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QUALITY ANALYSIS OF THE 2016 QUANTITATIVE PRECIPITATION ESTIMATES IN THE FRENCH ALPS

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1. CONTEXT

In less than 40 000km², the French Alps region comprises very various sub-regions from the Mediterranean Sea shore to the top of the Alps (4810 m), including several mountain massifs with summits close to or above 4000 m. In this region, the quality of radar Quantitative Precipitation Estimation (QPE) can be locally limited due to radar beam blockages, the distance to the radars, and the altitudes of measurement close to levels affected by various error-inducing phenomena. In recent years, Météo-France has made important investments to improve this quality, both in the data processing and the installation of new radars (Tabary et al., 2013), and by the use of products of other radar operators. In December 2015, the French national QPE mosaic (1km-5min resolution) started assimilating several new local radar QPEs, estimated from the Swiss instantaneous rainfall rate mosaic (Faure et al., 2015), and from measurements of 3 new polarimetric X-band radars installed by Météo-France at altitudes 1740 m, 1770 m, and 1910 m (Kabeche et al., 2011), and recently qualified for operational use.

This paper concerns a study realised at the beginning of 2017, to evaluate the impact of these new assimilations, and to characterise the quality of the current radar QPE mosaic in the north part of the French Alps at the beginning of 2017, in order to identify the needs for new improvements which could necessitate future investments or complementary solutions.

2. METHODOLOGY

In this region (figure1), daily measurements of around 450 rain-gauges, and hourly measurements for more than 220 of them, have been compared to corresponding values of the operational radar QPE mosaic for the entire year 2016. The mosaic values used was the real time production, without any addition or correction (*i.e.* the actual delivered QPE). One can note that the maximal altitude of the rain-gauges in this study was 2100 m. A number of criteria have been estimated, both spatially integrated and estimated punctually for each rain-gauge station. The results have been analysed at the scale of the entire mountain chain, as for each mountain massif or large valley of major interest (high population, industry, tourism, natural hazards vulnerability).

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The section 3 presents some of this analysis results which are enlightening about the spatial variability of the radar QPE quality in the northern French Alps in 2016, and the improvement of the radar QPE quality from 2015 to 2016.

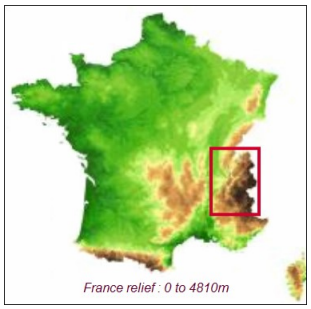

Figure 1: Study area location

3. MAIN RESULTS

3.1 Spatial variability of the radar QPE quality

Figures 2 and 3 show spatially integrated maps for two common annual criteria, estimated routinely by Météo-France each year, between the operational radar QPEs and rain-gauges measurements. In these figures, the green dashed lines represent limits of the French departments. The brown thin lines delineate the Alpine massifs as defined in the SAFRAN meteorological analysis system for surface variables, which is based on climatically homogeneous zones (Durand, 1993). The violet crosses represent the radar locations.

These maps are good representations of the great variability of the radar QPE quality in the north part of the French Alps in 2016, and allow to compare the radar QPE performance from one year to another. The regional tendency on these pictures is well representative of the punctual results estimated for each stations:

- The best radar QPE quality is observed for the external massifs (Chablais, Aravis, Bauges, Chartreuse, Vercors), and for the perialpine areas, particularly from Geneva to Valence in France.
- The medium quality concerns numerous internal massifs, for which the radar QPE are, on average, underestimated compared to rain-gauges measurements. Some massifs also include small and well delineated areas affected by important underestimations owing to the treatment of ground clutter. This ground clutter processing uses data acquired at more elevated angles of measurement (so at highest

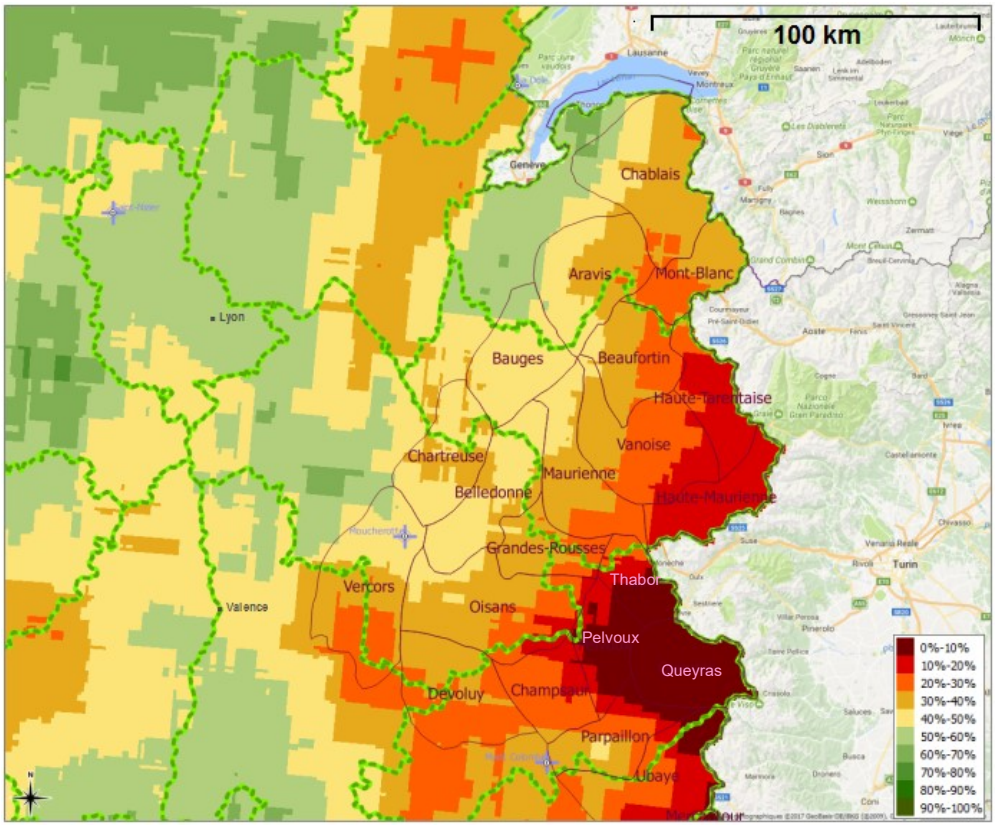

Figure 2: 2016 annual score map estimated for daily precipitation ≥10mm: percent of daily radar/rain-gauge ratios values included into the interval [0.8 ;1.25]. Green to red and brown = best to lowest quality. Thin brown lines: massifs limits.

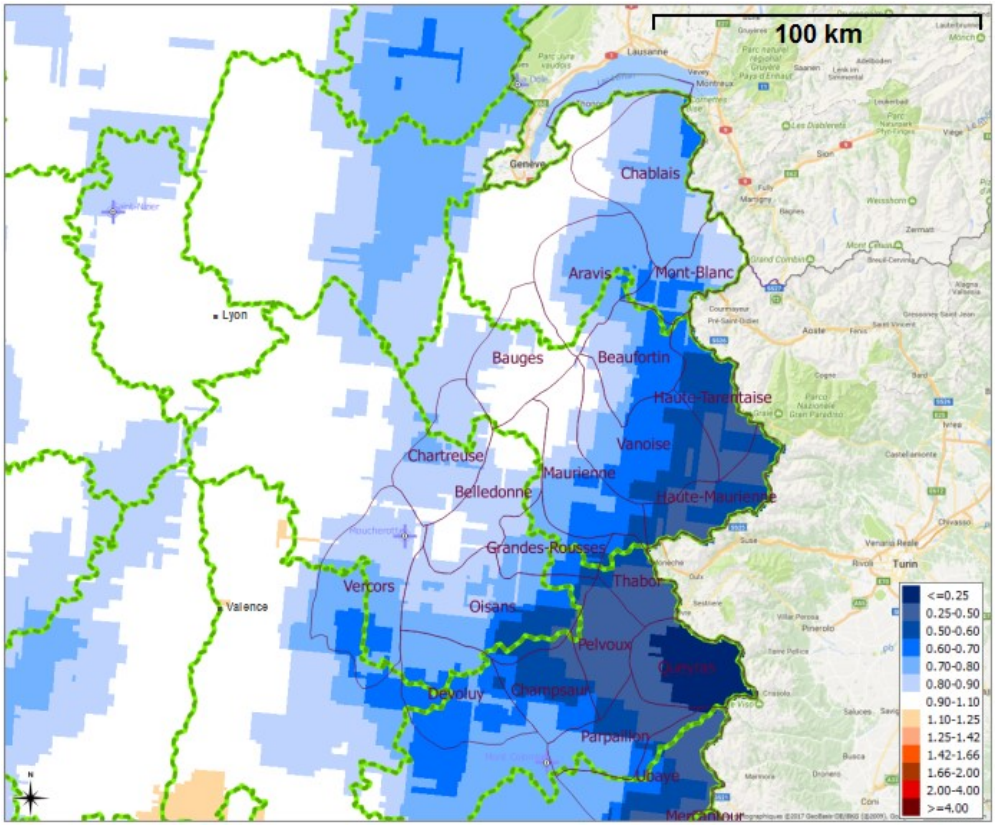

Figure 3: 2016 annual score map estimated for daily precipitation ≥10mm: median value of the daily radar/rain-gauge ratios. Blue = median < 1.0 White to dark blue = best to lowest quality. In brown: massifs limits.

altitude), and affected by under-detection of the precipitations. The correction of this under-detection appears to be not efficient in this high mountainous context.

- In the most internal massifs or valleys (Queyras, Thabor, Ecrins-Pelvoux, Haute-Maurienne, Haute-Tarentaise, part of Vanoise), the radar QPE quality is weak, because of important radar beam blocking, the great distance to the radars, and in part the high altitude of the ground (see section 3.3).

3.2 Quality improvement from 2015 to 2016

Figures 4 and 5 show integrated maps representing the difference between the maps of criteria presented figures 2 and 3 for the year 2016, and the same maps estimated for 2015. In figure 4, the locations of the Swiss radars are indicated by black pictograms. The locations of the Alpine X-band radars of Météo-France are indicated by blue pictograms.

For a very large part of this Alps region, the percent of daily radar/rain-gauges ratios values included into the interval [0.8 ; 1.25] increases significantly in 2016, from +4% to more than +20% (figure 4). One can note no improvement for the most inner massifs, and even a small degradation (in green) in the East of the Savoie region (Haute-Maurienne, Haute-Tarentaise, Vanoise). The cause of this degradation is identified and will be corrected.

For the median values of the daily radar/rain-gauges ratios (figure 5), the improvement shows quite the same regional pattern.

The 2016 results also have been compared to the maps of the mean criteria values estimated between 2011 to 2015, rather than with the criteria values for the only year 2015. The same regional pattern is observed, but with a little less contrast. The reason is a very constant radar QPE quality in the north French Alps region from 2011 to 2015.

So, the year 2016 is really representative of a great improvement of the radar QPE quality in the northern French Alps for the all mountain chain, excepted the most internal massifs. This enhancement is due:

- For the area spreading from Chablais to Vercors, to the assimilation of the Swiss QPEs, and of the local QPEs of the new polarimetric X-band radar named Moucherotte, installed in the north-east border of the Vercors massif (just above the Grenoble conurbation).
- For the area from Vercors to Ubaye, to the assimilation of local QPEs from the Moucherotte radar and from the new polarimetric X-band radar named Colombis, installed at the limit with the Southern French Alps.

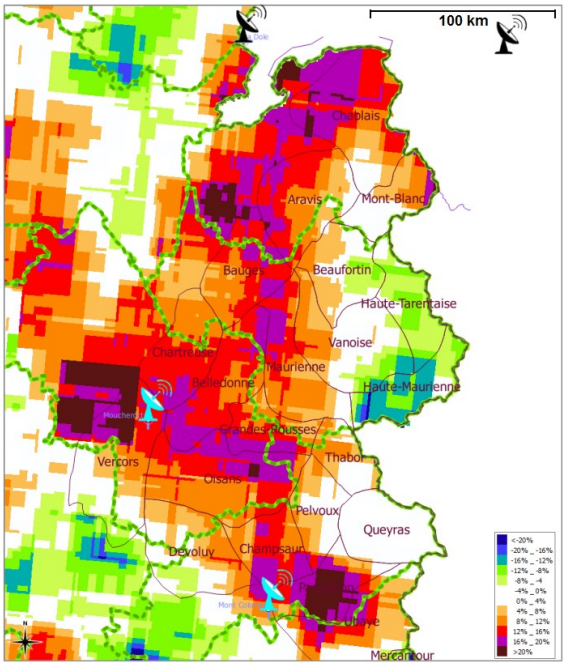

Figure 4: Improvement (orange to red and brown) between 2015 and 2016 of the percent of daily radar/rain-gauge ratios included into the interval [0.8 ; 1.25]. (for daily precipitation ≥10mm)

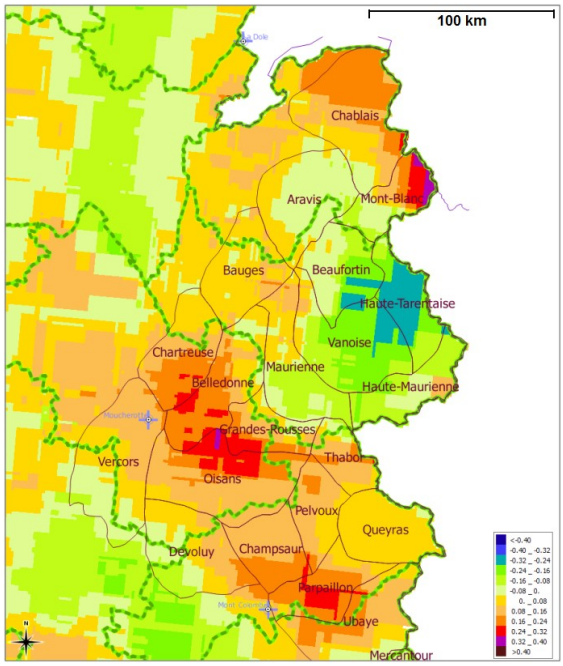

Figure 5: Improvement (orange to red), between 2015 and 2016, of the median value of the daily radar/rain-gauge ratios (i.e. closer to 1.0). (for daily precipitation ≥10mm)

3.3 Trend of the QPE's bias with altitude

The punctual comparisons between rain-gauges measurements and the corresponding radar QPE values show a general trend, with a radar QPE over-estimation for rain-gauges at low altitude, and an increasing underestimation for rain-gauges at high altitudes.

Figure 6 shows that the ratio values between the annual precipitation accumulation for each rain-

gauge station and the corresponding radar estimates, are significantly correlated with the altitude of the ground stations (correlation coefficient *R* equal 0.733). If only the more significant precipitation events are selected (*i.e.* daily rain-gauge values above 10 mm), the result (and the picture) is quite the same (with R = 0.729).

This trend can also be observed locally at the scale of each large valley and mountain massif, as for example for the Grenoble area, the greatest conurbation of the French Alps (figure 7).

This trend has been linked to altitudinal gradients of precipitation observed at ground level in the Alps in many studies, and not taken into account by the current radar data processing, which tends to estimate precipitations for a single reference level.

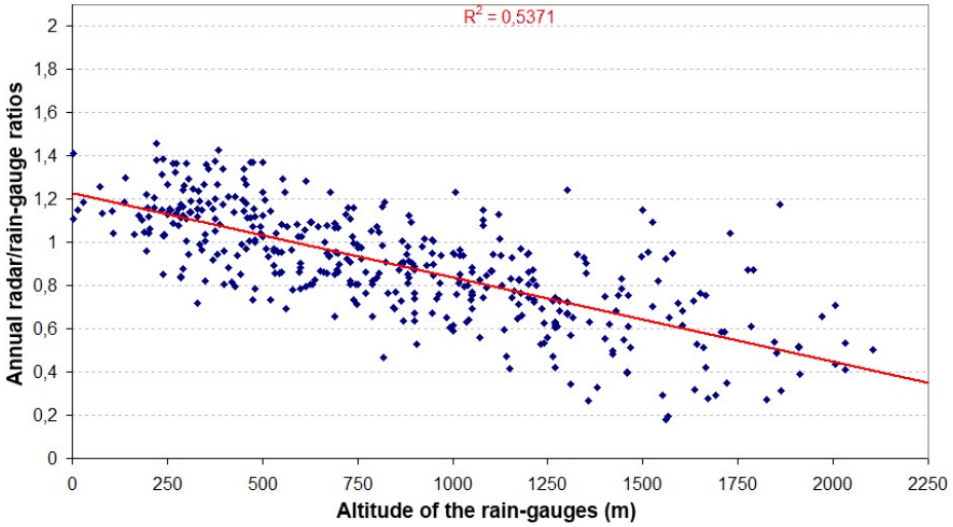

Figure 6: Mean annual radar/rain-gauge ratio values in function of the rain-gauges altitudes. For 430 daily rain-gauges (R² = square correlation coefficient). Year 2016.

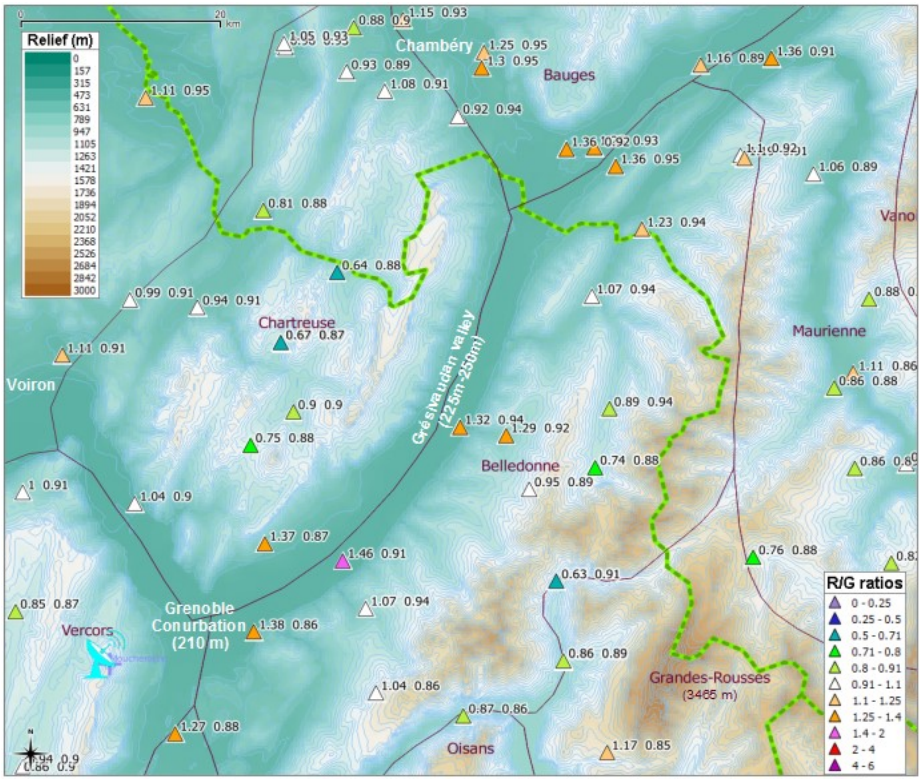

Figure 7: Criteria values in 2016 for each daily ground station over the Grenoble area. Numbers for each station: first, mean annual radar/rain-gauge ratio value (also used for pictogram color); then, correlation coefficient between radar and rain-gauge daily values.

4. DISCUSSION AND PERSPECTIVES

The quantitative precipitation estimation in high mountain areas is not an easy task, an from many years the French Alps region is characterised by a poor radar QPE quality, the lowest of the Mainland France territory. During the last years, Météo-France has installed and operated four polarimetric X-band radars in the Alps, at altitudes varying from 1740m to 2580m. Météo-France has also setting up bipartite agreements in order to use in real time products from other radar operators in this region (MeteoSwiss, Novimet).

The presented results show the important improvement of the radar QPE quality provided in northern French Alps by the Swiss radar products, and by two new X-band radars operated by Météo-France (Moucherotte and Colombis). These results help to validate the interest of the above-mentioned investments.

Two other X-band radars operated by Météo-France will contribute to improve the radar QPE in the south part of the study area, particularly for the inner Queyras massif: the Maurel radar, currently in operation but unfortunately off duty from January to October in 2016, and the Vars radar which would be qualified for operational use of its QPE products at the end of 2017. Since March 2017, the national radar QPE mosaic is also assimilating local QPEs provided by the private company Novimet, from its Alpine polarimetric X-band radar located at the top of the Mont Vial summit (1547m), in the south of the French Alps near the Mediterranean coast. So, new improvements are expected to be observed in 2017 in the southern French Alps thanks to these three radars.

The experience feedback has also shown that some of the current radar data processing algorithms used to provide the quantitative precipitation estimates, are closer to their limits in high mountain areas, and need to evolve. Several developments are under way, which should contribute to improve the radar QPE quality in the Alps region in the future.

Furthermore, Météo-France is also supporting research studies concerning the use of other data sources, or the use of opportunistic data, to complete the radar measurement and the ground measurement of precipitation when possible. These approaches could contribute to improve the quality of the QPE in the areas where it's difficult, or too expensive, to improve the radar coverage and the ground stations measurements.

5. ACKNOWLEDGEMENT

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