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Improvement of the French radar rainfall accumulation product

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Abstract. This paper describes the new algorithm (PANTHERE) for the calculation of rainfall accumulation, using volume radar scans. There are 6 successive steps in the new data processing: dynamic identification of ground clutter, correction of the occultation masks, correction of VPR, synchronisation of the data, linear combination, 5 min accumulation .

The algorithm has been tested during two experiments, in autumn 2002 and 2003, with 2 radars in the south-east of France. The comparisons with the former algorithm (HYDRAM) and with rain gauges show an improvement of the quantitative estimation of rainfall.

1 Introduction

A project, named PANTHERE, is currently being run, aiming at 1) renewing two ageing radars of the french network, 2) adding six more radars over the period 2004–2006 and 3) introducing new techniques such as volumic exploration, Doppler processing and polarimetry. In that context, a new algorithm for the calculation of radar rainfall accumulation has been developed, using volumic exploration, and tested with two radars in the south-east of France, Bollene in 2002 and Nîmes in 2003.

The main goal is to correct some problems of the radar measurement:

- discontinuities at the change of elevation angles when using concentric composite images;
- use of a single elevation angle for each pixel, that leads to permanent ground clutters in some sectors;
- underestimation because of beam blockage, especially in mountainous regions;
- overestimation (especially in winter) due to bright band;
- underestimation at long ranges.

Successive steps are done to dynamically identify ground clutters, correct the occultation masks, correct the VPRs and use all the data above each pixel. The improvment of the quantitative estimation of rainfall is made easier using volume scans, but the algorithm is suitable even with only 2 elevation angles.

2 Description of the algorithm

There are 6 steps in the new data processing (Fig. 1):

1. dynamic identification of ground clutter: instead of correcting the data, we determine for each pixel and each elevation angle if the measurement is ground clutter or rain. As the identification is dynamic, we can deal with both anomalous propagation and rain on relief.

2. correction of the occultation masks: we use a numerical model to compute the degree of beam blocking and to correct the data accordingly.

3. correction of VPR

4. synchronisation of the data

5. weighted linear combination: we use all the volume data, with a specific weight for each elevation angle, depending on the type and quality of the measured reflectivity.

6. 5 min accumulation

Concurrently, weights are calculated for each pixel at each step, to estimate the dubiousness of the corrected data. The final weights are used for the linear combination (step 5) and could be used as an estimation of the rainfall accumulation quality.

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Table 1. Variance threshold.

radar	statistic ground clutter area	variance value	quality value
Bollène	yes	>4 dB	rainfall echo $\omega1$=1
		< 4 dB	ground clutter $\omega1$=0
	no	> 3dB	rainfall echo $\omega1$=1
		< 3 dB	ground clutter $\omega1$=0
Nîmes	yes	> 3 dB	rainfall echo $\omega1$=1
		< 3 dB	ground clutter $\omega1$=0
	no	> 2.5 dB	rainfall echo $\omega1$=1
		< 2.5 dB	ground clutter $\omega1$=0

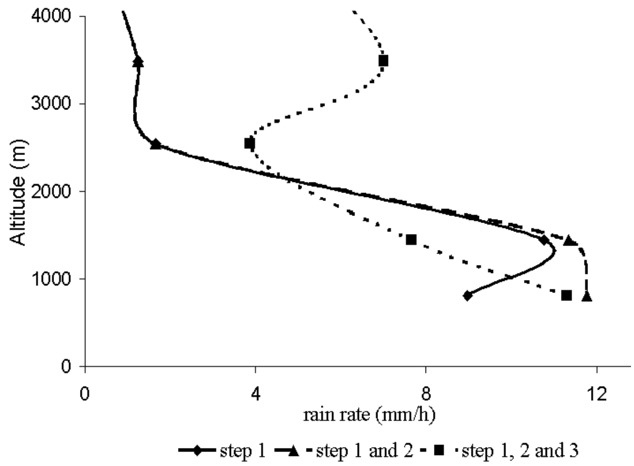

Fig. 2. Evolution of VPR after each step of the processing.

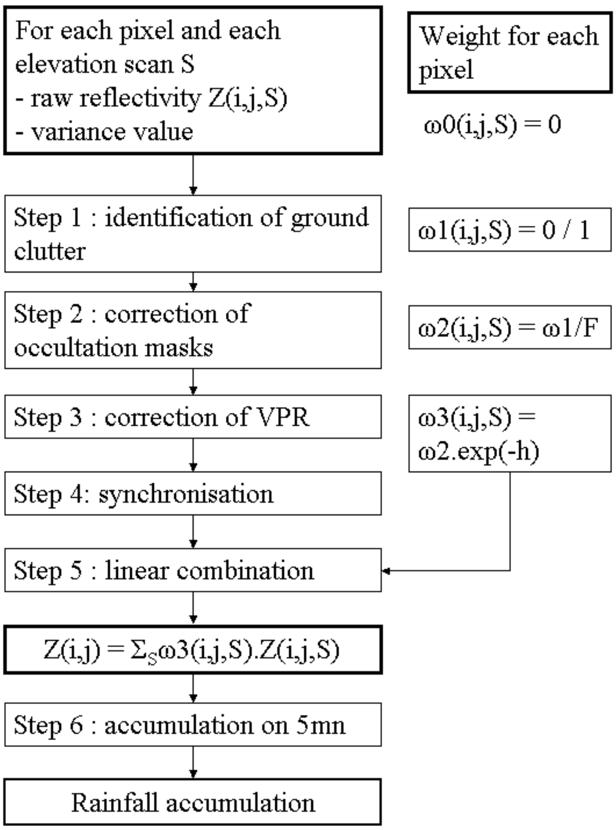

Fig. 1. New algorithm PANTHERE.

2.1 step 1: identification of ground clutter

The variance of the reflectivity measurement is calculated to determine for each pixel at each elevation angle if it is a ground clutter or rain. In the first case, the weight is equal to 0, in the second to 1.

With a statistical ground clutter map, the algorithm can be improved by using two different thresholds of variance depending if the pixel is inside or outside statistical ground clutter area (Table 1).

2.2 step 2: correction of the occultation masks

Using a digital elevation model (SURFILLUM), the degree T of beam blocking is calculated (for example, T equal to 100% means that the beam is totally blocked). Then a correction factor F is defined as

F = $(100/(100\text{-}T))^{1/b}$ where b comes from Z-R relation.

The weight is empirically set to $\omega2 = (\omega1/F)^{1/3}$

The exponent 1/3 means that data with a mask up to 50% can be corrected with confidence. Data maskek by more than 80% are not corrected.

2.3 step 3: correction of VPR

This step is adaptable according to the type of radar processing, volumic or not (cf. Gueguen, ERAD04-P-00144).

First, an instantaneous VPR is defined, then an hourly average VPR is calculated, using a quality control, and finally the correction is applied to the pixels.

The weight only depends upon the altitude of the measurement and is set to $\omega3 = \omega2 \exp(-h/h0)$

where h is the altitude, h0 = 1000 m

2.4 step 4: synchronisation

The corrected data and the weight are put to the same reference time, using a motion field.

2.5 step 5: linear combination

A linear combination of the synchronized data is done for each pixel, using weights and each of the elevation angle (16 for Bollene, 10 for Nîmes).

2.6 step 6: accumulation on 5 minutes

An oversampling (of about 1 min) is done, using the motion field, to avoid the effect of discontinuous timescale radar data.

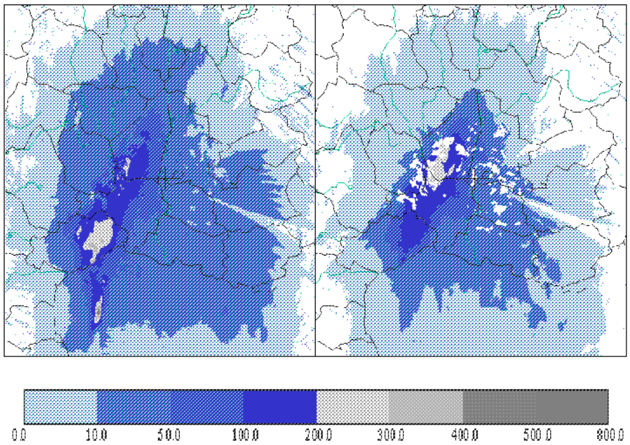

Fig. 3. Bollene 10–12 december 2003: Panthere (a), Hydram (b).

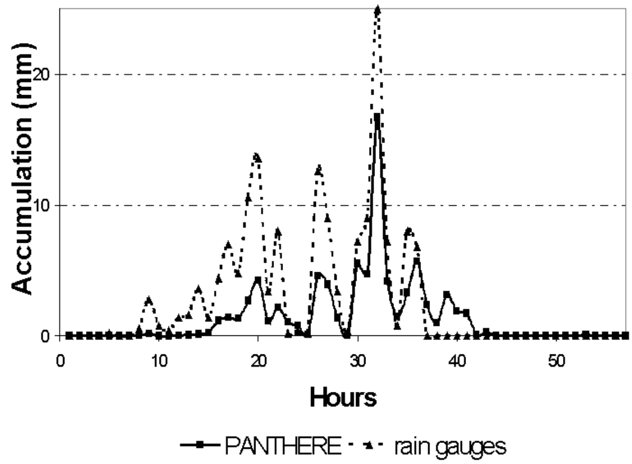

Fig. 4. Temporal evolution of radar data and rain gauges in ground clutter area.

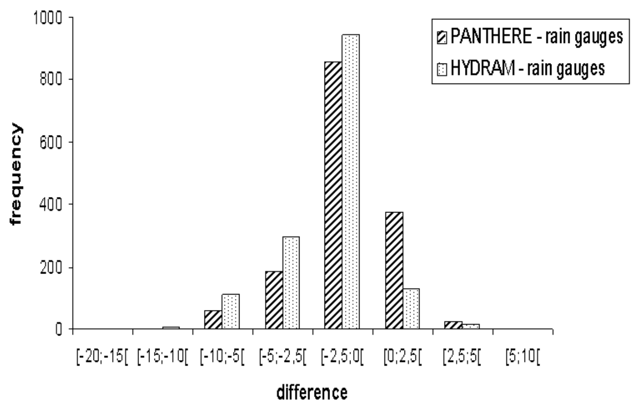

Fig. 5. Differences between Panthere and Hydram when compared with raingauges.

2.7 case study: Nîmes 02 December 2003 at 03.40 UTC

Figure 2 shows the evolution of radar rain rate depending on altitude, after ground clutter identification (step 1), after ground clutter identification and masks correction (step 1 and 2), after ground clutter identification, masks correction et VPR correction (step 1, 2 and 3). Step 2 allows to raise the rain rate for the elevation angle with an occultation mask. After the VPR correction (step 3), there is a complete change in the form of the rain profile, with the disappearance of the intensity peak in the lowest part of the atmosphere, and the increase of data at higher altitude.

3 Quantitative validation of Panthere rainfall accumulation

5 rainfall events between september and december 2002 (Bollene) and 4 rainfall events between september and december 2003 (Nîmes) are studied.

The differences between the two accumulations (Fig. 3) are:

- higher accumulation with Panthere, specially far from the radar;
- appearance of very high accumulation with Panthere (south-west of the radar);
- better measurement on the occulted areas;
- large differences inside and near the ground clutter areas.

3.1 Tools of validation

Two ways of validation are used.

The first one is the study of convective rains, on short temporal and spatial scales : for hourly radar and gauges accumulations, calculation of statistical criteria of comparison and calculation of the temporal evolution of the differences.

The second one is a spatial study of the whole event, on the whole radar domain : calculation of the differences between Panthere and Hydram, and calculation of the evolution of radar data with the distance of the radar.

The three types of problems are separately studied.

3.2 Ground clutter areas

The statistic results show an average statistic connection between radar pixels and raingauges, not good enough, and an underestimation of the radar compared with the raingauges. The differences are higher when the ground clutters are strong (Fig. 4).

The results of the algorithm depend strongly on the value of variance threshod.

All this means that the algorithm is not good enough, even if there is an improvment of the rain rate measurement.

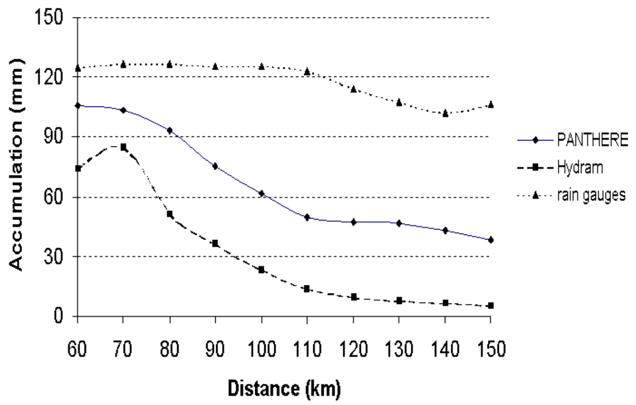

Fig. 6. Bollene 14–16 november 2002: evolution of the accumulation as a function of distance.

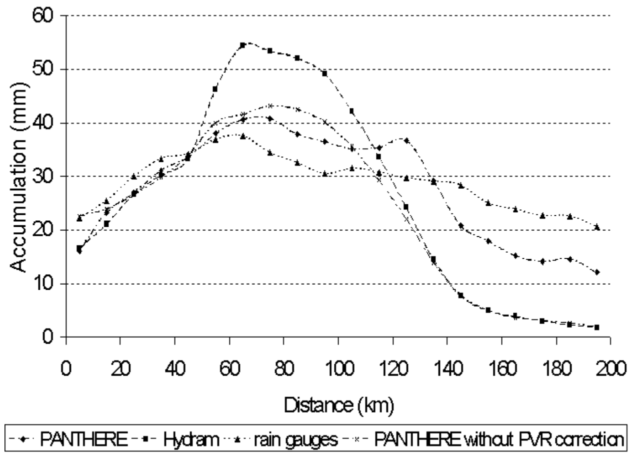

Fig. 7. Bollene 16 november 2002: evolution of 4 types of accumulation.

3.3 Occultation masks

Figure 5 shows that Panthere underestimates less than Hydram, compared with the raingauges. We can see that Panthere has a stronger overestimation, but not more than 5 mm per hour, that means a relatively weak overestimation.

Panthere accumulation is globally better than Hydram, even if it is too small far from the radar compared with the raingauges (Fig. 6).

3.4 Correction of VPR

3.4.1 Correction of the bright band

Figure 7 shows the evolution of 4 types of accumulation : Panthere with and without VPR correction, Hydram, raingauges. Hydram is very high between 60 and 100 km, because of a bright band. Compared with raingauges, the measurement is better when using Panthere with VPR correction. There is a diminution of about 60% of the bright band.

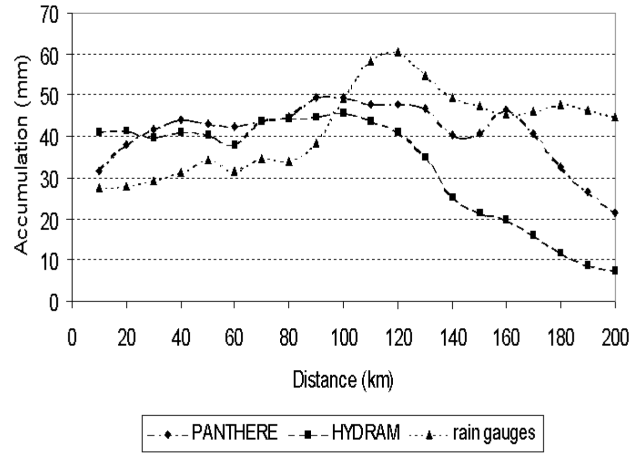

Fig. 8. Bollene 09–10 october 2002: evolution of 3 types of accumulation.

3.4.2 Amelioration of the range of quantitative use

Figure 8 shows the evolution of 3 types of accumulation: Panthere, Hydram and rain gauges. Hydram is decreasing very quickly from 100 km, even though rain accumulation is increasing. Panthere is better, decreasing only from 150 km.

This amelioration is partly due to the VPR correction, but also because we use a very low elevation angle (0.4°).

4 Summary

The validation of Panther accumulation, done with volumic data on 2 radars of south-east of France, shows a great amelioration of rain rate measured with radar: data available on ground clutter areas, good correction of occultation masks, correction of VPR leading to a biggest area where quantitative use is possible. These corrections are however not perfect, specially on ground clutter areas. But information on quality of the data could be given to the users, using the weights calculated for each pixel.

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