COMPARATIVE STUDY OF LIDAR MEASUREMENTS FROM CALIPSO AND GROUND BASED

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ABSTRACT

In this study we compare the aerosol profiles retrieved by CALIOP over Bucharest with those obtained by the multiwavelength Raman lidar system (RALI), as part of the validation effort in the framework of EARLINET. Correlative measurements are regularly performed at Bucharest site (44.348 N, 26.029 E), in the SSW part of the city. Our results indicate that CALIPSO lidar underestimates the attenuated backscatter coefficient in the lower atmospheric layers, where the instrument's signal-to-noise ratio decreases sharply. The underestimation becomes much bigger when cirrus clouds are present. The two data sets, ground-based and space-borne agree within 10% for altitudes > 4-5 Km, except when clouds are present. The differences in the correlative measurements results are affected by the atmospheric instability and/or non-homogeneity of the atmosphere, related to averaging procedure of satellite data.

1. INTRODUCTION

Climatological information on the vertical distribution of aerosol in the lower atmosphere is needed to assess the effects of aerosols on climate, due to their high variability, both in space and time [1]. For this purposes NASA launched the satellite Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO) as part of the A-Train on April 2006. On board is the Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP). CALIOP is a two-wavelength backscatter lidar which also measures linear depolarization at one wavelength, 532 nm. It aims to get daily profiles of extinction coefficients and linear particle depolarization of clouds and aerosols around the whole globe [2, 3]. CALIOP has a small footprint and a revisit time of 16 days therefore correlative ground-based lidar observations are necessary in order to investigate the representativeness of these satellite observations. EARLINET, the European Aerosol Research Lidar Network, started correlative measurements for CALIPSO in June 2006. This is the best approach to provide the necessary information to fully exploit the information from the satellite mission [4].

Validation results of CALIOP level 1 attenuated backscatter coefficient profiles using coincident observations performed with ground-based backscatter lidar have been reported in previous studies [e.g. 4, 5, 6,7].

As part of the validation effort in the framework of EARLINET, correlative measurements are regularly performed at Bucharest site (44.348 N, 26.029 E), in the SSW part of the city, using a multiwavelength Raman lidar system.

2. STUDY APRROACH

2.1 CALIOP level 1B data

The Level 1 data include lidar calibrated and geo-located profiles with associated browse imagery. The received backscatter signals are averaged onboard vertically over height and partly horizontally over consecutive laser shots. Further calibrations are performed at the ground base to receive the attenuated backscatter signals, which are the range corrected lidar signals normalized with the lidar constant. They are available at the NASA Langley Research Center Atmospheric Science Data Center as level 1B data. These data are the basis for the following algorithms to calculate extinction profiles [2, 3].

The vertical resolutions of lidar profiles are 30 m and 60 m respectively at 532 nm and 1064 nm for all the altitude ranges shown in this study.

2.2 Ground based lidar measurements

The ground-based Raman lidar is located in the suburb of Bucharest, in Magurele (44.348 N, 26.029E), a flat pre-urban environment of south-eastern Romania.

RALI employs a Nd-YAG laser emitting at 1064, 532 and 355 nm and the radiation is collected at 1064, 532p (parralel), 532s (cross), 355, 607, 387 and 408 nm. By use of combined analog and photon counting detection in combination with a total 330 mJ / 9 ns laser pulse and a 400 mm / 4047 mm focal length Cassegrain telescope, the dynamic range extends up to 15 Km, depending on atmospheric conditions. The lidar system is estimated to achieve full overlap at about 0.7 km. More details on experimental apparatus and data analysis are reported in [8]. Based on calibrated depolarization measurements, linear volume and particle depolarization profiles at 532 nm can also be extracted. RALI also measures the backscatter signal at 1064 nm, and with this it is well suited to validate the CALIOP data.

2.3 Description of the correlative procedure

We followed EARLINET strategy for correlative measurements for CALIPSO, defined on the base of the analysis of the high resolution ground track data provided by NASA.

According to this plan, measurements made within 2 h and 40km of the satellite overpass is considered case1 type of validation measurement [4, 5].

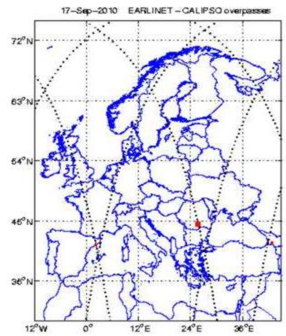

Figure 1. Bucharest's lidar station (red square) and CALIPSO ascending and descending orbits over passing Bucharest (cross lines), on 17 September 2010.

In Figure 1, the CALIPSO overpasses (nighttime on 00:30 UT and daytime on 11:29 UT) are presented for the case study of 17 September 2010, as an example for procedure demonstration purposes. The location of the ground-based station is 14 km far from the satellite track for the daytime case. The attenuated ground-based backscatter profiles used for this study were calculated from range-corrected lidar signals averaged around CALIPSO overpass time for a time period of 4-10 minutes.

3. RESULTS AND DISCUSSIONS

A total of 43 CALIPSO overpasses were scheduled for our station in 2010. Out of these, only 9 were performed (mostly due to weather conditions). Out of these, 4 cases were found to be inappropriate for comparison due to either considerable minimum distance (>30Km) between satellite tracks and ground-based station location, or due to low clouds.

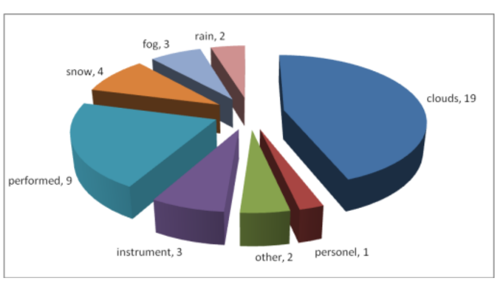

Figure 2. CALIPSO case 1correlative measurements during 2010

Only five coincidences were found to be reasonable for analysis during 2010: March 25th, April 10th and 26th and September 17th (daytime), and July 28th (nighttime). Results obtained for these study cases were found to be highly dependent on atmospheric stability and homogeneity around the measurement point.

Table 1 Correlative measurements- study cases

Date In 2010	Time of CALIPSO overpass	Distance between observations	Observations
25 March	11:30:40-11:31:00	14 km	Clear sky-good agreement between the two data sets
10 April	11:30:20-11:30:40	13km	Low sparse clouds (2Km), elevated depolarizing layers, unstable atmosphere; good agreement only above the water clouds
26 April	11:30:00-11:30:20	10km	Cloud at 3km in CALIPSO data, but no clouds in the ground based data
28 July	00:34:30-00:34:50	24km	Layers at 3 and 5km in CALIPSO data; but no clouds in the ground based data
17 Septe mber	11:29:00-11:29:20	14km	Cirrus clouds at 7.5 and 11 Km, consistent in the two data sets

For March 25th case there is a perfect match at all altitudes between the satellite and ground base measurements, except in the boundary layer. RALI's Range Corrected Signals (RCS) shows that one hour around the CALIPSO overpass time the atmospheric structure is quite stable and clear (Figure 3). A complex layer structure is depicted for September 17th. The CALIPSO's total attenuated backscatter at 532 nm and the ground-based lidar's RCS are presented in Figure 4, with the white lines pointing the time of correlative measurements.

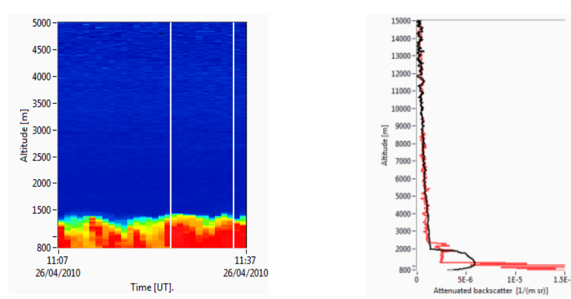

Figure 3. Case study 25 March 2010: RCS from ground-based lidar (left panel); attenuated backscatter (right panel) from CALIPSO (red line) and ground-based lidar (black line)

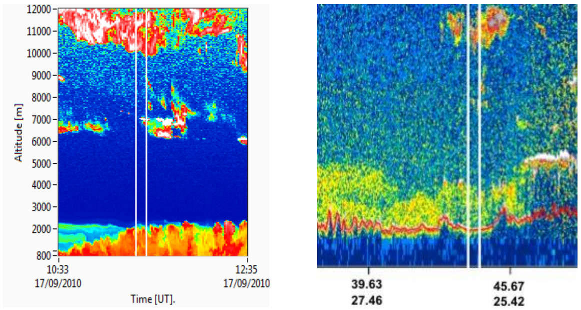

Figure 4. Case study 17 September 2010: the temporal evolution of the RCS from the ground-based lidar (left panel) and total attenuated backscatter measured at 532 nm by CALIPSO (right panel). The solid white line highlights measurements in coincidence with overpass over ground-based lidar location

Both systems are able to detect a thick cirrus cloud at 12 Km, a thin cirrus at 7 Km and the PBL height around 1.8 Km. Figure 5 shows the comparison between averaged vertical profiles of attenuated backscatter (left panel) and aerosol backscatter (right panel) for the coincident time interval. Profiles are obtained from CALIPSO level 1 data (red lines) and ground-based lidar system (black lines).

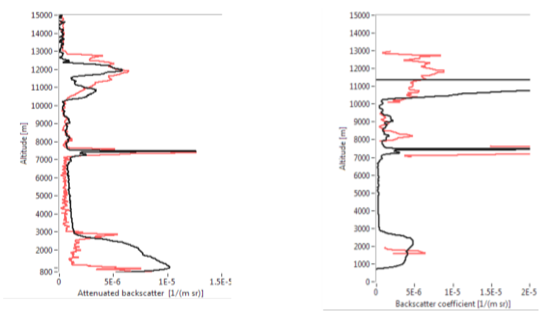

Figure 5. The comparison on vertical profiles of attenuated backscatter (left panel) and aerosol backscatter (right panel) measured by CALIPSO (red lines) and ground-based lidar (black lines) system on 17 September 2010

Basically, the two profiles of aerosol attenuated backscatter coefficients show the presence of 2 cirrus clouds one at about 11 km and the other at about 7 km, however a clear discrepancy can be observed below 3 km. Now turning to the aerosol backscatter data and comparing the available retrieved data we have noticed that satellite data is missing for several height regions and somehow there is no the difference between the two retrievals at about 2 km altitude. Still good agreement found in the region 8-10 km.

Figure 6 is related to the correlative measurements of April 26th, 2010. As can be seen from the attenuated backscatter at 532 nm, the two profiles are very similar for the upper troposphere, while important disagreement is recorded below 3 Km. CALIPSO shows the presence of a thin cloud at this altitude, not detected by the ground-based lidar. This case would have been a good comparison case, in principle, because the closest distance between observations is around 10 Km.

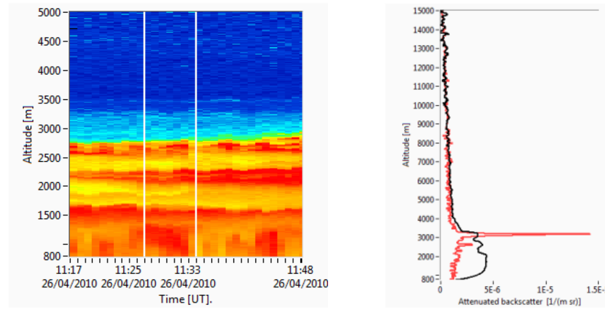

Figure 6. Case study 26 April 2010: zoom in for lower troposphere, RCS from ground-based lidar (left panel); comparison on vertical profiles of attenuated backscatter measured by CALIPSO (red line) and ground-based lidar (black solid line) system (right panel)

In order to further analyze the reason of the disagreement, we have been using the MSG2 data to depict clouds cover near our site. Infrared channel 10.8 µm, reveals the cloud top heights, based on standard atmospheric model. Retrievals from SEVIRI correspond to 3 Km^2/pixel. Detailed description can be found in [11].

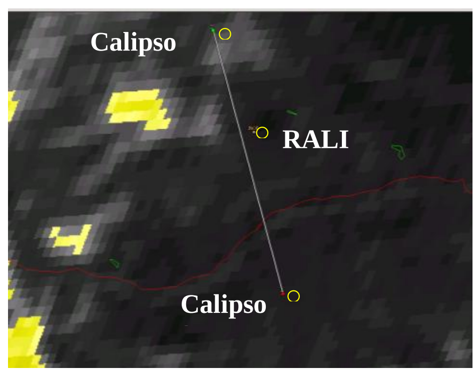

Figure 7. Satellite imagery of cloud top height for April 26 2010, 11:15 GMT with CALIPSO descending orbit (white line) over passing Bucharest (RALI) location; Yellow pixels indicating clouds top height over 3 km and grey shaded area cloud top at about 2.5 km

During the regular procedure for comparing the ground based and CALIOP data we have been averaged 20 s of the satellite data around the closest position to our site. The track during this time, for April 26^{th} case is drawn in figure 7 as the white line. The grey shaded area around CALIPSO position 1 indicates clouds at about 2.5 km altitude, which are not present over RALI's measurement site. So, even though we are trying to averaged satellite measurements very close to ground based ones, sometimes, when sparse clouds are present, this technique needs help of other sensors for further analysis of the atmospheric conditions' description.

The same type of behavior we have noted when comparing the results of July 28th, and April 10th.

Disagreements at low altitudes are observed for all cases, probably due to high variability of the aerosol content in the planetary boundary layer or the low signal-to-noise ratio of the satellite lidar, which is consistent with similar studies [e.g. 9, 10].

4. CONCLUSIONS

In this study we focused on 5 synchronous daytime and nighttime measurements during 2010 performed by a ground based multiwavelength lidar during CALIPSO overpasses, following EARLINET procedure. The comparison between the two data sets was limited by several factors related to both availability of data and procedure approach.

The best condition for a validation study between these two data sets proved to be a clear atmosphere (or a wide cloud field) over a 100 km area around the ground based measurement site. The differences in the correlative measurements results are affected by the atmospheric instability and/or non-homogeneity of the atmosphere, related to averaging procedure of satellite data.

Our results indicate that CALIPSO lidar underestimates the attenuated backscatter coefficient in the lower atmospheric layers. The underestimation becomes much bigger when cirrus clouds are present, as also noted in other studies.

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