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Comparison of two vpr identification methods

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Abstract. In autumns 2002 and 2003, two radar located in Southern France were operated with a volume scanning strategy : Bollene, a S-band radar with 8 elevation angles from 0.4 to 18 degrees and Nîmes, a C-band with 6 elevations angles from 0.6 degrees to 14 degrees.

The considerable amount of data recorded during these experiments allowed us to test two correction methods for the effect of the VPR and to compare their results.

The first method is a direct observation of the VPR using all the measurements of the different scans. The VPR's vertical resolution is 200 m. The value for each 200 m thick layer is the average of the reflectivity values of one hour.

The second method uses a simplified algorithm proposed by H. Andrieu. It is based on the comparison between an observed VPR and a series of climatological VPR. The observed VPR is deduced from the ratio between the measurements of two different elevation angles. The climatological VPRs are elaborated by using meteorological data like the zero degree isotherm height. Two types of climatological VPR are defined: the first one with a bright band is used to correct the reflectivity values in the case of stratiform structure, and the second one without bright band is used in the case of convective structure.

1 Introduction

In autumn 2002 and 2003, two S-band radars of the French operational network were operated with a volume scanning strategy. These radars are located in the South-East of France, a region prone to heavy rain events. The Bollène radar (resp. the Nîmes radar) performed 8 sweeps (resp. 6 sweeps) every 5 min and explored a total of 12 (resp. 10) independent elevation angles every 15 min.

The data collected during the "BOLLENE-2002" experiment, allowed to define a VPR (vertical profile of reflectivity) restitution method directly from volumetric radar data (Joss and Lee, 1995; Germann and Joss, 2001). The algorithm developed was implemented in the software which provides, in real time, the radar rainfall accumulations, during the "Nîmes-2003" experiment.

Another VPR identification method was used for a few years on another radar of the network, the Toulouse radar. This radar explores only 2 elevation angles every 5 min and the method is based on 1) the computation of ratio curves between high and low elevations 2) " a priori" VPR candidate 3) the height of the freezing level provided from a numerical model (Andrieu and Creutin, 1995).

The experiments BOLLENE-2002 and NIMES-2003 thus constitute the opportunity of testing the two methods on actual events and compare the their respective performances.

Section 2 describes the direct method. Section 3 recalls the principles of the indirect method, implemented on the radar site of Toulouse and presents the evolutions tested. Section 4 is a comparison and a discussion of the two algorithms.

2 The direct method

2.1 The algorithm

The direct method retrieves VPRs from radar data collected at all the elevation angles. The input data are the Cartesian images (1 km^2,512×512 km) of reflectivities which are converted in rainfall intensity maps. The algorithm consists of the following steps :

1. An instantaneous VPR is determined with the measurements within a radius of 50 km around the radar in order to minimize the beam filtering effects. Ground clutters and shielded areas are already excluded from the calculation. The profile is calculated between 600 and 5000 m above sea level with a vertical resolution of 200 m. In addition, the number of points taken into account in each section is counted.

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2. In order to make the VPR estimation less sensitive to small-scale spatial and temporal fluctuations, data are averaged, in a running way, over an hour.

3. A quality-check allows filtering out unrealistic hourly profiles: a VPR is considered to be valid only if all the 200 m slices between 600 and 2000 m have more than 20% of their volume filled with rain. If this criterion is not verified a climatological profile (−1.5 dB/KM, Germann, 2000) is used.

2.2 Examples and discussion

It is rather difficult to evaluate the quality of the method, as no independent data are usually available. Thus, to assess the performances of the procedure, we look at the consistency of the VPR.

The VPRs obtained in stratiform rain illustrated by the Fig. 1 are well defined and consistent. They show a distinct bright band. Even though the retrieval of the VPR was done by using the range to 50 km, the effect of the beam filtering can be noticed on Fig. 2.

In convective rain,(see Fig. 2) the VPRs are very irregular and show more fluctuations as expected.

A complete validation of the method , made by comparing corrected data rainfall accumulations with rain gauges, shows that the use of these VPRs allows reducing the overestimation due to bright band (by 60%) and the underestimation at long ranges.

In conclusion, the advantages for the method are:

1. This method is simple to implement in an operational context and is not really computationally expensive.

2. The profile is deduced only from radar data.

While the drawbacks are:

1. The method requires a volumic scanning of at least 8 or 10 elevation angles.

2. The retrieved profile is smoothed by the antenna gain pattern, so the bright band may not be enough corrected.

3 The indirect method

3.1 The principles of the method

Some radars of the French network are too old to be operated with a full volume scanning strategy. For this reason, a second VPR identification method, already in operation on the Toulouse radar since 1997, has been considered, with the aim of obtaining a method that guarantees a good restitution of the VPR at any time in an operational context.

The data recorded during these two experiments allowed us to propose some evolutions of this method in order to take advantage of the volume measurements:

1. More elevation angles are used to calculate the ratio curves. High elevation angles however are not taken into account as they may not be representative of the same area as low elevation angles. So, we work with the data recorded at the elevation angles 0.8°, 1.2°, 1.8°, 2.4° and 3.6° for the Bollène radar and 0.6°, 1.3°, 2.5° and 3.6° for the Nîmes radar and we can calculate 10 ratio curves can be obtain for the Bollène radar and 6 for the Nîmes radar.

2. A "family" of simulated VPR is generated by changing two parameters : the height of the 0°C isotherm and the magnitude of peak of the bright band.

3.2 The observed ratio curves

To reduce the amount of data when calculating ratio curves, for each elevation angles, we made hourly rainfall accumulations (from the Cartesian images. Nevertheless, the operational procedure will work in a running way by a time step of 5 min.

First, each observed ratio curve R(b,h,r) is calculated by step of 1 km as follows:

$$R(b,h,r) = \Sigma_{i,j/d(i,j)=r}\theta(b,h,i,j) * C_h(i,j)/ \Sigma_{i,j/d(i,j)=r}\theta(b,h,i,j) * C_b(i,j)$$

Where C_h(i,j) and C_b(i,j) are respectively the accumulated precipitation of the highest and lowest elevation angles, r is the distance from the radar. θ(b,h,i,j) = 0 if:

1. C_h(i,j) is ground clutter or located in an area of strong partial beam blocking.

2. C_b(i,j) is ground clutter or located in an area of strong partial beam blocking.

3. C_b(i,j) =0.

4. r is more than 150 km.

5. r is less than 10 km.

The Fig. 3 presented an actual example of the observed ratio curves obtained with this procedure.

3.3 The quality-check

A quality-check to eliminate the cases where not enough rain is recorded close to the radar to calculate the ratio curves is made. The idea is to test the area where the bright band can occur. This area is limited by the ranges corresponding to the height of the 0°C isotherm +/−600 m. The criterion chosen requires that each 1 km circle of this area have 20 rain echoes at least. If this criterion is satisfied, the ratio curve is valid. In the case where all the possible ratio curves are invalid, the climatological VPR is used.

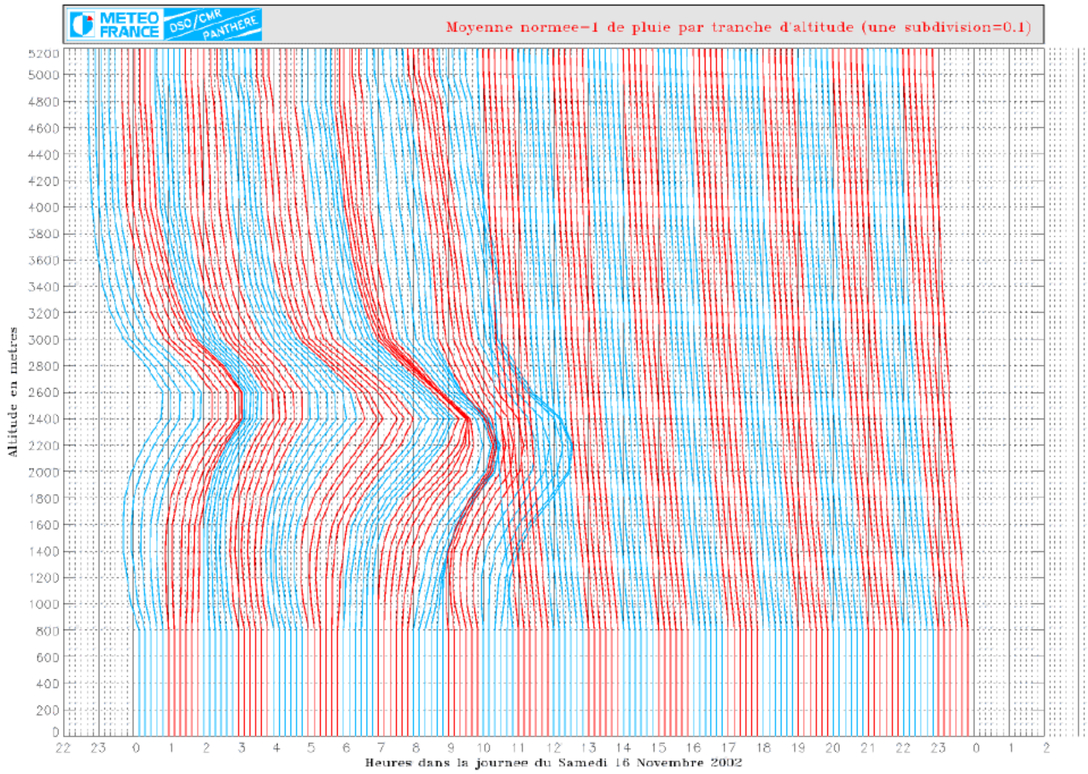

Fig. 1. Time series of VPR obtained with the direct method in a stratiform rain situation (16 November 2002).

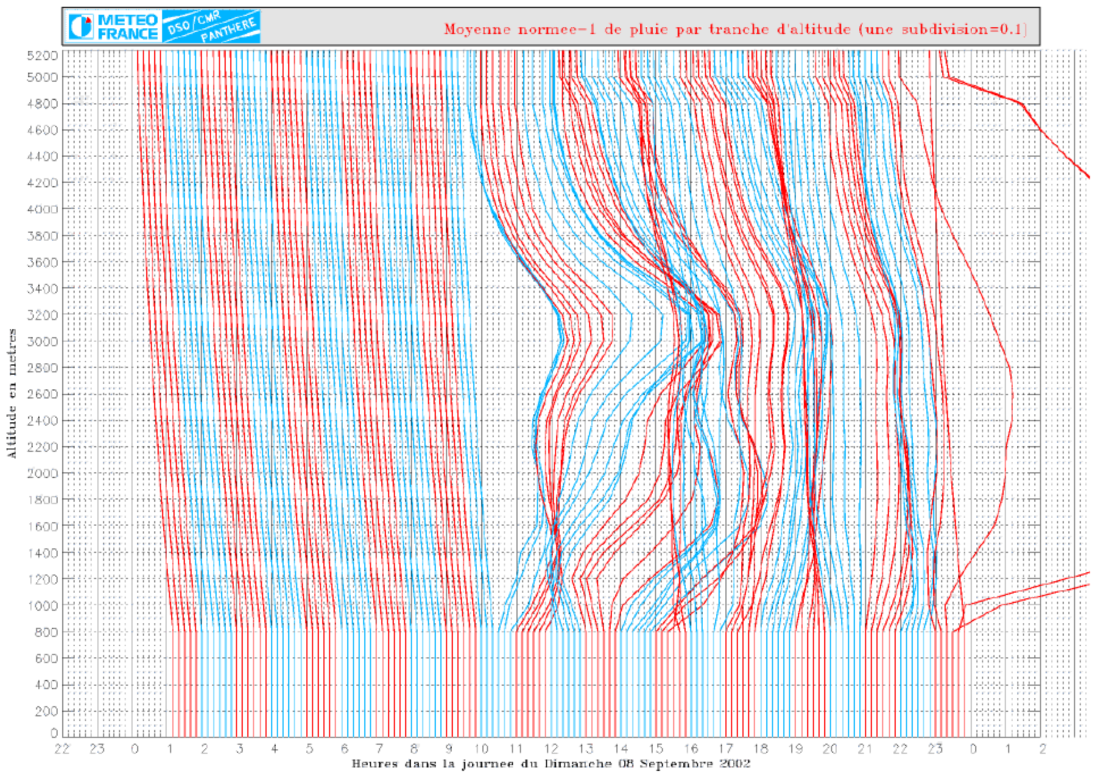

Fig. 2. Time series of VPR obtained with the direct method in a convective rain situation (8 September 2002).

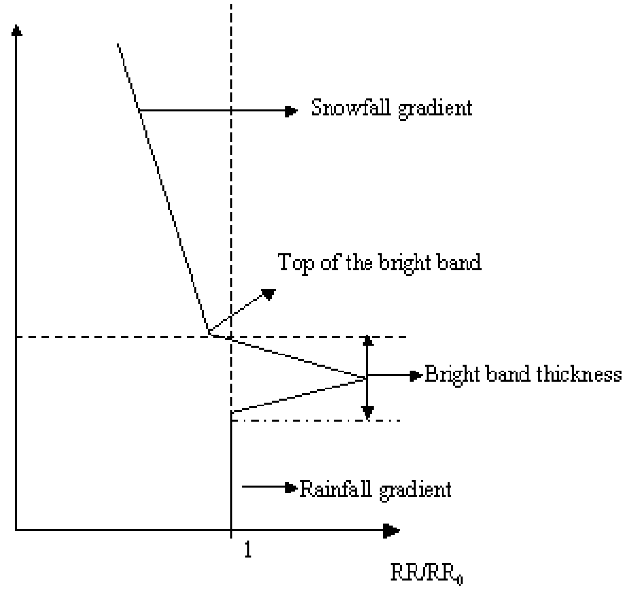

Fig. 3. A schematic representation of the VPR.

3.4 Simulated VPR

The VPR is defined by 4 points (see Fig. 4) , which give the limit of the three layers used to represent the bright band, and 5 parameters can change:

1. The snowfall gradient above the bright band top
2. The height of the bright band top
3. The bright band thickness
4. The bright band amplitude
5. The rainfall gradient

In this study, to generate the simulated VPR, we vary two of these parameters. Thus, the bright band top can vary between 600 m below the height of the 0°C isotherm to 600 m above the height of the 0°C isotherm by steps of 200 m. The height of the 0°C comes from a meteorological numerical model. And the bright band amplitude can vary between 1 to 2.5 by step of 0.5. The others characteristics are fixed as follows:

– The snowfall gradient = −1.5 dB/km
– The bright band thickness = 800 m
– The rainfall gradient = 1

Using these values, a family of 28 simulated VPR is generated (see Fig. 5). From each simulated VPR of the family and for each elevation angle, the relative rainfall rate is deduced, as the mean value of the VPR intercepted by the radar beam. Then, the simulated ratio curves can be easily calculated for each couple of elevation angles.

The selected VPR for the correction of the radar data is the simulated VPR of the family deduced from each simulated ratio curve which leads through as closely as possible to each valid observed ratio curve. The Fig. 6 shows the simulated ratio curves associated with the observed curves of the Fig. 3.

3.5 Discussion: advantages and drawbacks of the method

The advantages of the indirect method are :

1. Beam filtering effects are included in the analysis.
2. The assumption of the method is that vertical and horizontal variability of rain can be separated.

The drawbacks of the method are :

1. The method is more complex and computationally expensive.
2. VPR candidates have to be proposed.

4 Comparison of the results and conclusion

It should be recalled that the objective is to propose a method which gives correct results with all the radars of the operational network, and it is clear that only the indirect method matches this requirement. But, the direct method allowed us to correct efficiently the radar accumulations, therefore we can use the resulting VPR to evaluate the efficiency of the indirect method. The methods are applied to several actual rain situations, including stratiform and convective precipitations: 5 were observed during BOLLENE-2002 experiment and 5 during NIMES-2003 experiment. Here, only two events are presented.

1. 16 November 2002 (BOLLENE-2002) is a stratiform rain event (Fig. 7).
2. 2 December 2003 (NÎMES-2003) is a situation which combined stratiform and convective rains and resulted in devastating floods in the Hérault region (Fig. 8).

In order to perform the method both in a volumetric and a non-volumetric context, indirect VPR were produced first, with 5 (Bollène) or 4 (Nîmes) and then with only two elevation angles (1.8°/0.8° for Bollène and 1.3°/0.6° for Nîmes).

1. The examination of the VPR time series shows that: The indirect method is efficient to detect the bright band. But, in the non-volumetric context the detection starts 1 or 2 h later and also stops 1 or 2 h earlier.
2. The bright band top is accurately located, and its amplitude is well estimated. The fact that beam filtering are considered, the VPR is more peaked that the one obtained with the direct method.
3. The climatological VPR is selected consistently with the direct method.

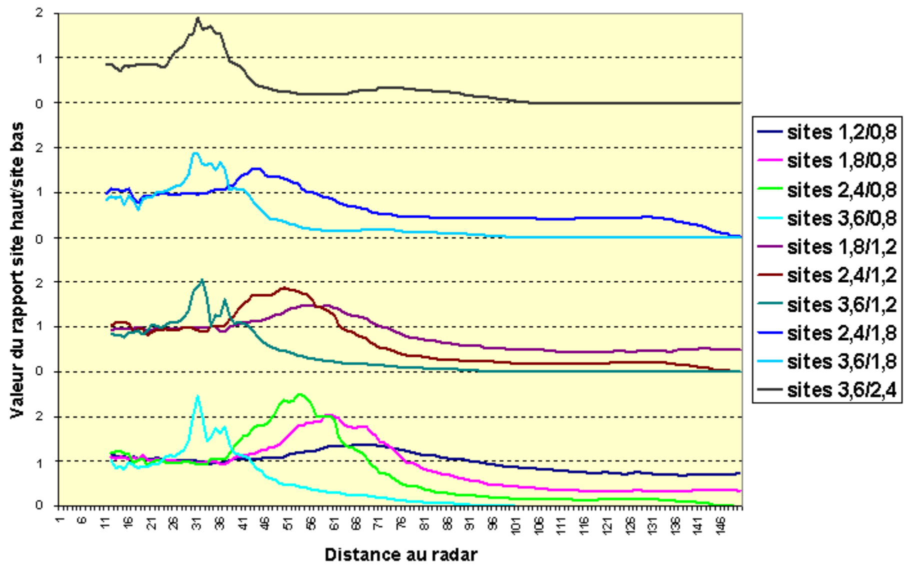

Fig. 4. Example of observed ratio curves (16 November 2002 – 02:00 UTC).

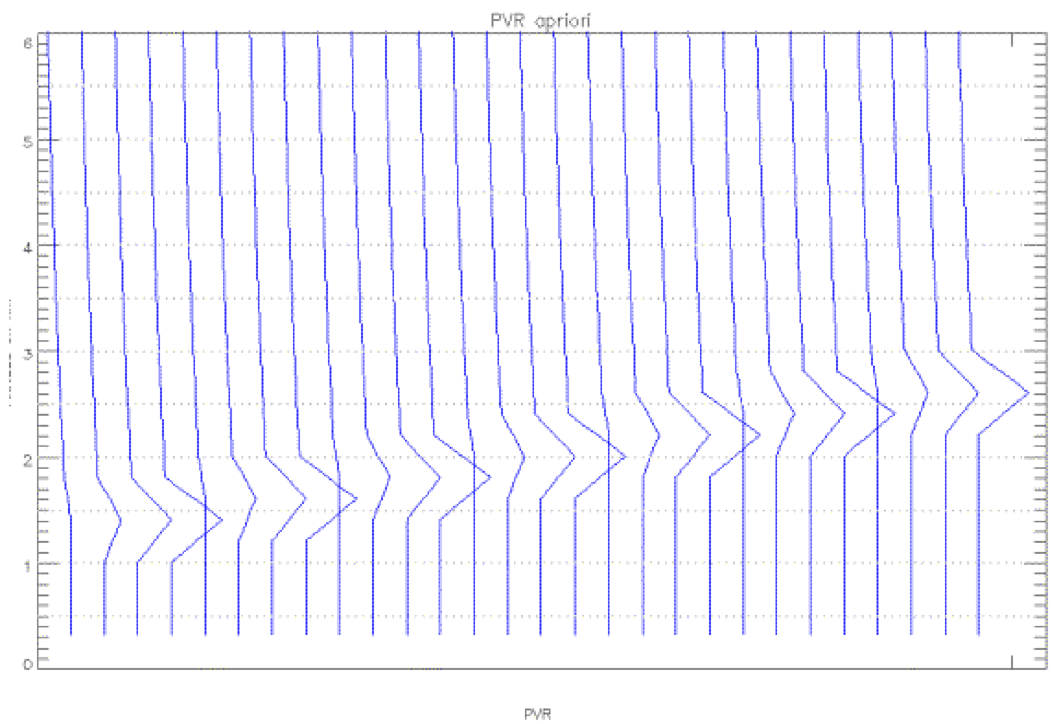

Fig. 5. The series of simulated VPR (16 November 2002 – 02:00 UTC).

Last, to investigate the benefit of using a larger family of simulated VPR, we look at the results obtained with the method in the two elevation angles context and with only two simulated VPR. The bright band top is determined by the height of the 0°C isotherm from the numerical model and the bright band amplitude is equal to 1 (VPR without bright band) or to 2.5 (VPR with bright band). Looking at the results obtained on the situation of the 16 November 2002 (Fig. 9), we see that the procedure is unable to detect the bright band, because the height of the 0°C isotherm forecasted by the model don't allow to determine the bright band top accurately, and the VPR selected is without bright band.

5 Summary

We described two VPR restitution methods and compared their results, using a rather large sample of actual situations,

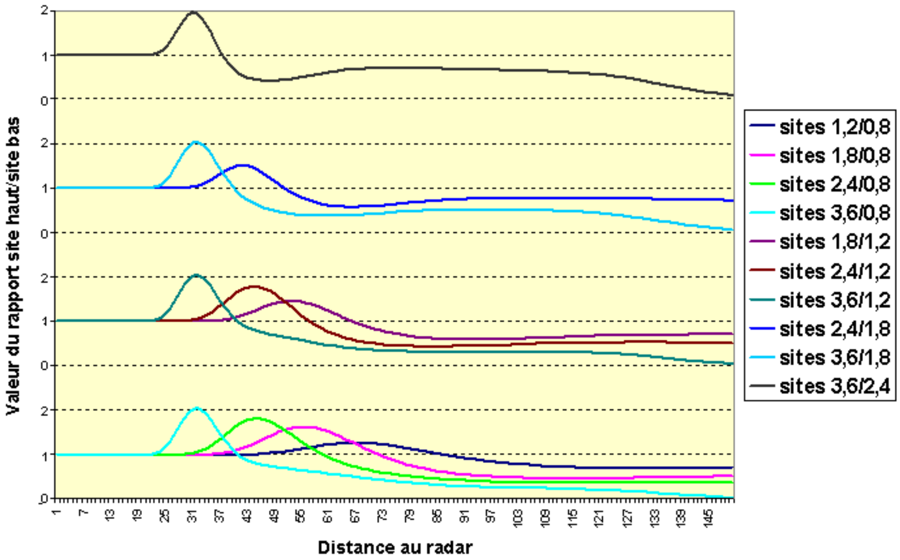

Fig. 6. The simulated ratio curves associated with the observed ratio curves of Fig. 4 (16 November 2002 – 02:00 UTC).

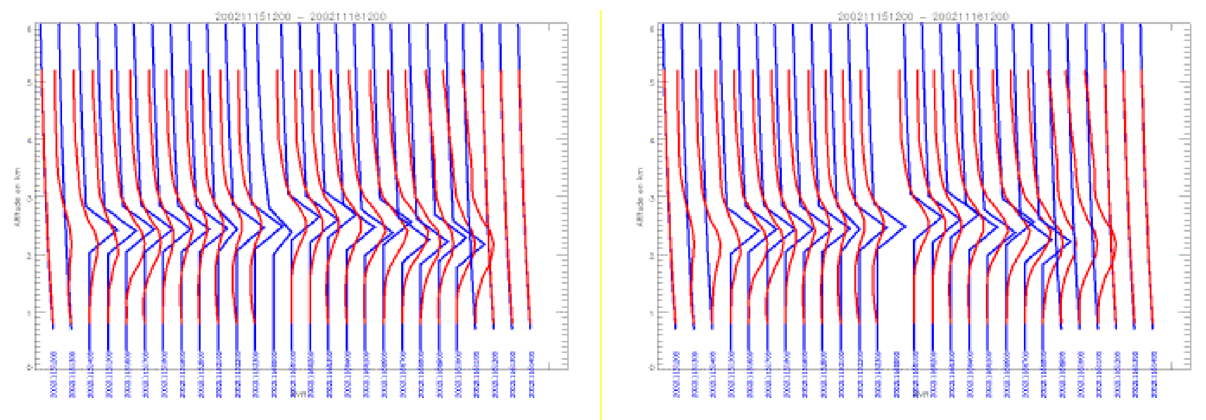

Fig. 7. Direct VPR (in red lines) and indirect VPR (in blue lines) obtained with 5 elevation angles (on the left) and with 2 elevation angles (on the right) – 15–16 November 2002.

in order to evaluate the performance of the indirect method that is the one that will be deployed on the French operational radars.

We can conclude that the indirect method allows a good determination of the VPR even in a non-volumetric context. In addition, using simulated VPR avoid to provide unrealistic VPR.

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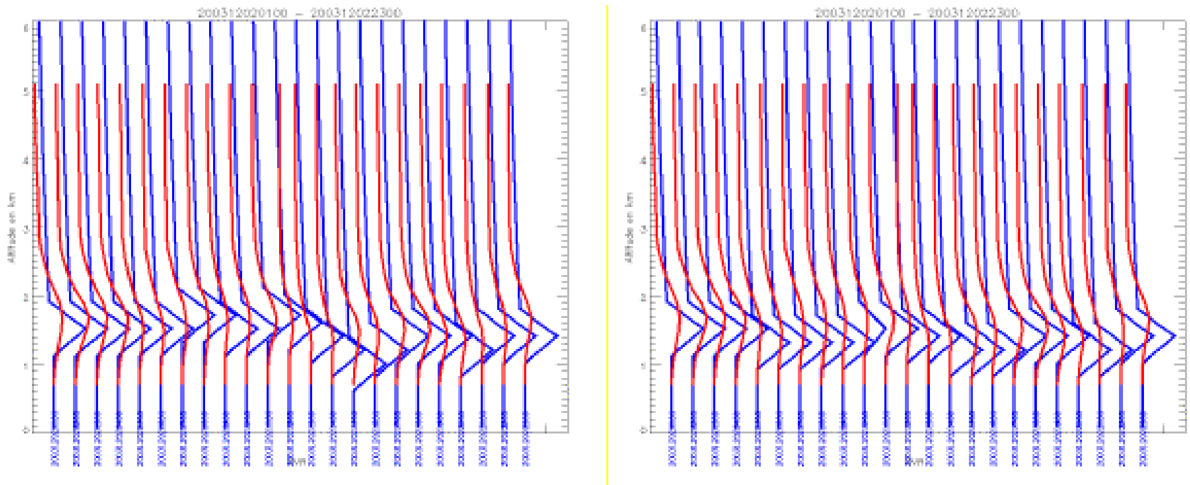

Fig. 8. Direct VPR (in red lines) and indirect VPR (in blue lines) obtained with 4 elevation angles (on the left) and with 2 elevation angles (on the right) – 2 December 2003.

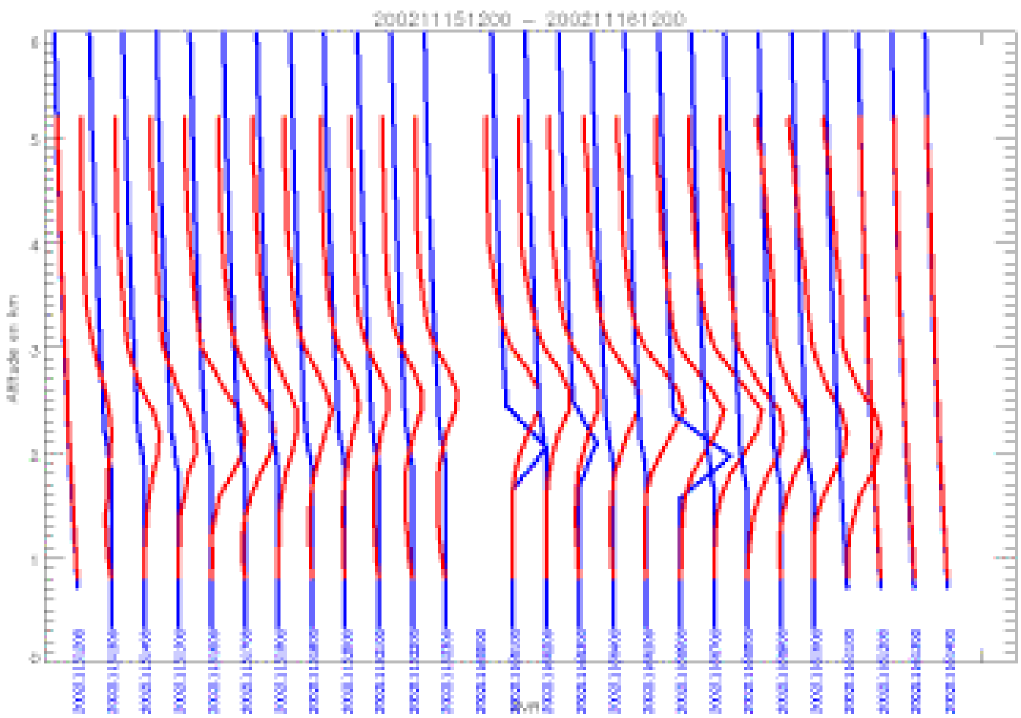

Fig. 9. Direct VPR (in red lines) and indirect VPR (in blue lines) with 2 elevation angles and 2 simulated VPR – 15–16 November 2002.