P7.6 RADAR DATA QUALITY CONTROL: EVALUATION OF SEVERAL ALGORITHMS BASED ON ACCUMULATING RAINFALL STATISTICS

M. Robinson[1,2], M. Steiner[3], D.B. Wolff[1,4], C. Kessinger[5], and R.A. Fulton[6]

[1]NASA Goddard Space Flight Center, Code 912, Greenbelt, Maryland
[2]Center for Earth Observing and Space Research, George Mason University, Fairfax, Virginia
[3]Dept. of Civil and Environmental Engineering, Princeton University, Princeton, New Jersey
[4]Science Systems and Applications, Inc., Lanham, Maryland
[5]National Center for Atmospheric Research, Boulder, Colorado
[6]National Weather Service Hydrology Laboratory, Silver Spring, Maryland

1. INTRODUCTION

The primary function of the TRMM Ground Validation (GV) Program is to create rainfall products that provide a basis for evaluation of satellite-derived precipitation measurements for selected sites within the tropics. An important step in creating high-quality GV products is radar data quality control. Quality control (QC) processing of TRMM GV radar data is based on procedures that are not fully operational and require significant human interaction to assure satisfactory results. Despite continuous manual tuning, the TRMM GV QC algorithm still can not completely remove all types of spurious echoes. In an attempt to improve the current operational radar data QC procedures for TRMM, a comparison of several QC algorithms has been conducted. The results of this effort are valuable beyond the TRMM community and beneficial to any operational efforts dealing with large amounts of radar data.

In this study, six different radar QC algorithms are applied to specific WSR-88D radar data from Amarillo, Texas and St. Louis, Missouri, where contamination from anomalous propagation (AP) is significant. The QC algorithms are evaluated and compared based on their ability to remove AP without removing significant precipitation. Expanded radar data QC algorithm comparison analyses focusing on additional sources of spurious echo contamination and larger data sets are underway. Preliminary determinations are made as to whether a more automated radar data QC algorithm is a viable alternative to the current, labor-intensive QC algorithm employed by TRMM GV.

2. RADAR QC ALGORITHMS

The six radar data QC algorithms compared in this study each utilize distinct methodologies to identify and remove spurious echoes:

No QC: Completely uncorrected radar data.

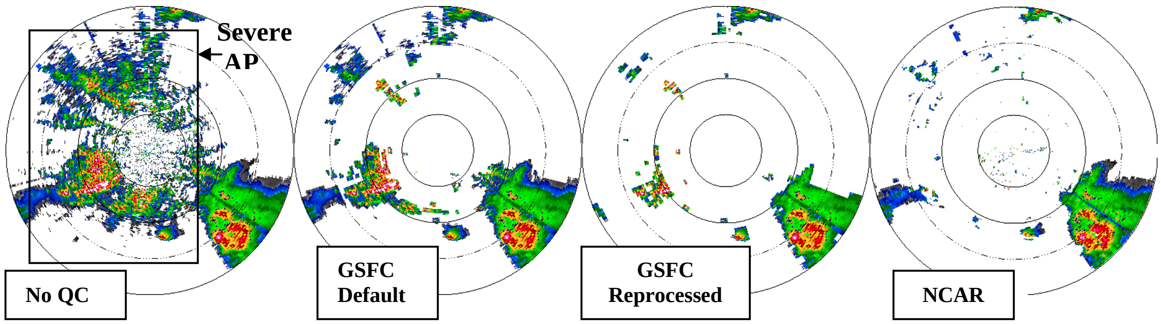
GSFC Default: The automated TRMM GV algorithm used for initial QC of radar data. The algorithm uses eight adjustable parameters, three echo height thresholds and five radar reflectivity thresholds, to remove spurious echoes (Kulie et al., 1999). These parameters comprise the logical expressions that define the echo removal criteria of the QC algorithm. In this version of the algorithm, the threshold parameters are set at default values. Radar echoes are masked within ~5x5 km^2 windows (in polar coordinates) by the algorithm if any of the echo removal criteria are satisfied.

GSFC Reprocessed: The operational TRMM GV radar QC algorithm where the height and reflectivity echo removal parameters are manually tuned for specific QC concerns beyond the ability of *GSFC Default*. Manual tuning of the algorithm yields much better results in terms of spurious echo removal, but data processing with the *GSFC Reprocessed* algorithm is quite labor-intensive.

NEXRAD: United States National Weather Service (NWS) automated QC algorithm currently used within the WSR-88D rainfall estimation algorithm (Fulton et al., 1998). The "tilt test" is a vertical echo continuity check utilizing knowledge that the areal extent of AP often rapidly decreases as the antenna elevation angle increases. When the algorithm detects a decrease in the total reflectivity echo area from the first to second elevation angles exceeding a specified threshold, the entire base-scan data is discarded, and data from the second and higher elevation angles are used. Prior to the tilt-test, both persistent and transient clutter echoes can be eliminated by Doppler velocity filtering imposed by the forecasters, and higher elevation angles are used in localized regions where the radar beam consistently intercepts the terrain to minimize ground contamination and shadow problems resulting from terrain blockages.

*PU: D*eveloped at Princeton University, the PU radar QC algorithm makes use of the three-dimensional reflectivity structure. Radial Doppler velocity information is not used as part of the algorithm. The algorithm makes use of the vertical extent of radar echoes, the spatial variability of the reflectivity field, and the vertical gradient of reflectivity to identify and remove spurious echoes. In addition, for pixels that were removed by the algorithm and would otherwise leave a hole in a rainfall area, echo information from the second elevation scan is used to fill gaps in the base scan data (currently without considering vertical profile information).

Corresponding author address: Michael Robinson, NASA/Goddard Space Flight Center, Code 912.1, Greenbelt, Maryland 20771; email: mrobin@radar.gsfc.nasa.gov



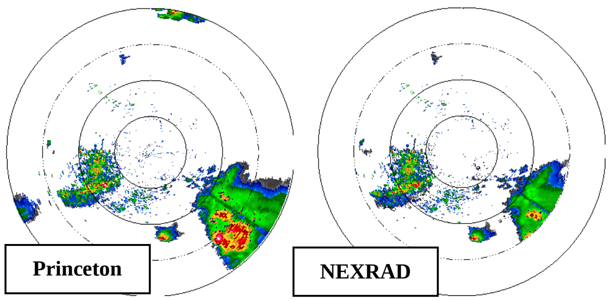
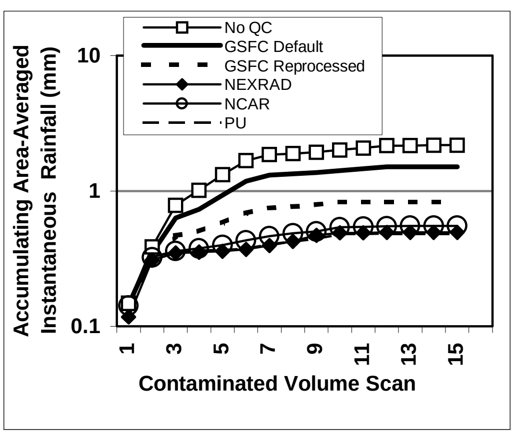


Fig. 1. Amarillo, Texas WSR-88D base-scan (0.5°) reflectivity data on 24 May 1995, 0204 UTC edited for each quality control algorithm. Dashed circle in each panel denotes 150 km range from radar. The truncation of NEXRAD data at 150 km is NOT a function of the QC algorithm and should be ignored. All qualitative and quantitative QC algorithm performance comparisons are conducted within 150 km of the radar.

A) Contaminated Volume Scans



B) Precipitation-Only Volume Scans

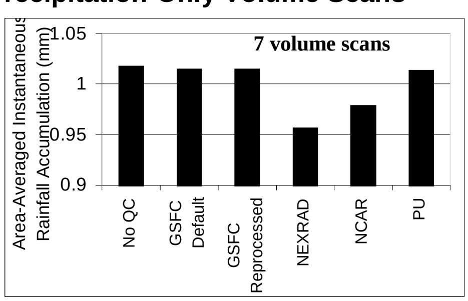
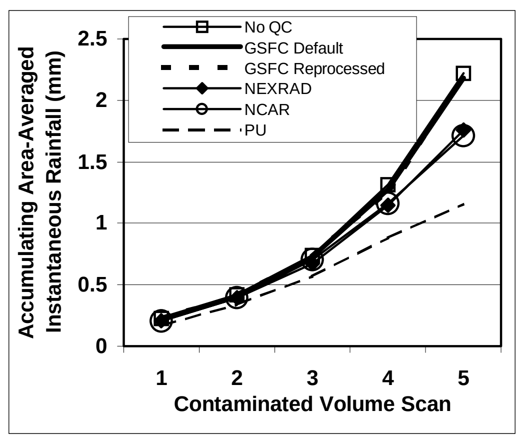


Fig. 2. Area-averaged radar rainfall accumulations for each QC algorithm applied to 24 May 1995 reflectivity data from Amarillo, TX. Accumulations from contaminated scans ONLY are illustrated in (a) while (b) demonstrates accumulations from scans containing ONLY precipitation.

A) Contaminated Volume Scans



B) Precipitation-Only Volume Scans

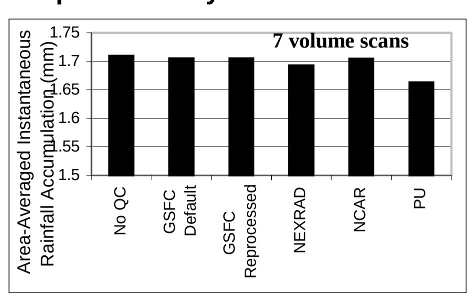


Fig. 3. Area-averaged radar rainfall accumulations for each QC algorithm applied to 07 July 1993 reflectivity data from St.Louis, MO (embedded AP case study). Accumulations from contaminated scans ONLY are illustrated in (a) while (b) shows accumulations from scans containing ONLY precipitation.

NCAR: Developed at the National Center for Atmospheric Research, the NCAR AP Clutter Mitigation Scheme is a planned enhancement to the NEXRAD Open Radar Product Generator. This algorithm consists of four parts, one of which is the Radar Echo Classifier (REC), described in detail by Kessinger et al. (2001). The REC uses the base data fields of reflectivity, radial velocity, and spectrum width as input into fuzzy logic algorithms that estimate the echo type for each range gate. Currently, three algorithms are used: the AP detection algorithm (APDA), the precipitation detection algorithm (PDA), and the clear air detection algorithm (CADA). In this study, base data from each case study are input into each REC algorithm. The thresholded APDA and CADA outputs are used to remove regions determined to be clutter or clear air return from the "corrected" reflectivity field.

3. METHODOLOGY AND RESULTS

Each radar data QC algorithm is applied to two case study data sets consisting of hourly volume scans. The quality controlled radar data from each algorithm is then used to generate instantaneous radar rainfall statistics. The same Z_e-R relationship, $Z = 300R^{1.4}$, is used to convert radar reflectivity to rain rate for each algorithm. Note that the NEXRAD algorithm results are based on using a lower hail threshold (53 dBZ) than the others (60 dBZ) when converting QC'ed radar data to rain rates.

The first case study is based on WSR-88D radar data from Amarillo, Texas on 24 May 1995. These radar data are contaminated with widespread, intense AP that coexists with (but is not embedded within) legitimate precipitation. The performance of each QC algorithm in removing this intense AP is exemplified in Figure 1. The GSFC algorithms, whether using fixed or tunable threshold parameters, have great difficulty removing the more intense AP echoes. The persistence of this intense contamination in GSFC QC data results in erroneously high rainfall amounts upon conversion to radar rainfall rates (Fig. 2a). Radar QC by the NCAR, PU, and NEXRAD algorithms is more successful in removing strong AP. NCAR greatly reduces the areal coverage of the intense AP (Fig. 1), leaving only widespread, isolated pixels of intense spurious returns. Both PU and NEXRAD greatly reduce the intensity of AP echoes by utilizing data from higher elevation angles, but neither are as effective as NCAR in reducing the contaminant's areal coverage. In terms of area-averaged rainfall though, these three QC algorithms are similarly effective in reducing the adverse effects of AP contamination.

In terms of each algorithm's interaction with legitimate precipitation, the GSFC and PU algorithms are most effective in maintaining precipitation echoes (Fig. 2b). Rainfall accumulations from NCAR QC data containing only precipitation returns are reduced as the QC algorithm occasionally removes echoes at the edge of convective cores. Much of the reduction of NEXRAD QC rainfall accumulations in Fig. 2b is the result of applying of a lower Z_e-R hail threshold. Continued investigations have demonstrated that NEXRAD QC accumulations are relatively low since higher tilt data and resultant weaker reflectivity returns are utilized when AP is detected.

The second case study highlights the performance of the QC algorithms in removing intense AP embedded within convection. Analysis of WSR-88D radar data from St. Louis, Missouri on 07 July 1993 demonstrates that the GSFC algorithms have no affect on embedded AP (Fig. 3a). NCAR QC is more successful in mitigating the adverse effects of embedded AP contamination on rainfall accumulation. NCAR is able to remove large areas of intense AP but a significant number of strong spurious echo pixels are able to persist. Suggestions of improvements by NEXRAD are misleading since it is the lower hail threshold that reduces rainfall accumulations from AP, not the QC algorithm itself. The PU algorithm performs very well in this particular case in replacing contaminated base-scan data with higher-tilt information, while maintaining the overall integrity of the precipitation field. This results in less evidence of contamination in the radar data (Fig. 3a) and—although the algorithm also slightly reduces accumulations from legitimate precipitation (Fig. 3b)—this trade off may be acceptable.

4. SUMMARY AND CONCLUSIONS

A comparison of six radar data QC algorithms has been conducted, focusing on the removal of spurious echoes associated with AP. Based upon the results of this study, evidence suggests that either of the automated NCAR and PU algorithms may be a viable alternative to the current, labor-intensive QC procedure employed by TRMM GV. Each of these algorithms performs well in removing strong AP echoes while not removing true precipitation echoes. The performance of the QC algorithms is strongly dependent upon the type of spurious echo present. In specific cases, the GSFC algorithm, even with the added need for manual intervention, may perform better than the other fully automated procedures.

5. ACKNOWLEDGEMENTS

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