THREE-YEAR SYSTEMATIC AEROSOL LIDAR RATIO MEASUREMENTS OVER ATHENS, GREECE (2003-2006)

A. Papayannis(1), G. Tsaknakis(1), R.E. Mamouri(1), G. Chourdakis(2) and G. Georgoussis(2)

(1) National Technical University of Athens, Physics Department, Laser Remote Sensing Laboratory, Heroon
Polytechniou 9, 15780 Zografou, Greece, apdlidar@central.ntua.gr
(2) Raymetrics S.A., Kanari 5, Glyka Nera, Athens, Greece, chourdakis@raymetrics.gr

ABSTRACT

We present vertical profiles of the aerosol optical properties obtained by a two-wavelength UV Raman lidar system in a three-year period (January 2003 to January 2006) over Athens, Greece. These profiles were obtained at 355 nm, on a systematic basis, in the frame of the post-EARLINET project. Mean height profiles of the aerosol extinction, backscatter and lidar ratio are shown along with their seasonal variation. Air mass back-trajectory analysis, along with a cluster analysis, related the lidar ratio and aerosol optical thickness values to air masses of different origin (i.e, Saharan dust, biomass burning, marine or continental aerosols).

1. INTRODUCTION

Tropospheric aerosols play an important role in earth's radiation budget through the scattering and absorption of the incoming and outgoing radiation. This can yield to local radiation balance and climate changes (local cooling or heating effects) depending on the aerosol chemical composition [1]. Monitoring the optical properties of aerosol particles is of crucial importance in studies of climate change, atmospheric modelling and satellite image correction.

It is well known that tropospheric aerosols are highly variable in time and space because of the non uniform distribution of their sources and the strong influence of meteorological conditions on aerosol concentration and their optical, chemical and microphysical characteristics. The different types of aerosols depend on their source regions and can be categorized mainly as mineral dust, sea salt, volcanic, carbonaceous, or sulphate aerosols all originating from various natural and anthropogenic sources.

The laser remote sensing technique has been proved to be a very reliable tool to monitor the temporal and spatial evolution of aerosols in the atmosphere and evaluate their basic optical properties in the troposphere under various atmospheric conditions [2-5]. In particular, the Raman lidar technique is the most suitable one to obtain, simultaneously, independent vertical profile measurements of the aerosol optical properties (aerosol extinction, backscatter, lidar ratio, Angström coefficient) in the troposphere [6].

The Eastern Mediterranean region has been recently characterized as an air pollution crossroad [7]. In addition to local sources, aerosols from different sources (i.e. Saharan desert, forest fires, industrial activity, etc.) converge. Therefore, in addition to the maritime aerosols from sea spray and mineral dust from North Africa, anthropogenic aerosols from the highly populated urban sites and industrial areas of central and eastern Europe, as well as seasonal biomass burning are present [5].

2. EXPERIMENTAL SETUP

The NTUA Raman lidar system is based on a frequency tripled Nd:YAG laser, witch emits pulses of 75 mJ output energy at 355 nm with a 10 Hz repetition rate. The optical receiver is a Cassegrainian reflecting telescope with a primary mirror of 300 mm diameter and of focal length f=600 mm, directly coupled, through an optical fiber, to the lidar signal multi-channel detection box. The PMT detectors used are operated both in the analog and photon-counting mode and the spatial raw resolution of the detected signals is 15 m.

The elastically backscattered lidar signal at 355 nm is detected both in the analog and photon-counting mode, while the inelastically backscattered Raman signal by the atmospheric N_2 at 386.7 nm is detected only in the photon-counting mode. Narrow-band interference filters are used to suppress the atmospheric background noise at the various detected wavelengths (Full-Width-at-Half-Maximum (FWHM): at 355 nm and 386.7 nm is 3 nm. Optical transmission: at 355 nm is 50%, and at 386.7 nm is 60%).

3. RAMAN LIDAR SYSTEM CALIBRATION-METHODOLOGY

The NTUA Raman lidar system has been calibrated both at hardware and software level [8-9] during the EARLINET project. The determination of the lidar ratio profile has been computed using the Raman lidar technique for determining independently the particle extinction and backscatter vertical profiles according to the methodology provided by Ansmann et al. [6].

4. EXPERIMENTAL RESULTS

Vertical profiles of the aerosol optical properties were obtained by a two-wavelength UV Raman lidar system (335 nm and 386.7 nm) in a three-year period (January 2003 to January 2006) over Athens, Greece. These profiles were obtained on a systematic basis, in the frame of the post-EARLINET project. Thus, an aerosol lidar ratio climatology was created for various atmospheric conditions which could be used to relate lidar ratio values with the aerosol source region. As an example, the mean height profile of the lidar ratio, in the 0.5-4 km altitude height region, during Saharan dust outbreaks reaching Athens, (mostly S, SW winds), is shown in Fig. 1.

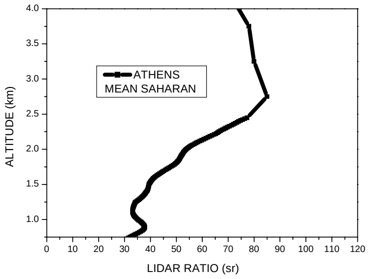

Fig.1. Mean height profile of the lidar ratio during Saharan dust outbreaks reaching Athens.

The corresponding mean value of the lidar ratio (only for Saharan dust outbreaks) is found equal to 53±1 sr [3]. Air mass back-trajectory analysis, along with a cluster analysis, related the lidar ratio and aerosol optical thickness values to air masses of different origin (i.e, Saharan dust, biomass burning, marine or continental aerosols). Thus, higher lidar ratio values in the free troposphere are generally correlated with air masses coming from southerly directions and this could be related to aerosols originating from the Saharan dust region [3].

Mean values of the lidar ratio during the “winter” period (October to March) were found equal to 37±8 sr, while during the “summer” period (April to September) were found equal to 32±6 sr. This lidar ratio climatology could also be useful for satellite data retrieval applications and for calibrating elastic backscatter lidar systems.

ACKNOWLEDGEMENTS

This project was funded by the GSRT/PENED 2003 (03-ED-169) Project, the EU-European Social Fund, the EPAN Program and RAYMETRICS SA.

REFERENCES

1. Houghton J. T., et al. Climate Change 2001: The Scientific Basis, Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), Cambridge University Press, London, 2001.

2. Amiridis V., et al. Four-year aerosol observations with a Raman lidar at Thessaloniki, Greece, in the framework of European Aerosol Research Lidar Network (EARLINET), *JOURNAL OF GEOPHYSICAL RESEARCH*, Vol. 110, D21203, doi:10.1029/ 2005JD006190, 2005.

3. Papayannis A., et al. Measurements of Saharan dust aerosols over the Eastern Mediterranean using elastic backscatter-Raman lidar, spectrophotometric and satellite observations in the frame of the EARLINET project, *ATMOSPHERIC CHEMISTRY AND PHYSICS*, Vol. 5, 2065-2079, 2005.

4. Balis D., et al. Optical properties of Saharan dust layers as detected by a Raman lidar over Thessaloniki, Greece, *GEOPHYSICAL RESEARCH LETTERS*, Vol. 31, L13104, doi:10.1029/2004GL019881, 2004.

5. Balis D., et al. Raman lidar and sun-photometric measurements of aerosol optical properties over Thessaloniki during a biomass burning episode, *ATMOSPHERIC ENVIRONMENT*, Vol. 37, 4529-4538, 2003.

6. Ansmann A., et al. Combined Raman elastic-backscatter lidar for vertical profiling of moisture, aerosol extinction, backscatter, and lidar ratio, *APPLIED PHYSICS B*, Vol. 55, 18-28, 1992.

7. Lelieveld J., et al. Global air pollution crossroads over the Mediterranean, *SCIENCE*, Vol. 298, 794–799, 2002.

8. Pappalardo G., et al. Aerosol lidar intercomparison in the frame of EARLINET: Part III: Aerosol extinction Raman lidar algorithm intercomparison, *APPLIED OPTICS*, Vol. 43, 5370-5385, 2004.

9. Matthias V., et al., Vertical aerosol distribution over Europe: Statistical analysis of Raman lidar data from 10 European Aerosol Research Lidar Network (EARLINET) stations, *JOURNAL OF GEOPHYSICAL RESEARCH*, Vol. 109, D18201, doi:10.1029/ 2004JD004638, 2004.