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# REPRESENTATIVENESS OF AEROSOL MEASUREMENTS: EARLINET-CALIPSO CORRELATIVE STUDY

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## ABSTRACT

The high variability of tropospheric aerosols, both in space and time, is the main cause of the high uncertainty about radiative forcing related to tropospheric aerosols and their interaction with clouds. Because of the lack of high resolution aerosol global vertical profiles, the vertical mixing has not been considered so far in studies of spatial and temporal variability. The CALIPSO mission provides the first opportunity to investigate the 4-D aerosol and cloud fields in detail. However, because of the CALIOP small footprint and the revisit time of 16 days, 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, right after the CALIPSO launch. An integrated study of CALIPSO and EARLINET correlative measurements opens new possibilities for spatial (both horizontal and vertical) and temporal representativeness investigation of polar-orbit satellite measurements also in terms of revisit time.

## 1. INTRODUCTION

The high variability both in space and time of tropospheric aerosols is the main cause of the high uncertainty about radiative forcing related to tropospheric aerosols and their interaction with clouds [1]. Until now, the mesoscale variation of tropospheric aerosols has been analysed typically on the base of column-integrated measurements of aerosol optical properties. It was found that there is a little variability for distances below 20 km, while a sharp increase in the aerosol field variability is observed over horizontal scales of 20-100 km, probably due to the horizontal extension of main aerosol sources and sink regions [2]. In literature, the vertical mixing was not considered in the study of spatial and temporal variability because of the lack of high resolution global vertical profiles. This factor can lead also to significant horizontal inhomogeneities due to large vertical concentration gradients and it is therefore a large source of variability typically not considered in the models. A first attempt to address representativeness issues also in terms of vertical profiling was possible thanks to the LITE mission, the first experience with lidar in space. However, a statistically significant amount of data is needed to address representativeness issues, and since the LITE mission lasted for only 11 days, it could not provide the necessary database to address these issues.

In the context of representativeness study, the CALIPSO mission provides a first opportunity to study the 4-dimensional distribution of aerosols and clouds on a global scale. High-resolution vertical profiles provided by CALIOP, the lidar onboard CALIPSO, allow the inspection of stratospheric and free-tropospheric layer dynamics and the investigation of complex effects of mixing processes that influence the microphysical and optical properties of aerosols and clouds. However, because of the small footprint and the revisit time of 16 days, how well these CALIOP measurements represent the atmospheric conditions of a surrounding area over a longer time is a important issue to be investigated. An

integrated study of CALIPSO and EARLINET correlative measurements opens new possibilities for spatial (both horizontal and vertical) and temporal representativeness investigation of polar-orbit satellite measurements also in terms of revisit time. In fact, EARLINET provides well-established high quality data that can be considered as a reference point for aerosol studies. In addition, the geographical distribution of EARLINET stations over Europe allows to investigate a large variety of different aerosol contents in the free troposphere and the local planetary boundary layer [3-8].

## 2. EARLINET MEASUREMENTS FOR CALIPSO CORRELATIVE STUDIES

Since June 2006, measurements are performed at EARLINET stations in coincidence with CALIPSO overpasses according to a strategy for correlative measurements developed within EARLINET. This strategy has been optimized and consolidated in the frame of a dedicated ESA study aiming at a long-term aerosol and cloud data base from ground-based and satellite-borne lidars which started on April 1, 2008 [9]. Correlative measurements have been intensified especially taking into account the geographical distribution of the lidar stations which are grouped in four different clusters: Central European, Western Mediterranean, Central Mediterranean and Eastern Mediterranean. Following the measurements strategy established for this ESA study, EARLINET correlative measurements are performed at single stations in correspondence of CALIPSO overpass within 100 km (Case A measurements) simultaneously with stations in the same cluster (Case B measurements) and for large scales at stations in different clusters during interesting additional cases like Saharan dust intrusions and forest fires (Case C measurements) [10]. 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 variability on different horizontal scales, from regional to continental. In order to investigate the temporal variability of aerosol/clouds fields, we use records of measurements lasting 150 minutes (centered around the time of the overpass) performed at EARLINET station whenever atmospheric conditions allow it.

## 3. REPRESENTATIVENESS STUDY METHODOLOGY

Two different approaches for the correlation study are used according to the actual strategy for the correlative measurements: a point-to-point comparison, in which each EARLINET observation is compared with the corresponding CALIPSO overpass measurement and a multiple-point approach, for different scenarios, such as long-range aerosol transport, in which multiple-point observations are compared to appropriate horizontal averages along the satellite cross section. In particular, the spatial variability of aerosol/cloud fields is investigated through CALIPSO–EARLINET differences for almost simultaneous measurements performed at different relative horizontal distances (from 0 to 750 km with Case A and B measurements and larger distances with Case C measurements). The 150 minutes time series of measurements performed during Case A measurements allow to study the temporal variability independently of the spatial variability. Finally, observations of long-range transport over Europe provide information on the variability on larger horizontal scales and within different time intervals. In these situations variability can be particularly high both in terms of geometrical and optical properties [see for example e.g. 6;8;11-12], therefore point-to-point comparisons would be not sufficient and a specific subset of CALIPSO data related to Europe and surrounding areas has to be considered.

Furthermore, the large database collected during more than 2 years of correlative measurements within the ESA study will allow climatological and statistical analysis for each identified cluster of EARLINET stations, for specific scenarios (such as Saharan dust intrusion over Europe), seasons and for each type of identified cloud (water, mixed phase and ice clouds), in terms of geometrical and optical properties and intensive properties. CALIPSO is acquiring data since June 2006 and at the same time EARLINET stations are performing correlative measurements for CALIPSO data full exploitation. These almost 4-years data allow the investigation of the aerosol and cloud content over Europe in a climatological sense. Seasonal statistical analysis is possible from CALIPSO and EARLINET data. Space vs groundbased comparison will be carried on with a point-to-point as well as a multiple point approach. A point-to-point comparison based on Case A overpasses is essential to understand if CALIPSO measurements are representative of corresponding EARLINET station area in a climatological sense and if there are “systematic” deviations due to assumptions needed in the CALIPSO retrievals. A multiple point comparison performed on the 4 clusters area will extend the representativeness study, in a climatological sense, to larger areas.

## 4. FIRST RESULTS

First examples of spatio-temporal study variability based on specific cases where a large number of EARLINET observations are available or interesting conditions occurred, have been carried out [10]. Comparisons of CALIPSO and EARLINET backscatter measurements at 532 nm have been performed for a fixed maximum distance lower than 100 km and different time shifts, for a fixed time shift of 10 min and different horizontal distances, and for different temporal and spatial distances. This kind of analysis performed on many different events can provide an estimate of the typical scale-length for aerosol spatial and temporal variability.

A first example of representativeness study on climatological sense carried out starting from Case A measurements related to Leipzig station is reported in the following. For each overpass, only the CALIPSO profile closest in time and space is selected. The backscatter coefficient at 532 nm is considered in this example, because it is a primary product of CALIPSO and there is a large number of data available from EARLINET stations. Figure 1 reports the count distributions of backscatter at 532 nm values measured during the CALIPSO overpasses by CALIOP and by EARLINET Leipzig station, in Spring, Summer and Autumn. The bad weather conditions and the presence of low clouds limit the number of correlative ground-based measurements and the availability of aerosol profiles, so that the comparison for the Winter season is not possible at the moment. During Spring a good agreement is found. In particular, for this period, it results that the occurrence of backscatter values, collected in the layers identified by CALIPSO as aerosol layers, is higher for small backscatter values and decreases as backscatter increases. However in satellite data as well as in EARLINET data it is evident a peak in the occurrences for values around 0.00125 $km^{-1}$ $sr^{-1}$. In Summer period, the agreement is less good but this could be related to the limited data available for this period. For Autumn, there is some agreement for values below 0.002 $km^{-1}$ $sr^{-1}$, in fact the 2 distributions decrease fast with the increase of backscatter observed values, but in CALIPSO data many large values in backscatter are collected. This is probably due to a misclassification of some layers. Probably this problem will be solved in the Version 3 of the CALIPSO Level 2 profile data.

The representativeness study will be continued using both the point-to-point and multiple point approach for all the EARLINET correlative data and the CALIPSO Level 2 profile data Version 3 when available.

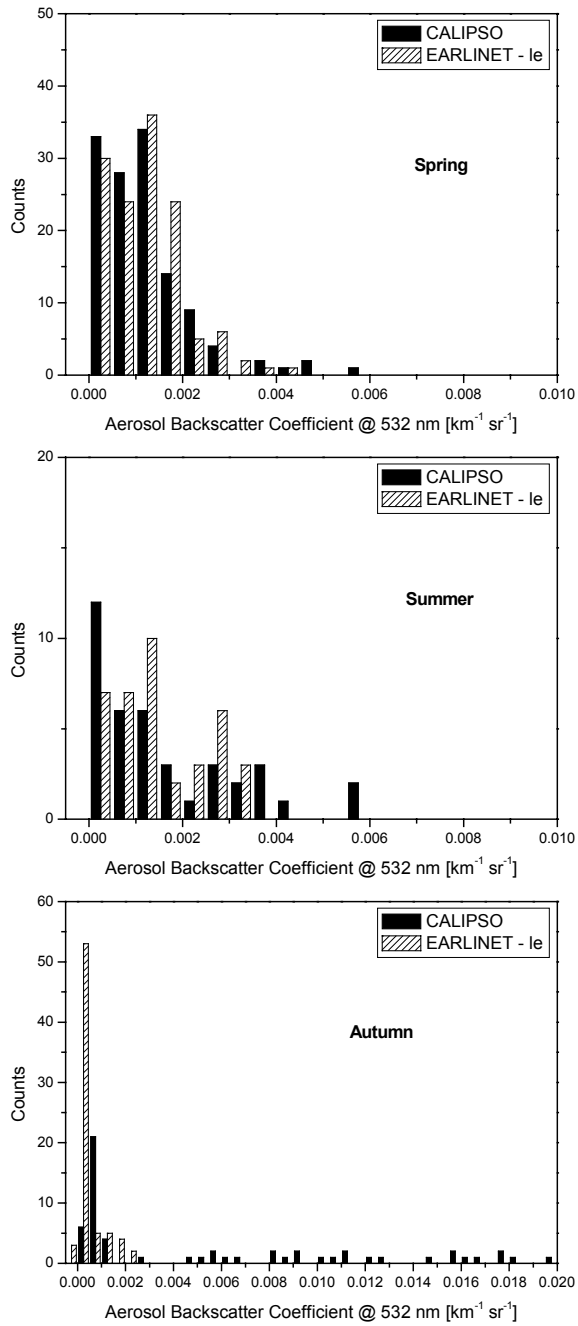


Figure 1. Count distributions of values of aerosol backscatter coefficient at 532 nm measured during Spring, Summer and Autumn at Leipzig EARLINET station and by CALIPSO in correspondence of CALIPSO overpass (Case A measurements).

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