INVESTIGATION OF REPRESENTATIVENESS OF CALIPSO AEROSOL OPTICAL PROPERTIES PRODUCTS BY EARLINET CORRELATIVE MEASUREMENTS

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ABSTRACT

The almost six-years long database of aerosol and cloud vertical profiles provided by CALIPSO (Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations) is at the present the longest database of aerosol optical properties at global scale. This database is a unique tool for the characterization of aerosol 4D distribution at global scale. However, CALIPSO has a small footprint and a revisiting time of 16 days, and therefore how well these measurements represent the atmospheric conditions of a surrounding area over a longer time is a big issue to be investigated. Because of its geographic coverage and the large number of advanced Raman aerosol lidars, EARLINET, the European Aerosol Research Lidar Network, offers a unique opportunity for the validation and full exploitation of the CALIPSO mission. CALIPSO Level 2 and Level 3 data products are investigated in terms of their representativeness by comparison with EARLINET measurements. Comparisons for the Level 2 profiles available in both version 2 (40 km as horizontal resolution) and version 3 (5 km) releases highlight the issue of finding a best compromise between the high resolution and the high signal-to-noise ratio. Representativeness of monthly averages provided in Level 3 data is investigated using EARLINET-CALIPSO correlative measurements. The study will furthermore benefit from the availability of the 12-years long-term database of EARLINET climatological data available from May 2000.

1. CALIPSO PRODUCTS FOR AEROSOL STUDY

CALIPSO is the first satellite mission involving a lidar specifically designed to study aerosols and clouds. CALIPSO was launched on April 28, 2006, ushering in a new era of space-based lidar measurements on a nearly global scale [1]. The good performances of CALIPSO and the absence of evident biases in the CALIPSO raw signals were demonstrated through devoted comparison with EARLINET ground based data applying an ad-hoc methodology [2,3]. Aerosol optical properties provided by CALIPSO (i.e. Level 2 products) are typically in agreement within errors and uncertainties with ground based reference lidar stations. Comparisons performed in cases of high dust load showed the influence of multiple scattering on the aerosol retrieval from space borne lidars and how this effect can be mitigated within the retrieval [4]. For the aerosol study, CALIPSO provides, as Level 2 products, aerosol layers properties (boundaries, layer-mean backscatter and extinction values) and profiles of the aerosol backscatter and extinction at 532 and 1064 nm plus depolarization ratio at 532 nm. Furthermore tropospheric monthly mean profiles of aerosol extinction at 532 nm on a uniform spatial grid of 5° longitude x 2° latitude are currently provided as Level 3 aerosol data product.

2. EARLINET-CALIPSO CORRELATIVE MEASUREMENTS

EARLINET provides long-term, quality-assured aerosol data and, because of its geographical distribution over Europe, allows us to investigate a large variety of different aerosol situations with respect to layering, aerosol type, mixing state, and properties in the free troposphere and the local planetary boundary layer [5].

With a network on a continental scale it also becomes possible to study the representativeness of the limited number of satellite lidar cross sections along an orbit against long-term network observations. EARLINET developed a specific observational strategy for CALIPSO correlative measurements, which started already from June 2006 [3]. While the majority of EARLINET stations contributed on a voluntary basis to this measurement program in the first two years of the mission, a dedicated ESA activity supports correlative EARLINET-CALIPSO observations at 16 selected EARLINET stations from April 1, 2008 to October 31, 2010. These 16 stations have been grouped in 4 clusters: Central Europe (Germany and The Netherlands), Western Mediterranean (Spain), Central Mediterranean (Italy), and Eastern Mediterranean (Greece and Bulgaria). Following the measurement strategy established for the ESA-CALIPSO study, EARLINET correlative measurements are performed by a single station in correspondence with a CALIPSO overpass within 100 km (Case A measurements), simultaneously to more stations of the same cluster (Case B measurements) and at large scales by stations of different clusters during interesting additional cases like Saharan dust intrusions and forest fires (Case C measurements). In this way, horizontal distance between CALIPSO and EARLINET selected stations covers a large interval: 0-100 km for Case A with almost 60% of the cases within 50 km, 120-750 km for Case B with almost 70% of the cases within 500 km and also larger distances for Case C measurements. This allows to investigate the horizontal variability on different scales, from regional to continental one. In order to investigate the temporal variability of aerosol fields, 150 minutes lasting records of measurements (centered around the overpass) are requested whenever atmospheric conditions allow it.

3. LEVEL 2 PROFILES

The spatial variability of aerosol/cloud fields is investigated through CALIPSO–EARLINET differences for almost simultaneous measurements performed at different horizontal relative distances (from 0 to 750 km with Case A and B measurements and larger distances with Case C measurements). The 150 minutes lasting time series of measurements performed during Case A measurements allow to study the temporal variability independently by the spatial one. In the following we report an example of this kind of representativeness study.

The 26-31 May 2008 observation period has been selected for a correlation analysis for both single-point and multiple-point observations, because this is a period with a large number of performed measurements: 15 for Case A, 7 additional for Case B, and 56 additional for Case C measurements, with a total of 420 EARLINET files available for this period .

3.1 Version 2

For a quantitative study, we compare the count distributions of CALIPSO and EARLINET backscatter-coefficient measurements for horizontal distance below 100 km (Case A measurements), with different time shifts. The agreement can be quantified through the linear correlation coefficient of the two count distributions (Figure 1a). The correlation coefficient between CALIPSO and EARLINET backscatter counts distributions, for distance below 100 km remains around 0.9 for time shifts (Δt) up to 30 minutes and decreases to 0.76 for 30 min $< \Delta t <$ 60 min, 0.56 for 60 min $< \Delta t <$ 120 min, 0.57 for 120 min $< \Delta t <$ 720 min. Therefore, for time shifts larger than 30 minutes the two observations are not correlated, implying that on a spatial scale of 100 km the aerosol time variability for this event is of the order of 30 minutes.

Similarly, we observe (Figure1b) a strong dependence on the horizontal distance with a sharp decrease of the correlation coefficient from 0.9 for a distance < 100 km to 0.76 for distances between 100 and 200 km. The correlation coefficient continues to decrease with the increase of the horizontal distance between the CALIPSO and EARLINET observations.

3.2 Version3

Version 3 data could in principle permit the investigation of satellite measurements representativeness on a shorter horizontal scale thanks to the better horizontal resolution with respect to the Version 2 (5 km against 40 km). The same approach applied on Version 2 data is applied to the Version 3 dataset for the 25–31 May 2008 case.

In particular, the availability of 5-km profiles for CALIPSO results directly in a factor of 8 for the number of profile comparisons to be considered for the study and to be uploaded on the relational database (here multiplied by 2, because absolute and relative difference files are to be uploaded).The maximum distance both in terms of space and time has been reduced with respect to the V2 study because of this multiplying factor, in order to obtain a more efficient database. The number of comparisons in terms of aerosol backscatter-coefficient profiles at 532 nm (the

most abundant) available with the current EARLINET database for this Saharan dust case is 11552, when maximum distances of 2000 km and 720 minutes are considered. The same approach is applied to the Version 3 data. Figures 1c and 1d report the correlation coefficient between the CALIPSO and EARLINET aerosol backscatter count distributions as a function of the temporal and horizontal distance, respectively. Low values of the correlation coefficients are found for all distances considered and no reasonable behavior with respect to the distance is obtained.

This would lead to the wrong conclusion that there is no link between the observation distance (both in time and space) and their correlation. Results obtained from Version 2 are strongly in disagreement with these plots, indicating instead that the main cause of this unphysical result lies in the new release of the CALIPSO data.

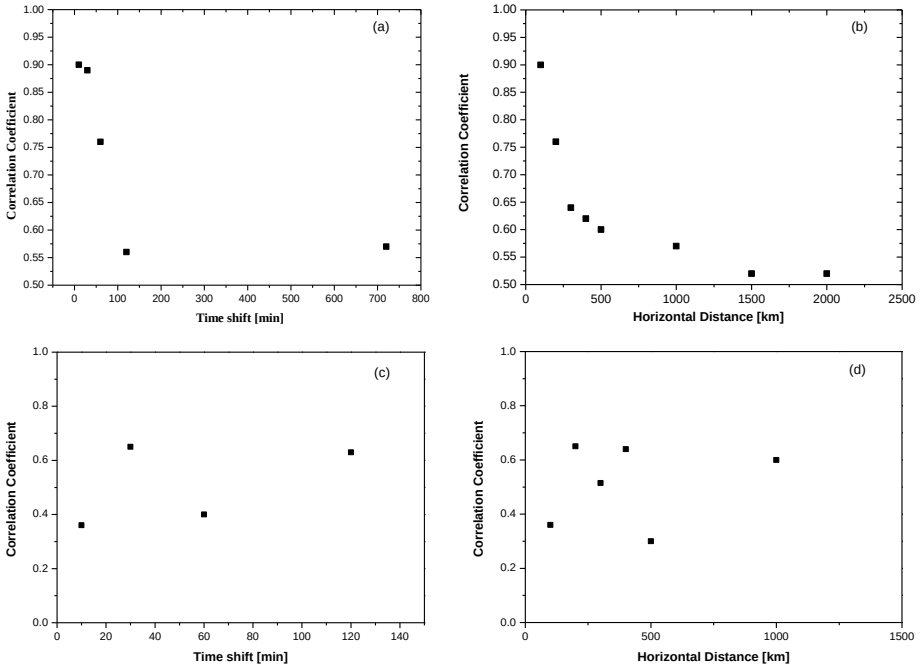

Figure 1. Correlation coefficient between the CALIPSO and EARLINET aerosol backscatter count distributions as a function of the temporal and horizontal distance: for horizontal distance below 100 km (Case A measurements) with different time shifts (a) and for different horizontal distances (b) with Version 2 data; the same, but with Version 3 data: (c) and (d).

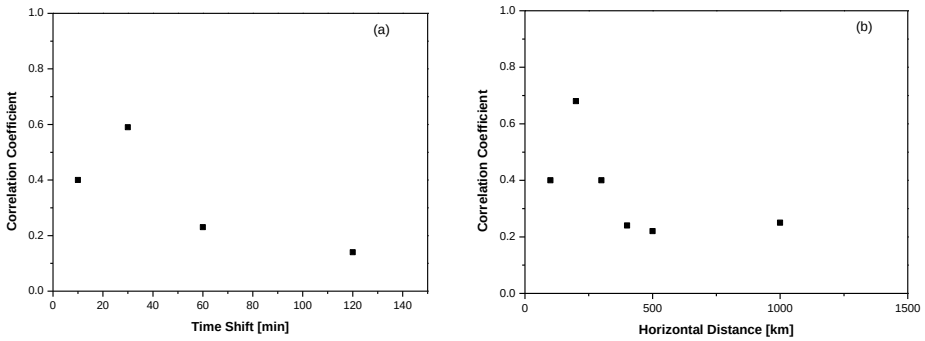

Figure 2. Correlation coefficient between the CALIPSO and EARLINET aerosol backscatter count distributions as a function of the temporal and horizontal distance: for horizontal distance below 100 km (Case A measurements) with different time shifts (a) and for different horizontal distances (b) with Version 2 data. Calculation has been performed considering the count distribution of backscatter values within the mean profiles calculated for each class of horizontal and temporal distances.

To better understand this point, the different count distribution were investigated and we found that these distributions show a high occurrence of low and high backscatter values in the CALIPSO observations, not present in the EARLINET profiles. It is likely that the noise affecting CALIPSO 5-km profiles is the cause of the high occurrence of both too small and too high aerosol backscatter values.

A devoted approach should be suited for the Version 3, because the lower SNR inhibits this kind of study based

on the count distribution. Reasonable results could be obtained, if an average is considered. This could be performed for example considering the count distribution of backscatter values within the mean profiles calculated for each class of horizontal and temporal distances. In such a way, the correlation coefficient (Figure 2) decreases with the distance following the behavior observed for Version 2 data. The only exception is the shorter distance class (100 km, 10 minutes) which has a low value of the correlation, probably because the noise in the CALIPSO data is not removed .

In spite of the promising capability of exploring short-distance representativeness thanks to the 5-km profiles, the results obtained applying the methodology used for Version 2 data on Version 3 profiles suggest that these latter profiles are not the most suitable to be handled for this kind of investigation. A more detailed study about SNR versus averaged horizontal resolution for CALIPSO V3 data is needed for a more complete and exhaustive representativeness study.

4. LEVEL 3 PROFILES

Since December 2011, a new product is released by NASA: the CALIPSO Lidar Level 3 Aerosol Profile Product. This is a tropospheric product that reports monthly mean profiles of aerosol optical properties on a uniform spatial grid at altitudes below 12 km. Four types of level 3 data files are generated each month depending on sky conditions and temporal coverage and are separated into day/night segments. The information contained in these Level 3 data could be really interesting from a climatological point of view, but their reliability and uncertainty should be studied and quantified. In particular, the representativeness of the data should be investigated into detail because of the long (16 days) revisiting time of this polar satellite. Monthly mean averaged profiles provided within Level 3 CALIPSO data products can be investigated by taking advantage of this expertise and the availability of the wide database of CALIPSO correlative measurements performed within the EARLINET network.

Figure 3 shows, as an example, the comparison of the extinction coefficient profiles for both CALIPSO observations and Napoli EARLINET station for the September 2008 period. CALIPSO satellite overpassed the assumed grid 6 times and the coincident measurements with Napoli station were 3. The correlation between the two profiles is quite satisfactory; nevertheless it suffers from the mismatch of the measurements averaged and the horizontal distance of the measurements within the CALIPSO uniform grid. As observed in the lowermost part of the figure the more significant influence of the local boundary-layer aerosol differentiates the values of the

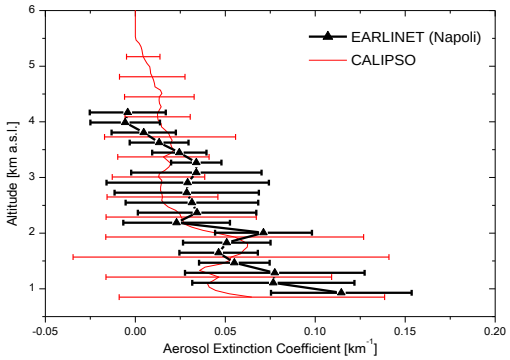

Figure 3: Monthly extinction coefficient profiles at 532 nm comparison measured at Napoli EARLINET station and obtained from CALIPSO observations within the grid containing the EARLINET station during September 2008.

profile [2]. This kind of study will furthermore benefit from the availability of the 12-years long-term database of EARLINET climatological data available from May 2000. Results will be presented at the conference.

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