P7.5 AN IMPROVED METHODOLOGY FOR GROUND CLUTTER SUBSTITUTION BASED ON A PRE-CLASSIFICATION OF PRECIPITATION TYPES

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1. Introduction

Radar data contamination due to ground echoes is a common problem in any radar configuration, more so in mountainous areas. Addressing ground clutter contamination can be seen as a double task: first detection and elimination of contaminated areas, and second, substitution of removed contaminated values for suitable ones. Different algorithms that use reflectivity information, or Doppler data have been developed to remove such contamination ([*Lee et al.*, 1995], [*Bellon and Kilambi*, 1999], [*VanAndel and Kessinger*, 1999], see a revision of methodologies in [*Steiner and Smith*, 1997]).

The way of performing ground echoes substitution can be either vertical or horizontal interpolation. The first one utilizes the shape of the vertical profile of reflectivity (VPR) to extrapolate non-contaminated values measured aloft, over the area affected by ground clutter ([*Joss and Lee*, 1995], [*Bellon and Kilambi*, 1999]). On the other hand, the horizontal substitution interpolates non-contaminated neighboring values located at the same height or elevation as the contaminated echoes ([*Galli*, 1984], [*Bellon and Kilambi*, 1999]). These procedures are limited by the size of ground clutter regions and the spatial variability of the rainfall field. It is difficult to assess which of the two options is the most satisfactory.

The aim of this work is to propose a substitution methodology that combines horizontal and vertical approaches through considering the type of precipitation. The idea of this approach is to apply horizontal interpolation in those areas of precipitation with low reflectivity gradients (generally considered as stratiform rain). On the contrary, vertical extrapolation will be applied in areas with large reflectivity gradients (usually associated to convective precipitation). In this latter case the VPR tends to have a uniform shape with height, that favors vertical substitution, and the relation between the rain at a point and its surroundings is less clear (which invalidates the idea of horizontal interpolation). Then, this methodology attempts to combine the horizontal and vertical approaches considering the spatial variability of the rainfall field. The proposed methodology uses a simplified approach to identify the convective regions, based in the use of an intensity threshold level. This simplified approach intends to be a first level of complexity solution, useful in an operational context.

2. Evaluated methodologies of substitution:

The methodology of substitution outlined above is compared with four other substitution techniques in order to verify its performance, that are:

1) Pure vertical substitution: based on the substitution of ground echo values by the first non-contaminated value located over their vertical.

2) Pure horizontal substitution: ground echoes are substituted by interpolating neighbor values from their same elevation. The interpolation is applied establishing a Delaunay triangulation for all non-contaminated data. Then, each contaminated value is substituted by means of a distance–weigthed scheme that considers the reflectivity at the vertexes of the triangle that contains the point to be substituted.

3) The substitution methodology used by the radar network of the Spanish National Institute of Meteorology (INM). This methodology uses a combination of horizontal and vertical substitution that is applied to polar radar data by means of the following criteria: for each identified ground clutter it looks for a substitute located at its same elevation, first considering the azimutal neighbors (right and left), and afterwards considering the radial ones (front and rear). In the case that none of them is free of contamination the same procedure is repeated in the next elevation, employing then as a first candidate the value located at the vertical of the point that is been substituted. This procedure is repeated along the subsequent elevations until that one non-contaminated value is found. Notice that this method does not determines a substitute by averaging a certain number of values.

4) Finally the proposed method based on a simplified recognition of the type of precipitation to perform an horizontal + vertical substitution uses the following scheme: as a first step the pure horizontal substitution is applied to all ground echo regions. Next, these substituted which exceed a certain threshold related to convective precipitation (we used 45 dBZ) are substituted once again but now using the first non-contaminated value located at its vertical. This latter value is accepted as a final substitute if it is greater than the one resulting from the horizontal substitution (otherwise the first substitute is preserved).

In our analysis all the methodologies are applied over polar radar data, and the triangulation is established from the cartesian positions of the polar data in order to define the triangles considering the actual positions of the valid points.

The different methodologies have been tested using as a reference the ground echoes measured by the volumetric scanning C-band radar of the INM located at Barcelona (0.9° 3-dB beamwidth, λ=5.6 cm, 20 elevation angles). The Figure 1 depicts the radar location and the average ground echoes pattern observed at the first radar elevation (0.5°) derived during non-precipitating conditions and in absence of anomalous propagation. In order to generate a tri-dimensional echoes pattern, a similar map was obtained for the rest of elevations affected by terrain-induced returns. Although our analysis is limited to the substitution of the ground echoes registered at the first radar elevation it is necessary to determine this tri-dimensional echoes pattern because some of the tested methodologies look for non-contaminated substitutes at higher elevations.

In order to define a region where to apply the substitution techniques, a threshold of 23 dBZ (1 mm/h using the Z-R Marshall-Palmer relation) is used to establish the minimum intensity of the ground clutter that should be substituted.

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To test the different methodologies it is necessary to have measurements of reference to compare them against the substituted values, and asses the quality of the results. For this purpose the three-dimensional structure of the echoes pattern is rotated in order to locate them in an area initially free of problems. At this new location the value of reference is known (since now these data is not contaminated), and the substituted values are the ones resulting from applying the different methodologies to the ground echoes pattern at this new location. The rotation angle used is –67.57 degree, corresponding with –80 positions in the azimutal direction (radar maps are composed by 420 values in the azimutal sense and 120 in the radial sense, with a 2 km radial resolution). After the rotation, ground echoes that remain still over contaminated regions are not considered in the analysis.

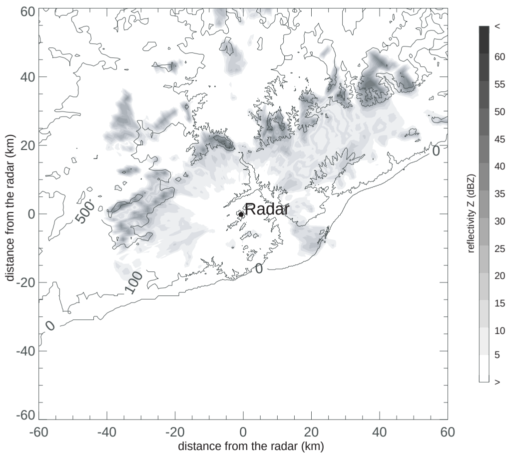

Figure 1. Ground echoes pattern up to 60 km from the radar for the firs elevation (0.5°) of the INM radar at Barcelona.

3. Evaluation of the different methodologies of substitution:

The different methods have been applied over a event registered by the C-band radar of the INM located in Barcelona on June 10th 2000, with a time duration of more than 24 hours. This event was characterized by the mix of types of precipitation, with a first markedly convective part, followed by a stratiform period. The comparison of reference and substituted values are shown in Figure 2 in terms of instantaneous rainfall intensities (i.e. reference and substituted values for each radar map), hourly rainfall accumulations, and total rainfall accumulation for the whole event. The Marshall-Palmer $Z = 200R^{1.6}$ relation is used to transform the reflectivity into rain intensity. The results have been marked with different symbols as a function of its range of distances from the radar. The performance of the different methods has been estimated by means of different statistics: the Nash efficiency, the square correlation (r^2) and the average error between the substituted and reference values.

Figure 2, column 1 (instantaneous values) shows that the proposed substitution method provides better results than the rest of methodologies, basically as a result of the good efficiency, and r^2, since all of them exhibit a similar average error, except for the INM method whose performance is well below the other ones. The results also show that the horizontal substitution tends to underestimate the high and intermediate intensities.

For the hourly accumulations (see Figure 2 column 2) once more the proposed method shows the best adjustment, although all the methods provide similar average errors. Moreover, notice that only the proposed method and the vertical substitution correct the high intensities in a proper way. Nevertheless, this latter methodology and the INM method exhibit a clear underestimation of a group of intermediate intensities (from 0 to 20 mm), located between 40 and 60 km from the radar. As before, the INM method leads to a greater dispersion between the reference and the substituted values as compared to the rest of the methods.

Finally, the total accumulation of the event (Figure 2 column 3) shows similar results: the proposed substitution remarkably improves the performance of the rest of methods. The vertical substitution clearly exhibits two tendencies, and two families of points can be observed: the first one located around the line of right adjustment (1:1), and the second one showing a clear underestimation due to the decreasing of precipitation with height in the stratiform periods of the event. This twofold tendency is also present in the results of the INM methodology but it is less severe. On the other hand, the horizontal substitution exhibits a clear underestimation of the medium to high rainfall accumulations. It confirms that this substitution do not enables a good correction of the convective values.

4. Conclusions

This work analyzes a methodology to substitute radar data contaminated by ground echoes for a proper rain-related reflectivity value. The proposed methodology intends to combine the horizontal and vertical substitution methodologies through considering the most adequate approach as a function of the spatial variability of the rainfall field: horizontal for stratiform rain and vertical for convective.

The results for the analized event suggest that, among the four analyzed methods, the proposed horizontal + vertical substitution provides the best performance. Future work should be done in order to asses the factors that can affect the accuracy of the proposed methodology (as the substitution threshold, or the convective threshold, or the size of the ground echo regions), as well as to analyze its performance in a wider number of cases.

4. Acknowledgements:

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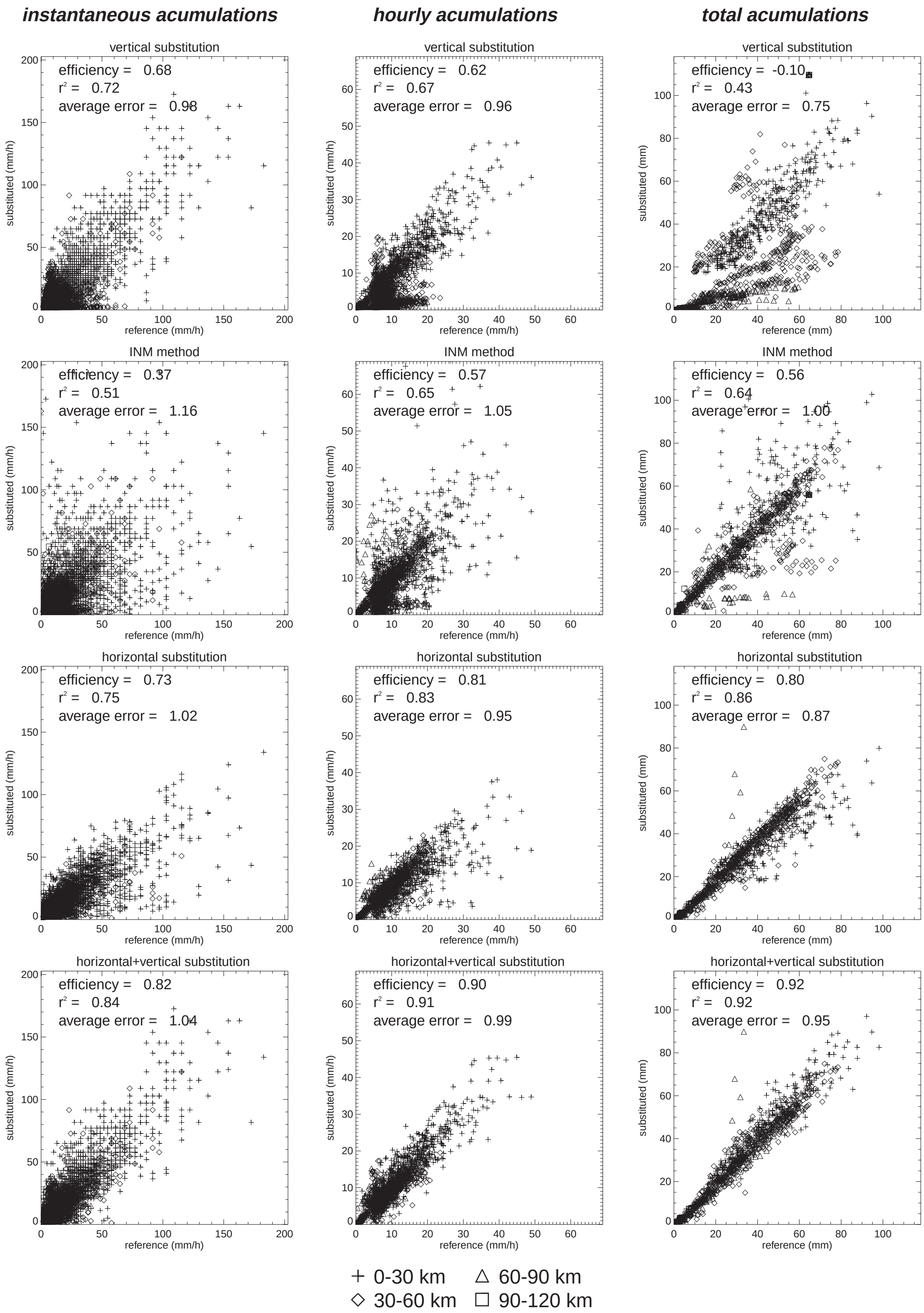

Figure 2. Evaluation of the different methodologies of substitution for analyzed the event. The figures show the comparison of reference and substituted values for different accumulated periods. The goodness of the different methods is tested through the estimation of the Efficiency, the square correlation (r^2), and the average error between the reference and substituted values.