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Improvement of DIAL ozone measurements using an additional Raman channel

V.Matthias, V.Wulfmeyer, J. Bösenberg

Max-Planck-Institut für Meteorologie

Bundesstraße 55, 20146 Hamburg, Germany

Phone: +49 40 4123 5087 Facsimile: +49 40 41173 298

E-mail: vom@lidarm.dkrz.de

Introduction

One of the major problems in the evaluation of UV-DIAL ozone measurements in the lower troposphere is the error in the ozone concentration in regions with strong gradients in the aerosol distribution.The additional measurement of the Raman scattering of nitrogen allows more precise determination of ozone density profiles [1]. If the wavelength of the Raman channel is chosen in the solar-blind region, these measurements can be performed during daytime.

Ozone DIAL with an additional Raman channel

The Max-Planck-Institut für Meteorologie is running a UV-DIAL for the determination of ozone profiles in the lower troposphere. The system is based on a KrF excimer laser with a wavelength of 248.5 nm. Additional wavelengths are generated by Raman shifting in either hydrogen or deuterium. Three elastically scattered signals and the Raman scattered signal can be measured simultaneously. Using the wavelength of 277 nm, the first Stokes line in hydrogen, the Raman scattering of nitrogen occurs at 296 nm, which lies within the solar-blind region.

As the Raman cross section is $6.5 \cdot 10^{-4}$ times smaller than the Rayleigh cross section at 277 nm, one needs a stray light rejection of $5 \cdot 10^{-6}$ to get less than 1 % elastically scattered light in the Raman channel. This is achieved by the combination of the already existing spectrometer with a new grating monochromator.

A resolution of 15 minutes in time and 240 m in height has been achieved up to an altitude of 2.5 km, with SNR better than 10.

3-wavelength method

In most cases, the measurement of the Raman scattered light allows the direct determination of the aerosol particle extinction coefficient, however in the UV one has to consider the ozone absorption. In principle, this can be taken into account using the DIAL measurement. By this way, one has to use an iteration scheme, considering a DIAL and a Raman LIDAR equation [2].

An improved algorithm for evaluating the ozone concentration using three independent LIDAR signals is the developed 3-wavelength method. In contrast to an iteration, this method is based on

an analytical solution of three LIDAR equations.
There are five unknown parameters in a LIDAR equation in the UV, which are aerosol particle backscatter and extinction, both in dependance on height and wavelength, and the ozone number density in dependance on height. Assuming the wavelength dependance of aerosol backscatter and extinction, the best way to get one equation out of three LIDAR-equations is to first eliminate the unknown ozone absorption and aerosol particle extinction. The remaining equation has two solutions for the aerosol backscatter coefficient. In most cases, one of them can be excluded since it would yield unreasonably high values. An iteration scheme will not necessarily find the correct solution.
With the 3-wavelength method, the additional information supplied by the Raman channel is used to determine aerosol backscatter and extinction profiles independently. This gives more accurate results for the aerosol correction of the ozone concentration.

Results

As an example, figure 1 shows the calculated ozone profiles of a measurement made on May 11th 1993 with DIAL and the 3-wavelength method, respectively. The differences are substantial, up to 30 $\mu g/m^3$ at a height of 2300 m. The reason for this is the rather strong gradient in aerosol backscatter, which is different for the 3-wavelength method and the Klett method [3], respectively. The evaluation with the 3-wavelength method supplies a height-dependent LIDAR ratio (figure 2), which can't be calculated using the Klett algorithm. This is one of the main advantages of the method. The absolute values of the LIDAR ratio depend on a calibration, but the gradients don't differ very much

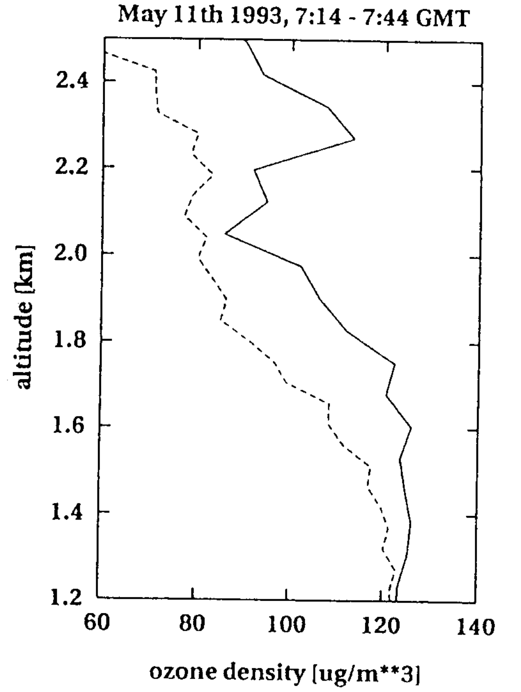

Figure 1: *Ozone density, evaluated with the Klett method (solid lines) and the Trilambda method (dashed lines)*

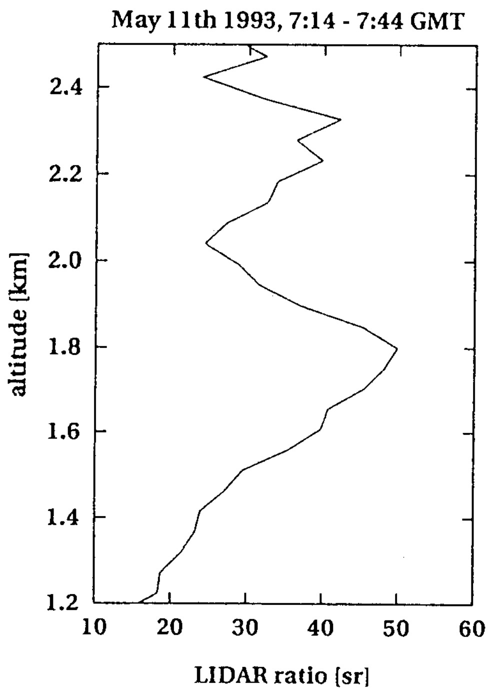

Figure 2: *LIDAR ratio evaluated with the 3-wavelength method, assuming β_{aer}/β_{ray} = 0.4 in 1500 m.*

using different calibrations. The comparison of the evaluation with DIAL and the 3-wavelength method, respectively, shows the advantages of the latter.

References

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