Reconstruction of radar reflectivity in clutter areas

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Introduction

The production of Radar Quantitative Precipitation Estimates (QPE) requires processing the observations to ensure their quality and its conversion into the variable of interest (e.g., precipitation rates).

Some of the steps involve the reconstruction of the meteorological signal in areas where the signal is lost (e.g. due to total beam blockage or severe path attenuation by heavy rain) or strongly contaminated, for instance, in areas affected by ground or sea clutter. For uncorrected moment data, the reconstruction needs (1) the identification of clutter-affected areas, and (2) the reconstruction of the meteorological signal.

Here, an alternative reconstruction method is proposed using the space and time structure of the field in the reconstruction.

The methodology

The reconstruction is done by linear combination of non-contaminated values: $\hat{Z}(\mathbf{x}) = \sum_{i=1}^{n} \lambda_i Z(\mathbf{x}_i)$.

Under the ordinary kriging formulation, the reconstruction weights are the solution of the linear equation system:

$$\begin{bmatrix} \gamma_{11} & \cdots & \gamma_{1n} & 1 \\ \vdots & \ddots & \vdots & \vdots \\ \gamma_{n1} & \cdots & \gamma_{nn} & 1 \\ 1 & \cdots & 1 & 0 \end{bmatrix} \begin{bmatrix} \lambda_1 \\ \vdots \\ \lambda_n \\ \xi \end{bmatrix} = \begin{bmatrix} \gamma_1 \\ \vdots \\ \gamma_n \\ 1 \end{bmatrix}$$

The semivariogram

It measures the field variability and has been estimated locally around the areas to be reconstructed.

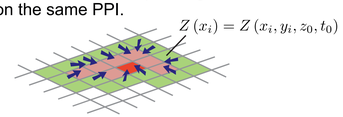
$$\begin{aligned} \gamma_{ij} &= \gamma(\Delta_{ij}) \\ &= \tfrac{1}{2} Var[Z(\mathbf{x}) - Z(\mathbf{x}+\Delta_{ij})] \\ &\approx \frac{1}{2N_{ij}} \sum_{i=1}^{N_{ij}} [Z(\mathbf{x}_k) - Z(\mathbf{x}_k+\Delta_{ij})]^2 \end{aligned}$$

Implementation aspects

The developed methodology is based on combining 3 reconstruction methods:

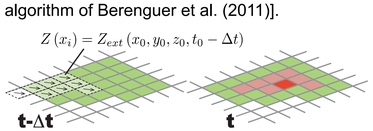
Horizontal interpolation

The signal in the contaminated area is reconstructed by interpolating the clutter-free bins on the same PPI.



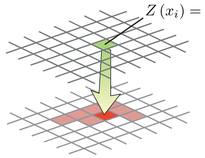
Time extrapolation

The contaminated bin is replaced with the non-contaminated measurement from the previous scan [considering the motion of the precipitation field as estimated with the tracking algorithm of Berenguer et al. (2011)].



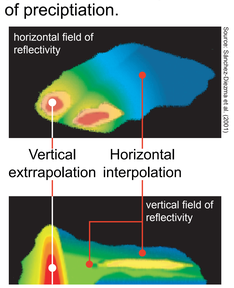
Vertical extrapolation

The contaminated bins are replaced with the value from the closest non-contaminated observation in the vertical.



Reference technique (Sánchez-Diezma et al., 2001)

Sánchez-Diezma et al. (2001) proposed to use either horizontal interpolation or vertical extrapolation based on a pre-classification of the type of precipitation.



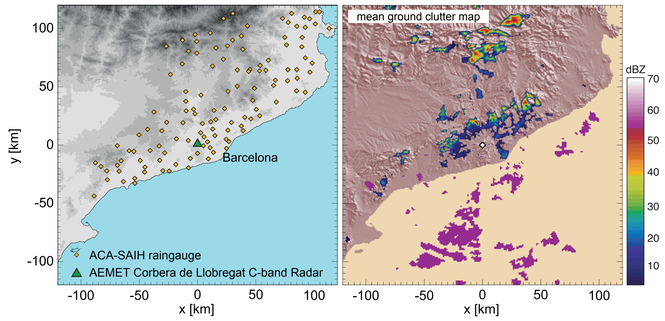
Analyzed configurations

HOR: horizontal interpolation.
VER: Vertical extrapolation.
TIM: Time extrapolation.
HV: Horizontal interp. + Vertical extrapolation.
HT: Horizontal interp. + time extrapolation.

Study area

The algorithm has been implemented as a part of the chain of correction algorithms applied to the measurements of the Corbera de Llobregat C-band radar (5.4 cm) of the Spanish Agency of Meteorology.

In this study, raw radar have been process to mitigate the effect of beam blockage using the algorithm of Delrieu et al. (1995). Areas affected by clutter have been identified with the fuzzy logic algorithm of Berenguer et al. (2006).



125 rain gauges of the Catalan Water Agency have been used in the validation of the methodology.

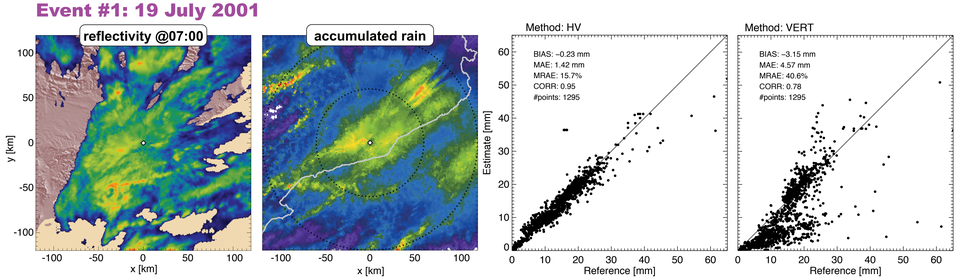
Results

Reconstruction

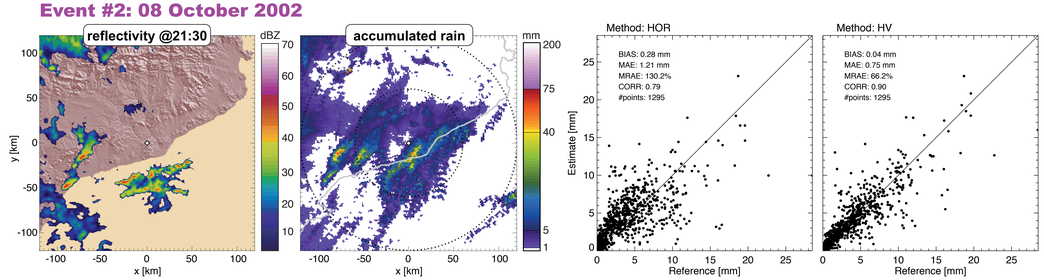
The weather signal is reconstructed over the mean clutter pattern but rotated to a clutter-free area. The original measurements are used as reference.

	19 July 2001						08 October 2002					
	HOR	VERT	TIM	HV	HT	SD2001	HOR	VERT	TIM	HV	HT	SD2001
Bias [mm]	0.03	-3.15	0.19	-0.23	0.03	-0.09	0.28	-0.27	-0.26	0.04	0.28	-0.05
MAE [mm]	1.39	4.57	1.62	1.42	1.46	1.33	1.21	0.79	1.43	0.75	1.19	0.96
MRAE [%]	17.2	40.6	26.1	15.7	17.2	15.5	130.2	51,5	72.9	66.2	127.9	67.8
corr	0.96	0.78	0.90	0.95	0.96	0.96	0.79	0.91	0.61	0.90	0.79	0.84

Event #1: 19 July 2001



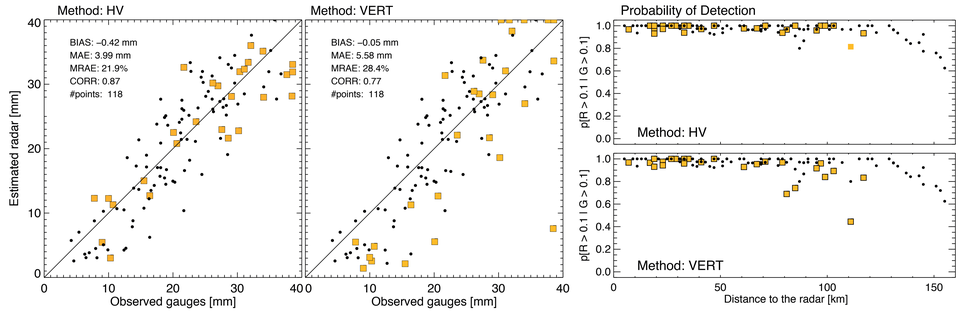
Event #2: 08 October 2002



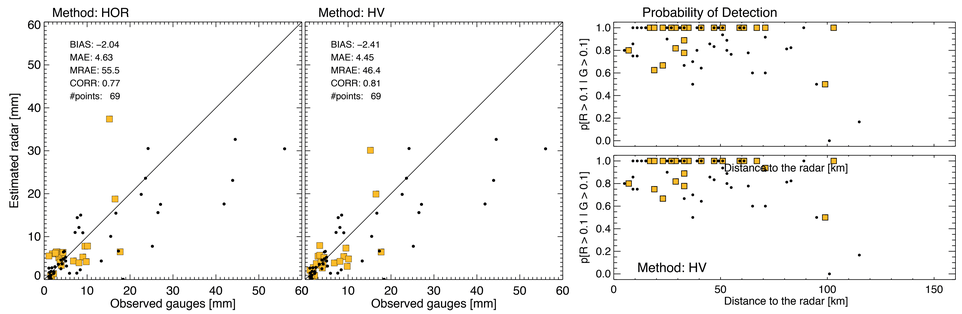
G-R comparison

Comparison of radar rainfall estimates with collocated raingauges. The orange squares indicate the raingauges located in areas affected by ground clutter in mean propagation conditions.

Event #1: 19 July 2001



Event #2: 08 October 2002



Conclusions

- We have developed a method for the reconstruction of radar observations using non-contaminated observations in the horizontal, in the vertical and/or from the previous time step.
- The method adapts to the weather situation through the use of the semi-variogram, which is estimated locally.
- The method based on the use of 3-D observations (HV) is the one that showed the best performance in two significantly different situations. Contrarily, HOR showed the worst performance in the convective situation, and VER is not useful in widespread events.
- On the other hand, the methods that use information from the previous times steps (HT and TIM) showed an intermediate performance for both cases, and past information did not seem to have a major contribution to the reconstruction.

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