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IMPROVING RADAR RAINFALL MEASUREMENT STABILITY USING MOUNTAIN RETURNS IN REAL TIME

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1. INTRODUCTION

Attenuation is one of the most severe problems affecting the rainfall estimates by meteorological radars at short wavelengths (5 cm and less). Therefore, most of the operational networks, (essentially C-band radars outside USA), are seriously affected by attenuation, particularly in Europe. In general radar attenuation is related to the reflectivity of the targets along a given beam path, and it is a field with values varying all over radar measurements.

Additionally, in some cases, attenuation can affect the whole radar reflectivity field due to the occurrence of heavy rain over the radome. In this case, the wet radome surface can attenuate the signal in all directions (Manz *et al.*, 1999), producing an effect of general subdetection on the measured reflectivity fields. A similar effect could also be observed due to instabilities on the radar signal related to electronic fluctuations, which could lead to general under or overestimations of the entire field (Della-Bruna *et al.*, 1997). This kind of over/subdetection could become critical in some cases, and it also may lead to improperly apply other usual correction procedures if signal stability is not controlled and corrected before.

During the event of June the 10^{th}, 2000 in Catalunya, the radar of the Spanish Instituto Nacional de Meteorología in Barcelona (INM) suffered an impressive case of general subdetection (see Figure 1). This severe rainfall event yielded more than 200 mm in less than 3 hours, producing important damages (a bridge in the motorway between Madrid and Barcelona collapsed).

When the squall line approached the radar, the reduction of the signal between two consecutive images was so important that it led us to carefully study the event, and to develop an algorithm able to detect signal instabilities of the radar measurements and warning in real-time. A first algorithm was developed and implemented at the INM center in Barcelona in 2000. This algorithm was based on the Mountain Reference Technique (Delrieu and Creutin, 1995) using the mountain returns as references to control stability (Sempere-Torres *et al.*, 2001). After two years of operational experience the algorithm has been improved and reformulated.

2. ASCMORE: Attenuation and Stability Control using the MOuntain REturns.

The basis of the proposed methodology is to control radar signal stability through the analysis of temporal variations of ground clutter returns. The two essential hypothesis are that (a) fluctuations affect all pixels in the same way, (b) the mountains' return distribution shape is not affected, but just biased by a constant factor. So the comparison of the observed clutter against the mean clutter map can provide a measurement of the stability of the signal.

To control the correct performance of the radar, a mean clutter map has been generated for the volumetric scanning C-band radar of the INM located at Barcelona Main radar characteristics are 0.9° 3-dB beamwidth, λ=5.6 cm, 20 elevation angles. A series of 700 radar maps (i.e approximately 5 days of radar data) were selected to calculate the mean map, in which only values over 23 dBZ are considered as valid pixels (to compare only clear interceptions of the main lobe). These data were carefully overviewed to ensure non-precipitating conditions and absence of anomalous propagation.

At each time step radar stability is analyzed by comparing the ground clutter measured at the first elevation of the present radar scan against the average clutter map, which is taken as the correct reference. The algorithm is applied in two steps.

2.1. Selection of the valid pixels.

The observed echoes located at the position of the labeled reference groundclutter are selected, and a double criteria of validity is applied in order to accept them as valid pixels. The two selected tests are:

2.1.1. Test of rejection by rain

To avoid the use of groundclutter pixels in which the observed ground echoes are affected by rain, the region of 5 km around the labeled pixel is analyzed and only if the mean value of this neighborhood is under 20 dBZ the pixel is considered as valid for the comparison.

2.1.2. Test of rejection by attenuation

To avoid the use of pixels which values could be affected by in-rain attenuation, the Path Integrated Attenuation (PIA) between the radar and the groundclutter location is calculated using the directly computed PIA from the observed data (the 'apparent' PIA suggested by Hildebrand, (1978) and Meneghini (1978).

2.2. Computation of the correction factor.

In this new version of the algorithm, the Cumulative Distribution Function (CDF) of the observed values at the valid labeled pixels are compared with the CDF of the averaged ones. The correction factor is computed by the difference between means, and a quality criteria is calculated using the Nash-efficiency between both CDFs.

The analysis of different case studies have shown that this new methodology to calculate the correction factor is better than the one used in the first version of the algorithm (using linear regression between observed and reference values). In particular this method turns out to be less influenced by outlayers, more stable under anaprop conditions and it is able to

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propose fair estimates even with a reduced number of valid points (at less 10 points are required).

In the case of insufficient number of valid points or if the similarity between both CDFs is not high (Efficiency < 0.7), the correction factor cannot be computed as proposed. Therefore, to avoid sudden changes on the radar fields (flashes between two consecutive images due to the application/non application of the correction) the continuity of the rainfall field mean is imposed. So the CDF of the previously observed radar scan and the present one (only the pixels considered as rainfall) are compared and the correction factor is calculated as the difference between the means.

Some case studies are presented in Figure 2.

3. CONCLUSIONS

The experience of the operational use of the algorithm and the analysis of different case studies have allowed us to point out the following conclusions:

- Even during light rain events it exists attenuation due to rain over the radome, that in C-band radars are usually around 4 dB.
- When heavy rain is falling over the radar, this general attenuation can produce severe underestimation (several cases over 10 dB have been observed).
- Electronic fluctuations not related to precipitation effects can sometimes appear. In the studied radar they can oscillate between +2 and –2 dB.
- The original algorithm was properly working in most of cases, but it was very sensitive to the number of valid reference pixels, situation that occurs when intense cells are just over the radar. The new version of the algorithm is able to work better in these cases (reduced number of valid pixels) and it is able to use the rainfall field to ensure continuity. This solution can be acceptable if it is applied to fill short periods (10 to 20 minutes).

As general conclusion it can be noted that the mountains echoes are not just an annoying problem (something to eliminate) but that they can be an useful reference, so it can be suggested to save and use them to improve radar data quality.

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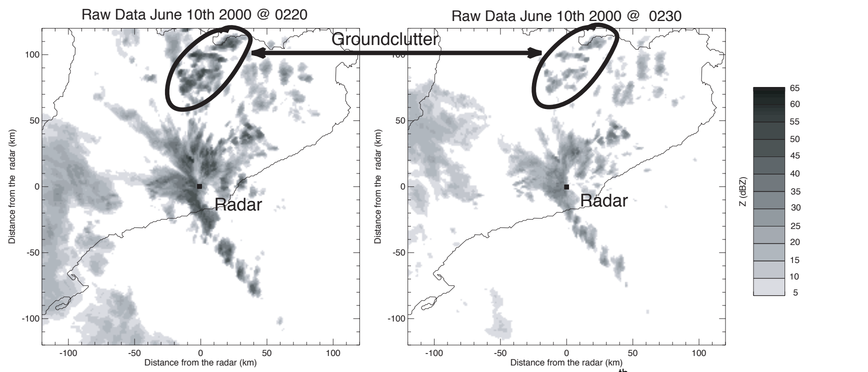

Figure 1: Consecutive raw images from the INM radar at Barcelona during the event of June 10th 2000 at Catalunya. In ten minutes (between 02:20 and 02:30) there is a general change due to attenuation by rain over the radome of more than 10 dB. The effect is clear when comparing the ground clutter echoes (circled) which should be of approximately constant value.

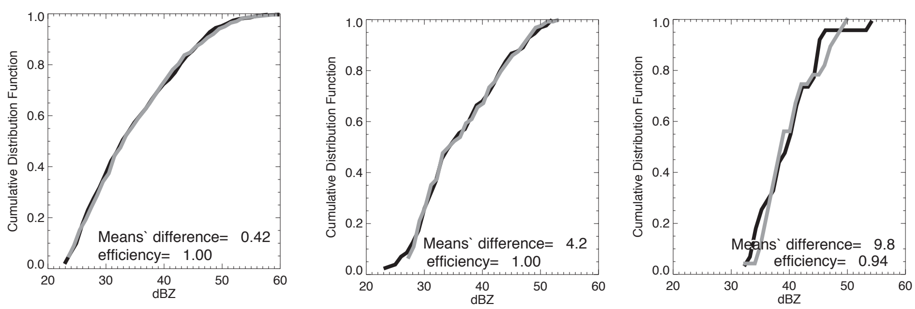

Figure 2: Comparison of Mountain returns CDFs for three cases: a) Clear air situation on 21/10/00 @ 07:00, 862 valid points; b) Light rain over the radome on 3/4/02 @ 15:30, 128 valid points and c) Heavy rain over the radome on 15/07/01 @ 11:50, 8 valid points. In black the reference mean CDF and in grey the observed CDF corrected by the difference of means (should be identical).