

Atmos. Meas. Tech. Discuss., referee comment RC2
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Comment on amt-2022-192

Anonymous Referee #1

Referee comment on "Investigating the dependence of mineral dust depolarization on complex refractive index and size with a laboratory polarimeter at 180.0° lidar backscattering angle" by Alain Miffre et al., Atmos. Meas. Tech. Discuss., <https://doi.org/10.5194/amt-2022-192-RC2>, 2022

The paper presents laboratory measurements of the particle linear depolarization ratio (PLDR) for dust particle samples of different size and refractive indexes (RIs). The work is worth publishing in AMT journal, since it provides useful insights for the dust PLDR measurements with lidars in the ambient atmosphere.

The use of English in the manuscript though is not optimum, and needs major re-write, focusing especially on the grammar and syntax used. Some corrections are provided here, but the authors are strongly advised to check the manuscript thoroughly, and improve it.

Moreover, discussion on the dependence of PLDR on the dust shape and on larger dust particles (with diameter $>20\mu\text{m}$) is missing and should be included, at least in the form of discussion.

Also, please be more specific about the definition of the QWP ψ angle. You use 2 or 3 different descriptions for this angle in the manuscript.

Major and general comments:

The maximum size (diameter) considered in the study is $10\mu\text{m}$ (as shown in Fig. 1), excluding the full size range of dust particles in the atmosphere (e.g. Ryder et al., 2019).

Include this info in the abstract, introduction and discussion.

The dependence of PLDR on dust particle shape is not included in this analysis. Include this in the abstract, introduction, discussion and discuss in the manuscript.

"PDR" should be changed to "PLDR" throughout the manuscript, since "PDR" may also denote to e.g. the particle circular depolarization ratio (PCDR). Moreover, the use of word "lidar" is not necessary, thus change "lidar PDR" to "PLDR".

Do not use parentheses to provide values in the manuscript, unless necessary. For example, write $180^{\circ} \pm 0.2^{\circ}$ instead of $(180^{\circ} \pm 0.2^{\circ})$, or 355, 532nm instead of (355,532) nm. Change throughout the manuscript.

Specific comments:

Line 11, "...accurate values...": Quantify by providing the retrieval uncertainties of PLDR here.

Line 29, "... (Kosmopoulos et al., 2017) ...": Include "... (e.g., Kosmopoulos et al., 2017) ...".

Line 51, "... (Hofer et al., 2020) ...": Correct to "...Hofer et al. (2020) ...". When referring to the work done in the publication, the correct way to provide the reference is "Author et al., (Year)" and not (Author et al., Year). Correct all corresponding references throughout the manuscript.

Line 57, "... (Lindqvist et al., 2014) ...": Include also the work of Gasteiger et al. (2011).

Line 59, "... (Luo et al., 2022) ...": Include also the work of Huang et al. (2022).

Line 80, "... the dust lidar PDR actually depends on the complex refractive index ...": It also depends on the size and the shape of the dust particles, include this info here.

Line 84, "... accurate values...": Provide uncertainty of the retrieved PLDR to quantify "accurate".

Line 86, "... (Burton ...)": Include "... (e.g. Burton ...)".

Lines 86-87, "Since... we here investigate...": Replace with "Since the wavelengths are determined from the available lidar measurements, we here investigate...".

Line 90, "... (Di Biagio et al., 2019) ...": Include "... (e.g., Di Biagio et al., 2019) ...".

Line 91, "... short-wave radiations...": Replace with "... short-wave radiation...".

Line 98, "... to particle sizes larger than 800 nm...": Provide the minimum and maximum diameters of dust particles in the samples used in this study. Include comment on the limitations of this study with respect to the size range, considering the absence of larger dust particles, with diameters $>20\mu\text{m}$, which are present in the ambient atmosphere, as measured in e.g. Ryder et al. (2019).

Lines 107-108, "... of an electromagnetic radiation ... air.": Rephrase as "... of electromagnetic radiation ... of complex refractive index $m=n+ik$, in ambient air."

Line 124, "... $m=2.25+0.9i$...": Contact Go et al. to verify this value.

Line 125, "... dust sample involving a mixture...": Replace with "... dust sample that is a mixture..."

Lines 129-131, "Effective... wavelength.": Rephrase as "Miffre et al. (2016) derived the values of $m=...$ at 355 nm and $m=...$ at 532 nm, using effective-medium approximations.

Line 133, "Asian dust... however a...": Replace with "Asian dust is also considered, as an important case study of natural mineral dust sample, presenting a..."

Line 135: Provide the CRI of Asian dust.

Lines 142-143, "For each ... (SD)": Rephrase as "For each dust sample presented in Section 2.1 we consider two size distributions (SDs), in order to investigate the dependence of the dust PLDR on the particle size:".

Lines 144-145, "The coarser... regions,": Rephrase as "The coarser SD plotted with a grey line in Fig. 1. This SD is more representative of mineral dust particles close to dust regions, although it does not cover the full range of large dust particles measured close to dust sources, showing particles with diameters $>50\mu\text{m}$ (e.g. Ryder et al., 2019).".

When the word "figure" is in the beginning of the sentence it is written as "Figure", otherwise it is written as "Fig.". Correct throughout the manuscript.

Line 146, "A finer SD Figure 1,": Rephrase as "A finer SD, plotted with a black line in Fig. 1,".

Lines 146-147: Measurements of long-range transported dust particles have shown particles with diameters $>20\mu\text{m}$ (e.g. Weinzierl et al., 2017), thus the SD plotted with the black line is more representative of fine dust and not of long-range transported dust. Rephrase accordingly.

Lines 162-163, "The dust... Bohren and Huffman, 1983)": Rephrase as "The dust PLDR can be described using the scattering matrix formalism (Mishchenko et al., 2002; Bohren and Huffman, 1983).".

Lines 168-169, "if single-scattering ... Bohren and Huffman, 1983)": Rephrase as "with the assumptions of single-scattering, and for macroscopically isotropic and mirror-symmetric mediums (Mishchenko et al., 2002), the scattering matrix is bloc-diagonal and the scattered light Stokes vector is calculated as shown in Eq. 1 (Mishchenko et al., 2002; Bohren and Huffman, 1983):".

Lines 173-174, "... the wavelength ...information...": Rephrase as "... wavelength λ (hereafter noted as a subscript), and carry information...".

Line 175, "... wave vector of the radiation.": Rephrase as "... wave vector of the electromagnetic wave.".

Line 177, "Indeed... ($\theta=\pi$),": Rephrase as "At $\theta=\pi$,".

Line 183, "... $F_{12,\lambda}=0$..": Replace with "... $F_{12,\lambda}=F_{34,\lambda}=0$..".

Lines 191-192, "For... dust PDR.": Delete this sentence, since it is a repetition.

Lines 192-193, "... $F_{22,\lambda}$... the dust PDR..": Replace with "... $F_{22,\lambda}$ vary with the scattering angle, in principle, the dust PLDR...".

Lines 194-195, "The deviation... since...": Replace with "The deviation of $F_{11,\lambda}$, $F_{12,\lambda}$ and $F_{22,\lambda}$ at near-backscattering angles, compared to their value at exact backscattering angle cannot be easily evaluated with scattering calculations, since...". Include here also numerical approximations used to calculate the scattering properties of irregularly-shaped dust particles for lidar applications, e.g. the work of Gasteiger et al. (2011), Konoshonkin et al. (2020).

Line 201, "Hence and as a result,...": Replace with "Hence,...".

Line 203, "... lead to zero depolarization.": Replace with "... have PLDR=0".

Lines 203-203, "In what...reading, ...": Replace with "For simplification reasons, hereafter...".

Line 206, "In Miffre et al. (2016), for the first time to our knowledge, ...": Miffre et al. (2016) refer that the π -polarimeter was the one built in David et al. (2013). Provide info and the corresponding reference here.

Line 209, "... inserting a specified...": Replace with "... inserting a well-characterized...", if this is the case.

Line 210, "... on the way from the laser pulse to the dust samples, ...": Replace with "... between the emission and the dust samples, ...".

Line 211, "... to cover ...": Replace with "... covers ...".

Line 212 "... Pi-polarimeter ...": Replace with "... n-polarimeter ...".

Lines 213-214, "Moreover, ... polarization states, ...": Rephrase as "Moreover, in order to decrease the retrieval uncertainty of the PLDR the polarization state ... is analyzed for a set of different polarizations states of the incident light, ...".

Line 216, "... which follow ... providing ...": Replace with "... which scatter the light as described by the Mie theory (Mie, 1908), provided ...".

Line 221, "... the lidar PDR ... (Mishchenko et al., 2002).": Replace with "... the PLDR at 355 and 532 nm simultaneously, for an aerosol sample.". I do not understand why you use the work of Mishchenko et al., (2002) as a reference here.

Lines 226-229, "Interestingly, ... intensity.": Change to "We can formulate the PLDR measurements of dust particles, using successive Mueller matrices denoting to the optical elements of the n-polarimeter and the scattering medium, encountered by the laser pulse from the laser source to the dust particle sample then back to the light detector. The measured backscatter intensity is provided in Eq. 5.

Lines 233-239: Delete parentheses and brackets, where no necessary.

Lines 233-234, "Where... polarization state.": Replace with "Where η_λ is the optoelectronics efficiency of the light detector and ... while $S_{ti}=[1,1,0,0]^T$ is the Stokes vector of the incident laser light."

Line 237, "... radiation incident...", Replace with "... incident laser light...".

Lines 237-238, "... if ψ is the modulation angle of the QWP.": Replace with "...with ψ the modulation angle of the QWP."

Lines 238-239, "... at wavelength λ ... follows:": Replace with "... at wavelength λ is calculated as shown in Eq. 6:".

Line 245, "This ratio ... $I_\lambda(\psi)$, ...": Replace with "This ratio can be obtained from

measurements of $I_\lambda(\psi)$, for different ψ angles of the QWP, ...".

Line 245-246, "... then adjusting ... then b_λ/a_λ ." : Provide here the methodology you use to derive b_λ/a_λ from the measurements of $I_\lambda(\psi)$. Is it a least-squares fit? Discuss the uncertainties of the retrieved b_λ/a_λ .

Line 246, "Accurate evaluations of the dust PDR..." : Provide uncertainties, otherwise replace with "The dust PLDR...".

Lines 252-253, "... VIS-photodetectors ... $I_\lambda(\psi)/I_{\lambda,0}$... " : Replace with "... VIS-photodetectors is adjusted ... signal-to-noise of I_λ measurements. For example, Fig. 3 provides simulations of $I_\lambda(\psi)/I_{\lambda,0}$..."

Lines 255-258, "The curve ... size-dependent." : F_{11} - F_{22} and F_{12} are both shape, size and RI depended. Discuss and change text accordingly.

Line 264, "Accuracy on the retrieved..." : Replace with "Accuracy of the retrieved...". Include in this Section a reference of the work of David et al. (2013) since more info about what is discussed, is provided there.

Lines 269-270, "In the n-polarimeter, ... emerging from..." : Replace with "For the n-polarimeter, ... emitted from...".

Line 272, "Polarization cross-talks..." : Replace with "Polarization cross-talk...".

Line 274, "... backscatter radiation, to be fully negligible." : Replace with "... backscatter radiation, are fully negligible."

Line 276, "Also, the emitting PBC being used..." : "Also, the PBC at the emission side is used ...".

Line 277, "...any possible mismatch..." : What do you mean by this? Please rephrase/explain.

Line 279, "Spectra cross-talks... wavelength cross-talks are...": Replace with "Spectra cross-talk... wavelength cross-talk is...".

Line 282-283, "However, the single scattering... are moving...": Replace with "However, the single-scattering approximation (Mishchenko et al., 2007), is ensured in our laboratory backscattering experiment, where the particles are moving...".

Line 287, "... has been added to our experiment by considering...": Replace with "... has been added to the π -polarimeter for our experiment by including...".

Lines 288-290: "The corresponding... to get...": Replace with "The corresponding scattered light intensity $I_{\lambda}(\theta_o)$ is quantified similarly to Eq. 5, considering a scattering angle of θ_o , and that the QWP and the PBC only act on the detector side, while S_{ti} equals $[1,1,0,0]^T$, to get...".

Line 290: Provide the full equation for $I_{\lambda}(\theta_o)$, including the Mueller matrix sequence, similar to Eq.5.

Lines 291-293, "Once the variations... number concentration.": Provide example (with plots) here or in the appendix.

Line 319, "Normalized backscattered light intensity": Explain with what you normalized the backscattered light intensity.

Lines 319-324, "Figure 4... Asian dust.": Replace with "Figure 4: Normalized backscattered light intensity $I_{\lambda,N}$ of Arizona (a) and Asian dust (b) for finer SD (left panels) and coarser SD (right panels), using the laboratory π -polarimeter at lidar exact backscattering angle ($\theta=\pi$) at 355 (blue) and 532 nm (green). The experimental data points are fitted with Eq. 6 to derive $F_{22,\lambda}/F_{11,\lambda}$, and then the dust PLDR is derived using Eq. 7. Care should be taken when comparing $I_{\lambda,N}$ for Arizona and Asian dust, since the applied voltage to the UV and VIS-photodetectors was adjusted to increase the signal-to-noise ratio, as explained in Section 3.4. The Arizona dust PLDR is higher than that of Asian dust."

Lines 325-327, "Tab. 1... Section 3.2.": Replace with "Table 1: Laboratory measurements of the PLDR of Arizona and Asian dust at 355 (blue) and 532 nm (green), for the finer and coarser SD. The PLDR is calculated with Eq. 7 after the derivation of $F_{22,\lambda}/F_{11,\lambda}$ using the laboratory π -polarimeter presented in Section 3.2.

Line 296, "...calculated by considering the covariance of I_λ and $I_\lambda(\theta_0)$." : Provide more info about this calculation.

Line 298, "... standard deviations..." : Provide more info: is this the variability of the measurements? Is this the measurement error? Or a combination?

Lines 304-308, "The observed... dust sample." : Both maximum and minimum values would vary if the size or the shape varies, since F_{11} - F_{22} and F_{12} both depend on size and shape.

Line 308, "...could be adjusted..." : Replace with "...could be fitted...".

Lines 309-311, "The accuracy... lidar PDR." : Replace with "The uncertainty of $F_{22,\lambda}/F_{11,\lambda}$ results from the measurement errors of the laboratory μ -polarimeter."

Line 309-310, "The uncertainty of $F_{22,\lambda}/F_{11,\lambda}$... μ -polarimeter." : Provide the methodology for deriving the uncertainties.

Lines 331-333, "By applying... (Fig. 5b)." : Preplace with "By applying the same methodology, we obtained the PLDR of silica and hematite, as presented in Fig. 5 and Table 2."

Line 333, "...and hematite primarily depends..." : Replace with "... and hematite depends...". Why "primarily"? What about the shape dependence?

Line 335, "...depends on the D:" : Replace with "...depends on the particle diameter:".

Line 340, "Figure 5... (b-plots)." : Replace with "Figure 5: Same as Figure 4 for silica (a-plots) and for hematite samples (b-plots)."

Line 343, "...hematite." : Replace with "...hematite samples."

Discussion Section: No discussion is provided on the effect of dust shape. Comment on this and highlight the lack of this analysis in the Section.

Line 349, "Otherwise, ...different.": Replace with "Moreover, the PLDR is wavelength-dependent and the size distribution used are different from other studies."

Lines 350-354, "... calibration procedures... silica lidar PDR,...": Replace with "... calibration procedures (e.g. Freudenthaler, 2016; Belegante et al., 2018; Miffre et al., 2019). Although in such lidar field experiments the measured PLDR is usually that of dust mixtures (Miffre et al., 2011), the comparison with our laboratory findings remains interesting. In lidar retrievals (see for example Tesche et al., (2009)), a dust PLDR of 30 % is often used. The laboratory δ -polarimeter verifies this assumption by providing the silica PLDR..."

Lines 359-362, "To highlight... hematite lidar PDR.": Discuss the effect of size and shape of these two different samples.

Line 365: Discuss also the effect of shape.

Line 366: The works of Kahnert (2015) and Kahnert et al. (2020) do not consider the coarser dust particles, thus the effect of shape is expected to be lower. Please discuss.

Line 378, "...is resumed to..." Replace with "... is comprised of..."

Line 385, "... to the case study where...": Replace with "...for the case study that..."

Line 390, "... are given... depolarization ratios...", Replace with "... are provided in Appendix A and depend only on the depolarization ratios..."

Line 394-395, "...of light absorbent in the...": Replace with "...of light corresponding to the absorbent of the..."

Line 398, "...and become quantitative, ...": Replace with "... and provide a quantitative analysis, ..."

Line 399 "...dust, as well as other δ - and other lidar wavelengths.": "...dust, other lidar wavelengths, as well as the effect of shape and δ ..."

Lines 403-404: Discuss shape dependence, as well.

Line 406, "... composed of a light...", Replace with "...composed of...".

Line 409, "...coarser S)": Replace with "... coarser SD)".

Line 410: Replace "Conclusions" with "Summary and conclusions", since you also provide a summary of the work here.

Line 415, "... (Tesché...)": Replace with "... (e.g. Tesché...".

Lines 415-417: Include also that the investigation of the dependence of PLDR on the dust particle shape is not included in this analysis.

Line 419, "... accurate...": Quantify (or delete).

Line 422, "... cannot be quantified...": Replace with "... cannot be analytically calculated...".

Line 423, "... mineral dust.": Replace with "... mineral dust, although there are numerical approximations that provide the PLDR of dust particles, which though haven't succeeded -as of yet- to reproduce the spectral dependence of lidar LR and PLDR measurements (e.g. Gasteiger et al., 2011)."

Line 424, "...which are given...": Replace with "...provided...".

Lines 427-428, "The precision... Section 3.": Replace with "The precision of the retrieved dust PLDR is detailed in Section 3."

Lines 430-431, "...proves that ... this huge difference...": Replace with "...provides values of the PLDR of coarser silica of 33 ± 1 % while that of coarser hematite is only 10 ± 1 %. In Section 4, this large difference...".

Lines 433-437, "As a result... lidar instruments.": Provide comment on particle shape.

Line 439, "... other δ and other wavelengths.": Replace with "... other δ and other wavelengths, as well as other shapes."

Line 443, "... instructive (Burton et al., 2016; ...": Replace with "... instructive (e.g. Burton et al., 2016; ...".

Line 443, "Numerical outlooks...": Replace with "Outlooks...".

References:

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