EARLINET for long term aerosol observations

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ABSTRACT

Lidar techniques represent the most suitable tool to obtain information on the aerosol vertical distribution and therefore to close this kind of observational gap. Lidar networks are fundamental to study aerosol on large spatial scale and to investigate transport and modification phenomena.

EARLINET, the European Aerosol Research Lidar Network, is the first coordinated aerosol lidar network, established in 2000, as a research program funded by the European Commission in the frame of the 5th framework program, with the main goal to provide a comprehensive, quantitative, and statistically significant data base for the aerosol distribution on a continental scale. After the end of the project, the network activity continued based on a voluntary association. On March 2006, the EC Project EARLINET-ASOS (Advanced Sustainable Observation System) started on the basis of the EARLINET infrastructure. This infrastructure project will improve the continuing observations and methodological developments that are urgently needed to provide a multi-year continental scale data set.

At present, EARLINET consists of 25 lidar stations distributed over Europe.

EARLINET data can contribute significantly to the quantification of aerosol concentrations, radiative properties, long-range transport and budget, and prediction of future trends on European and global scale. It can also contribute to improve model treatment on a wide range of scales and to a better exploitation of present and future satellite data.

EARLINET started correlative measurements for CALIPSO since June 2006. A strategy for correlative measurements has been defined on the base of the analysis of the high resolution ground track data provided by NASA. The expected outcome from this study is a statistically significant data base of correlated measurements to be used for the validation and full exploitation of the CALIPSO mission and for supporting the continuous, harmonized observation of aerosol and clouds with active remote-sensing techniques from space over the next decade, including CALIPSO, ADM-Aeolus, and EarthCARE.

1. EARLINET

EARLINET, at present, includes 25 lidar stations distributed over Europe, as shown in figure 1. The geographical distribution of the current 25 EARLINET stations covers the whole European continent from Madrid to Belsk and from Andøya to Athens. There are midlatitude near-costal stations like Bilthoven, Cabauw, Hamburg but also lidar sites with continental climate like Belsk and Minsk. The Mediterranean Sea is covered by 3 Spanish stations in the west, 5 sites in Italy, and 2 Greek stations in the east.

Figure 1 also shows the geographical distribution of the different kinds of EARLINET stations: 7 standard backscatter lidars are reported in blue, 9 Raman lidar stations with a Raman channel for independent measurements of aerosol extinction and backscatter are reported in green. Finally the red dots represent 9 multi-wavelength Raman lidars (elastic channel at

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1064 nm, 532 nm, 355 nm, Raman channels at 532 nm and 355 nm, plus depolarization channel at 532 nm) for the retrieval of aerosol microphysical properties.

EARLINET stations perform measurements almost simultaneously 3 times per week following a regular schedule: one daytime measurement per week around noon, when the boundary layer is typically well developed, and two night-time measurements per week, with low background light, in order to perform Raman extinction measurements. Besides routine measurements that provide a long unbiased dataset for aerosol climatological study, additional observations are performed to address specifically important events like Saharan dust, forest fires, volcanic eruptions, and photochemical smog.

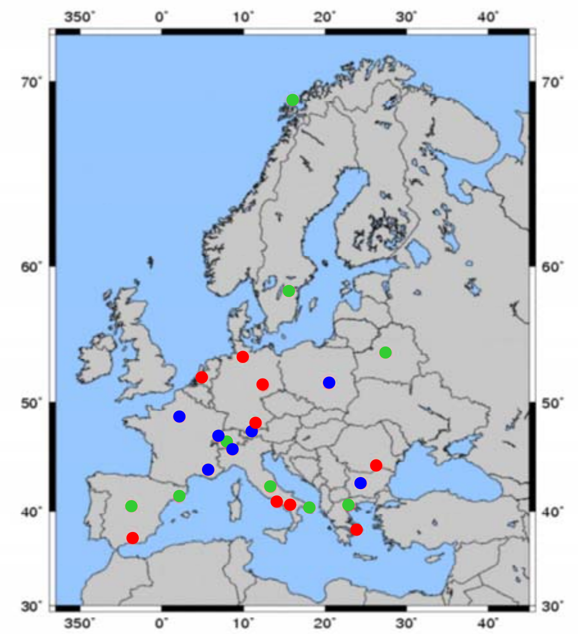

Figure 1: Geographical location of the 25 EARLINET stations. Blue dots represent standard backscatter lidars, the green dots the Raman lidar stations and the red ones the multiwavelength Raman lidar stations.

Data quality is assured by a specific program for the quality assurance. The quality of the different instruments participating to the network is checked through direct intercomparison with reference transportable systems and through tools, developed and optimised within the network, for the continuous quality check of the instruments. The quality of the retrieval algorithms for both backscatter and Raman lidar data used by the EARLINET stations is continuously checked and improved thanks to blind intercomparison exercises and developed tools. This data quality control establishes a common European standard for routine quality assurance of lidar instruments and algorithms and ensures that the data products provided by the individual stations are homogenous and permanently of the highest possible quality according to common standards.

2. OVERVIEW OF THE EARLINET DATABASE

The EARLINET database represents the largest database for the aerosol distribution on a continental scale [1]. The collection of measurements started in May 2000 and at present the database contains about 17000 aerosol profiles in terms of extinction, backscatter and lidar ratio, whereas lidar ratio data have been retrieved from simultaneous and independent lidar measurements of aerosol extinction and backscatter. It is an important source of data that contributes to the quantification of anthropogenic and biogenic emissions and concentrations of aerosols, quantification of their budgets, radiative properties and prediction of future trends. It contributes therefore to the improvement of the understanding of physical and chemical processes related to aerosols, their long-range transport and deposition, and their interaction with clouds.

The database contains two kinds of files: *e*-files and *b*-files. The *e*-files contain vertical profiles of aerosol backscatter coefficient and of aerosol extinction coefficient retrieved independently from Raman lidars without *a-priori* hypothesis on existing relation between them. Both parameters are reported with the same vertical resolution and with their statistical errors. The *b*-files contain vertical profiles of aerosol backscatter coefficient. This coefficient has been retrieved from elastic-backscatter lidar signal with assumptions on the vertical profile of lidar ratio or from the combination of Raman and elastic measurements but with a higher vertical resolution respect to what reported in the corresponding *e*-files. In both the *e*-files and *b*-files, the dust layer height and the mixing layer height are included. All the files include additional information such as: geographic coordinates of the lidar station, time duration of the measurement, effective space resolution, used wavelengths, used analysis technique. The files are organized in different categories related to regular (performed systematically three times per week) and special conditions. *Climatology*: regular measurements; *Cirrus:* observations of cirrus clouds; *Diurnal cycles*: diurnal and seasonal cycle of aerosols in the boundary layer; *Volcanic eruptions:* observations of the Etna eruption events in 2001 and 2002, and the most recent eruptions from Mt Redoubt and others in 2009; *Forest Fires:* observations of large forest fires; *Photosmog:* observations of photochemical smog episodes in large cities; *Rural/urban:* nearly simultaneous measurements at pairs of stations that are sufficiently close to minimize the effect of large scale patterns, but sufficiently apart to reflect the differences in the surrounding (urban versus rural or prerural); *Saharan dust:* special observations of Saharan dust outbreaks using dust forecast; *Stratosphere:* stratospheric aerosol observations and detection of smaller scale features of stratospheric aerosol distribution; *CALIPSO:* correlative measurements in coincidence of the CALIPSO overpasses.

EARLINET data have already conducted to a first statistical analysis of the aerosol optical properties over Europe [2], climatological studies [3], long range transport [4], aerosol characterization and implication of dust in the weather forecast modeling [5]. Moreover, retrieval algorithms for aerosol microphysical properties were developed and tested extensively with synthetic data and with real multiwavelength lidar data

[6,7]. In these studies lidar data were used for long-term monitoring of climate relevant aerosol optical properties. In particular, the mean value, the variability and the distribution of the most important aerosol parameters within PBL such as extinction and backscatter coefficient, lidar ratio, optical depth, Ångström coefficient, were studied. Moreover annual cycle and seasonal behavior during the year were obtained for the same optical parameters allowing the comprehension of the relevance of the different orography of the EARLINET stations. Correlation analysis between measured lidar ratio values and the origin and path of the air masses on the base of the backward trajectory analysis have been also performed [8-13].

The climatological measurements and their analysis are continuing within EARLINET and the expected outcome is the most comprehensive data source for the 4-D spatio-temporal distribution of aerosols on a continental scale. Synergies with AERONET and MODIS data are in progress. An important point is also the cooperation with other lidar networks distributed globally (e.g.: MPLNET, Asian network, CISLINET, REALM, ALINE), and here EARLINET will give a strong contribution to the implementation of the GAW Atmospheric LIdar Observation Network (GALION) [14].

3. THE EARLINET-CALIPSO EXPERIENCE

Because of its geographical coverage and its high data quality, EARLINET represents an optimal tool to validate satellite lidar data and to support the fully exploitation of the information from present and future satellite missions.

EARLINET ground based lidars as reference points are strongly necessary to increase and validate the accuracy of aerosol optical properties retrieved from CALIPSO, the first satellite mission with a lidar on board specifically designed for aerosol and cloud observation [15,16]. In particular EARLINET Raman station's data are important to validate and improve, if it is the case, the aerosol retrievals from the pure backscatter lidar on board CALIPSO. EARLINET Raman lidars allow to investigate intensive optical parameters (like lidar ratios and Ångström exponents) and their dependences on the specific aerosol and cloud types, information strongly needed for the development and optimisation of space-borne lidar algorithms.

Furthermore, 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. Since April 2008, the European Space Agency supports the EARLINET-CALIPSO correlative measurements program, with two main goals: providing conversion factors in dependence of aerosol and cloud type, and investigating representativeness of CALIPSO data in describing aerosol and cloud fields through correlation analysis with EARLINET measurements.

Since June 2006, EARLINET has extended its program of measurements in order to perform measurements also in correspondence of CALIPSO overpasses and these correlative observations have been further intensified with the ESA study. Within the EARLINET correlative program for CALIPSO, still in progress, a great experience has been gained in developing suitable strategies, on the base of the analysis of the high resolution ground track data provided by NASA, for correlative observations, validation and full exploitation of satellite lidar data. In particular, each EARLINET station performs measurements as close as possible in time and space to CALIPSO ones, within 4 h and 100 km. Additional measurements are performed in order to take advantage from the geographical coverage of the network, especially in interesting cases of aerosol transport, like Saharan dust outbreaks.

After more than 3 years of correlative observations, more than 3500 correlative files are available for comparisons.

First systematic comparison between EARLINET and CALIPSO data (both Level 1 and Level 2 data) are promising [17,18].

The horizontal and temporal variability of aerosol/clouds fields on different scales is studied following two different approaches: a point-to-point comparison, in which each EARLINET observation is compared with the corresponding CALIPSO overpass measurement and a multiple-point approach, in which observations of more EARLINET stations are compared with satellite data opportunely averaged, for different scenarios, such as long-range aerosol transport [19-20].

The data base from the long-term EARLINET-CALIPSO measurement program will contribute to the development of cloud and aerosol-type classification schemes and of conversion algorithms to relate space-borne lidar observations made with different instruments onboard the CALIPSO, ADM-Aeolus [21], and EarthCARE [22] missions. This is an important activity to establish a harmonized long-term, global, 4- dimensional aerosol and cloud data set. This requires the long-term, ground-based support of space-borne missions with multiwavelength lidar instruments at different locations in order to build up a comprehensive database of ground-truth information.

There is a strong need to continue such kind of activities during future space-borne lidar missions. In addition, the currently established global aerosol lidar network GALION (Global Atmosphere Watch Aerosol Lidar Observation Network) will allow us to extend the groundbased observations from the continental to the global scale and to improve our understanding of the variety of natural and anthropogenic aerosol sources.

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