CALIPSO LEVEL 3 DATA EXPLOITATION BY EARLINET CORRELATIVE MEASUREMENTS

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ABSTRACT

The almost six-years long database of aerosol and cloud vertical profiles provided by CALIOP (Cloud-Aerosol Lidar with Orthogonal Polarization) is at the present the longest database of aerosol optical properties profiles at global scale. This database is a unique tool for the characterization of aerosol 4D distribution at global scale. A new CALIPSO data product has been released on December 2011: the Level 3 data, i.e. monthly mean profiles of the aerosol extinction evaluated on 5° longitude x 2° latitude grid. These profiles provide a suitable database for climatological studies and comparison/assimilation in climate models. Before proceeding in this sense, the first issue to address is understanding how much these profiles can represent the 4D space on which they are evaluated. High quality profiles of aerosol optical properties provided by the European Aerosol Research Lidar Network (EARLINET) offers a unique opportunity for the exploitation of the CALIPSO Level 3 data products.

1. CALIPSO AEROSOL PRODUCTS

On April 2006, the launch of CALIPSO (Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation) satellite, the first satellite mission involving a lidar specifically designed to study aerosols and clouds, ushered in a new era of space-based lidar measurements on a nearly global scale [1]. The primary instrument aboard CALIPSO is the Cloud-Aerosol LIdar with Orthogonal Polarization (CALIOP) lidar, which is designed to acquire vertical profiles of elastic backscatter at two wavelengths (1064 nm and 532 nm). In addition to the total backscatter at the two wavelengths, CALIOP also provides profiles of linear depolarization ratios at 532 nm. Since the beginning of CALIPSO mission, two levels of data have been produced: Level 1 and Level2 data. Level 1 data are the so-called attenuated backscatter profiles at 532 and 1064 nm, where attenuated backscatter profiles are the raw signals, unless of the background subtraction and a calibration constant. Aerosol optical properties profiles are provided in Level 2 products. A specific sub-category of level 2 products provides information about aerosol/clouds optical properties within identified layers.

CALIPSO has been providing global information on vertical profiles of both aerosol and clouds optical properties and layering nearly continuously since June 2006 [1]. The good instrument up-time performance of CALIPSO, the absence of evident biases in the CALIPSO raw signals, and the reliability of aerosol optical properties as retrieved by CALIPSO algorithm

were demonstrated through comparisons with ground-based lidar measurements [2, 3]. The influence of multiple scattering on the aerosol retrieval from space borne lidars was showed in cases of high dust load through comparison with ground-based reference system [4].

In December 2011, a new product was 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. In particular, the representativeness of the data should be investigated into details because of the long (16 days) revisiting time of this polar satellite.

2. EARLINET

EARLINET, the European Aerosol Research LIdar NETwork (www.earlinet.org), is a coordinated network of stations that make use of advanced lidar methods for the vertical profiling of aerosols. At present, the network includes 27 lidar stations distributed over Europe, as shown in Fig. 1. EARLINET was established in 2000 with the main goal of providing a comprehensive, quantitative, and statistically significant database of the aerosol distribution on a continental scale [5]. EARLINET provides long-term, quality-assured aerosol data and, because of its geographical distribution over Europe, allows one 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. The backbone of EARLINET network is the quality assurance of instruments/data and a common schedule for performing the measurements. Inter-comparison exercises both at instrument and algorithm levels [6-8] and routine quality assurance procedures of lidar instruments and algorithms ensure that the data products provided by the individual stations are permanently of the highest quality possible.

EARLINET lidar observations are performed at each station on a regular schedule of one daytime measurement per week around noon (when there is a well developed boundary layer) and two nighttime measurements per week (Raman extinction measurements), when the signal-to-noise Raman signal is higher. Further coordinated observations are addressed to monitor special events such as Saharan dust outbreaks, forest fires, photochemical smog and volcanic eruptions.

Figure 1. EARLINET lidar stations (status at May 2012)

3. EARLINET EXPLOITATION OF CALIPSO LEVEL3 PROFILES

Because of its geographic coverage and the large number of advanced Raman aerosol lidars, EARLINET, offers a unique opportunity for the validation and full exploitation of the CALIPSO mission.

EARLINET developed a specific observational strategy for CALIPSO correlative measurements, which started already from June 2006 [3]. During the first two years of CALIPSO mission, the majority of EARLINET stations contributed on a voluntary basis to this measurement program. From April 1, 2008 to October 31, 2010, more measurements were performed thanks to the support of ESA for a dedicated study based on correlative EARLINET-CALIPSO observations at 16 selected EARLINET stations. In particular, the representativeness of vertical profiles of aerosol optical properties were investigated through a CALIPSO-EARLINET integrated approach. The main outcome of this investigation was that the optimal balance between the signal-to-noise ratio and the resolution is an essential factor for the data representativeness [9].

This expertise gained within EARLINET and the availability of the wide database of CALIPSO correlative measurements performed within the EARLINET network are a good starting point for the investigation of the monthly mean averaged profiles provided within Level 3 CALIPSO data products. The study could also benefit from all measurements performed in systematic way by EARLINET since the beginning CALIPSO mission. Furthermore the availability of the 12-years long-term database of EARLINET climatological data available from May

2000 is an added value for this kind of climatological investigation. 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.

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. At the present time, only extinction profiles are provided in CALIPSO Level 3 data. As first step of the study, only night segment of CALIPSO orbit are considered. In this way, the CALIPSO Level 3 extinction profiles can be directly compared and evaluated against EARLINET extinction profiles, typically retrieved only for nighttime measurements because of the low signal-to-noise ratio of Raman measurements.

All EARLINET measurements available in the 1 month – 2°x5° CALIPSO Level 3 grid of the 4D space are considered, even if these measurements were not performed as CALIPSO correlative measurements. This means that also climatological regular EARLINET measurements and measurements performed for monitoring and investigating special cases are considered. The comparison between each CALIPSO Level3 profile with the corresponding EARLINET average calculated in this way allows one to understand if the Level3 profile well represents the (temporal) averaged mean profile as observed by EARLINET stations.

Figure 2 shows, as an example, the comparison of the extinction coefficient profiles for both CALIPSO observations and Napoli EARLINET station for September 2008. CALIPSO satellite overpassed the assumed grid 6 times during September 2008. The extinction profiles available for Napoli station for the same period are 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 profiles close to the ground [2].

However, it has to be taken into account that the two profiles are the results of an averaging procedure on observations made in different points of the 4D space. Therefore differences are expected in these two profiles. The relevant question here is if the CALIPSO Level 3 data are representative of what observed by the ground-based lidar. For this evaluation, the error bar around the Level3 profile is an important parameter to consider. Error bars, reported in Fig.2 around the CALIPSO profile, represents the standard deviation of CALIPSO Level 2 profile averaged for obtaining the Level 3 averaged profile. Therefore these error bars (and similarly those reported for the EARLINET profile) indicate the variability at each altitude of the extinction profile on the 4D grid box. For the specific case reported here as example, the EARLINET extinction values fall always within the CALIPSO Level 3 error bars, indicating that the Level 3 data (extinction profile + standard deviation) well represents the EARLINET observations.

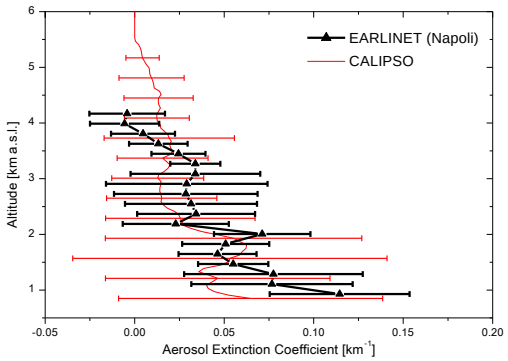

Figure 2: CALIPSO Level 3 monthly extinction coefficient profile at 532 nm for September 2008 on the grid containing the Napoli EARLINET station and monthly averaged extinction profile as measured by Napoli EARLINET station for the same period.

Further results based on data from more EARLINET stations and investigation on the dependence of Level 3 data representativeness as a function of the satellite-ground-based site distance will be showed at the conference.

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REFERENCES

1. Winker, D. M., W. H. Hunt, and M. J. McGill, 2007. Initial performance assessment of CALIOP. *Geophys. Res. Letts.*, **34,** L19803, doi:10.1029/2007GL030135.

2. Mona L., G. Pappalardo, A. Amodeo, G. D'Amico, F. Madonna, A. Boselli, A. Giunta, F. Russo, V. Cuomo, 2009. One year of CNR-IMAA multi-

wavelength Raman lidar measurements in correspondence of CALIPSO overpass: Level 1 products comparison, *Atmos. Chem. Phys.*, **9**, 7213-7228.

3. Pappalardo, G., et al., 2010. EARLINET correlative measurements for CALIPSO: First intercomparison results, *J. Geophys. Res.*, **115**, D00H19, doi:10.1029/2009JD012147.

4. Wandinger, U., M. Tesche, P. Seifert, A. Ansmann, D. Müller, and D. Althausen, 2010. Size matters: Influence of multiple scattering on CALIPSO light-extinction profiling in desert dust, *Geophys. Res. Letts*., **37**, L10801, doi:10.1029/2010GL042815.

5. Bösenberg, J., et al., 2003. EARLINET: A European Aerosol Research Lidar Network to establish an aerosol climatology, *Rep. 348, Max Planck Inst. für Meteorol.*, Hamburg, Germany.

6. Böckmann, C., et al., (2004). Aerosol lidar intercomparison in the framework of the EARLINET project. 2. Aerosol backscatter algorithms, *Applied Optics*, **43**, 977-989.

7. Matthias, V., et al. (2004). Aerosol lidar intercomparison in the framework of the EARLINET project. 1. Instruments. *Applied Optics*, **43**, 961-976.

8. Pappalardo, G., et al.. Aerosol lidar intercomparison in the framework of the EARLINET project. 3. Raman lidar algorithm for aerosol extinction, backscatter and lidar ratio, *Applied Optics*, **43**, 5370-5385.

9. Wandinger U., A. Hiebsch, I. Mattis, G. Pappalardo, L. Mona, F. Madonna. 2011. Aerosols and Clouds: Long-term Database from Spaceborne Lidar Measurements, *Final report, ESTEC Contract 21487/08/NL/HE.*