

EVALUATION OF CALIOP L2 AEROSOL EXTINCTION AND BACKSCATTER PROFILES WITH GROUND-BASED LIDAR MEASUREMENTS IN INDIA AND SOUTH AFRICA

Tero Mielonen¹, Elina Giannakaki^{1,2}, Ali Omar³, Antti Arola¹, Kari E.J. Lehtinen^{1,4}, Mika Komppula¹

¹*Finnish Meteorological Institute, Kuopio Unit, FI-70211, Finland, tero.mielonen@fmi.fi*

²*Laboratory of Atmospheric Physics, Aristotle University of Thessaloniki, Greece*

³*NASA Langley Research Center, Hampton, VA, USA*

⁴*University of Eastern Finland, 70211 Kuopio, Finland*

ABSTRACT

In this study we evaluated CALIOP Level 2 aerosol extinction and backscatter profiles with measurements from a multi-wavelength ground-based lidar, Polly^{XT}, at two locations: Gual Pahari, India, and Elandsfontein, South African Republic. Ground-based measurements were conducted for a year at both sites. All the overpasses which were inside a 2x2 degree box centered on the measurement sites were taken into account. However, due to technical issues with the ground-based lidar and thick clouds we were only able to get about 30 comparison profiles for the Elandsfontein site and 16 profiles for the Gual Pahari site. Preliminary results from the comparison look promising. In several cases, CALIOP is able to measure similar aerosol profiles as Polly^{XT}. Naturally, there are also differences. These can be explained by different air masses due to the distance between the measurements, changes in cloud cover, multiple scattering and differences in the lidar ratios assumed in CALIOP retrieval and measured with Polly^{XT}.

1. INTRODUCTION

Aerosols in the atmosphere affect significantly radiative forcing, chemical processes in the atmosphere, cloud properties and air quality [1]. However, modeling of atmospheric aerosols and their climate effects are demanding tasks. The models have to use numerous simplifications that can have significant effects on the results. The vertical structure of aerosols is one of them. For the validation of aerosol profiles used in climate models, spaceborne lidar CALIOP [2,3] provides the best data set because it is global and measured with a single instrument. However, before CALIOP measurements can be used for model validation, the measurements have to be validated with ground-based measurements at as many locations as possible.

In this study, the quality of the Level 2 aerosol extinction profiles (v3.01) from CALIOP measurements are evaluated with ground-based multi-wavelength Raman lidar measurements done at two locations: Gual Pahari, India and Elandsfontein, South African Republic. Only few lidar measurements have been carried out at

these areas and typically the measurement campaigns have been relatively short in previous studies [e.g. 4,5].

2. MEASUREMENT SITES

The ground-based measurements used in this study were conducted at two locations: Gual Pahari, India (28.43N, 77.15E, 243 m a.s.l.) and Elandsfontein, South African Republic (26.25S, 29.43E, 1745 m a.s.l.). The measurements in India and South African Republic were performed in the periods March 12th 2008 - March 31st 2009 and December 11th 2009 - January 31st 2011, respectively.

The Gual Pahari site is located about 20 km south of New Delhi, representing a semi-urban environment surrounded mainly by agricultural test fields and light vegetation. The station is located in an area where only electric-powered vehicles are allowed. There are no major local pollution sources, except the road between Gurgaon and Faridabad about 0.5 km to the south-west of the station. Anthropogenic sources in the region 25 include traffic, city emissions and power production [6,7]. In addition, one main source of aerosols is smoke particles that originate from anthropogenic activities (e.g cooking). Natural sources of aerosols include biomass burning aerosols that are advected from South Asia as well as mineral dust particles which are frequently transported from the Saharan and Thar deserts over Gual Pahari. The average temperatures were at their highest during the summer (28.1 °C), but the maximum temperature was found during the spring season (42.5 °C). This was due to much higher diurnal temperature gradient during the spring. During the winter, the coldest nights reached 0 °C [8].

The Elandsfontein site is located on the top of a hill approximately 200 km east of Johannesburg. The average altitude of the surrounding area varies between 1400 and 1600 m above sea level, while the hill top with the measurement site is 1750 m above sea level. The shortest distance to the Indian Ocean is approximately 350 km. The Drakensberg Mountains between the ocean and the site reach heights of 2000–3500 m a.s.l. The major pollution sources within a 50 km radius include six coal-fired power plants to the west and north, a petrochemical coal plant to the south-

west, and the site is also occasionally impacted by metallurgical plants to the north of the site. However, there are no major pollution sources within a radius of 20 km of the site. In the sector between north-east and south-east only one major point source occurs. The vegetation around the site is dry grassland pasture and farmland with annual precipitation of about 700 mm. The rainy season is from October to March with very little rain during the winter. The maximum daytime temperatures in summer and winter are on average 26 °C and 17 °C, respectively. [9]

The measurements from both sites belong to the frame of the EUCAARI (European Integrated project on Aerosol Cloud Climate and Air Quality interactions) project [10].

3. POLLY^{XT}

The measurements were conducted with a seven-channel Raman lidar called “POLLYXT – Portable Lidar sYstem eXTended” [11]. The lidar system is completely remotely controlled, and all the measurements and data transfer are performed automatically. The instrument is equipped with an uninterruptible power supply (UPS) and an air conditioning system (A/C) to allow for safe and smooth continuous measurements. A rain sensor is connected to the roof cover in order to assure a proper shutdown of the instrument during the rain. When the sensor detects a rain, a signal is sent to the data acquisition software which in turn shuts down the laser and ends the measurement. In addition to these, the system is equipped with airplane radar that shuts down the laser in case an airplane is detected. The type of the laser used is Inlite III from Continuum. It emits simultaneously light pulses at three wavelengths with pulse energies of 180 mJ, 110 mJ, and 60 mJ at 1064 nm, 532 nm, and 355 nm, respectively. The emitted radiation is linearly polarized at 355 nm. A beam expander is used to enlarge the beam from approximately 6 mm to about 45 mm before it enters the atmosphere. The backscattered signal is collected by a Newtonian telescope which has a main mirror with a diameter of 300 mm and a focal length of 900 mm. The receiver’s field of view is 1 mrad. The output of the instrument includes vertical profiles of the particle backscattering coefficient at three wavelengths (355, 532 and 1064 nm) and of the particle extinction coefficient at two wavelengths (355 and 532 nm). The extinction coefficient is retrieved with the Raman method by using the in-elastic backscattering from the nitrogen molecules (at 387nm and 607 nm). The vertically-integrated extinction coefficient gives the aerosol optical depth (AOD). In addition, such size/composition-dependent, intensive particle quantities as the extinction-to-backscatter ratio,

commonly known as lidar ratio, the Ångström exponents (AE) related to backscatter and extinction, and depolarization ratio at 355 nm can be determined. The lidar ratio gives indication of particle properties and origin by giving the ratio of the extinction to backscatter coefficients. When having the lidar ratio at two wavelengths, some indication of particle size is retrieved. Also the AE provides information on the particle size. The depolarisation channel (355 nm) of the lidar enables us to separate spherical particles from non-spherical and hence ice-containing clouds from water clouds. Finally, the height and the evolution of the boundary layer top and night-time residual layer can be defined from the lidar data, along with the height and thickness of different cloud and aerosol layers. The vertical resolution of the system is 30 m. Depending on the cloudiness, the whole troposphere can be monitored. Each backscatter profile was determined using the method by [11]. The radiosonde data supplied by the Department of Atmospheric Science at University of Wyoming were used to account for the molecular backscattering. In case of night-time measurements, also extinction and lidar ratio profiles were determined. An overlap function was used to correct for the incomplete overlap of the laser beam and the receiver field of view at low altitudes. The automatically retrieved backscatter plots are available at <http://polly.tropos.de/lidar/>.

4. CALIOP

The Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO) satellite [2,3] was launched successfully in April 2006, and data has been available from June 2006 onward. CALIPSO carries the Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP) instrument, which can measure the vertical structure of the atmosphere at three channels, from the intensity of that part of the (pulsed) laser light that is scattered back to the lidar receiver. Two of these channels, at 532 nm, are orthogonally polarized and one channel measures the total backscattered signal at 1064 nm. The diameter of the laser pulse at ground level is about 70 m. CALIOP has a spatial resolution of 333 m along the orbital path. The satellite repeat cycle is 16 days [12]. Due to the small footprint, CALIPSO covers only 0.2% of the Earth’s surface during one repeat cycle [13]. In this study we used level 2, version 3.01, aerosol backscatter and extinction profiles. The data was downloaded from <http://eosweb.larc.nasa.gov/>.

5. EVALUATION METHOD

For the comparison, we selected all the CALIOP overpasses which were inside a 1x1 degree or 2x2 degree box centered on the lidar sites. We screened our data for clouds and stratospheric features using

Atmospheric Volume description (AVD). Cloud Aerosol Discrimination (CAD) score, which reflects our confidence that the feature under consideration is either an aerosol or a cloud, was also used. In this study we screened out features with CAD score greater than -80. CALIPSO extinction Quality Control (QC) flags were also used. We used solutions where the lidar ratio is unchanged during the extinction retrieval (extinction QC = 0) or if the retrieval is constrained (extinction QC = 1). For the Gual Pahari site we obtained 40 overpasses for the 1x1 degree box and 79 for the 2x2 degree box while for the Elandsfontein site there were 28 and 101 overpasses, respectively. Hourly averaged backscatter and extinction profiles centered on the CALIOP overpass time were calculated from the Polly^{XT} measurements. Due to cloudiness and technical issues, Polly^{XT} data was not available for all the overpasses. Next, we calculated averaged CALIOP profiles from the measurements inside one latitude degree path centered on the lidar sites. In the end, we had 10 useful overpasses from both sites for the evaluation with the 1x1 degree boxes. For this set, typical distances between the CALIOP tracks and lidar sites were around 50 km. The use of the 2x2 degree box provided 20 additional profiles for Elandsfontein and 6 profiles for Gual Pahari with typical distances around 100 km.

6. RESULTS

In Gual Pahari, the preliminary results look promising. CALIOP is able to measure similar aerosol profiles as Polly^{XT} for most of the cases. There were some differences in the CALIOP lidar ratios and measured lidar ratios which caused differences in the extinction profiles. Other discrepancies are probably due to multiple scattering and the distance between the instruments which enables the measurement of different air masses and changes in the cloud cover. In Elandsfontein, the evaluation was more difficult due to persistent cloudiness. However, for the overpasses with clear sky, the agreement between the instruments was good, both in the location of the layers and in the amount of extinction. Example profiles from both sites are shown in figures 1 and 2, which represent cases with good agreement between the instruments. For these examples, the distances between the instruments were around 50 km.

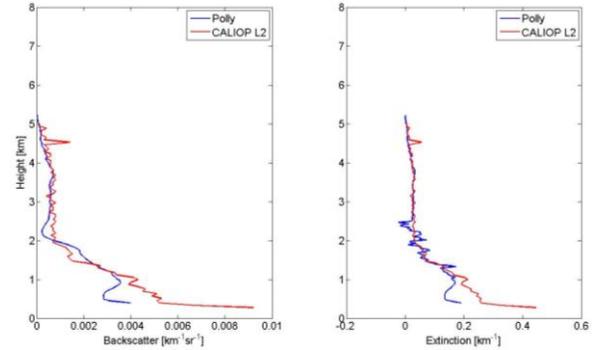


Figure 1. Backscatter and extinction profiles from PollyXT and CALIOP measured at Gual Pahari 20th March 2008 with overpass time at 20:55 UTC.

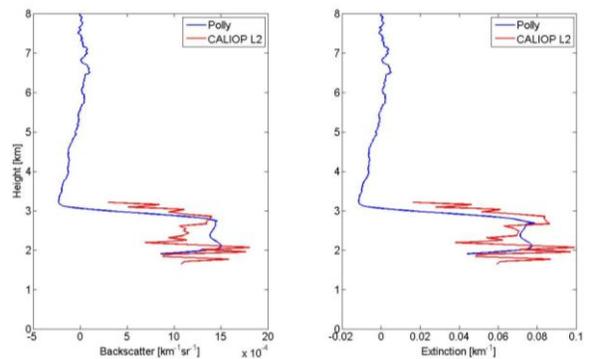


Figure 2. Backscatter and extinction profiles from PollyXT and CALIOP measured at Elandsfontein 27th May 2010 with overpass time at 12:06 UTC.

7. CONCLUSIONS

We have evaluated CALIOP level 2 extinction and backscattering profiles at two locations: Gual Pahari, India and Elandsfontein, South African Republic. At both sites, approximately one year of ground-based multi-wavelength Raman lidar measurements have been made. The distances between the CALIOP overpasses and the sites range from 50 km to about 100 km. We found about 30 comparison profiles for the Elandsfontein site and 16 profiles for the Gual Pahari site. Preliminary results indicate that the instruments mainly agree well. The main reasons for the differences come from the distance between the CALIOP track and the measurement sites. The distance enables differences in air masses and cloudiness. In addition, we found differences in the lidar ratios used in the CALIOP retrieval and measured with Polly^{XT}. In the future, all the concurrent measurements will be studied in more detail.

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