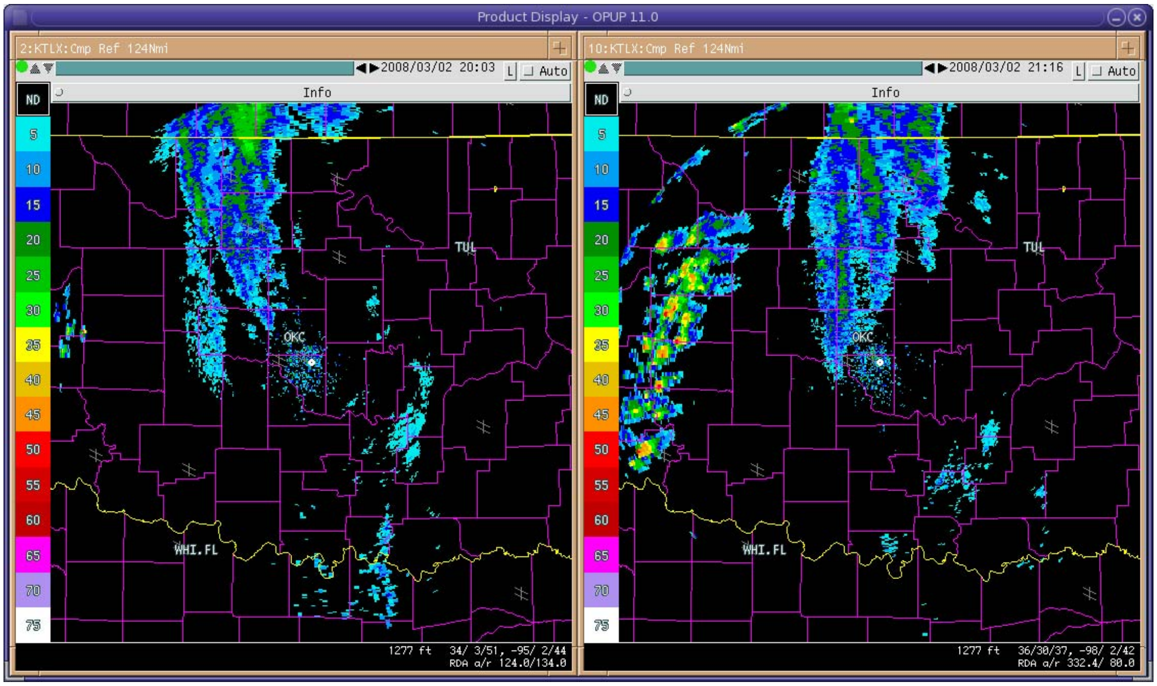

Figure 2: KTLX Composite Reflectivity 20:03Z and 21:16Z

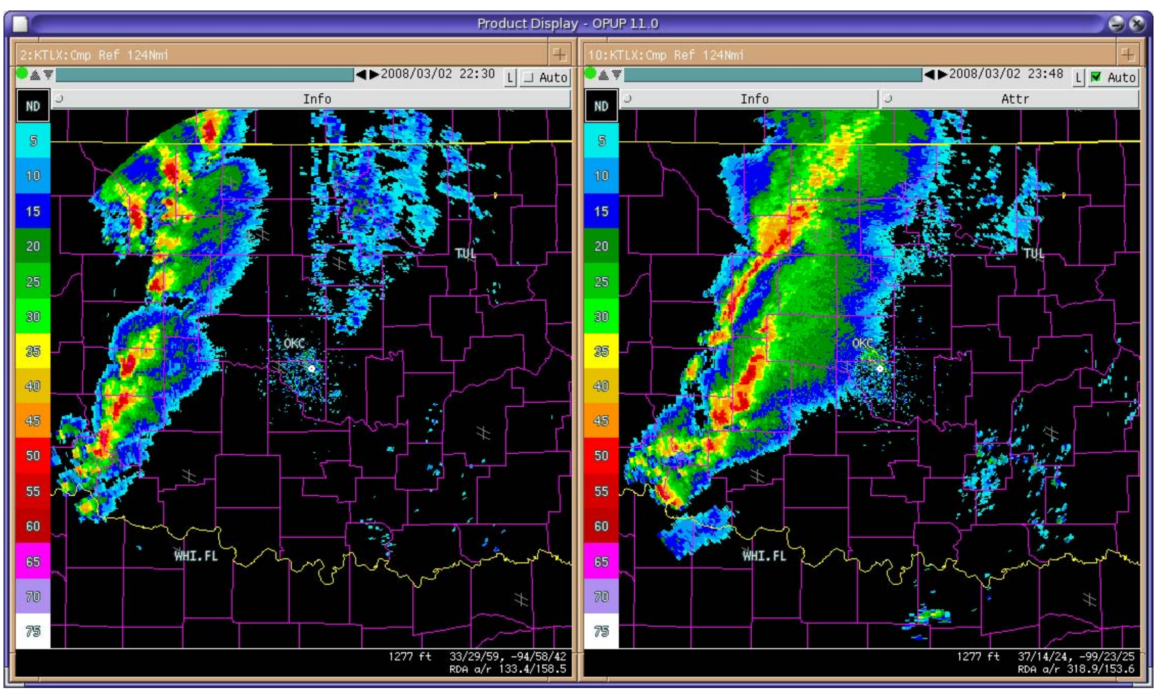

Figure 3: KTLX Composite Reflectivity 22:30Z and 23:48Z

The Level II data from 02/2000Z through 03/0000Z for this event was reprocessed using the AVSET emulation program executing on a ROC test bed RPG. For this 4-hour time period, the AVSET-controlled volume scan times averaged 212 seconds. Focusing on the 3-hour period prior to and including the tornado, the AVSET-controlled VCP 11 volume scan times averaged 198 seconds (see Figure 4). Had AVSET been available, KTLX would have produced 66 volume scans during the 4-hour period rather than the 49 volume scans executed by the standard VCP 11.

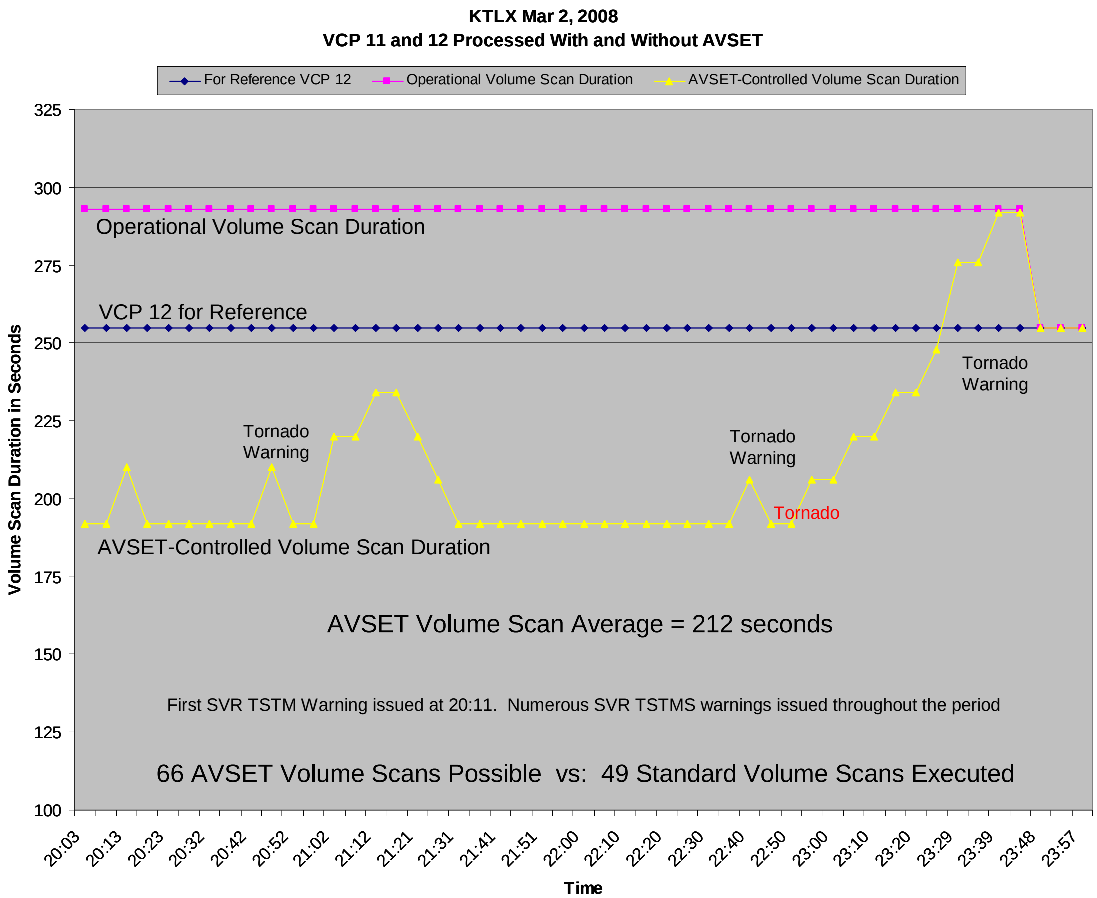

Figure 4: AVSET VCP Performance vs. VCPs 11 and 12

The abscissa of the graph is UTC time as the event unfolds. The ordinate is volume scan duration in seconds. The magenta trace is the actual volume scan time (seconds) the data were collected and processed using standard operational VCP (VCPs 11 and 12). The yellow trace represents the volume scan duration (seconds) achieved using the AVSET function to control the termination of the volume scan. The dark blue trace represents the volume scan duration of VCP 12 and is provided for reference.

NOTE: The yellow trace illustrates that, as the storms move toward the radar, AVSET adds elevations (volume scan duration increases). When the storms are very close to the radar, AVSET does not impact the volume scan time.

5.2 KFFC March 15, 2008

A line of severe convective weather formed northeast of Atlanta in the early afternoon of March 15, 2009, as sampled by the Atlanta WSR-88D (KFFC). This storm complex moved southeastward throughout the afternoon and early evening hours (see Figures 5 and 6). These severe storms produced multiple tornadoes that ranged from EF0 – EF3 strength rankings.

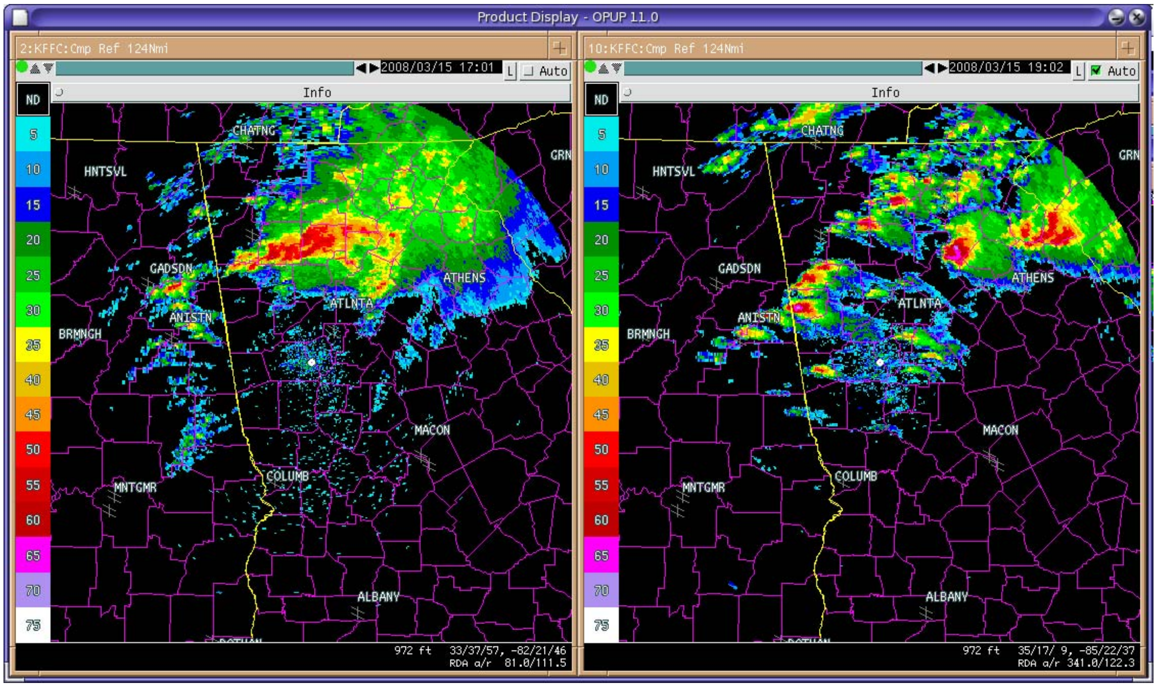

Figure 5: KFFC Composite Reflectivity 17:01Z and 19:02Z

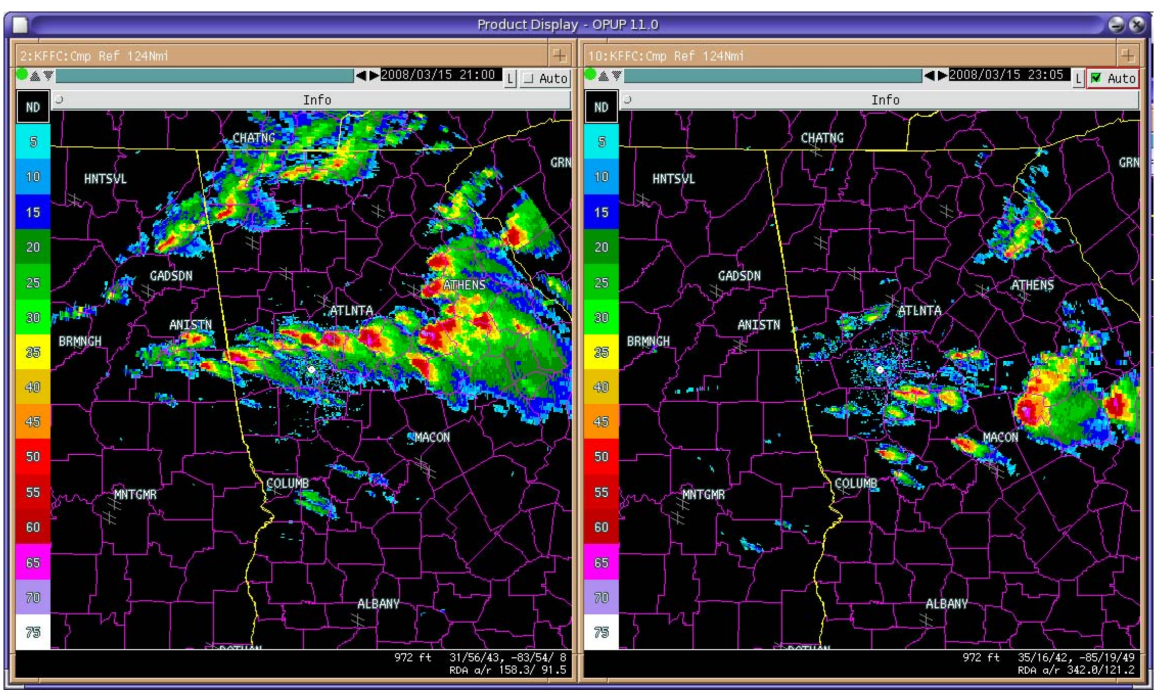

Figure 6: KFFC Composite Reflectivity 21:00Z and 23:05Z

The KFFC Level II data for the 1601Z-2359Z time period was reprocessed using the AVSET emulation program with AVSET active and inactive. A volume scan duration comparison is provided in Figure 7.

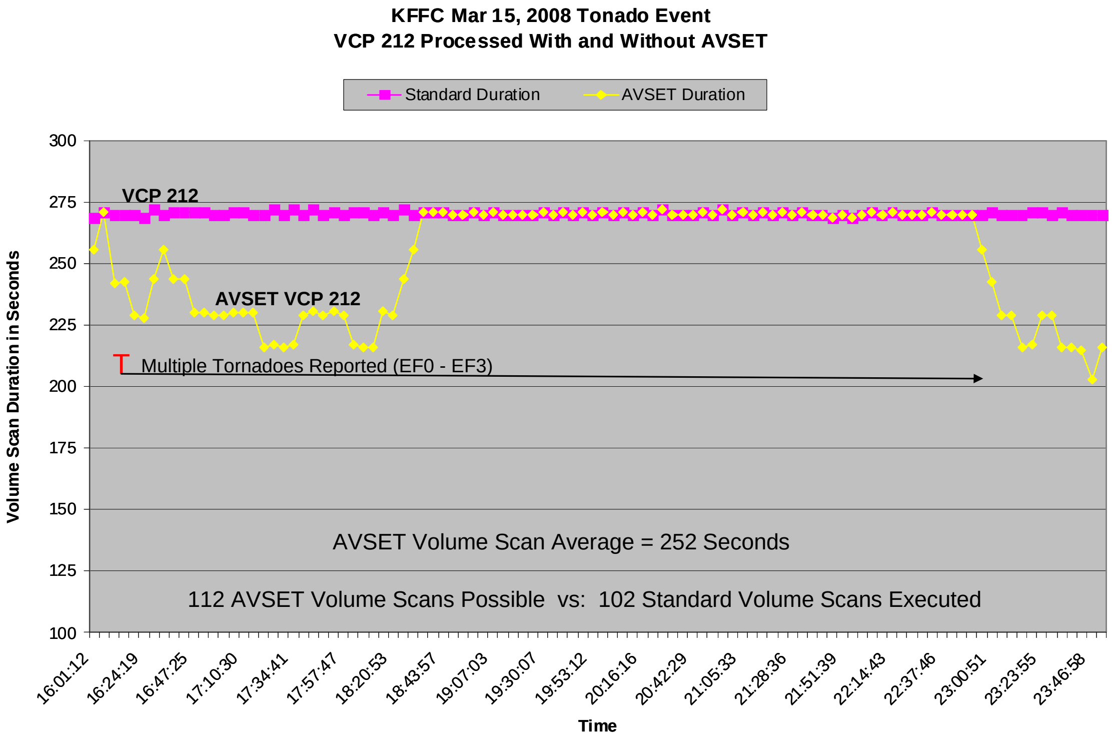

Figure 7: AVSET VCP Performance vs. VCP 212

As with the previous example, the abscissa is the UTC time as the event unfolds and the ordinate is volume scan duration in seconds. The magenta trace is the actual volume scan time (seconds) the data were collected and processed using standard operational VCP 212. The yellow trace represents the volume scan duration (seconds) achieved using the ASVET function to control the termination of the volume scan.

NOTE: The yellow trace illustrates that, as the storms move toward the radar, AVSET adds elevations (volume scan duration increases). When the storms are very close to the radar, AVSET does not impact the volume scan time and, as the storms move away, AVSET terminates the volume scan at lower elevations (volume scan duration decreases).

5.3 KDMX May 25, 2008

During the afternoon of May 25, 2008, a significant area of severe thunderstorms moved through northeast Iowa. One cell produced a large, violent tornado that struck several communities in northeastern Iowa. At the same, time another storm formed south of the radar location and propagated eastward. This new storm also became severe and produced a small tornado (see Figures 8 and 9).

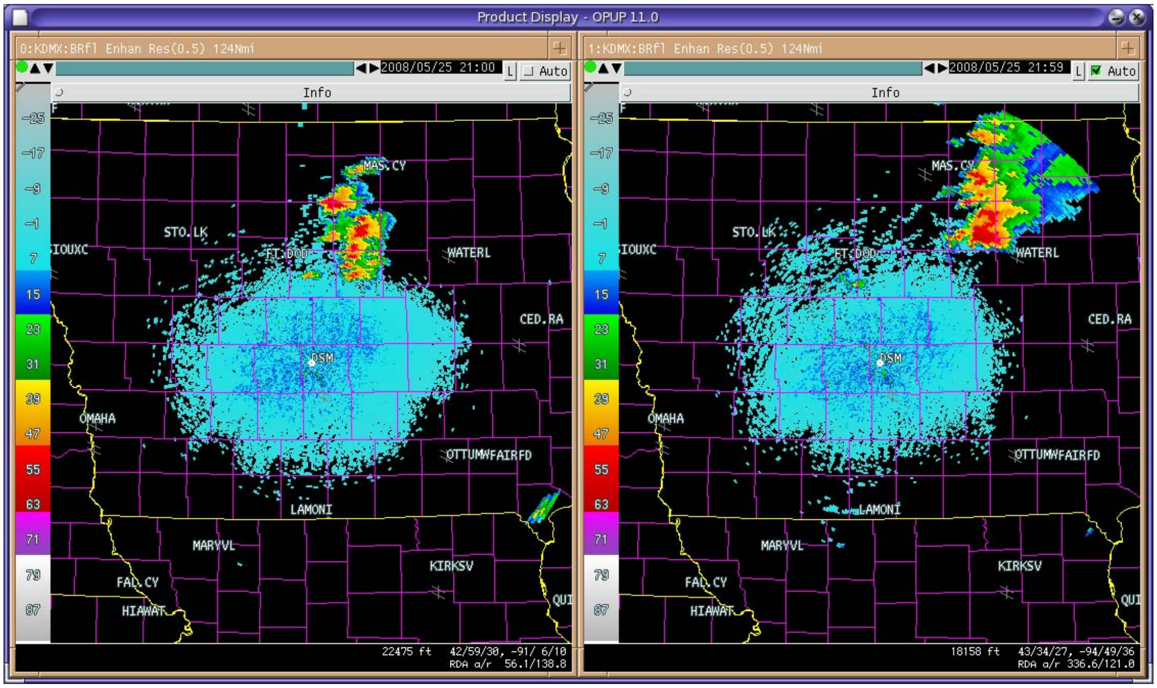

Figure 8: KDMX Reflectivity Products 21:00 and 21:59

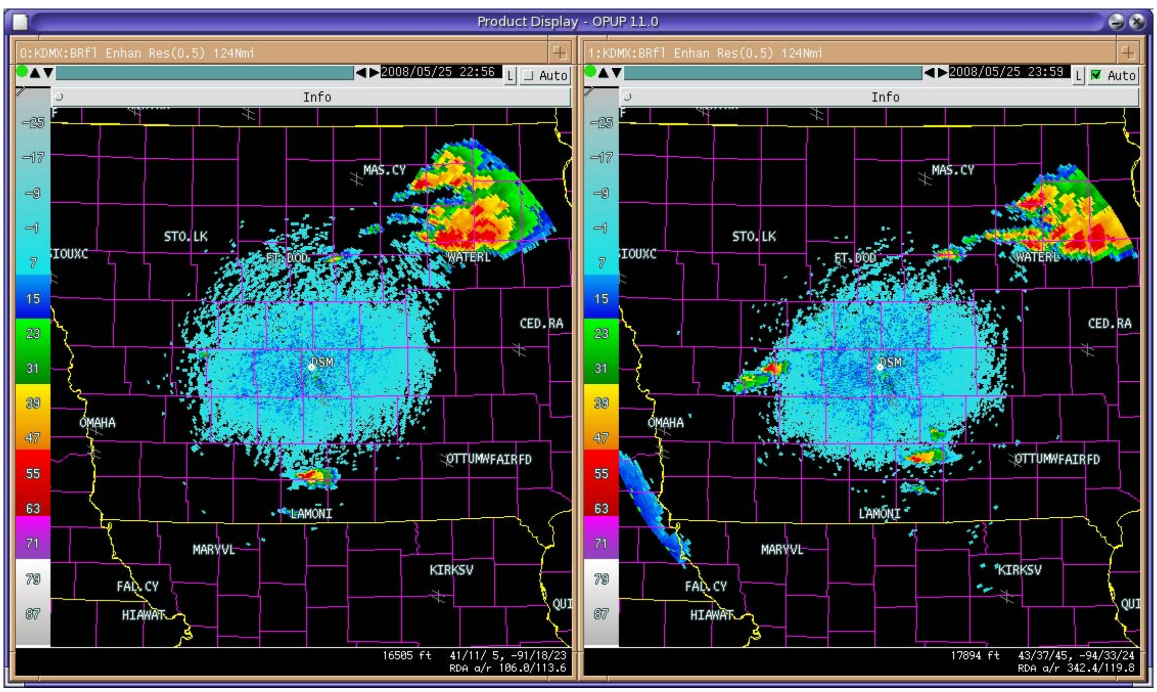

Figure 9: KDMX Reflectivity Products 22:56 and 23:59

AVSET provides the fastest volume scan updates when storms are located away from the radar location. This event, as sampled by the Des Moines (KDMX) radar, illustrates this fact. Level II data from this event was reprocessed with and without AVSET active and the volume scan duration results are presented in Figure 10.

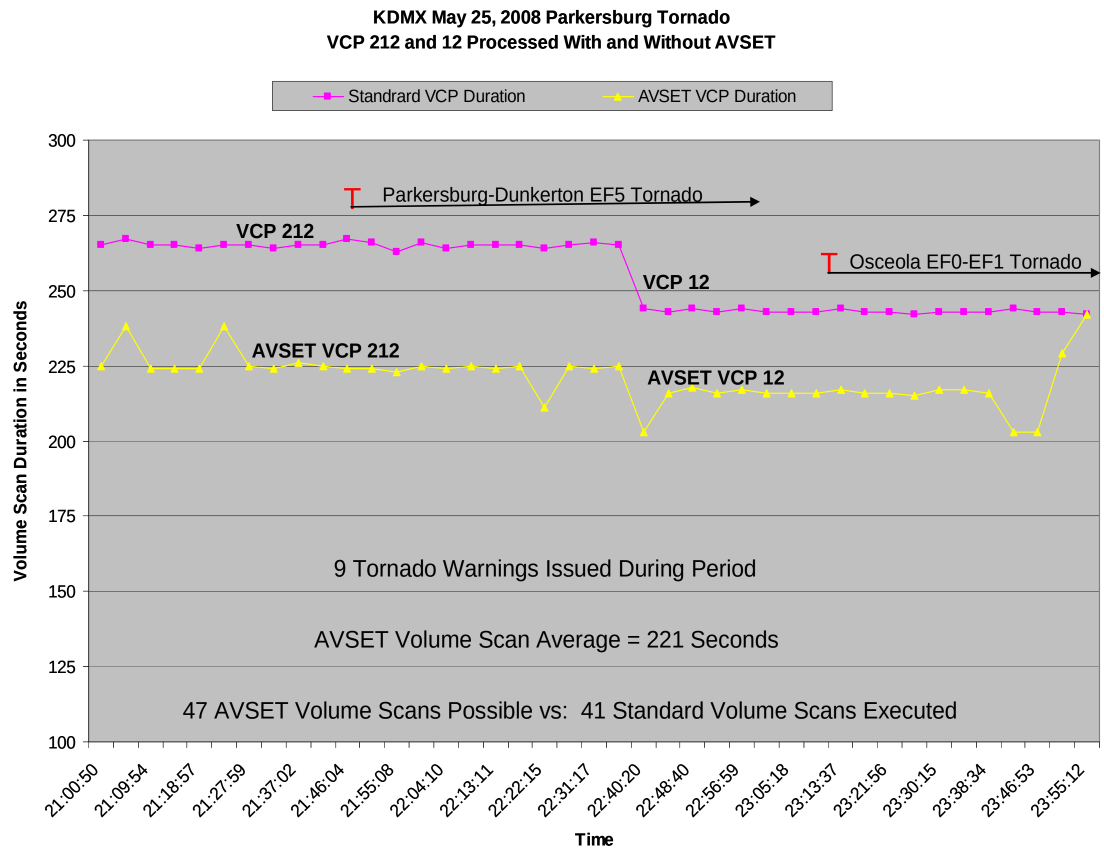

Figure 10: AVSET VCP Performance vs. VCPs 212 and 12

This graph has the same format as the previous examples, where the abscissa is the UTC time as the event unfolds. The ordinate is volume scan duration in seconds. The magenta trace is the actual volume scan time (seconds) the data were collected and processed using standard operational VCP (VCPs 212 and 12). The yellow trace represents the volume scan duration (seconds) achieved using the ASVET function to control the termination of the volume scan.

6. SUMMARY

AVSET represents a paradigm shift in operational volume scanning for the WSR-88D.

When enabled, the AVSET function evaluates the return on each elevation above 5° and terminates the current volume scan after the radar has scanned all elevations with return that exceeds the AVSET thresholds. The net result of AVSET is a shortened elapse time between data collection at low elevation angles (and generating volume-based products) during periods when no significant data are available on the higher elevation tilts. For example, ASVET can reduce the volume scan duration of VCP 12 by over 60 seconds and of VCP 11 by approximately 100 seconds.

Unlike other schemes to produce faster volume scan updates, AVSET does not impact the quality of the base data estimates. The antenna rotation rates, data acquisition schemes, moment estimation method and data processing techniques do not change with AVSET.

AVSET has not yet been approved for fielding. For now, AVSET is under review in the National Weather Service Operations and Services Improvement Process (OSIP) program. The OSIP program orchestrates the coordination process between data acquisition programs, user system programs and the NWS communications infrastructure support system. Through the OSIP process, possible impacts on user display systems and the bandwidth required to support AVSET volume scan update rates are being addressed.

7. REFERENCE

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]