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Aerosol climatology of tropospheric aerosols over Athens, Greece using an elastic-Raman Lidar system in the frame of EARLINET and beyond (2000-2004)

C. Tsamalis (1), G. Tsaknakis (1), **A. Papayannis** (1), C. Chourdakis (2), G. Georgoussis (2)

(1) Physics Department, National Technical University of Athens, Athens, Greece (apdlidar@central.ntua.gr / Fax: +30 210-7722928 / Phone: +30 210-7722992)

(2) Raymetrics S.A., 5 Kanari str., Glyka Nera, 15354 Athens, Greece (chourdakis@raymetrics.gr / Phone: +30 210-6655800)

Regular measurements of aerosol backscatter, integrated backscatter, and optical depth using an elastic-Raman lidar system, at 355 and 532 nm, have been performed over Athens (37.9^o N, 23.6^o E), Greece, since May 2000. Most of the lidar data were obtained in the frame of the EARLINET project (2000-2003) and also beyond, up to April 2004. The lidar profiles were obtained in the lower troposphere typically from 500 m to 5000 m above sea level (asl). The high quality of the lidar data has been previously assured by extensive inter-comparison at software and hardware levels within the frame of EARLINET (Boeckmann et al., 2004; Matthias et al., 2004; Pappalardo et al., 2004). The large set of lidar profiles acquired by the elastic lidar (550 aerosol backscatter profiles) and the Raman lidar (115 aerosol extinction profiles) system has been used for statistical evaluation studies. Mean values and variances of the aerosol backscatter profiles, integrated backscatter, and optical depth have been evaluated. The corresponding seasonal cycle of these quantities shows highest values during the summer period and secondary maxima during the autumn/spring period. Small fluctuations have been found only during the winter months. High aerosol integrated backscatter values were found during the summer period, due to larger dust concentrations in the lower troposphere.

0.1 Introduction

Atmospheric particles and mainly the mineral dust particles, play a crucial role in the earth's radiation balance and climate (direct and indirect effects) by scattering and absorbing both incoming and outgoing radiation (IPCC, 2001). To derive long time series of the aerosol vertical distribution on a continental scale the European lidar network EARLINET (European Aerosol Research Lidar Network) was established in 2000 (Boesenberg et al., 2003). In the frame of this project an elastic-Raman lidar system based on the 2^{nd} and 3^{rd} harmonic of a Nd:YAG laser performs regular measurements of the aerosol backscatter, integrated backscatter and optical depth over Athens, since May 2000. In this paper we present results concerning the aerosol climatology from a set of aerosol lidar data obtained over a 4 years period (2000-2004). Mean values and variances of the aerosol backscatter profiles, integrated backscatter and optical depth have been evaluated.

We calculated the aerosol volume backscatter coefficient β_{aer} at two wavelengths, 355 nm and 532 nm, using the Klett inversion technique (Klett, 1981 and 1985), and evaluated the integrated backscatter coefficient (IB) and the aerosol optical depth (AOD), in combination with concurrent N_2-Raman measurements at 387 nm. IB and AOD values were calculated using the following equations:

$$IB = \int \beta_{aer}(z)dz, \quad AOD = \int \alpha_{aer}(z)dz$$

About 550 vertical profiles of β_{aer} in the lower troposphere were obtained and the mean values and variances, as well as their monthly and the seasonal evolution and those of IB (at 355 and 532 nm) and AOD (at 355 nm), were estimated. IB and the vertical profiles of β_{aer}, at both wavelengths, and the AOD at 355 nm, show the highest values during the summer and autumn months, due to higher dust concentrations in the lower urban troposphere over Athens. Winter months show the lowest values of β_{aer}, IB and AOD. This is closely related to the origin of the air mass trajectories ending over Athens, in conjunction with the prevailing meteorological conditions during these periods and in association with the corresponding planetary boundary layer (PBL) height.

We also evaluated the mean value of β_{aer} for different seasons and in three different tropospheric regions: a) 0-1 km (inside the PBL), b) 1-2 km (PBL-entrainment zone) and c) 2-5 km (free atmosphere). At 355 nm [in region (a)] β_{aer} shows highest values in autumn with a second, less prominent peak, in summer and a minimum value in winter. In region (b) β_{aer} shows highest values in summer with a second, less prominent peak, in autumn, and a minimum value in winter. In region (c) β_{aer} shows highest values in summer with a second, less prominent peak, in spring, and a minimum value in winter. These results are again closely related to the origin of the air mass trajectories ending over Athens, in conjunction with the prevailing meteorological conditions during these periods and in association with the corresponding planetary boundary layer (PBL) height. At 532 nm β_{aer}, in regions (a) and (c), behaves as discussed previously at 355 nm. However, in region (b) β_{aer} shows highest values in summer with a second, less prominent peak, in spring and a minimum value in winter. This means that larger aerosols are present in the upper PBL-entrainment zone during spring-time closely related to air masses coming the Saharan dust region.

The values of IB, at 355 nm, range between 0.015 sr^{-1} and 0.02 sr^{-1}, except for the winter months (December – January) where they are down to 0.0011 sr^{-1} and the month of August where they peak up to 0.029 sr^{-1}. The corresponding standard deviation ranges between 30% - 45%. At 532 nm, again during the winter months (December to February), the IB shows the lowest values (around 0.004 sr^{-1}), while on May the IB reaches 0.011 sr^{-1}, while during the summer months (July, August) the IB peaks around 0.013 sr^{-1}. The rest of the year the IB values are around 0.008 sr^{-1}. At 532 nm the corresponding standard deviation is higher (between 50% and 75%). Since the IB is closely related to the aerosol concentration, it is evident that during summer time it takes its maximum values (due to the transport of dust aerosols from the Saharan dust region, as shown by Papayannis et al., 2004), while during winter time, it takes its lowest values of the year, since the wind pattern is changing drastically. The month-to-month variation of the IB data shows higher values during the summer months due to larger dust concentrations in the lower troposphere. Mean AOD values at 355 nm were found equal to 0.45 and 0.35, up to 2 km height and inside the PBL, respectively.

0.2 Conclusions

A large set of lidar profiles acquired by an elastic lidar (550 aerosol backscatter profiles) and a Raman lidar (115 aerosol extinction profiles) system has been used for statistical evaluation studies of the aerosol properties over Athens during a 4 years period (2000-2004). Mean values and variances of the aerosol backscatter profiles, integrated backscatter and optical depth have been evaluated. The corresponding seasonal cycle of these quantities shows highest values during the summer period and secondary maxima during the autumn/spring period. Small fluctuations have been found only during the winter months. High aerosol IB values were found during the summer period, due to larger dust concentrations in the lower troposphere.

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0.4 References

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