Comments on the manuscript: “Retrieval of aerosol backscatter, extinction, and lidar ratio from Raman lidar with optimal estimation” by A. C. Povey et al.

It was demonstrated for the first time by Shcherbakov (2007) [1], hereafter Sh07, that the quality of aerosol-profiles retrievals from Raman-lidar signals can be improved by the use of a regularized algorithm. (One should well distinguish between size distribution retrievals, which have an over forty-year history, and retrievals of extinction-, backscattering-, and lidar-ratio profiles.) Since then, several approaches were proposed [2-5], and the issue becomes slowly but surely important for lidar groups.

Another approach is proposed by Povey et al. The algorithm is based on Bayesian statistics to solve a nonlinear inverse problem (see [6], Chapter 5) and retrieve aerosol profiles from Raman-lidar signals.
The work by Povey et al. can be published in the Atmospheric Measurement Techniques. At the same time, the manuscript needs revisions.

Major comments:

1. The most important question that arises from the manuscript is why the nonlinear inverse problem is solved whereas there exists a straightforward way to a linear one? Generally, nonlinear problems are much more time consuming. The authors should discuss the advantages of their choice.

2. Page 9303, lines 21-29.
It is well known that Bayesian statistics and the technique of regularization for inverse problems are tightly connected. Moreover, Bayes’ law is frequently used as motivation for variational regularization methods of Tikhonov type (see e.g., [7-8]). Thus, the Bayesian approach doesn’t assure that a solution is always better and less smoothed compared to a solution of Tikhonov type. In my opinion, the solution quality depends first of all on agreement between used a priori information (constraints) and properties of functions to be retrieved. An approach may be interesting just due to the used a priori information. To summarize briefly, $\mathbf{S}_a$, $\mathbf{S}_\varepsilon$ and $\mathbf{x}_a$ are the most important components.

Equations (14) and (21) by Sh07 have much in common with the equations of Section 2.1 when a linear problem is considered, the state expected before the measurement $\mathbf{x}_a = \mathbf{0}$, and $\gamma \mathbf{H}^{\mathrm{T}} \mathbf{H} = \mathbf{S}_a^{-1}$.

3. Page 9309, lines 21-27.
In my personal opinion, simulations are (unconsciously) too adapted to an algorithm when aerosol layers are modeled by Gaussian peaks. There exists an excellent set of synthetic lidar signals, which were simulated with really realistic experimental and atmospheric conditions by the EARLINET community (see, e.g., [9]). The set was used in a number of works (see, e.g., [1-5]). If the authors of the manuscript are willing to demonstrate the performance of the proposed approach, they have to do that with the EARLINET’s set of synthetic lidar signals.

4. Page 9306.
Equations (10) – (11) are given without rigorous explication of employed notations. Not all used assumptions are underscored. The reference on Ansmann et al. (1992) is needed.

There are mathematical notations that are unusual for the lidar community. That make difficult to understand algorithm details even for an experienced reader. For example, why the trapezium rule (12) is used whereas Eqs. (10) – (11) are given in terms of cubic splines?

It seems to me that cubic splines are employed only with the aim to use the single axis with 33m spacing. If that is the case, Eqs. (10) – (11) should be done in terms of the paper Ansmann et al. (1992).
If the inverse problem is solved in terms of cubic-splines coefficients much more details of the algorithm must be outlined in Section 2.3.

5. Page 9305, lines 18-22.
The idea to retrieve lidar-ratio profiles instead of extinction profiles was proposed and justified by Sh07. Moreover, it constitutes the second milestone of the Sh07's algorithm. The reference on Sh07 is needed.

6. Page 9320, lines 11-16.
It is very surprising that the simulations and the applications led to the conclusion that the backscatter-extinction configuration is the most advantageous. Based on general considerations, I would expect that the log-backscatter – lidar-ratio configuration was the best one. I may suggest thorough reexamining of the matrix $\mathbf{S}_a$ that was employed as a priori information for the logarithm of backscattering.

Specific comments:

1. Page 9306, lines 3-4.
In my personal opinion, setting all negative values to zero is the worst approach to the problem of unrealistic values. It has only cosmetic effects on plots. A sophisticated approach to the problem of nonnegative values can significantly improve the quality of retrievals (see, e.g., [10]).

2. Section 2.3, the last three paragraphs.
As it was mentioned above, the matrix $\mathbf{S}_\varepsilon$ is one of the most important components of the proposed approach. Unfortunately, the work by Povey (2013) is not available online. It would be favorable for the manuscript if the authors provided a plot of diagonal elements of the matrix $\mathbf{S}_\varepsilon$ that corresponds to Fig. 14.

3. Page 9308, lines 16-18.
Please, provide the $\mathbf{x}_a$ value at some height, e.g., that one that corresponds to Fig.14. The value of the scale height is not sufficient.

4. Page 9309 and Fig. 3.
It is difficult to accept that the $\mathbf{S}_a$ matrix with box-like features that are produced by layers of unusually large aerosol concentration during a single launch could be more appropriate than a matrix $\gamma \mathbf{H}^{\mathrm{T}}\mathbf{H}$ of Tikhonov type.

According to the equation on the page 9306, $\mathbf{S}_a$ and $\mathbf{x}_a$ consist of two blocks. It would be useful for a reader to see values of the second block of $\mathbf{S}_a$ and $\mathbf{x}_a$ for the "lidar ratio configuration".

5. Page 9313, lines 19-20; and Figure 14.
Figure 14 has the pronounced striped structure. The structure is a direct consequence of retrieval/measurement errors of E_L, which are very large. That can be expected because the algorithm (10)-(11) is equivalent to the near-end solution of the lidar equation (elastic).

6. Figure 14c.
What is the meaning of the white area on the backscatter plot? There is no white color on the color-scale.

References.

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