1-year long operational application of Vertical Profile of Reflectivity in the retrieval of the rain rate at the ground: impact and problems.

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1 Introduction

The application of Vertical Profile of Reflecitvity (VPR) reconstruction and correction is considered a key point in the framework of precipitation estimate at the ground level from radar reflectivity data, so that several techniques have been developed in the past to address this issue.

Nevertheless its operational use opens questions like the spatial variation of the precipitation vertical development, which is due to the mixing of convective and stratiform precipitation or simply to the incline of the bright band, and makes difficult using a unique VPR in the whole area of observation. Another point is the presence of melting layer or snow at the ground level which should be automatically recognized and dealt with, because it produces a variation in the relation between reflectivity and rain rate.

In this work are presented the results of a 1-year long operational application of a simple method of VPR reconstruction and correction which applies a single time-space averaged profile, distinguishes between snow, melting and liquid precipitation at the ground level and corrects reflectivity data. No stratiform-convective separation is adopted.

Reflectivity corrected data are used to retrieve the intensity of precipitation at the ground level and the hourly cumulated precipitation is obtained with an advective algorithm that takes into account the precipitation movement.

The mean impact of VPR application is evaluated and the effect of the spoiling factors evidenced; moreover some representative cases are analyzed. The results show that the application of the profile correction on the average improves the rain rate estimate, but crucial points, such as hydrometeors phase at the ground and convection, should be dealt with to avoid locally negative effects.

2 Vertical Profile of Reflectivity correction scheme

The scheme of VPR identification (Fornasiero, 2008) is based on the work of Germann and Joss (2002): the VPR is retrieved as a time-space weighted mean of the reflectivity values collected in the first 70 km from radar position and in the area free of mountains, divided in vertical layers of 200 meters.

The profile is then analyzed to determine its quality and if it is representative of 1) rain at the ground 2) melting layer at the ground or 3) snow at the ground.

To obtain this classification at first a maximum of at least 5 dBZ in the profile is searched. Then, the three main cases are identified:

- No maximum is found and the temperature at the ground is lower than maximum snow temperature: snow profile.
- A maximum is found and the temperature is higher than maximum melting layer temperature: liquid precipitation at the ground.
- A maximum is found and the temperature is lower than maximum melting layer temperature: melting at the ground.

In case of melting above the ground, to identify the first layer below the bright band (called ‘liquid level’) the profile is interpolated using a parameterized function. If the interpolation fails the profile is rejected.

Only reflectivity values collected above the ‘liquid level’ are corrected using the profile.

3 Verification

The mean impact of VPR application is evaluated by converting the corrected reflectivity into rain intensity at the ground, then cumulating over one hour and finally coupling with raingauge measurements. The verification is carried out in comparison with the standard operational reflectivity processing scheme, that does not include VPR correction, (Fornasiero, 2008) and it is conducted by means of the statistical indices BIAS, and RMSE (Root Mean Square Error). The first index gives an idea of the sign of mean error (over- or underestimation) while the second attaches importance to large errors.

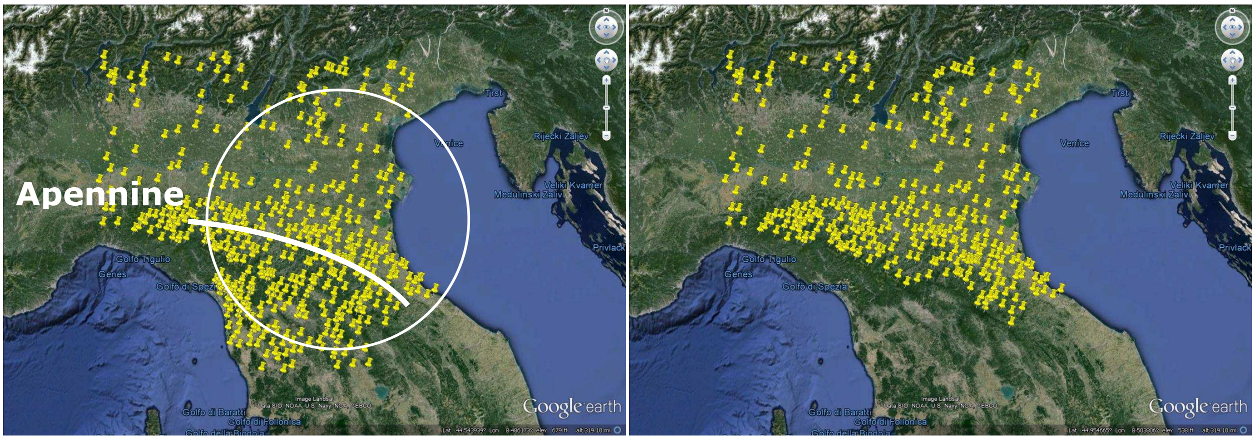
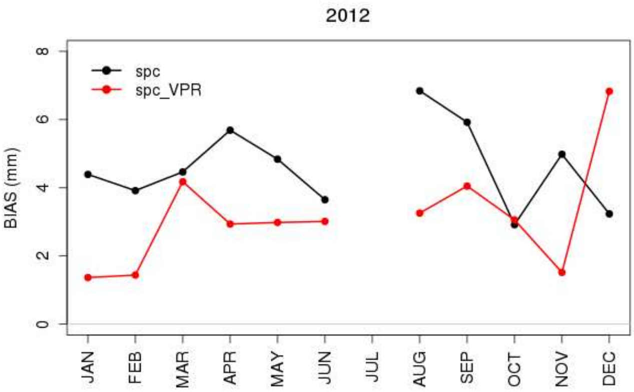
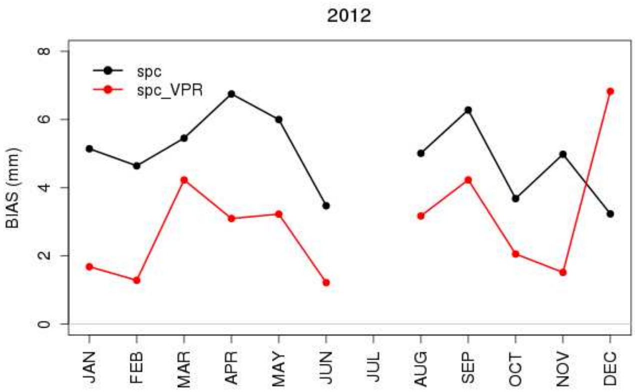


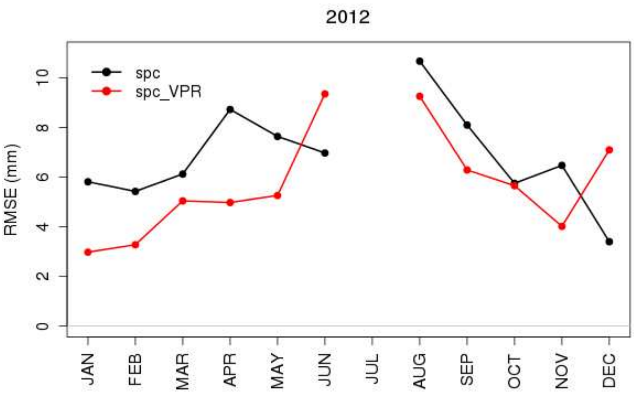
Figure 1. Position of the raingauges for the calculation of the scores. On the left are all the available stations, on the right the stations beyond the Apennine Mountains are excluded.

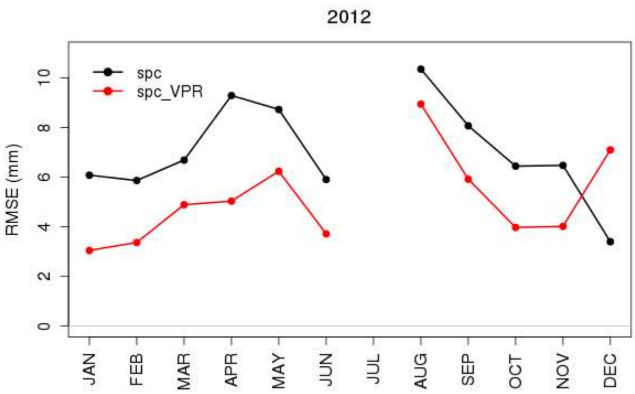
All raingauges

Reduced raingauge set









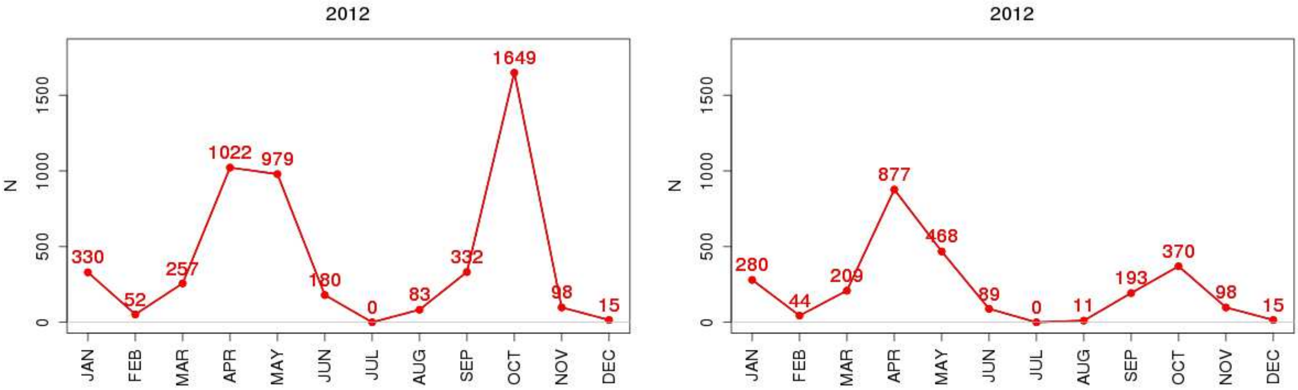


Figure 2. Scores obtained in the whole radar area (on the left) and excluding raingauges beyond the Appennines ridge (on the right).Number of points used to calculate the indices (bottom panels).

In Figure 1 the position of all the available raingauges is shown in the left panel. It is indicated the line of the Apennine ridge and the area covered by the radar located in San Pietro Capofiume (SPC). In the right panel, it is shown the raingauge network, excluding the bulk of the stations positioned beyond the mountains. The statistical scores are computed for the two raingauge sets. In Figure 2 the BIAS and the RMSE are shown in the top and middle panels. On the left are shown the results for the whole raingauge set and on the right for the reduced one. In the plots, each point refers to a month of data, so that statistical index is calculated aggregating all the pairs of hourly precipitation in the considered month. In the bottom panels of Figure 2 the number of occurrences is plotted as a reference. The plots are used to compare the performance of VPR correction (red line) against the standard operational correction (black line)

In July VPR correction was not applied due to the convective regimes in the Po Valley and no statistics is available. Regarding to the left side of Figure 2, a mean improvement is shown in most of the months. In October the VPR gives no improvement, in June the RMSE is increased and the BIAS reduced, and in December a worse result is shown.

Reducing the area used for verification (right panels of Figure 2), only December still shows a worsening of BIAS and RMSE due to VPR correction. A general improvement can be observed confirming that the VPR spatial variability plays a crucial role.

An in-depth investigation shows three main causes of the original error increase, due to the VPR correction .

The first one is represented by the bright band incline. Figure 3 shows a reflectivity section at a given time of a case study when the bright band height variation reaches 800 m along a distance of 30 km. 70 km from the radar the bright band peak is approximately 2000 m high, 100 km far from radar it is approximately 2800 m high. Considering a bright band width of 500-1000 m this means that in the area where the measure intercepts the bright band, the overestimation is increased instead to be corrected from the application of a VPR calculated in the first 70 km of range.

Figure 4 shows the hourly cumulation retrieved from non corrected and from corrected fields in the same time window as the reflectivity section in Figure 3; in yellow are marked the raingauges where the radar error is higher than 10 mm after VPR correction. Far from radar and beyond the Apennines mountains the overestimation due to the bright band is increased instead to be reduced.

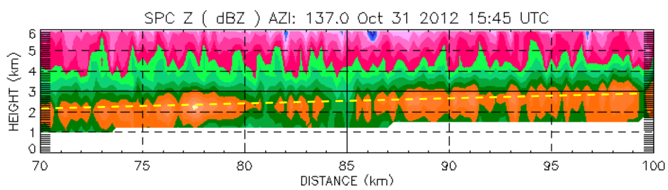


Figure 3 Vertical section of reflectivity on 31 October 2012 at 15:45 UTC

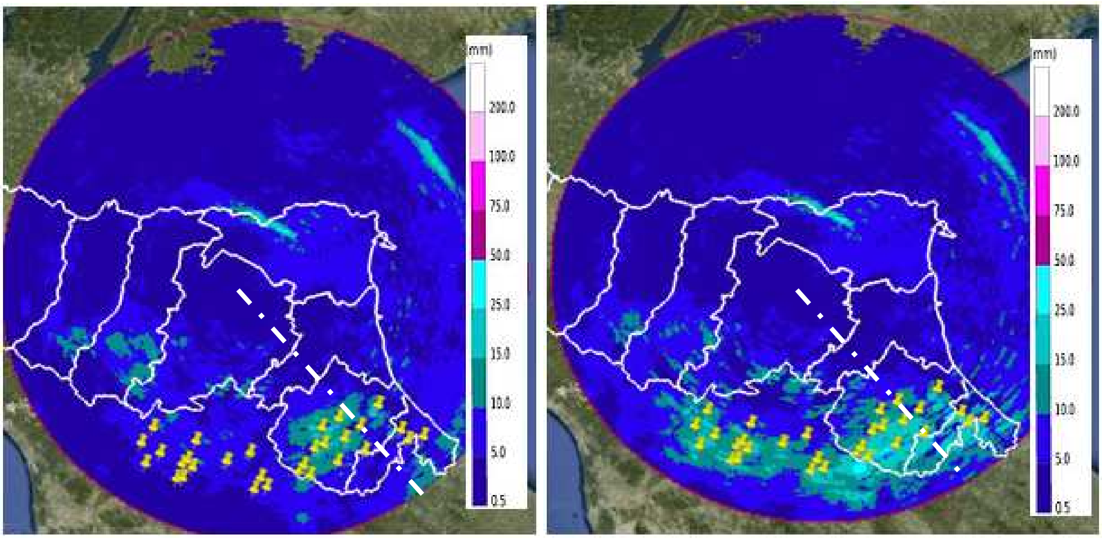


Figure 4 Rain hourly accumulation on 31 October at 16 UTC before (on the left) and after (on the right) VPR correction. In yellow are marked the raingauges where the difference between radar hourly accumulation after VPR correction and raingauges measure is higher than 10 mm. In white is marked the section of Figure 2.

The second problem is represented by the melting at the ground. If the algorithm of VPR correction does not recognize and handle this situation the correction introduces an overestimation in the whole area. In Figure 5 is represented a VPR with bright band at the ground and the map of applied correction. In the whole area the correction is positive and reaches 12-14 dBZ beyond the Apennines mountains.

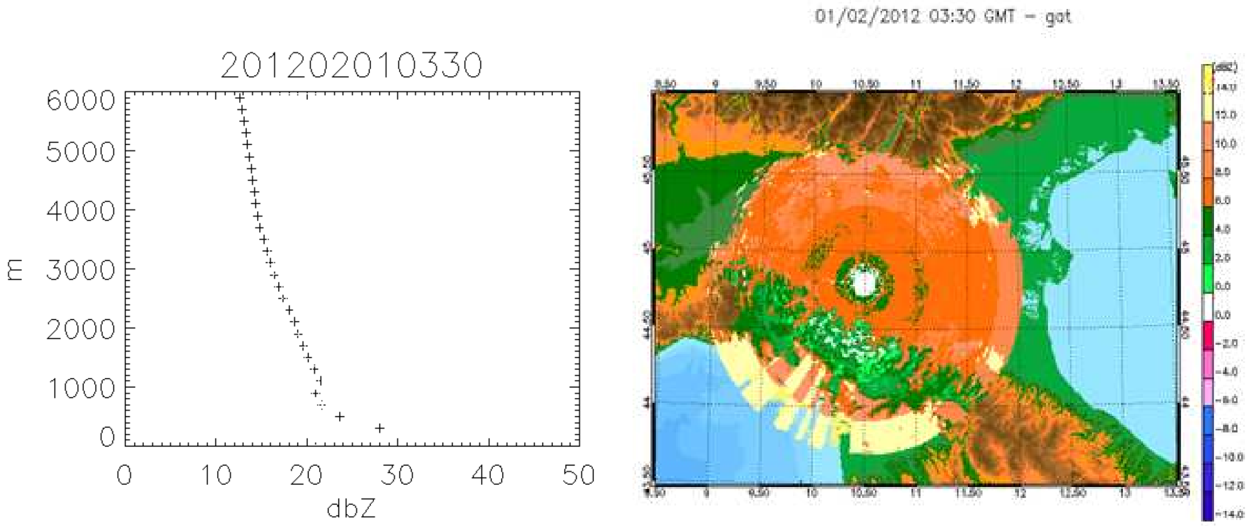


Figure 5. VPR (on the left) and VPR correction map (on the right) on 01 February 2012 at 03:30 UTC

The third problem is represented by the mixing of stratiform and convective precipitation. If the profile, retrieved in an area where stratiform precipitation is predominant, is applied to a convective cell, an overestimation is generated.

In Figure 6 are represented a profile retrieved at a time of ‘mixed precipitation’ and the applied correction. Below (Figure 7) is represented a section with a convective cell at the time of Figure 6 and finally, in the bottom, the hourly cumulation obtained without and with VPR correction (Figure 8) in the time window containing the instant of Figure 6. Yellow markers indicate rain gauges were the radar overestimation is higher than 10 mm after VPR correction. They are concentrated close the convective section marked by a white dashed line.

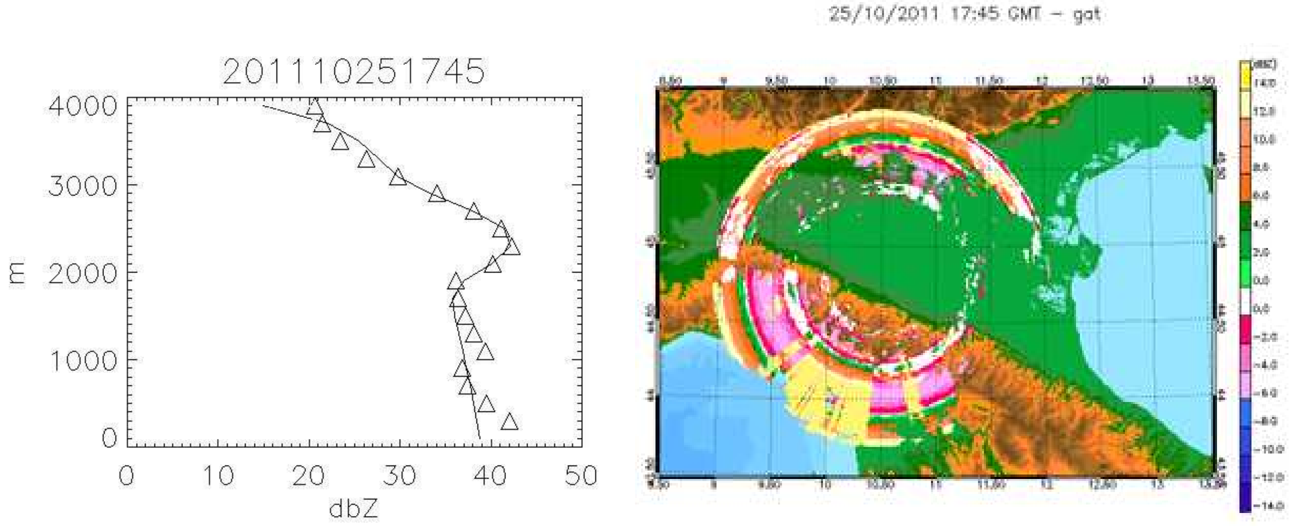


Figure 6. VPR points and their fitting function plot (on the left) and VPR correction map (on the right) on 25 October 2011 at 17:45 UTC.

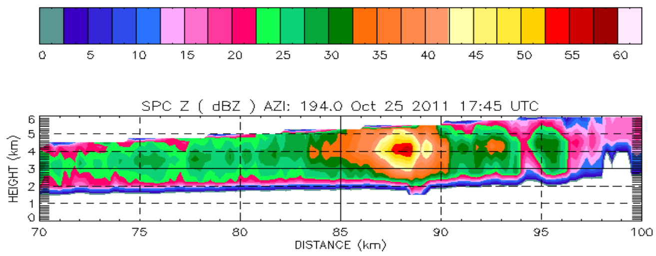


Figure 7. Vertical section of reflectivity on 25 October 2011 at 17:45 UTC

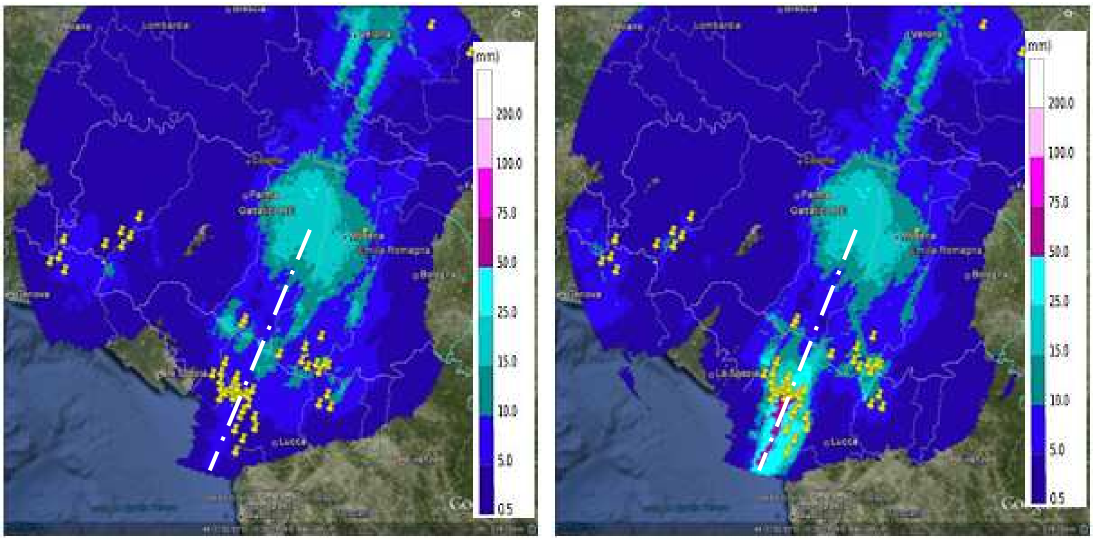


Figure 8. Rain hourly cumulation on 25 October 2011 at 18 UTC before (on the left) and after (on the right) VPR correction. In yellow are marked raingauges position where the difference between radar hourly accumulation after VPR correction and raingauges measures is higher than 10 mm. In white the section of Figure 7.

4 Conclusions

The application of vertical profile of reflectivity correction contributes, on the average, to produce more reliable precipitation estimates.

In some cases it introduces errors, especially when the homogeneity of the profile in the area is not guaranteed. Three cases were described here where this occurs: bright band incline, melting at the ground and mixed stratiform-convective precipitation. These cases should be dealt with to obtain a method of VPR correction which is in general applicable with ameliorative effect.

References

Fornasiero A. Radar quantitative precipitation estimation at Arpa-Sim . A critical approach to retrieve the precipitation at the ground level [Conference] // Fifth European Conference on radar in meteorology and hydrology. - 2008.

Germann U. and J. Joss Mesobeta Profiles to Extrapolate Radar Precipitation Measurements above the Alps to the Ground Level [Journal] // Journal. - March 2002. - Vol. 41. - pp. 542-557.