117

REAL TIME SPATIALIZED BIAS CORRECTION OF THE FRENCH OPERATIONAL 5'-1KM² QUANTITATIVE PRECIPITATION ESTIMATION PRODUCTS USING PAST RADAR AND RAIN GAUGE HOURLY ACCUMULATIONS

Dominique Faure*, Valérie Vogt, Pierre Tabary
Météo-France, Toulouse, France
Emmanuel Moreau
Novimet, Vélizy, France

1. INTRODUCTION

The Weather Radar Centre of Météo-France is responsible for operating the French weather radar network and producing in real time the best 5'-1km² national Quantitative Precipitation Estimation (QPE). Every 5 minutes, all PPIs of all operational radars (26 in the metropolitan France area in 2013) are processed by a complex, multi-module QPE treatment chain (including ground-clutter identification and elimination, partial beam blocking correction, vertical profile of reflectivity correction, synchronization using an advection field, correction for precipitation-induced attenuation, generation of a QPE quality map, …) and mosaicked (using quality indices for each pixel). The requirement is to disseminate the national QPE mosaic before 2 minutes after each 5 minutes cycle of scanning.

Since 2006 the QPE processing includes an adjustment of the real-time 5' single-radar QPE using past hourly radar and rain gauge precipitation estimations. This adjustment is realized independently for each radar, and uniform for all the radar coverage area. The adjustment factor (the mean field bias) is estimated using a filtering technique from the measurements made over the past hours (up to 40h) by all rain gauges located up to 80 km from the radar, and the corresponding radar estimations. In the filtering technique, more recent and larger hourly depth of rainfall has a greater weight in the adjustment factor estimation. The main assumptions of the method are 1) the persistence of the calibration factor from one hour to the next one, and 2) the uniformity of the correction across the entire radar coverage area. Several parameters have been defined in order to try to respect these hypotheses, limiting variations in time of the calibration factors, and forcing its value to a mean monthly fallback value when the rain is too weak for a reliable estimation.

The return of experience shows that this uniform adjustment for all the radar coverage area is not well suitable for the impact of spatialized sources of errors imperfectly corrected by the treatment chain. For the next version of its data processing, Météo-France has designed a new spatialized adjustment factor. This adjustment varies in time and space, and is still estimated every hour independently for each radar before mosaicking, using past hourly single-radar QPE and rain gauges measurements.

* *Corresponding author address:* Dominique Faure, Météo-France DSO/CMR/DEP, Toulouse France;
Email: Dominique.faure@meteo.fr

2. METHOD

The new method estimates an adjustment factor value for each pixel of a single-radar QPE map, and is based on an iterative three-step downscaling of the adjustment procedure centered on each pixel. This downscaling use three decreasing fixed sizes *A* of local square shaped estimation areas (*A* = 128x128 km², 64x64 km² then 32x32 km²). This downscaling allows, when it's possible, to progressively adjust locally the adjustment factor value by taking into account results calculated for the larger areas (fig. 1). This new method still includes a temporal filtering as well as a forcing to a fallback value when the estimation is not possible. The temporal filter memory decreases with the size of the local area considered, reflecting the correlation between the spatial and temporal variability of the adjustment factors. The resulting spatialized adjustment factor is independent for each radar, with the following characteristics required:

- an estimated hourly value for each pixel, variable in time, with a spatial and temporal continuity
- a mean default value estimated each month for each radar with human expertise, applied in case of dry weather
- a relatively smooth behavior for weak rainy activity, close to the default value
- a good reactivity in case of heavy rain, but with a limited fluctuation of the factor values in time and space
- an automatic smoothly fall back to the default value after the end of the rain.

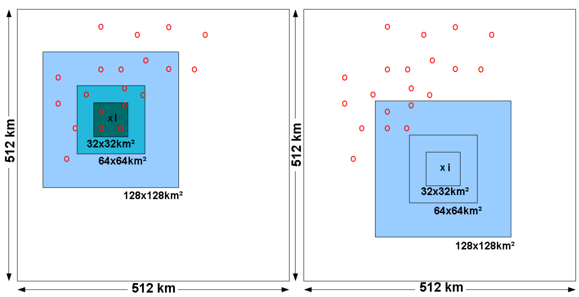

Figure 1: Determination of the smallest local area A usable for each pixel i, in function of the number of rain gauge values available (red circles):
- Left, smallest local area = 32x32km²
- Right, smallest local area = 128x128km²
Radar image size = 512x512km² ; Pixel size = 1x1km²

This adjustment factor estimated each hour is used during the next hour to adjust each 5 minutes QPE radar product. At the hour H, for each pixel *i*, the adjustment factor F is estimated iteratively for the three sizes of A area as:

$$F_A^H(i) = \frac{\sum_{t=H-\Delta tA}^{H} \omega_{t,A} P_{t,A} + C_A}{\sum_{t=H-\Delta tA}^{H} \omega_{t,A} R_{t,A} + \frac{C_A}{F_{Default}(i)}} \quad (1)$$

With, depending on the size of local area A:

- ΔtA is the dimension (in hour) of the temporal summation for the size of the local area considered ;
- $\omega_{t,A} = 2^{\frac{-t}{TA}}$ is a decreasing time-dependant weighting suited for each size of local area ;
- $P_{t,A} = \sum_{j=1}^{n_{t,A}} P_{t,j}$ and $R_{t,A} = \sum_{j=1}^{n_{t,A}} R_{t,j}$ are the local sum of rainfall values for rain gauges and corresponding radar pixels, with $n_{t,A}$ the number of available j pairs of values in the local area A under the following conditions:

$$P_{t,j} \geq 0.6mm \ ; \ R_{t,j} \geq 0mm \ ;$$

$$\frac{1}{20} < \frac{P_{t,j}}{R_{t,j}} < 20 \text{ ; if } n_{t,A} < nseuil \text{ , } n_{t,A} = 0 \text{ ;}$$

- C_A is a constant minimum depth of rainfall fixed for a size of local area, to minimize the factor fluctuation in case of weak rainy activity ;
- $F_{Default}(i)$ is the default value of the adjustment factor for the pixel i if the estimation can't be made for the size of the local area (i.e. $n_{t,A} = 0$ for all the t hours). $F_{Default}(i)$ is the adjustment factor estimated for the immediately larger local area ($F_{Default}(i) = F_{A-1}^H(i)$), except for the largest area for which $F_{Default}(i)$ is the monthly default value unique for all the pixels.

Finally, the adjustment factor used for all the radar estimates the next hour is $F_{Amin}^H(i)$, $Amin$ being the size of the smallest local area for which the estimation is made for this pixel i.

3. BEST SET OF PARAMETERS DETERMINATION

The determination of the best set of parameters for the method has been realized in two steeps.

First, several variants of the new algorithm, and several sets of parameters, have been evaluated in a large statistical analysis using a complete set of two years of data from 24 radars and more than 1100 rain gauges. A set of criterions has been used to evaluate the results by comparison with rain gauges measurements. This evaluation has been realized for three classes of hourly depth of rainfall, and three classes of radar pixels quality corresponding roughly at three ranges of distance from the radar, but also at important local impacts of sources of errors (mask of the radar beam, use of measurement at high altitude). The results show that the spatialized adjustment provides globally better accordance between radar QPE and rain gauges measurements than the uniform one, particularly for medium and low radar pixel quality (mainly range above 100km).

Secondly, 10 rain events representative of very different type of rainfall and situation have been detailed. For each case study, only measurements of a single radar have been used. Figure 2 presents the mean result for medium radar pixels quality and the best set of parameters finally selected for the spatialized adjustment (presented in table 1). The four criterions are Nash Criterion, correlation coefficient, mean relative bias, and Root-Mean-Square Error.

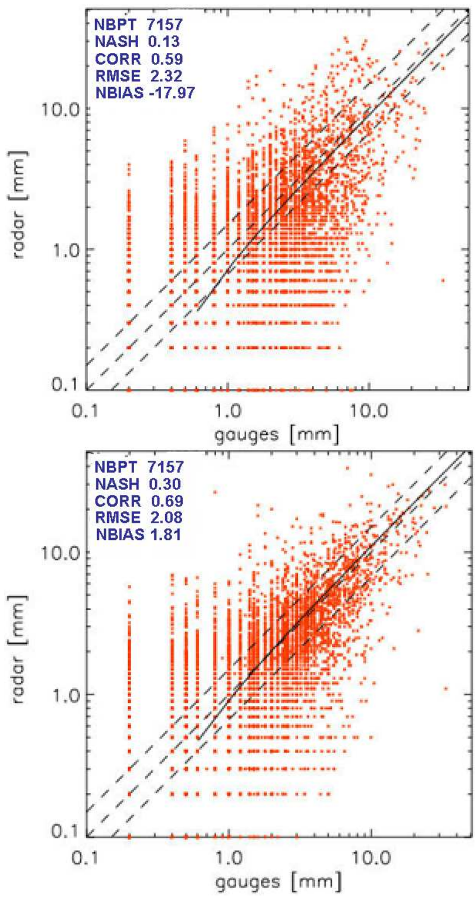

Figure 2: Comparison between the evaluation of the radar QPE for the current uniform adjustment (top) and the new spatialized one (down), for 10 rain events and medium radar pixels quality (mainly 100-200km range from the radar). Parameters used for the spatialized adjustment are given in Table 1.
The comparison with rain gauges measurements results in better validation criterions values for the new method (NBPT = number of couple of hourly values).

	32x32km²	64x64km²	128x128km²
TA	1h	2h	4h
C_A	2mm	5mm	10mm
ΔtA	3h	6h	12h
$F_{Default}(i)$	$F^{H}_{64*64km^2}(i)$	$F^{H}_{128*128km^2}(i)$	monthly default value
$nseuil$	3	3	3

Table 1: The final set of parameters selected.

4. CASE STUDY: THE DRAGUIGNAN RAIN EVENT

The 15 June 2010 an extreme rain event occurred in the Var region, southeast France. The exceptional depth of rainfall (up to 400 mm) on a large area caused important flooding particularly in the town of Draguignan, resulting in 26 casualties.

Figure 3 presents, for the *Collobrières* radar, the evolution of the spatialized adjustment factor values in four places (cities of Avignon, Cannes, Marseille and Toulon), and compares this evolution with the uniform adjustment factor values. The spatialization algorithm is given in equation (1), and the set of parameters in table 1. This spatialization allows to adjust the correction to the spatial evolution of the radar/rain gauges ratios, which appears to be very important between the four locations.

Figure 4 shows the impact of the spatialization on the radar QPE for a single hour. By comparison to the uniform adjustment factor value for this hour (1.85), the map of the spatialized adjustment factor values shows an increase of the adjustment value near Toulon and at long distance from the radar (yellow to red colors), and a decrease of the adjustment value near Avignon (blue colors). The *Collobrières* radar being located just at the south-east of the more intense rain cell, the decreasing in the west (near Avignon) could be due to attenuation of the radar beam by rainfall. The spatialized adjustment factor map seems consistent with other information, and the number of good accordance between radar and rain gauges (square pictograms) increase of +53% by comparison with the result for the uniform adjustment.

5. CONCLUSION

The final adjustment of radar QPE by rain gauges measurements is not a new topic, but the implementation in real time for operational products is still a not easy task, particularly at the scale of a country. Compromises must be done, and in order to diffuse resulting products in time it is generally necessary to correct future estimations with past observations, which is a main difficulty as we know that radar QPE errors can be highly localized in space, and greatly variable in time.

The large statistical analysis realized, and the detailed analysis of 10 case studies, show that the spatialisation of the adjustment by hourly rain gauges measurements proposed in this paper increase the mean accuracy of the real-time 5 minute single-radar QPE. The set of parameters finally selected seems quite well guarantee the respect of the initial requirements.

This new spatialized adjustment will be used in the next version of the operational adjustment of the French national radar QPE.

6. ACKNOWLEDGMENTS

The study was directed by Valérie Vogt and Pierre Tabary, and the data treatment realized by Novimet.

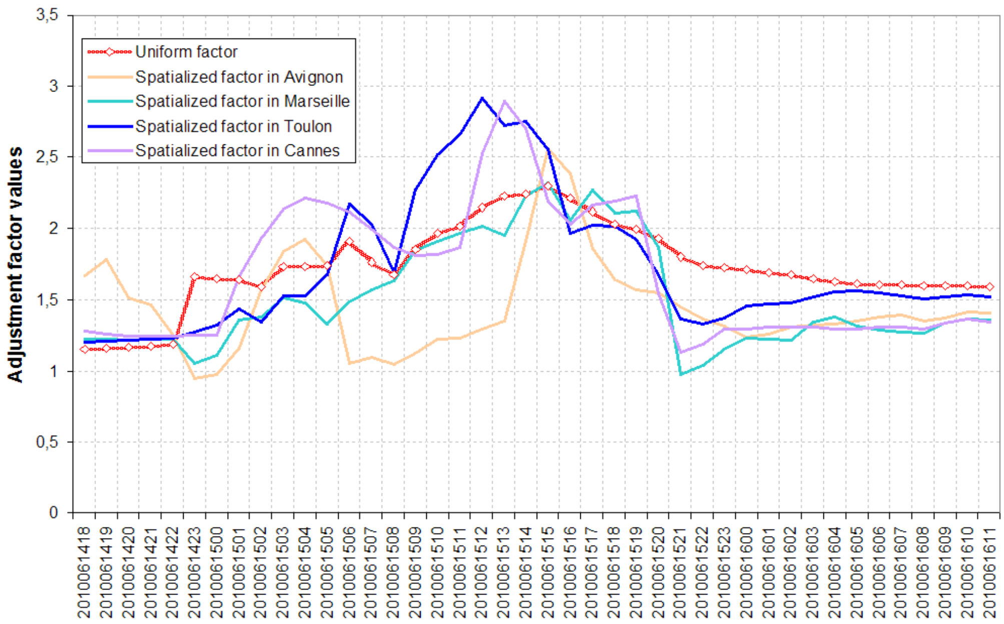

Figure 3: Comparison of the behavior of the uniform adjustment factor and the spatialized one for different locations, from the 14 June 2013 18hTU to the 16 June 2013 11hTU (Collobrières radar).

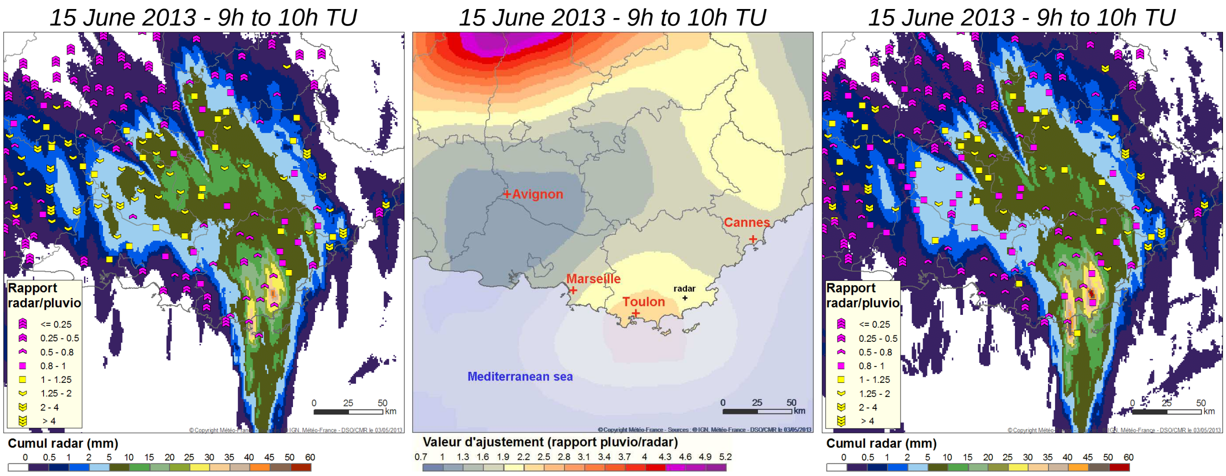

Figure 4: Left, the hourly amount of rain for the Collobrières radar QPE adjusted with the uniform hourly adjustment factor (the value is 1.85 for this hour). Right, the hourly radar QPE adjusted with the spatialized adjustment. Middle, the values of the spatialized adjustment factors used. Pictograms indicate radar/rain gauge ratios.