Dear Referee,

thank you for your detailed review and valuable comments. We tried to address the issues you mentioned.

Sincerely,
Hans Grob

Referee's specific comments

1a. Section 4: "We introduced a new method for polarimetric calibration of polarized sun and sky radiometers. In contrast to pevious calibration methods, it can simultaneously determine orientation and diattenuation of a polarized channel. This reduces the experimental effort, as only measurements at a single degree of polarization are necessary." There are other mentions of the novelty of the polarimetric calibration as presented in the paper. However, polarimetric calibration using a single degree of polarization to simultaneously determine orientation and diattenuation of a polarized channel is common practice, typically using a rotating high–extinction polarizer.

We agree that the calibration methods themselves are not novel. Yet, all literature currently being cited on the calibration of sun photometers (esp. AERONET) lack a rigorous mathematical derivation of the formalism and a description of the corresponding calibration process. This and the fact that diattenuation and polarizer angles can be determined in a single step are – in out opinion – actual improvements over the existing methods. Especially as this allows for the use of a less sophisticated polarized light source (see later).
However, "novel" is maybe a bit of an exaggeration in this case, so the wording was changed.

1b. P5 ll. 14: "Since the angle of the plate can be determined with high accuracy, also the DoLP is known to a high precision." Is the word "precision" used instead of "accuracy", because there is uncertainty in the refractive index of the glass plates? What is the total uncertainty in the POLBOX output DoLP?

We meant to say that the high accuracy of the DoLP from the POLBOX stems from that fact, that angles can (arguably) be determined rather precise, experimentally.
The wording was changed.

Additionally, the DoLP uncertainties from Li 2010, 2018 are cited. These are then used to determine the induced uncertainty in the calibration

of the diattenuation D.

1c. The POLBOX can generate DoLP between 0 and ∼58 %. It seems like the polarimetric calibration only uses a single DoLP, i.e. the maximum DoLP. What is the advantage of using the POLBOX at a single DoLP of 58 % vs a high–extinction polarizer which would provide the maximum possible calibration signal?

Yes, this is true. In fact, POLBOX was as employed it was historically used for SSARA, and the people at Lille kindly granted us access. The possibility of setting an arbitrary DoLP is not needed in our method.
Also, as now mentioned in the text, the uncertainty of D seems to be limited by the uncertainty of the DoLP produced by the POLBOX. A polarizer with a higher precision would likely improve the calibration of D.
(Furthermore, it can be argued that a higher DoLP would improve the fit to Eq. (17) as it increases the amplitude of the cosine.)

2a. The validation and interpretation of the aerosol retrieval results using the AERONET comparisons would probably benefit from having error bars on both the SSARA and AERONET retrievals. For example, the effective radii are somewhat different, but it is unclear how significant the differences are, and the refractive index seems to lack sensitivity as pointed out by the authors, but it does vary on the ±0.1 level. Another example is the coarse mode AOD during the Sahara dust event which matches the AERONET retrievals very closely, but the fine mode AOD is off in a seemingly systematic way.

This is true. However, AERONET also does not provide any errorbars on their results. AERONET is currently working on a method to determine the errors based on perturbations of the measurement data. This is computationally very expensive. In the future, a similar approach could be applied to our retrieval. For now, the residual is shown. While this is by no means a proper uncertainty consideration, it is used as a proxy for the quality of the inversion.

2b. It is pointed out that the direct sun total AOD is never used as a constraint in the aerosol retrievals, in contrast to AERONET, because direct sun measurements might not be available in cloudy situations. To better understand the discrepancies in the retrieval results, it may be instructive to analyze the effect of using direct sun constraints whenever available.

The decision not to include direct sun measurements in the retrieval process was consciously made early in the design process for the reasons mentioned in the paper. In hindsight, it would have been smarter to allow it, for exactly the cases you describe. Unfortunately, due to the structure of the code, this ability can hardly be added without changing the solver and other core components of the retrieval. Future retrieval designs should include this possibility.

Still, while the statement that direct measurements would improve the retrieval results might seem somewhat intuitive (more information yields better results), it is purely speculative at this point and probably should not be made without prior studies. Therefore, we changed the wording of this statement.

Referee's detailed comments

P2 ll. 2: "not good enough to properly resolve": What would be the required resolution?

Clarified and required resolution quantified.

P2 lls. 13–17: Since the paper is about a groundbased instrument, consider using the following references for GroundSPEX and GroundMSPI:

- Van Harten et al., AMT 7:4341-4351, 2014
- Di Noia et al., AMT 8:281-299, 2015
- Diner et al., Atmosphere 3:591-619, 2012

References added.

P3 ll. 4: "SSARA is... Munich": Provide reference, or is this it?
P3 ll. 13: "channels 13–15 are equipped with linear polarizers": Has this been published before, or is this a recent addition?

This is the first paper describing the instrument in depth. Additionally, SSARA took part in the SAMUM and SALTRACE campaigns, as mentioned in the introduction. The respective papers also contain information about the instrument. The polarized channels have been added in 2015 but not been used or described since.

P3 ll.14: "linear polarizers": What kind of polarizers?

Clarified. The filters are film sheet polarizers.

P4 Tab. 1: Consider adding column "direct sun/diffuse sky"

Column added to respective table.

P4 ll. 10: "simultaneously, because it does not use a filter wheel": How long does the AERONET filter wheel sequence take?

Clarified.

P5 ll. 6: Add "Li et al., 2018"

Done.

P5 ll. 22: "exiting light" → "refracted light inside the glass"

Changed.

P6 Fig. 2: Consider adding dimensions and angle theta.

Adding the angle in 2D is confusing. However, the caption has been updated in an effort to clarify the setup.

P7 ll. 8: "transmission values": amplitude or intensity transmission?

Clarified.

P7 ll. 26: "It is independent of the intensity of the incoming radiation I_0". But it is retrieved from sequential measurements at different POLBOX angles, so light source stability is not unimportant.

Clarified.

P8 Tab. 2 (caption): "unpolarized, so... D=0": It is not uncommon for non–polarimetric channels to exhibit diattenuation. The POLBOX experiment could be used to quantify and potentially correct polarization sensitivity in the non–polarimetric channels.

This is true and should be examined during the next calibration. However, due to time constraints we did not perform the necessary measurements of the unpolarized channels behind the POLBOX to characterize their diattenuation in this calibration session. The caption is changed to clarify $D = 0$ is an assumption and a short paragraph has been added as an explanation.

P4 Tab. 1: Channels 4 and 13–15 are very similar. Have their radiances been compared?
P14 lls. 9–13: Was the radiometric calibration on Mount Zugspitze compared to the radiometric calibration in the LOA lab using SphereX?

They have not been compared yet.
TODO: this.

P15 ll. 8: "A ground albedo of 0.15... is used for all wavelengths": Is that a good assumption? What kind of surface was assumed?

Clarified.
TODO: this.

P16 ll. 25: "AOD data" → "AOD data in Fig. 9"

Changed.

P16 ll. 29: "as shown in sensitivity studies": Reference?

Reference added.

P17 ll. 5: "in space": How realistic is this explanation at the deployment location?

The measurements site was close to the coast in Cyprus, where the different aerosol types described in the text could generally coincide. As a matter of fact, the presence of different aerosol types was one of the reasons

Cyprus was chosen as the location for the campaign. However, is this argument remains valid for the given days can only be speculated (see also next point).

P17 ll. 6: "in time. . . 15 min": Figure 9 shows very stable direct sun AOD for hours.

This is true, so in this case, variation of AOD over the scanning time is probably not the explanation for the deviation. We removed the "scanning time" argument from the sentence.

P18 Fig. 9: Dont forget to point out that the direct sun results match AERONET very well.

Noted in the caption of Fig. 9 and the introduction to the case studies (Sect. 3.2).

P20 (bottom): "single degree of polarization": Was the POLBOX used at different DoLP settings, for example to validate the accuracy of the polarimetric calibration?

No, this has not been done yet. Ideally, the calibration would be performed using a high–performance polarizer, and check be done with POLBOX.

P21 ll. 10: "error of up to 1.9 % in total radiance and 3.9 % in DoLP" → "error of up to ±1 % in total radiance and ±2 % in DoLP"

Changed.