

## **P4.1 IMPACTS OF THE AUTOMATED VOLUME SCAN EVALUATION AND TERMINATION (AVSET) ON THE WSR-88D VELOCITY-AZIMUTH DISPLAY (VAD) WIND PROFILE (VWP)**

Vincent T. Wood<sup>1</sup> and Joe N. Chrisman<sup>2</sup>  
<sup>1</sup>NOAA/OAR/National Severe Storms Laboratory,  
<sup>2</sup>WSR-88D Radar Operations Center,  
Norman, Oklahoma

### **1. INTRODUCTION**

Based on a recent field survey of Steadham (2008), 62% of the eighty operational National Weather Service Forecast Office (NWSFO) staff surveyed expressed a strong need for either faster Volume Coverage Patterns (VCPs) or more frequent low elevation scans. With this group of respondents, more frequent low-elevation scans (37%) and faster VCPs (25%) were specified as the most important scanning strategy improvements. Under many meteorological situations, the rapid evolution of significant low-altitude weather events may not be adequately observed given the rigid update cycles for the operational VCPs (typically ~5 minutes for VCP 12). If one could dynamically control the number of scanning angles based on the sampled meteorological return, one could achieve faster volume scan updates. This possibility led to the epiphany of the so-called “Automated Volume Scan Evaluation and Termination” (AVSET) function developed by Chrisman (2008, 2009). The AVSET function primarily was designed to terminate the current volume scan after the radar scanned all the elevations with significant radar return. AVSET results in shortened elapsed time between data collection on low elevation angles during periods when no significant data are available on the higher elevation angles.

Currently, the WSR-88D VAD algorithm collects Doppler velocity data points, when available, along a VAD circle at all elevation angles before wind speeds and directions are computed for the specified heights required by the WSR-88D Velocity-Azimuth Display (VAD) Wind Profile (VWP). Impacts of the AVSET functionality on the VWP have not been well addressed. This is a motivation for further investigation in this paper.

### **2. OBJECTIVE**

The purpose of this study is to evaluate AVSET's basic design of terminating a volume scan earlier than does a standard volume scanning pattern. For this study, the VAD modification extends the VAD range on the last elevation angle sampled by AVSET. The range allows retrieval of VAD data points at higher altitudes than what is normally achieved with the legacy WSR-88D VAD algorithm. Estimated wind speeds and directions based on the AVSET-controlled WSR-88D

VAD/VWP algorithms are compared to those of the legacy WSR-88D VAD/VWP without AVSET.

### **3. METHODOLOGY**

Level II data sets obtained from the National Climatic Data Center (NCDC) were used to test and assess impacts that AVSET might have on the WSR-88D VAD/VWP algorithms. A special computer code was modified in order to reprocess the Level II data sets on the Radar Operations Center (ROC) test bed Radar Product Generator (RPG) computer to output a file containing VAD data (Doppler velocity and reflectivity), date/time, height, and site ID. This code emulated the AVSET functionality. The VAD data files allowed one to look at the VAD and VWP displays with and without AVSET active. One exhibited comparisons of one data set suitable to evaluate AVSET's basic design of terminating a volume scan earlier than a standard VCP. The data set must contain enough radar volumes to produce a complete VWP product. Furthermore, the set was chosen based on availability of a sounding taken within an hour of the first or last time shown on the VWP display and near a selected WSR-88D. Proximity soundings (rawinsondes) near the WSR-88D were used to verify the wind estimates displayed by the VWPs; the soundings are available online at <http://raob.fsl.noaa.gov/>.

### **4. AVSET FUNCTIONALITY DESCRIPTION**

The AVSET functionality has been described by Chrisman (2008, 2009) and therefore is not presented in this paper, due to a limited space. Interested readers are encouraged to read the complete description of the AVSET functionality developed by Chrisman (2008, 2009).

Figure 1 illustrates the benefits of AVSET saving the VCP volume scan duration for different precipitation-mode VCPs. The AVSET function can shave up to 100 seconds off the duration. Given the best possible situation, the function terminates a current volume scan after completion of the second elevation angle above 5°. Consider an illustrative example in VCP 11 (or VCP 211) (Fig. 1a). If the AVSET function terminates the volume scan after completion of the last elevation angle of 8.7°, the resulting volume scan duration would be shortened by 70 seconds, before preparing for the start of a new volume scan. In other words, the duration would have been approximately 210 seconds which is about 70 seconds faster than the standard volume scan duration. The benefits of AVSET diminish (increase) as

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*Corresponding author address:* Vincent T. Wood, National Severe Storms Laboratory, 120 David L. Boren, Blvd., Norman, OK 73072. E-mail: Vincent.Wood@noaa.gov

a storm approaches (recedes) the radar. The amount of time savings achieved by AVSET depends heavily upon the active VCP, the range of a storm from the radar, and the areal coverage of radar return.

The 5° elevation angle is chosen to ensure that (a) the AVSET function does not impact the precipitation accumulation algorithms, (b) the function does not execute on Clear-Air Mode VCPs because the VCPs do not sample above 4.5°, and (c) the cone-of-silence for AVSET-terminated VCPs will be smaller than that for Clear-Air Mode VCPs.

## 5. EFFECT OF AVSET ON THE VWP/VAD

Normally, the legacy WSR-88D VAD algorithm collects Doppler velocity data points along a VAD circle before computing a wind speed and direction at a specified height and VAD range (i.e., horizontal range of VAD analysis) close to the radar (FMH-11-Part C, 2006). For the VWP, up to 30 heights can be specified from 1 kft (0.3 km) to 70 kft (21 km) MSL. One vertical profile is computed for each volume scan for display on the VAD Wind Profile (VWP). Any volume coverage pattern completes one volume scan by scanning all of the predefined elevation angles. The profile representing magenta dots is shown in Fig. 2a for a schematic 40-kft (12-km) thunderstorm located 100 n mi (185 km) to the radar. The default value of the VAD range in the operational VAD algorithm is 16.2 n mi (30 km).

The modification to the VAD algorithm extended the VAD range on the last elevation angle terminated by AVSET to allow retrieval of VAD data at higher altitudes than what was normally possible with the legacy WSR-88D VAD method. This is given in Fig. 2b, wherein the VWP profile is represented by magenta dots. When the VAD algorithm was complemented with the use of AVSET, the first task of the algorithm was to keep the VAD range fixed (close to the radar) while collecting Doppler velocity data points around the circumference of a circle between the beginning and ending azimuths at a specified slant range and elevation angles. This process continued until the AVSET function terminated the current volume scan after the radar scanned all the elevations with significant return. One vertical profile was computed for each volume scan for display on the VWP. The endpoint of the profile occurs at the last elevation angle terminated by AVSET (Fig. 2b).

## 6. CASE STUDY

In this section, we considered a case study in which we evaluated the performance of the WSR-88D VAD/VWP algorithms to be complemented with the use of AVSET. Experimental results provided by the algorithms with and without the AVSET functionality were documented and compared.

On 2 March 2008, a cold front approached east-southeast in Oklahoma, producing hail, high winds and a couple of tornadoes. Fig. 3 shows that strong winds veered from the south-southeast at the surface to the

southwest at mid-latitudes, and to the west-southwest at high altitudes. The base reflectivity and velocity products from the Norman WSR-88D KTLX valid at 2334 UTC 2 March 2008 are shown in Fig. 4. All Doppler velocities must be properly dealiased prior to the VAD/VWP algorithm performances. An example of this case study was produced using the AVSET emulation program to process Level II data collected by the operational KTLX WSR-88D (Chrisman 2009).

For the entire 22 volume scans of the VWP displays between 2215 and 2357 UTC of the standard volume scans, the AVSET-controlled and standard volume scans show that the AVSET-controlled VCP times averaged 218 seconds (3 minutes and 38 seconds), whereas the standard VCP times averaged 291 seconds (4 minutes 51 seconds). Not shown in Fig. 5, due to limited space, are the VWP displays (deduced from the standard volume scans) that show similar winds between 2215 and 2305 UTC. During the 1.5-hour period between 2215 and 2357 UTC, AVSET would have enabled KTLX to produce more volume scans than would the legacy VCP (Chrisman 2009).

The legacy and AVSET-controlled WSR-88D VWP displays for KTLX show non-missing and missing winds (Fig. 5). The missing winds resulted from (a) the lack of number of data points along the VAD circle [the requirement that there be at least 25 data points was not satisfied], (b) the root-mean-square (RMS) difference [between Doppler velocity measurements and fitted sine curve on the circle] exceeds the RMS velocity threshold, and/or (c) the mean of the sine curve [being offset from zero Doppler velocity] exceeds the symmetry threshold.

The AVSET-induced VWP elevation angle and slant range combinations (Fig. 6b) resulted in additional wind data between 22 kft (7 km) and 35 kft (11 km) and between 2251 and 2303 UTC (Figs. 5b), comparing to the wind data deduced from the legacy VAD/VWP algorithms (Fig. 5a). Note that the VAD circles were extended with increasing slant ranges in the AVSET function (Fig. 6b), comparing to those in Fig. 6a. We were curious what the Doppler velocity data points looked like on the VAD circle at these heights and times. This is discussed subsequently, focusing on the magenta rectangles shown in Fig. 5.

Wind data deduced from the legacy and AVSET-controlled VAD algorithms were compared at the same heights but at different slant ranges (shown by magenta rectangles in Fig 7). Non-missing wind vectors resulted from a small sector between 240° and 350° azimuth at which plenty of data points were available. The double cross adjacent to the number of data points within the parenthesis (Fig. 6) indicates that the mean of the sine curve was offset from zero Doppler velocity (e.g., Figs. 7a and 7d). Since the offset was greater than the Symmetry threshold, there was a bad fit and, therefore, no wind speed and direction were computed. Because the 110°-sector of good data points along the VAD circle appeared seemingly narrow, it is impossible to determine a mean of the sine curve and the wave's amplitude, owing to the lack of data points distributed uniformly on the VAD circle. If there were other cells

close to the observed cell shown in Fig. 4, a large areal coverage of radar return would result in sufficient number of good data points distributed in any large azimuth sector of the VAD circle at the last elevation angle. As a consequence, new wind data aloft would appear on the VWP display.

As the storm continued to advance toward the radar, meteorological return began to traverse the increasing, upper elevations with decreasing slant ranges (Fig. 6). As a consequence, wind data deduced by the legacy and AVSET-controlled VAD/VWP algorithms became identical at high altitudes beyond 2334 UTC (Fig. 5a) and 2311 UTC (Fig. 5b). The benefits of AVSET diminished as the storm approached the radar.

Estimated wind vectors deduced by the legacy and AVSET-controlled VAD/VWP algorithms at high altitudes (Fig. 5) were approximately perpendicular to the radar viewing direction from KTLX, agreeing with wind sounding (Fig. 3). Although the differences between the wind speeds and directions appear to be insignificant, it is suggested that a sparse distribution of data points (25 or more data points) in a narrow azimuth sector could seriously bias the VAD-deduced wind.

## 7. CONCLUSIONS

The performance of the AVSET-controlled (experimental) WSR-88D VAD/VWP algorithms was presented and compared with those obtained from the legacy WSR-88D VAD/VWP. The results show that the AVSET functionality does a good job of (a) allowing retrieval of more wind data at higher altitudes with extended slant ranges than do the legacy WSR-88D VAD/VWP algorithms, and (b) reducing the elapsed time between data collection on low elevation angles during periods when no significant data are available on the higher elevation angles. However, the results furthermore suggest a potential problem related to a limited areal coverage of radar return about a storm top which resulted in insufficient number of non-missing data points distributed in a narrow azimuth sector of the VAD circle. This sparse distribution can seriously bias a VAD-deduced wind speed and wind direction.

Although the AVSET-controlled VAD/VWP algorithms with extended VAD ranges appear to be an attractive candidate for operational applications, it is

recommended that the algorithms be further modified to allow retrieval of more wind data on the circumference of a circle at the last three elevation angles when the AVSET function terminated a current volume scan after the last elevation angle of, for example, 6.4° in Fig. 8, was completed. The main reason for this is to increase an areal coverage of radar return above the storm top which, in turn, results in the increased number of data points distributed on each of the VAD circles. Three circles could be combined on the median VAD circle at a selected VWP height, before the wind speeds and directions were computed.

## 8. ACKNOWLEDGMENTS

The lead author appreciates the assistance of Randy Steadham, Richard Murnan, Steve Smith, and Dave Zittel of the ROC. Discussion with Rodger Brown of NSSL and Don Burgess of CIMMS are graciously acknowledged. The author would like to thank Dave Jorgensen of NSSL for reading and making suggestions in this paper. Eddie Forren of NSSL provided technical expertise in implementing the tools and ensuring that the author had access to the data.

## 9. REFERENCES

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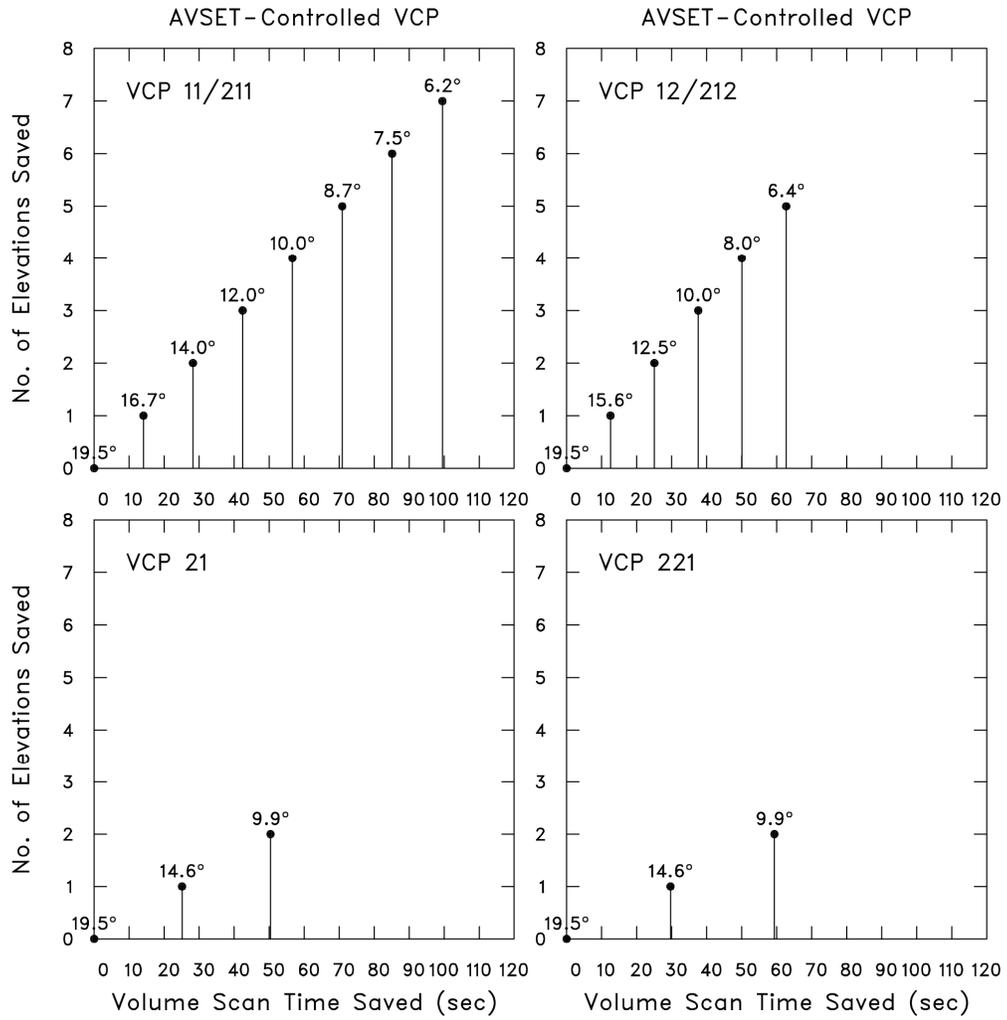


Fig. 1. Volume scan time saved (seconds) verse number of elevations saved for the precipitation mode VCPs 11/211, 12/212, 21, and 221.

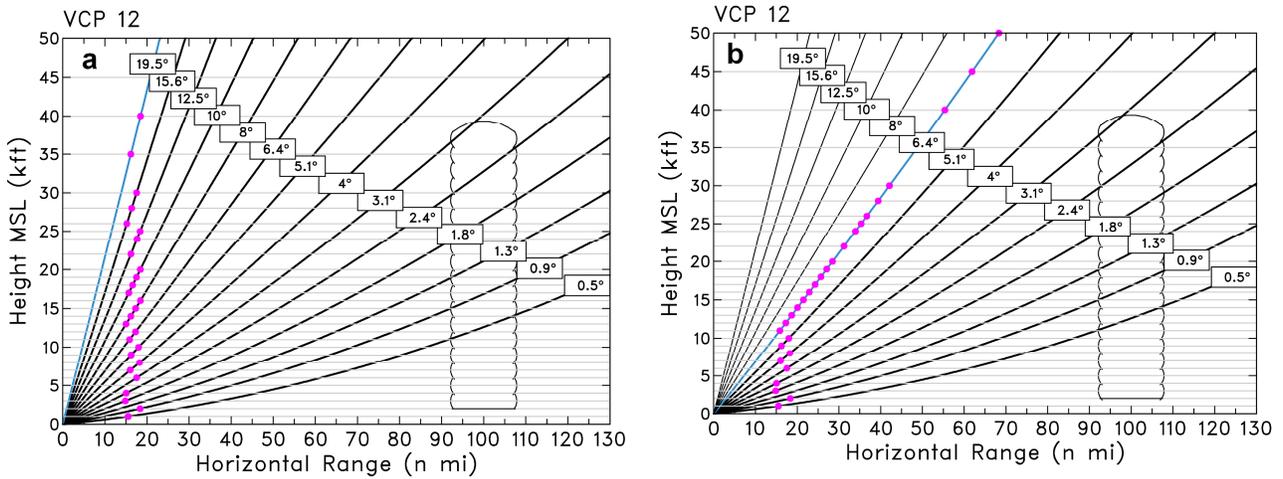


Fig. 2. Vertical cross section of conventional scanning strategy VCP 12 and superimposed (magenta dots) VWP heights (a) without AVSET and (b) with activated AVSET and extended VAD ranges on the last elevation angle (blue curve). A 40-kft (12-km) thunderstorm, depicted by its 18-dBZ surface, is shown at 100 n mi (185 km) from the radar. Gray horizontal line represents height in kft. The blue curve represents the completion of the last elevation angle at which AVSET would terminate if the thresholds are not met, assuming that there are no other cells closer to the radar.

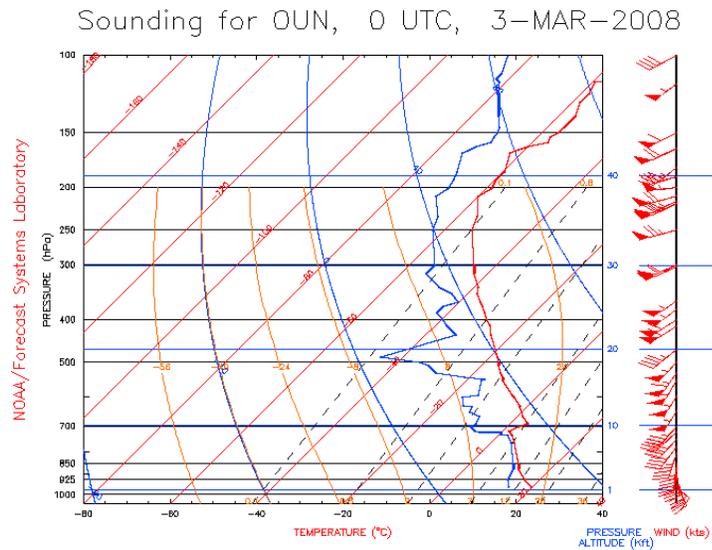


Fig. 3. Norman, OK, sounding valid at 00 UTC 3 March 2008 with skew  $T$ -log  $p$  diagram representing thermodynamic and kinematic characteristics of the environment. The wind plotting convention is flag, 50 kt; barb, 8-12 kt; half-barb, 3-7 kt; and circle, <3 kt. Pressure altitude (kft) is shown by blue horizontal line.

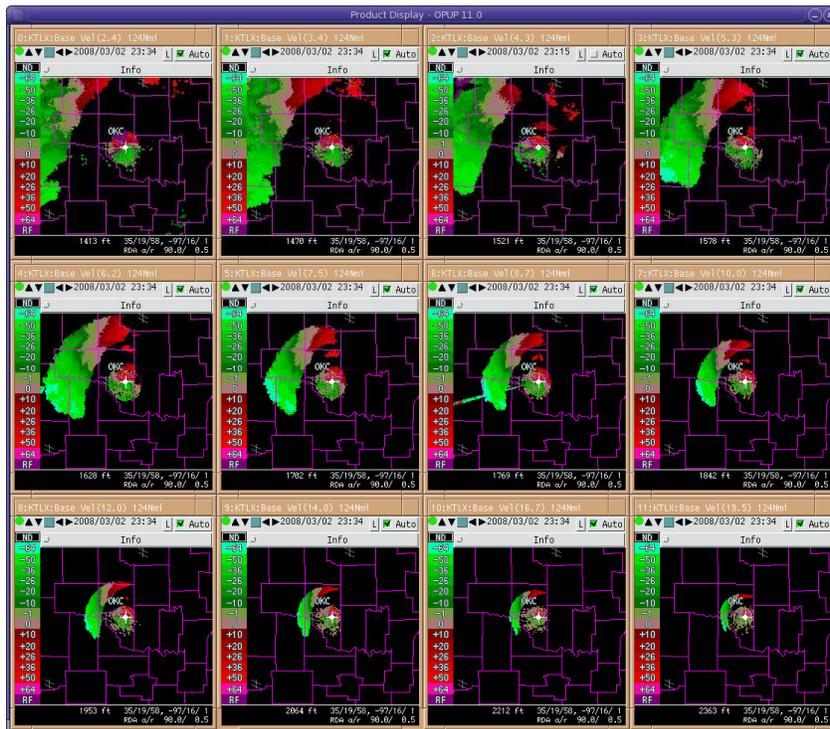
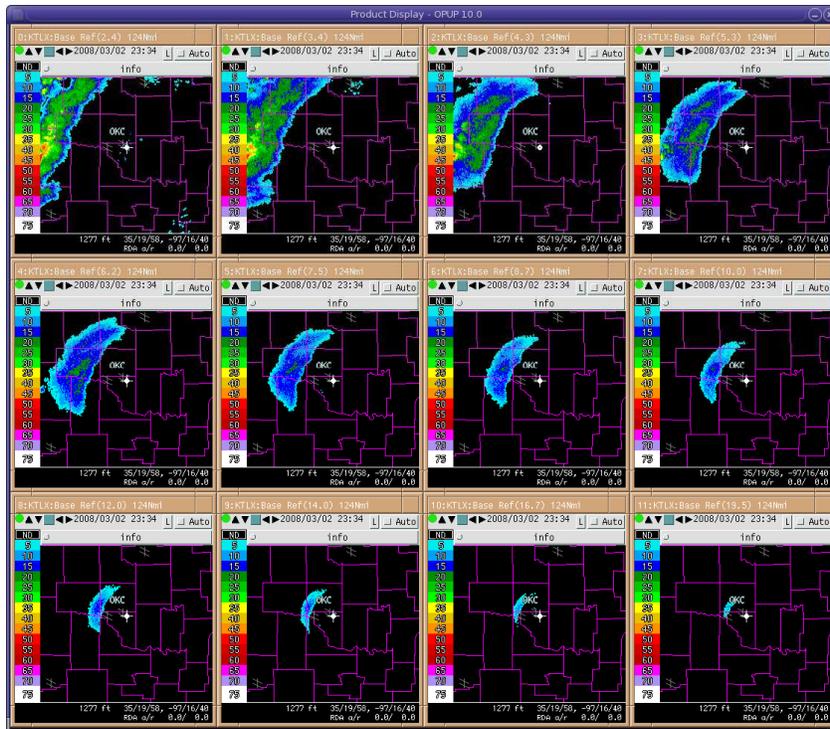


Fig. 4. Base reflectivity (top) and velocity (bottom) products in each window are displayed from the Norman WSR-88D KTLX valid at 2334 UTC 2 March 2008. The images are from the highest twelve elevation slices within a volume scan of VCP 11. Number within the parenthesis at the top of each window represents elevation angle. Courtesy of Joe Chrisman of ROC Engineering Branch.

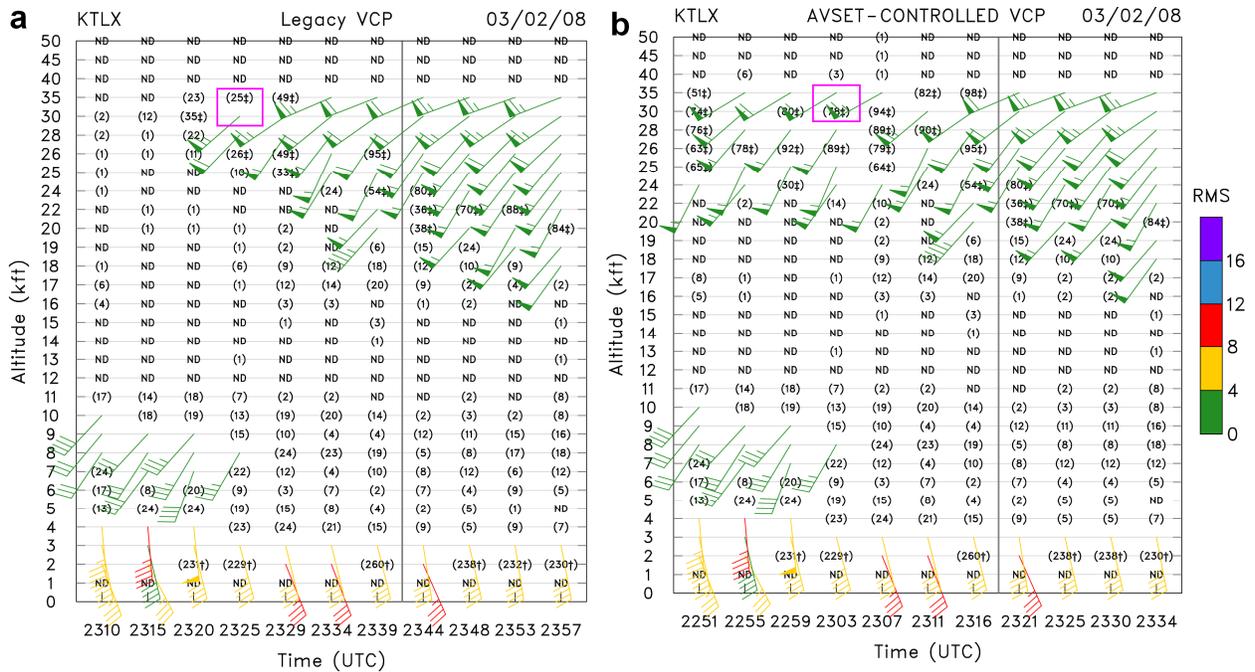


Fig. 5. (a) Legacy and (b) AVSET-controlled VWP for the Norman WSR-88D KTLX valid at (a) 2310-2357 and (b) 2251-2334 UTC 2 March 2008. The wind plotting convention is flag, 50 kt; barb, 8-12 kt; half-barb, 3-7 kt; and circle, <3 kt. Wind vectors are colored according to the RMS difference [shown in the right portion of panel b] between Doppler velocity measurements and fitted sine curve on the VAD circle. ND represents no data. Number within the parenthesis represents number of non-missing data points along the VAD circle. Single cross (+) adjacent to the number inside the parenthesis indicates that there are 25 or more non-missing data points, but RMS difference (kt) is greater than the RMS velocity threshold (default value 9.7 kt [ $5 \text{ m s}^{-1}$ ]). Double cross (‡) adjacent to the number inside the parenthesis indicates that there are 25 or more non-missing data points, but the mean of the sine curve is offset from zero Doppler velocity and is greater than the Symmetry threshold (default value of  $13.6 \text{ kt}$  [ $7 \text{ m s}^{-1}$ ]). Abscissa is UTC time; ordinate is height in kft, as shown by gray horizontal lines. The gray vertical line represents the switch from VCP 11 to VCP 12, and magenta rectangle refers to discussion in the text.



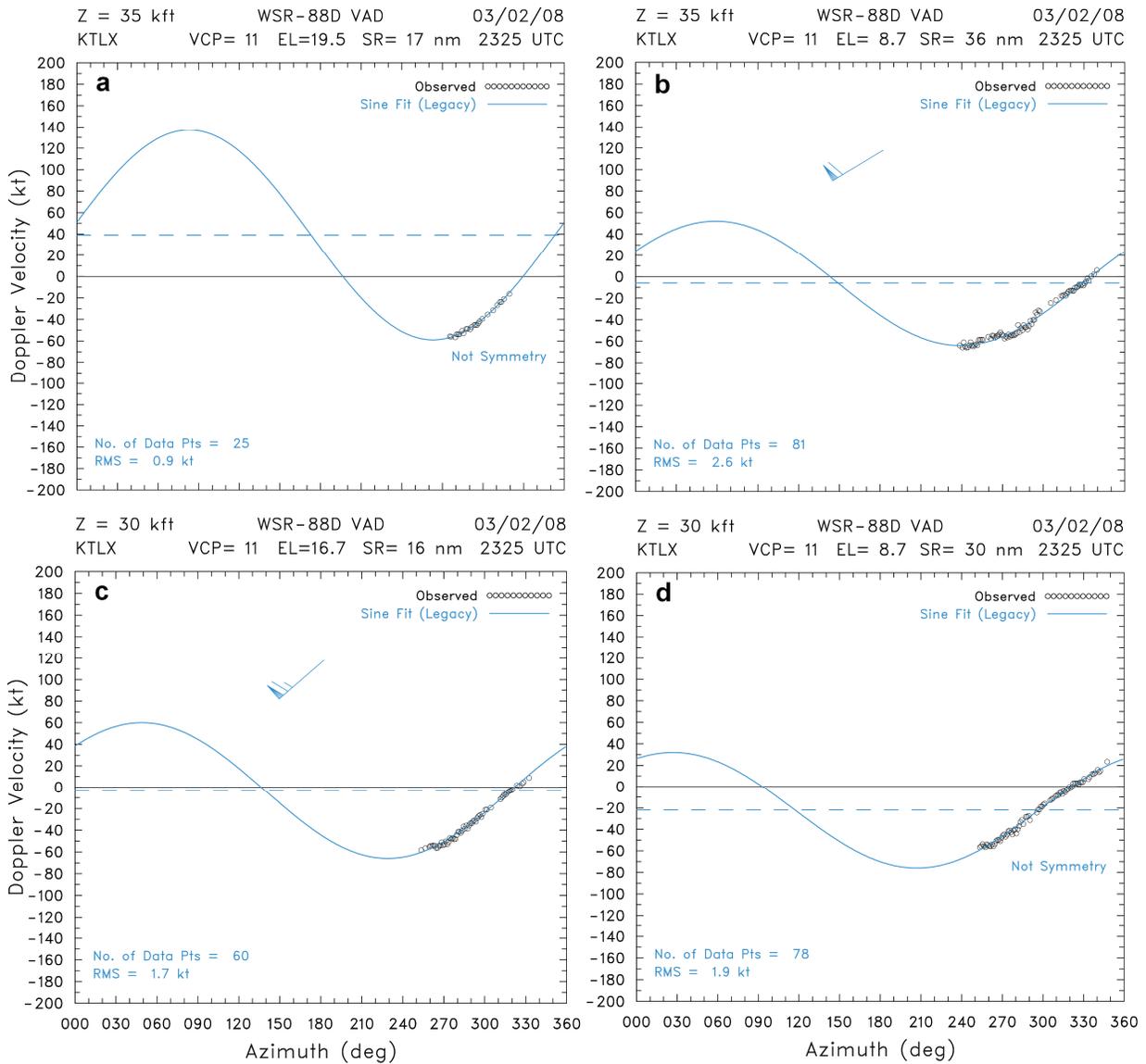


Fig. 7. Velocity (ordinate)-azimuth (abscissa) display produced by the legacy (panels a and c) and AVSET-controlled (panels b and d) VAD algorithm at (a) 35 kft (11 km) (19.5° elevation angle at slant range of 17 n mi [30 km]), (b) 35 kft (8.7° elevation angle at slant range of 36 n mi [67 km]), (c) 30 kft (9 km) (16.7° elevation angle at slant range of 16 n mi [30 km]), and (d) 30 kft (8.7° elevation angle at slant range of 30 n mi [55 km]) with VCP 11. Black circle curve refer to observed Doppler velocity values; blue curve refers to the fitted sine curve. Blue wind vectors plotted in each panel correspond to those within the magenta rectangle at 2325 UTC, as shown in Fig. 5. Blue horizontal dashed line represents the offset from zero Doppler velocity with the Symmetry threshold (default value of 13.6 kt [ $7 \text{ m s}^{-1}$ ]). Number of non-missing data points and RMS difference (kt) between Doppler velocity measurements and the fitted sine curve are indicated in the lower, left portion of each panel.

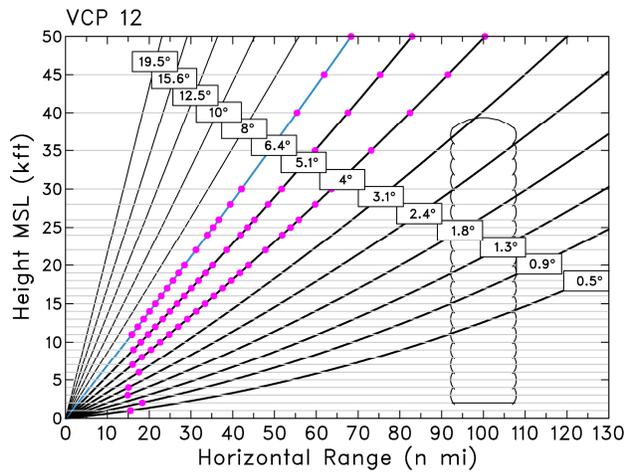


Fig. 8. Vertical cross section of conventional scanning strategy VCP 12 and superimposed (magenta dots) VWP heights with activated AVSET and extended VAD ranges on the last elevation angle (blue curve). A 40-kft (12-km) thunderstorm, depicted by its 18 dBZ surface, is shown at 100 n mi (185 km) from the radar. Gray horizontal line represents height in kft. The blue curve represents the completion of the last elevation angle at which AVSET would terminate if the thresholds are not met, assuming that there are no other cells closer to the radar.