Answer to Anonymous Referee #1

Thank you for your positive evaluation of our preprint and the helpful comments. Below we address your individual comments and describe the corresponding changes to the revised manuscript version. For the sake of clarity our answers are given in bold.

GENERAL REMARKS

The manuscript presents an exhaustive description of a novel four-wavelength photoacoustic aerosol absorption spectrometer, together with the results of carefully conducted assessment studies of instrument performance. The instrument evaluation is completed by an instrument intercomparison study with filter-based light absorption measurement instruments at a rural background station in Finland. The assessment reports method-characteristic parameters like limit of detection, precision, and accuracy. The study is carefully designed and performed. The presentation of the results is well structured and clear. The manuscript fits well into the scope of the journal and can be accepted for publication, after few technical corrections have been implemented.

SPECIFIC COMMENTS

The only point which may call for clarification is the use of the term “ultimate detection limit”. In the manuscript this term is used together with “detection limit”. The authors may want to clarify whether the two terms are used synonymously or have a different meaning.

The terms “ultimate detection limit” and “detection limit” have different meanings here. We use the former in context of the Allan deviation analysis shown in Fig. 5, where the “ultimate detection limit” is defined by the minimum 1-σ deviation of < 0.1 1/Mm that is observed before the drift stability of the instrument increases the deviation for averaging times longer than 1000 to 3000 seconds. Although the “ultimate detection limit” is a characteristic of the instrument, it is of little practical use, as also mentioned by Fischer and Smith (2018).

A more accurate indicator is the “(practical) detection limit”, which is defined by the actual time sequence of particle-filtered background measurements taken under real operational conditions. This approach provides a more realistic understanding of how the PAAS-4λ measurements are affected in long-term monitoring applications. For the long-term field measurements presented in the manuscript, background measurements are taken every 30 minutes with an averaging time of 1 minute per laser. Analyzing the particle-filtered laboratory data for such a measurement sequence in Fig. 6 gives a 1-σ

detection limit of 0.4 1/Mm in a good accordance with the 60s averaging result from the Allan analysis (Fig. 5).

We changed Fig. 5 and its caption to clarify the terms "Ultimate Detection Limit" and "Practical Detection Limit". In the manuscript, the latter term is used synonymously with "Detection Limit".

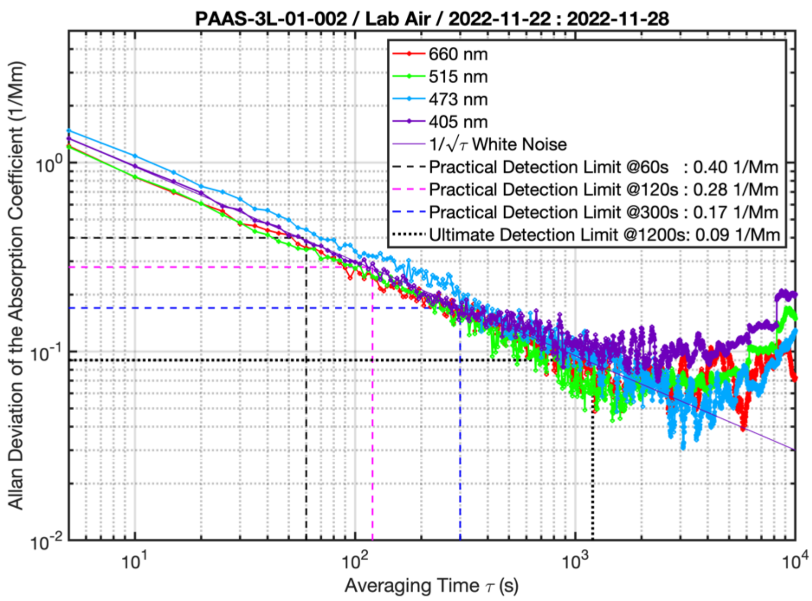


Figure 5. Allan deviation analysis of a 40h background measurement. The instrument sampled particle-filtered laboratory air with a basic averaging time of 5 s per laser wavelength. A white noise characteristic slope is plotted for the 405 nm wavelength (thin purple line). Signal drift starts between 1000 to 3000 s averaging time resulting in an ultimate detection limit of less than 0.1 Mm^{-1} for these averaging times. More practical detection limits for averaging times of 60 s, 120 s, and 300 s are indicated by black, magenta, and blue dashed lines, respectively.

The following minor issues are mostly suggestion for rephrasing for the sake of more clarity or readability.

MINOR ISSUES

Line 15: The expression "measured across the filter thickness" may be replaced by "measured by light transmission through the filter.

Changed as suggested.

Line 29: Replace "for a several years data set" by "based on a multi-year data set".

Changed as suggested.

Line 43: References might be added for the use of the AAE to separate biomass burning aerosol (Sandradewi et al., 2008; Kirchstetter et al., 2004) and dust (Petzold et al., 2009) from fossil fuel combustion aerosol.

Added as suggested.

Line 75: The description of the photoacoustic process reads like it works only for externally mixed particles. Suggestion for rephrasing: "in an aerosol containing light-absorbing particulate matter compounds".

Changed as suggested.

Line 93: Suggestion "are presented in more detail".

Changed as suggested.

Line 110: Beam ellipticity might be reported as digits with similar decimal places, i.e., 1.1:1.0.

Changed as suggested.

Line 220: Rephrase: "measured prior to …"

Rephrased to: "Therefore, each laser unit's emission spectrum is evaluated using a compact Czerny-Turner CCD spectrometer (CCS100/M, Thorlabs Inc., USA) with a spectral accuracy better than 0.5 nm within the 350 nm to 700 nm spectral range, before being installed into PAAS-4λ."

Line 299: Shouldn't it read. "… the same procedure is applied to …"?

Changed as suggested.

Line 323: Suggestion: "… sample from a main inlet …"

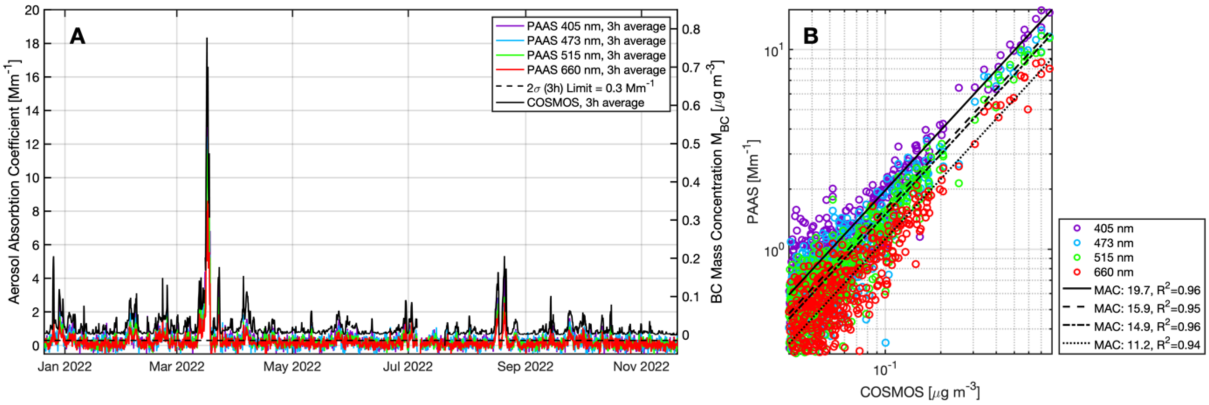
Changed as suggested.

Line 340: Please correct: "…long data gaps … rather result from …".

Corrected.

Figure 10: Plotting the y-axis with a log scale might better show the good data agreement at the low b_abs values.

We investigated this suggestion and concluded that plotting graph A of Fig. 10 with logarithmic y-axis does not improve the visibility of the data agreement. However, we found that plotting graph B on double logarithmic scale does improve the visibility of the data agreement. Fig. 10 will be changed accordingly in the revised manuscript.



Section 5: This section presents more a summary than conclusions. It should be modified or the section header should be adjusted.

Changed to "Summary"

Reference list: Most of the journals are given with their full names, but some are referred to with abbreviations. Then, some of the journal names start with capital letters, others don't. This should be made consistent.

The reference list will be made consistent in the revised manuscript.

References

Kirchstetter, T. W., Novakov, T., and Hobbs, P. V.: Evidence that the spectral dependence of light absorption by aerosols is affected by organic carbon, Journal of Geophysical Research, 109, D21208, 10.1029/2004JD004999, 2004.

Petzold, A., Rasp, K., Weinzierl, B., Esselborn, M., Hamburger, T., Dörnbrack, A., Kandler, K., Schütz, L., Knippertz, P., Fiebig, M., and Virkkula, A.: Saharan dust refractive index and optical properties from aircraft-based observations during SAMUM 2006, Tellus Series B-Chemical and Physical Meteorology, 61, 118–130, 10.1111/j.1600-0889.2008.00383.x, 2009.

Sandradewi, J., Prevot, A. S. H., Weingartner, E., Schmidhauser, R., Gysel, M., and Baltensperger, U.: A study of wood burning and traffic aerosols in an Alpine valley using a multi-wavelength Aethalometer, Atmospheric Environment, 42, 101-112, 10.1016/j.atmosenv.2007.09.034, 2008.