Performance Simulation of a Raman Lidar for the Retrieval of CO2 Atmospheric Profiles

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The roto-vibrational Raman lidar technique, traditionally used to measure water vapor mixing ratio profiles, has been explored in the past decades for the application in CO_2 profile measurements. Despite the high potential, because of the low signal-to-noise ratio characterizing CO_2 roto-vibrational Raman signals, the poor precision achieved by these measurements prevented an adequate diffusion of the technique. As new technological solutions for laser sources, spectral selection and signal detection has been designed, new interest has arisen and a new generation of lidar systems is now being developed for its exploitation.

The objective of this study is to investigate the current feasibility and the limits of a ground-based Raman lidar system dedicated to the measurement of CO_2 profiles. Therefore, the characteristics and performance of a lidar system for the estimation of CO_2 atmospheric profiles were investigated through a set of numerical simulations.

In this study the possibility of exploiting one or both Raman lines of the ν_1:$2\nu_2$ resonance is investigated. As some roto-vibrational O_2 lines lie in the same spectral range and represent a potential source of contamination for the CO_2 Raman lidar measurements, an accurate evaluation and quantification of this and other (e.g., aerosol, absorbing gases) contamination sources was carried out for an appropriate band selection. Thus, the optimal position and width of the filter for the measurement of the Raman backscattering from CO_2 was defined. The signal integration over the vertical and over time required to reach a useful signal-to-noise ratio both in day-time and night-time needed for a quantitative analysis of carbon dioxide sources and sinks was evaluated. Finally, the capability to estimate variability of the CO_2 mixing ratio was assessed.

The above objectives were obtained developing an instrument simulator code consisting of a radiative transfer model able to simulate, in a spectrally resolved manner, all laser light interaction mechanisms with atmospheric constituents, the background signal, and all the devices present in the considered Raman lidar experimental setups.