Atmospheric Measurement Techniques Discussions

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Reply on RC2

Karolina Sarna et al.

Author comment on "Estimating the optical extinction of liquid water clouds in the cloud base region" by Karolina Sarna et al., Atmos. Meas. Tech. Discuss., https://doi.org/10.5194/amt-2020-504-AC2, 2021

Response to Anonymous Referee #2

- *Equations 2-5:*
  *The presentation of Eqs.2–5 needs to be improved. It was hard to follow and check the derivations because of a few errors, such as alpha'_m in Eq. 3 should be jus alpha', and the term S/z^2 should be S*z^2 in Eq. 4, which according to my calculations would be redundant (or it is in Eq. 3).*

Response:
Indeed we agree that the equations 2 to 5 need to be improved. In Eq 3 alpha'_m should be just alpha_m and the extra fraction in eq 4 was removed. The changes will be submitted in the new version of the manuscript.

- *It would be easier to follow, when the expression on page 3 line 11:S is the extinction-to-*
  backscatter ratio (S = alpha (z)/beta_(z) here assumed to be range independent within the cloud) and for the water clouds and wavelengths in the range from 200 to 1064 nm it
  is around 16 sr (Yorks et al., 2011).... would be placed right before Eq. 2 and by adding to Eq. 2 =S (beta_c + beta_m).

Response:
We agree with the comment, this will be adjusted in the new version of the manuscript.

- *Finally, to my opinion, to obtain Eq.6, the apparent (i.e., multiple-scattering influenced) lidar ratio is needed in the Klett method (not the single-scattering lidar ratio, 18sr), and this quantity varies with multiple scattering impact and thus changes with height. Please clarify this, and state this clearly.... How did you overcome this effect?*

Response:
As explained in section 4.1.2 of the paper we are applying a correction for the multiple scattering (MS). This correction eliminates the need to use an effective S. We will underlie it in section 2 of the revised manuscript for clarity and provide reference to appropriate subsection.

- *Section 3: Please provide more information of the computed scenes! Which form do the*

vertical
profiles have? How many values of the extinction coefficient did you test?
Later on in Section 4.4, you report that the accuracy of ' for the whole data set was 95%.
What is the data set?

Response:
A more detailed description of the scene used will be provided in the revised version of the manuscript. The whole data set used for this study was showed on Figure 1. In total there were 450 profiles tested and an example of the profile was provided on Figure 2 and 4.

- *Section 4.1.1 In Figure 2, what is the reason for the large negative extinction value (Klett) at 190 m height? Juts provide more information to better understand the problem. To my opinion, the normalization of the signal is a major potential drawback of the method, i.e., to accurately determine' to initialize the inversion. This need to be discussed in more detail, e.g., what is the influence of the selection of the normalization range?*
  What do you get when you vary it from the cloud base up to the limit (where SNR < 20)?
  I am concerned about this, because Eq.(7) is only valid if the extinction coefficient remains constant with height, which is not the case in the clouds that you considered (with an increasing extinction coefficient profile). Usually the aerosol-free troposphere is used as boundary condition. And this is precisely the biggest problem in attempts to invert lidar signals within clouds, the lack of a boundary condition because of the complete attenuation of the laser light throughout the cloud. I am surprised that you got good results applying Eq. (7)

Response:
The negative value at 190m height is related to the difficulty of accurately retrieving extinction by the slope method in the cloud base region. The values close to the cloud base (one bin below to the beginning of the cloud base) are almost always giving negative values (since in this area the true cloud extinction is not constant and is indeed rapidly increasing in a relative sense). For this reason, we can only use the slope method within the cloud, where the extinction is not changing as rapidly in a relative sense, to estimate alpha_0. We know that the slope method is only strictly valid if the extinction is constant. However we chose an altitude as deep into the cloud as the SNR allows. This helps ensure that relative extinction is constant enough so that the boundary value extinction is accurate enough to be useful in the backward Klett solution. Note: Klett, 1985 (https://doi.org/10.1364/AO.24.001638) showed that extinction profiles below z_{o} can rapidly converge to the true results in optically thick conditions even with somewhat large errors in \alpha_{o}. This explains our results. Figure 2 is presented to show exactly this effect: it is only possible to use it higher within the cloud. This issue will be better explained in the revised version of the manuscript.

- *Page 4, line 28: Should it be ... ATB(z)=P'(z)z^2? You have P(z)z^2 ... without prime?*

Response:
Indeed, this will be corrected in the manuscript

- *Page 5, line 31: multiple scattering signal instead of multiple signal? It should be written somewhere that you refer to single scattering + multiple scattering when you 'talk' about multiple scattering signals.*

Response:
Indeed, this will be corrected in the manuscript

- *Fig.4: Why do you use here the optical thickness? The blue solid line in Fig.4 should be the same as the black line in Fig.2, right? But I do not see that!*

Response:
The optical thickness is used in order to visualize the clear relation between the thickness of the cloud and the accuracy of the retrieved value of the cloud extinction.
The black line from Fig 2 presents only the retrieval of the extinction in accordance with the slope method, in the whole retrieval this method is only used to retrieve the value of alpha_0 and initiate the inversion. Therefore, the blue solid line form Figure 4 and black line from figure 2 are not the same.

- *Why is alpha in units of (m-1 sr) and not (m-1)? ... in Figs.2,4,6 (in Fig.6,both axes). Fig.4 top line ... Retrieval*

Response:
This can be changed in the reviewed version of the manuscript.

- *Fig.6 : Why did you divide the presentation into four different optical thickness classes? I think all results could be shown in ONE figure. Furthermore, more explanations and a detailed description of the dataset would be helpful. Please state in the figure caption explicitly: What is n, what is E, what is A.*

Response:
The presentation was divided into four bins of optical thickness to clearly illustrate the relation between the cloud optical extinction and optical thickness and the effect on the accuracy for different values of the cloud optical thickness. It can be presented on one plot but then this dependence will be less visible.

- *From my point of view, the only (really) new aspect presented in this paper is the so-called resolution correction presented in the Appendix A. So, the question arises: Is the Appendix the best place for this important aspect? I would include it in the main paper body. To continue, it was not easy to follow the developments in the Appendix. There are many mistakes in the middle part that need to be corrected.*
  Eq. A3: I think the whole expression should be divided by z?Eq. A4, A5 and A6: C should large.... not c?
  Eq. A6: Remove C/2, ... just B_i=1/2 (Bi,1+B_i,2) (without C)
  Page 10, Line 16: ... ratio ... instead of ... difference... , and ... illustrated....
  I do not understand: What is the impact of such assumptions (A8 and A9)? Please, provide more details.
  Eq. A8: Minus instead of plus? ...tau(z+...) – tau(z), and also ... tau(z-...) – tau(z)?
  Eq. A10: Middle term 1 – (...) ? of alpha' and then the term on the right there is one alpha instead
  Eq. A11: There is a minus 1 missing on the numerator, and also in Eq. A12

Response:
The derivation of the resolution correction was moved to the appendix to increase the readability of the paper. It is an important part of the paper but we believe that the detail derivation is better placed in the appendix. The formulas in the appendix were reviewed and corrected in the revised version of the manuscript.