P14.6 FACTORS AFFECTING THE PRECISION OF RADAR MEASUREMENT OF RAIN. AN ASSESSMENT FROM AN HYDROLOGICAL PERSPECTIVE

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1. Introduction

A great variety of errors affect radar measurements of rain [*Zawadzki*, 1984] and an important effort has been devoted to their study. The relative importance of most of these errors has been discussed and several correction procedures have been suggested [*Joss and Waldvogel*, 1990]. Besides, some effort has been devoted to analyze their importance from a hydrological perspective, as well as to assess the degree of performance of the different procedures of correction.

The aim of this work is to present a simulation based study of some of these errors and their hydrological consequences. The followed procedure uses radar measurements to generate a high-resolution three-dimensional rainfall field that is used as reference. Then, through simulation, this field is 'degraded' in order to reproduce a number of radar errors. This work is centered in the errors with the distance to the radar and the variation of the Z-R relations as a function of the type of rain. Next, different correction procedures are applied to the degraded field in order to obtain the 'corrected' ones. The hydrological analysis is made by using the reference field and the degraded and corrected ones as input of a previously adjusted hydrological model, reproducing the response of a real basin and comparing their respective outputs.

2. Methodology of simulation

The developed methodology of simulation involves four basic parts:

a) **Generation of the reference rainfall field**. The reference field has been generated by interpolation of volumetric radar data registered close to the radar. We use polar volumes measured by the C-band radar of the Spanish Instituto Nacional de Meteorología (INM) located at Barcelona (0.9° 3-dB beamwidth, $\lambda=5.6$ cm, $\tau= 2\mu s$, 20 elevation angles). Each volume contains 20-PPI maps, formed by 420 (azimutal) x120 (radial, each 2 km) values. The purpose of the interpolation is to generate a high density rainfall field (250x250 m^2 resolution) over a volume of 20x20x10 km^3, although the radar information is coarser in the radial sense. Thus, the interpolation procedure generates a reflectivity field that both, respects the structure of the radar rainfall field, and exhibits certain variability at the scale of the grid of the reference field. A tri-dimensional interpolation is applied to the volumetric information: the interpolated values are calculated as the average of the n nearest neighborhood. A value of n=2 was selected as adequate in order to obtain a desirable low scale variability (this selection was performed in a qualitative manner).

b) **Simulation of how radar samples this field from a certain distance**. Next, to simulate how radar observes the reference field at a certain distance. a convolution between the radar equation and that field is performed (this new field will be called the degraded field). The result is the reflectivity measured by the radar at the resolution volumes that it samples. We have simulated the scanning strategy of the C-band radar of the INM at Barcelona. Thus, the simulation deserves 20-PPI polar radar maps of 420 (azimutal) x 360 (radial, with a resolution of $\tau c/2$, in our case 300 m) values for each reference field.

c) **Correction of the the degraded field**. In this step the degraded field are corrected to consider the effect of a double Z-R relationship (for convective and stratiform rain) and also the correction of the VPR..

d) **Hydrological assessment of the different errors and corrections**. Finally the different fields have been introduced in an hydrological model. The basin used for the hydrological analysis is the Ample river basin, located at the eastern Pyrenees, and characterized by intermediate to high steeps, typical in many Mediterranean basins. The hydrological model used is a semi-distributed rainfall-runoff model that is applied at cell resolution of 1 km^2 (see a detailed description in *Corral et al. 2000 and Corral et al. 2001*. The runoffs related with the different generated rainfall fields are then compared in order to analyze the hydrological consequences of the different errors and corrections.

3. Hydrological influence of the errors with the distance from the radar

. The simulation procedure has been applied over different events registered at the C-band radar of the INM at Barcelona, which include a variety of rainfall types. We will comment along different examples the most interesting features of this analysis.

Figure 2 (first row) shows the results of a first analyzed event with a duration of more that 24 hours, and characterized by intense convective activity. This first row compares the field observed by the radar at 100 km and the reference field (both are transformed into rain intensities using the Z-R Marshall-Palmer relationship). The comparison of 'instantaneous' values clearly shows the important disparity between degraded and reference values, basically due to the variation of the reflectivity with height.

In this first row the total accumulations significantly filters out part of these differences, although still remains a certain disagreement. At that light, the likeness of the two runoffs could be considered as surprising.

This result shows how the hydrological model is filtering out a significant part of the spatial variability of the rainfall field, although it can also be favored by the rural characteristics of the basin, that smoothes the low scale variability of the rainfall field. The remaining differences between the runoffs can be due to a general slight underestimation of the degraded field as a result of the variation of the VPR (due to the fact that the radar is measuring the rain at a certain height above the ground).

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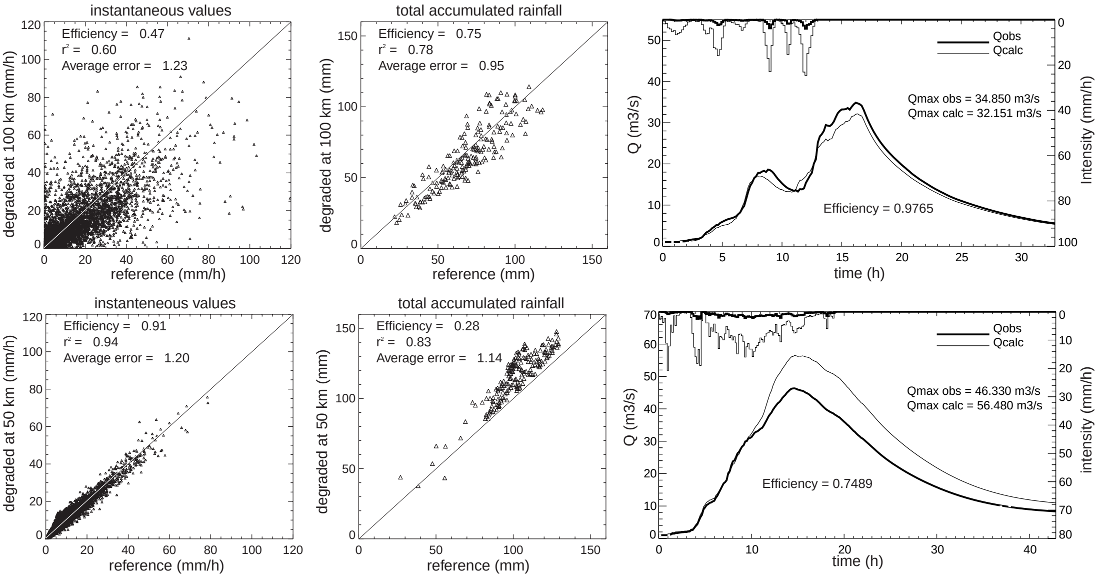

Figure 2. Result for the two analyzed events. Comparison of reference and degraded values for the 'instantaneous' (values at each field) and the total rainfall accumulated values. Right hand graph shows the resulting runoff for the two fields (Qobs for the reference field , and Qcalc for the calculated at certain distance form the radar).

Figure 2 (second row) shows the results for a second event, basically stratiform. In this example the degraded field have been calculated at 50 km from the radar (again the Marshall-Palmer Z-R relation ship is used to calculate the rainfall intensities). Notice the small disagreement between degraded and reference values in the comparison of 'instantaneous' data, clearly favored by the proximity of the degraded field from the radar.

Now the total accumulation comparison shows the general overestimation due to the bright band influence (in this event located at 2 km height). Nevertheless, the bright band influence is still more evident in the comparison of the runoffs (with an overestimation of the reference peak flow of 20%).

4. Assessment of different procedures of correction

The next step is to analyze the hydrological effect of different corrections applied to the 'degraded' fields. In this sense we have studied the effect of considering a double Z-R relationship (for convective and stratiform rain) and also the correction of the VPR. Regarding the analyses of the influence of a double Z-R relation we have applied the following procedure: first the algorithm of [Steiner et al., 1995] is applied to identify the convective regions. Next, the algorithm proposed by [Sánchez-Diezma et al., 2000] is applied in order to refine the identified convective areas in which the bright band has been identified. Finally a double Z-R relation is applied for each type or rain. In order to provide a general result we have used for convective rain the actual Z-R relation used by NEXRAD for this type of precipitation ($Z=300R^{1.4}$). The stratiform $Z=200R^{1.6}$ Marshall-Palmer relation has been used for the rest of rainfall field. The influence of considering a double Z-R relationship is then established by applying a double Z-R relation to the reference field, and comparing this field with the degraded one, transformed into rain through a single (Marshall-Palmer) or a double Z-R relation.

Figure 3 (first row) shows an example of this analysis. The left hand graph compares the total accumulated rainfall of the reference field showed in the first row of Figure 2, with the degraded field (calculated at 50 km from the radar) when using a single Z-R relation. The result exhibits a significant underestimation of the highest accumulations, although the average error is not large. At the right hand the discharges associated to these two fields are compared, showing a noticeable underestimation of the peak flow (nearly a 20%).

Figure 3 (second row) depicts the same comparisons but when a double Z-R relation is also applied to the degraded field. Notice the good agreement between the two variables(rainfall and hydrographs), which is reasonable since the convective regions in the reference and degraded fields are very similar. These results indicates the relevant importance of considering a double Z-R relation in convective events.

Moreover they suggest that the influence of the variation of the Z-R relations could be more pronounced in terms of runoffs (since the hydrological response of a basin could be more sensitive to the highest intensities) than in terms of the total accumulated rainfall (where the error in the higher intensities could be attenuated by the lower intensities, that are more frequently registered).

Concerning the hydrological analysis of the correction of the VPR we have applied a simple methodology of correction based in the method proposed by [*Koistinen*, 1991]. This method provides a representative VPR (by means of the data registered close to the radar) that afterwards is used to extrapolate the radar measurements to the ground. We have center our analysis in the influence of the spatial variability of the VPR on the performance of that correction (basically due to the different VPR shapes in convective and stratiform rain with presence of bright band). The correction is then applied considering two possible approaches:

a) A general VPR is determined without considering its spatial variability, and the correction is applied to the whole degraded field.

b) From regions affected by the bright band a representative VPR, and the VPR correction is applied only over these regions in the degraded field.

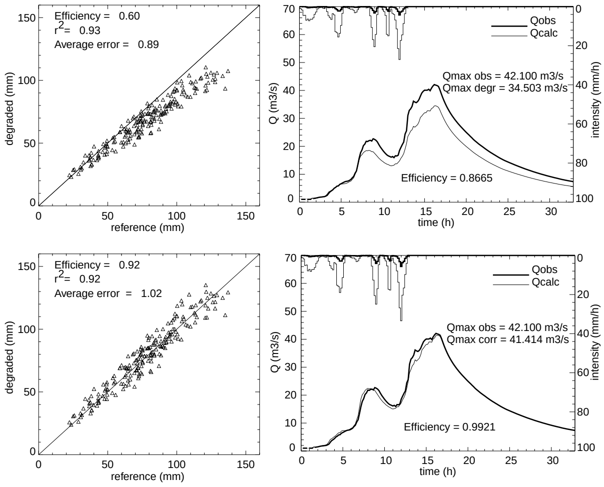

Figure 3. Influence of considering a double Z-R relationship. First row: comparison of reference (Qobs, with double Z-R) and degraded at 100 km from the radar (Qcalc) when using a single Z-R relation. Second row: as before but using a double Z-R in the degraded field.

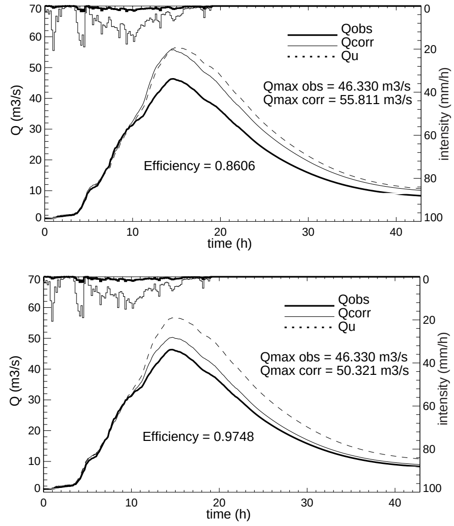

Figure 4. Influence of the VPR correction. Above: when the representative VPR is determined without considering its spatial variability, and the correction is applied to the whole degraded field. Below: the representative VPR is determined from regions affected by the bright band and the VPR correction is applied only over these regions in the degraded field. Qu, dashed, represents the uncorrected discharge at the basin outlet.

Figure 4 shows an example that compares the discharges for the two VPR correction approaches. In this example we use the reference field presented in Figure 2 second row, and the filed observed at 50 km from the radar. The Figure shows the discharge of the reference field, the one resulting when no VPR correction is applied (in dashed line) and the ones corresponding with the PVR corrections.

Notice that the discharge corresponding to a general VPR hardly reduces the overestimation due to the bright band. Besides, when the spatial variability of the VPR is considered, and only the areas affected by the bright band are corrected, the differences between the outflows are less significant. As the first approach considers all the information close to the radar, the VPR is smoothed at the height of the bright band, due to the mixture of profiles with or without bright band enhancement. Thus the extrapolation is not effective in areas contaminated by the bright band. As this latter is the principal responsible of the discharge overestimation the correction is not satisfactory.

5. Conclusions

The present simulation based work has allowed us to observe the importance of the errors with the distance from the radar, most of them induced by the variation of the reflectivity with height. Regarding the hydrological effect of these errors, we have observed that the bright band contamination gives rise to a expectable overestimation of the outflows. Besides, in the convective events, an important part of the over-underestimation due to the VPR is filtered out by the hydrological model, so that the reference and degraded discharges could be very similar. This result can be due to both, the fact that the analyzed basin has rural characteristics (which can reduce its sensitivity to the rainfall variability) or the difficulties of the hydrological model to reproduce the effects of this variability. it would be necessary to analyze which would be the results over urban basins, in general more sensitive to rainfall variability and with faster response time.

Regarding the correction of some radar errors we have studied the influence of the variation of the Z-R as a function of the type of rain. We have found that the effect of this error could be more important in terms of runoffs than in terms of the total accumulated rainfall. The cause could be the higher sensitivity of the hydrological model to the large intensities. Finally we have analyzed the hydrological effect of the VPR correction. The study has shown that this correction is more effective when it considers the spatial variability of the VPR . In our study the best results were obtained when this correction was applied only to those areas affected by the bright band (where the correction is more necessary).

Further research should be done in order to repeat the analysis in a wider type of rainfall situations and considering the simulation of another type of radar errors (as those due to the orography or the attenuation).

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7. References

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