# AEROSOL EXTINCTION ALGORITHM INTERCOMPARISON FOR THE RAMAN LIDAR IN THE FRAME OF EARLINET

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The application of the procedure commonly used in the analysis of Raman lidar measurements of aerosol extinction is not straightforward. In particular, the difficulty arises from the need to calculate the derivative of the logarithm of the ratio between the atmospheric number density and the range corrected lidar-received power in conjunction with data averaging and handling operations. An incorrect accomplishment of data acquisition and data analysis can determine a miscalculation in the estimation of both the aerosol extinction coefficient and the statistical error. For this reason, great care is necessary in handling data in order to retrieve the extinction coefficient profile starting from Raman signals.

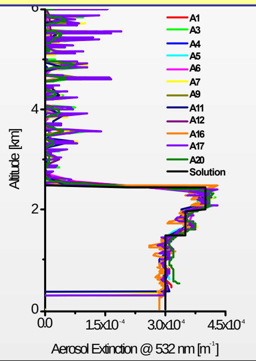
Due to the importance of the Raman technique and the difficulty to handle Raman lidar data, three different cases of data simulations have been prepared in order to test and to improve Raman algorithms used by each group within the EARLINET network. These cases cover a wide variety of experimental conditions, such as different level of noise and aerosol properties that vary with the time. In addition, the simulations serve to draw attention to special problems in the analysis of Raman lidar data, such as appropriate averaging and error determination.

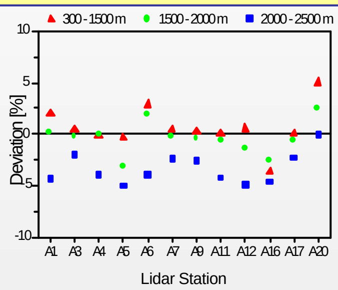
In the simulations, a US standard atmosphere with a ground pressure of 1013 hPa and a ground temperature of 0°C, a tropopause height of 12.0 km, and isothermal conditions above were assumed. Moreover, an incomplete overlap of laser beam and receiver field of view below 250 m was introduced.

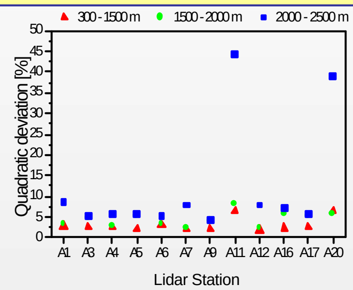
| ID | LIDAR STATION | DATA PROCESSING IN RAMAN ALGORITHM |
|---|---|---|
| A1 | JUNGFRAUJOCH | Sliding average |
| A2 | NEUCHATEL | Sliding average |
| A3 | LEIPZIG | Sliding linear least-squares fit |
| A4 | ATHENS | Sliding average filter and polynomial fit |
| A5 | HAMBURG | Sliding average |
| A6 | KUEHLUNGSBORN | Binning |
| A7 | L'AQUILA | 2nd order digital filter Savitzky-Golay |
| A9 | THESSALONIKI | Least-square fit |
| A11 | NAPOLI | Sliding linear least-squares fit |
| A12 | LECCE | Linear fit |
| A16 | ABERYSTWYTH | Linear and quadratic fit |
| A17 | POTENZA | Sliding linear least-squares fit |
| A20 | POTSDAM | Kaiser filter for data smoothing |

**CASE 1:** a simple step-wise changing extinction profile. Two different signals, one with a shot noise for 10000 and the other with a shot noise for 1000 laser pulses, were simulated. Only results for 10000 laser shots are reported.

| GROUP | ALTITUDE RESOLUTION |
|---|---|
| A1 | 60 m |
| A3 | 150 m |
| A4 | 180 m up to 500 m<br>1350 m up to 9000 m |
| A5 | 150 m up to 3000 m<br>510 m above |
| A6 | 200 m (1-5 km)<br>500 m (5-10 km)<br>1000 m (10-20 km) |
| A7 | 105 m |
| A9 | 75 m |
| A11 | 135 m |
| A12 | 150 up to 3000 m<br>450 m above |
| A16 | 15 m up to 2.5 km |
| A17 | 135 m |
| A20 | 15 m |



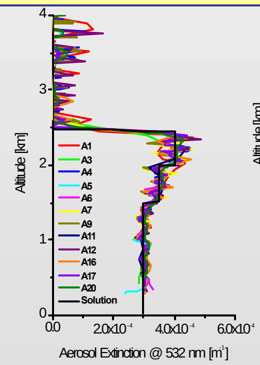



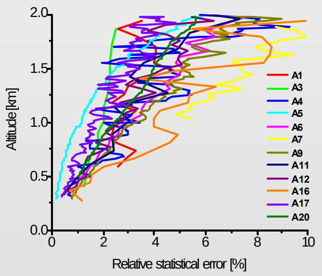



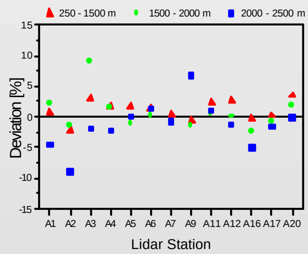

*Deviations and quadratic deviations between the results for each lidar station and the solution, calculated for 3 different mean values relating to three different ranges of heights (300-1500 m, 1500-2000 m, 2000-2500 m) corresponding to the three first steps present in the solution.*

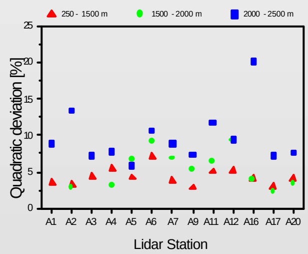
**CASE 2:** the same simple step-wise changing extinction profile as case 1, but in this case a series of 15 profiles (30 min), with 3600 laser shots each, were simulated. Solutions with a maximum statistical error of 10% in the 500 - 2000 m height range have been requested.

| GROUP | ALTITUDE RESOLUTION |
|---|---|
| A1 | 75 m |
| A2 | Variable from 80 m to 210 m up to 3375 m and fixed 210 m above |
| A3 | 120 m |
| A4 | 120 m up to 500 m<br>950 m up to 9000 m |
| A5 | 90 m up to 2900 m<br>270 m above |
| A6 | 45 m up to 2500 m<br>495 m above |
| A7 | 65 m |
| A9 | 135 m |
| A11 | 55 m |
| A12 | 75 m up to 3000 m<br>450 m above |
| A16 | 150 m up to 3000 m<br>600 m above |
| A17 | 120 m up to 2800 m<br>330 m above |
| A20 | 150 m |



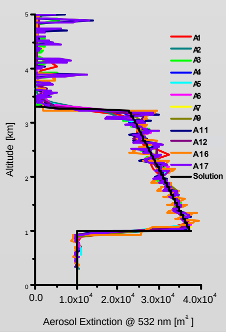



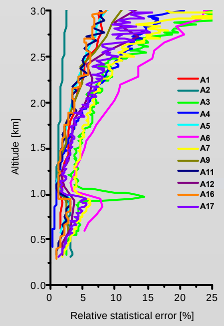

*Relative statistical error calculated as a function of the height.*
*Deviations and quadratic deviations between the results for each lidar station and the solution, calculated for 3 different mean values relating to 3 different ranges of heights (250-1500 m, 1500-2000 m, 2000-2500 m) corresponding to the three first steps present in the solution.*

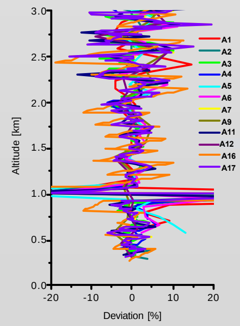
**CASE 3:** a series of 20 profiles corresponding to 3600 laser shots each, with an abrupt change of aerosol properties after the first 10 profiles, were simulated. Simulated data were provided without any solution; this was a real blind solution. Solutions with a maximum statistical error of 10% in the 500 - 2500 m height range have been requested.

| GROUP | ALTITUDE RESOLUTION |
|---|---|
| A1 | 90 m |
| A2 | 90 m up to 400 m<br>and 270 m above |
| A3 | 180 m |
| A4 | 100 m up to 500 m<br>900 m up to 9000 m |
| A5 | 120 m up to 3600 m<br>270 m above |
| A6 | 90 m up to 3300 m<br>300 m up to 3500 m<br>600 m above |
| A7 | 65 m |
| A9 | 165 m |
| A11 | 55 m |
| A12 | 150 m up to 3700 m<br>450 m above |
| A16 | 150 m up to 4000 m<br>600 m above |
| A17 | 120 m |

| | 0 - 1000 m | | 1000 – 3200 m | |
|---|---|---|---|---|
| Group | deviation from the solution [%] | quadratic deviation from the solution [%] | deviation from the solution [%] | quadratic deviation from the solution [%] |
| A1 | 24.56 | 44.93 | -2.35 | 10.24 |
| A2 | 5.47 | 22.01 | -1.67 | 6.00 |
| A3 | 5.48 | 20.42 | -0.46 | 6.20 |
| A4 | 8.12 | 18.75 | -1.22 | 6.15 |
| A5 | 7.20 | 8.29 | -0.32 | 9.03 |
| A6 | 7.45 | 10.58 | 0.97 | 5.58 |
| A7 | 5.06 | 20.70 | -0.37 | 8.65 |
| A9 | -1.58 | 2.38 | 1.75 | 4.34 |
| A11 | 1.54 | 8.08 | 0.06 | 7.89 |
| A12 | -0.39 | 1.44 | 1.52 | 5.89 |
| A16 | 10.47 | 44.80 | 0.28 | 12.19 |
| A17 | 4.75 | 20.62 | -0.49 | 8.65 |
| mean values | 6.51 | 18.58 | -0.19 | 7.57 |




**This intercomparison showed that the aerosol extinction evaluation can be accomplished with good accuracy for all participating groups. The goal of this intercomparison was to compare different Raman algorithms by taking into account statistical errors due to signal detection and errors introduced by operational procedures on the data.**

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