5.1 AEROSOL LIDAR MEASUREMENTS IN THE FRAMEWORK OF EARLINET

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1. INTRODUCTION

EARLINET, the European Aerosol Lidar Research Network, is the first aerosol lidar network, established in 2000, with the main goal to provide a comprehensive, quantitative, and statistically significant data base for the aerosol distribution on a continental scale. The use of these data can contribute significantly to the quantification of aerosol concentrations, radiative properties, long-range transport and budget, and prediction of future trends. It can also contribute to improve model treatment on a wide range of scales and to a better exploitation of present and future data from satellite remote sensing for a variety of parameters.

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EARLINET consists of 22 lidar stations distributed in 12 European countries, as shown in figure 1.
Lidar observations are performed on a regular schedule of one daytime measurement per week around noon, when the boundary layer is usually well developed, and two night time measurements per week, with low background light, in order to perform Raman extinction measurements. In addition to the routine measurements, further observations are devoted to monitor special events such as Saharan dust outbreaks, forest fires, photochemical smog and volcano eruptions.
Data quality has been assured by intercomparisons at instrument level using the available transportable systems (Matthias et al., 2004). The quality assurance also included the intercomparison of the retrieval algorithms for both backscatter and Raman lidar data (Böckmann et al., 2004; Pappalardo et al., 2004).

EARLINET observations have been supported by the DREAM dust model activities: case studies of some major dust storms, and daily dust forecasts indicating the incoming dust events (Nickovic et al., 2001).

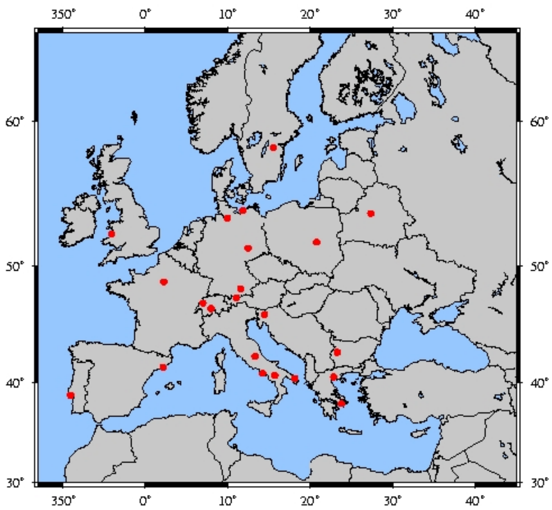

Figure 1. Map of the EARLINET lidar stations.

2. EARLINET DATABASE

EARLINET measurements started in May 2000 and are still continuing for most of the stations even after the end of the EARLINET Project (February 2003). Up to now the EARLINET database represents the largest database for the aerosol distribution on a continental scale.
This database contains more than 15000 aerosol profile data and the content of the database is still growing in spite of the formal end of the project.
All the files are divided in different categories related to regular and special conditions:

- Climatology (regular measurements)
- Cirrus
- Diurnal cycles (diurnal and seasonal cycle of aerosols in the boundary layer)
- Volcanic eruptions (observations of the Etna eruption events in 2001 and 2002)
- 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 pre-rural)
- 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 and its interdependence with dynamics and heterogeneous chemistry).

In particular, the EARLINET database contains a large data set concerning the ratio of aerosol extinction to backscatter (lidar ratio) retrieved from simultaneous and independent lidar measurements of aerosol extinction and backscatter. This is by far the largest data set of lidar ratio data on continental scale covering more than 3 years of systematic observations (Bösenberg et al., 2003) and it is very important for the characterization of the aerosol and it is greatly important for the estimation of aerosol extinction from pure backscatter lidar measurements as for the validation of future spaceborne lidar missions such as for example, CALIPSO (Winker et. al., 2004).

Table 1. The EARLINET Raman lidar stations.

LIDAR STATION	code	LAT	LON
Aberystwith - UK	ab	52.4 N	4.06 W
Athens - GR	at	37.97 N	23.79 E
Hamburg - D	hh	53.57 N	9.97 E
Kühlungsborn - D	kb	54.12 N	11.77 E
L’Aquila - I	la	42.34 N	13.33 E
Lecce - I	lc	40.33 N	18.10 E
Leipzig - D	le	51.35 N	12.43 E
Napoli - I	na	40.83 N	14.18 E
Potenza - I	po	40.6 N	15.72 E
Thessaloniki - GR	th	40.5 N	22.9 E

Within EARLINET, 10 lidar stations have the capability of measuring Nitrogen Raman scattering in the UV simultaneously to the elastic backscatter; among these lidar stations, two have the capability to measure Nitrogen Raman scattering also in the visible domain

(Kühlungsborn and Leipzig), as reported in table 1.

3. LIDAR RATIO DATA ANALYSIS

The analysis reported in this section refers to the period May 2000 – December 2002, corresponding to the formal measurements period of the project.
All the collected lidar ratio data have been divided between regular measurements, establishing the climatology, and special measurements (Saharan dust outbreaks, forest/industrial fires, photochemical smog episodes, volcanic eruptions etc.).

A statistical analysis on climatological data has been performed: mean values of the lidar ratio data in the Planetary Boundary Layer (PBL) have been calculated for each station and for winter (October-March) and summer (April-September) periods (figure 2). The seasonal variation and the frequency distribution have been studied and reported in figure 3. The statistical distribution of the lidar ratio is broad for all stations. Mean values range from 32 sr to 76 sr and no significant seasonal dependence is observed respect to the strong seasonal dependence observed for the aerosol optical depth (Matthias et al., 2004). However, a strong variability (about 40% in average) has been observed along the vertical profiles in the PBL for all the stations and for the whole dataset.
A correlation analysis of the mean lidar ratio values in the PBL with air mass origin has been performed by using the 96 hours analytical back-trajectories provided by the German Weather Service. Higher lidar ratio values measured in Southern stations are correlated with air masses coming from Saharan regions. High lidar ratio values measured in central Europe seem to be correlated with air masses coming from east direction related to more continental and polluted aerosols, while lower values have been observed for air masses coming from the ocean, representing more maritime aerosols.

Lidar ratio measurements in the free troposphere have been studied in case of special events as Saharan dust outbreaks and volcano eruptions.
In case of Saharan dust outbreaks, high lidar ratio values (up to 90 sr at 355 nm and up to 80 sr at 532 nm) have been observed in the free troposphere over Germany (Ansmann, 2003).

Anomalous high lidar ratio values (50-60 sr) have been observed in southern Italy, in the free troposphere around 3-4 km of altitude during the last two eruption events of the Etna volcano and these values are consistent with submicron sulfate particles (Pappalardo, 2004).

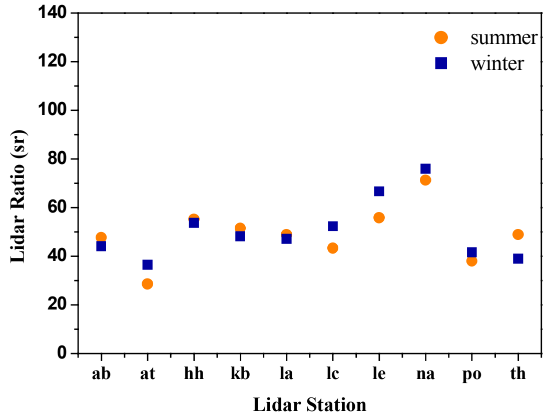

Figure 2: Mean lidar ratio values calculated for each lidar station in the Planetary Boundary Layer starting from May 2000 – December 2002 data.

4. CONCLUSIONS

EARLINET is the first lidar network that has produced the largest data base for the aerosol distribution on continental scale.
This database is still growing and at present it is already useful to fill partially the gap in the scientific knowledge about the vertical distribution of aerosols in the atmosphere which is necessary for a better understanding of aerosol effects on climate.
In this paper, in particular, a statistical analysis on the mean values of the lidar ratio data in the Planetary Boundary Layer and a correlation analysis with air mass origin have been showed. The observed large variability of the lidar ratio demonstrates how it is important to continue this kind of systematic observations on continental scale also for validation of future spaceborne lidar missions.

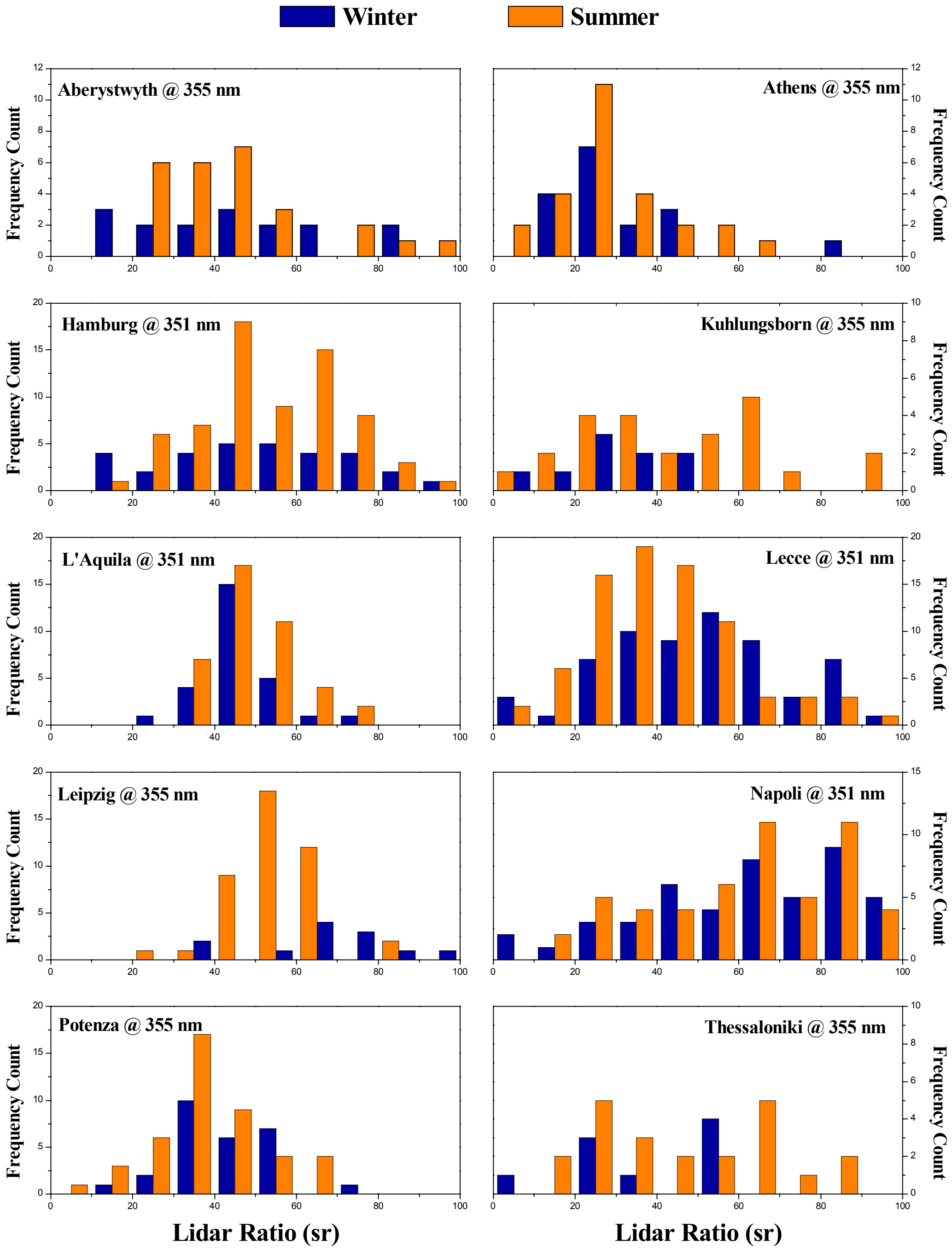

Figure 3: Frequency distribution for winter and summer periods of the mean values of the lidar ratio calculated in the PBL starting from all the climatological data (May 2000 – December 2002) for each lidar station.

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