Aerosol optical properties by means of a sunphotometer and LIDAR system in Buenos Aires Argentina.

Propiedades ópticas de aerosoles medidas con un fotómetro solar y un sistema LIDAR en Buenos Aires, Argentina.

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ABSTRACT:

A sunphotometer from AERONET network and a multiwavelength LIDAR system were employed to obtain the diurnal aerosol optical thickness from UV up to the near IR spectral region. Tropospheric aerosol optical properties were measured at the same time by two collocated systems at CEILAP in the Buenos Aires suburbs. Aerosol profiling capabilities from the LIDAR were reinforced by the use of the sunphotometer to solve the uncertainties in the LIDAR equation.

Key words: Aerosol, LIDAR, backscatter, extinction, aerosol optical thickness.

RESUMEN:

Un fotómetro solar que pertenece a la red AERONET y un sistema LIDAR multilongitud de onda son empleados para obtener el espesor óptico de aerosoles durante el día en la región espectral UV - IR. Las propiedades ópticas de los aerosoles troposféricos son medidas simultáneamente con los dos sistemas instalados en el CEILAP, en las afueras de Buenos Aires. Para reforzar la solución de la ecuación LIDAR se utilizan los datos obtenidos por el fotómetro solar.

Palabras clave: Aerosol, LIDAR, retrodifusión, extinción, espesor óptico de aerosoles
REFERENCES AND WEB LINKS.


1.- Introduction.

A Multiwavelength LIDAR System (MWLS) operates systematically at CEILAP (CITEFA - CONICET since December 17, 2003. The MWLS is used to calculate the extinction and backscatter vertical profiles and to retrieve the optical properties and aerosols in the boundary layer and the troposphere between 300 m and 13.5 km. A collocated AERONET sun-photometer is also operational since October 18, 1999.

Multiwavelength LIDAR systems give the information on altitude distributions of aerosol microstructure parameters. The synergy between these two systems is studied and used to solve the uncertainties in the LIDAR equation.

2.- Methodology.

In order to obtain the atmospheric backscatter and extinction profiles from the LIDAR signal is necessary to invert the LIDAR equation. The mathematical solution for this problem involves an equation system with two unknown parameters, the atmospheric extinction (m$^{-1}$) and the atmospheric backscatter (m$^{-1}$sr$^{-1}$). These parameters are intensive properties of the radiated matter. If we propose that only their extensive properties (aerosol concentration) change with the altitude it is possible to conceive a constant relation between them. In 1981 James Klett [1, 2] proposes a LIDAR inversion algorithm based on the hypothesis of a constant relation between backscatter and extinction. Later this algorithm is refined by Fernald, [3]. The atmosphere is decomposed in a known molecular profile and an unknown aerosol profile from which a constant relation between the variables to solve is known. This proportionality constant ($k_p$) is the aerosol backscatter-to-extinction ratio and depends of the type of aerosol, the LIDAR wavelength and, in the case of hygroscopic aerosols of the humidity profile.

To estimate this value we have used an iterative Fernald inversion algorithm that varies $k_p$ between 0 up 1/70 [4] and compares the integrated results of the aerosol retrieved extinction (LIDAR aerosol optical thickness) coefficient with the sunphotometer aerosol optical thickness calculated for the LIDAR wavelength. The best fit (minimum quadratic error) will determine the total column $k_p$ estimation for the profiles. Clear sky is assured by the sunphotometer that only measures in this condition.

3.- Results.

The day selected to perform this study is December 16, 2004. The normalized aerosol backscatter LIDAR profile on Figure 1 shows the boundary layer evolution from 10 h to 19 h local time (solar time + 1 h). The evolution of the aerosol optical thickness measured with the AERONET sunphotometer is presented in Figure 2 for the same period. This value is retrieved for seven wavelengths from 340 nm up to 1020 nm. Both figures have the same signature, with a minimum value during the morning and a maximum during the afternoon.

Figure 1. Normalized Aerosol Backscatter 1064 nm.
As we said before aerosol backscatter and extinction when retrieved from the LIDAR equation are both dependent on the choice of the $k_p$ value. It is important to notice that the extinction is much more affected than the backscatter. We show an example in the next Figures 3 to 8. The integrated backscatter as a function of $1/k_p$ is shown on Figure 3, 4 and 5 for different wavelengths. Different hours were considered to shown these values.

Figure 3 shows that there is almost no influence of $k_p$ on the 1064 nm LIDAR return. This is due to the small influence of the aerosol extinction on the aerosol backscatter profile. As far as the extinction become more important (as in the UV region – Figure 5) the $k_p$ dependency become more evident. In Figure 4 the change with $1/k_p$ has intermediate dependence in comparison with Figures 3 and 5.

Figure 6, 7 and 8 presents the aerosol optical thickness (LIDAR – AOT) dependency of $1/k_p$ for 1064 nm, 532 nm and 355 nm.
We can see for all cases that the LIDAR–based aerosol optical thickness is almost linearly dependent of $1/k_p$ and that when $k_p$ tends to infinity the extinction tends to zero.

Choosing the best $k_p$ for the whole time series, we compared the AOT calculated from aerosol extinction profile with the AOT measurement with the sun-photometer. Since the sun-photometer is measuring the AOT at seven different wavelengths it is possible by using the Ångström law to estimate AOT at the LIDAR wavelength. Figure 9, 10 and 11 shows the aerosol optical thickness obtained with sun-photometer and LIDAR.

Figure 8. Aerosol Optical Thickness at 355 nm versus $1/k_p$.

Figure 11. Aerosol Optical Thickness temporal evolution at 355 nm.

Figure 12, 13 and 14 shows the aerosol extinction profile for the three LIDAR wavelengths.

Figure 9. Aerosol Optical Thickness temporal evolution at 1064 nm.

Figure 10. Aerosol Optical Thickness temporal evolution at 532 nm.

Figure 11. Aerosol Optical Thickness temporal evolution at 355 nm.

Figure 12. Aerosol Extinction at 1064 nm.

Figure 13. Aerosol Extinction at 532 nm.

Figure 14. Aerosol Extinction at 355 nm.
From the atmospheric sounding we obtained that the averaged relative humidity was about 70%. Following Ackerman studies [5] that links the relative humidity with the $k_p$ for different aerosol types and LIDAR wavelengths, we estimated that the present aerosol type in the atmosphere was probably continental.

4.- Conclusion.
Along this work it was shown that the backscatter to extinction ratio ($k_p$) can be easily obtained by means of sunphotometer based aerosol optical thickness and LIDAR data for the following conditions: clear sky (no clouds) conditions, well mixed diurnal atmospheric boundary layer and no aerosol advection. In this case aerosol backscatter is almost insensitive along the wavelength domain to the choice of the $k_p$. Conversely aerosol extinction was proven to be almost linearly dependent to the inverse of this value. Limitation of this procedure is that only one $k_p$ per profile can be obtained. Nevertheless in this case it was shown that using only one $k_p$ per wavelength and per day it is possible to estimate the whole atmospheric extinction as proven in the last figures.

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