Effects of Changing the WSR-88D
Hail Detection Algorithm (HDA) WTSM Offset

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1. INTRODUCTION

This paper explains and illustrates the effects of changing the adaptable parameter Warning Threshold Selection Model (WTSM) offset of the WSR-88D Hail Detection Algorithm (HDA). In April 1998, each WSR-88D site was urged to change its WTSM offset to a new value that is dependent upon radar height. As explained in a letter to all WSR-88D sites (Belville 1998), the change will affect only the Probability of Severe Hail (POSH) (%) estimates from the HDA and will "eliminate most of the bias caused by high radar elevations and will create a common, accurate frame of reference (MSL [mean sea level]) in the warning threshold for all sites." This paper shows quantitatively how much the POSH estimates will decrease for various radar heights, freezing levels, and Severe Hail Indices (SHIs). With this information, a forecaster will know how the new WTSM offset will effect the HDA at his/her site(s)

2. ANALYSIS METHODOLOGY

To determine how much the POSH would vary as a result of the new WTSM offset values, the POSH equation (below) was solved with both the default and new WTSM offsets, and their difference taken (default minus new). The POSH equation is:

$$\text{POSH} = 29 * [\ \text{Ln}\ (\text{SHI} / \text{WT})] + 50,$$
$$\text{where WT} = 57.5\ H_0 + \text{WTSM offset}$$

where SHI is the Severe Hail Index and H_0 is the freezing level (km). See Witt et al. (1998) for a detailed explanation of the POSH equation. The equation was solved for radar heights of 500 to 10,000 feet (MSL) in increments of 500 feet. For each radar height the freezing level was varied from 8000 to 18,000 feet (MSL) in increments of 1000 feet and the SHI was varied from 50 to 500 (10^5 J/m/s) in increments of 50 (10^5 J/m/s). The radar heights tested are within a few hundred feet of WSR-88D radar heights, and the range of freezing levels is typical of the vast majority of environments that support severe hail development. The SHI values tested range from a storm with a shallow, elevated, marginally high reflectivity core (SHI=50) to one with an extremely deep, elevated high reflectivity core (SHI=500). A radar height of 0 feet was not included because at that height, the new WTSM offset would equal the old offset. Unlike the WSR-88D algorithm, POSH estimates were not rounded to the nearest 10% to eliminate rounding biases in the POSH differences. Before POSH differences were computed, as in the WSR-88D algorithm, POSH estimates exceeding 100% were set to 100% and WTSM values below 20 (10^5 J/m/s) are set to 20.

3. RESULTS

As expected, in all cases, POSH estimates using the new WTSM offsets are less than those using the default WTSM offsets, and, generally, the differences are greater as the radar height increased. For each radar height, using an SHI of 100 (10^5 J/m/s), the POSH differences were plotted vs. the freezing height. Figures 1-5 follow and depict POSH differences at 20 radar heights.

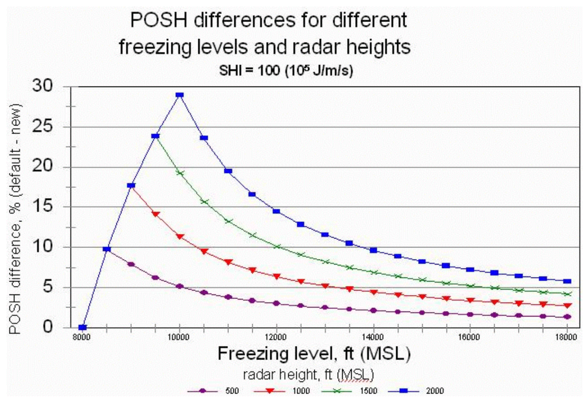

Figure 1. Differences in POSH estimates in percent between the new and default WTSM offset given radar heights of 500, 1000, 1500, and 2000 feet (MSL) and freezing levels of 8000 to 18000 feet (MSL). Each line represents the differences in POSH estimates for one radar height for various freezing levels. The POSH estimates using the new WTSM offset will be lower.

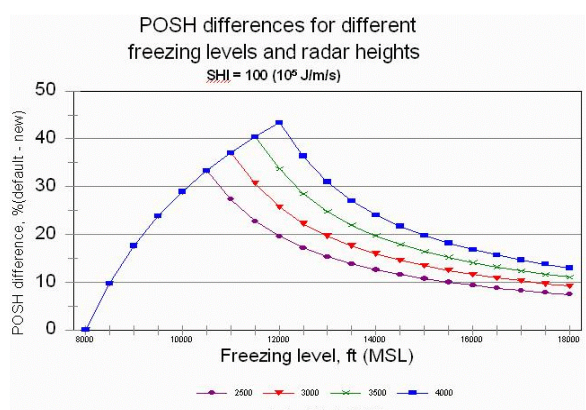

Figure 2. Same as Figure 1 except for radar heights of 2500, 3000, 3500, and 4000 feet (MSL).

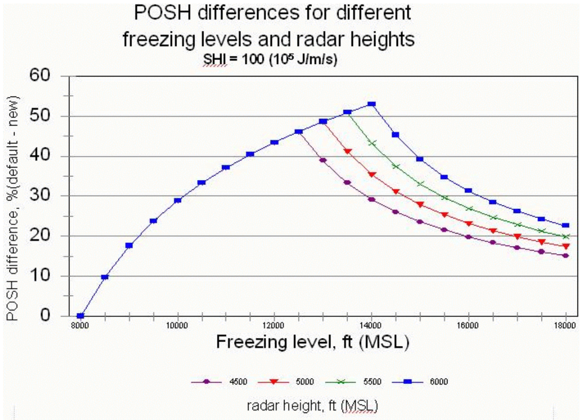

Figure 3. Same as Figure 1 except for radar heights of 4500, 5000, 5500, and 6000 feet (MSL).

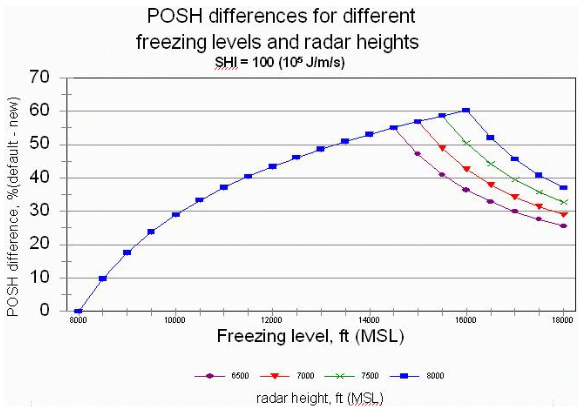

Figure 4. Same as Figure 1 except for radar heights of 6500, 7000, 7500, and 8000 feet (MSL).

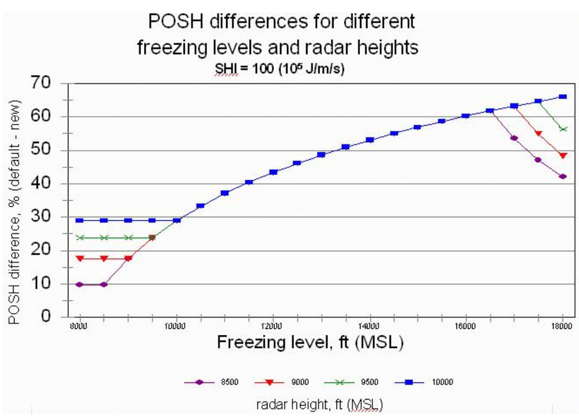

Figure 5. Same as Figure 1 except for radar heights of 8500, 9000, 9500, and 10000 feet (MSL).

Table 1. Maximum POSH differences for various radar heights using an SHI of 100 (10^5 J/m/s).

Radar Height (ft (MSL))	Maximum POSH Differences
500	10 %
1000	18 %
2000	29 %
3000	37 %
4000	44 %
5000	49 %
6000	53 %
7000	57 %
8000	60 %
9000	63 %
10000	66 %

4. DISCUSSION

Figures 1 through 5 also illustrate that as the radar height increases, the greatest POSH differences occur at higher freezing levels. At lower radar heights, the greatest differences in POSH are at a relatively low freezing level, but at the highest radar heights, the greatest differences are at relatively high freezing levels. For example, in Figure 1 at a radar height of 500 feet, the greatest difference is at a freezing level of 8,500 feet; in Figure 3 at a radar height of 5000 feet, the greatest difference is at a freezing level of 13,000 feet; and at a radar height of 10000 feet, the greatest difference is at a freezing level of 18,000 feet. For radar heights below 8500 feet, the POSH differences are zero at freezing levels at or below 8000 feet. This is because the WTSM is initially below 20 (10^5 J/m/s) and then reset to 20. Note that for the highest radar heights, (in Figure 5) POSH differences are constant at freezing levels at and below the radar height;if the freezing level is below the radar level, the freezing level is set to the radar level.

Realizing that not all storms have an Severe Hail Index (SHI) of 100 (10^5 J/m/s), the POSH differences for different values of SHI were evaluated. Physically, the SHI can be thought of as a measure of the magnitude and depth of the reflectivity core above the freezing level. For a given freezing level and radar height, as the SHI decreases from 100 to 50 (10^5 J/m/s), there are no changes in the POSH differences. Although SHIs below 50 (10^5 J/m/s) were not tested, as the SHI decreases from 50 to 0 (10^5 J/m/s), the POSH differences rapidly go to zero as the POSH estimates would also go to zero.

As the SHI increases to more than 100 (10^5 J/m/s), the POSH differences decrease. Figure 6 illustrates this point; it is a graph of the freezing level vs. POSH differences for a radar height of 10,000 feet (MSL) in which each line represents a different SHI. POSH differences decrease because POSH estimates increased to the point that they topped out at 100%. The higher the SHI and the lower the freezing level, the more likely the POSH estimates are to be 100%; hence, the POSH difference is 0%.

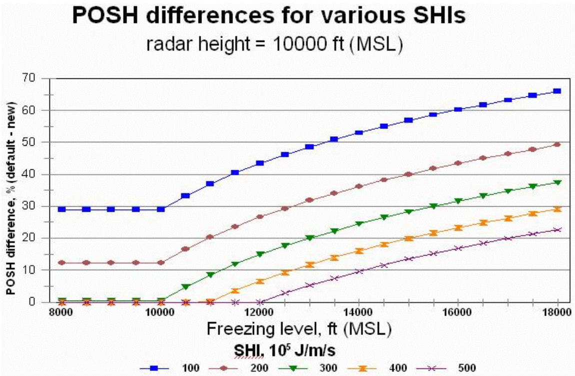

Figure 6. Differences in POSH estimates between the new and default WTSM offset for various SHIs at a radar height of 10000 feet (MSL) and freezing levels of 8000 to 18000 feet (MSL). The curves represent differences in POSH estimates for SHI values for various freezing levels. The POSH estimates using the new WTSM offset will be lower.

5. CONCLUSIONS

The new WTSM offsets will lower POSH estimates at radars above sea level but will have the greatest effect on higher elevation radars. The POSH differences depend on 1) SHI, 2) radar height, and 3) freezing level.

POSH differences for all radar heights are greatest when SHI values are at or below 100 (10^5 J/m/s); as SHI increases (above 100), the POSH differences decrease. In other words, the new WTSM offset lowers POSH estimates the most for marginal storms. Huge storms resulting in large SHIs (>300) still will have high POSHs (near 100%), and POSH differences will be smaller, especially at lower freezing levels. Even at the highest radars, POSH differences will be small or zero for large SHIs.

The greater the radar height, the more the new WTSM offset will lower POSH estimates. POSH differences will range from less than 10% for radars near or below 500 feet to up to nearly 70% for radars at 10,000 feet.

As radar height increases, the greatest POSH differences occur at higher freezing levels. For example, at a radar elevation of 1000 feet, the greatest POSH differences occur at a freezing level of 9000 feet; at a radar elevation of 10,000 feet, the greatest POSH differences occur at a freezing level of 18,000 feet.

If you have done any evaluation of the HDA and the new WTSM offset, or, if you have any questions regarding the new WTSM offset, please contact Mark Fresch at the OSF at (405) 366-6530.

6. REFERENCES

Belville, J. D., 1998, Recommended Parameter Changes to Improve WSR-88D Hail Detection Algorithm Estimates. Letter to WSR-88D URC Chairpersons, OSF Memo 12023-01-D6.02(1),15 pp. [Available from the Operational Support Facility, 1200 Westheimer Drive, Norman, OK 73069]

Witt, A., M. D. Eilts, G. J. Stumpf, J. T. Johnson, E. D. Mitchell, and K. W. Thomas, 1998: An enhanced hail detection algorithm for the WSR-88D. *Wea. Forecasting*, **13**, in press.

7. ACKNOWLEDGEMENTS

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