VALIDATION OF A GROUND-BASED WATER VAPOR RAMAN LIDAR SYSTEM IN ATHENS, GREECE

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ABSTRACT

Water vapor is one of the most important greenhouse gases, since it causes about two third of the natural greenhouse effect of the Earth's atmosphere. To improve the understanding of the role of the water vapor in the atmosphere, extensive water vapor profiles with high spatio-temporal resolution are therefore necessary. A ground-based Raman lidar system is used to perform water vapor measurements in Athens, Greece (37.9^{o}N, 23.6^{o}E, 200 m asl.).

Water vapor mixing ratio measurements are retrieved from simultaneous inelastic H_2O and N_2 Raman backscatter lidar signals at 387 nm (from atmospheric N_2) and 407 nm (from H_2O). Systematic measurements are performed since May 2006. A specially-developed software code is used to retrieve water vapor vertical profiles in the lower troposphere (0.5-3 km range height asl.). The lidar observations are complemented with radiosonde measurements. Radiosonde data are obtained daily (at 00:00 UTC and 12:00 UTC) from the National Meteorological Service of Greece which operates a meteorological station at the "Hellinikon" airport (37. 54^o N, 23.44^o E, 15m asl) in Athens, Greece. First results of the systematic intercomparison between water vapor profiles derived simultaneously by the Raman lidar and by radiosondes are presented and discussed.

1. INTRODUCTION

Water vapor is the most influential greenhouse gases, since it absorbs infrared radiation emitted from Earth's surface and lower atmosphere more than any other constituent, thereby causing about two third of the natural greenhouse effect of the Earth's atmosphere [1]. Moreover, the water vapour vertical and horizontal distribution is characterized by a strong spatial and temporal variability which is generally strongly influenced by the large-scale atmospheric circulation (i.e. front movement, stratosphere to troposphere exchange processes) and local convection phenomena.

To improve the understanding of the role of the water vapor in weather and climate prediction and test global warming models, extensive and systematic water vapor profiles obtained with high spatio-temporal resolution are therefore required.

Lidars have been used to obtain the water vapor vertical profiles not only in the lower troposphere (where the water vapour field presents an enhanced spatial and temporal variability which cannot be followed by infrequent radiosonde launches) but also in the whole free troposphere since the 1960s [2-5]. In particular, the Raman lidar technique is the most suitable one to obtain, simultaneously, independent vertical profile measurements of water vapor and aerosol optical properties in the troposphere [4].

2. EXPERIMENTAL SETUP

The main purpose of the NTUA Raman lidar is the measurement of the mixing ratio of water vapor to dry air during nighttime. The 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 signals by N_2 at 387 nm and by H_2O at 407 nm are detected only in the photon-counting mode. Narrow-band interference filters (IF) are used to suppress the atmospheric background noise at the detected wavelengths. 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
387 and 407	3	60

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

3. METHODOLOGY -SYSTEM CALIBRATION

The water vapor profile, in mixing ratio units (g/kg), is determined by inverting the ratio of the lidar signals corresponding to the 355 nm-Raman shifted laser beam that is backscattered by H_2O and N_2 atmospheric molecules. This ratio is proportional to water vapor concentration, since the molecular N_2 can be assumed to have constant mixing ratio within the altitude range of measurements. In order to retrieve the water vapor in mixing ratio units, it is necessary to estimate a profile of a constant K(z), depending on the instrumental characteristics, by comparison with an independently measured water vapor mixing ratio profile (e.g. by radiosonde).

A special software code for real-time lidar signal processing was developed offering also the possibility of applying different digital filters in order to retrieve water vapour mixing ratio profiles with low uncertainties, especially in the lower troposphere where the small amounts of water vapor content require a careful data analysis. The detailed inversion procedure has been previously described by Whiteman et al. [3, 6].

The NTUA Raman lidar system has been calibrated through systematic direct intercomparisons in the 0.5-3 km height region asl., with simultaneously launched radiosondes obtained at “Hellinikon” airport (37. 54^o N, 23.44^o E, 15m asl) in Athens, Greece. Such example of intercomparison (30-min Raman water vapor profile) is shown in Fig. 1 (March 22, 2006).

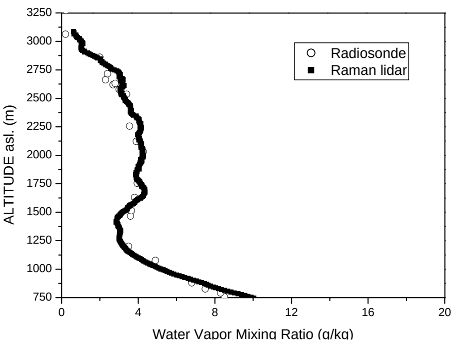

Fig. 1. Raman lidar-radiosonde intercomparison (30-min Raman water vapor profile) performed on March 22, 2006 in Athens, Greece.

The analysis of the systematic intercomparison data between water vapor profiles derived simultaneously by the Raman lidar and by radiosondes, showed that under most meteorological conditions, the absolute error in the retrieved 30-min water vapor profile by the Raman lidar generally remains less than 12%.

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