SRH STSD 2007-03
October 2007

Technical Attachment

The National Weather Service Estimated Actual Velocity Radar Tool

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1. Introduction

A radar analysis tool has been introduced into the Advanced Weather Interactive Processing System (AWIPS) in the Operational Build 8.2 software called the Estimated Actual Velocity (EAV) radar tool. The EAV is expected to help meteorologists in both convective warning decision making and in long term warning analysis and verification.

The EAV was created to give meteorologists another tool to assist in the real time assessment of actual wind speeds in the environment detectable by the WSR-88D. This additional wind speed information may help warning meteorologists and those tasked with issuing long term public forecast advisories and warnings.

2. Use of The Estimated Actual Velocity Tool

This new WSR-88D tool is expected to give meteorologists a better estimate of actual two dimensional wind speeds than the base velocity product. Since Doppler radar can only detect the wind speed component directly toward or away from the radar (i.e. radial velocity), it samples wind speeds less than the full two dimensional wind speed. The EAV tool adds the component perpendicular to the radar beam using an input wind direction.

Some possible uses of the EAV tool are discussed below. However, it is likely that additional uses of the EAV will be developed as it is incorporated into National Weather Service forecast office operations.

A primary use of the EAV is to provide a better estimate of wind speeds associated with a squall line. For example, suppose a north to south oriented squall line moving from west to east contains 60 kt westerly winds at the height of the 0.5 degree radar beam. If the radar beam is sampling the 60 kt westerly winds along the 315 degrees radial (crossing at a 45 degree angle), the radial velocity component measured would be 46 kts. If the forecaster was able to estimate the westerly wind direction accurately behind the squall line from the echo geometry or using representative surface observations, the EAV would provide an estimate of the actual two dimensional wind speed of about 60 kts. This would provide more confidence in issuing severe thunderstorm warnings and follow-up statements, particularly when base velocity measurements are below severe criteria (50 kts). For a given user defined wind direction, the EAV will estimate the two dimensional wind speed for any point where base velocity data are available (with certain limitations outlined in Section 4).

Another use of the EAV is to estimate actual wind speeds in a blizzard. The definition of a blizzard includes both heavy snow and wind speed conditions. The NWS definition of a blizzard is "Sustained wind or frequent gusts greater than or equal to 35 mph accompanied by falling and /or blowing snow, frequently reducing visibility to less than ¼ mile for three hours or more" (National Weather Service Instruction 10-513). For example, consider a winter weather situation with a northerly (from 360 degrees) low level jet intensifying behind a strong surface cyclone over an area where you have limited surface observations but reasonable radar coverage at close to moderate range. Suppose the radar base velocity shows 26 kt winds at 2,000 feet AGL along the 30 degree radial (crossing at a 30 degree angle), and a forecaster is interested in knowing whether the wind speed could be significantly higher due to sampling considerations. If the northerly wind direction could be accurately estimated from model forecasts or somewhat uniform regional surface observations, the EAV would suggest the actual wind is only 30 kts. This would only marginally support blizzard conditions if that wind speed was representative of what was occurring at the surface.

A third possible use of the EAV tool is estimating actual wind speeds in a tropical cyclone. The definitions of a hurricane and a tropical storm are wind speed dependent (NWS Instruction 10-604). For example, suppose a land-falling tropical cyclone to the west of the radar site is observed to be moving from 230 degrees (southwest to northeast) and the winds in the right quadrant are blowing from the same direction (230 degrees). If the radar is sampling 70 kt radial winds in the right quadrant along the 270 degree radial (crossing angle is 40 degrees), the EAV would suggest the two dimensional winds at that level could be 91 kts. The EAV could also be used to determine a range of potential wind speeds by varying the input wind direction. In this instance changing the estimated wind direction by +/- 10 degrees (220-240 degrees) would yield a range of speeds from 81 to 109 kts.

Other uses of the EAV tool include estimating actual wind speeds in gradient wind storms (dust storms), and terrain forced winds such as gap flow winds and Santa Ana wind storms, when base velocity data are available.

3. Concept and Development of the Estimated Actual Velocity Tool

The EAV tool is based on the concept that the WSR-88D detects a wind component toward (or away) from the radar site, with the other wind component being perpendicular to it. If a meteorologist can accurately estimate the wind direction at a point on the radar screen, then a rather simple calculation would yield the estimated actual velocity

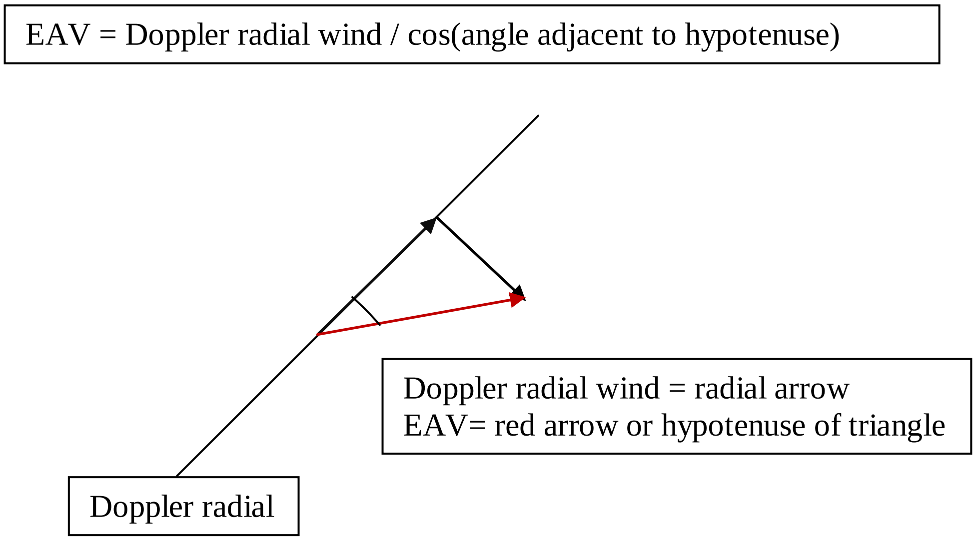

Figure 1. Diagram showing the theory behind the Estimated Actual Velocity computation.

Figure 1 shows the concept and application of the EAV tool in AWIPS. The EAV is calculated using the Doppler radial wind speed (from the base velocity product) and the wind direction (input by the meteorologist). These values are applied to the solution of a right triangle oriented along the radial (Wooten and Drooyan, 1971). The length of the hypotenuse of the right triangle equates to the estimated two dimensional wind speed. This equation can be applied to the radial wind at any point along a Doppler radial (where a base velocity wind is available).

EAV = Doppler radial wind / cos(angle adjacent to hypotenuse)

The solution to this equation requires the user to input an estimated wind direction. This is accomplished in AWIPS by starting the EAV tool, and orienting the EAV tool's baseline along the estimated wind direction at that point on the WSR-88D radar display (preferably a base velocity display). The EAV equation is then solved to produce the estimated actual velocity, which is displayed on the AWIPS screen.

A table of estimated actual velocity values based on different crossing angles and radial Doppler wind speeds is provided in Table 1. This table, which was the predecessor of the EAV tool, was developed at the NWS Weather Forecast Office in Shreveport, LA, and it has been used through the years during severe weather situations to assist the warning meteorologists in their warning decision making.

ACTUAL WIND DIRECTION IN DEGREES OFF RADAR BEAM (#)

DOPPLER WIND (KTS)	0	10	20	30	40	50	60	70	80	90 DEGREES
5	5	5	5	6	7	8	10	15	29	CAN
10	10	10	11	12	13	16	20	29	57	NOT
20	20	20	21	23	26	31	40	58	115	BE
22	22	22	23	25	29	34	44	64	126	DETER-
26	26	26	28	30	34	40	52	76		MINED
30	30	30	32	35	39	47	60	88		
36	36	37	38	42	47	56	72	105		
40	40	41	43	46	52	62	80	117		
50	50	51	53	58	65	78	100	146		
60	60	61	64	69	78	93	120			
64	64	65	68	74	84	99	128			
70	70	71	74	81	91	109				
80	80	81	85	92	104	124				

ESTIMATE OF ACTUAL WIND (KTS)

$$X = \text{ESTIMATE OF ACTUAL WIND} = \frac{\text{Y (DOPPLER WIND IN KNOTS)}}{\text{COS}(\#)}$$

Table 1. The estimated actual wind based on radial Doppler wind (left axis) and angle of true wind direction crossing the radar beam (top axis).

To launch the EAV tool in AWIPS D2D, the user should first load a velocity product (e.g. Z/V All Tilts) and select “Estimated Act Vel” from the “Tools” menu (Figure 2). The baseline that appears on the screen (Figure 3) is interactive, and the user can orient the baseline at a point to estimate the wind direction at that point. The calculation of EAV is done automatically at both end points of the baseline as long as a base velocity is available, and the angle off the radial is less than 75 degrees. No EAV will be calculated for off-radial angles greater than 75 degrees.

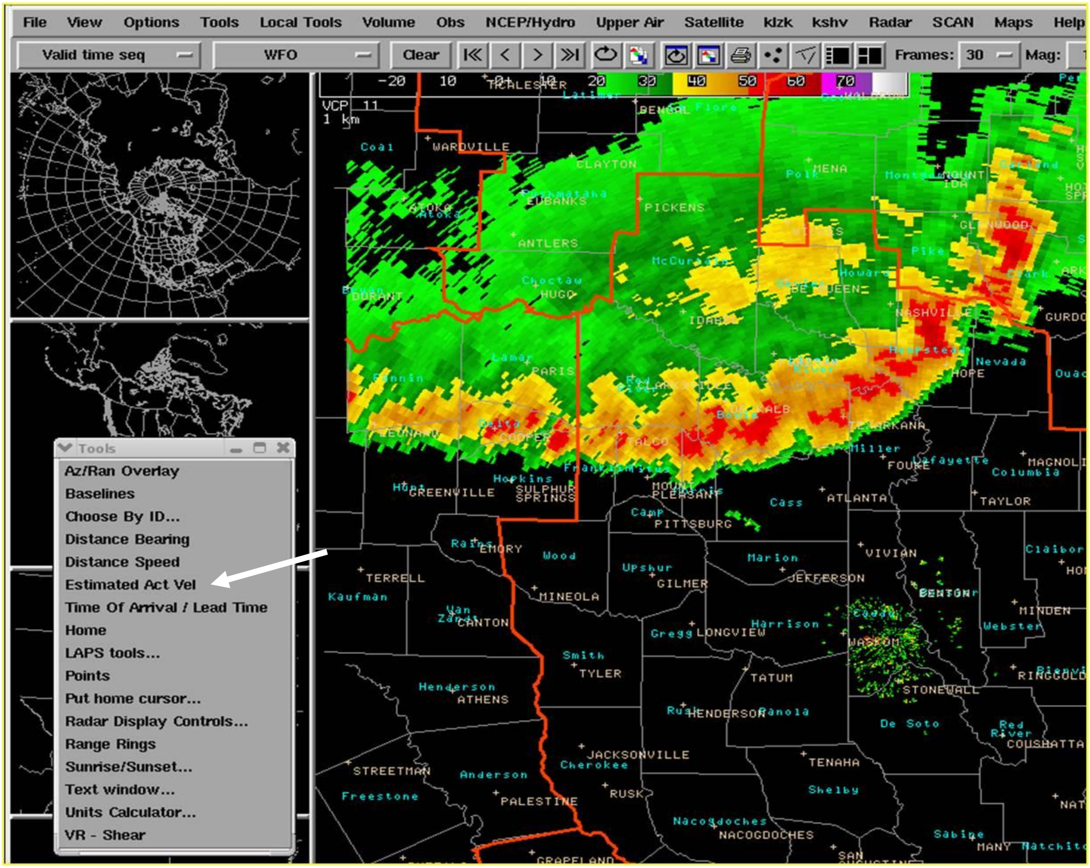

Figure 2. The Estimated Act Vel item is available on the Tools menu of AWIPS D2D.

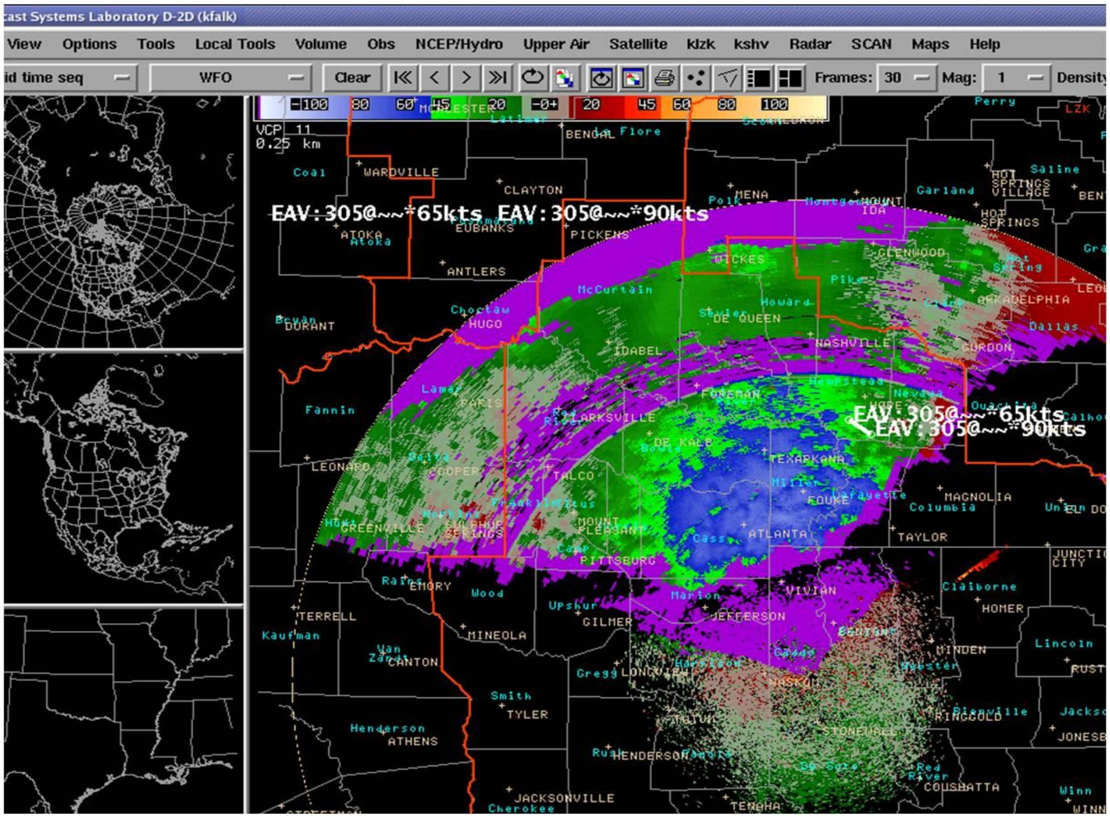

Figure 3. Sample application of the Estimated Actual Velocity tool. The 0.5 degree base velocity data are shown with the EAV tool. The KSHV RDA is in the lower right of the screen. The base velocity was 50 knots at the point where EAV was 90 knots. The baseline was oriented along the estimated wind direction at that point by the meteorologist. Significant wind damage was reported with this event in southwest Arkansas (Murrell, 2006), where the EAV was calculated. Note that the EAV configuration file was changed for the delimiter for large angles (>50 degrees off radial) to read "~~*" instead of "~~" in this figure.

4. Strengths and Limitations, and Suggested Use of, the Estimated Actual Velocity Tool

As with any radar tool, the EAV has strengths and limitations on its use. Several are listed below, with some suggestions for use of EAV.

Strengths:

a. The EAV can be used to provide better estimates of wind speeds in severe straight-line wind storms, hurricanes, and blizzards, and other localized wind phenomena, provided the wind direction is estimated accurately.
b. The EAV uses little computer resources.
c. The mouse cursor readout will give an EAV at the cursor point in addition to the baseline end points. This effectively applies the specified wind direction from the

baseline to any radial velocity in the display, allowing for easier sampling of many radar gates.

d. When the off-radial wind direction becomes large (> 50 degrees), the readout will change from "~" to "~~" to indicate the large angle. A parameter file is configurable in AWIPS that contains this delimiter (see /awips/fxa/data/localization/nationalData/eavConfigTable.txt). This is intended to raise awareness that the potential error in the EAV estimate is starting to become significant in the calculation. It is recommended to set the "~~" delimiter to a more readable "~~*" in the configuration file for EAV.

Limitations:

a. The EAV will produce erroneous results if the input wind direction is not representative at the point being evaluated. (see Table 1to evaluate the effects of errors in wind direction).
b. The EAV is dependent on accurate radial base velocity at a point, and large beam volumes can sometimes not resolve small areas of strong winds.
c. As wind direction becomes more perpendicular to the radar beam, the EAV can become so large that is not reliable. There is an absolute cutoff of EAV data for off-radial angles of 75 degrees or more . The user can define a cutoff angle less than 75 degrees. A cutoff of EAV data for wind directions somewhere between 70–75 degrees off the radial is recommended.
d. The wind speed measured at the lowest tilt is many times not representative of the wind speed measured at the ground, particularly in situations of stable boundary layers.

Suggestions:

a. The user should ensure the estimated wind direction is accurate for each point to be evaluated, whether using the end points on the wind direction baseline, or the mouse cursor readout of the EAV. Both ends of the baseline will give an EAV value. When setting the wind direction baseline, a short baseline in a area of constant wind direction should be used. For higher crossing angles, errors of 10 to 20 degrees in wind direction can lead to significant errors in the EAV.
b. The user should not assume the wind direction is the same at both ends of the wind direction baseline.
c. It is recommended to keep both ends of the wind direction baseline within an inbound or outbound wind area. One should not set the wind direction baseline across a zero knot isodop from inbound to outbound winds (or vice versa). This invites an incorrect wind direction, making the EAV calculation inaccurate.
d. The EAV tool can be used with 8 bit or 4 bit base velocity products, or with 8 bit SRM products. The recommendation is to use the 8 bit base velocity products. If used on 8 bit SRM, the base velocity wind value will be used to calculate EAV, and not the SRM value. The EAV tool will not work on 4 bit SRM products.

5. Acknowledgments

I thank Jeff Craven (SOO, WFO Milwaukee, WI) for help in the research and development of the EAV tool. Mike Magsig (NWS Warning Decision Training Branch) was also a great help in the development of the EAV and in the development of related training materials. He also provided comments and suggestions for this paper. Jim Ramer (Global Science Division, NOAA's Earth System Research Laboratory) assisted in the AWIPS programming of the EAV.

6. References

Murrell W., 2006: Widespread Wind Damage from 2 June 2004 Derecho in the ArkLaTex. NOAA/NWS Technical Attachment SRH SSD 2006-3, 9 pp.

Wooten, W., and I. Drooyan, 1971: *Elementary Functions*. Wadsworth Publishing Company, Inc., 311 pp.