Dear Referee #1,

many thanks for your comments which have allowed to improve the paper as demonstrated in the revised manuscript.

The authors make an interesting attempt to apply technique previously developed by Gobbi et al for sun photometers to lidar measurements. The main issues in their approach are: 1. Necessity to assume well mixed PBL to extrapolate the particle extinction to the ground. 2. Necessity to assume the lidar ratio to get particle extinction.

In the revised paper, we have taken into account different sources of systematic errors, including the ones that you mention. To this end, we adopted the iterative numerical procedure suggested by Di Girolamo et al., (1994) and Marenco et al. (1997) to invert the lidar signal profiles under the constraint of a measured total AOT. Using this method, the lidar ratio is the result of the iterative procedure so that it has been natural to account for variations of lidar ratio due to uncertainties in input parameter and errors due to the extrapolation of the particle extinction to ground. The used methodology and the uncertainty discussion have been presented in Section 2.2 of the revised manuscript. An excerpt of Section 2.2 of the revised manuscript is reported below for your convenience:

" 2.2 **Aerosol parameters from lidar measurements**

The UNILE lidar system was designed to derive vertical profiles of the aerosol extinction (α(z)) or backscattering (β(z)) coefficient at 355 nm, 532 nm and 1064 nm, respectively and of the volume depolarization ratio (δ(z)) at 355 nm during day time measurements. The approach proposed by Fernald (1984) and Klett (1985), which requires an *a priori* value of the aerosol extinction-to-backscatter ratio (also referred to as the aerosol Lidar Ratio, LR), is commonly used to invert lidar signal profiles and extract aerosol extinction and backscattering coefficient profiles. The assumption that LR is known *a priori* is likely the largest source of systematic error within this lidar inversion procedure. However, this uncertainty can be largely reduced if additional information is available. Takamura et al. (1994) considered the possibility of removing the indeterminacy in LR by combining lidar data with independent measurements of the aerosol optical thickness. Then, Di Girolamo et al. (1994) and Marenco et al. (1997) suggested an alternative inversion technique, which through an iterative procedure allows one to determine α(z) and β(z) by using as boundary conditions (1) the AOT of a selected altitude range and (2), as in the Fernald-Klett approach, the total backscattering coefficient β_T (due to molecules (β_M) and aerosol (β)) at a far-end reference height z_f. This last approach was used in this study to extract aerosol extinction profiles at 355 nm, 532 nm, and 1064 nm, respectively from UNILE lidar measurements. AOT values at the lidar wavelengths were retrieved from AERONET sun/sky photometer measurements co-located in space and time. An AERONET sun/sky photometer operates at the UNILE lidar site since the year 2003 and it provides AOTs with accuracy of ± 0.01, according to Dubovik et al. (2002). Hence, it was required that the AOTs calculated from the aerosol extinction profiles should not exceed (within ± 0.01) the corresponding AOT values retrieved from co-located sun/sky photometer measurements. More specifically, the lidar AOTs at 355 nm, 532 nm, and 1064 nm, respectively, were calculated from the corresponding α(z) profiles by assuming that α(z) values did not vary with altitude below the height (z_i) where the lidar system was estimated to achieve full overlap. The full overlap height varies within 0.5-1.0 km a.g.l. for the lidar system of this study. Note that the planetary boundary layer (PBL) height varies within 0.4-1.0 km a.g.l at the monitoring site of this study (De Tomasi and Perrone, 2006; De Tomasi et al., 2011). Aerosol particles are well mixed within the PBL and as a consequence, it is reasonable to assume that α(z) values did not vary with altitude below ~ 1 km a.g.l.. The far-end reference height was chosen, for each profile, in a region where the lidar signal followed the molecular profile and hence, it was assumed $\beta_T(z_f) \cong \beta_M(z_f)$. Note that the assumption of an altitude independent lidar ratio to retrieve $\alpha(z)$ profiles was still necessary for the iterative procedure used in this study. A discussion on this assumption is reported in Sect. "Sensitivity test on the lidar ratio vertical profiles for 28 July 2011". Uncertainties in the retrieved $\alpha(z)$ profiles include statistical uncertainties due to the presence of noise on the received lidar signals and systematic uncertainties as the ones due to the assumed molecular profile, the reference backscattering coefficient value, the total measured AOT, the AOT contribution of the atmospheric layer below the overlap height z_i, and the lidar ratio variability. Radiosonde measurements at the meteorological station of Brindisi (http://esrl.noaa.gov/raobs/) that is 40 km north-west of the monitoring site of this study were used to define air density vertical profiles and decrease the uncertainty associated to the Rayleigh scattering calibration. The uncertainty on the reference backscattering coefficient value was accounted for by assuming that the aerosol backscattering coefficient varied from a nil value up to $5x10^{-7}$ $(m\ sr)^{-1}$ at $z = z_f$. The error on the AOT contribution of the lowermost atmospheric layer located at $z < z_i$ a.g.l. was accounted for by allowing to the AOT contribution within the $(z_i - z_f)$ atmospheric layer (AOT_1) to decrease up to 20% of a reference value $AOT_{1,ref}$. To this end, a 2-step numerical procedure was used. In the first step, extinction coefficient profiles at the lidar wavelengths were calculated from the inversion of the lidar signals trough the implemented iterative procedure, by setting that extinction coefficients did not vary with altitude from the ground up to the overlap height $z_{i.}$ Then, the AOT contribution of the $(z_i - z_f)$ atmospheric layer ($AOT_{1,ref}$) at each lidar wavelength was calculated. In the second step, extinction coefficient profiles were calculated from the implemented iterative procedure by allowing to AOT_1 to decrease up to 20% of the determined reference value $AOT_{1,ref}$. In fact, the condition that $\alpha(z)$ values did not vary with altitude from the ground up to z_i could be responsible for an underestimation of the AOT contribution of the lowermost atmospheric layer (AOT_2). The inversion of the lidar signals trough the implemented iterative procedure is not demanding much computation time so that a few thousand extinction profiles at 355 nm, 532 nm, and 1064 nm, respectively were easily generated by changing boundary conditions. Angström exponent profiles were calculated from the generated extinction profiles. The mean extinction profile at each lidar wavelength was then calculated by averaging all corresponding extinction profiles determined by the iterative procedure and the $\alpha(z)$ uncertainty was set equal to one standard deviation of the mean value. A similar procedure was used to calculate mean profiles of Angström exponents and corresponding uncertainties. Angström exponent differences were calculated from Angström exponent mean profiles. Corresponding uncertainties were calculated by the law of error propagation"

…………The authors understand these issues and try to estimate uncertainties due to height variation of lidar ratio. Thus they make calculations assuming that above certain height all lidar ratios (LR) are 10% increased and show that it doesn't affect the results significantly. For this I should mention that 10% is not too much, variation of LR can be significantly stronger. Besides, for ratio of extinctions (for Angstrom exponent) this LR enhancement is partly compensated. Probably the situation will be more severe when LR at different wavelengths are changed differently. The uncertainty of estimation of the fine mode radius and relative contribution looks to be too high at this stage, but the approach is interesting and may be this technique applied to Raman lidars will provide results with better accuracy

The analysis of the effects due to the use of altitude independent lidar ratios has been approached in a totally different way in the revised manuscript, as it is outlined in the following. In the new approach, the whole aerosol layer has been divided in two "selected" aerosol layers which are supposed to be characterized by different mean lidar ratio values at each lidar wavelength. Then, it has been allowed the AOT of each aerosol layer to vary of a given percentage, by keeping unchanged the AOT of the whole aerosol layer. The inversion of the lidar signals trough the implemented iterative procedure has been carried out for each aerosol layer. As a consequence, the lidar ratio values retrieved from the implemented iterative procedure for one layer are different from the ones of the other layer. Then, Angström coefficients and differences have been evaluated for both layers to investigate the effects of using different LRs for the two layers at 355 nm, 532 nm, and 1064 nm, respectively. Finally, it is worth noting that in this paper, altitude-resolved information about the aerosol fine mode radius is considered as an estimate. In fact, precise measurement of the aerosol fine mode-radius is hard to perform even with in situ optical counters, that is, almost impossible to achieve by lidar remote-sensing. Our approach aims mainly at providing an altitude-resolved coarse-to-fine relationship and an indication about changes in the fine-mode approximate radius.

Additional comments

Table 1. The real part of ref. index n=1.483 for dust looks to be quite low. In principle AERONET may underestimate n for dust. What happens if more typical value like 1.55 is considered?

Effects of refractive index changes (in the range between m=1.33 and m=1.53) on this approach have been presented and discussed in the section illustrating Figure 2 of Gobbi et al., Atmos. Chem. Phys. 2007. Such discussion showed changing refractive index to affect essentially the retrieval of fine mode radius with small effects on fine/coarse contribution. In particular, that section pointed out that:

"For a given point, maximum Rf indetermination is of the order of ±25% for refractive index varying between m=1.33–0.0i and m=1.53–0.003i. At the same time, the fine mode extinction fraction, spans a range of the order of ±10%.Within this level of indetermination, the scheme is robust enough to provide an operational classification of the aerosol properties."

Following this comment, a test has been implemented to verify the change in the graphical scheme generated by switching from the original refractive index used for dust (1.48) to the one suggested by the reviewer (1.55). In this respect, the imaginary part of the refractive index was also changed to fit the higher values reported from laboratory measurements performed on dust samples (e.g., Wagner et al., Atmos. Chem. Phys. 2012). The new dust refractive indices at the three wavelengths were then: 1.54-0.015; 1.55-0.008, and 1.54-0.004. The graphical framework obtained by using these last dust refractive index values is shown by yellow lines Figure A. This test showed the average change in all the 49 grid points to be of about 7%.

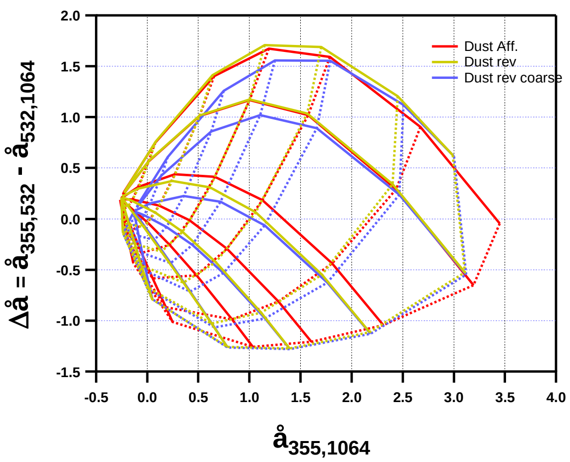

Fig. A Graphical framework for the aerosol characterization calculated according to Gobbi et al. (2007) for n_c = 1.483 and k_c = 0.0035 (red lines, Dust aff.), and n_c= 1.55 and k_f = 0.008 (yellow lines, Dust rev.) at 532 nm. The bleu lines (Dust rev. coarse) represent the graphical framework obtained by increasing of 50% the coarse mode radii of the dust distributions.

Fig.1 It is not clear what the coarse mode radius was used in calculations? How does choice of the coarse mode parameters influence the analysis presented?

Rc values are specified at line 7, page18543 of the ACPD manuscript. Effects of changes in the coarse mode radius have been discussed in Gobbi et al., 2007 (end of page 454):

"After verifying that values of the coarse modes do not vary significantly in the 440, 870 nm range (e.g., O'Neill et al., 2001), the four pairs (each pair corresponding to one of the four Rc values) have been averaged to provide a single (η, Rf) combination. Therefore, each (η, Rf) grid point plotted in our figures represents the average of the relevant coarse modes results."

More specifically, Plate 2 in O'Neill et al., JGR 2001 well illustrates the very small effect varying coarse mode radii has on å and Δå. However, we made an additional run changing (increasing by 50%) the coarse mode radii of the dust distributions leading to the graphical framework represented by blue lines in Fig. A.

Complex refractive index can be also height dependent, especially for dust layers. Probably it will not affect results to much, but still it should be commented.

Aerosols from continental Europe, the Atlantic and Mediterranean Sea, and the African deserts are frequently advected over southeastern Italy and Fig. 14 of the submitted manuscript has revealed that fine particles due to anthropogenic pollution and coarse particles of natural or anthropogenic origin could be found at any altitude sounded by the lidar. It is also worth noting that refractive indices as well as depolarization ratios depend on the percentage contribution of coarse dust particles and on the optical property changes that have undergone from the source area up to the monitoring site. As a consequence, it is not easy to properly select complex refractive indices dependent on altitude.

p.18552 ln.13 "So, resuspended soil and/or desert dust particles have likely been responsible for the volume depolarization ratios revealed by Fig. 5a" Volume depolarization of 2% is too low to be an indicator of dust particles presence. It would definitely be more informative if authors show particle depolarization on the figures.

Particle depolarization ratios will be provided in the revised manuscript.