

General comments

In this manuscript (amt-2018-370), authors describes the three-signal depolarization calibration for lidar systems proposed by Reichardt et al., 2003 by means of the Stokes-Müller formalism. This allowed them to take into account some lidar polarizing effects. Additionally, authors presented the experimental setup and some results (a case study and an analysis of the temporal evolution of the depolarization calibration) to validate the procedure. Both the theoretical and experimental basis are well described in a well-written and structured paper. Since lidar depolarization seems to be in the spotlight of atmospheric science due to its application in aerosol/cloud microphysical retrievals (and thus, in aerosol-cloud interaction), I would recommend its publication whether the following comments are considered by the authors.

A small discussion about the advantages and disadvantages of this method, in comparison with others already implemented, would be extremely useful for the community as far as lidar design is concerned.

Specific comments

Page 4, line 3: *'In the alignment process, the cross-polarized axis is found when the count rates are at the minimum.'*

This process seems to be inaccurate because the change of the signal due to several degrees can be masked by the signal noise. Did you check the accuracy of this procedure? Could you provide the uncertainty?

Page 4, line 18: *'Based on this theoretical framework we will derive three lidar equations for our three measured signal components.'*

I think that the theoretical framework has not been presented yet. Please, considered to change by *'Based on the theoretical framework of ____, we will derive [...].'*

Page 5, lines 10-14: *'In our approach, ...'*

I recommend to mention the Figure 3 somehow. It will be easier to understand this paragraph following the steps of Figure 3.

Page 5, line 18: *'We introduce the so-called cross-talk term ϵ'*

In the line 1 of the same page, it is stated that the notation and explanations of previous manuscripts are used. However, the term 'cross-talk' is mainly used to describe non-ideal beam-splitter cubes instead of the depolarization of the outgoing laser light (emitting block). If I properly understood, the cross-talk term would correspond to the depolarisation of the laser light after crossing the transmission block (a kind of linear polarisation parameter a_L , according to the Freudenthaler's paper). Additionally, I would say that the angle θ in this manuscript corresponds to the angle α in the Freudenthaler's paper. For the sake of clarity, it would be very

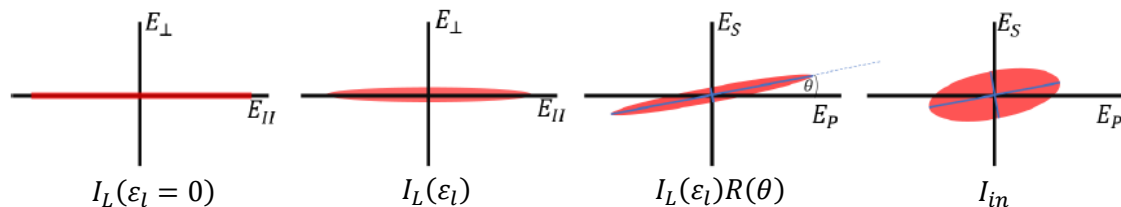
helpful for the community whether the same nomenclature is used or, at least, a small mention about the connections is included.

Page 6, line 2 and Eq (6):

According to the Freudenthaler's paper, the rotation $R(\theta)$ proposed in this manuscript is a particular case of the emitting block, being other polarizing effects omitted such as the diattenuation. It would be helpful for the readers to have a list of parameters considered ideals.

Page 6, Figure 3:

It would be helpful for future readers to link each step in the figure with the term, as follow:



Page 7, line 13: 'A commonly used method for the calibration *is the to* insert an extra polarization filter[...]'

Typo?

Page 8, line 6: 'Because identical polarization filters are used in our lidar setup, we can assume $Dp = Ds^{-1}$.'

What do you mean with 'identical'? Even the same model of polarizer made by the same company might show quite different behaviors. Additional details should be addressed to support this sentence.

Page 9, line 2: '[...] based on a measurement example, we demonstrated that the impact of this assumption can be neglected in our system.'

Could you provide any indication about the validity of this assumption in other systems?

Page 10, line 11: 'liquid-water clouds where multiple scattering by droplets produce steadily increasing depolarization with increasing penetration of laser light into the cloud [...]' and Page 17, line 21: 'the volume of the depolarization ratio does not depend on the field of view of the receiver, however in multiple scattering regime (e.g. in liquid water clouds), it does [...]'.

Could the multiple scattering be a problem for the depolarization calibration?

Page 10, line 29: *'Then ξ_{tot} can be estimated in a region (defined by height z_{mol}) with dominating Rayleigh backscattering [...]*

This is the most important handicap I detect in this method. ξ_{tot} must be estimated in a particle-free region where the SNR used to be quite low. This is the same handicap of the classical molecular calibration, including a more complicated lidar system since three channels are required instead of two. So, why is this method more advisable?

Page 11, Eq. (42):

Which is the meaning of the term 'C'? I was not able to find its definition. From Eq. (41) to Eq. (42), I got that $C = X_{\delta}$. Please, specify it.

Page 12, line 10 and caption of Figure 6:

Whereas it is stated that the height range goes from a few meters below the cloud base up to 240 m above (page 12 line 10) in the caption of the Figure 6, it is noted that 16000 data points were obtained. Could you explain the huge number of data points in this small height range?

Page 13, line 8: *'The cross-talk factor has a large impact on the retrieval of the volume linear depolarization ratio only in the region with low depolarization ratios.'*

Please, include whatever is necessary to demonstrate this sentence.

Page 15, line 8: *'4.2 Long-term stability of the polarization lidar calibration and performance'* and Page 17, line 18: *'Long term studies indicated the robustness and stability of the three-signal lidar system over long time periods.'*

The calibration stability was analyzed between April and November 2017 (8 months). I would use 'long-term' for larger periods and thus, I suggest replacing 'long-term stability' by 'temporal stability'.

Page 15, line 15: *'The selected large attenuation of the channels prohibited an optimum detection of high-level dust layers and ice clouds.'*

Could you explain how the large attenuation prohibited an optimum detection of dust layers but allowed the determination of ξ_{tot} using the molecular depolarization ratio?

Page 15, line 15:

Typo: double space 'can be__noted'.

Page 17, line 2: *'based on three telescopes with a polarization filter on the front'.*

Do authors mean three 'channels'?

Page 17, line 13: *'However, it needs a strong depolarizing medium for its application, e.g., water clouds.'*

This phrase might be confusing. Please, clarify that the strong depolarization comes from the multiple scattering not because the liquid droplets.