P 4.7 **ENHANCED VELOCITY AZIMUTH DISPLAY WIND PROFILE (EVWP) FUNCTION FOR THE WSR-88D**

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1. INTRODUCTION

One of the most widely used products in the Weather Surveillance Radar – 1988 Doppler (WSR-88D) product suite is the Velocity Azimuth Display (VAD) Wind Profile (VWP) product (Figure 1). The VWP product provides a time verses height wind profile for the volume above the radar location.

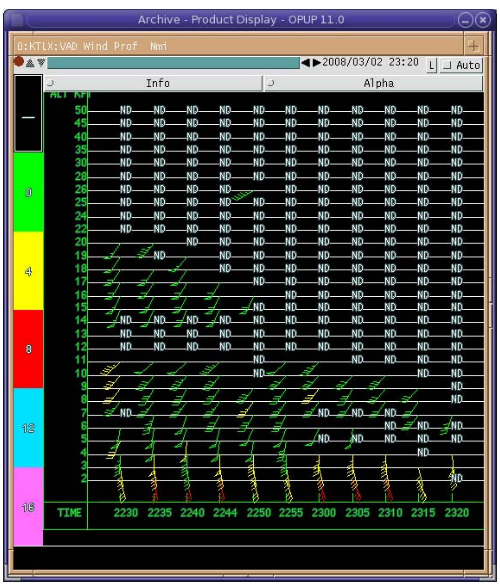

Figure 1: VWP Product from KTLX

The VWP product uses the wind estimate derived by the Velocity Azimuth Display (VAD) algorithm for each desired VWP height. The VAD wind estimate for each height is based on the data available for a single elevation/slant range pair. This assumes that adequate return is available using the single elevation/slant range pair to calculate a representative wind estimate for the particular height. In many meteorological situations this is not a valid assumption.

The Enhanced Velocity Azimuth Display Wind Profile (EVWP) function is designed to improve the availability and accuracy of VWP wind estimates. The EVWP function employs the VAD algorithm to produce multiple VAD wind estimates for each desired VWP height. Each of these VAD wind estimates is derived using a different elevation/slant range pair. At the end of the volume scan, the EVWP function selects the "best" VAD estimate for each height. These "best" wind estimates are used to build the final VWP product.

2. BRIEF OVERVIEW OF THE VAD ALGORITHM

The following overview of the VAD algorithm is presented for reference, only. It is not intended as an exhaustive description of the details of the algorithm. For additional information, refer to the Federal Meteorological Handbook Number 11 (FMH-11) Part B, Chapter 3 (http://www.ofcm.gov/fmh11/fmh11.htm).

The VAD algorithm calculates the horizontal wind speed and direction using the velocity data obtained from a particular elevation at a constant (slant) range that corresponds to the desired height. The algorithm performs a harmonic analysis, (i.e., calculates the best fit sine wave regression equation) on the Doppler velocity data collected from the resulting circle. Using the best fit sine wave, the algorithm calculates the Root Mean Square (RMS) difference of the velocity data points. This initial RMS value is used to identify base velocity data point outliers. To reduce the impact of residual clutter return on the VAD wind speed and direction

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

estimate, the base velocity data point outliers that are biased toward zero are discarded. If the number of remaining base velocity data points is greater than the threshold (default 25) a second regression analysis is performed. From this second best fit sine wave, the final RMS and Symmetry (offset of the zeroth harmonic from the constant zero line) are calculated (see Figure 2). If both of the RMS and Symmetry values are below their defined thresholds (default 5 m/s and 7 m/s, respectively), the algorithm computes a wind speed and direction for the height. If either the RMS or Symmetry exceed their defined threshold then the wind speed and direction for the height is set to “No Data”. For each VWP height, the VAD algorithm populates the VAD data array with either the calculated wind speed and direction or the “No Data” flag.

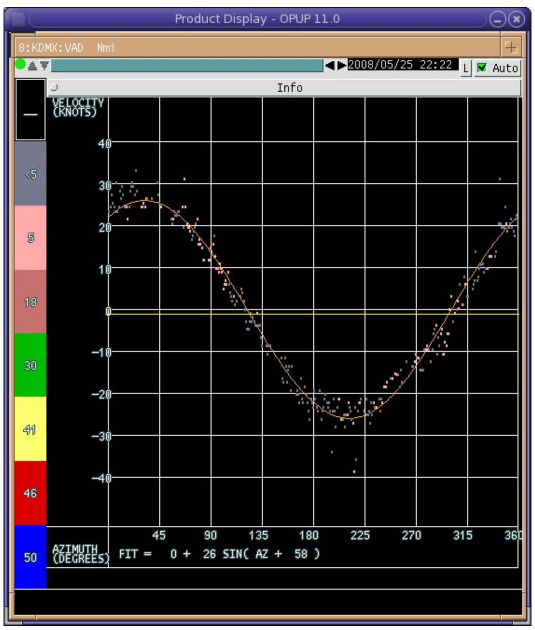

Figure 2: VAD Product with Zeroth Harmonic Added (Yellow)

3. BUILDING THE CURRENT VWP PRODUCT

At the beginning of each volume scan, the VAD algorithm calculates the elevation/slant range pair for the active volume coverage pattern (VCP) required to achieve the heights specified for the VWP product (see Figure 3). The VAD algorithm uses a slant range parameter (default = 30 km) to guide the selection of the elevation angle for each required height. For any particular height, the elevation angle with slant range closest to the slant range parameter is used to compute the wind.

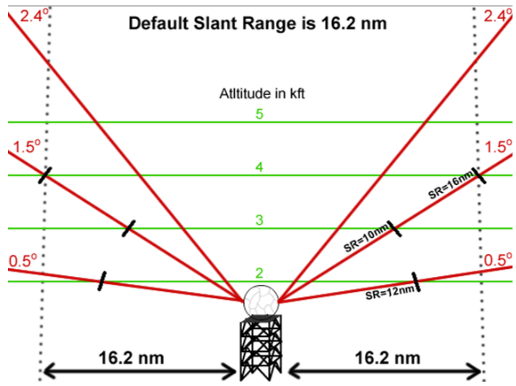

Figure 3: VAD Elevation Processing

The VAD wind estimate for each height is based on the data from a single elevation/slant range pair. (For Clear-Air Mode an average of three range bins is used.) This assumes that adequate return is available using the single elevation/slant range pair to calculate a representative wind estimate for the particular height. The computed wind estimate for each height is stored in the VAD data array and, at the end of the volume scan, is used to build the VWP product.

4. EVWP CONCEPT

The concept behind the EVWP function is the fact that each VWP height is achieved at different slant ranges depending on the elevation (see Figure 4). Additionally, using multiple elevation/slant range pairs for a given height increases the likelihood of sampling valid return from which to derive a representative wind estimate for that height.

Figure 5 illustrates the number of VAD estimates possible, executing VCP 12, for each VWP height for a radar sited at 500ft MSL (the slant range for this example is limited to ≥10km and ≤120km).

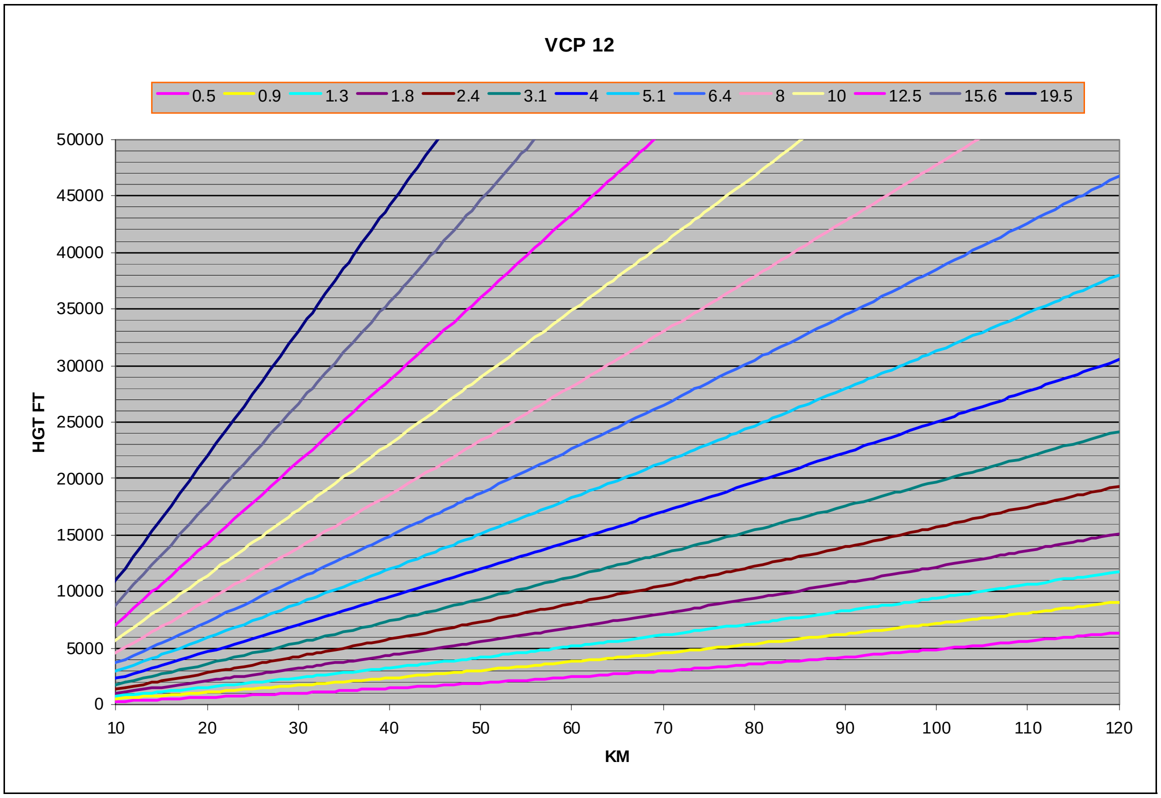

Figure 4: VCP 12 Elevations Plotted on Range / Height Grid

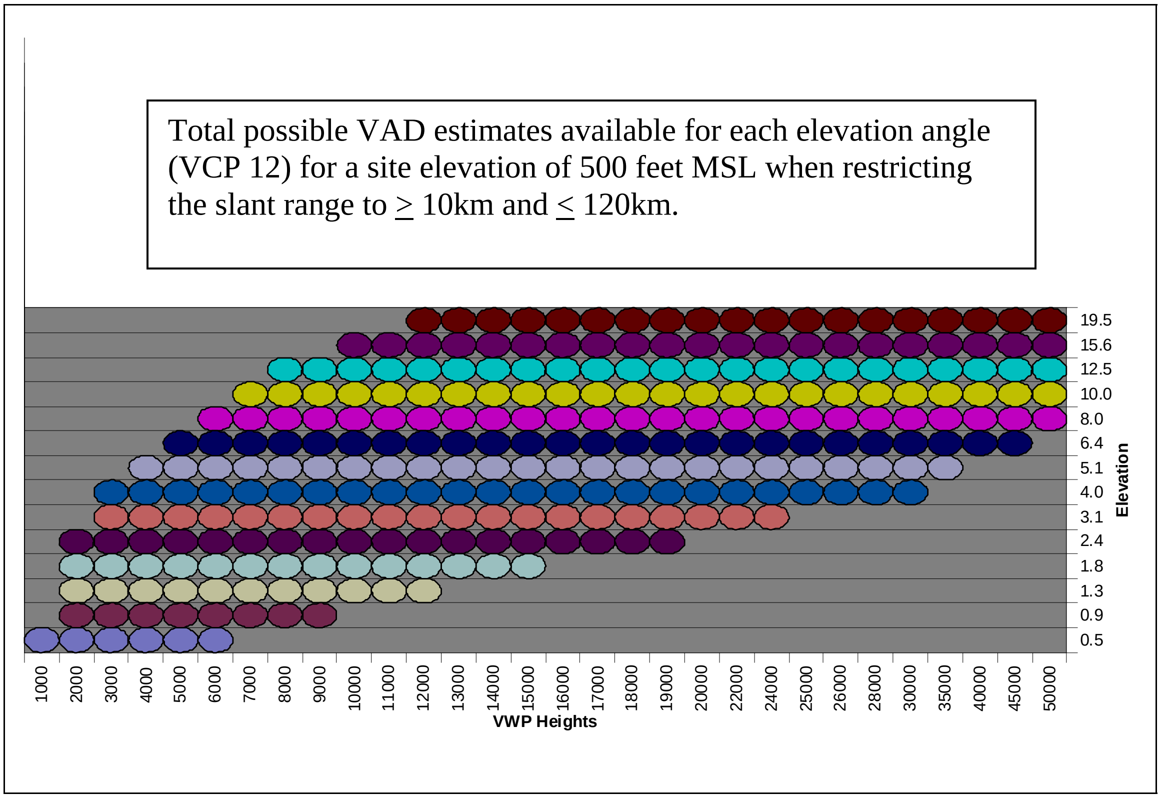

Figure 5: Possible VAD Estimates for each Height

5. EVWP FUNCTIONAL DESCRIPTION

Each volume scan the VAD algorithm[1] executes its normal processes to produce a single wind estimate for each desired VWP height. These "Original" VAD wind estimates are stored in the VAD data array to be used to build the VWP product. Additionally, at the beginning of each volume scan, the EVWP function calculates every possible elevation/slant range[2] pair for the active VCP that achieves a height specified for the VWP product (refer to Figure 2). As each elevation is scanned, the EVWP function passes these additional slant ranges to the VAD algorithm to process. The VAD algorithm computes a wind estimate for each height (identified slant range) intersected by the elevation scan. Each wind estimate is passed to the EVWP function for validation. If the wind speed is <u>GREATER</u> than two times the estimate's RMS error <u>AND</u> the absolute value of its Symmetry value <u>MINUS</u> its wind speed is <u>LESS</u> than -6m/s, <u>THEN</u> the wind estimate is considered a ***valid*** Supplemental wind. Any wind estimates that do not meet these criteria are discarded. The valid Supplemental wind estimates are stored in the EVWP data array and may be used to build the VWP product.

Note[1]: There are no modifications to the VAD algorithm.

Note[2]: The EVWP function restricts the slant range to $\geq$10km (to reduce the impact of residual ground clutter) and $\leq$120km (to constrain the size of the VAD analysis circle).

6. BUILDING THE VWP PRODUCT WITH THE EVWP FUNCTION

At the end of the volume scan, the EVWP function determines which VAD estimate to use for each height in the VWP product based on the decision logic presented in Table 1.

Table 1: EVWP Decision Table

Original VAD Estimate Available?	Valid Supplemental VAD Estimate(s) Available?	VWP Wind Plot
NO	NO	ND (No Data)
YES	NO	Original VAD Estimate
NO	YES	Supplemental VAD Estimate with Lowest RMS
YES with RMS $\leq$2m/s	YES	Original VAD Estimate
YES with RMS >2m/s	YES	VAD Estimate (either Original or Supplemental) with Lowest RMS

This decision logic ensures that the Supplemental wind estimates are **<u>ONLY</u>** used to supplement or improve the VWP product winds.

7. ORIGINAL VWP / ENHANCED VWP COMPARISION EXAMPLES

To support meteorological testing, the EVWP function was installed on a Radar Operations Center (ROC) test bed Radar Product Generator (RPG) and the associated display code was installed on an Open System Principal User Processor (OPUP). These test bed assets are used to process Level II data collected from multiple operational WSR-88Ds. To facilitate evaluation of any improvement provided by the EVWP function, the test code produces an "Original" VWP product and an "Enhanced" VWP (EVWP) product that incorporates the winds estimates selected by the EVWP function. The following three cases are representative of our results, to date.

7.1 KDMX May 25, 2008

Figure 6 presents the 0.5º Base Reflectivity images from the Des Moines, Iowa WSR-88D (KDMX) for 23:17Z and 23:59Z, respectively. The "Original" VWP product (slant range of 30km) and EVWP product for this time period are presented as Figure 7. The skew-t diagrams from two nearby upper-air stations (KOAX and KDVN) are provided in Figure 8.

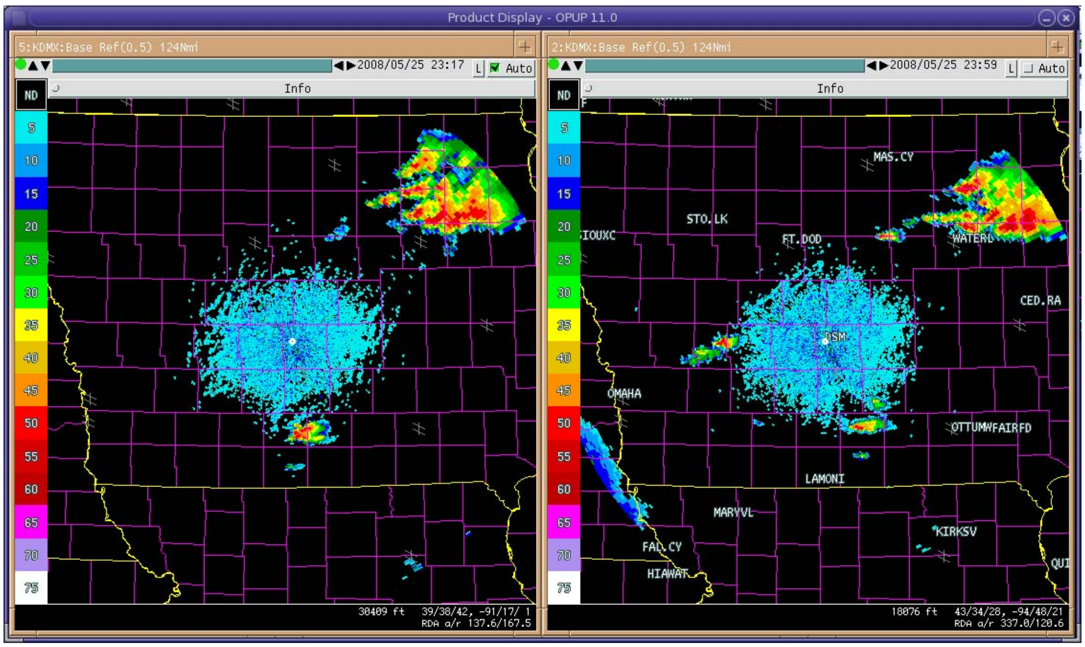

Figure 6: KDMX Reflectivity Products from 23:17Z and 23:59Z

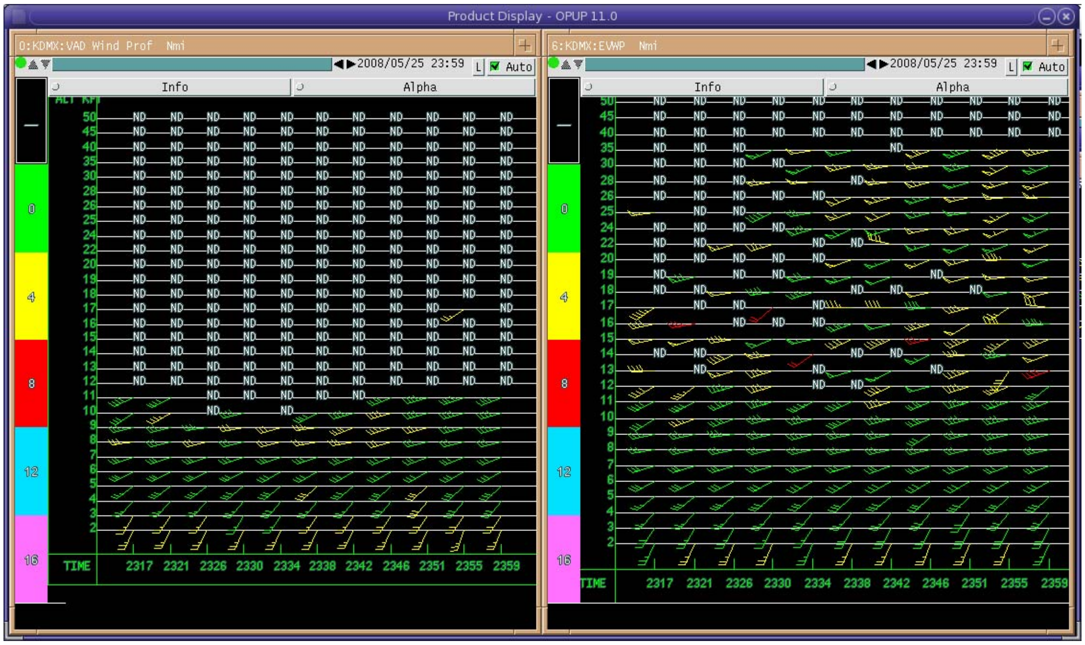

Figure 7: KDMX VWP and EVWP Comparison

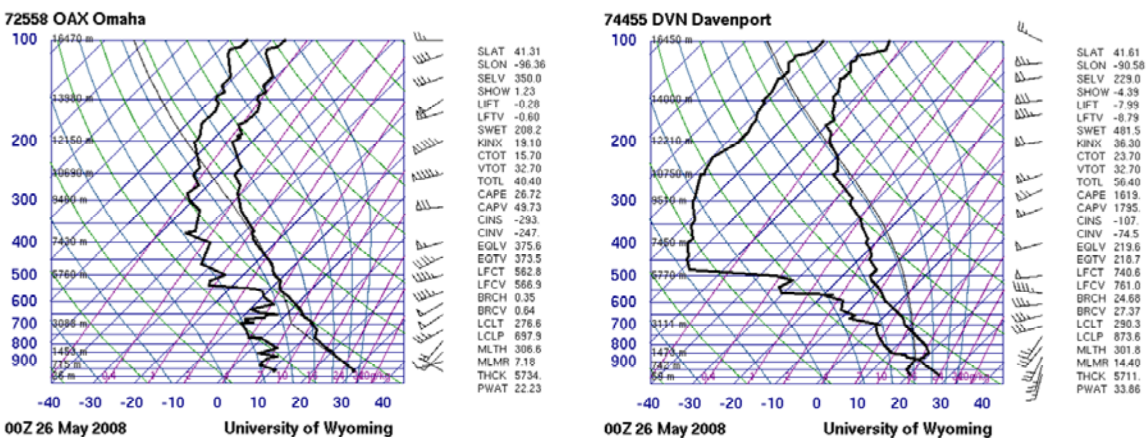

Figure 8: KOAX and KDVN Skew-Ts 00Z May 26, 2008

7.2 KTLX March 2, 2008

The Base Reflectivity images in Figure 9 depict the location of the convective weather at 22:30Z and 23:20Z, with respect to the Norman, OK WSR-88D (KTLX). During this event, one confirmed tornado occurred at 2246Z, approximately 75nm NW of KTLX radar. The "Original" VWP product (slant range of 30km) and EVWP product for this time period are presented as Figure 10.

The skew-t diagrams from two nearby upper-air stations (KAMA and KOUN) are provided in Figure 11.

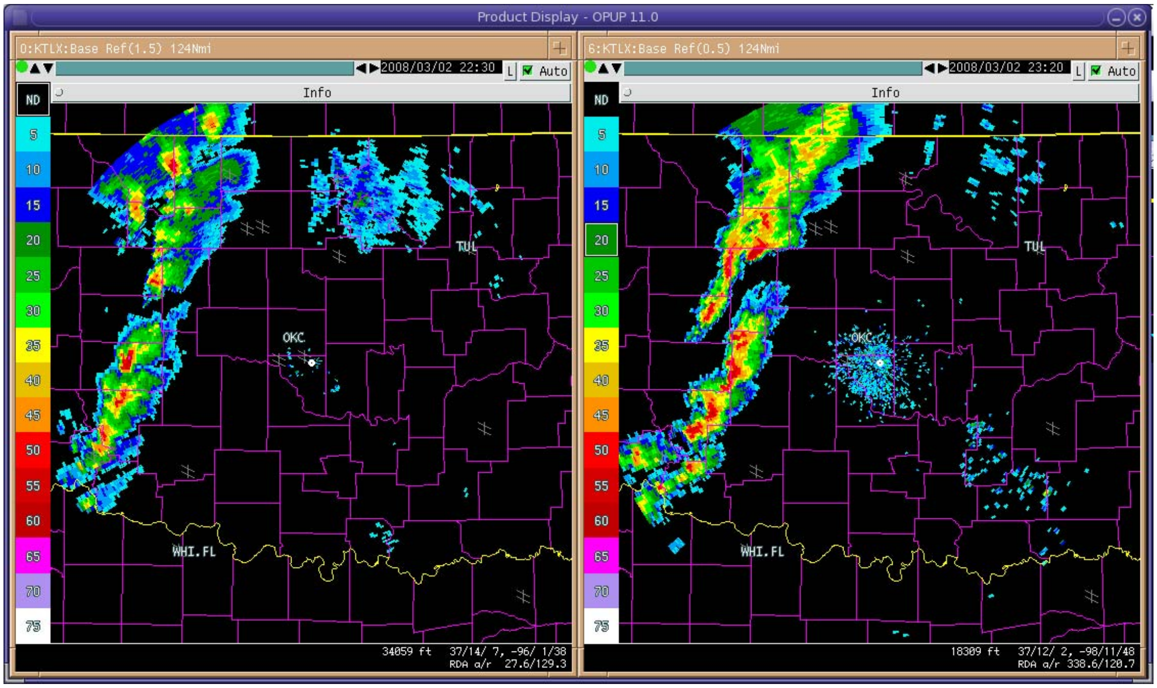

Figure 9: KTLX Reflectivity Products from 22:30Z and 23:20Z

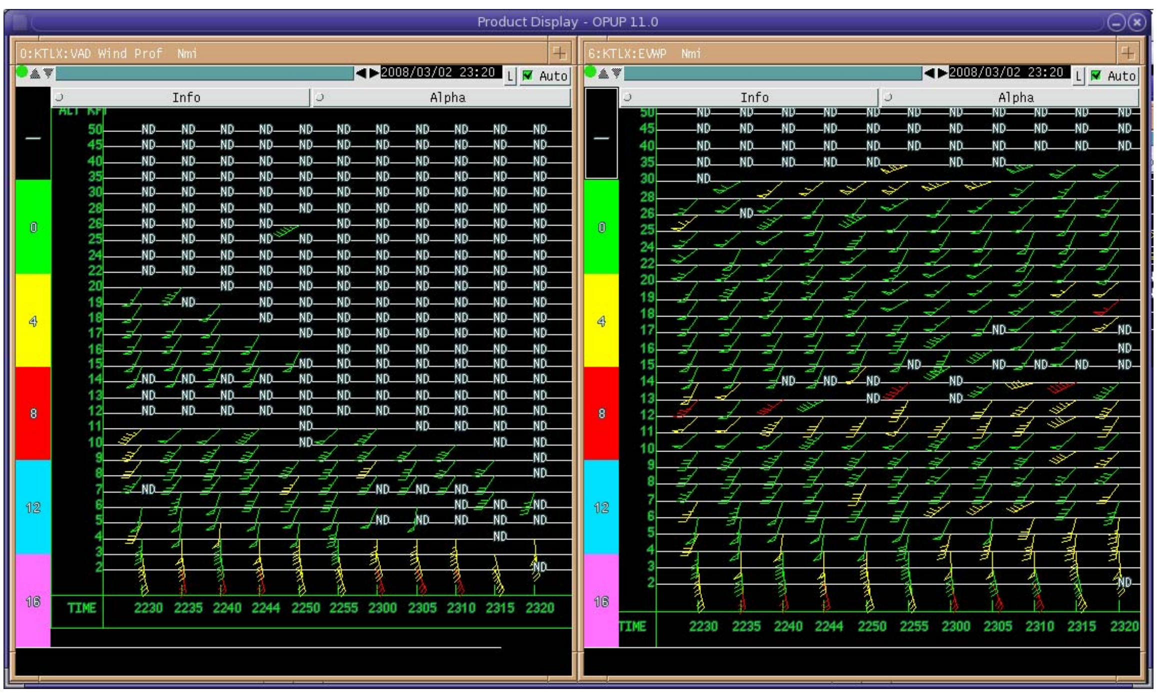

Figure 10: KTLX VWP and EVWP Comparison

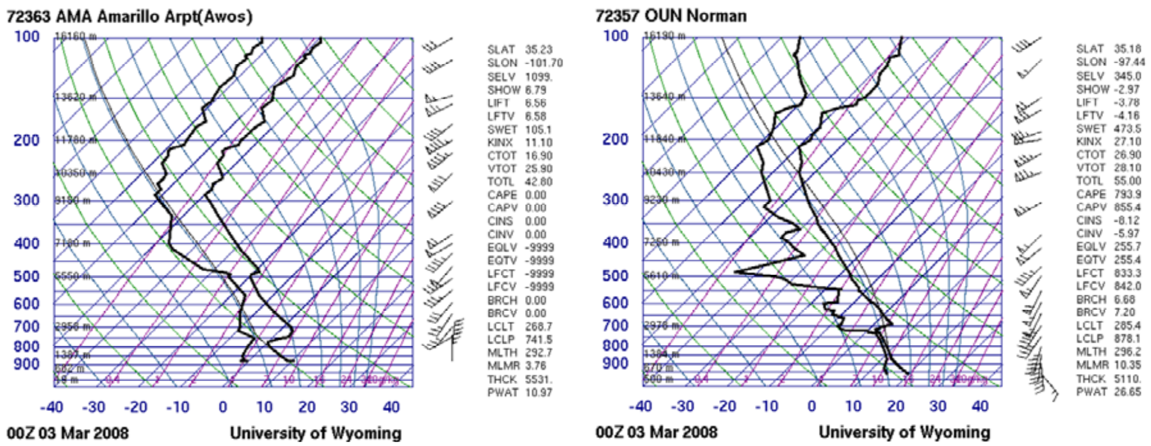

Figure 11: KAMA and KOUN Skew-Ts 00Z Mar 3, 2008

7.3 KRAX August 7, 2008

Figure 12 presents the Base Reflectivity images from the Raleigh, NC WSR-88D (KRAX) for 21:03 and 21:45Z. The "Original" VWP product (slant range of 30km) and EVWP product for this time period are presented as Figure 13. The skew-t diagrams from two nearby upper-air stations (KGSO and KMHX) are provided in Figure 14.

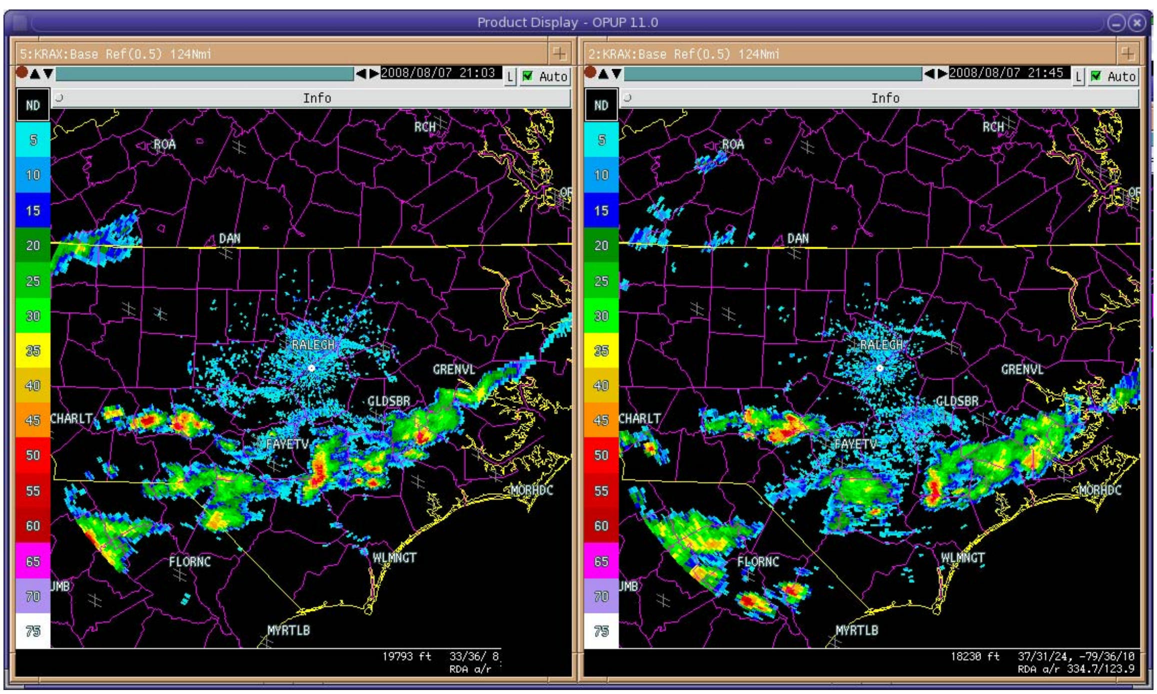

Figure 12: KRAX Reflectivity Products from 21:03Z and 21:45Z

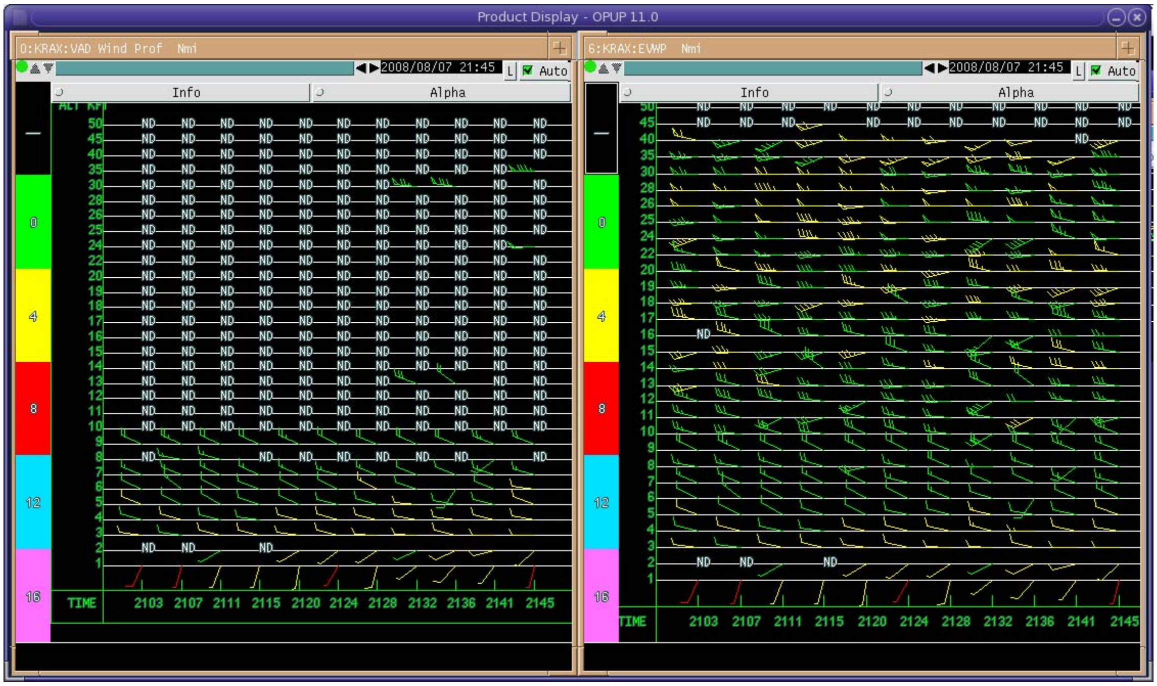

Figure 13: KRAX VWP and EVWP Comparison

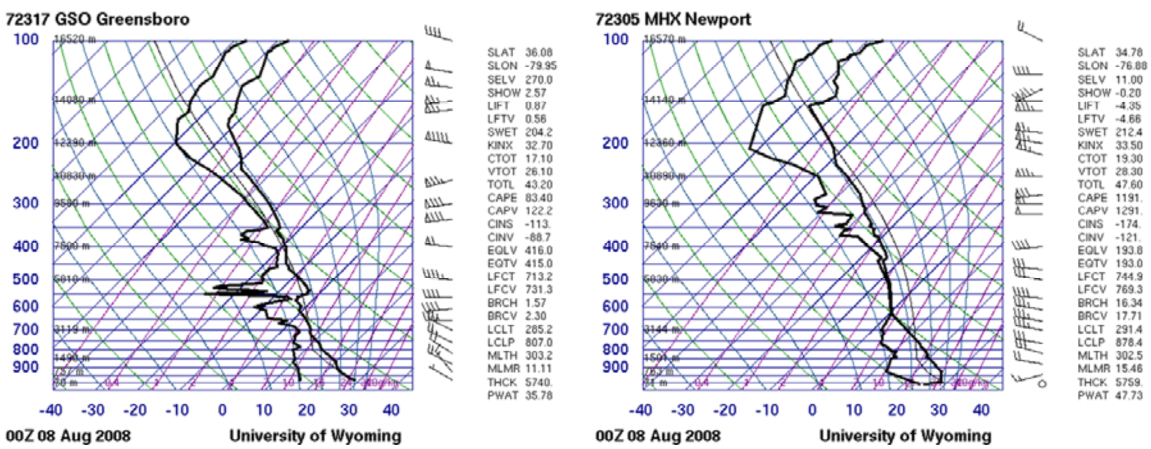

Figure 14: KGSO and KMHX Skew-Ts 00Z Aug 8, 2008

8. SUMMARY

The EVWP function is still undergoing developmental testing at the WSR-88D ROC. Results of testing, to date, indicate that the EVWP function consistently provides additional wind estimates not initially processed by the legacy VAD/VWP algorithms. Additionally, the inclusion of these Supplemental wind estimates on the VWP product can improve the overall operational usability of the VWP product.

The EVWP function could be ready for implementation into the WSR-88D baseline software as early as 2012. The design of the EVWP function is to provide additional wind estimates to augment the wind data available for inclusion on the VWP product. This implementation will not change the basic format of the VWP product and therefore, will not impact downstream processing and display systems.