P6R.14 A QUALITY CONTROL ALGORITHM FOR NPOL DURING CRYSTAL-FACE

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1. INTRODUCTION

Radar data often must be interpreted in order to determine if the power returned is from hydrometeors, or if it is from artifacts from noise in the system or from returns from non-meteorological echoes. All radars have the potential to have some of these artifacts appear in the data. It takes a trained eye to identify these echoes to avoid misinterpretation. Some radars are subjected to more occurrences of these artifacts due to their technical design (e.g. antenna design).

The NASA 10 cm polarimetric Doppler radar (NPOL) has an unique antenna design that has resulted in issues that need to be addressed during the quality control procedure. It was designed with an ultra-modern, flat panel antenna that is self-contained and fully portable. The antenna was constructed with a mesh-like reflector which cuts down on wind loading and makes NPOL quickly deployable in any weather situation. However, the design has introduced issues with data quality and reliability, including an increased occurrence of sidelobes, backlobes, and other non-precipitation echoes.

NPOL was deployed during the Cirrus Regional Study of Tropical Anvils and Cirrus Layers - Florida Area Cirrus Experiment (CRYSTAL-FACE) in south Florida during July 2002. The dataset generated by NPOL includes high-resolution volume scans of the atmosphere with a temporal resolution of 10 minutes. To improve the quality of the data, a quality control algorithm was developed and implemented to address the issues previously mentioned.

2. QUALITY CONTROL ALGORITHM

The quality control (QC) algorithm is designed to make two passes through the raw data. Two passes are done due to the extensive nature of the tests in the second pass, which examines adjacent range gates around the analysis range gate. By running two passes, the data that are compared with the analysis location in the second pass will already have been tested to insure some reliability of the data. A flow chart of the algorithm is shown in Figure 1 along with a description given in Table 1.

Removal of non-precipitating echoes has been studied and attempted by others, which were considered and incorporated in the QC algorithm when possible. For example, Steiner and Smith (2002) examined the three-dimensional reflectivity field to determine and remove artifacts from the radar volume scans. A modified section of this algorithm was included in the current QC algorithm. The test searches and identifies the highest sweep in which echo was recorded over any given reflectivity gate. This method is labeled as the echo-top test in this algorithm and is explained below in more detail.

In the QC algorithm, if reflectivity data are present, it will be run through three tests in the first pass. The first test is a range dependent correlation test. Precipitation is found to generally have correlation coefficient (ρ_{hv}: correlation between the horizontal and vertical polarized channels) values greater than 0.7 (Ryzhkov et al. 1994). Correlation coefficient values were decreased with range to reduce the chance of precipitation being removed due to possible polarimetric attenuation. This test was only performed on range gates below 4 km in height to eliminate the chance of removing reflectivity values in the anvil region because ice crystals tend to have lower ρ_{hv} values compared to other hydrometeors (Straka et al. 2000). If a data point passes the range dependent ρ_{hv} test as potentially real echo, it is tested with the minimum reflectivity test portion of the QC algorithm.

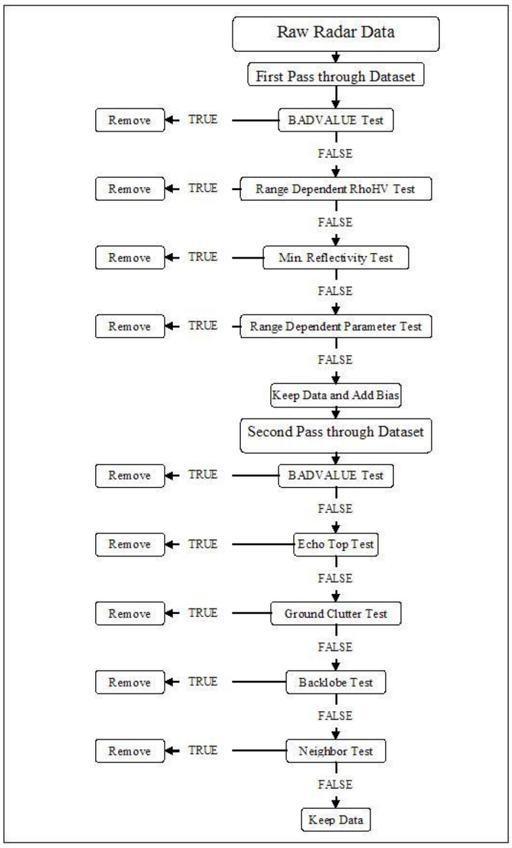

Figure 1: Flow chart of the quality control algorithm used on the CRYSTAL-FACE NPOL dataset.

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The minimum reflectivity test will remove any reflectivity values that are below a minimum threshold in the lowest two sweeps of the dataset. The minimum threshold is currently set at 0.0 dBZ for the CRYSTAL-FACE data before a bias correction is applied. It is known that cirrus clouds usually have rather low reflectivity values due to the inclusive particle habits and concentrations. Therefore, this test is restricted to only perform in the lowest two sweeps to try and eliminate the potential removal of cirrus anvil data.

Table 1: Tests and Removal Descriptions.

Range Dependant RhoHV Test	Rng gates in the lowest 4 km having ρ_{hv} values < 0.8, 0.7, 0.6, 0.5 for ranges out to 25, 50, 100, and 150 km respectively
Minimum Reflectivity Test	Z < 0.0 dBZ & sweep < 2
Range Dependant Parameter Test	Testing Z, V, and ρ_{hv} using different thresholds at different ranges
Echo Top Test	ρ_{hv} < 0.8 and a vertical extent visible only in the first sweep
Ground Clutter Test	Rng < 50 with ρ_{hv} < 0.9 and near zero V, or Rng <= 15 with near zero V, or Rng < 10 with Z < 30 in the lowest 2 sweeps and ρ_{hv} < 0.95
Backlobe Test	Hgt < 4 and Z 180° from current rng gate > 25 dBZ and the difference between the two Z values is between 21 and 26 dB
Neighbor Test	If only 3 or less surrounding 8 rng gates have reflectivity values
Bias Correction	Addition of 5.2 dB
Remove	Set Z to -999.0

If the data point passes the second test, it is sent to a third test, which performs a range dependant check utilizing the reflectivity, velocity, range and correlation values. Echoes with near zero velocities, low correlation values, and rather low reflectivity values are removed from the volume scan. A problem may occur with real echoes moving parallel to the radar giving a near zero velocity. The correlation and reflectivity thresholds were set to try and lower the false removal occurrence in this test. If the values meet these criteria, the reflectivity value is removed. Rather coarse thresholds were set in the last portion of this test to help in the removal of extreme anomalous propagation cases. It tests reflectivity values that are greater than 20 dBZ near zero velocities. It then removes those values that have a ρ_{hv} less than 0.99.

Range gates that obtain values passing the first three tests without being removed are then printed with the known NPOL bias correction of 5.2 dB as corrected QC'ed reflectivity. The values are then ready to be processed through the second pass containing four more extensive tests. These tests rely on surrounding data points for examination; by passing the tests in the first pass, they are more reliable for comparisons in the second pass.

The first test in the second pass looks at the vertical extent of the echo. If the reflectivity is only seen in the first sweep with a correlation value less then 0.8, the value is removed. This method is a modified portion of the technique used by Steiner and Smith (2002). If the range gates pass this test, they are sent to the ground clutter test, which compares values within 50 km from the radar. Ground clutter is generally easy to decipher using ρ_{hv} values. Ryzhkov et al. (1994) have shown ground clutter ρ_{hv} values are between 0.2 and 0.3, so most of the ground clutter should have been removed from the range dependent ρ_{hv} test. However, some ground targets have been noticed to have higher correlation values, so further examination of the data had to be performed. A higher ρ_{hv} threshold was placed on the data for range gates within 15 km from the radar along with near zero velocities. Storms that happen to propagate parallel to the radar would have near zero velocities, but should remain as real echo due to their higher ρ_{hv} values.

The next test is invoked to detect and remove backlobes. This artifact is well known to NPOL. Backlobes are caused by energy traveling through the mesh-like reflector after it leaves the feed horn. The electromagnetic waves reflect off hydrometeors behind the reflector and send them back to the radar. The returned energy will give a false echo and record the data at the opposite azimuth, but at the same range as the actual echo. The backlobe image will be recorded as a mirror image of the real echo. This process is depicted in Figure 2. Through previous examination, it was found that the reflectivity values of backlobes are about 21 dB to 26 dB lower than that of the actual echoes.

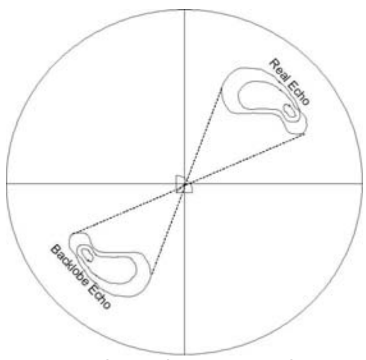


Figure 2: Diagram of the formation of backlobes. The radar is located at the center of diagram pointing towards the backlobe echo (Southwest). Missed radio waves travel through the meshed antenna from the feed horn and are returned from a thunderstorm behind the radar (northeast) causing the backlobe to appear in the display as a mirrored image of the real echo.

The neighbor test is the fourth and final test of the algorithm. The reflectivity value is removed if there are only three or less of the surrounding eight range gates containing reflectivity values. This helps remove some of the speckled appearance that occurs from the previous tests, as well as from random noise in the receiver. This test may also smooth some edges around real precipitation, but should be rather insignificant in the amount removed.

All values that pass these tests are considered valid precipitation echoes, and are saved to an output file as corrected reflectivity. The uncorrected reflectivity values are also resaved to the output file in order to keep the raw dataset accessible.

3. RESULTS

Five cases were chosen to determine how well the algorithm performs with specific artifacts. The five cases include a volume scan with indication of backlobes, sidelobe, anomalous propagation (AP) outside of precipitation, embedded AP (inside precipitation), and pure precipitation with a minimization of other artifacts. The uncorrected and corrected base scan images of each of the five cases can be seen in Figure 3. Visual confirmation shows that the algorithm does a fairly decent job at removing the artifacts in question. In the case of extreme AP (Figure 3d), most of the artifact was removed. However, there still remains a speckled appearance from the AP in the corrected image suggesting that the algorithm has a few issues yet to be resolved.

In the case of the AP outside of precipitation (Figure 3c), the only real precipitation appears to be in the far northern portion of the viewing area. The algorithm does leave a scattered portion of the AP in the corrected image, but removes 97% of the range gates containing reflectivity values. In Figure 3e, the pure precipitation case, the majority of the echoes in the image are of real echoes. The algorithm removed 55% of the reflectivity gates, which is reasonable due to the amount of range gates associated with the ground clutter near the radar.

The algorithm visually proved relevant, but the location of each test within the algorithm came under question. The algorithm was tested by switching the order of the individual tests within their corresponding pass. Six different sequences within the algorithm were performed along with the original sequence. The number of range gates removed by each test and the total amount removed from the volume scan were recorded, along with the total number of range gates with reflectivity values. It was found that the order in which the tests are performed has no effect on the total number of range gates removed from the data; only on the number removed by each test.

4. DISCUSSION

With the visual acceptance of the corrected reflectivity images, there still remains several issues worth considering, which have not been resolved. There are still some remnants of non-precipitating echoes in the corrected images. The majority of these range gates are left over from AP artifacts. There is also the issue of removing too much data and eliminating some range gates that are meteorological echo.

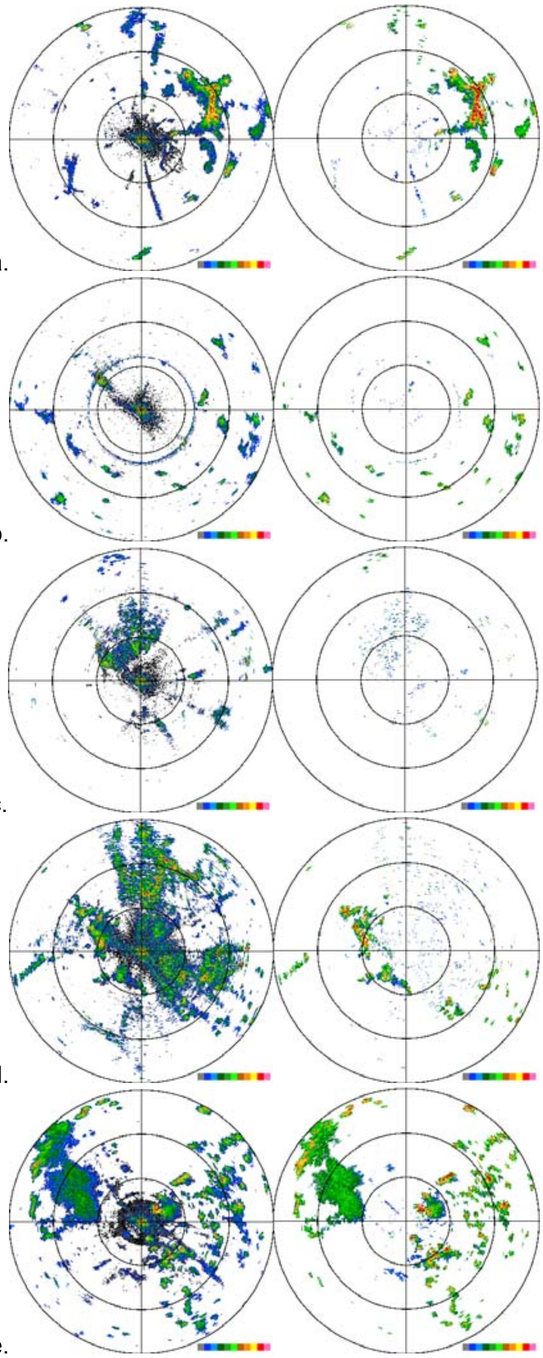
a.
b.
c.
d.
e.


Figure 3: Left images are uncorrected base scan reflectivity with the right images displaying the corrected base scan reflectivity. Artifacts include a.) Backlobes at 2021 UTC 05 July, b.) Sidelobe at 0551 UTC 08 July, c.) AP on at 1203 UTC 03 July, d.) embedded AP at 0401 UTC 07 July, and e.) all precipitation echo at 2101 UTC 07 July.

The minimum reflectivity test has the potential to remove some valid echo in the lowest two sweeps. However, precipitation in the lower sweeps tends to be larger than the set threshold of 0.0 dBZ before bias correction; having low significance on rainfall estimation and leaving little concern for false removal of precipitating echoes.

Issues with the range dependent parameter test and the ground clutter test are associated with the use of the velocity parameter as a test criterion. Valid echo has the chance to be removed if it is moving parallel to the radar. The near zero velocities will fulfill part of the criteria for removal. However, the ρ_{hv} threshold should keep the range gate from being removed. Problems exist only if polarimetric attenuation occurs, allowing the ρ_{hv} to drop below the given threshold. This problem should only be a concern with values farther from the radar compared to the range at which ground clutter occurs.

The echo top test has the potential to remove reflectivity values of shallow precipitation at far ranges from the radar. There is also the ρ_{hv} threshold in this test to try and eliminate the chance of removing the valid echoes.

The last known concern with the algorithm comes with the backlobe test. There may exist a problem if scatter thunderstorms are located across the viewing area. A cell in its final lifecycle stage directly 180 degrees from a mature, strong cell may meet the criteria for removal if the differences in their reflectivity values lie between 21 and 26 dB. The chances for this scenario are small, but still possible. Another scenario would be in a case for stratiform precipitation with embedded thunderstorms; removing values from the stratiform precipitation 180 degrees from the actual thunderstorm.

5. CONCLUSIONS

The current algorithm has been implemented on the dataset collected by NPOL during CRYSTAL-FACE in July of 2002. It performs two passes through the volume scan utilizing parameters, such as, reflectivity, velocity and correlation coefficient values in several tests to determine whether or not the range gate is actual precipitation compared to non-precipitating artifacts. Issues still remain unresolved for each of the individual tests within the algorithm. For example, one of the main issues is the removal of valid precipitation echo due to polarimetric attenuation or shallow vertical extent. Nonetheless, the algorithm has performed with exceptional expectations, both visually and numerically.

6. ACKNOWLEDGEMENTS

This work was supported under NASA Grant NAG5-11509.

7. REFERENCES

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