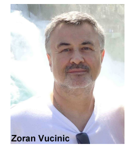
# Comparison of polarimetric techniques for precipitation estimation in Serbia

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## 1 Introduction

New dual polarization radar in Serbia, Selex Gematronik METEOR 600S, has been in operation on the Jastrebac location (21.443350E, 43.391160N and height above MSL 1522 m) since September 2013. This is the second radar in Serbia with dual polarization, however the first one with all dual polarization parameters (on the location Fruska Gora only ZDR is available). Rainbow 5.31.0 software is used for data analysis and display, which allows the rainfall intensity algorithm with and without using dual - poll parameters, and also the correction of data depending on meteor/non meteor classification.

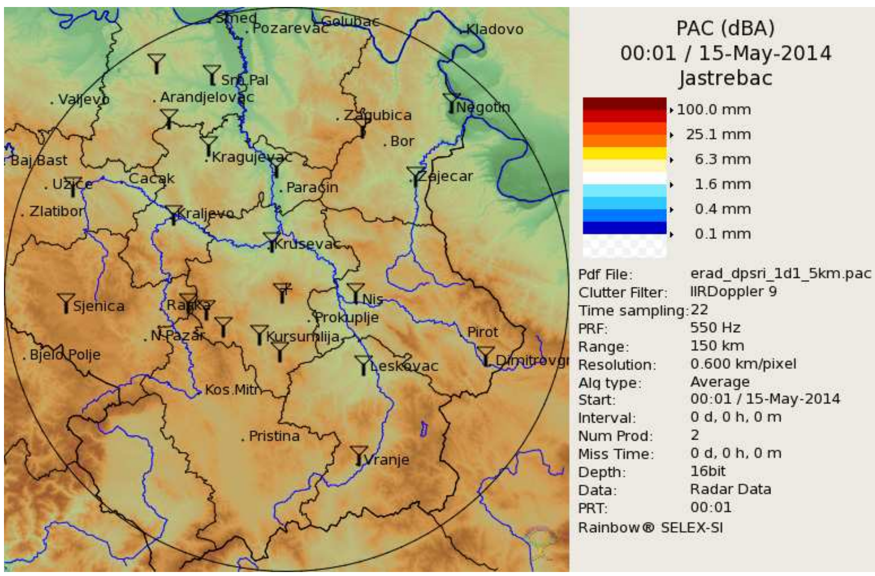


*Figure 1:Teritory covered by 150 km range radar data with available rain gauges*

We used hourly and daily amount of precipitation from the rain gauge networks and compared them with the data obtained from the radar parameters using SRI (Surface Rainfall Intensity) and DPSRI (Dual Polarization Surface Rainfall Intensity) algorithms. For precipitation estimation we used 150 km range radar data, as shown in Figure 1. There are 22 rain gauges in this area, but due to the terrain configuration, the defined surface rain intensity product provides data only for 5 of them.

Rain gauge networks used in this paper are comprised of weighing rain gauge OTT pluvio2 200* and MicroStep-MIS MR2** rain gauge (tipping bucket), their locations are provided in the Table 1.

*Table 1:Location of rain gauges.*

| Location | E | N | Height above MSL (m) |
|---|---|---|---|
| Prolom Banja* | 21.400016 | 43.046686 | 659 |
| Lukovska Banja* | 21.033199 | 43.165570 | 663 |
| Blazevo* | 20.923132 | 43.247353 | 983 |
| Kopaonik** | 20.800000 | 43.280000 | 1710 |
| Kursumlija** | 21.270000 | 43.130000 | 382 |

This paper is a preliminary study with the purpose of defining a best solution for radar based estimation of precipitation.

## 2 DATA

In order to perform analysis, three days (13, 14 and 15 May 2014) with the strong stratiform cloudiness above the territory of Serbia were selected, for which data about hourly precipitation sums from automatic rain gauges as well as manual measured daily precipitation sums from the network of main meteorological stations in Serbia were available.

On the radar Jastrebac, Scheduler was activated running volume scan every 5 minutes. Volume scan encompasses 12 elevations, in a range from 0.5 to 25°, collecting all availabe data types (dBuZ,dBZ,V,W,ZDR,uPhiDP,PhiDP,KDP,RhoHV), PRF=550 and given the terrain configuration, Doppler filter is being used to ensure that clutters don't affect radar data.

Based on the volume data obtained by such scanning, for the purpose of this analysis, the products were generated in order to make them comparable with the rain gauge data. Surface Rain Intensity (SRI) products were generated first based on the data about radar reflectivity and Dual Pol Surface Rain Intensity (DPSRI), which in the calculation of precipitation intensity utilize dual polarization features. For calculation of precipitation accumulation and precipitation sums on the location of rain gauge, we have selected this product primarily because of DPSRI product existence in Rainbow5 software, in which the correction of precipitation intensity is defined on the basis of dual polarized data types.

The SRI generates an image of the rainfall intensity in a user-selectable surface layer (SRI level), and for user-selectable parameters in Z-R relation ($Z = aR^b$ , Z in [$mm^6/m^3$] and R in [mm/h]). The SRI data are processed on this terrain-following layer, i.e. at a constant height above ground. The ground heights are usually calculated from an orographical map (DEM model). This map is also used to check for regions, where the user-selected surface layer is not accessible to the radar. The defined Z-R relation is used for every location of the SRI plane, i.e. it is independent of geographical location and height.

The DPSRI algorithm basically performs in the same way as for the SRI, i.e. an image of the rainfall intensity in a user-selectable, terrain-following layer is generated. The only difference to SRI is that the rainfall rate is not only calculated from dBZ data, but from dual polarization data.

The polarimetric measurements are used to calculate a rainfall rate R automatically, For S-Band radars, the prototype NEXRAD algorithm is used (Software Manual Rainbow 5, Products and Algorithms, 2013, Ryzhkov et al., 2005):

$$R = \frac{R(Z)}{0.4 + 5.0\left|Z_{dr} - 1\right|^{1.3}} \qquad \textit{for } \mathrm{R(Z)} < 6 \textit{ mm/h}$$

$$R = \frac{R(K_{dp})}{0.4 + 3.5\left|Z_{dr} - 1\right|^{1.7}} \qquad \textit{for } 6 < \mathrm{R(Z)} < 50 \textit{ mm/h}$$

$$R = R(K_{dp}) \qquad \textit{for } \mathrm{R(Z)} > 50 \textit{ mm/h}$$

where $R(Z) = {}_{1/b}Z^{1/b} \Leftrightarrow Z = aR^{b}$, and $R(K_{dp}) = 44.0\, K_{dp}^{0.822}$, for *KDP* > 0, and Z-R parameters a and b are user selectable.

In our case, considering the height of the radar Jastrebac, SRI and DPSRI products were generated for the 1.5km level from the ground. The standard Z-R relationship $Z = 200R^{1.6}$ was used for the case of stratiform cloudiness for both products.

From both products obtained in such manner, Precitipation Accumulation products were generated first for the 1-hour accumulation period on every hour, subsequently with emanating products Point Rainfall Total (PRT) for the locations of automatic rain gauges shown in Figure 1. However, due to radar altitude, terrain configuration and the nature of SRI level that follows the same, for rain gauges on low altitudes and greater distance from the radar, the precipitation intensity couldnt be determined with this product, hence only locations shown in Table 1 were taken into account in the further analysis. Figures 2 and 3 illustrate the aforementioned, depicting SRI and DPSRI products combined with PRT products obtained from the same ones.

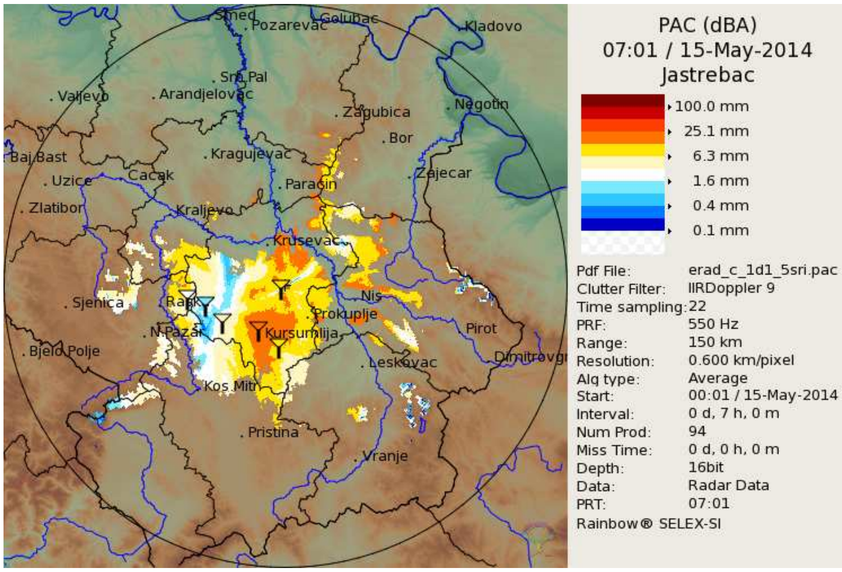


*Figure 2:Precipitation accumulation and Point Rainfall Total product generated from Surface Rainfall Intensity*

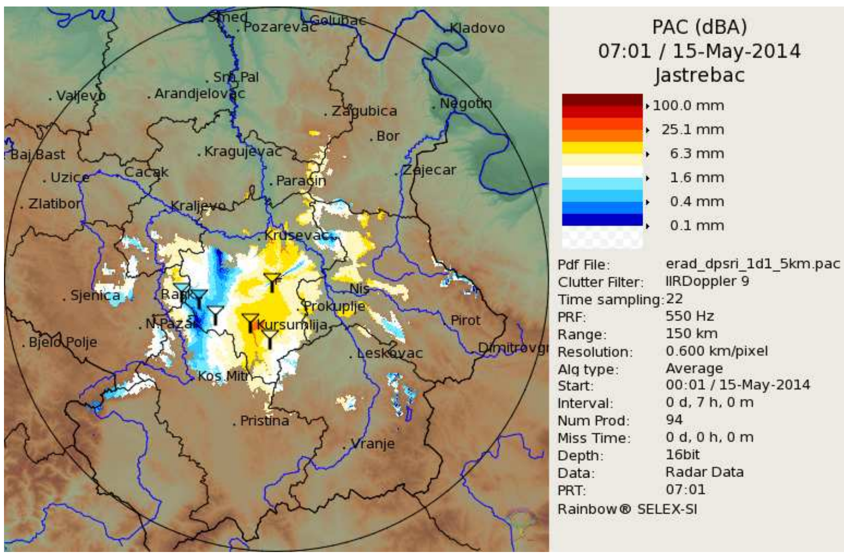


*Figure 3:Precipitation accumulation and Point Rainfall Total product generated from Dual Polarization Surface Rainfall Intensity*

With the processing of PRT products obtained with Rainbow 5 software, the data basis suitable for futher analysis was prepared.

## 3 RESULTS

Scattering plot of pairs:

1. Radar precipitation sums obtained from SRI – precipitation sums measured with rain gauge and
2. Radar precipitation sums obtained from DPSRI - precipitation sums measured with rain gauge

as well as calculation of correlation coefficient and linear regression equation are firstly performed for all available data (Figures 3a and 3b). Given the fact that results for calculation without correction on the basis of dual-polarized parameters and the utilization of those were not on the satisfactory level, the analysis is carried out for the each available location separately (Figures 4a and 4b).

*Table 2: Correlation coefficient and dependent equation of 1-hour precipitation sums measured with automatic rain gauge from the amount determined on the basis of radar data*

| data | Radar precipitation sums from SRI | | Radar precipitation sums from DPSRI | |
|---|---|---|---|---|
| | Coefficient correlation | Equation | Coefficient correlation | Equation |
| All automatic rain gauges | 0.50 | y = 0.5477x + 0.5363 | 0.51 | y = 0.9557x + 0.5556 |
| Blaževo | 0.85 | y = 0.7710x + 0.3548 | 0.85 | y = 1.4188x + 0.3848 |
| Lukovska Banja | 0.86 | y = 0.6534x - 0.1072 | 0.85 | y = 0.9315x + 0.0332 |
| Prolom Banja | 0.75 | y = 0.6526x + 0.4467 | 0.75 | y = 1.3947x + 0.4362 |
| Kopaonik | 0.04 | y = 0.1652x + 0.9525 | 0.01 | y = 0.0417x + 0.9819 |
| Kuršumlija | 0.24 | y = 0.1289x + 0.2573 | 0.23 | y = 0.2051x + 0.2662 |

Based on the analysis of the obtained data, we have concluded that radar measured precipitation sums from defined products are not suitable for the location MS Kopaonik. Products, SRI and DPSRI caluculated precipitation intensity on the specific height from the surface, which in our case was 1.5km. As the altitude of MS Kopaonik is 1522 m, it means that the precipitation intensity was determined on the altitude of 3.0 km and having in mind it implies intensive, though stratiform cloudiness, its highest radar reflectivity was substantially below that level. That is the reason why radar determined precipitation sums are significantly below the measured ones and why the strong correlation between radar determined and measured values can't be established.

The poor results for the location MS Kursumlija could not be explained this way. Therefore, the daily precipitation sums were generated as well, making comparison for that MS with manually measured daily precipitation sums (Table 3). In this particular case, it turned out that 24-hour accumulation of precipitation calculated with radar using dual-polarized features corresponds well with the measured precipitation sums. Since MicroStep-MIS MR2 rain gauge (tipping bucket) is on this location, we can assume that the extreme precipitation intensity in specific time intervals led to skipping in registration of precipitation sums, hence this data was regarded as non-representative.

*Table 3: Comparison of 24-hour preciptiation sums measured manually on MS Kursumlija with sums obtained by radar*

| 24-hour precipitation | 15.05. | 16.05. |
|---|---|---|
| Measured manually | 18.4 | 6.3 |
| Calculated on the basis of SRI | 32.7 | 14.8 |
| Calculated on the basis of DPSRI | 19.6 | 8.2 |

For the other three location, equipped with weighing rain gauge OTT pluvio$^2$ 200, coefficient correlation is ≥0.75, hence those data are taken into consideration of difference of precipitation sums determined by radar with and without using dual-polarized parameters. Those data are shown in Table 4 as well as in Figures 4 and 5.

Generally speaking, for those data, one can conclude that correlation between 1-hour precipitation accumulations measured by radar and rain gauges is identical for both types of calculation, nevertheless, the amount of precipitation is overestimated when dual polarization features are not in use, whereas, when the precipitation intensity has undergone corrections on the basis of dual-polarized parameters, 1-hour accumulations of precipitation are smaller than those measured by rain gauge.

Table 4 shows correlation coefficient and linear regression equation separately for two cases when 1-hour precipitation sums were below 0.5mm and those above that amount. The conclusion that can be drawn is that the best results were obtained for the locations 35 to 45km from the radar location and for the precipitation sums above 0.5mm/h.

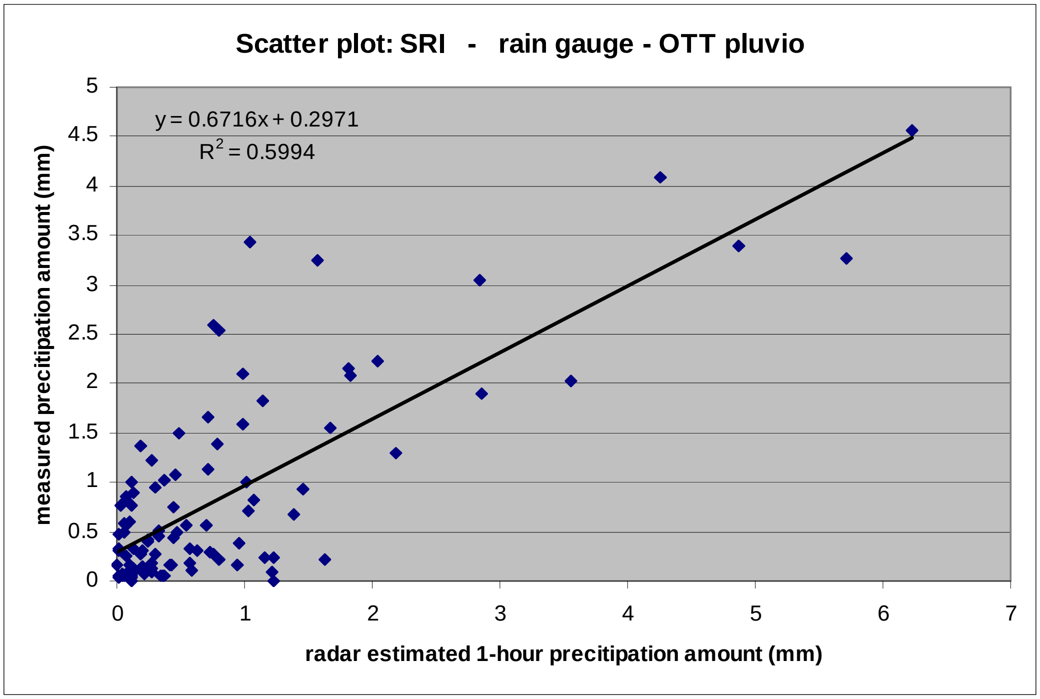


*Figure 4: Scatter plot showing the relationships between radar estimated precipitation amount based on reflectivity and measured precipitation amounts*

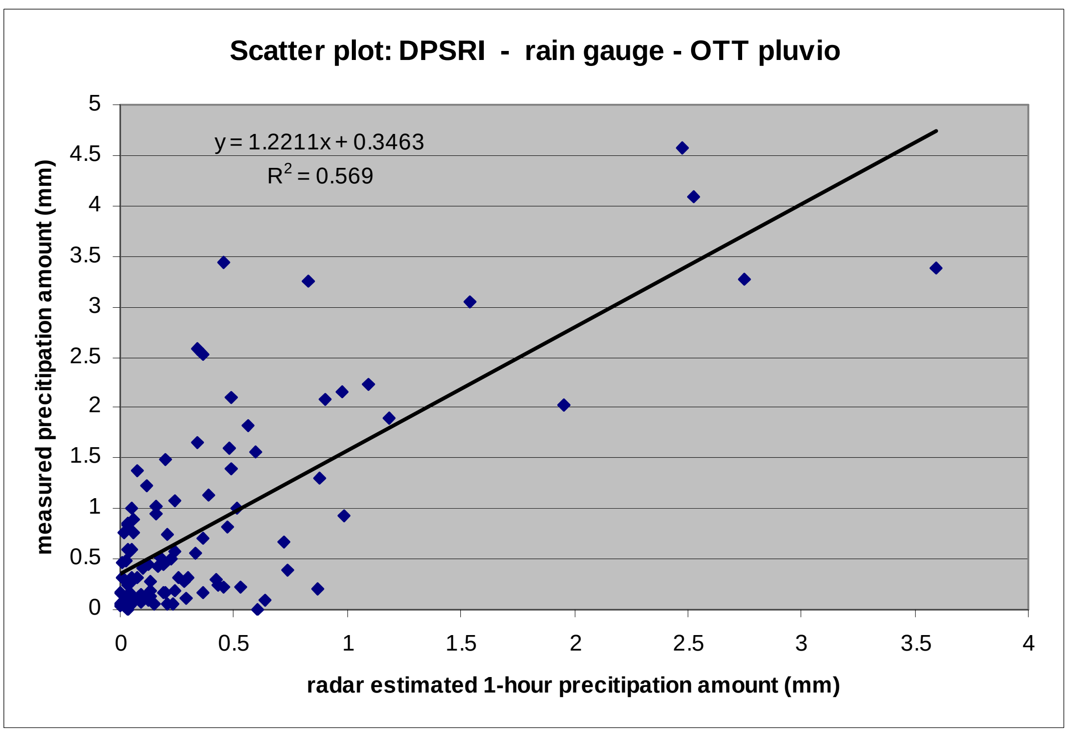


*Figure 5:: Scatter plot showing the relationships between radar estimated precipitation amount based on dual-pol data and measured precipitation amounts*

*Table 4: Correlation coefficient and dependent equation of 1-hour precipitation sums measured with automatic rain gauges OT from the amount determined on the basis of radar data.*

| data | Radar image precipitation from SRI | | Radar image precipitation from DPSRI | |
|---|---|---|---|---|
| | Correlation coefficient | Equation | Correlation coefficient | Equation |
| weighing rain gauge OTT pluvio$^2$ 200 | 0.77 | y = 0.6716x + 0.2971 | 0.75 | y = 1.2211x + 0.3463 |
| weighing rain gauge OTT pluvio$^2$ 200, r<0.5mm | 0.25 | y = 0.6663x + 0.2657 | 0.50 | y = 2.2274x + 0.197 |
| weighing rain gauge OTT pluvio$^2$ 200, r>0.5mm | 0.71 | y = 0.6372x + 0.3972 | 0.76 | y = 1.1798x + 0.3537 |

## 4 CONSLUSION

The results obtained in this preliminary study are optimistic with regard of finding the best solution for radar based estimation of precipitation and further research.

## References

**Bringi V.N., Thurai M., and Hannesen R., 2004.** Inproved Dual-Polarization Radar Applications – Algorithm AMS-Gematronik GmbH- 68 pp.

**Selex Systems Integration GmmbH,** Instruction Manual Rainbow® 5 Product&Algorithms Release 5.31.0 (2010-11-01)