Calibración del Ceilómetro Mediante Teledetección de la Dispersión Molecular

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ABSTRACT

Earth's atmosphere consists primarily of gases, aerosol particles and clouds play significant roles in shaping conditions at the surface and in the lower atmosphere. Aerosol particles are liquid or solid particles suspended in the air, whose typical diameters range over four orders of magnitude, from a few nanometers to a few tens of micrometers. They exhibit a wide range of compositions and shapes that depend on their origins and subsequent atmospheric processing. The perturbation of electromagnetic radiation by aerosol particles is designated aerosol radiative forcing (RF). Aerosol RF is characterized by large spatial and temporal heterogeneity due to the wide variety of aerosol sources and types, the spatial nonuniformity and intermittency of these sources, the short atmospheric lifetime of aerosol particles, and the chemical and microphysical processing that occurs in the atmosphere. Aerosols interact both directly and indirectly with the Earth's radiation budget and climate. As a direct effect, the aerosols scatter sunlight directly back into space. As an indirect effect, aerosols in the lower atmosphere can modify the size of cloud particles, changing how the clouds reflect and absorb sunlight, thereby affecting the Earth's energy budget. Aerosol measurements can also be used as tracers to study how the Earth's atmosphere moves. Because aerosols change their characteristics very slowly, they make much better tracers for atmospheric motions than a chemical species that may vary its concentration through chemical reactions. Despite substantial progress, several important issues remain, such as measurements of aerosol absorption and vertical profiles. Significant efforts are needed to address them. Current observational capability requires algorithm refinement to improve retrievals of aerosol properties such as size distribution, particle shape, absorption, and vertical distribution. These measurements are essential to reducing uncertainties associated with the estimate of aerosol radiative forcing.

For accurate modeling of the corresponding radiative forcing, knowledge of the vertical distribution of particle macro- and microphysical parameters is needed. During recent years, ground-based lidars have become important tools for profiling tropospheric aerosol particles using either single or multiple wavelengths. For example, it is shown that advanced lidar systems such as those being operated in the framework of the European Aerosol Research Lidar Network (EARLINET) are excellent tools for aerosol

profiling. The advantage of using a lidar system is that it can provide relatively continuous altitude-resolved measurements of aerosol properties without perturbing the aerosol or its surroundings. For quantitative studies of the optical properties of tropospheric aerosol, Raman lidars have proven to be most useful. This lidar type measures elastically backscattered light simultaneously with Raman backscattering from molecules (nitrogen or oxygen), thus allowing independent calculation of particle backscatter and extinction coefficients without the need for critical assumptions about atmospheric parameters. Microphysical properties of aerosol particles can be retrieved through mathematical inversion information on the particle extinction and backscatter coefficients at multiple wavelengths obtained by Raman lidars. The signal measured with these systems can be processed using algorithms that provide the particle backscattering coefficient, βp(z), retrievals based on forward integration in real-time applications. However lidar systems are expensive and their maintenance require constant supervision. In consequence, establishing a Raman lidar network with the required spatial and time resolution is not possible.

With the establishment of ceilometer networks by national weather service a discussion commenced to which extent these simple backscatter lidars can be used for aerosol research. Nowadays, new studies have focused in the use of ceilometers, primarily designed for cloud detection, to obtain additional atmospheric data as the planetary boundary layer (PBL) height. Though primarily designed for the detection of clouds it was shown that at least observations of the vertical structure of the boundary layer might be possible. However, an assessment of the potential of ceilometers for the quantitative retrieval of aerosol properties is still missing. Calibration of the ceilometer is essential to obtain this quantitative information. Usually lidar systems are calibrated trough Klett analytical solution of the lidar equation. But in the case of ceilometers this technique is difficult to be applied due to the technical deficiencies of these instruments (low intensity pulse emission and monochromatic laser emission).

In this paper we discuss an alternative method proposed by Martucci to obtain the calibration factor C'_L from a ceilometer, with the idea of retrieving the attenuated backscattering coefficient β^*. This method calibrates the ceilometers using the free aerosol part of the atmosphere (Figure 1 molecular region), comparing the expected molecular signal with the ceilometers signal within this region. The principal advantage of this method is that it does not need any additional data from others advanced instruments as photometers or Raman lidars. This method, only use the ranged corrected signal RCS(z) retrieved from a ceilometer and a molecular backscattering profile $\beta_{mol}(z)$ model, calculated using collocated and coincident air temperature and pressure profiles. Although the theoretical aspect of this method is described in another work, the implementation of the method is not defined in any publication. For this reason, the key aspect of this thesis is proposes a new data processing and data validation technique for this methodology.

Concerning methodological aspects, the thesis includes a detailed description of the pre-processing steps to be applied to raw ceilometers signals. Principal issues on calibrating ceilometers are consequence of the low energy per pulse of the laser of ceilometers , which make the signal noise ratio (SNR) too low for calibration in the molecular region. In this work we will apply different statistics methods to increase the SNR, trough temporal and vertical data processing. And we will define which measurement periods are proper for our calibration method. This process will result in a RCS(z) profile, which can be compared, trough normalization and derivative methods, to the modeled molecular backscattering profile $\beta_{mol}(z)$. The methodology will be applied in different atmosphere conditions. In the end we will obtained a calibration factor C'_L computed using all the measurements.

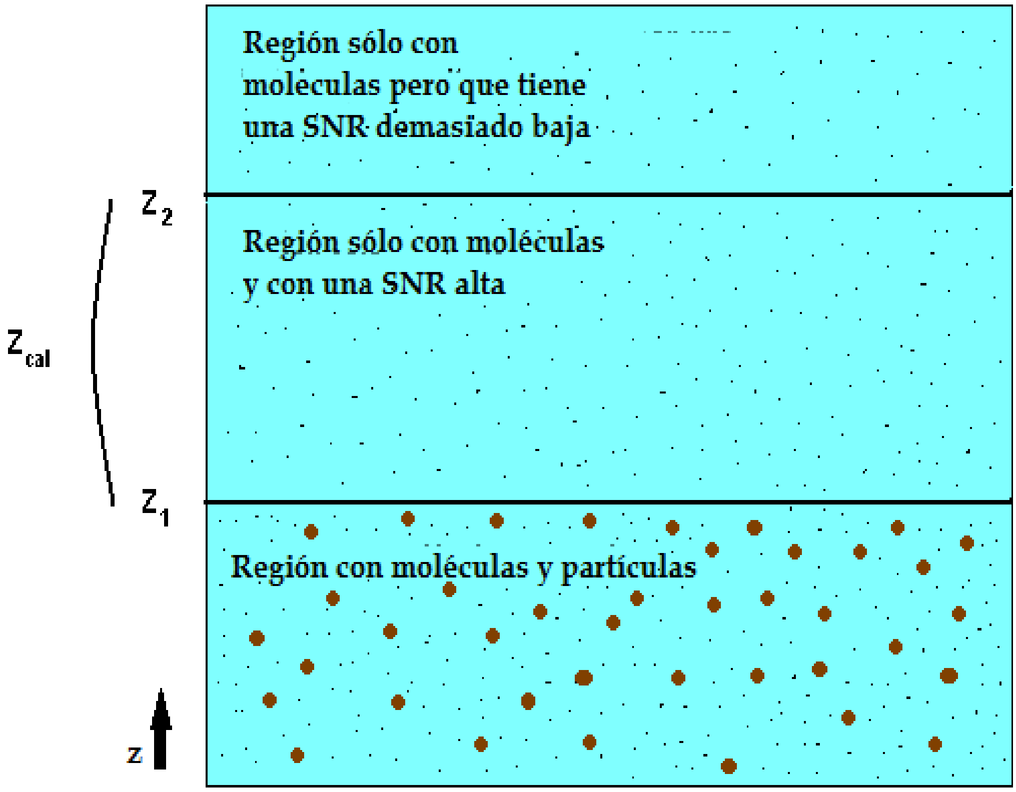

FIGURE 1. Schematic of the calibration region Z_{cal}

The thesis is organized as follows:

Chapter 1, introduces the problem and the objectives of this thesis. Also this chapter resumes the thesis structure

Chapter 2, introduces key concepts of aerosol theory and active optical remote sensing. Presents the methods to retrieve optical properties from lidar measurements.

Chapter 3, devoted to the instrumentation and the experimental site, covers key aspects about the instruments used in this thesis: ceilometer Jenoptik CHM15k and Raman lidar LR 321 D400.

Chapter 4, introduce the methodological aspects and presents the calibration methods for a ceilometer.

Chapter 5, explain the methodology implementation. A detailed description of the preprocessing of raw ceilometer signals is included.

Chapter 6, presents the calibration factor obtained C'_L trough multiple measurements obtained in three different months and compare the resulting attenuated backscattering coefficient with the same coefficient obtained by a calibrated Raman Lidar.

Chapter 7, presents a summary of the main conclusions of this work together with an outline of future research activities.

Keywords: aerosol particles, attenuated backscattering coefficient, backscattering coefficient, backscattering molecular profile, ceilometer, extinction coefficients, lidar, planetary boundary layer, radiative forcing, Raman Lidar, ranged corrected signal, signal noise ratio, molecular region