THE METEO-FRANCE SINGLE-RADAR AND COMPOSITE QPE OPERATIONAL PRODUCTS

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1 Introduction

In 2000, the French precipitation radar network consisted in 18 radars (fig. 1). Until recently, none of these were Doppler nor polarized, and an ambitious project, named PANTHERE, was launched in 2001 by Météo-France and the Ministère de l'Ecologie et du Développement Durable to upgrade the network. This project aims to fill some gaps in the network and to introduce "new technologies" : volumetric observation, Doppler and dual polarization (Parent du Chatelet et al., 2005).

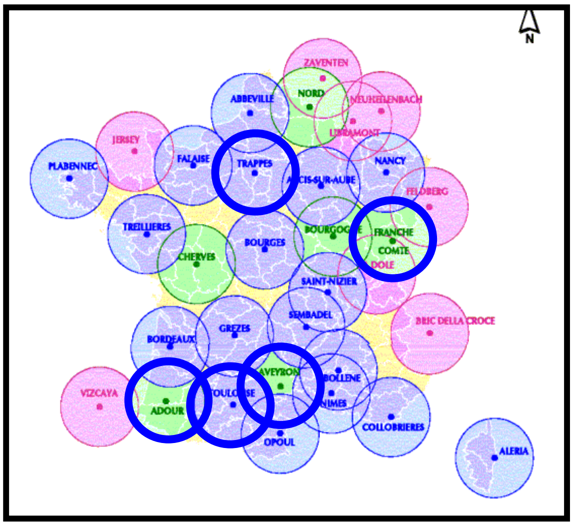

Fig. 1 : Map of the French precipitation radar network in 2006. The 6 new Panthere radars are in green, and the foreign radars are in pink. Each radar is surrounded by a 100 km radius circle. In a first step, the 5 radars surrounded by a thick blue circle will be equipped with dual-polarization.

Thanks to the impulse of the PANTHERE project, 6 new radars have been installed and 2 old radars (Trappes and Toulouse) are being replaced, the first of them, in Trappes, by a C band dual-polarized radar. After a one year experiment designed to test the improvement of products with the dual-polar technology, it was decided at the end of 2005 to transform 4 more radars to dual polar (see figure 1).

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During the same time, a "triple PRT" Doppler scheme was designed (Tabary et al., 2006) to measure radial wind speed up to 60 m/s with the radars and a numerical receiver has been developed to equip the old radars with Doppler. The entire network will be Doppler in 2008 and the radial velocities, as well as the reflectivities, will then be assimilated by the new numerical forecast model AROME (Caumont et al., 2006)..

Finally, a new quantitative precipitation product has been developed. This paper aims to describe the operational version of this product, which is now available for our users. After reminding the main characteristics of the individual radar product with its quality indexes, we give the main characteristics of the composite product, and finally describe a new radar-gage calibration method that we plan to use in operational in 2007.

II. The new individual radar QPE

The product is extensively describe in Tabary, 2005. It consists in 5 mn rainfall accumulations product built with the radar data available within the past 5'. Each pixel is associated with a dynamic quality index ranging from 0 to 100, which depends on the measurement conditions (ground echoes, shielding, altitude above ground level, ..).

<u>*Main features of the processing*</u>

Correction for partial beam blockage. The SURFILUM software (Delrieu et al, 1995), with a numerical terrain map, is used to compute the amount of beam blockage by the relief around the radar. But these maps generally don't take into account other small artificial obstacles such as trees, or towers. To do this, we complete the computations by a carefully examination of radar images accumulated over a long period, where the effect of such blockage is clearly visible. For each radar, we generate a static correction map with a factor for each pixel and each elevation angle.

Ground clutter. Ground echoes - and anomalous propagation - are dynamically detected by the pulse-to-pulse fluctuations of the reflectivity which is much larger for rain than for ground returns.

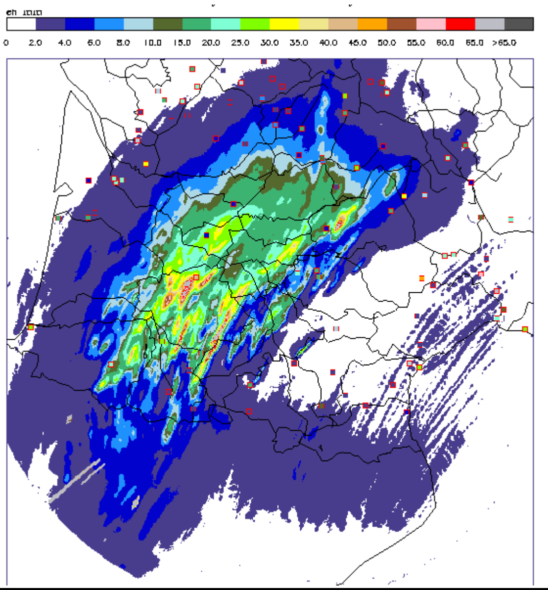

Fig. 2. Example of 12 hours accumulation of the Panthere QPE product for an individual radar. Toulouse radar, from 2006 June 19th 18h00 to June 20th 06h00.

VPR corrections. A VPR algorithm has been implemented. It is based on a conceptual model (Kitchen et al., 1996; Andrieu et al., 1995) of the reflectivity profile. The vertical profile is define by four parameters : freezing level height, bright band thickness, brightband peak, and decreasing rate above the bright band. Every 5 minutes, these parameters are adjusted to give the best fit with the radar data of the previous hour.

Advection correction. As the radar QPE is a combination of different PPIs with a 5 minute period, it is necessary to correct for advection. The advection field is obtained by maximizing the correlation between two successive images separated by 5 minutes. The PPIs are then synchronized at the beginning of the 5-minute period. Pixels for which data are missing, due to ground echo or strong blockage, are filled using the preceding 5-minute measurements extrapolated by the advection field. Through this process, for some pixels the data can originate several 5-minute periods before, and for each pixel we define what we call the "advection age". For instance, it is equal to 5 if the data is filled by a measurement made 5 minutes before (advected one time); it is equal to 10 if the data is filled by a measurement made 10 minutes before (advected two times).

Quality indexes. At the beginning of the process, the index is set to 100 (best quality) for each pixel and elevation. It is set to zero for ground clutter, and it decreases with increasing altitude above ground level, with beam blockage severity, and with the "advection-age", like :

$$\omega = 100 \exp(-\frac{h}{h_0}) \exp(-\frac{age}{T_0}) (1 - block) \qquad (1)$$

where h is the height above terrain, ho = 1000m, age is the advection-age, To=20', block is the beam blockage (0.3 for a 30% blockage for example).

If the advection-age is greater than 30 minutes, or the beam blockage greater than 0.8, or the altitude greater than 10km, the quality index is forced to zero.

Weighted linear combination and QPE generation. After applying these processing, the pixel data is computed by a simple linear combination of the reflectivities Zi for the different PPIs, weighted by the quality indexes ω_i :

$$Z = \frac{\sum_i \omega_i Z_i}{\sum_i \omega_i} \qquad (2)$$

The quality index ω associated with the pixel is obtained from the largest weight that entered into the combination :

$$\Omega = \mathrm{MAX}_i \ (\omega_i) \qquad (3)$$

To avoid undersampling problems due to the 5-minute sample time, the advection field is used to generate one image per minute. These images are added together to generate the final QPE product, from the simple Marshall-Palmer Z/R relationship.

III. The new mosaic radar QPE

Individual radar QPEs are concentrated every 5 minutes and a nation-wide, 1km^2 in resolution, QPE composite is generated. The composition rule in overlapping areas is again based on the weights Ω by a simple weighted linear combination of the available data for the pixel, issued from 1, 2 or 3 radars.

Each mosaic is accompanied by a quality mosaic obtain from the maximum weight that entered into the combination.

To illustrate the individual radar QPE, we present in Figure 2 an example obtain with the Toulouse radar, and accumulated over 12 hours. Figure 3 is the mosaic product over France for the same situation. Note on this example the absence of any discontinuity that are usually observed in single radar accumulation maps (see fig. 2). The corresponding quality index map is presented in figure 4. There is a strong dependence of quality with range to the radars. and the quality is higher over the mountains than over the valleys.

IV. Calibration by rain gages

Accurate calibration of the precipitation radars is still a major problem for meteorological services : the accuracy needed for hydrological applications is difficult to obtain by simple electronic calibration and it is still necessary to combine radar data with rain gages data to insure a correct estimation.

More and more meteorological services are using real time calibration by gages (see for example Anagnostou, 1998), using a global correction factor applied on the entire radar domain, or a spatially non-uniform correction (Seo, 2002).

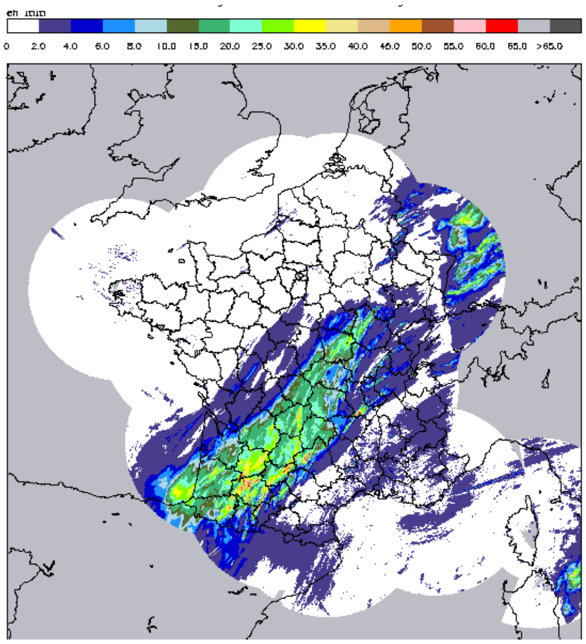

Fig. 3. Example of 12 hours accumulation of the mosaic Panthere QPE product. Same situation than fig. 2 : accumulation from 2006 19 jun. 18h00 to 20 jun. 06h00.

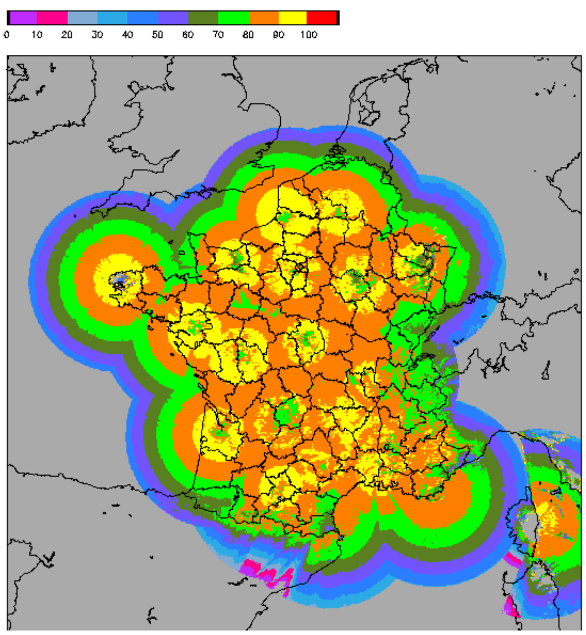

Fig. 4. Quality index map corresponding to the mosaic QPE of fig. 3. Note the strong dependence with distance to the radars, and the influence of reliefs.

In our previous HYDRAM QPE (Cheze and Helloco, 1999), the calibration was done on a monthly basis to compute a correction factor, named “Hydram Factor” HY, which was applied to the radar data during the following month. This method generally gives acceptable results but we occasionally experienced problems, sometimes severe, particularly in the Mediterranean area, SE of France where the most severe storms occur in autumn, after a long dry summer period, during which the radar/gage comparison is not possible, and there is a real need for an automatic procedure.

Consequently we decided to test a real time radar-gage adjustment by a coefficient computed each hour h using the radar and gages accumulations over the previous hours (from h-10T to h). The basic formula used to compute this factor is

$$C_h = \frac{\sum_{t=h,h-10T}^{h} \omega_t R_t + Acc.HY}{\sum_{t=h,h-10T}^{h} \omega_t G_t + Acc} \qquad (4)$$

Where :

$$\omega_t = 2^{-\frac{h-t}{T}} \qquad (5)$$

ω_t is a time filtering function, with a half-width T ; G_t is the spatial and hourly rain accumulation over the available gages ; R_t is the spatial and hourly rain accumulation over radar pixels above the selected gages ; HY is the previous Hydram factor, and Acc is a “recall factor”. When it is raining, the left part of the formula is larger than the right part and the factor C_h is equal to the ratio of the radar to gage accumulation, weighted by the time filtering function ω_t. On the contrary, for weak rain or no rain, the right part of the equation is larger than the left one and the factor C_h is equal to the Hydram factor HY. The “recall factor” Acc, express in mm like an accumulated rain, governs the tenseness of the transition between calibration by gages, and HY.

An example of time variation of radar rain estimates versus time is presented in fig. 5 for the Nîmes radar, and for a 6 days duration rain event. In this example, as for many others, the corrected radar data are much closer to gages than the un-corrected ones. This is true for any values of the filtering parameters Acc and T. But for some cases (non presented here), specifically for small storm cells, the agreement is better with weak filtering (small T and Acc values). Nevertheless, considering that gage measurements are less confident for these kind of event, we decided to applied large filtering values of 80mm for the “recall factor” Acc, and 16 hours for time filtering T. Using these values, we tested the efficiency of the method for 7 radars, and during a 6 months duration period. The main result is presented in the two scatter plots of fig. 6. After calibration correction, the mean normalized bias drops from 0.85 to 0.91, and the correlation from 0.92 to 0.95. This result recovers various situations : some radars were quite well calibrated and did not need gage calibration, although others were biased. The calibration is obviously much more efficient for these last radars.

Considering these results, we have decided to perform a operational test, in real-time, during the 2006 autumn with 6 radars situated in the SE region of France (Bollene, Nîmes, Opoul, Collobrières Montclar and Sembadel). In case of positive result, the method will be included in the operational processing for all the radar of the French Network.

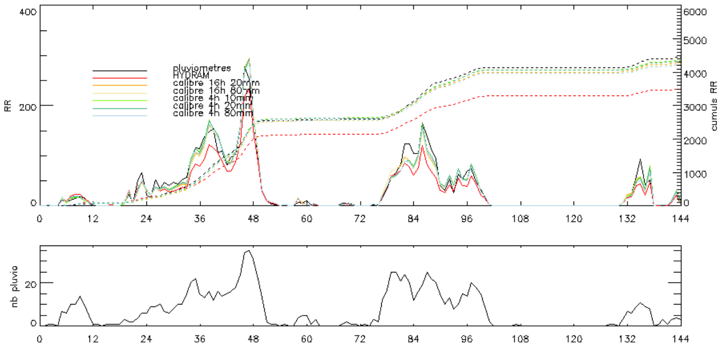

Fig. 5. Rain rate measured by the Nîmes radar and gages for a 6 days event (from sep. 5th 2005 00h00 to sep.11 2005 00h00). The lower diagram shows the number of gages available in real time; the upper diagram shows the aerial-hourly accumulated rain for gages and radar (G_t in black and R_t in red), and the radar data corrected by the Ch factor of eq. 4, and for different values of the Acc "recall factor" and of the half-width time filtering factor T. The accumulated values of rain measurements (by gages, corrected and uncorrected radar are also presented).

	Without calibration	With calibration
Normalized bias	0.85	0.91
Correlation coeff.	0.92	0.95

Table 1. Normalized biases and correlation coefficients when comparing radar estimates - with and without calibration - to gages data. Data for 7 radars and for 6 months (May 1st to October 31th 2005).

V.Conclusions and future work

With the new Panthere QPE rain accumulation product, the French radar processing incorporates some improvements already used in other countries (ground clutter supression, beam-blockage correction, VPR estimate and correction). The new original dynamic quality index, provided with the accumulation product, will allow the users to identify the area where the measurement is questionable. This will be particularly useful for the hydrological models.

The mosaic accumulation product, easier to operate than a number of individual radar QPEs, will be more and more used for now-casting and assimilation by models. In such a mosaic product, the range to the radar information is no more visible, and it is unusable without quality index.

The calibration by gages will probably be included in the operational software in 2007. And we will continue our efforts to more and more improve our QPE products : adaptation of the Z/R relationship to the event, automatic calibration with dual-polarization techniques, and Z/R relationship adapted to the drop size diameter using dual-polarization techniques.

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References

Anagnostou, E.N., and W.F. Krojewski, 1998 : Calibration of the WSR-88D precipitation processing subsystem. Wea. Forecasting, 13, 396-406.

Andrieu, H. J.-D. Creutin, 1995 : Identification of vertical profile of radar reflectivity for hydrological applications using an inverse method. Part I : Formulation. J. Appl. Meteor., 34, 225-239.

Caumont, O., V. Ducrocq, G. Delrieu, M. Gosset, J. Parent du Chatelet, J. P. Pinty, H. Andrieu, Y. Lemaitre and G. Scialom 2006 : A radar simulator for high resolution NWP simulations of the 8-9th September 2002 flash flood over Southern France. Accepted by J. Geophs. Res., 2006.

Cheze, J.-L., and F. Helloco, 1999 : The HYDRAM project of Météo-France : a quality-based approach for quantitative measurements. Prepr. 29th Conf. on Radar Meteorology, 12-16 jul. 1999, Montreal.

Faure, D., G. Delrieu, P. Tabary, J. Parent du Chatelet and M. Guimera 2005 : Application of the hydrologic visibility concept to estimate rainfall measurement quality of two planned weather radar. Atmospheric Research, 77 232-246.

Kitchen, M., 1996 : Towards improved radar estimates of surface precipitation rate at long range : Q. J. R. Meteorol. Soc., 123, 145-163.

Parent-du-Chatelet J., P. Tabary, and M. Guimera, 2005 : The Panthere project and the evolution of the French operational network : rain estimation, Doppler winds, and dual-polarization. Prepr. 32th Int. Radar Conf., Albuquerque, 2005.

Tabary, P., 2005 : The new French operational radar rainfall product, Part I : Methodology. Submitted to Wea. Forecasting.

Tabary, P., F. Guibert, L. Perier, J. Parent du Chatelet 2006 : An operational triple-PRT Doppler scheme for the French radar network. Accepted by J. Atmos. Ocean. Tech., March 2006.

Seo, D.-J., and J.P. Breidenbach, 2002 : Real-Time correction of spatially non-uniform bias in radar rainfall data using rain gage measurements. J. Hydrometeor. 3, N°2, 93-111.