

PERFORMANCE ESTIMATION OF BUCHAREST MULTIWAVELENGTH LIDAR DURING THE EARLI09 CAMPAIGN

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Aerosolul atmosferic, inclusiv norii, joacă un rol decisiv în bilanșul radiativ al Pamântului. Structura verticală este complexă și mereu schimbătoare. Sistemele lidar folosesc radiația laser pentru a excita atmosfera. Semnalul retroîmprăștiat este apoi detectat și analizat. Dincolo de limitările datorate zgomotului (de fond sau electronic), sistemele lidar au și limitări geometrice care trebuie estimate. Scopul campaniei EARLI09 a fost de a compara sisteme lidar mobile de referință sau nu din EARLINET în diverse condiții atmosferice. Evaluarea datelor s-a făcut folosind SCC, analiză calitativă și cantitativă.

Atmospheric aerosols, including clouds, play an important role in the earth's radiation budget. Their vertical structure is complex and changing continuously. Lidars make use of a laser to excite the atmosphere. The backscatter signal is detected and analyzed. Apart from noise limitations (background radiation and electronic noise of the components), lidars also have geometrical limitations which have to be assessed. The purpose of EARLI09 campaign was to compare reference and non-reference mobile lidar systems in EARLINET in various atmospheric conditions. The evaluation of data has been done using Single Calculus Chain (SCC), qualitative and quantitative analysis.

Keywords: lidar, aerosol, EARLINET, intercomparison

1. Introduction

Atmospheric aerosols, including clouds, play an important role in the earth's radiation budget. Their concentrations in the atmosphere vary widely with altitude, time, and location. Their vertical structure of the profiles is complex and changing continuously. The physical properties of aerosols determine whether they contribute to the net heating or cooling of the Earth's climate. **LIDARs (LIght Detection And Ranging)** are laser based systems for atmosphere sounding,

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which allow suspended particulate detection along the sounding direction, with a very good precision and in a very short time (seconds).

RALI (Raman Aerosol Lidar), the multiwavelength lidar system of National Institute of R&D for Optoelectronics is a state-of-the-art instrument, operating at seven wavelengths and with a maximum of 12 channels. Several technical characteristics are shown below.

Transmitter:

- YAG:Nd laser, 10Hz, 330mJ total, 4ns, 3 harmonics (1064, 532, 355 nm output wavelengths)
- 2 exit axes: VIS+IR, UV
- beam expanders: 5x, 4x

Receiver:

- Cassegrain telescope, 400mm, 1mrad (initial), 4m focal length
- 4 elastic channels (1064, 532 (cross and parallel), 355nm), 2 Nitrogen vibrational Raman channels (607, 387nm) and water vapor channel (408nm)
- 1 channel only analog (1064nm), 1 channel only photon counting (408nm), 5 channels double detection
- 40MS/s, 12 bit acquisition

As described in previous papers [00], by using elastic and Raman channels, it is possible to extract both extinction and backscatter coefficients simultaneously. Advanced lidar systems – such as RALI - delivers at the same time elastic and inelastic Raman signals, which can be used into the inversion procedure to obtain all optical parameters, because they describe the same atmosphere. Usually, Nitrogen molecules are used to obtain the Raman signal, because Nitrogen is considered a gas with constant concentration over time and has a proper Raman spectrum, easy to be separated from Rayleigh signal.

2. Methodology

Lidars are optoelectronic instruments, therefore limited by noise (background radiation and electronic noise of the components), and optics/geometry. The main purpose of EARLI09 campaign – EARlinet Reference Lidars campaign 2009 - was to compare reference and non-reference mobile lidar systems in EARLINET in various atmospheric conditions and to validate all channels showing acceptable deviations. A secondary objective of the campaign was to test the SCC 0 for the processing of all data acquired, to adjust and improve instruments and data handling procedures. The campaign was organized at the Institute for Tropospheric Physics, in Leipzig, Germany, from May 4th to May 29th, 2009. During 24 days of measurements, 12 groups from all over Europe operated 16 lidar systems and a total number of 90 channels. 58 of the total channels are daytime channels (elastic backscatter channels), and only 32 involves Raman nighttime technique. The measurements were taken for 3-hours sessions whenever the weather permitted, 1-minute time resolution.

In order to fulfill both campaign's objectives, only raw data were provided by each group, converted to NetCDF and uploaded on a dedicated server, then processed using SCC. This decision was made to exclude any contribution from data handling procedures – which are different for various groups – and to evaluate only the performance of the instruments. Nevertheless, in order to deal with such a variety of channels and data, the SCC needed supplementary parameters, which have been given in the header of the NetCDF files. All RCS at the same detection wavelength and obtained at exactly the same time interval were considered for analysis. In order to compare these outputs, the spatial resolution of each RCS was reduced at 60m (the biggest spatial resolution of all channels) and the signals normalized in a particular range and plotted against each other.

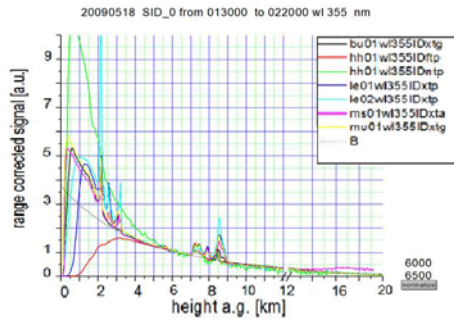


Fig.1. Normalized RCS for all 355 channels, May 18

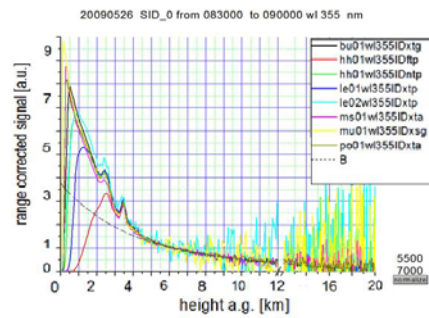


Fig.2. Normalized RCS for all 355 channels, May 26

Note that the choice of the normalization interval affects the result, especially in the near range. This is due to the specific optical design of each channel (which affects the overlap function), but also due to the position of the systems, which in some cases do not “see” the same air column. Although for climatological and even air quality studies the distance between lidars is not relevant, for the instruments intercomparison this distance – combined with the inclination angle of several systems and with high turbulence conditions inside Planetary Boundary Layer - become important. On the other hand, the distance between lidars cannot be reduced too much due to the specific of this technique. At the critical level, the light beam transmitted by one of the systems in the atmosphere can be collected by other system's telescope and corrupt the signal. Having in mind that the air columns sounded by the instruments are not exactly the same, significant differences between channels can still be observed (Figs.1 and 2). For example, at the beginning of the campaign the Hamburg instrument showed non-realistic high analog signals (see Fig.1), due to improper fixing of the optical fiber. After realignments, the signal was significantly improved (see Fig.2).

For quantitative data evaluation we start by considering the average of all normalized signals as the reference for a certain wavelength. This can be done if the signals considered have the same degree of confidence, but during the EARLI09 became clear that some of the systems will not work accurate enough and cannot be trusted. Therefore, these channels should be excluded to avoid corruption of the reference signal. By consequence, we first computed the median signal of all similar channels. Then, for each channel the deviation by bin is calculated against this reference and the channels which overpass a particular threshold are excluded from the calculus in the second step. Depending on the requirements, the threshold can be decreased (if the requirements are not so demanding) or increased. The signals which passed the test are again averaged and the deviations are computed against the new reference, this time a more accurate approximation of the best signal. For the entire altitude interval where the deviation of a particular channel is below the threshold, the conclusion is that the channel is providing accurate signals. This way, the best region of the best channels is evaluated.

4. Results

The 2-steps procedure described above was applied to several datasets collected from groups participating in EARLI09, after the pre-processing of data using SCC. In the figures bellow the results obtained for May 25 (daytime session: Figs. 3 and 4, nighttime session: Fig. 5) are shown. The threshold value for all channels considered is 10%.

Left panels show the normalized RCS at 1064, 355, and 387nm. Right panels show the corresponding final deviations of the selected channels. Channels which do not appear in the right panel are excluded in the first step of the procedure. Note that for the same system, the behavior of various channels is different. For example, Potenza system is not performing well at elastic channels (Figs. 3 and 4) and is excluded due to high deviations against reference, but Raman channels are performing better and are selected (Fig. 5).

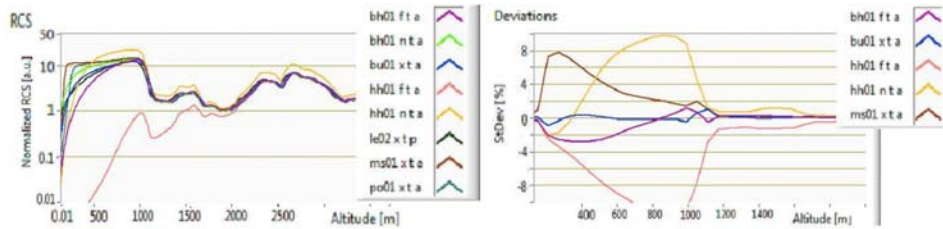


Fig 3 Normalized RCS for all 1064nm channels (left) and deviations for selected 1064nm channels (right)

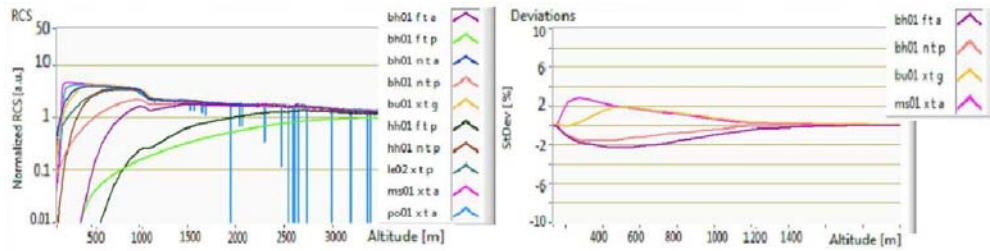


Fig. 4. Normalized RCS for 355nm channels (left) and deviations for some 355nm channels (right)

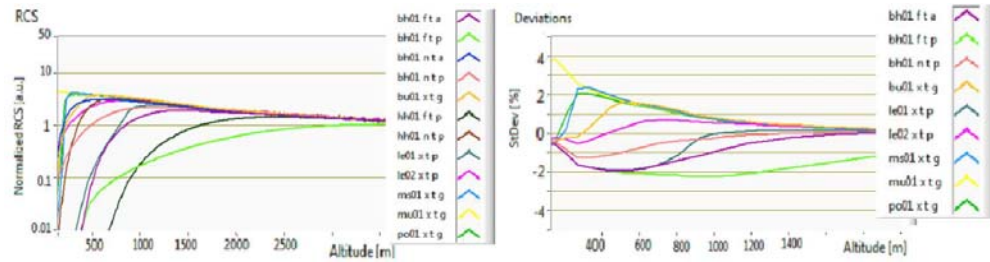


Fig. 5. Normalized RCS for 387nm channels (left) and deviations for some 387nm channels (right)

In case of RALI, all channels are selected by the algorithm for a threshold of 10%. Nevertheless, the deviations in the near range are much higher than in the far range. This is due to the relatively high full overlap (around 800m), which is caused by the narrow field of view of the telescope, but also due to the combined analog-photon counting detection, which decreases the deviations in the far range. Also, for all channels the deviations from the reference are below 2%.

It must be considered that the input RCS in this study are those provided by the SCC during EARLI09 campaign. Due to conversion problems, not all the groups managed to submit the necessary parameters, so that in some cases no gluing was performed for analog and photon counting channels, which are accounted separately in the graphs and marked with indexes “a” for analog and “p” for photon counting. In case of RALI, the gluing parameters were submitted in time, therefore the graphs show the combined signal, marked with index “g”. Consequently, the dynamic range for which the deviations of the signals are small is significant increased comparing with other channels.

5. Conclusions

EARLI09 campaign was an important opportunity to assess the performances of the Bucharest multiwavelength system, to optimize its operation and to test data handling procedures and programs. RALI demonstrated a good stability and accuracy. For the optimization of the system, we increased the telescope's field of view (from 1mrad to 1.7mrad) in order to lower the overlap by keeping the 400mm telescope and changing the field stop diameter (from 4mm to 7mm). With these new settings, the minimum range achieved was 700m and the maximum range approx. 20000m (depending on the channel). All channels worked properly and data pre-processing, conversion and submission was done in time. The evaluation of data was done using SCC and qualitative analysis during campaign. A more complex procedure was developed and tested on the datasets submitted by all groups involved in EARLI09. This study demonstrates that the result is dependent on the normalization interval and on the threshold up to which a channel is considered appropriate, as well as on the altitude interval relevant for the application. RALI has passed the test for a threshold of 10% deviation from the reference signal, for all channels.

More work will be dedicated in the future for the depolarization calibration and evaluation of various algorithms for overlap correction.

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