

Interactive comment on “Assessment of aerosol’s mass concentrations from measured linear particle depolarization ratio (vertically resolved) and simulations” by A. Nemuc et al.

A. Nemuc et al.

nnicol@inoe.ro

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We would like to thank the reviewers for their time and valuable comments related to the paper “Assessment of aerosol’s mass concentrations from measured linear particle depolarization ratio (vertically resolved) and simulations”. We really appreciate your efforts to help us deliver a better article and we consider very important your assessments. We addressed each of the comments and made revisions in the paper. Please find below each of the reviewer’s comments, our clarifications and details of the modifications made in the revised paper. _____

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Comments Anonymous Referee #3 What kind of validation can be suggested?

Our reply

A validation method could be based on simultaneous and co-located airborne measurements of the total mass concentration. In the absence of such measurements, we could only use the comparison with mass concentration profiles derived by LIRIC (see Fig 6d and Fig.9d for the two case studies described in the manuscript). _____

I think the sensitivity study should be added to understand how sensitive technique is to the choice of components depolarization coefficients. How accurate will it work when depolarization is low?

Our reply

Whenever the measured depolarization is higher than 3 %, the algorithm considers that a certain load of non-spherical particles is present, in addition to the spherical one. In this mixture, the pure low depolarizing component is characterized by a particle depolarization of 3%, and the pure high depolarizing component is characterized by a particle depolarization of 35%. The algorithm will be able to split and further obtain the mass concentration of the two components. The example in Fig. 9 actually shows that the retrieval is able to provide correct information even if only one component is predominant (95% of the total is smoke) and the fact that the method works fine even for low depolarization. The choice of using fixed values for depolarization ratio of each component is described in details by Tesche et al 2009a- page 14 _____

The authors assumed RH=70%. How variation of RH will affect their results?

Our reply

Both smoke and continental polluted have a hydrophilic behavior, while desert dust seems to be almost entirely hydrophobic. As we stated in our manuscript, in OPAC Mineral aerosol particles (pure desert) are assumed not to depend on humidity. Fig.1 of Nicolae et al.2012 presents the variation of mass-extinction ratio with the proportion

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of the critical component (soot for urban/smoke, mineral transported for mineral dust and sulfates for volcanic dust) for 0% (empty markers) and 50% (plain markers) relative humidity (RH). It can be noticed that for dust there is no influence related to humidity. Also Ångström coefficients (AE) are almost constant regardless the humidity: AE = 0.15 for 50% RH up to 0.2 for 80% RH. Mass-extinction ratios for urban/smoke slightly depends on humidity and the values are: 2.98 at RH= 50% and 3.18 at RH=80%. The choice for using OPAC results for RH=70% in our analysis is related to the most frequent RH value measured by our microwave radiometer during the studied period between 2-5km. A manuscript is under preparation for a detailed analysis of optical properties of pure components derived from OPAC and best choices for deriving mass concentrations profiles lidar measurements. We rephrased in our manuscript the following statement (page 5933): "In this study we used the OPAC results at an average relative humidity (RH) of 70 % since this was the most frequent RH value measured by our microwave radiometer during the studied period between 2 and 5km. The average mass extinction efficiency used for low-depolarizing component (smoke) is $3.14 \pm 0.43 \text{ m}^2 \text{ g}^{-1}$ and $0.62 \pm 0.04 \text{ m}^2 \text{ g}^{-1}$ for high-depolarizing component (mineral dust). OPAC results for RH=0% and 50% are presented in Fig.1 of Nicolae et al. (2012)" _____

Specific comments 1. Introduction should be improved, for me it seems a bit chaotic, I would make it shorter. Authors mention things not related to this study.

Our reply

The introduction tried to underline the following issues: why to study aerosol, lidar for aerosol measurements, lidar network results, previous methods for separation of aerosol into-spherical non-spherical particles, previous depolarization measurements and about Tesche et al. method. For example: p.5926, ln.4 " : : features such as clouds, wind, ozone: : ." Why should wind or ozone be mentioned? – Our reply We rephrased the paragraph as follows: "Active Remote sensing techniques such as Lidar have been proved to provide real-time measurements of the aerosol profile (e.g. Heese

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et al. 2012, Ansmann et al. 2012)." _____

Ln.26. "Moreover, particle volume tends to extinct more light with increasing non-sphericity." Particle extinction coefficient weakly depends on shape. So this statement should be reconsidered.

Our reply-

We agree that the dependence is weak but we just wanted to point out that there is still a possible source of error when calculating mass concentrations using algorithms that assumes spherical shape for aerosol particles. p.5926, ln.9. "Based on the assumption that non-spherical particles have a spheroidal shape: : ." Particles have irregular shape, the ensemble of randomly oriented spheroids just mimics their optical properties. Our reply- We will rephrase the paragraph as follows: "LIRIC uses photometer-derived volume-specific backscatter and extinction coefficients for spherical as well as non-spherical particles for both fine and coarse modes (Wagner et al., 2013), based on the assumption that ensemble of randomly oriented spheroids mimics the optical properties of irregular shape particles". _____

p.5928. ln 3-9. These are known things so can be skipped.

Our reply

We agree that these things are known but we included them for a better understanding of the lidar dynamic range _____

Ln 10. "To minimize the noise, the laser beam has a low divergence 1.085 mrad @ 1064 nm, 1.124 mrad @ 532 nm, 1.57 mrad @ 355 nm), and: : ." 1.57 mrad at 355 nm is very large divergence, normally in lidar measurements this value is _0.2 mrad. What is divergence of beam in the detection module? Does it affect depolarization measurements?

Our reply

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We agree with the reviewer observation and we added in the final form of the manuscript right after the above text the following: "...before the beam expansion and is 0.22mrad@1064nm and 532 nm , 0.39mrad @355nm after..."

p.5928 Ln.26 – p.5929 Ln.12 Description of photon counting and analog detection is too simplified and can be skipped. Otherwise the authors should do it more deep, discussing corrections used and details of gluing procedure.

Our reply

We agree that the description is simplified. This was done like this because the main goal of this study was not the detailed description of this procedure, so we added in the text: "A more detailed description of the procedure can be found in Mielke B. (Analog + Photon Counting Bernd Mielke <http://www.licel.com/analogpc.pdf>)"

Ln.15 ": : backscatter and extinction coefficients profiles can be derived relatively without assumptions for Raman lidars: : " Angstrom is still assumed, and for backscattering coefficient corresponding error is accumulated.

Our reply

The uncertainties of the wavelength dependence of the extinction coefficients between emitted and Raman-shifted wavelength and of the atmospheric density profile add up to <5% (Müller et al. 2003), and thus are of minor importance. A detailed description of the error analysis for the Raman method can be found e.g. in Ansmann et al., 1992 and Ferrare et al., 1998.

Müller, D., I. Mattis, U. Wandinger, A. Ansmann, D. Althausen, O. Dubovik, S. Eckhardt, and A. Stohl, Saharan dust over a central European EARLINET-AERONET site: Combined observations with Raman lidar and Sun photometer, *J. Geophys. Res.*, 108(D12), 4345, doi:10.1029/2002JD002918, 2003. Ansmann, A., U. Wandinger, M. Riebe-

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sell, C. Weitkamp, E. Voss, W. Lahmann, and W. Michaelis, combined Raman elastic-backscatter lidar for vertical profiling of moisture, aerosols extinction, backscatter, and lidar ratio, *Appl. Phys. B*, 55, 18– 28, 1992 Ferrare, R. A., S. H. Melfi, D. N. Whiteman, K. D. Evans, R. Leifer, and Y. J. Kaufman, Raman lidar measurements of aerosol extinction and backscattering, Part 1, Methods and comparisons, *J. Geophys. Res.*, 103, 19,663– 19,672, 1998.

p.5930. Ln.10 ": : is estimated using the system dependent molecular-depolarization, estimated for a aerosol free region: : " The filter bandwidth and assumed molecular depolarization coefficient should be provided.

Our reply

We added in the text the following statement: "For RALI system we assumed the molecular depolarization coefficient to be 0.02 for a 0.5nm fwhm filter bandwidth"

p.5931 Ln.5 ": : certain classifications are possible and the following four general aerosol classes are associated with different sources and are expected to have different optical properties (Chaikovsky et al., 2004)" For classification I would also recommend reference: Dubovik, O., Holben, B. N., Eck, T. F., Smirnov, A., Kaufman, Y. J., King, M. D., Tanré, D., and Slutsker, I.: Variability of absorption and optical properties of key aerosol types observed in worldwide locations, *J. Atmos. Sci.*, 59, 590-608, 2002.

Our reply

We agree with the reviewer's suggestion and added the reference.

Ln.24 ": : extinction profiles of each component are calculated using the separated backscatter contribution and measured LR profile." Do authors use the same lidar ratio for all components? But these are different.

Our reply

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We agree that a clarification is needed in here. We followed the same procedure as is described in details by Tesche et al.(2009a and b). We used different lidar ratios for the components. The statement has been modified as follows: "extinction profiles of each component are calculated using the separated backscatter contribution and a constant typical LR for each component: LR=35 sr for pure dust and LR=80 sr for pure smoke). The typical values measured for pure dust 36.4 ± 9.2 sr were reported by Mona et al. (2012) from CALIOP data over North Africa. Tesche et al.[2011] measured LR values of 79 ± 17 sr at 532 nm for pure biomass-burning aerosols transported from southern West Africa out over the Atlantic Ocean. Ansmann et al.[2009] measured LR values of 70–80 sr at 355 and 532 nm indicating the presence of fresh smoke".

p.5934 ln.10. Are fractions of dust and smoke calculated from backscattering or extinction coefficients?

Our reply

We think your question is related to results in Fig. 3 and the answer is that the fractions are calculated by splitting the backscatter coefficients using the same procedure as described in the text, while the ratios represented in Fig.3 are related to the mass concentration profile of dust and smoke calculated from the extinction profiles of the two components. _____

Fig.9 Above 3 km particle depolarization is about 3%, there is no depolarization enhancement and still authors calculate dust fraction. What makes them think that it is dust? This question is probably related to all measurements with low depolarization. Again, sensitivity study is necessary.

Our reply

The algorithm is always separating the backscatter coefficient into the two components. In fact in Fig. 9 mass concentration profile for the dust component is very

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small, confirming the presence of smoke and not of dust. Whenever the measured depolarization is higher than 3 %, the algorithm considers that a certain load of non-spherical particles is present, in addition to the spherical one. In this mixture, the pure low depolarizing component is characterized by a particle depolarization of 3% , and the pure high depolarizing component is characterized by a particle depolarization of 35%. The algorithm will be able to split and further obtain the mass concentration of the two components. The example in Fig. 9 actually shows that the retrieval is able to provide correct information even if only one component is predominant (95% of the total is smoke) _____

Interactive comment on Atmos. Meas. Tech. Discuss., 6, 5923, 2013.

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