Jane C. Krause*, A. E. Daniel, B. M. Taylor
Centuria Corporation, WSR-88D Radar Operations Center, Norman, Oklahoma
R. L. Ice, US Air Force, WSR-88D Radar Operations Center, Norman, Oklahoma
W. David Zittel, US National Weather Service, WSR-88D Radar Operations Center, Norman, Oklahoma

1. INTRODUCTION

In 2006, the Radar Operations Center (ROC) transitioned from the Weather Service Radar-1988 Doppler (WSR-88D) legacy Radar Data Acquisition (RDA) to the Open RDA (ORDA). Clutter filter settings were selected based mostly on Level I (I and Q) sets from (ROC) testbed radars and Oklahoma City, OK (KTLX) operational radar, all of which are located in central Oklahoma. These data sets were not optimal for selecting values of dB-for-dB additional clutter suppression that would sufficiently remove clutter at radar sites with more variable terrain. Based on these data sets and a volume of light snowfall from Denver, CO (KFTG), the decision was made to use an upper threshold of 60 dB for the dB-for-dB additional suppression to remove clutter residue. However, mountainous terrain sites have had persistent clutter residue problems with the use of this threshold. Engineers at the ROC recently acquired Level I data from the Pueblo, CO (KPUX) radar and have conducted a more in-depth analysis of clutter parameters using this mountainous terrain data.

2. BACKGROUND

The WSR-88D radar performs clutter suppression using two steps. First the Clutter Mitigation and Detection (CMD) algorithm identifies which bins have clutter (Ice, 2009). Gaussian Model Adaptive Processing (GMAP) clutter suppression, a frequency domain suppression algorithm offered in the SIGMET RVP8, is then applied to those bins and if the amount of clutter suppression reaches certain thresholds, additional suppression is added using dB-for-dB censoring. The GMAP algorithm then attempts to rebuild weather signal that may have been suppressed from the data by fitting a Gaussian curve using the remaining power spectrum. If the dB-for-dB suppression is too aggressive, then there is not enough signal left for GMAP to rebuild the weather signal, and those locations will have missing data. Thus, it is important to suppress enough to remove unwanted data, but also to leave enough residual signal to allow GMAP to rebuild as much signal as possible (Ice, 2007).

Clutter residue is problematic for forecasting in numerous ways. While a user can easily spot these returns in reflectivity as clutter residue, automated algorithms might not, especially if the algorithms do not incorporate dual-polarimetric variables to identify non-meteorological signal. This residue may be incorporated into rainfall accumulation algorithms if the residue is strong enough, can cause discontinuity in rainfall algorithm results if an exclusion zone is used, can inhibit velocity analysis due to bias from the clutter residue, and is also a visual nuisance for users (Ray, 2007).

While insufficient clutter suppression is problematic, excessive suppression can also be a problem. In areas prone to flooding, excessive suppression can cause an underestimation of total precipitation estimates in rainfall algorithms. It can also cause "holes" in sections of data where precipitation has been suppressed below threshold levels. This is also a nuisance problem for users, who would view the missing data in the precipitation field but realize that there is likely some amount of precipitation in that area.

Tuning the dB-for-dB censoring in mountainous terrain will be beneficial if it provides more reliable results for users. With the advancements made with the ability to record and use Level I data to evaluate algorithm performance, a more thorough examination of clutter suppression settings can be made to determine whether improvements can be made without degradation of needed meteorological data.

3. METHODOLOGY

The WSR-88D KPUX radar has persistent clutter residue caused by the Wet Mountain Range to the southwest of the radar (Figure 1).

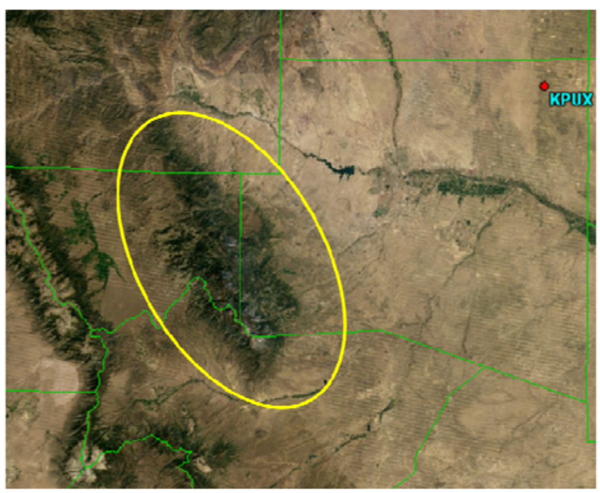

Figure 1. Topographic map taken from Gibson Ridge Analyst, with the Wet Mountain Range circled.

* Corresponding Author Address: Jane C. Krause, Centuria Corporation, WSR-88D Radar Operations Center, 1313 Halley Circle, Norman, OK, 73069
e-mail: Jane.C.Krause@noaa.gov

The views expressed are those of the authors and do not necessarily represent those of the Radar Operations Center.

The dB-for-dB settings are not aggressive enough to remove the strong clutter targets caused by the mountains. Figure 2 contains images of clutter residue from the Wet Mountain Range. The clutter is persistent and a nuisance problem, particularly when precipitation is in the vicinity of the mountains. Figures 2a and 2c show clear air reflectivity and correlation coefficient, respectively, showing the location of the clutter. Likewise, Figures 2b and 2d demonstrate the nuisance of discerning the precipitation from the clutter residue in that area.

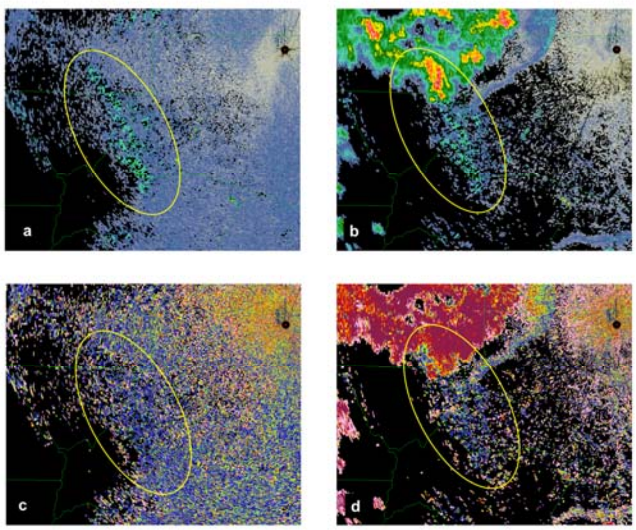

Figure 2. Clutter residue in KPUX data. Figures 2a and 2c show clear air VCP 31 data, reflectivity and correlation coefficient, respectively. Likewise, Figures 2b and 2d show both precipitation and clutter residue in VCP 212 data.

In July, 2013, a Level I data recorder was sent to the site, and several days' worth of raw I and Q data containing both clear air and scattered precipitation was recorded. By feeding this data through the WSR-88D data playback system, a more complete analysis of clutter suppression performance was made.

The data playback system was used to process the data with varying settings for the dB-for-dB censoring thresholds. There are two thresholds and suppression values that can be set, an intermediate and upper boundary. At the lowest levels, GMAP suppression is used without additional suppression. At the lower threshold, an additional amount of suppression is added for each dB of suppression that is applied by GMAP. At the upper threshold, an even higher amount of additional suppression is applied for each dB of suppression that is applied by GMAP. The current default threshold settings are 25 dB for the lower and 60 dB for the upper, with additional suppression values of 0.15 dB and 1.0 dB of suppression, respectively. Figure 3 shows the levels of additional suppression that is applied.

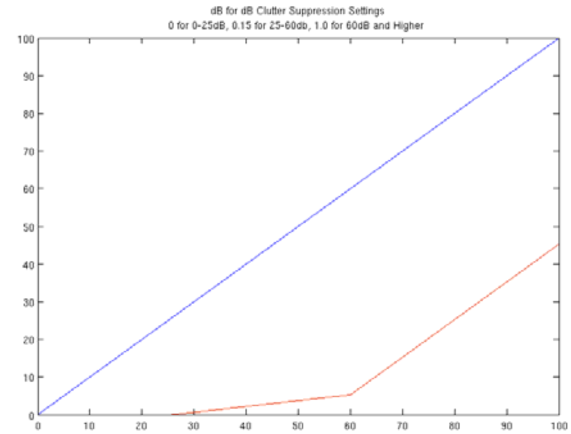

Figure 3. Default dB-for-dB additional suppression (red line).

To investigate the performance of suppression values, various experimental settings for suppression were used. For the mountainous terrain data, adjustments to the upper threshold setting provided significantly more impact on performance, while adjustments to the lower threshold produced a negligible impact. As a result, investigating the lower threshold was abandoned in order to focus on upper-level suppression thresholds.

The upper threshold was set at 45, 50, 55, and 60 dB, respectively, with objective and subjective analysis performed. No change to the 1.0 dB value for the greatest suppression was made. The Level II data was also processed by RPG algorithms to examine precipitation accumulation over a 24-hour period and determine impacts on precipitation for both legacy and dual-polarimetric algorithms.

4. RESULTS

Scatter plots of cluttered data against uncluttered data were made in order to evaluate both the amount of suppression that has been achieved and determine the impact on the quantity of remaining data points after suppression (Figure 4).

When examining the default threshold of 60 dB, we can see that there are more data points returned by the GMAP algorithm than for the remaining thresholds. The 55 dB threshold has fewer data points remaining, but the general pattern of the data appears to be sustained. At both 50 and 45 dB, more severe signal loss is observed, with 45 dB showing significant degradation in the amount of available data. Using this method of evaluation, it appears that a 55 dB suppression would have the most potential for removing clutter residue without significantly impacting the overall field of data.

Figure 5 contains four reflectivity images at a time when there was precipitation over the northwest portion of the Wet Mountain Range, and Figure 6 contains corresponding correlation coefficient values and is provided to discern precipitation from clutter. For the 60 dB threshold, the clutter residue is clearly observed in the image. For 55 dB, the amount of clutter residue is significantly decreased, without

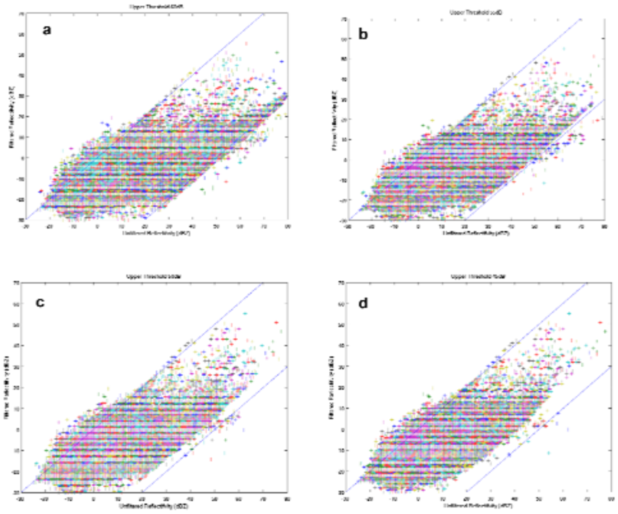

Figure 4. Scatter plots of filtered data against unfiltered data, with the lower line being the 50 dB suppression line, for the (a) 60,(b) 55, (c) 50, and (d) 45 dB thresholds

protruding into the nearby precipitation. At 50 dB, more of the residue is removed, but it appears to protrude into the nearby precipitation, and at 45 dB more significant amounts of precipitation have been suppressed out of the data.

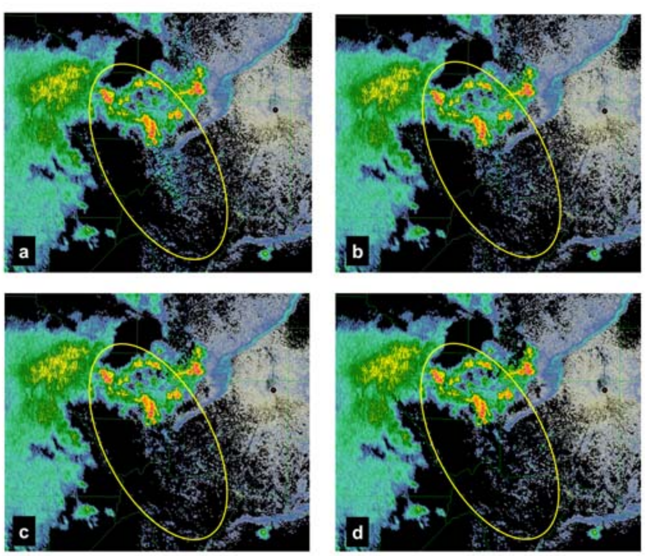

Figure 5. Reflectivity images from KPUX using the (a) 60, (b) 55, (c) 50, and (d) 45 dB thresholds.

Precipitation totals for legacy rainfall algorithms are shown in Figure 7. For the default 60 dB threshold, precipitation has accumulated over the 24-hour period in locations where there is only clutter residue. Using a 55 dB threshold removes a significant amount of the erroneous accumulations. Slightly more erroneous accumulation is removed with the 50 dB and 45 dB thresholds, but the most significant impact comes from the adjustment of the upper threshold from 55 dB from 60 dB.

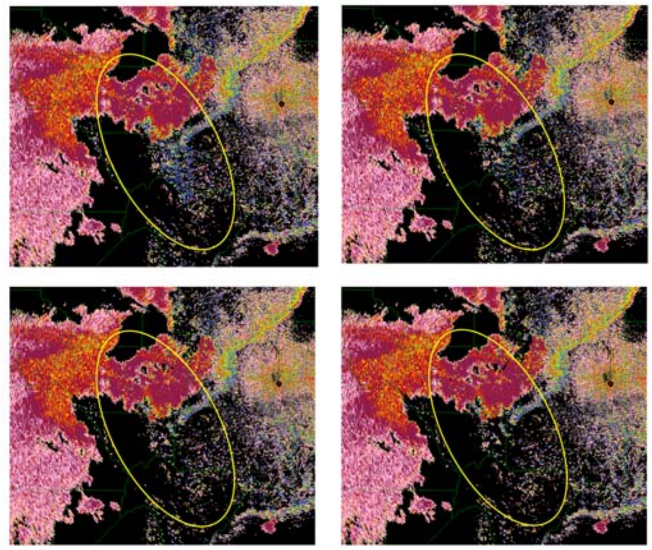

Figure 6. Corresponding correlation coefficient images for Figure 5. (a) 60, (b) 55, (c) 50, and (d) 45 dB thresholds

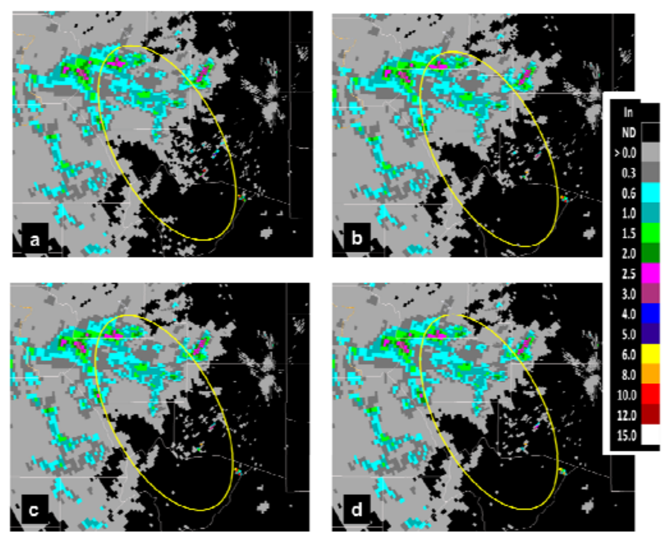

Figure 7. Legacy precipitation total algorithm results using 24 hours of data for the (a) 60, (b) 55, (c) 50, and (d) 45 dB thresholds. (Scale ranges from >0.0 to 15.0 inches.)

Dual-pol precipitation accumulation results are presented in Figure 8. While there are differences across the range of values, there is very little impact on the overall results, due to the use of the dual polarimetric values to adjust precipitation accumulations depending on type of precipitation and to remove other extraneous reflectivity, such as biological returns.

While this is not a snowfall case, the data was also fed through the snowfall accumulation algorithm to determine impacts. This process can be especially helpful for determining the impacts on accumulations for smaller amounts of precipitation. The results can be found in Figure 9. A significant amount of

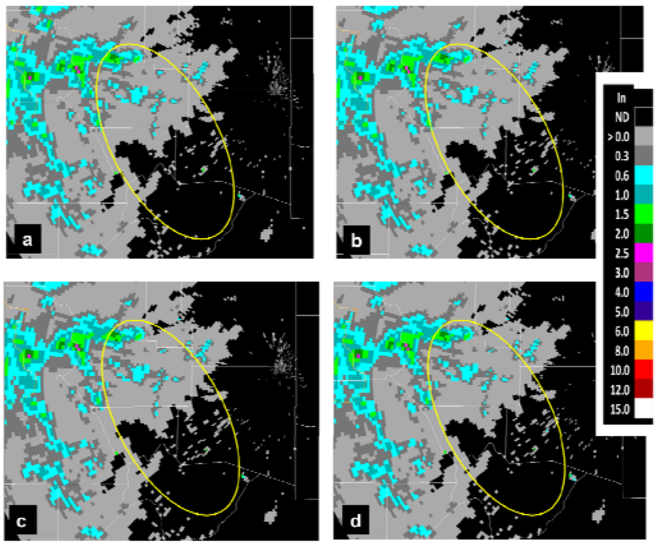

Figure 8. Dual-polarimetric precipitation algorithm results using 24 hours of data for the (a) 60, (b) 55, (c) 50, and (d) 45 dB thresholds. (Scale ranges from >0.0 to 15.0 inches.)

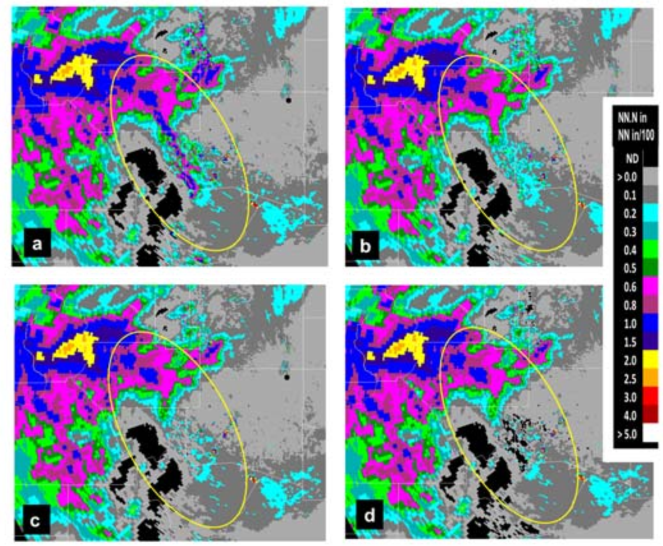

Figure 9. Snowfall accumulation algorithm results using 24 hours of data for the (a) 60, (b) 55, (c) 50, and (d) 45 dB thresholds. (Scale ranges from >0.0 to >5.0 inches.)

erroneous snowfall accumulation amounts are calculated when the 60 dB threshold is used, with totals equivalent to those locations where there is heavier precipitation over the 24-hour period. Changing the threshold to 55 dB removes much of that accumulation, leaving a small amount of accumulation that will not have an operational impact. With 50 dB, there is even more accumulation loss and with 45 dB, there is degradation of the data. There is concern that with the 50 or 45 dB thresholds that when there is a lighter amount of precipitation that there will be degradation of the accumulation amounts.

5. CONCLUSIONS

Using raw data collected from a mountainous terrain site allowed a more complete examination of the effects of mountainous terrain clutter on Level II data and on precipitation accumulation algorithms. Results show that changing the upper threshold for residue censoring to 55 dB from 60 dB will provide more aggressive clutter suppression without causing a degradation of precipitation accumulation algorithm performance. This will improve the data for both users and algorithms, allowing for more effective forecasting and a significant decrease in existing nuisance problems.

REFERENCES

Ice, R. L., Rhoton, R. D., Krause, J. C., Saxion, D. S., Boydstun, O. E., Heck, A. K., Chrisman, J. N., Berkowitz, D. S., Zittel, W. D., Warde, D. A., 2009: Automatic Clutter Mitigation in the WSR-88D - Design, Evaluation, and Implementation. AMS, 34th Conference on Radar Meteorology, Williamsburg, VA.

Ice, R. L., Rhoton, R., Saxion, D. S., Ray, C. A., Patel, N. K., Warde, D. A., Free, A. D., Boydstun, O. E., Berkowitz, D. S., Chrisman, J. N, Hubbert, J. C., Kessinger, C., Dixon, M. & Torres, S., 2007: Optimizing Clutter Filtering in the WSR-88D. 23rd International Conference on Interactive Information Processing Systems for Meteorology, Oceanography, and Hydrology.

Ray, C. A. & Chrisman, J. N., 2007: A Data Quality Comparison of the WSR-88D Legacy Radar Data Acquisition (RDA) to the Open RDA (ORDA) in a Challenging Clutter Regime. 23rd International Conference on Interactive Information Processing Systems for Meteorology, Oceanography and Hydrology, AMS, San Antonio, TX..