P5.2

CORRECTING AND ENHANCING AP MITIGATION WITHIN ORPG COMPOSITE REFLECTIVITY PRODUCTS FOR FAA SYSTEMS

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1. INTRODUCTION

The Open Radar Product Generator (ORPG) of the WSR-88D (NEXRAD) radar network provides the Federal Aviation Administration (FAA) with radar products crucial for FAA weather forecast and monitoring systems. As an example, Composite Reflectivity Products (CRPs) are relied upon by Air Route Traffic Control Centers (ARTCC) for crucial guidance of air traffic.

However, errors within composite reflectivity data must be identified and properly removed prior to use by air traffic controllers. Anomalous propagation (AP) is a significant source of erroneous reflectivity within CRPs. AP edit algorithms have been used to remove the effects of AP and have been successful in many instances. However, AP mitigation within ORPG CRPs has always produced an unfortunate and systematic side effect by reducing reflectivity intensities in regions of precipitation by as much as 15 dbZ. Clearly, this could mislead air traffic controllers and produce a potentially dangerous situation when misinformation is given to pilots. This has prompted the removal of AP-edited CRPs from the display system of the Weather and Radar Processor (WARP) used at ARTCCs.

The erroneous reduction in reflectivity magnitudes appears to be a systematic problem as it exists regardless of the precipitation system, geographic location, or season. Thus, an evaluation of the AP mitigation technique is performed. As a result, a modification to the technique is devised and demonstrated to completely remove all erroneous reductions in reflectivity intensities while the ability of the technique to remove AP remains unchanged.

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2. AP MITIGATION

Composite Reflectivity Products provide the highest reflectivity above a resolution element from all elevation scans within a particular volume scan. In some instances, the highest reflectivity value may unfortunately result from anomalous propagation (AP) of the radar beam.

AP occurs through an interaction of the radar beam with the atmospheric environment and/or physical objects surrounding the radar. Radars receive power returns from both meteorological and non-meteorological objects. Non-meteorological signals can result from scatterers within the atmosphere such as dust, insects, and birds all of which can produce “clear-air” returns of up to 30 dBZ. Additionally, ground clutter can exist when the radar signal reflects from permanent structures such as buildings, trees, and the surface of the earth.

The vertical structure of the planetary boundary layer can also provide a favorable condition for non-precipitation returns. The radar’s electromagnetic beam can be trapped or ducted when energy propagating at shallow angles with respect to the earth’s surface is refracted back towards the surface of the earth. This typically occurs as a result of large vertical temperature and/or moisture gradients in environments of strong nocturnal temperature inversions, thunderstorm outflows, or when warm, dry air is advected over a cool, moist layer.

2.1 *AP-Removal In ORPG CRPs*

AP removal within ORPG CRPs is made possible through the use of reflectivity, velocity, and spectrum width data with AP (typically containing relatively high reflectivity) identified as having velocities and spectrum widths near zero. The AP technique is applied in separate regions surrounding a radar based on range and elevation scan (Smalley and Bennett 2001). The threshold of velocity and spectrum width below which reflectivity returns are designated as AP can vary within each separate region.

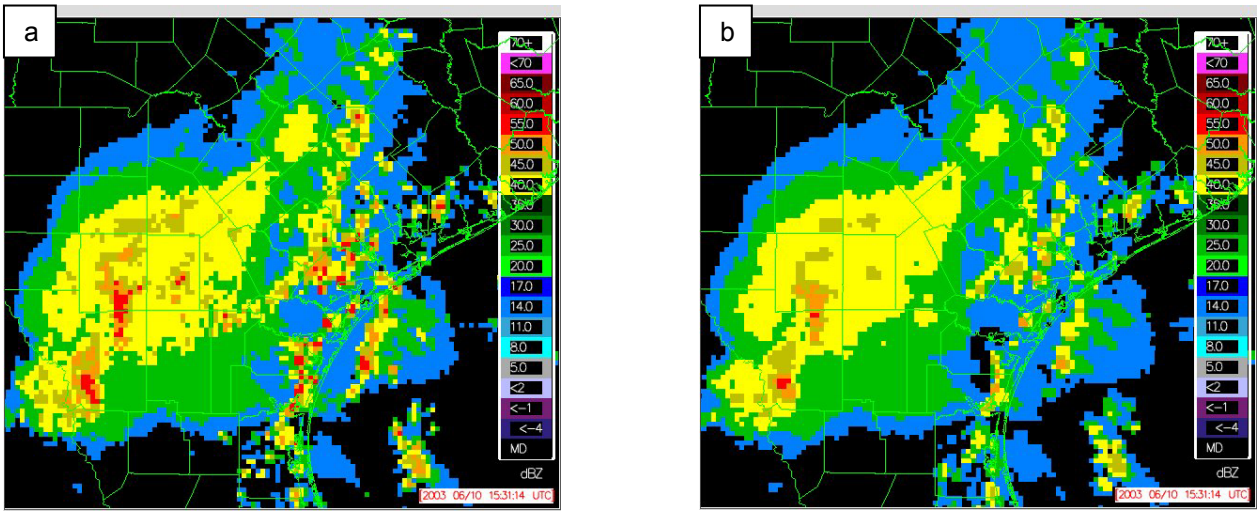

FIG. 1. Composite reflectivity of a convective event containing little or no AP on June 10, 2003 surrounding the Corpus Christi, TX WSR-88D (KCRP) radar. AP removal is not used in a) while AP removal using a median filter applied across the entire reflectivity image is shown in b).

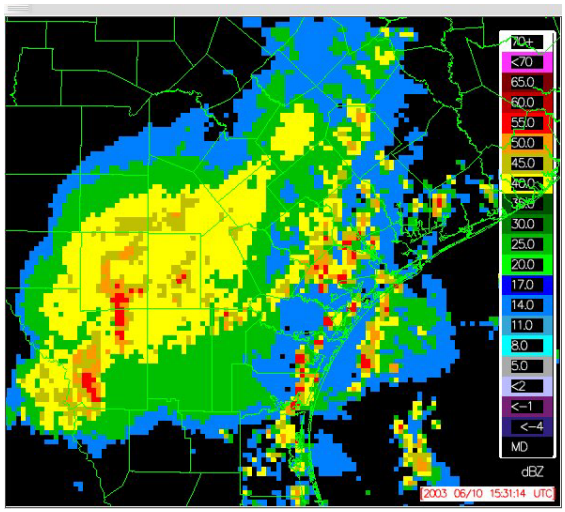

FIG. 2. Same as FIG. 1b except AP is removed using a median filter in clutter regions only.

Once data has been deemed as AP or precipitation, a median filter is used to expand on the identification of AP using single gate analysis. It is considered likely that other gates are AP if enough of the neighbors in the filter window are also AP. Currently, the median filter calculates a new averaged reflectivity value at a gate ***regardless*** of whether the data point is determined to be precipitation or AP. Thus, the filter acts to smooth out reflectivity returns in areas of precipitation producing a reduction in reflectivity intensities.

Because the current version of the median filter smoothes all reflectivity data, results of the modification are particularly dramatic for convective cases that contain relatively small maximum reflectivity cores on the order of 10 to 20 km with sharp reflectivity gradients. This is especially noticeable in a convective event near Corpus Christi, TX on June 10, 2003 (FIG. 1). A number of convective cells with maximum reflectivities above 50 dBZ exist along the coastline. Very little, if any, AP is present along with the convection. However, the maximum reflectivity values of most cells in the AP-

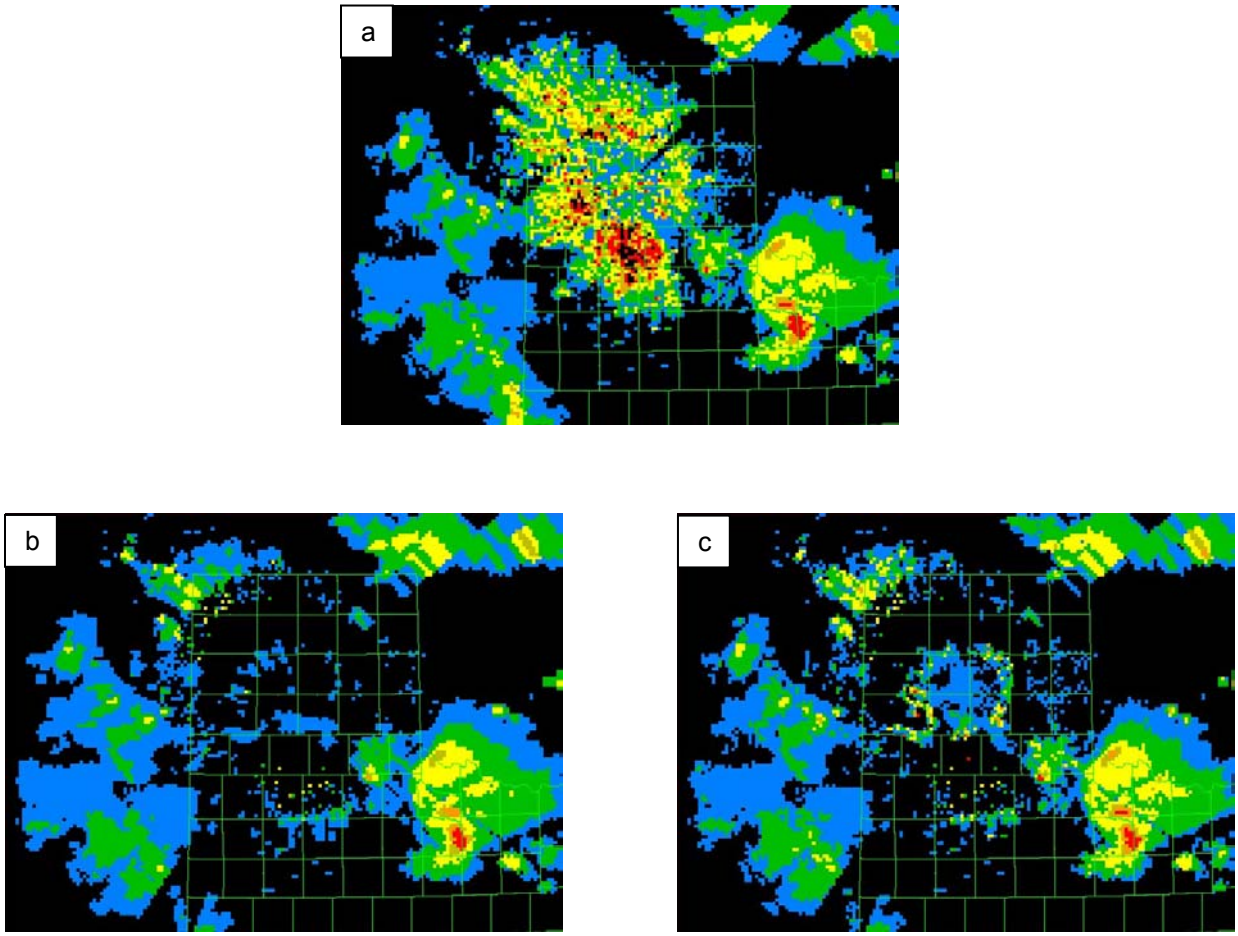

FIG. 3. AP case on May 25, 1994 surrounding the Amarillo, TX WSR-88D (KAMA) radar; a) AP removal is not used, b) AP removal used with median filter across entire image, and c) AP is removed and median filter is used in clutter regions only.

mitigated CRP (FIG. 1b) are reduced to below 50 dBZ.

2.2 *Median Filter Modification*

A solution to this problem is realized by calculating a new averaged reflectivity value only if the median filter determines a data point to be AP. Hence, reflectivity values within precipitation regions will not be adjusted by the filter as a result.

Figure 2 shows the modified median filter output when applied to the Corpus Christi convective event. Figure 2 and Figure 1a are nearly identical demonstrating that very few changes are made to the reflectivity field, as should occur since little AP exists.

By modifying reflectivity values only in non-precipitation regions of the reflectivity field, AP is still properly removed while reflectivity intensities associated with precipitation are not reduced. Figure 3 shows an example of extensive AP surrounding the Amarillo, TX WSR-88D on May 25, 1994. Figure 3b displays the current ORPG version of AP-mitigated composite reflectivity which effectively removes most AP across the Texas panhandle. However, convective cells in the southeastern portion of the panhandle and into north Texas are also reduced in intensity. These cells are left untouched by the new median filter while still removing most of the AP (FIG. 3c).

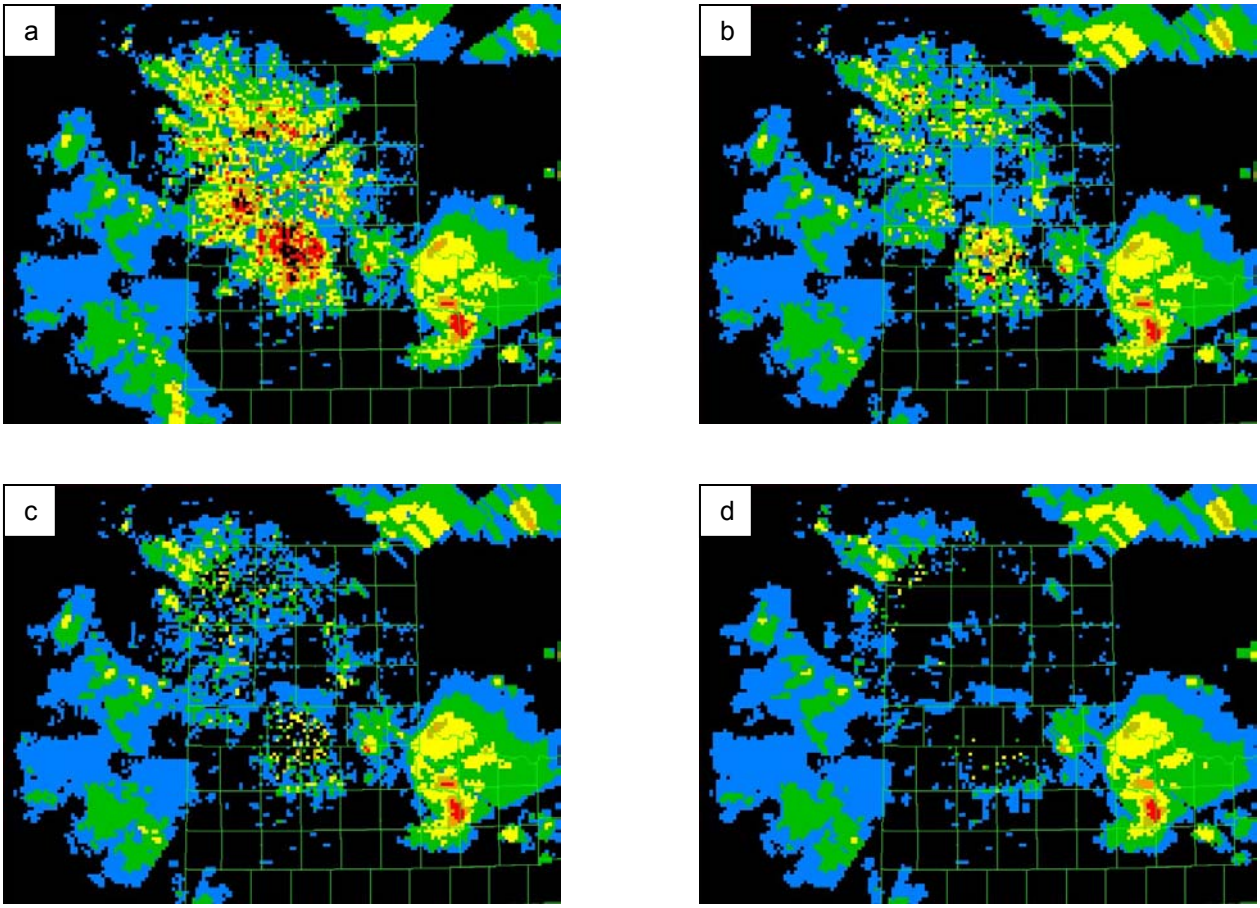

FIG. 4. Reproduction of Figure 6 of Smalley and Bennett (2001). The AP mitigation technique is applied (using median filtering across the entire image) using four different adaptable parameter sets: a) original set when the AP technique was first implemented in ORPG composite reflectivity products, b) “MIT/LL”, c) “Min. dBZ + Incr. Dop.”, and d) the current and optimal set.

The ORPG Fortran code has been modified to institute the changes within the median filter for this study. The modification is applied without adding any new lines of code making it extremely simple. Potentially, it also reduces the amount of CPU time needed to produce AP-mitigated CRPs by bypassing a portion of the median filter code when precipitation returns are being examined.

2.3 *Adaptable Parameter Set*

The AP mitigation technique contains 17 adaptable parameters that have been optimally tuned to remove AP while preserving the integrity of precipitation data (Smalley and Bennett 2001). However, it is possible the adaptable parameter set may become sub-optimal when using the new modification. The Amarillo AP event is re-examined using the new modification while varying the adaptable parameter set in the same manner as found in Smalley and Bennett (2001).

Figure 4 is a recreation of Figure 6 from Smalley and Bennett (2001) showing the improvement in the AP mitigation technique as the adaptable parameter set is optimally tuned. Figure 5 is the same as Figure 4 except the new modification to the median filter of the AP mitigation technique is employed. Basically the same progression is seen in the tuning of the adaptable parameter set suggesting, at least for this AP case, that the original optimal adaptable parameter set may indeed remain optimal when disallowing median filtering in precipitation regions.

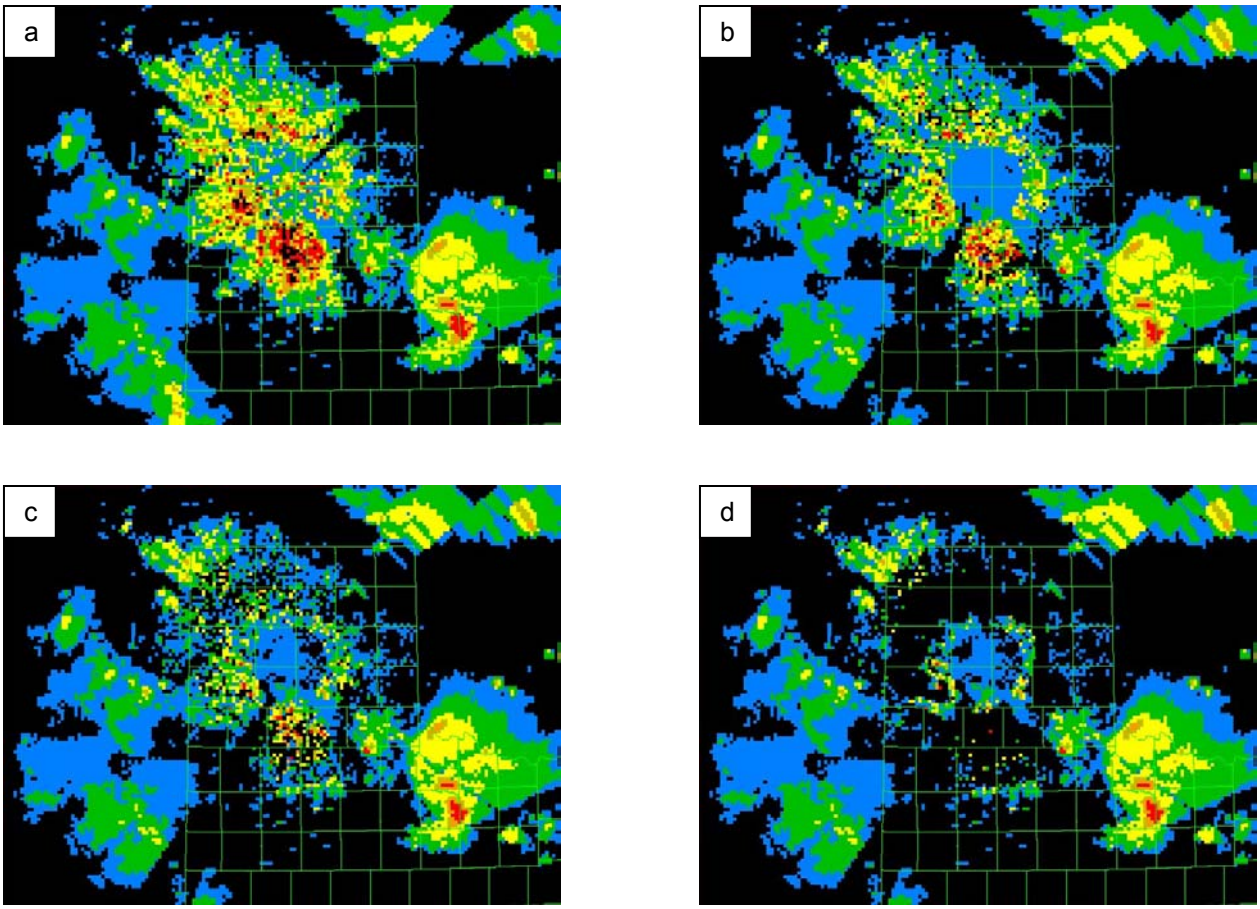

FIG. 5. Same as Figure 2 except the new modification to the AP technique is employed so that median filtering is not used within precipitation regions.

3. SUMMARY

ORPG AP-mitigated Composite Reflectivity Products erroneously reduce the maximum reflectivities within precipitation systems. The source of this problem has been traced to the use of a median filter as had been previously suspected (Smalley and Bennett 2001).

A simple modification to the median filter allows a new averaged reflectivity value to be applied only to returns designated as AP while leaving precipitation returns unchanged. The effectiveness of the AP mitigation technique at removing AP remains the same when the modification is implemented.

Efforts are ongoing to include this correction in the AP-mitigation technique in a future ORPG build.

The technique is effective at removing many examples of AP including nocturnal temperature inversion events. However, improvement is still needed in other instances such as when AP is present yet reflectivity, velocity, or spectrum width information is unavailable.

It is worth noting additional studies being made to enhance AP removal using ORPG products. Radar mosaic generation algorithms developed for the FAA WARP program are currently being evaluated for their effectiveness in using multiple radars to remove non-precipitation returns. The use of products other than CRPs such as ORPG's high resolution VIL has also been advocated because it inherently de-emphasizes AP (Smalley and Bennett 2002).

4. ACKNOWLEDGMENTS

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5. REFERENCES

Smalley, David J. and B. Bennett, 2002: Using ORPG to enhance Nexrad products to support FAA critical systems. Preprints, *10th Conference on Aviation, Range, and Aerospace Meteorology*. Portland, OR, Amer. Meteor. Soc.

Smalley, David J. and B. Bennett, 2001: Recommended improvements to the Open RPG AP-Edit Algorithm. Massachusetts Institute of Technology/Lincoln Laboratories, 37 pp.