Aerosol characterization by multi-wavelength lidar measurements

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The lidar system of the Lecce Physics Department has been upgraded, during 2011, to a multi-wavelength system. The scientific motivation for this is the fact that measuring the scattering of aerosol particles for various angles,wavelengths, and polarization allows to retrieve their size distribution, shape, and refractive index. In a mono-static lidar system the angle is fixed to 180° by the geometry of the experiment, but the use of different wavelengths is possible. The optical properties of the atmospheric aerosols that can be retrieved by a single wavelength lidar are the backscattering coefficient (β) and the extinction coefficient (α), provided that an elastic backscattering signal and a molecular inelastic signal (Raman scattering from N_2) are detected. Such optical properties are related to the composition of aerosols by an equation that in principle states an ill-posed problem. However, it has been shown that measurements of the elastic signals at three different wavelengths, together with two Raman signals are sufficient, using some regularization techniques, to solve the equation. This is the reason why the most used laser for aerosol lidar are frequency tripled Nd:Yag lasers, that emit at 1064, 532, 355 nm. Our lidar system is based on such kind of laser. At 355 and 532 nm, both α and β can be directly measured. In the infrared, only backscattering measurements are possible. Apart these two quantities, other intensive quantities that are mainly related to the aerosol size distribution and shape can be measured. The depolarization ratio D is the ratio between the 90° polarization rotated and the polarization conserving backscattering coefficient, and the Angstroem coefficient is defined between two wavelengths as :

$$\mathring{A}(\lambda_1, \lambda_2) = -\frac{\Delta ln(\alpha(\lambda))}{\Delta ln(\lambda)} \qquad (1)$$

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The UNILE lidar system operates within the European Aerosol Research Lidar Network-EARLINET-ASOS (European Aerosol Research Lidar Network-Advanced Suitable System) since 2000. Diurnal lidar measurements are performed on regular basis on Monday around 13.00 UTC. Nighttime lidar measurements are performed every Monday and Thursday (http://www.earlinet.org/) after sunset [1].

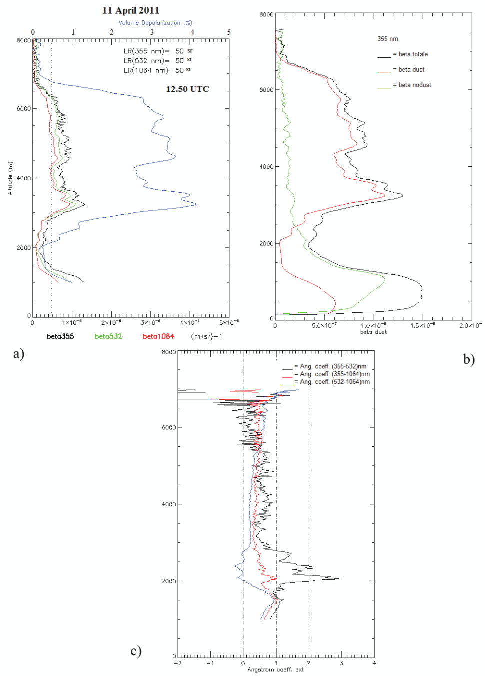

Figure 1. (a) Aerosol backscattering coefficient profile β at 355 nm (black), 532 nm (green) e 1064 nm (red) and volume depolarization ratio profile D(blue) on 11 April 2011, (b) separation of dust (β-dust, red) and non-dust (β-nodust, green) contribution in the β at 355 nm, (c) extinction-related Angstrom coefficient calculated between (355nm-532nm) (black), (532nm-1064nm) (blu), (355nm-1064nm)(red) for the same day.

To characterize the optical properties of different aerosol types observed over the monitoring site aerosol backscatter coefficient (desert dust, marine and continental aerosol), volume depolarization ratio, Angstrom coefficient vertical profiles, and lidar ratio values are used. In addition, analytical back-trajectories are used to infer the advection of different aerosol types at the monitoring site. A particular case study classified as long range dust event is shown in . Using the volume depolarization D and the aerosol backscattering coefficient β profiles it was also possible to separate within a single profile of β the contribution of the dust and the non-dust by applying the method of Tesche [2] to the particular case study of 11 April 2011. Once separated the contributions of the two different aerosols types (dust and non-dust) within a single profile of β it

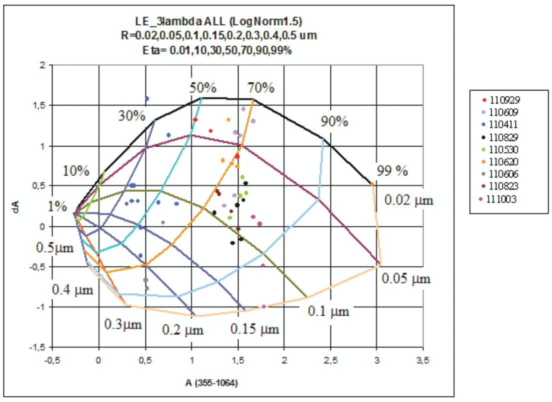

Figure 2. Classification of aerosol properties as a function of Angstrom exponent $\mathring{A}$(355nm, 1064nm) and differences d$\mathring{A}$= $\mathring{A}$(355nm, 532nm) - $\mathring{A}$(532 nm, 1064 nm) for a bimodal size distribution, lognormal and refractive indices $m = 1.44 - 0.0080i$ (355 nm), $m = 1.45 - 0.0047i$ (532 nm) and $m = 1.46 - 0.0024i$ (1064 nm). In μm are given fixed values of the radius of the fine mode (Rf) and the % contribution of the fine mode to the total AOD (h). The dots represent the ($\mathring{A}$, $\mathring{A}$) values calculated from the lidar measurements and the different colors indicate the different days chosen as case studies.

was possible to calculate, from the columnar size distribution data provided by our sun photometer (belonging to the world network AERONET http://aeronet.gsfc.nasa.gov/) in the day taken as a case study, the altitude dependent size distribution considering the dust and non dust fraction present at each vertical level. The same method was applied to calculate the refractive index variable with altitude by considering the various types of aerosols (dust and non-dust) and the fraction of dust and non-dust present at each vertical level chosen with the final aim of radiative forcing computing.

Finally, it was used the method proposed by Gobbi [2] to classify the aerosol properties as a function of the Angstrom exponent $\mathring{A}$ (355nm, 532nm), $\mathring{A}$ (532nm, 1064nm), $\mathring{A}$(355nm, 1064nm) and differences $d\mathring{A}$ = $\mathring{A}$(355nm, 532nm) - $\mathring{A}$(532 nm, 1064 nm) calculated using the lidar measurements for some particular cases of the 2011 study. The scheme proposed by Gobbi and some case studies selected from the lidar measurements acquired in Lecce in 2011 are shown in Figure 2.

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