5.17 NEXRAD DATA QUALITY: AN UPDATE ON THE AP CLUTTER MITIGATION SCHEME

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1. Introduction

The AP (anomalously-propagated) Clutter Mitigation Scheme (Kessinger et al. 2001) is being implemented within the Open Radar Product Generator (ORPG) (Saffle and Johnson 1998; Saffle et al. 2001) of the Weather Surveillance Radar–1988 Doppler (WSR-88D) of the National Weather Service (NWS). This scheme is designed to remove automatically the additional ground clutter caused when atmospheric conditions are favorable for refractive bending of the radar beam towards the surface. Removal of this additional ground clutter is needed since it is a contaminant within the radar base data fields that causes erroneous radar-derived rainfall estimates within the WSR-88D precipitation processing subsystem (PPS; Fulton et al. 1998; O'Bannon 1998) as well as errors in interpretation. Currently, the WSR-88D data quality control system removes the AP clutter by manual application of additional ground clutter filters. Automation of clutter filter control is a desired goal of the AP Clutter Mitigation Scheme.

The AP Clutter Mitigation Scheme consists of four parts: the Radar Echo Classifier (REC), the Reflectivity Compensation Scheme (Z-Comp), clutter background map augmentation, and clutter filter control and is discussed in Kessinger et al. (2001). This paper discusses the REC and the Z-Comp algorithms as deployed on the NCAR S-Pol radar (Keeler et al. 2000) during real-time operations of the Improvement of Microphysical Parameterization through Observational Verification Experiment (IMPROVE) field program that was conducted by the University of Washington. The algorithms were run in series such that the output from the REC defined regions where the Z-Comp algorithm was used to correct the filtered reflectivity field. Initial deployment of the AP Clutter Mitigation Scheme on the S-Pol radar has allowed algorithm testing to occur within an operational environment before final deployment on the WSR-88D.

2. Radar Echo Classifier

The Radar Echo Classifier (REC) is an expert system that uses "fuzzy-logic" techniques (Kosko, 1992) to estimate the type of scatterer measured by the WSR-88D. Details of the algorithm are described within Kessinger and Van Andel (2001). Currently, three algorithms have been designed and tested: the AP Detection Algorithm (APDA) detects regions of anomalously-propagated (AP) ground clutter return, the Precipitation Detection Algorithm (PDA) defines convective and stratiform precipitation regions, and the Clear Air Detection Algorithm (CADA) defines return from insects in the boundary layer. These algorithms have been developed using data from several WSR-88D and the S-Pol radars (Kessinger et al. 1999).

3. Reflectivity Compensation Scheme

The Reflectivity Compensation Scheme (Z-Comp) uses a Gaussian approximation for precipitation spectra and a simulated WSR-88D clutter filter to estimate the correction that offsets the clutter-filter-induced (negative) bias in the reflectivity. Details of the algorithm design and implementation are in Ellis (2001). The Z-Comp method has been tested quantitatively using WSR-88D time-series data (Archive 1) collected at the Memphis (KNQA) WSR-88D.

Within the AP Clutter Mitigation Scheme, output from the REC PDA determines where the Z-Comp method is applied such that only regions of precipitation are compensated. This prevents undesired compensation of reflectivity values within ground clutter return.

4. Testing During IMPROVE

The REC and the Z-Comp algorithms were tested during real-time operations of the IMPROVE field program that was conducted by scientists from the University of Washington. The experiment was held from early January to mid-February 2001 along the coast of Washington. The NCAR S-Pol radar was located at the Westhaven State Park, a few hundred feet from the edge of the Pacific Ocean.

The S-Pol radar is a 10 cm wavelength, polarimetric radar. It uses a four-pole elliptical, high pass ground clutter filter with passband edges of ± 0.5 m s^{-1}. The WSR-88D clutter filter for low suppression has passband edges of ± 1.2 m s^{-1}; for medium suppression, passband edges are ± 1.6 m s^{-1}. Because of its comparatively narrow width, the S-Pol ground clutter filter removes less data from the power spectra when compared to a WSR-88D. For future tests, the clutter filters on S-Pol will be modified to more closely resemble the WSR-88D filters.

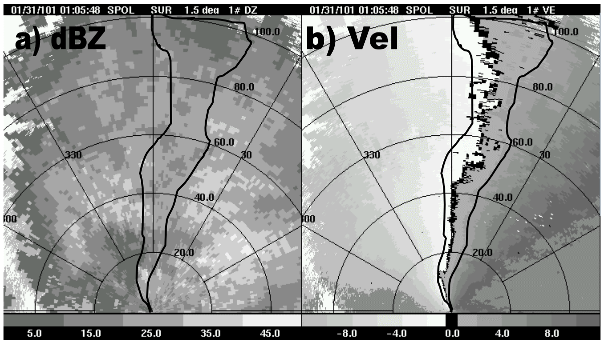

Figure 1. Data from the NCAR S-Pol radar on 31 January 2001 at 0105 UTC for the 1.5^o elevation angle. Fields shown are a) filtered reflectivity (dBZ) and b) radial velocity (m s^{-1}). Inbound radial velocity values are negative (light gray shades); outbound values are positive (dark gray shades); values between $\pm$0.5 m s^{-1} are shaded black. The black contoured region encloses velocity values within $\pm$2 m s^{-1}.

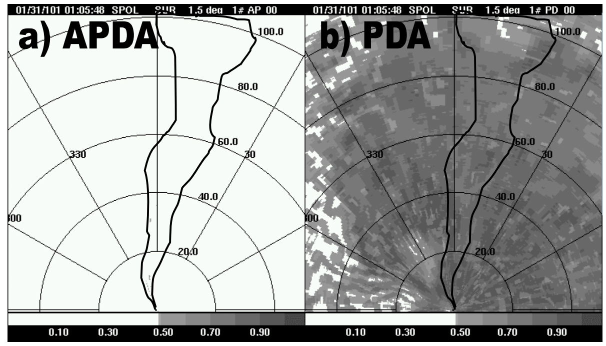

Figure 2. Thresholded output from the Radar Echo Classifier is shown for the scan in Figure 1. Algorithm output shown is a) the AP Detection Algorithm and b) the Precipitation Detection Algorithm.

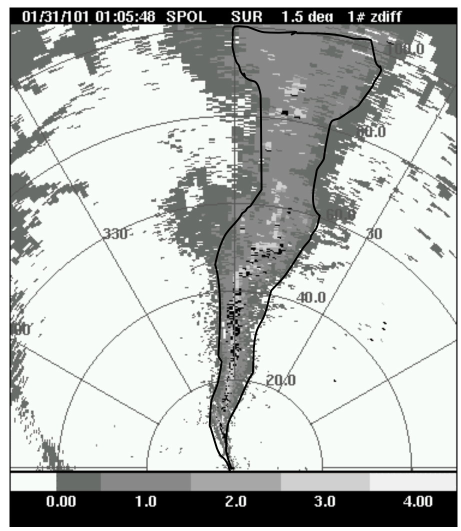

Figure 3. Difference field for ($Z_{comp} - Z_{filt}$) is shown for the scan in Figure 1. Differences in excess of 4.5 dB are shaded black.

5. Case Study from IMPROVE

Near 2300 UTC on 30 January 2001, a large, northwest-southeast oriented region of stratiform precipitation was nearly stationary within the S-Pol operating domain. The precipitation persisted over the next four hours with a gradual reduction in the area of the echo. Maximum reflectivity values were about 45 dBZ. During this interval, the winds were from the west with little variation in direction. Figure 1 shows the S-Pol reflectivity and radial velocity data on the 1.5^o elevation angle at 0105 UTC.

The ground clutter filter was in use on S-Pol, making this an excellent case for examining the performance of the Z-Comp algorithm. The contoured region in Fig. 1 approximately encloses radial velocity values within $\pm$2 m s^{-1} and is where the Z-Comp algorithm will have the maximum effect on the corrected reflectivity estimates and the subsequent radar-derived rainfall estimates. Within the contoured region, the spectrum width values (< 1 m s^{-1}; not shown) are smallest within 50 km of the radar.

The Radar Echo Classifier was run on the scan above with results shown in Fig. 2. Because the elevation angle is at 1.5^o and the ground clutter filter was in use, few ground returns are present, in agreement with the APDA results (Fig. 2a). The APDA does not falsely detect the precipitation echo as clutter. The PDA correctly diagnoses the precipitation echo (Fig. 2b).

Using the PDA output to define the region of interest, the Z-Comp algorithm is run on this scan to correct the negative bias in the reflectivity field. Figure 3 shows the difference field when the filtered reflectivity field (Z_{filt}) is subtracted from the compensated reflectivity values (Z_{comp}), i.e., ($Z_{comp} - Z_{filt}$). Largest compensation of the reflectivity values occurs within the contoured region between ranges of 0-50 km where the radial velocity values are within $\pm$2 m s^{-1} and the spectrum width is <1 m s^{-1}.

To show the improvements in radar-derived rainfall estimates that the Z-Comp method allows, the storm-total, accumulated rainfall is calculated. The NEXRAD Z-R equation, ($Z=300R^{1.4}$), is used and the amounts accumulated over the four hours. The storm total rainfall amount for the filtered reflectivity field is shown in Fig. 4a while the rainfall amount for the compensated reflectivity field is shown in Fig. 4b. Maximum rainfall amounts are about 19 mm for each. In Figure 4, rainfall amounts $\geq$5.5 mm are shaded dark gray to enable the improvement in rainfall amounts within the contoured region to be seen. A significant increase in accumulated rain is realized through the use of the Z-Comp algorithm. Figure 5 shows the rainfall amount difference field ($R_{comp} - R_{filt}$) from the two

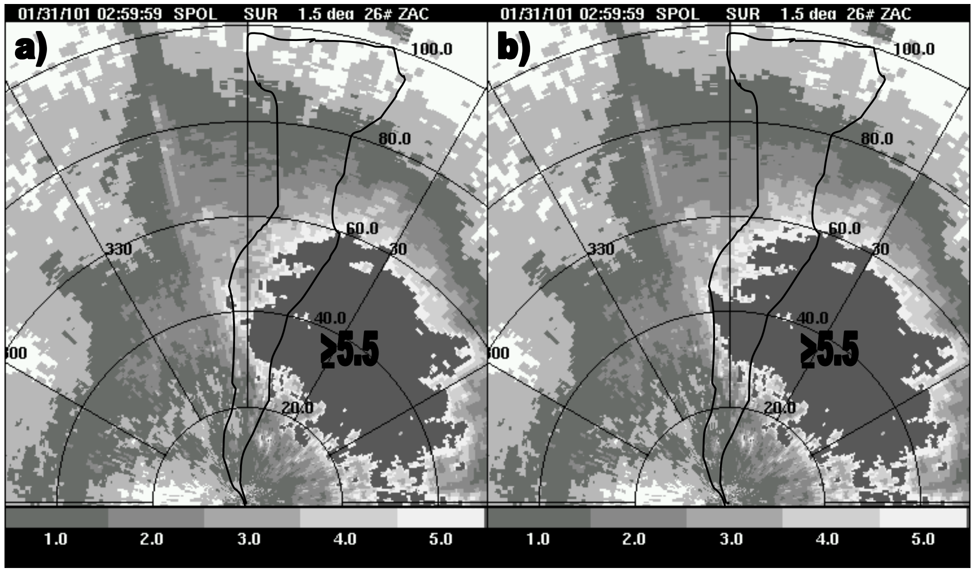

Figure 4. Accumulated radar-derived rainfall amounts (mm) for the four-hour period of 30-31 January 2001. Rainfall amounts are derived using the a) filtered reflectivity field having negative bias induced by the clutter filter and b) the compensated reflectivity field where the negative bias is corrected. The contoured region approximately encloses radial velocity values between ± 2 m s^{-1}. Rainfall amounts $\geq$5.5 mm are the darkest gray shade.

reflectivity fields. The maximum difference is 4-5 mm, a significant proportion of the total rainfall amount of about 19 mm.

6. Summary and Future Work

An example case, with integrated results from the REC and Z-Comp algorithms, was shown. Results indicate an improvement in the rainfall estimates after the Z-Comp method is applied. Refinements of the REC and Z-Comp algorithms continue. The next field deployment of the S-Pol radar will be during the IMPROVE2 field program to be held during November-December 2001 near the Oregon Cascades mountain range. Real-time testing of the AP Clutter Mitigation Scheme will continue.

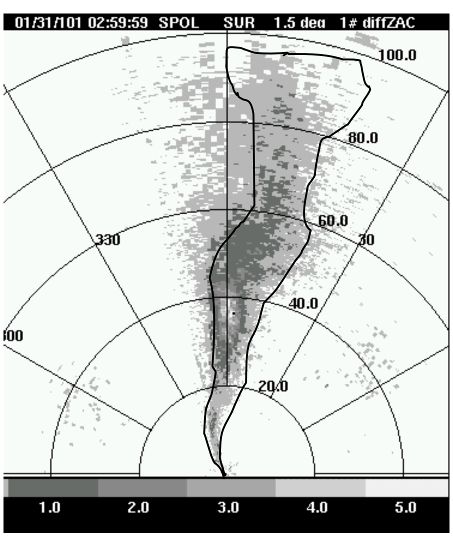

Figure 5. Difference field (mm) for ($RainAcc_{comp}$ – $RainAcc_{filt}$) is shown for the ~4 hour duration storm event.

7. Acknowledgements

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8. References

Ellis, S.M., 2001: Compensating reflectivity for clutter filter bias in the WSR-88D, *Preprints, 17th Int'l IIPS Conf.*, AMS, Albuquerque, NM, 14-18 Jan 2001, 142-145.

Fulton, R.A., J.P. Breidenback, D.J. Seo, D.A. Miller, and T. O'Bannon, 1998: The WSR-88D rainfall algorithm. *Wea. and Forecast.*, **13**, 377-395.

Keeler, R.J., J. Lutz and J. Vivekanandan, 2000: S-Pol: NCAR's polarimetric Doppler research radar, *IGARRS-2000*, IEEE, Honolulu, HI, 24-28 Jul 2000, 4pp.

Keeler, R.J., C. Kessinger, J. Van Andel, and S. Ellis, 1999: AP clutter detection and mitigation: NEXRAD implementation plan, *Preprints, 29th Radar Met.Conf.*, AMS Montreal, 12-16 Jul 1999, 580-581.

Kessinger, C., S. Ellis, J. Van Andel, 2001: NEXRAD Data Quality: The AP Clutter Mitigation Scheme, *Preprints, 30th Int'l Conf. Radar Meteorology*, AMS, Munich, Germany, 19-25 Jul 2001, 707-709.

Kessinger, C., and J. Van Andel, 2001: The Radar Echo Classifier for the WSR-88D. Preprints, 17th Int'l IIPS Conf., Albuquerque, 14-18 Jan 2001, AMS, p 137-141.

Kessinger, C., S. Ellis, J. Van Andel, 1999: A fuzzy logic, radar echo classification scheme for the WSR-88D, *Preprints, 29th Int'l Conf. Radar Meteorology*, AMS, Montreal, Canada, 12-16 July 1999, 576-579.

Kosko, B., 1992: *Neural Networks and Fuzzy Systems: A Dynamical Systems Approach to Machine Intelligence*. Prentice-Hall, N.J.

O'Bannon, T., 1998: The enhanced WSR-88D precipitation processing subsystem. *Preprints, 14th Int'l IIPS Conf.*, AMS, Phoenix, AZ, 11-16 Jan. 1998, 267-270.

Saffle, R.E., and L.D. Johnson, 1998: NEXRAD product improvement: An overview of the continuing program to evolve the WSR-88D system to an Open Systems Architecture, *Preprints, 14th Int'l IIPS Conf.*, AMS, Phoenix, AZ, 11-16 Jan. 1998, 230-234.

Saffle, R.E., M.J. Istok, and L.D. Johnson, 2001: NEXRAD open systems – progress and plans. *Preprints, 17th Int'l IIPS Conf.*, AMS, Albuquerque, NM, 14-18 Jan 2001, 97-100.