DESIGN AND DEVELOPMENT OF AN 8-WAVELENGTH RAMAN-DIAL SYSTEM FOR THE RETRIEVAL OF OZONE, WATER VAPOR AND THE OPTICAL AND MICROPHYSICAL PROPERTIES OF AEROSOLS IN THE TROPOSPHERE

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ABSTRACT

An 8-wavelength Raman-DIAL system has been designed and developed for the retrieval of ozone, water vapor and the optical and microphysical properties of aerosols in the troposphere in the Eastern Mediterranean region over Athens, Greece (37.9^{o}N, 23.6^{o}E, 200m asl.). The system is a combined Raman-DIAL and is based on a frequency tripled/quadrupled pulsed Nd:YAG laser and the Raman shifting technique by the N_2 and H_2O atmospheric gases. The Raman lidar system is used to perform both aerosol and water vapor measurements; aerosol backscatter and extinction coefficients are retrieved in the 0.3-7 km height region from simultaneously received backscatter elastic lidar signals at 355 nm, 532 nm and 1064 nm and inelastic N_2 Raman lidar signals at 386.7 nm and 607 nm, whereas water vapor mixing ratio measurements are retrieved from simultaneously received N_2 and H_2O Raman signals at 386.7 nm and 407 nm, respectively. The differential absorption lidar (DIAL) technique is used to retrieve ozone vertical profiles in the free troposphere (0.3-6 km) at two wavelengths in the ultraviolet region (289-316 nm).

Systematic measurements are to be performed since June 2006. A specially-developed software code will be used to retrieve the water vapor and ozone profiles, as well as the optical properties (extinction, backscatter, lidar ratio, optical depth) and the microphysical properties of aerosols in the atmosphere. The major technical characteristics, as well as the first measurement results obtained by the Raman-DIAL system are presented.

1. INTRODUCTION

Atmospheric aerosols have large influence on earth's radiation budget. Recent estimations on the possible impact of aerosols (both direct and indirect effects) on the radiative forcing (cooling effect) in a global average are of the same order of magnitude as the CO_2 effect (warming effect) [1]. However, high uncertainties still exist concerning the indirect and direct effects, which are connected with the aerosol influence on climate. In addition, very little is known about the vertical distribution of the microphysical properties of aerosol over in the Eastern Mediterranean region and especially over Greece; this information could be used as input data to global aerosol models to accurately predict their impact on climate.

Ozone plays a significant role in the gas-phase chemistry of the troposphere as an important oxidant and as a major precursor of the hydroxyl (OH) radicals, which in turn act as removal agents, through oxidation, for a large number of trace gases in the troposphere. In addition, ozone influences the radiative balance of the troposphere, since it is a strong absorber in the infrared and the ultraviolet part of the spectrum [2]. The recent increase in the tropospheric ozone concentration, at both of the Earth's hemispheres, is of major concern to the scientific community worldwide [3-4].

The laser remote sensing technique combining the Raman and the DIAL techniques is a unique tool able to provide the vertical distribution of ozone, water vapor and the optical and microphysical properties of aerosols in the troposphere with very high temporal and spatial resolution.

2. EXPERIMENTAL SETUP

2.1 The UV DIAL system

The ultraviolet DIAL system was implemented in 2003 at the Laboratory of Laser Remote Sensing of the Atmosphere at the National Technical University of Athens, Greece, located at the Zografou Campus (28.88 N, 39.89 E). The system is able to perform ozone measurements in the troposphere (0.3-6 km) with a high temporal (20-40 min) and spatial (300–1000 m) resolution, during daytime and nighttime conditions. The DIAL system is based on a frequency quadrupled Nd:YAG laser (266 nm) and subsequent stimulated Raman shifting in a high-pressure deuterium (D_2) cell. Thus, the emitted laser beams, at a 10Hz repetition rate, have energies of the order of 12 mJ and 8 mJ at 289 nm and 316 nm, respectively. The backscattered laser radiation is collected by a 250-mm diameter Newtonian telescope and the wavelength separation is performed by a Czerny-Turner flat grating (4960 lines/mm) spectrometer. The retrieval of the tropospheric ozone profile is based on the DIAL equation [5], which takes into account both statistical and systematic errors, occurring during the signal acquisition and processing. The retrieved vertical ozone profiles have been validated by intercomparison with simultaneously released ozonesondes.

2.2 The Raman lidar system

The Raman lidar system of NTUA is designed to perform continuous measurements of suspended aerosols particles in the Planetary Boundary Layer (PBL) and the lower free troposphere, covering the 0.3-7 km height region. It is based on the second and third harmonic frequency of a compact pulsed Nd:YAG laser, which emits simultaneously pulses of 75 mJ, 130 mJ and 140 mJ of output energy at 355 nm, 532 nm and 1064 nm, respectively, with a 10 Hz repetition rate. The optical receiver is a Cassegrainian reflecting telescope with a primary mirror of 300 mm diameter and a focal length f =600 mm, directly coupled, through an optical fiber, to a multichannel lidar signal detection unit. 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 signals (355 nm, 532 nm, 1064 nm) are detected both in the analog and photon-counting mode, while the inelastically backscattered Raman signals are detected only in the photon-counting mode (Raman scattering by N_2 of 355 nm beam at 386.7 nm; Raman scattering by H_2O of 355 m beam at 407 nm; Raman scattering by N_2 of 532 nm beam at 607 nm). Narrow-band interference filters (IF) are used to suppress the atmospheric background noise at the various detected wavelengths. The Raman lidar system has been validated both at hardware and software level during the EARLINET project [6].

Table 1 presents the Full-Width-at-Half-Maximum (FWHM) and the corresponding transmission of the interference filters used.

Wavelength (nm)	FWHM (nm)	Transmission (%)
355	3	50
386.7	3	60
407	3	60
532	0.5	50
607	3	70
1064	1	70

Table 1. FWHM and the corresponding transmission of the IF filters used.

3. METHODOLOGY

The optical properties of the atmospheric aerosols (extinction, backscatter, lidar ratio, optical depth) are retrieved using the Raman inversion technique [6], while the microphysical properties of aerosols will be retrieved by using a special software code to be developed in the frame of the EARLINET-ASOS European Union project (2006-2011). Systematic measurements are to be performed starting on June 2006.

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.

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