Vertical profiles of aerosol properties from 3-wavelength elastic lidar signals and collocated sun/sky photometer measurements

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Lidars represent nowadays the best devices to retrieve aerosol vertical profiles. Aerosol effects on climate depend on the vertical distribution of aerosol properties. As a consequence, several numerical approaches have been developed to invert lidar signals at multiple wavelengths to particle parameters. Most lidar system can only provide elastic lidar signals during daytime. Therefore, the development/improvement of numerical procedures based on elastic lidar signals is of peculiar importance. Chaikovsky *et al.* (2012) have developed a numerical tool (LIRIC, LIdar/Radiometer Inversion Code) to retrieve vertically resolved aerosol microphysical properties by combining backscatter coefficient measurements at 3 wavelengths and sun/sky radiance measurements. This activity was performed in the frame of European Project Aerosol Clouds, and Trace gases Research InfraStructure Network (ACTRIS, http://www.actris.net/). A technique which relies on a constrained iterative inversion (CII) procedure and graphical framework (GF) has recently been used by Perrone et al. (2014) to estimate the dependence on altitude of the aerosol fine mode radius and of the fine mode contribution to the aerosol optical thickness. It is denoted as CII-GF technique. The performance of LIRIC and the CII-GF technique have been analyzed to better investigate their ability in characterizing the dependence on altitude of aerosol properties from elastic lidar signals at 355, 532, and 1064 nm, respectively, and collocated AERONET sun/sky photometer aerosol products. In addition to extinction coefficient and lidar ratio (LR) vertical profiles at the lidar wavelengths, LIRIC provides the vertical profiles of fine- and coarse-mode particle concentrations and of the fine mode fraction. The CII technique assumes that LRs are height independent and uses a GF to estimate the aerosol fine-mode-fraction and fine-modal-radius vertical profiles. The aerosol classification framework allows estimating the dependence on altitude of the aerosol fine-modal-radius and of the fine-mode-fraction from the Ångstrom exponent spectral difference versus the 355-1064 nm-Ångstrom exponent plot. Three case studies representative of typical aerosol scenarios of the Central Mediterranean have been selected to investigate the performance of LIRIC and the CII-GF technique and evaluate benefits and weaknesses. The comparison of the LIRIC extinction coefficient profiles with the corresponding profiles from the CII-procedure has revealed that the differences varied with altitude and wavelength (λ_i) and decreased with the λ_i increase. As a consequence, the differences between the Ångstrom exponents from LIRIC and the CII procedure varied with z and the wavelength pair. Ångstrom exponents are good indicators of the dominant aerosol size. Then, the results on the Ångstrom exponent inter comparison have clearly indicated that the differences between LIRIC and corresponding CII-aerosol parameters were mainly linked to the altitude dependence of the aerosol particle size embedded in the aerosol products from the two numerical techniques. In fact, the plot on the GF of the Ångstrom exponent spectral difference versus the 355-1064 nm-Ångstrom exponent retrieved from the two techniques has shown that LIRIC and CII-procedure data points were on average on a framework area with similar variability range of the fine mode fraction values, in all case studies. By contrast, the CII- procedure data points were spread on a framework region revealing that the fine modal radius was height dependent while, the LIRIC data points were on average located on a curve with nearly constant fine modal radius. This last result is due to the LIRIC request that the integral of the retrieved concentration had to match the AERONET-derived column volume concentrations. In fact, the analysis of the three case studies has clearly revealed that the differences between the aerosol products from LIRIC and the corresponding ones from the CII-procedure were quite large when aerosol from different sources and/or from different advection routes were located at the altitudes sounded by lidar. Aerosol properties were weakly dependent on z on the 12 September, 2011 study case. As a consequence, we found that the differences between the LIRIC aerosol products and corresponding ones from the CII-GF procedure were on average smaller than the ones resulting from the other two study cases. Some results on the intercomparison of the aerosol products provided by LIRIC and the CII-GF technique for the September 12, 2011 study case, are reported in this note as an example. Dotted lines in Figs. 1a-1c show the LIRIC vertical profiles of the aerosol extinction coefficient ($\alpha_L(\lambda_i,\ \mathrm{z})$), the lidar ratio ($\mathrm{LR_L}(\lambda_i,\ \mathrm{z})$), and the fine mode fraction ($\eta_L(\lambda_i,\ \mathrm{z})$) at the lidar wavelength λ_i, respectively. The above reported profiles have been retrieved from LIRIC by combining lidar measurements performed on September 12, 2011 from 14:06 to 14:36 UTC and AERONET inversion products, retrieved from sun/sky photometer measurements (Lecce University) performed at 14.21 UTC. Solid lines in Figs. 1a and 1b show the aerosol extinction coefficient and lidar ratio profiles retrieved from the constrained iterative inversion procedure. The differences between the CII-procedure (solid lines) and the LIRIC (dotted line) extinction coefficients vary with altitude and decrease with the increase of λ_i. More specifically, they are within ± 1 SD of mean values at 1064 nm. Lidar ratios (Fig. 1b) from the CII-procedure are in accordance within ± 1 SD of mean values with corresponding values from LIRIC, which show a rather weak dependence on z. The solid green line in Fig. 1c shows that the fine mode fraction at 532 nm ($\eta(532\mathrm{nm},\ \mathrm{z})$) retrieved from the CII-GF technique is in good accordance with $\eta_L(532,\ \mathrm{z})$ within 1-2.5 km a.g.l. Ångstrom exponent profiles from the CII procedure also were in reasonable accordance with the corresponding profiles from LIRIC up to ~3 km a.g.l., indicating that the aerosol microphysical properties were characterized by a weak dependence on altitude on September 12,2011. Hence LIRIC and the CII-GF procedures provide aerosol parameters in reasonable accordance if aerosol properties vary weakly with the altitude. We believe that the LIRIC retrieval ability could be improved by taking into account the results on the changes with z of the fine modal radius, resulting from the CII-GF procedure. Work is on progress in this direction.

REFERENCES

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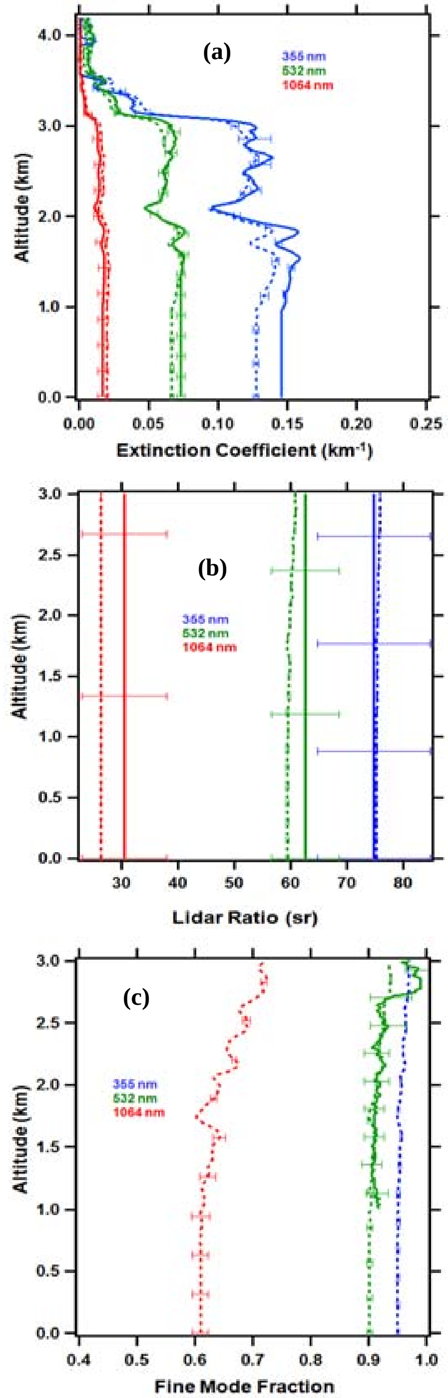

Figure 1. Vertical profiles of (a) extinction coefficients, (b) lidar ratios, and (c) fine mode fractions from LIRIC (dotted lines) and the CII-GF (solid lines) with corresponding uncertainties (error bars).