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Atmospheric Measurement Techniques Discussions

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 first like to express their gratitude to reviewer #1 for the careful comments on the work they have submitted for publication and the editor for the opportunity to improve the manuscript.

The actual aim of this article is not to describe and discuss the root cause of the noise of MERLIN system and the normality of the signal distributions, but rather to present and assess the biases that are produced by the averaging algorithms under the assumption of normal signal distribution (Qon,off). This assumption is not a rough approximation like it is often done, when one does not know better. It 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 propose to add details in the article to precise the physical nature of the noise and justify the gaussian distribution approximation.

A confusion could arise from an unclear definition of what authors call "signals". Qon and Qoff are called on-line and off-line signals in the article though they are not raw lidar signals (photo-electron count) measured by the detector. They are derived quantities from the backscattered signal (strictly positive count of photo-electrons by the detector). The received raw signals are the sum of the lidar signal and a background signal which is produced by background light, detector dark current and electronic offset. The computation of Qon and Qoff quantities from the raw signal includes an estimation of the energy of the backscatter signal and of the background signal. A subtraction of the background signal is then preformed which can lead to a negative value for Qon and Qoff (usually only Qon) for a very low target reflectivity. In the case where Qon is negative, it does not mean that no information is conveyed by the measurement but rather that the it is inaccessible due to the relatively high level of noise. Therefore, following the remarks of the reviewer #1, we propose to rename these quantities "calibrated signals" in the manuscript.

The fact that the manuscript highlights the mathematical aspects of bias correction algorithms is intended to insist on the generality of the approach. Their validity is then verified on the MERLIN system. The real noise parameters of MERLIN system used to simulate calibrated signals are taken into account via the simplified parametric equation giving the SNR from the reflectivity. The parameterization is deduced from instrumental characteristics and is provided by the sub-contractor (ASG) in charge of the development of the payload. The set of assumptions leading to this equation have not been detailed in the article though it could be interesting to explain it in appendix to the article. Figure 9 specifically shows this dependence of the on-line and off-line SNR to the reflectivity. The SNR distributions used in the article are then indeed based on the real MERLIN characteristics. A sentence will be added to the article to make this fact clear. An appendix detailing the assumptions to derive the SNR from the reflectivity will be added. Furthermore, the detector noise being predominant, the successive measurements Qon and Qoff can be considered as independent.

Concerning the reference to Werle et al. (1993), there is indeed no justification of the statement that the bias caused by real system drift is negligible compared to averaging processing biases. Thus, this statement will be removed from the final version of manuscript. Anyway, real system drift is out of the scope of this article. This digression is introduced to clarify the position of the article so that no confusion is possible when the term "bias" is used.

Reviewer #1: "I may be missing the point here but I fail to understand how a higher threshold of usable signal before the computation of the DAOD could mitigate the fact that the Taylor bias correction does not succeed in quantifying the bias on any of the four mean reflectivity values. That is equivalent of excluding low SNR cases, which may be valid for data quality control, but does not mitigate the fact that the approach does not succeed in those cases." In fact, when the threshold is set to be zero – which is the lowest mathematically possible value – we allow values down to this limit. A sample of Qon (hence SNRon estimate) that comes close to it would generate a large negative spike (1/SNRon^2) dominating all other values in the ensemble. Consequently, by choosing a higher threshold (strictly positive), we exclude the lower SNR cases and reach a better estimate of the bias for the remaining values. However, as noted by reviewer #1, when the SNR is low, the AVX and AVC methods does not succeed in estimating the XCH4 within the error specifications.

Furthermore, a table will be added to the appendix to show the results obtained by averaging quotients in order to quantify the bad performance of this scheme. A sentence will be added to clarify the distinction between DIAL and IPDA techniques. To avoid any confusion between bias and skewness, the expression "but skewed" will be

replaced by the expression "and present a bias" in the legend of Figure 3.

In addition to the modifications presented above, the authors will deal with minor comments as unclear syntax, grammar and spelling errors, numbering of figures, reference to relevant sources, broken links and numerical approximation consistency.

An updated version of the manuscript will soon be published following this response.

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