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Interactive comment on "Averaging Bias Correction for the Future Space-borne Methane IPDA Lidar Mission MERLIN" *by* Yoann Tellier et al.

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The authors would like to express their gratitude to Anonymous Referee #3 (AR3) for the careful comments on the work they have submitted for publication and again the editor for the opportunity to improve the manuscript.

Indeed, the authors wanted the approach to be general and the article to study and suggest algorithms to minimize the bias when horizontally averaging IPDA lidar data. The MERLIN lidar mission, a CNES/DLR joint mission (not ESA), provides the variables needed for the simulation, however, the results are not only applicable to this specific mission and can be generalized to other ones. The authors agree with AR3 that it could be beneficial to revisit this treatment with real MERLIN data once the mission launched, or for other missions. Nevertheless the study is performed here with simulated LIDAR signals derived from MERLIN mission parameters.

The use of a combined approach where the signals are averaged first before performing an averaging of DAOD or column mixing ratios does not seem to be the best method according to this study. The main reason why first averaging signals as much as possible is preferable is that the statistical bias correction for column averaging relies on the estimations of the on-line and off-line SNRs that are not perfect. When averaging signals, the SNR are averaged so that the variability is reduced and the statistical bias correction is better estimated. The simplified simulation performed on the three scenes shows that type 2 geophysical bias (due to the linearization of DAOD variations and the correlation of signal and transmission fluctuations) is very well estimated when the number of averaged shots is sufficient. A second reason not to perform a combined averaging scheme is that the averaging of signals produces an average XCH4 that is weighted by the off-line signal strength and thus take into account the relative information contained in each single signal. However, averaging DAOD or mixing ratios assigns uniform weights to each DAOD or column mixing ratio. Combining the two approaches would lead to a mixed weighting average XCH4 which can be confusing except if great care is taken when defining and using the respective weights.

As mentioned by AR3, “It is not obvious to me how or if the skewed distribution implies a bias.” And indeed, a skewed distribution does not imply a bias (a PDF can be skewed and have zero bias). The reference to the skewness of the DAOD distribution when the signals are normally distributed is misleading in the manuscript. Such a DAOD distribution is generally biased and skewed but the important point that should have been highlighted is the bias of the distribution not its skewness. Therefore, all reference to the skewness of the DAOD distribution in the revised manuscript will be cautiously reviewed and highlights will be put on bias aspects.

As suggested, the manuscript will be revised to clarify what is meant by the negative signal values. First the term “signal” can bring confusion and will be replaced by the term “calibrated signal” in the revised manuscript. The calibrated signal values can come to be negative as a treatment is performed to remove the background light power from the noisy measured signals. When we choose to filter out the negative calibrated signal values, as suggested by reviewer AR3, we deliberately chose to ignore the values that fall below the estimated background level even though they do convey information about the methane content of the column. Thus a positive bias appears due to the filtering process. By taking into account the filtering process (and general assumptions about the signal distribution) it is possible to correct this bias by introducing the truncated Gaussian distribution. The revised manuscript will develop some additional explanation about the bias produced by the filtering process.

In the typical conditions, the laser speckle is not the dominant source of the statistical fluctuation. The normality of the calibrated signal distributions is justified by real measurements (out of the scope of the article) and also by theory, since for the high number of photons (dark + signal approx. 1000) within the signal the Poisson statistics approximates (a shifted) Gaussian distribution already very well (central limit theorem). And the electronic part is also Gaussian because it is mainly thermal noise. The authors will add details in the article to precise the physical nature of the noise.

Clouds in the field of view have not been treated in the article as the goal was to explore and derive best algorithmic approaches to horizontally average with the least bias possible. The authors agree that the presence of opaque clouds can lead to a biased measurement as the contribution of hidden layers under the cloud would not be sounded by the instrument. Therefore, he processing chain of MERLIN mission includes a flagging protocol to separate between signals with or without opaque clouds. Two averaged XCH4 should be provided (clear-sky shots only and all shots). Concerning non-opaque clouds, as they would equally attenuate the off-line and on-line signals, they would only decrease the SNR but would not affect the measurement otherwise.

In addition to the modifications presented above, the authors will deal with minor comments (spelling errors).

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