366 RAD4ALP, THE NEW SWISS DOPPLER POLARIMETRIC WEATHER RADAR NETWORK: DATA QUALITY AND FIRST RESULTS

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1. INTRODUCTION

MeteoSwiss is currently engaged in the renewal of its operational radar network towards what will constitute its 4th generation. The new generation provides several major new features respect to the previous one, both at hardware and software level (See Germann et al. 2006 for an overview of the 3rd-one). Most relevant is the introduction of two new radar sites and the use of polarimetry in the whole network. This paper describes the main characteristics of the new setup. Section 2 provides an overview of the radar network and scanning strategy, section 3 describes the current signal processing, section 4 analyses the data quality, section 5 discusses the performance of the new polarimetric clutter filter under test. Conclusions and future developments are discussed in section 6.

2. RADAR NETWORK

The new weather radar sensors are the Meteor 635C from Selex-Gematronik (See the technical brochure “Meteor 600C and 635C Weather Radar”). The transmitted power is larger than 400 kW and the antenna half power beamwidth is 1°. A “short” pulse is transmitted, 0.5 μs, in order to get a high range resolution, 83.3 m. To minimize receiver losses, the former is mounted on the elevation antenna, allowing for an improved sensitivity. The radome is composed of quasi-random panel cuts in order to minimize its influence into the polarimetric variables. The systems are Doppler (providing Doppler velocity v_D and Doppler spectrum width w_D) and polarimetric with simultaneous transmission and reception of vertical and horizontal polarization. The basic polarimetric parameters provided are: horizontal and vertical reflectivity Z_h, Z_v, differential reflectivity Z_{dr}, co-polar correlation coefficient ρ_{hv} and co-polar differential phase ϕ_{dp}. In addition, the lag-1 and lag-2 standard deviations of the fluctuation, the wide band noise and the mean phase difference between consecutive scans are computed.

The scanning strategy consists on a very fast volumetric scan covering 20 elevations (numbered from 1 to 20 from -0.2° to 40°) repeated every 5 minutes. The volumetric scan is divided in two half scans, one covering the even elevations and the other covering the odd elevations. As a result, every 2.5 min the angular range of the volumetric scan is covered.

At the moment, 3 new sensors have substituted those of the 3rd generation in the sites of Albis, La Dôle and Monte Lema. Two new radars are planned for installation, one at la Plaine Morte, in the Vallais Canton, and the other on Weissfluhgipfel, in the Grisons Canton. The two new radars will enhance the coverage of some areas in the Alps, as well as provide backup for the current systems. It should be noticed that the new sites are at an altitude close to 3000 m. Fig. 1 shows the position of the radar sites.

Fig. 1 Sites of the rad4alp sensors. Pink: installed systems. Blue: Planned.

3. SIGNAL PROCESSING CHAIN

The basic polarimetric and Doppler moments are computed in high resolution (1° x 83.3 m) polar coordinates (Hereafter PH) at the radar site and transmitted to a central server for further processing. At the central server a detection tree (DT) clutter filter (Germann and Joss, 2004) is applied and the data is decimated to a range resolution of 500 m (Hereafter PL). The PL data is further processed to obtain secondary products such as precipitation intensity, hydrometeor type, probability and estimated size of hail on the ground, etc. The secondary products are then automatically distributed to the end users. They are as well displayed on an intranet website. The same site shows the polarimetric values and the non-clutter-filtered

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reflectivity of the 3 lowest elevations. This allows a quick assessment of the performance of the processing.

There are actually 3 parallel processing chains, one producing the operational products, another one devoted to final tests of products ready for deployment and a 3rd one devoted to the development of new products. This setup allows an early detection of bugs in the new products as well as a faster development.

The PH data are stored for several months only while the PL data and the secondary products are stored perennially, allowing the re-processing of the data and its use in climatological studies.

Currently, the polarimetric data are not used in the operational products. A new processing chain using polarimetry is being tested on the development chain. In the new chain, the DT filter incorporates additional steps where decisions are made according to thresholds on ρ_{hv}, the value of Z_{dr} in low Z_h and the radial textures of ρ_{hv}, ϕ_{dp}, Z_{dr} and Z_h. There have been also modifications in the way the passage from PH to PL is performed. In the operational version the PH polarimetric variables are averaged regardless of whether they correspond to noise or precipitation samples. The new version only considers precipitation samples to perform the averaging. In addition, the PL Z_{dr} value is computed as $10*\log10(\Sigma(Z_h)/\Sigma(Z_v))$, and the PL ϕ_{dp} value is obtained as the median of the valid samples.

4. DATA QUALITY

4.1 *Monitoring Parameters*

Receiver calibration is performed injecting a noise-like signal from a noise source with a known output power into the receiver front end when the radar is scanning at the two highest elevations. Thus a calibration is performed every 2.5 min. The injection of the signal is synchronized with the pulse repetition frequency so that it covers ranges from 32 to 65 km. While performing the same scan, the noise level is estimated from gates ranging between 67 and 97 km (see Gabella et al, 2010 for details).

Daily statistics of the performance of the system are computed. The pointing accuracy is monitored by comparing the known position of the sun with the measured position when the sun hits the main beam (Huuskonen and Holleman, 2007). The gain and the stability of the receiver of each individual polarimetric channel and the bias between them is monitored as well using sun hits (Holleman et al, 2010a and 2010b).

The bias of Z_h between radars is monitored by inter-comparing the hourly average of the PL reflectivity at collocated and equi-volumetric range bins. Only those bins not affected by clutter, not heavily affected by attenuation and with very low partial beam blockage are used in the inter-comparison.

Zdr, ρ_{hv} and ϕ_{dp} are monitored following similar techniques than those described in Figueras i Ventura et al. (2012).

Z_{dr} is monitored by computing its daily average in moderate rain (20-22 dBZ) for each azimuth and elevation using the PL data. A pixel is considered to be rain when the altitude of the main beam is below the iso-0° altitude obtained from the COSMO model (up to 50 km range), and it has low precipitation attenuation (less than 20° ϕ_{dp}) and high ρ_{hv} (more than 0.97°).

ρ_{hv} is monitored by computing its daily 80% quantile in rain for each elevation using PL data. The valid range is computed as for Z_{dr}. Data with Z_h between 20 and 40 dBZ is gathered.

The daily ϕ_{dp} offset is computed by identifying and calculating the average of the first 5 consecutive precipitating range gates in each azimuth and elevation (i.e. with valid reflectivity above 20 dBZ). The average of the collected data is then performed.

4.2 *Performance*

Long term monitoring of the ϕ_{dp} offset proofs the sensors to be rather stable. Albis has an offset of about -10°, Dole roughly 120° and Lema -60°. Fig. 2 shows as an example the Dole ϕ_{dp} offset in 2013.

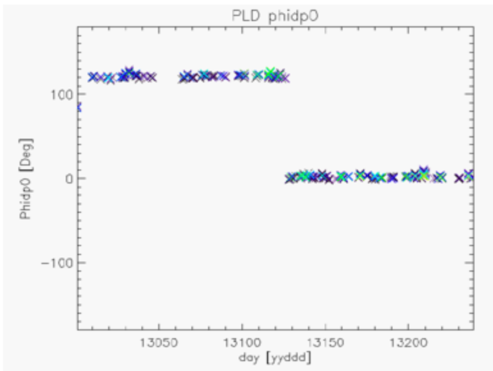

Fig. 2 Dole ϕ_{dp} offset in 2013. Bluish colors correspond to lower elevations. The offset has been software corrected from day 120.

The long term monitoring of ρ_{hv} reveals that the antenna characteristics are satisfactory and that the system is stable. Values of ρ_{hv} are roughly 0.99 for all the systems. Fig. 3 shows the ρ_{hv} monitoring of Albis as an example. The lower values at lower elevations may be attributed to the fact that operationally the measurement is influenced by noise and residual clutter.

The long term monitoring of Z_{dr} using both the sun and measurements in light rain shows that the sensors are reasonably stable. The biases of Albis and Dole are very close to 0 dB, particularly after a change in the calibration constant performed during summer but the bias of Lema is close to 0.8 dB as shown in Fig. 4. It should be noticed that the stringent criteria used for the estimation results in few measurements available during winter.

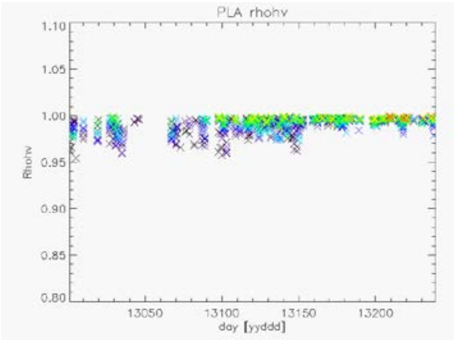

Fig. 3 Albis ρ_{hv} 80% quantile in rain in 2013.

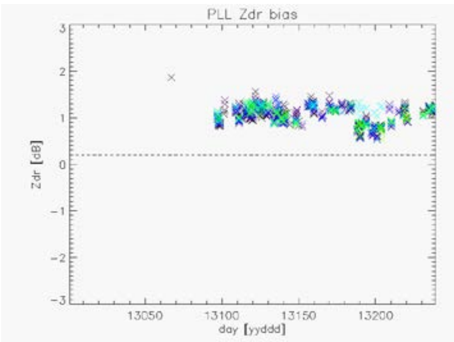

Fig. 4 Lema Z_{dr} bias in 2013.

The analysis of both the sun hits and the measurements of reflectivity show that for most of 2013 Dole and Lema were in very good agreement while Albis was underestimating respect to the other two radars. This situation improved quite a lot when an offset was introduced in the Radar Signal Processor constant in Albis. Currently the radars are in agreement within 1 dB.

5. POLARIMETRY IN CLUTTER FILTERING

So far the polarimetric parameters are not used in the computation of the operational products. A first step towards its introduction has been performed by introducing criteria based on the polarimetric variables in the dtfilter in the development processing chain. In addition the passage from high to low resolution of the polarimetric variables have been modified.

The new criteria have proved to effectively filter out clear air and far range ground clutter echoes. An example of such capacity can be seen in Fig. 5. The residual ground clutter signal visible in the quantitative precipitation estimation (QPE) product in Italy and France in the operational product (5a) is not visible in the one produced in the development chain (5b). At the same time, the light scattered rain north of Switzerland and the precipitation in Switzerland is well captured.

a)

b)

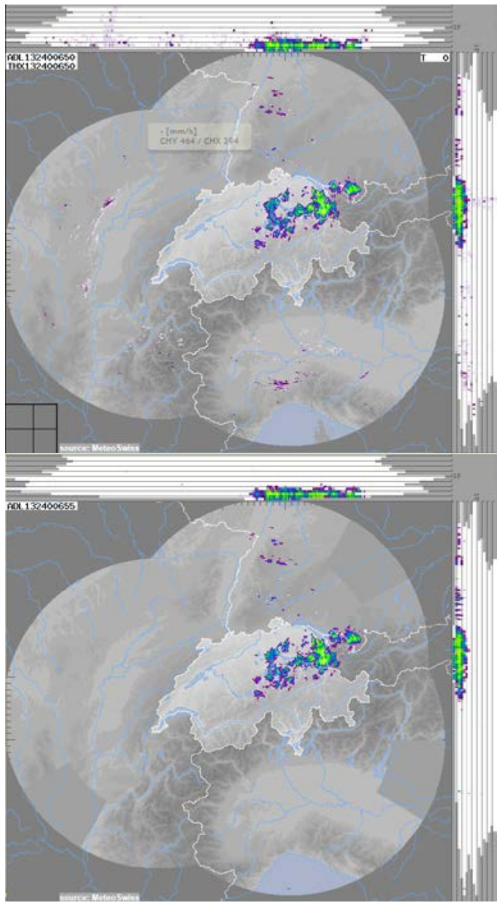

Fig. 5 Example of QPE product: a) Operational, b) Produced by development chain

The performance of the development chain have been further assessed by comparing radar QPE pixels with collocated rain gauge measurements. An example of such comparison can be seen in Fig. 6. The Figure shows the evolution of the hourly bias between radar QPE and rain gauge measurements. As shown in Fig. 6a the new clutter filter has little impact on the bias. It has also little impact on CombiPrecip, the product that corrects radar data using rain gauges (Fig. 6b) (See Sideris et al., 2013). The daily statistics for the event shown in Fig. 6 are shown in Table 1. They confirm that indeed the new clutter filter has little impact on the hydrological performance during rainy days.

6. CONCLUSIONS AND FUTURE WORK

The renovation of the Swiss Weather Radar Network underway will result in a significant enhancement of its capabilities in terms of coverage, sensitivity, accuracy and flexibility to develop new products. Currently 3 sensors have been upgraded. Tools to assess the performance of the systems have been developed. The new sensors have a satisfactory stability and are reasonably well calibrated, although Lema suffers from positive Z_{dr} bias.

Product	Bias [dB]	MRTE [mmh^{-1}]	Scatter [dB]
Dev R	-0.450	0.084	2.592
Dev R+ G	0.039	0.095	2.480
Op R	-0.543	0.082	2.642
Op R+G	0.033	0.094	2.405

Table 1 Statistics of the comparison between radar products and rain gauges. There were a total of 851 rain gauges measuring more than 0 mm in an hour and 508 rain gauges measuring more than 5 mm in an hour.

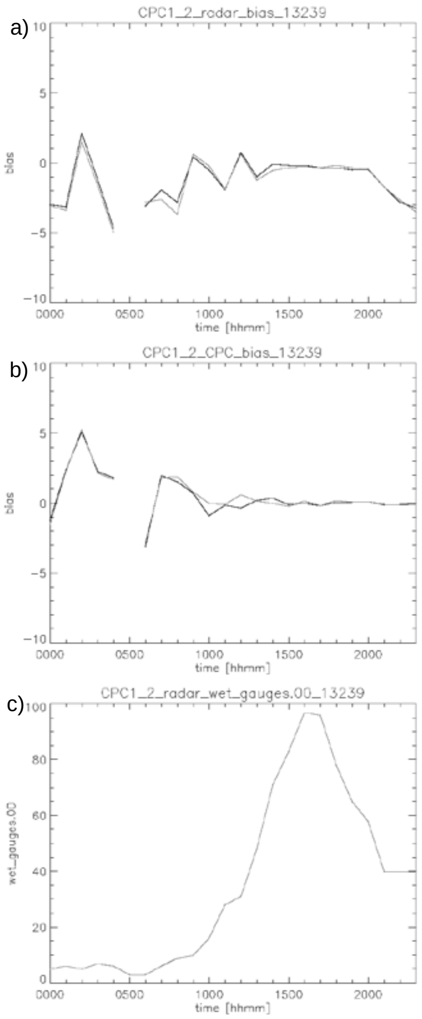

Fig. 6 Evolution of the hourly bias between radar and rain gauge measurements for the development (black line) and operational (grey line) products: a) radar only data, b) radar data adjusted with rain gauges (independent set), c) number of wet rain gauges during the hour.

A new DT filter using polarimetry is currently under test. The first results are satisfactory. The new filter successfully eliminates clear air and residual ground clutter without affecting the precipitation detectability or the performance of the radar QPE products.

The road ahead is to increase the operational use of the polarimetric data and use it extensively in QPE and hydrometeor classification. It should be noticed though that the fast scanning results in few independent samples being available to compute the polarimetric variables. Therefore they are heavily affected by fluctuation noise and techniques to minimize it, such as adaptive filtering of ϕ_{dp} or multi-lag estimators should be developed. The fast scan is necessary in order to minimize the impact of clutter in the Alps.

Another aspect that should be improved is the estimation of noise power. Currently it is performed at high elevation. However, the noise level is highly dependent on emission from the ground. Considering the Swiss orography, an estimation on a ray basis should be implemented. Regarding monitoring, the self-consistency technique should be introduced in order to monitor the absolute calibration of the reflectivity.

In the near future a correction of precipitation-induced attenuation using ϕ_{dp} is going to be introduced and the performance of K_{dp} to estimate rain is going to be analyzed.

It should also be evaluated the convenience of keeping the DT filter or substituting it by a probabilistic algorithm such as fuzzy logic or neural networks. In a second stage, the possibility of introducing Spectral polarimetry at the radar site will be evaluated.

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