COMPARISON OF GROUND-BASED LIDAR PROFILES WITH CALIPSO LEVEL 2 VERSION 3.01 DATA

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ABSTRACT

In the present work, the CALIPSO Lidar Version 3 Aerosol profiles are compared with ground-level profiles measured at Madrid (Spain). The new Cloud and Aerosol Discrimination Version 3 Algorithm improves the classification of dense aerosol layers due to the five dimensional probability density function, instead of the three dimensional used in Version 2. The Madrid air basin receives mineral dust contributions from long-range transport from the Sahara desert, producing dense aerosol layers than allows the study of the improvements of the new CAD algorithm. The Madrid lidar station belongs to the European Aerosol Research Lidar Network (EARLINET), a network of 25 European lidar stations aiming to derive a quantitative and statistically significant database on aerosol distribution over Europe. EARLINET joined the international program to obtain correlative measurements at CALIPSO overpasses within 80 km in order to support validation of its retrieved products. Two different data products have been compared: The "Total Backscatter_Coefficient_532" from level 2 Version 3 files and the Level 1 Version 3.01 data product called "Total_Attenuated_Backscatter_532" that must be compared with a simulated lidar profile calculated from the 532-nm extinction and backscattering coefficients profiles. Several cases of these situations are studied and the Version 2 and Version 3 CALIPSO data are compared.

1. INTRODUCTION

The Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) [1] is a satellite mission designed to measure the vertical structure and optical properties of aerosol and clouds over the globe, with the goal of increasing our understanding of the radiative effects of aerosols and clouds, presently the largest uncertainties in our ability to predict future climate change. The main instrument of this mission is CALIOP (Cloud-Aerosol Lidar with Orthogonal Polarization), a lidar designed by NASA that emits simultaneously two wavelengths (532 and 1064 nm) and counts with three receiver channels of backscattered signals: two channels measuring orthogonally polarized components of the 532 nm and one for 1064 nm. Validation of CALIPSO data products via intercomparisons with independent measurements is essential to produce a high quality dataset, as established by the international program. Existing measurement sites can provide data relevant to CALIPSO validation at times when the ground-track of the CALIPSO satellite is within a specified coincident distance, or the air masses are shown to be similar. The program seeks near-coincident (Within 2 hours and 40 km preferred but 4 hours and 80 km are acceptable) measurements relevant to CALIPSO observations during satellite overpasses throughout the lifetime of the mission. EARLINET [2, 3], formed by 25 European lidar stations, joined the validation program and have been performing correlative measurements at all stations within 80 km from the overpasses.

In this work we present a comparison of CIEMAT-Madrid EARLINET station with CALIPSO data obtained from June 2006, when the scientific data was first available, until October 2011, when the L2 data changed to version 3.02. The Level 1 Version 3 data product were released in November 2009 with a product maturity classification of Validated Stage 1, indicating that initial validation of the CALIOP attenuated backscatter products has been successful. The product called "Total Attenuated Backscatter 532" are compared with a simulated lidar profile, following a similar procedure as described in Mona et al.[4], calculated from the 532-nm extinction and backscattering coefficients profiles independently measured by an unpolarized elastic channel and a Raman channel [5]. The Level 2 data product, called "Total Backscatter Coefficient 532", can be directly compared with the backscattering coefficient profile provided by the ground system, but these profile products, released on May 2010, are still labeled with a "Maturity level: Provisional", meaning that only limited comparisons with independent sources have been made and only obvious artifacts fixed. Therefore the former, more elaborated, comparison is still necessary. The third release (Version 3) of the CALIPSO data products features a comprehensive restructuring and expansion of the Lidar Level 2 cloud and aerosol profile products [6]; significant enhancements to the Lidar Level 2 cloud and aerosol profile products; and the implementation of an improved calibration technique for the Lidar Level 1 532 nm daytime calibration.

The CIEMAT-Madrid station reported a first comparison with CALIPSO data [7] following the same strategy, but for Version 2 data products and between June 2006 and June 2008. In this work, the period has

been extended until October 2011 and the Version 3 data products, produced at a 5 km horizontal resolution instead of 40 km, are employed [8].

2. RESULTS AND DISCUSSION

CALIPSO satellite overpassed the Madrid station, within less than 80 Km horizontal separation, in 240 cases from 14 June 2006 to 31 October 2011. During that period, 109 correlative measurements were taken (45% of the total overpasses). For the other cases, the meteorological conditions (rain or low clouds) forbids the system operation in 54% of the cases, while in 41% the reason was instrument problems, and the rest were due to CALIPSO being off for orbit change or other reasons.

Anyhow, once the CALIPSO L2 files were downloaded, only in 117 files were aerosol profiles within less than 80 km to the Madrid station, and of those, only 60 were correlative with ground-level measurement, therefore, the L2 statistical comparison is somehow limited. Figure 1 shows the temporal distribution in month intervals, of the CALIPSO overpasses (gray bars), normally 4 times per month, two daytime and two nighttime overpasses, due to the sixteen days revisiting time of the satellite, except some months with only two cases. The squared bars represent the correlative measurements of the ground-level station for that month, and the black bars, those with aerosol profile in the level 2 version 3 datafiles.

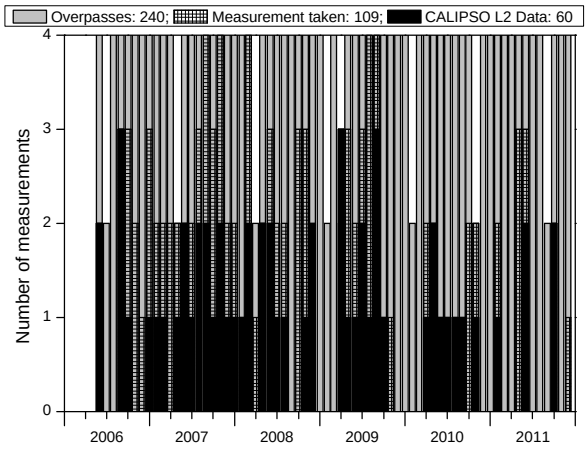

Figure 1. Monthly temporal distribution, from June 2006 to October 2011 of the CALIPSO overpasses (gray area), the correlative measurements taken at Madrid-CIEMAT station (squared area) and the Level 2 data files with aerosol information (black area) coincident with ground-level measurements taken.

The Madrid Station is located on the northwest border of the Madrid city, placed in the center of the Iberian Peninsula. The satellite groundtrack distance to the ground-level station ranges between 20 and 30 Km in the nighttime cases, that occur always to the east of the station, while daytime cases distances, placed to the west, range from 2 to 16 Km.

Figure 2 shows three examples (14 June 2006 at 13:29:45, 20 August 2007 at 02:25:48 and 19 June 2008 at 02:26:26 UTC) comparing the ground-level profile (black solid squares) with the CALIPSO level 2 profiles for version 2 (red solid dots) and version 3 (wine open dots). The two first cases correspond to nighttime measurements, when the Raman channel is operative, allowing the "simulated signal" to be calculated using the Raman signal to independently obtain the extinction, in order to compare it with the "Total Attenuated Backscattering 532" Level 1 product, averaged 15 laser pulses (5 Km horizontal) in order to make it comparable with the level 2 product. Top panel shows the case for 19 June, 2008 at 02:26:26 UTC where a good agreement between the CALIPSO and the ground-level profiles was observed. The variability of the version 3 profile is larger due to the smaller horizontal averaging (5 km resolution) respect to the version 2 (40 km resolution).

Middle panel of figure 1 shows the case for 20 August, 2007 at 02:25:48 UTC. For the Version 2 data, the CALIPSO level 2 aerosol data do not agree with the ground-level measurements. Version 3 improves significantly, providing a similar mixing layer height, although with smaller backscatter coefficient values.

In the bottom panel of figure 1, a case where the CALIPSO Version 2 data processing chain identified the dense dust layer as clouds, measured on 14 June, 2006 at 13:29:45 UTC, during a Saharan intrusion, is presented. As it can be observed, the discrimination algorithm correctly identified the highest part of the aerosol layer as aerosols, but then in discriminate the main part of it as cloud. Version 3 data slightly improves this situation, identifying the lowest part of the layer as aerosols, but such identification is not fully attained.

The "simulated signal" calculated from the extinction and backscatter profiles indicate that the CALIPSO Level 1 signal was right, so the problem with these files is probably produced by the identification as cloud or aerosol in the data processing chain. Anyhow, the "simulated signal" has been calculated using the extinction profile obtained by multiplying the lidar ratio assumed in the Klett-Fernald inversion by the backscattering coefficient profile because, as it was a daytime measurement, the Raman channel was blinded by the background light and no independently measured extinction profile was obtained. This might reduce the reliability of this profile, as the lidar ratio was assumed and not measured.

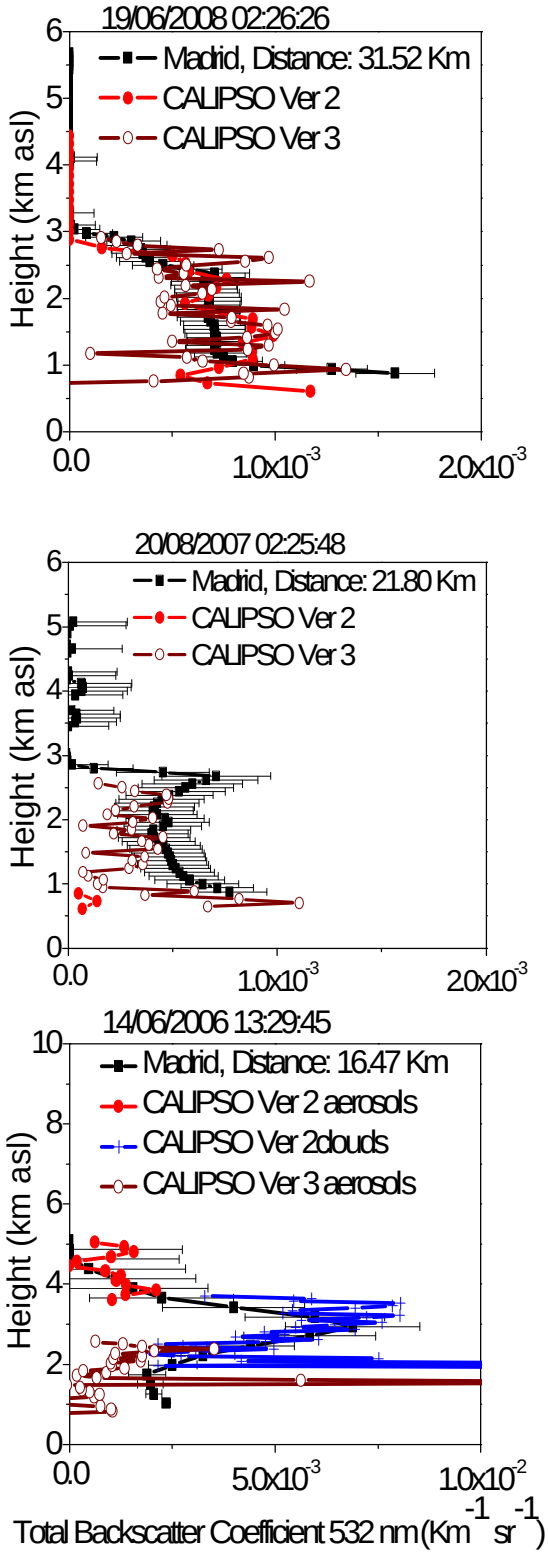

Figure 2. CALIPSO Level 2 data product "Total_Backscatter_Coefficient_532" for Version 2 (red solid dots) and Version 3 (Wine open dots) compared with the backscatter coefficient profiles provided by Madrid lidar station (Black squares).

3. CONCLUSIONS

Measurements from Madrid EARLINET lidar station have been compared with the simultaneous profiles obtained by CALIPSO between June 2006 and October 2011. The sparse number of level 2 files with aerosol information coincident with ground-level measurements (60) has prevented a deeper statistical analysis of the datasets. Analysis of the backscattering coefficient and the Total Attenuated Backscattering profiles have been performed comprising both Version 2 (40 km horizontal resolution) and Version 3 (5 km hor. res.) of the level 2 files. Some improvements of the last version have been found, despite its shorter horizontal resolution. Several cases were studied, showing a reasonable agreement in terms of backscattering coefficient magnitude despite the horizontal resolution of the CALIPSO products (5 Km), the averaging time of the ground-level station measurements (30 minutes), required in order to obtain adequate extinction profiles from the Raman channel, and the spatial separation between the CALIPSO groundtrack and the station (25 Km). Only cases with information on the Level 2 products have been analyzed in this work.

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