Anonymous Referee #4

Minor comments:

Lines 18-20: “lidar signals suffer from the uncomplete overlap [...]. This occurs because a part of rays [...] do not pass the receiver field stop”.

This sentence literally states that field stop always acts as a field diaphragm. This is true if the optical system is properly designed otherwise any optical device all along the optical path — from the telescope to the detector— can act as a field diaphragm. I suggest clarifying this in the text.

We agree with the reviewer’s remark. We have changed the sentence to “The overlap function of a lidar system can be defined as the ratio between the power scattered by a scattering volume at a given range that reaches the photodetector (excluding transmission losses) and the power scattered by the same scattering volume that reaches the telescope aperture (Comeron et al. 2011)”

Lines 30-50:

I would suggest rewriting this paragraph to show chronologically how the advances in overlap function retrieval have been implemented from the first tries and its inconveniences to the current state-of-the-art. This may help the reader to identify the framework in which this paper arrives.

We appreciate the suggestion of the Referee. We have included additional references to different approaches to the estimation of the overlap function.

Line 224: “This formula allows one to assess the errors committed when an erroneous lidar ratio is used”.

Does the lidar ratio affect the method described in Wandinger and Ansmann, 2002? If not, would the iterative method be more convenient? I do not find a clear comparison between the iterative method and the new one.

Yes, the lidar ratio affects indeed Wandinger and Ansmann method; it also requires an estimated or measured lidar ratio and, as happens with our proposal, if there exist an error in the guess it will produce an error in the overlap profile estimation.

Although using a different, explicit (as opposed to iterative) formulation, the method presented in this paper relies on the same basis than the one by Wandinger and Ansmann and respective results are indistinguishable for a sufficient number of iterations in the iterative method. We have added a sentence in the paper stating this fact at the end of section 4:

“Although using a different, explicit, non-iterative formulation, the method presented in this paper relies on the same basis as the one given by Wandinger and Ansmann. The reader can check that, for the same measured data and assumed lidar ratio, both methods, for a sufficient number of iterations in (Wandinger and Ansmann 2002), yield indistinguishable results”

Moreover, we have added at the end of section 2 the following sentence:

“Although based on the same principles as the iterative method proposed in (Wandinger and Ansmann 2002), the formulation of Eq. (15) has the advantages of not requiring iterations (admittedly, not a decisive issue with the current computing technology) and, more important, of providing insight on the effect of the assumed aerosol lidar ratio on the retrieved overlap function (see section 3) and on the systematic error incurred when the differential aerosol transmission at the emitted and Raman wavelengths cannot be neglected (see appendix B)"

Major comments:

Line 27: "The overlap function is usually zero […] grows up to one."

I do agree with this sentence. If so, why the retrieved overlap functions in Fig. 2 and Fig. 3 are larger than 1? Indeed, their behavior is the opposite: instead of increasing from 0 to 1, they decrease from a maximum (~1.05 in Fig. 1 top) to 1.

The statement in line 27 is in fact true if the system is ideally aligned. If that is not the case, as we can conclude that happens in the cases presented in the paper, the overlap function can show more complex profiles. In particular, if the laser beam axis and the receiver axis are slightly convergent, it can rise to a maximum value and then to stabilize to a smaller constant value for far ranges. Because we take conventionally as 1 this stable value, the maximum value can be higher than one. To make this clear we have:

a) replaced throughout the paper the term "full overlap" by "stable overlap"

b) We have re-written the paragraph starting in line 27 in the original manuscript. Now it reads (lines 26-29):

"In a perfectly aligned system, the overlap function is zero at the telescope aperture level and progressively grows up to a constant value, where all the backscattered radiation collected by the telescope aperture, or at least a constant proportion of it, reaches the photodetector. In practical cases, misalignments may make the overlap function dependence on range depart from the ideal behavior just described."

b) emphasized that the stable overlap value is normalized to 1:

"We assume as well that at that range the overlap function has attained a constant value that we set conventionally to 1" (lines 80)

c) added an explanation in section 4 (lines 249ss):

"Because we have arbitrarily normalized the profile to the reference height, where the overlap function has reached a stable value, values greater than one, as shown in figs. 2 and 3, at lower ranges are possible and reveal a non-perfect alignment, in particular, a slight crossing between the laser beam and the receiver field-of-view axes, leading to a loss of energy from the far range (see for example fig 1(a) in (Kokkalis 2017) with laser tilt A_{tilt}, half-width laser beam divergence LBD and receiver field of view $RFOV$ fulfilling the conditions $A_{tilt} + LBD > RFOV$ and $A_{tilt} - LBD < RFOV$)"

Lines 124-149: Section "Influence of the lidar ratio".

This section discusses the influence of assuming the lidar ratio. However, since elastic and Raman signals are available, the lidar ratio profile can be retrieved by independently estimating the extinction and backscattering coefficients. Why is it not used? Would the noisy retrieved lidar ratio profile be worse than the assumed constant lidar ratio? I suggest comparing the overlap function obtained assuming the lidar ratio and the one obtained with the retrieved lidar ratio profile. This comparison may be performed in section 4, contributing to the discussion, and clarifying the assumption.

The lidar ratio would have to be estimated in the stable overlap region (section 3 implies that it cannot be estimated in the zone subject to the overlap correction, as explained in the paragraphs added in the conclusions section). This makes it difficult to assure that it remains constant down to the varying overlap region, which would in turn introduce an uncertainty in the overlap function retrieval. We discuss the problems associated to the estimation of the lidar ratio needed to retrieve the overlap function in lines 278ss of the conclusions:

“Section 3 also cautions against trying to derive a lidar ratio using the corrected-for-overlap signal. Actually, one could be tempted to think of the following procedure: an overlap function is retrieved using a guessed aerosol lidar ratio; with that overlap function, the Raman signal is corrected and an aerosol extinction coefficient is calculated, which, divided by the aerosol backscatter, gives a new lidar ratio, which is turn used to retrieve a new overlap function, and so on. However, Eq. **¡Error! No se encuentra el origen de la referencia.** shows that this procedure does not converge, for, if a too low lidar ratio is used as first guess, the overlap function will be enhanced in the range with aerosol; when correcting with this enhanced overlap function, the Raman signal will be suppressed, which will give rise to an aerosol extinction coefficient lower than due and, consequently to a lower new lidar ratio. A similar reasoning goes on if the guessed aerosol lidar ration is too high. The determination of the required lidar ratio from Raman inversions needs atmospheric regions with both significant aerosol load and stable overlap. However, in cases with regions where both conditions are fulfilled, using the retrieved lidar ratio for overlap estimations requires assuming that the type of aerosol is uniform down to the ground. Moreover, as seen in section 3, in aerosol loaded scenarios, errors in the lidar ratio determination yield greater errors in the estimation of the overlap profile. A more conservative approach is to stay with situations with low aerosol load at low altitudes and use the aerosol backscatter profiles derived with the Raman method (e.g. fig. **¡Error! No se encuentra el origen de la referencia.**). together with a sun- or lunar-photometer AOD measurement, and find the aerosol lidar ratio that, multiplied by the integrated aerosol backscatter coefficient would, would yield the AOD measured by the photometer. However these techniques are out of the scope of this paper, which aims only at presenting the explicit formulation of the overlap function and discussing the effect of the assumed lidar ratio on the retrieved profiles.”

Line 150-215: Section “Results”

Following my comment on Line 224, I miss a direct comparison between the new method and the iterative one (Wandinger and Ansmann, 2002). I strongly suggest including it. Are the methods equivalent?

Yes: both methods are equivalent.

There are many features to be compared: computing time

Both methods are very quick in modern computers

, cost of assuming lidar ratio versus iteration,

Both methods assume a lidar ratio value

result stability,

We have not observed any unstability in the iterative method (Wandinger and Ansmann).

possibility to obtain uncertainties,

We have performed an uncertainty analysis with the Monte Carlo method (see lines 200-)

and so on. I want to clarify that my suggestion of including this assessment is not to decide if the paper should be published or not but to provide future readers with an impartial perspective of the impact of the new method.

As stated before, we have added the sentence at the end of section 4 (lines 258ss) has been included:

"Although using a different, explicit, non-iterative formulation, the method presented in this paper relies on the same basis as the one given by Wandinger and Ansmann. The reader can check that, for the same measured data and assumed lidar ratio, both methods, for a sufficient number of iterations in (Wandinger and Ansmann 2002), yield indistinguishable results"