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NORTHEAST AND EAST CENTRAL NEVADA 'VIL OF THE DAY'

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Introduction

Since its inception, the Weather Surveillance Radar - 88 Doppler (WSR-88D) has aided National Weather Service forecasters in the issuance of severe thunderstorm and tornado warnings. The algorithms that accompanied the WSR-88D, such as the Hail Detection Algorithm (HDA) and the Vertically Integrated Liquid (VIL) algorithm, have also aided forecasters by providing added information in the warning decision-making process. However, these algorithms are not without fault, and sometimes provide misleading and/or exaggerated information. A study done by Maddox et al. (1998) in southeast Arizona showed that the HDA Probability of Severe Hail (POSH - where severe hail equals or exceeds 3/4 in.) and probability of hail (POH) output often produces a considerable number of false alarms at high elevation radar sites. Forecasters at National Weather Service Forecast Office (WFO) Elko, NV, have also noticed the inflated POH and POSH values, particularly during summer thunderstorms. Since Build 10 has been implemented, the Warning Threshold Select Model (WTSM) value has been authorized to be changed to a value that would lower the POSH estimates. However, this new value has not been implemented at WFO Elko, NV, as of this writing.

Clearly, additional tools need to be developed at WFO Elko, NV, to help aid the forecaster in severe hail forecasting. There are two options that have been widely discussed in the literature, 'VIL of the Day' (VOD) and VIL density (a normalized form of VIL, typically using Echo Top or Storm Top). Paxton and Shepherd (1993) suggest using VIL as an indicator of severe thunderstorms in central Florida, and this was subsequently followed by Wilken's (1994) paper on VOD for use in Arkansas. The VOD value was found to be very useful to the forecasters at WFO Little Rock, AR. Several papers since then, such as Amburn and Wolf (1997), have dealt with VIL density, and VIL density will be investigated in a later paper. The goal of this paper is to introduce VOD to the forecasters at WFO Elko, NV, so they can use this value in the warning decision-making process.

Methodology

Northeast and east central Nevada contain varied topography ranging from broad valleys to narrow, steep mountain ranges. Mountain peaks in these ranges often exceed 10,000 feet. These mountain ranges effectively squeeze out most of the moisture resulting in very little rainfall in the valleys. In addition, the valleys are not well populated and approximately 75,000 people live in WFO Elko's area of responsibility which covers more than 47,000 miles. In order to account for the lack of storm reports, the study analyzed storms from the years 1997 through 2001. All storm spotter reports that included heavy rain and hail were analyzed for possible use in the study (120 reports). Of these original 120 reports, 78 contained hail, of which 15 were severe. These reports were then compared to storms using Archive level II data for the WSR-88D Algorithm Testing and Display System (WATADS), if possible. Due to the large number of days involved in the study, only 6 days were analyzed using WATADS. These 6 days were chosen because they had at least one severe hail report. All remaining storms were analyzed using Archive level IV data at the WSR-88D Principal User Processor (PUP), if the data was available. This effectively eliminated half the reports due to lack of data.

When comparing the reports to the storms in question, any duplicate report from the same thunderstorm also reduced the potential number of storms analyzed. However, there were only two storms that had duplicate reports. Storms that were within 15 nm of the WSR-88D's Radar Data Acquisition system were also not used as the VIL values would be lower due to inadequate sampling, thus removing another eight reports. Finally, several other reports were thrown out because the spotter reports were as much as 5 miles away from the center of the storm, and there was no way of knowing exactly what the storm was precipitating. (Obtaining distant reports about a possible severe thunderstorm is often done at WFO Elko, NV, because of the sparse population base, and because of the idea that 'A distant report is better than no report at all.') Only those reports where the center of the storm passed directly over, or within 2 miles of, the spotter report were used.

Using these considerations, a total of 20 storms were analyzed covering 16 days. Of these 20 reports, only 6 produced severe hail, 10 produced small hail (1/4 in. to ½ in.), and 4 produced only heavy rain. For each report, the greatest grid-based VIL (GBVIL) value and cell-based VIL (CBVIL) value was recorded for the volume scan containing the report, or any volume scan up to 20 minutes before the report was received.

Sounding data for each of the 12 UTC runs was analyzed for each day. If the 12 UTC run was not available or not representative, the 00 UTC run was used. The 12 UTC run was used as much as possible since it will be the 12 UTC run used primarily for calculating VOD for a typical round of diurnal thunderstorms which typically reach their peak at approximately 400 pm PDT (23 UTC). Several values were then extracted from the sounding for potential use in calculating VOD. These values were freezing level height (FZL) and Wet Bulb Zero height (WB0). The FZL and WB0 were chosen to analyze the sub-cloud environment of most Great Basin thunderstorms. The WB0 has the added feature of allowing for evaporational cooling as the rain and/or hail falls, and will give a more representative freezing level within the thunderstorm environment.

Results

Once the data was obtained, it was entered into a spreadsheet program for analysis. Basic statistical analyses were performed on the data, but no statistical tests were performed because of the limited data set, as all tests would fail. The first thing done was to plot all the reports using GBVIL versus FZL, and WB0. These two plots are shown in Fig. 1. GBVIL appears to correlate very well with both FZL and WB0. The r^2 values for FZL and WB0 are 0.643 and 0.699,respectively. Thus, in both cases, GBVIL shows a moderately strong correlation between both FZL and WB0, slightly stronger with WB0. However, CBVIL also shows an even stronger correlation with FZL and WB0 with r^2 values of 0.707 and 0.767, respectively.

However, this includes all reports from heavy rain to severe hail. The goal of this study is to try and differentiate between severe hail and non-severe hail if possible. Therefore, the r^2 values will be computed once again, this time without the heavy rain thunderstorms, in order to get a more accurate estimate of how well the values correlate. The results are shown in Table 1. It is seen that the values based on CBVIL correlate better, with the values for GBVIL slightly lower. Since the goal of this study is to try to find VIL values that will indicate severe hail, the hail cases are broken up again into small hail and severe hail for correlation values. These values are also shown in Table 1. For both cases, the r^2 values are significantly higher than all cases, or all hail cases together. It is interesting to note that the r^2 values are higher for the severe hail thunderstorms, but this appears to be a result of the smaller sample size of six storms. One final observation is that CBVIL correlates better with all the cases than GBVIL. However, since some of these values are still close, regression equations for both GBVIL and CBVIL will be computed as well as for both the small hail events and large hail events. There will be a total of eight regressions produced as a result when they are computed with FZL and WB0.

The next step was to perform simple linear regression for the small hail values and severe hail values. The resulting equations obtained for all cases are shown in Table 2. Figures 2 through 5 show graphs of the data as well as regression lines for both severe hail and small hail. These are the equations that can be used for VOD, but there are some important limitations of its use, and some assumptions made that may affect its reliability. These are described below.

Table 1. Table r^2 values for all cases matching VIL versus FZL or WBO. The cases are then progressively broken up based on hail, then hail size.

r^2	GBVIL-FZL	GBVIL-WB0	CBVIL-FZL	CBVIL-WB0
ALL CASES	*0.643*	*0.7*	*0.707*	*0.767*
HAIL CASES	*0.672*	*0.75*	*0.686*	*0.77*
SMALL HAIL	*0.749*	*0.788*	*0.747*	*0.796*
LARGE HAIL	*0.848*	*0.891*	*0.853*	*0.906*

Table 2. Regression equations for both small hail and large hail.

		INTERCEPT	SLOPE	REGRESSION EQUATION
SMALL HAIL	*GBVIL-FZL*	-22.88	4.09	GBVIL = 4.09 (FZL) - 22.18
	GBVIL-WB0	-30.4	5.15	GBVIL = 5.15 (WB0) - 30.4
	CBVIL-FZL	-26.77	4.28	CBVIL = 4.28 (FZL) - 26.77
	CBVIL-WB0	-35.02	5.43	CBVIL = 5.43 (WB0) - 35.02
LARGE HAIL	*GBVIL-FZL*	-7.54	3.7	GBVIL = 3.7 (FZL) - 7.54
	GBVIL-WB0	-19.59	5.0	GBVIL = 5.0 (WB0) - 19.59
	CBVIL-FZL	-11.85	3.81	CBVIL = 3.81 (FZL) - 11.85
	CBVIL-WB0	-24.94	5.32	CBVIL = 5.32 (WB0) - 24.94

Assumptions/Limitations

There were several assumptions made when identifying the storms. First, all spotter reports were considered accurate. This may not always be true given differences in training and/or experience, and any other factor that may influence the spotter giving the report. Second, all reports given by the spotter were believed to be the largest hail possible from that particular storm. This may not be the case as well since in most cases, only one spotter report was received for each storm. An attempt at limiting the effect of the second assumption was made by only using reports where the storm center crossed within 2 miles of the report, as mentioned above. However, it is still possible that the storm produced larger hail either before or after the spotter report. The third assumption dealt with the idea that the radar is accurately estimating VIL. This is not always the case depending on the scan strategy employed and the distance of the thunderstorm from the radar. In many cases, Volume Coverage Pattern (VCP) 21 was utilized for the storms where there are larger gaps between the elevation angles, particularly higher in the volume scan. Thus, the thunderstorm may not be sampled completely and this will result in an erroneous VIL value, especially close to the radar. Although VCP-11 employs more elevation angles and therefore would likely provide a better estimate of VIL due to better sampling close to the RDA, it was rarely employed on the storm days at WFO Elko. Fourth, when using GBVIL, there are a few considerations. In fast moving or tilted storms, GBVIL will not accurately estimate VIL for a thunderstorm, and CBVIL computed by the Storm Cell Identification and Tracking algorithm will be most accurate. However, most thunderstorms that occur in the northern and east central Nevada are pulse storms that form in low to moderate shear environment and generally move less than 25 kt. Thus, this method will work for the majority of thunderstorms that form in northeast and east central Nevada, but will not work for the occasional fast moving and/or tilted storms that can and do occur in the Great Basin.

Suggestions for Use

Since there are only a small number of severe hail thunderstorms used in the study, coming up with a regression line to separate severe hail from small hail thunderstorms was not done. Using this regression line would be tenuous at best given the small sample size. Instead, it is suggested that the small hail regression line be used instead to alert the forecaster that a thunderstorm is producing hail and should be looked at for further analysis. Concerning the use of GBVIL versus CBVIL, it is important for the forecaster to know at least one, and preferably CBVIL, since it will more accurately estimate VIL for a particular thunderstorm. However, since the alarm thresholds for VIL at the PUP and in AWIPS are based on GBVIL, the VOD produced for GBVIL should be used to set this alarm.

Since the regression line computed for small hail cases is recommended, it is best used as guidance as to the VIL needed to produce any hail in a thunderstorm. Using the above assumption, the heavy rain cases should fall to the right of the VOD regression line, and the two severe hail cases should fall to the left of the line. Another graph was constructed to determine if this was the case for the limited data set. This graph is shown in Fig. 6, and does exhibit the severe hail cases falling to the left of the line, and for the most part, the heavy rain cases falling well to the right of the small hail regression line. The one case where the heavy rain was above the line was from a strong thunderstorm that produced very heavy rain of 0.90" in 15 minutes. Although this storm only produced rain, using the small hail regression line, the forecaster would have correctly been notified of this storm, albeit for the wrong reason. Aside from this one case, this graph should add confidence to using the regression line for hail forecasting. However, it is still recommended that any forecaster use this output as a tool, and not base a warn/no warn decision solely on this information.

As for the difference for FZL and WB0, the line likely to produce the best results would be where GBVIL is based on WB0. Not only does this appear in the correlation coefficients, but there is a meteorological reason as well. In a thunderstorm, WB0 will most likely approximate the freezing level in a thunderstorm due to evaporational cooling, while FZL gives you the freezing level of the free atmosphere, and does not account for the thunderstorm environment at all.

Conclusions

A relationship for both FZL and WB0 to VOD was computed. This relationship worked fairly well for the limited data set involved. However, any statistical test performed would fail because of the limited data; thus, the VOD for small hail suggested cannot be considered very reliable and more research is needed to add to the data set. Therefore, this study is ongoing and will be improved with time.

References

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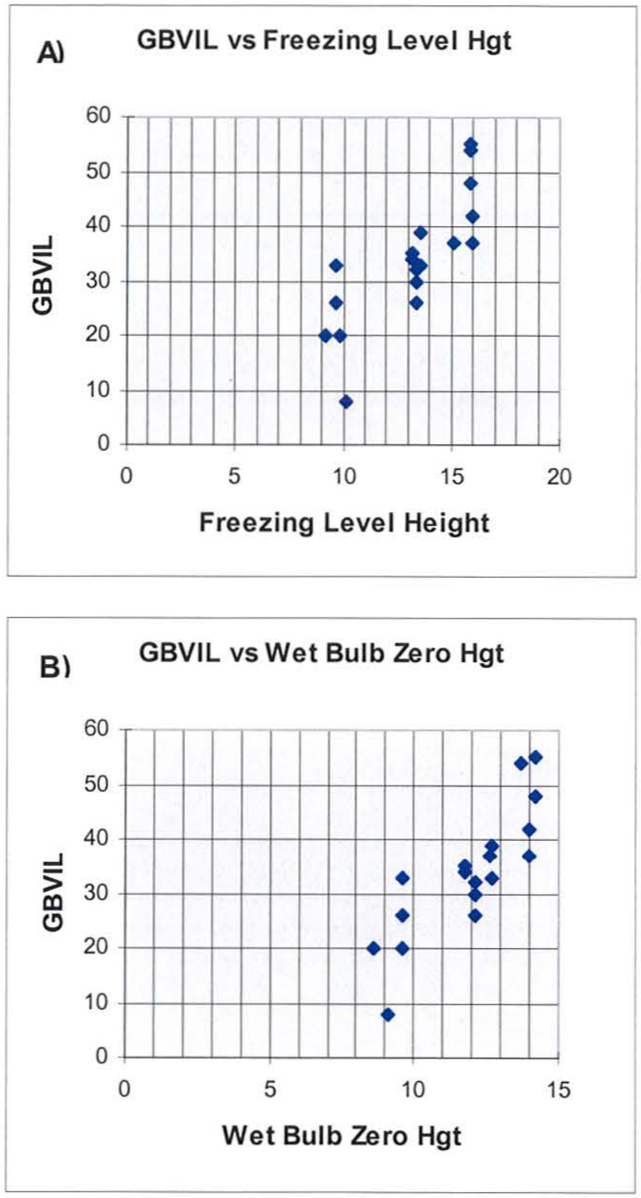

Figure 1. Plots of GBVIL versus FZL (a) and WB0 (b).

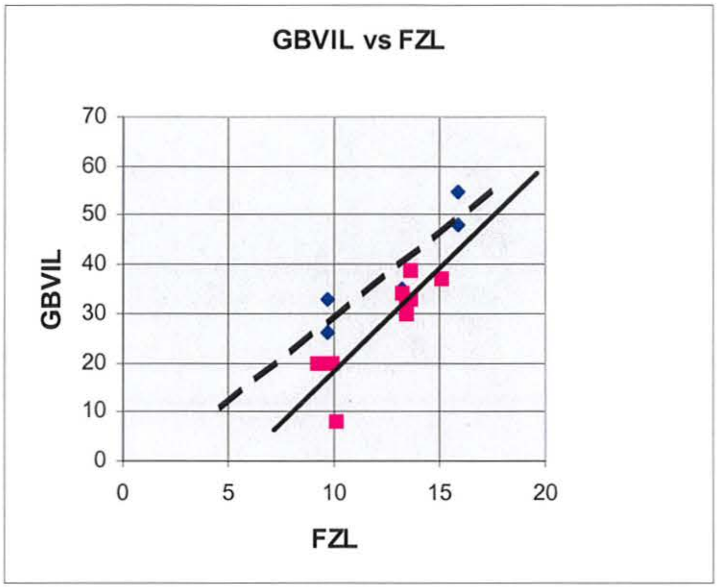

Figure 2. Graph of GBVIL versus FZL showing small hail cases (squares) with regression line (solid), and severe hail cases (diamonds) with regression line (dashed).

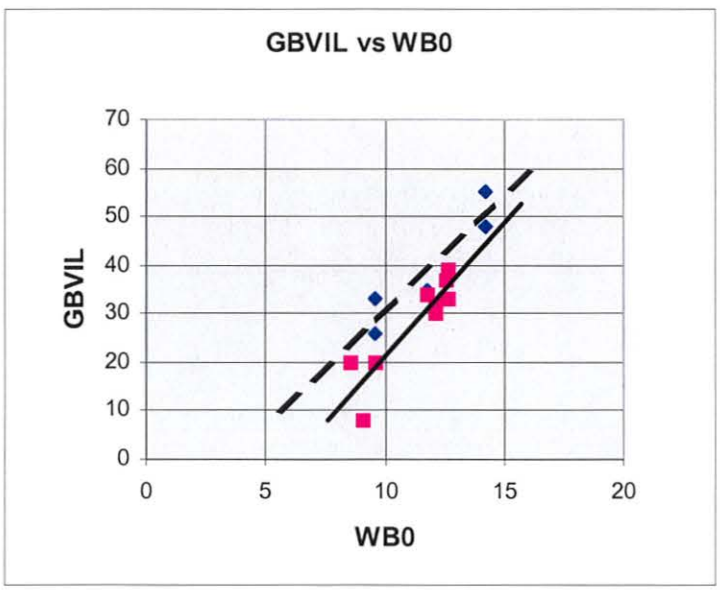

Figure 3. Same as Fig. 2, except graph of GBVIL versus WB0.

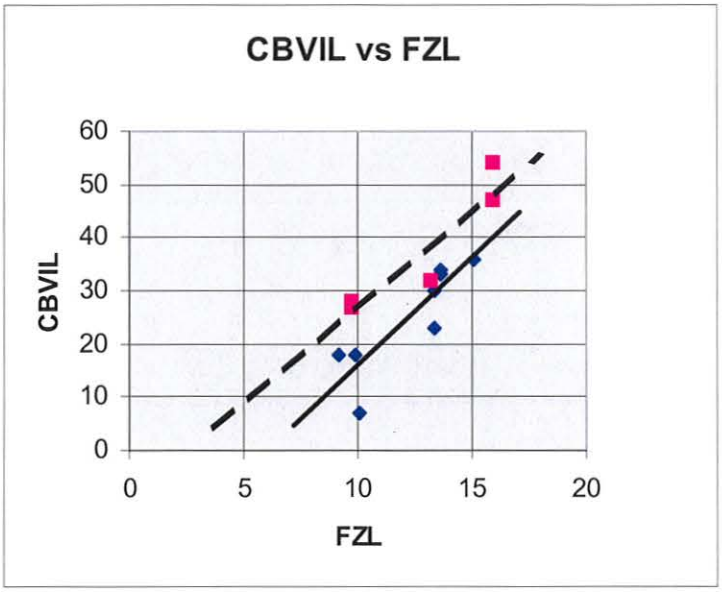

Figure 4. Same as Fig. 2 except for CBVIL versus FZL and severe cases are squares and small hail cases are diamonds.

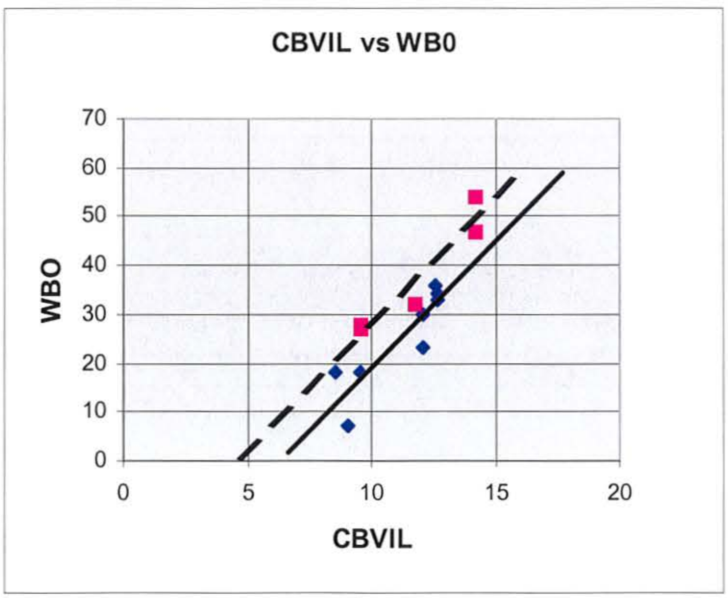

Figure 5. Same as Fig. 4 except for CBVIL versus WB0.

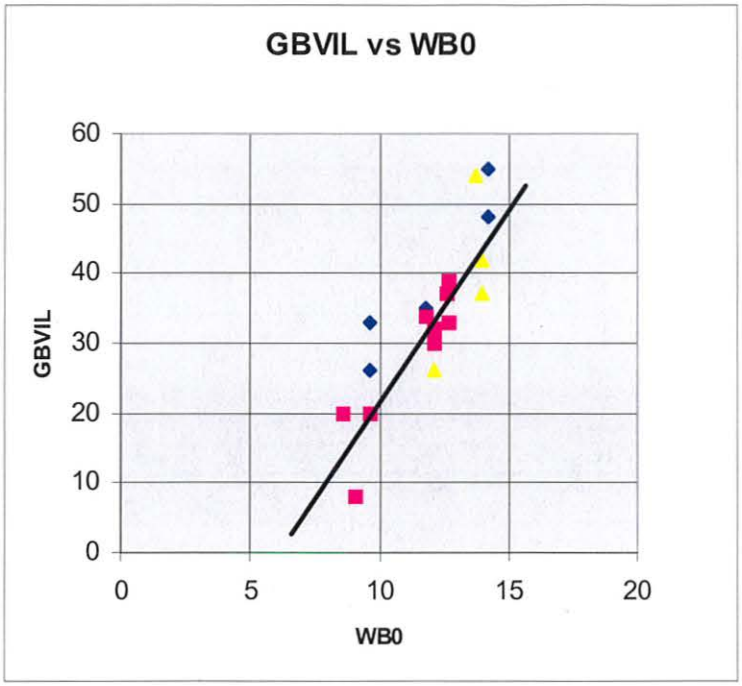

Figure 6. Graph of GBVIL versus WB0 where diamonds are severe hail cases, squares are small hail cases, and the triangles are the heavy rain cases. The line refers to the small hail regression line.