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Lidar and spectrophotometer investigation of the air quality over Sofia (Bulgaria): preliminary results

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1 Abstract

A six-month (from April 1 till October 30, 2004) observation of the atmosphere over the urban area of the Sofia city was carried out. An EARLINET scanning aerosol lidar, a spectrophotometer and a ground meteorological station were used during the observation. Multiple aerosol layers of variable thickness (200-600 m) were systematically observed in the planetary boundary layer. The aerosol extinction coefficient and the aerosol optical depth are determined and their variations are followed during the convective boundary layer formation.

Introduction

The atmospheric aerosol plays a significant role in the global change of the planet climate and influences the energy flows towards and from the earth surface both directly and indirectly through clouds of different types located at various heights (T. Takamura et al., 1994). Following the aerosol motion in the low troposphere, one could obtain information about the planetary boundary layer height.(P. Girolamo et al., 1999, Kolev I., et. al., 2000) According to the recent studies, a main parameter of the aerosol which significantly impacts the climate is the aerosol optical depth (AOD), (M. P. Utrillas et al., 2000, E. Gerasopoulos et al., 2003) namely, the integral extinction coefficient of the entire atmosphere. AOD and aerosol sise distribution can be determined measuring the direct solar radiation at certain wavelengths on clear sunny days. Such kind of tasks could be solved by combined use of lidar and spectrophotometer (P.. Devara et al., 1996, N. Kolev et al., 2005). The work aims at studying of certain optical characteristics of the atmospheric aerosol in the planetary boundary layer from 75 m (the lidar dead zone) to about 2500-3000 m. One could consider the results presented to complement the Raman lidar data obtained at greater heights and mainly after sunset.

Instrumentation

Specifications of the lidar (developed in the Institute of Electronics): **transmitter** - a standard NdYAG laser (operational wavelength 532 nm, pulse duration and energy 15-20 ns and 10–15 mJ, repetition rate 12.5 Hz; **receiving antenna** – a Cassegrainian telescope (main mirror diameter 150 mm, equivalent focal length 2250 mm); **photodetector** – a PMT with an interference filter (1 nm FWHM); **data acquisition and processing set** – 10 bit 20 MHz ADC and a PC. (B. Tatarov et al., 2000).

Specifications of the spectrophotometer (radiometer) (developed in the Central Laboratory of Solar-Terrestrial Influences): photographic objective, prism monochromator, CCD line (512 pixels), PMT, 10 bit ADC, and 8 bit specialized computer (44 KB RAM); spectrum range 550 $\div$1100 nm, spectrum resolution ($<$10 nm), photodetector dynamic range 10^4, time of data accumulation 50 ms$\div$10 s.(D. N. Mishev et al., 1992)

Experimental results and discussion

The conception of the experiment is the air quality over the urban area to be estimated on the basis of a combined analysis of the lidar, radiometric and meteorological data. The planetary boundary layer dynamics from a stable nocturnal stratification to a well developed mixing layer (ML) was being also followed by the lidar under different meteorological conditions. The aerosol extinction coefficient, aerosol optical depth and their variation during the CBL formation are also determined.

During the lidar observations 6000 profiles were recorded at a period of about 9–10 minutes. Each 150 profiles were averaged to increase the signal/noise ratio. The 40 profiles thus obtained were transformed into S–functions, for which the standard deviation and the first and second derivates were calculated, the latter two were used to determine the mixing layer height (L. Menut et al., 1999).

The gradual formation of the PBL from a stable nocturnal stratification (with multilayered temperature inversions which are characteristic of the region) to a well developed ML with a height of about H=1300-1600 m during summer period and H=600-800 m during autumn period.

A main indicator of the aerosol radiative characteristics is the optical thickness $\tau_{\alpha\lambda}$. Generally, $\tau_{\alpha\lambda}$ values in the solar spectral region are obtained from solar extinction measurements at ground level by means of sun photometer at several wavelengths (R. N. Halthore et al., 1996). The variation of $\tau_{\alpha\lambda}$ as a function of wavelength can be used to infer characteristics of atmospheric aerosol. The analysis of the $\tau_{\alpha\lambda}$values show that values corresponding to the 550 nm wavelength $\tau_{\alpha,0.55}$ occillate between 0.05 and 0.35.

The comparison between aerosol optical depth determined by lidar (0-2000m) and spectrophotometer shows a good agreement. It was found that the maximum AOD value during the summer is reached about two hours before the entire development of the CBL.

Conclusion

In this paper we determined the urban mixing layer height and its growth rate using an aerosol scanning lidar. Three different methods of the range corrected signal obtained from the aerosol backscattering are employed to retrieve the mixed layer height. The development of the mixed layer is consistent with that of the aerosol optical thickness except for solitary differences. Continuous and long term observations make it possible to estimate diurnal and seasonal variations of the mixed layer and aerosol optical depth. The results obtained could be considered to complement the Raman lidar data obtained at greater heights and mainly after sunset.

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