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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.

Anonymous Referee #1

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Overall Comments: The paper is in principle very interesting and tackles an important issue: how to best average IPDA lidar signals to reduce biases. The authors present several averaging schemes and evaluate the merits of each technique for the MERLIN mission. They take great care to use real data sets for latitude, longitude, altitude, surface pressure, relative reflectivity and meteorological data. However, their lidar analysis does not seem to be based on any real MERLIN parameters (e.g. laser power, detector noise, shot noise, etc). Instead, the authors seem to treat the lidar signals as purely mathematical quantities that can even take negative values. No real SNR and subsequent error or bias analysis based on the real MERLIN instrument is presented. The analyses by Ehret and Kimmel treat the errors correctly and relate them to physical quantities. Those papers could serve as a good guide. A key issue in their analysis

is "measurement noise". In fact, the statistical bias induced by measurement noise is central to the analysis. However, that measurement noise is never defined and its characteristics are never described. Is it shot noise? Detector noise? Or some other "measurement" noise? Is it always purely a Gaussian, or a Poisson or some other distribution? What is the source of the "measurement noise"? These assumptions and questions are central to their analysis but are not well defined.

In summary, it is difficult to agree with their conclusions given their purely mathematical approach. I would suggest they revise the paper and apply their analysis starting with the error analysis already presented by Ehret and Kimmel.

Abstract: This article discusses how to process horizontal averaging in order to avoid the bias caused by the non-linearity of the measurement equation with measurements affected by random noise and horizontal geophysical variability. This sentence is a bit confusing. Did the authors mean: This article discusses how to process this horizontal averaging in order to avoid the bias caused by the non-linearity of the measurement equation and measurements affected by random noise and horizontal geophysical variability?

To be precise: 0.07% of 1780 ppb is 1.25 ppb (see similar comment below)

Introduction: This technique relies on the Differential Absorption Lidar (DIAL) measurements of a space-borne laser. This sentence is somewhat redundant considering the previous sentence: "…based on an Integrated Path Differential Absorption (IPDA) lidar. If the authors wish to make a distinction between IPDA and DIAL or further explain the technique then I suggest they should do so.

Figure 2 is mentioned before Figure 1

I believe operational analyzes should be operational analyses (plural of the noun). Analyze (British spelling) is the verb.

ASCENDS mission (NASA carbon dioxide IPDA lidar mission) – the appropriate reference listed in the references is needed. In addition, I believe it is best to define acronyms fully the first time they are used.

The former bias being negligible compared to the latter. If I interpreted this statement correctly then the authors argue that: "…biases caused by real system drift…" are negligible compared to biases that are caused by the non-linearity of the IPDA lidar measurement equation. Is this justified by any experimental (or theoretical) evidence of the biases caused by real (MERLIN) system drift? I do not see how this statement is supported by any evidence. In fact, the reference cited earlier in the paragraph (Werle 1993) actually discussed biases caused by real system drifts.

1% of 1780ppb is 17.8 ppb and 0.2% is 3.6 ppb. I understand the authors round up or down but they just need to be consistent.

Given the statement: the single shot on-line and off-line random error is reduced by a factor of sqrt(150)$\sim$12, I don't quite understand the example the authors gave: For instance, for the typical reflectivity (0.1), the on-line and off-line signal to noise ratios are of the order of 7 and 16 respectively (resp.) and the equivalent SNRs for the averaged signals are resp. 78 and 192. But sqrt(150)*7 =86 and sqrt(150)*16=196 not 78 and 192.

This process greatly decrease the RRE should be: This process greatly decreases the RRE

Overview of IPDA equations and the MERLIN processing chain vmr looks like vnr after eq. (3) in my pdf copy

Averaging schemes and bias correction: a theoretical approach The expected value of an random variable should be: The expected value of a random variable

vmr looks like vnr in my pdf copy

…then derived from the pressure at every levels should be:…then derived from the pressure at every level.

I really do not understand the argument: Figure 3 illustrates the statistical bias, when on-line and off-line signals follow normal distributions. It highlights that, in this case, the DAOD derived from these signals is no longer normally distributed but skewed. First, I do not understand how Qon can be negative. Then even though I agree that the ratio of two normal distributions can produce a skewed distribution but that does not equate with bias. The DAOD could be skewed but have zero bias.

This sentence needs to be rewritten. It is confusing and not at all clear what the authors are trying to say: Consequently, this scheme is more sensitive to the less noisy measurements which, on the one hand, implies that the variance of average quantities is lower but, on the other hand, a correlation between methane concentration and reflectivity implies a bias.

Link missing: (cf. Appendix Erreur ! Source du renvoi introuvable.).

This scheme gives very bad performances should be: This scheme gives very bad performance.

The fourth scheme AVQ is dismissed because it "gives very bad performance". It would have been much better to show the bad performance otherwise we just have to trust the authors.

The total noise contributions affecting off-line and on-line signals are statistically independent. Are they statistically independent? How do we know that? Can they be correlated if they have the same source? Does that change the results?

Furthermore, due to the relatively high number of photons in a single pulse, we can assume that these random variables are normally distributed around a mean value. There was no mention about the actual number of photons in a single pulse prior to this statement so we do not actually know how many photons are in the signals, Q. If we are photon (shot) noise limited the distribution should be Poisson not normal. Also, in the cases where the SNR is low (i.e. "the relatively high number of photons" is low) does the randomness assumption still hold?

I fail to understand how either one or both lidar signals can take negative values. What does it physically mean for a lidar return signal to be negative? If the signal is completely absorbed or is very low (because of clouds or low reflectivity) then it can be zero but not negative.

I do not agree with the statement: This can actually happen as Qon,off correspond to the photon count from which the background has been subtracted. I do not agree that this explains “negative” signals! It means there is no signal and all we have is background noise (could be solar background or detector noise). That does not make the lidar signal negative!

Methodology to test averaging algorithms and their bias corrections How are the on-line and off-line signals computed purely from surface reflectivity and a random noise simulation? What assumptions were made for laser power, field of view, detector NEP etc etc.? Figure 8 fails to illuminate how Qon and Qoff are computed.

Figure 9 shows the theoretical dependence of the SNR to the reflectivity according to instrument characteristics (assumptions) but those characteristics are never listed.

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.

Figures Figure 1: On every averaging window, geophysical parameters altitude (or scattering surface elevation when there are clouds) or reflectivity vary. Should be: On every averaging window, geophysical parameters such as altitude (or scattering surface elevation when there are clouds) and reflectivity vary.

Figure 3: A significant part of on-line signals (orange) is negative – I do not understand how a signal can be negative. What part of Eq.(1) is negative for Qon? I could be missing something but it is not clear.

Table 1: Link error: Statistical bias due to measurement noise mixed with geophysical biases into the non-linear equation (cf. Appendix Erreur ! Source durenvoi introuvable.)

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