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Atmospheric Measurement Techniques Discussions

Interactive comment on "Experimental techniques for the calibration of lidar depolarization channels in EARLINET" *by* Livio Belegante et al.

Anonymous Referee #1

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The depolarization ratio is an important property to characterize different aerosol types. An exact measurement of this quantity is therefore an important issue. The manuscript describes a method to assess and to correct for the diattenuation of receiving optics and the rotation angle between the laser and the receiver. Both quantities can be determined by the use of the Delta 90° calibration, which is an important method for the proper characterization of a lidar system. The description (figures and formulas) needs to be improved. It is shown that these corrections lead to a significantly better result for the volume depolarization ratio (Fig 8). The lidar community will profit from these techniques. Therefore I recommend it for publication, although there are some mayor points that have to be improved:

Major Remarks

1. Equation (4) is wrong. If you multiply two vectors you'll get a scalar. The first vector (i_E, q_E, . . .) seems to be I_E, but should be the matrix M_E.

2. p6, l14 How do you assure that there is no misalignment of the additional polarization filters after the PBS? Or which error would a misalignment by 1° introduce to the depolarization? Please comment on this.

3. p8, l18 What do mean by "all effects"? Be more precise.

4. p8, l30 – p9, l8 I am not sure whether it is necessary to introduce the "45° calibration". The problems with this calibration are already discussed in Freudenthaler et al., 2009. Just keep the focus on the Delta 90° calibration. In the following text I would recommend to skip the quotation marks " " around the Delta 90° calibration.

5. p9, l26 You mention a set of two relative Delta 90° calibrations, but the equations (24) and (25) make use of only one calibration measurement.

6. p10, l5-9 This is a very important and interesting point. You will use only one calibration method (the Delta 90° calibration) to assess different parameters of your lidar system (at different positions in the system). It would be good to state this clearly already in the introduction, because this could be something like a red line through your paper. For persons not so experienced in the lidar business it would help to start with the calibration effort.

7. p10 chap. 3.2.1 A HWP calibrator works for single wavelength lidar systems only. In multiple wavelength lidar systems a HWP must be placed in front of each PBS, but not in front of the receiving optics. This should be mentioned.

8. p12, eq (26) and eq (27): Do you mean D_O ("O like orange") or D_0 (0 – zero)? You use both notations throughout the manuscript, not only in these two equations. Please choose one notation for the entire manuscript.

9. p13, l1, l4 What do you mean by "retrieved measured" and "simulated measured" ? It is simulated or measured? Maybe something like "simulated apparent calibration fac-

tor" (see Freudenthaler, 2016) and "retrieved calibrated signal ratio" as you call delta* in Fig 4. Please use one name for a certain quantity throughout the entire manuscript.

10. p13, l23 and Fig 5c How do you get the uncertainty of 25%? For the known value of alpha = 10° and D_0 = 0.25, Y would be -0.45. You have to assume some uncertainty for alpha and D_0, which you have not mentioned.

11. p13, chap 3.4.2 You discuss the possibility of correcting alpha with a HWP or mechanical rotator in front of the PBS. At this point you should discuss the possibility of turning the linear polarizer in front of the PMT (setup 2c) to correct for alpha. It should lead to similar results as the rotation of the PBS.

12. p15, l17 Why you use alpha(Y)? Is there a reason for the dependence on Y? Please explain it or change it. This holds for the following text.

13. p15, l31 and Table 3 You mention a correction of a_L. Please indicate the value and its uncertainty for a_L.

14. Fig 8 The color scale for the time-height plot looks unorganized and has no description. Why is there a grey line between the color plot and the color scale? The same holds for Fig 9a, 10a, 11a.

15. For all Fig 8 - 11 Please indicate the vertical smoothing length for your profiles.

16. p16, l25-30 and Fig 9 The Granada measurement is presented in unorganized way. I would recommend to skip it as you have already an example for Saharan dust over Potenza or to take into consideration the following comments:

- Every plot starts at a different height.

- Up to 7 or 8 km height would be sufficient.

- Heights are about ground or sea level?

- Why the back trajectories are calculated for so close height ranges? Why at 2000

UTC and not 2100 UTC?

- "One hour average", the red lines in Fig 9a show only 50 minutes.

- p16, l26-27 If the particle linear depolarization ratio is close to the molecular depolarization in the low aerosol height ranges, then something is wrong. The particle linear depolarization ratio depends on the aerosol type, if there are only few aerosols, the particle linear depolarization ratio gets noisy but not close to the molecular depolarization.

- 0.22 (two significant digits are enough) is quite low for mineral dust. Please compare it to literature values. It could be polluted or mixed dust.

- "several days" How many?

17. p16, l31 – p17, l3 and Fig 10 The Potenza case is better organized. Again: The plots up to 7 or 8 km would enlarge the interesting part (for example the Munich case is shown up to 5 km to focus on the interesting part). Height about ground level or about sea level is important for a mountain station like Potenza. The shown measurement starts on 6th August 2012 00:00 UTC, the profiles indicate 05.08.2012. The abbreviation PBL is not explained.

18. p17, l23 and Fig. 5 What do you mean by "effective diattenuation"? Where is the difference to "diattenuation" (of the receiving optics)?

19. p17, l33 – p18, l4 The HWP might be the best solution for single wavelength lidar systems. Please discuss the use of dual wavelength polarization measurements as well.

20. p18, l5-10 Not only here, but in the whole conclusion: Please do not forget to discuss the calibration by a linear polarizer.

21. Appendix, p19 How are your angles alpha, beta and gamma defined? As rotation around the propagation axis or with respect to the PBS? p15, l17 you state: "the ro-

tation of the plane of polarization of the laser with respect to the PBS: alpha(Y)." The axis of propagation and all angles around it are defined by the orientation of the PBS. Please make a clear statement when introducing the angles.

22. The cited literature seems to be at the situation of 2015 where the paper was submitted for the first time (except of the accompanying papers by Bravo-Aranda and Freudenthaler, both AMT 2016). Please update the reference list to include more recent publications.

23. Table 1: If we can rotate the emitted light with a HWP to +- 45°, it should also be possible to mechanically rotate the emission unit to +- 45° leading to the same result. A linear polarizer could also be placed in the emitter unit as described in Chapter 8.3 in Freudenthaler, AMT 2016. Please add these two possibilities in the column "position". A column for single or multiple wavelength use could be added, as the mechanical rotator and the polarizer rotator can be used for several wavelengths, whereas the HWP can be used for a specific wavelength only.

24. Table 2: How do you explain the differences between your Table 2 and Table 5 in Bravo-Aranda et al., AMT 2016 regarding the Munich lidar system? You report D_0 = 0.059 (at 532 nm ?), the other publication reports D_0 = 0.011 at 532 nm. Or is it valid for different years? The Potenza lidar system differs by the sign only, D_0 = +0.055 (this manuscript), D_0 = -0.055 (Bravo-Aranda, 2016).

25. Table 3: Please specify the height range (for "cloud" and "free troposphere") used for your average.

26. I dare that the figures (Fig 4-11) do not fulfill the standard of the journal. A professional plot program should be used.

Minor Comments:

- The Spanish institute affiliations are without street name, while all other institutes are located in a certain street and number.

- There should be a space between the number and the unit, for example 3.5 km and 532 nm. Please go through your entire manuscript to check this.

- p3,l2 methods (add plural s)

- p3, l14 "(\alpha)" is not necessary in the introduction.

- p4, l20-21 Change to normal fond (not italic, not bold).

- p6, l1 "All optical elements M_O can be described by Mueller matrices of diattenuators M_D with retardation M_ret" and rotation M_gamma. As you show in the next line (equation (8)).

- p7, eq (15) Please consider the rules for notation as you stated correctly on p3, l27 "bold italic fonts are used for the Stokes vectors, bold for the Mueller matrices and italic for the scalar variables". The same holds for G_S and H_S in eq (16) and (17).

- p7, l8 Use capital E as index. u_E = sin (2 alpha) * a_L

- p7, eq (21) Please use capital R and T.

- p8, l23 "This method" To which of the two mentioned methods you are referring. Be more precise.

- p8, l31 "the larger is the error . . ."

- p9, l21-22 "Table 1 summarizes main advantages and disadvantages when using different calibration techniques for the Delta 90° calibration." Put this sentence a little earlier (p9, l18), before you start describing how to find the zero degree position.

- p9 eq (24) What is eta*_pol ? It is not introduced. eta* would be sufficient.

- p10, l17 polarizing beam splitter

- p11, l5 and Fig 3 "optical rotator calibrator" please do not use different words for the same thing throughout your manuscript. "HWP calibrator" or "optical rotator calibrator" ?

- p11, l29 use \citet{} instead of \citep{} command.

- p12, l3-4 “measuring two depolarization channels at 532nm and a 90° setup” Reshape this part, the lidar does not measure a channel nor a setup.

- p12-13, chap. 3.4 You are talking about the depolarization ratio, not the polarization ratio. It occurs 5 times in this chapter the wrong expression.

- p13, l11-12 The polarization parameter (a) is not the atmospheric depolarization that you show in your figure.

- p13, l12 “the diattenuation parameter” of the receiving optics.

- p13, l22 “The analytical correction of alpha can be performed by” determining G_S, H_S and K “using Eq. (16), (17) and (21).”

- p15, l2-3 Already said on p12, l11-12

- p15, l16 polarization

- p15, l19-21 “we will only consider the post measurement analytical correction” and one line later you start with the experimental correction for alpha and Fig 7c. For the post measurement analytical correction, did you use alpha = 10° or alpha =-0.04°? Please state this clearly at the beginning of the discussion about the post measurement analytical correction.

- p15, l31 “lower values” – Give numbers.

- p15, l33 Put the citation in one bracket.

- p16, l19 “use the same”

- p17, l22 its placement . . . keep normal text fond

- p17, l27-28 “while the method[s] that use the calibrator in front of the PBS allow[s] to take into account . . .” Plural or singular?

- p18, l10 “number of lidar systems it can be applied to” You mean single wavelength lidar systems or what are the other limiting factors?

- p18, l20, l23 Do not use “+” in the text. Use “and”.

- p18, l26 0.01 - 0.03

- Appendix A: D has to be italic. M_S has to be written with a capital S.

- Keep the alphabetical order of your reference list (e.g. Reichardt should not appear after Winkler, page 25)

- When citing make sure, that David. G, et al, 2012 appears as David et al, 2012

- Table 3: The index “pol” in eta*_pol is not used elsewhere in the case study. In Fig 8 it is just called eta*.

- Fig 4 Please add in the caption “delta*” b) (0° : 10°) In my opinion the eta* plot (Fig 4c) is not useful to show. Or it has to be discussed in more detail. What are the implications for the parameter K?

- Fig 5 It would be better to show in Fig 5 a+b only the range from 0° to 20°.

- Fig 6 In the caption: “measured depolarization ratio” – “calibrated signal ratio delta*” would be better. Fig 6b in the title of the diagram the ‘ is missing for epsilon.

- Fig 8 In the caption “one hour average” – the red lines indicate just 45 minutes. What is correct?

References: Bravo-Aranda, J. A., Belegante, L., Freudenthaler, V., Alados-Arboledas, L., Nicolae, D., Granados-Muñoz, M. J., Guerrero-Rascado, J. L., Amodeo, A., D’Amico, G., Engelmann, R., Pappalardo, G., Kokkalis, P., Mamouri, R., Papayannis, A., Navas-Guzmán, F., Olmo, F. J., Wandinger, U., Amato, F. and Haeffelin, M.: Assessment of lidar depolarization uncertainty by means of a polarimetric lidar simulator, Atmos. Meas. Tech., 9(10), 4935–4953, doi:10.5194/amt-9-4935-2016, 2016.

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