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Atmospheric Measurement Techniques Discussions

Interactive comment on "Intercomparison of MAX-DOAS Vertical Profile Retrieval Algorithms: Studies using Synthetic Data" *by* Udo Frieß et al.

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We thank Referee #2 for his thoughtful and positive comments, as well as the careful proofreading. We reply to the individual comments point by point, with the original comments shown in *italic*, our replies in roman, and changes to the manuscript in **bold**.

Page 1, line 12 - Here, or in the main text (e.g., pages 35-36), provide some context for these RMS differences. Are these numbers negligible or significant? How do they compare to typical absolute values?

It is indeed useful to bring the deviations into relation with typical atmospheric values - although these can be very variable. The respective statement in the conclusions

has been replaced with: **Both OEM and parametrised algorithms, and also the analytic approach by NASA, show equally good performance in terms of the reproduction of the true atmospheric state, with a typical accuracy (in terms of RMS difference between true and retrieved state) of $(0.08 - 0.25)$ km^{-1} for surface aerosol extinction, and $(5.9 - 15.0) \cdot 10^{10}$ molec/cm^3 (or about 2.4 - 6 ppb) for HCHO and NO_2 surface concentrations. These deviations, and also a potential positive bias towards the a priori for OEM algorithms, can be quite significant for clean air conditions, but are relatively small in polluted areas where several tens of ppb of NO_2 and HCHO, and aerosol extinction of up to 5 km^{-1} can be present (e.g., Vlemmix et al., 2015). Total columns of trace gases can be retrieved with a higher accuracy than for aerosols, with slopes > 0.85 and correlation coefficients > 0.95 in most cases. However, the accuracy is expected to be higher for real atmospheric measurements (e.g. ?), since some of the scenarios within this study are quite arbitrary with the intention to test the algorithms under extreme conditions.**

The multi-panel figures include a lot of information, but it is difficult to read some of the text (e.g., the numbers in the panels of Figures 5-7) and to distinguish some of the features discussed in the text. I suggest looking at all of the multi-panel figures and enlarging text or making other revisions where possible to make them clearer and more easily readable.

Figures 5-8, and 11-14 indeed contain a lot of information, but we are convinced that it is important to show the averaging kernels and vertical profiles for each of the aerosol and trace gas scenarios in order to give the reader an impression of the performance of the algorithms under different atmospheric conditions. In order to improve the readability, we have made the following modifications to the figures: (1) Increase of font size for the degrees of freedom for signal in Figures 5-8; (2) Increase of font size for the RMS in Figures 11-14; (3) Larger legends in Figures 11-14, now moved to the top of the figures.

Page 1, line 11 - root mean square (not squares)

Done (here and anywhere else)

Page 1, line 12 - between THE true...

Done

Page 1, line 16 - emissions. Monitoring

Done

Page 2, line 19 - here and elsewhere, hyphenate "state-of-the-art"

Done

Page 2, line 23 - straightforward

Done

Page 3, line 7, 24, 24, etc. - Here and for all equations, include punctuation - add periods to equations where relevant.

Our impression is that it is rather unusual to add a period at the end of a single-line equation even if the sentence ends there, as this would cause an ambiguity as that the period might be interpreted as part of the equation.

Page 3, line 15 - define variables s and rho in Eqn 3

The following sentence has been added: **Here, ρ is the number density of the trace gas and s parametrises the light path length through the atmosphere.**

Page 4, line 8 - DOFS is more commonly used than DFS for Degrees Of Freedom for Signal

To our knowledge, both DOFS and DFS are used in the literature as abbreviation for the degrees of freedom for signal. For the sake of consistency, we would rather prefer to use DFS since this is the term that has been used by the main author in the past

(Frieß et al., 2006, 2011, 2016).

Page 4, line 20 - well-established

Done

Page 4, line 22 - should AVL be AVK?

Yes, this has been corrected

Page 5, Figure 1 - Should rightmost green box say "Reference dataset for dSCDs" rather than SCDs? Line 12 says that the dSCDs are the reference dataset.

This is correct, **SCDs** has been replaced with **dSCDs** in Figure 1.

Page 5, line 15 - reorder as: This dataset is referred to below as the ...

Done

Page 6, Table 1 - All acronyms should be defined here or in the text.

All acronyms for institutes, retrieval algorithms and RTMs are now defined in the description of the algorithms (Sections 3.1 - 3.8)

Page 7, line 22 and page 10, line 10 - a-priori is hyphenated here but nowhere else

The hyphen has been removed

Page 7, line 29 - grid points, (add comma) ... layer, which IS considered ...

Done

Page 8, line 23 - define MMF (it's not defined anywhere - also check that all acronyms are defined throughout)

See the reply to your comment above. In addition, a reference to the recently published AMTD paper describing MMF algorithm has been added.

Page 9, line 16 - and second, (add comma)

Done

Page 9, line 18,19 - move definition of (RAA) immediately after "relative azimuth angles"

Done

Page 9, line 28,29 - allows the uncertainty of the resulting profiles to be determined.

Done

Page 10, line 3 - quantify what "level of agreement" is used in flagging data

The agreement between forward modeled and measured dSCDs is judged based on the dSCD error. Details can be found in Beirle et al. (2018). The description of the MAPA algorithm has been modified as follows: **Flagging is based on different criteria: (1) The level of agreement between forward model and measurement as compared to the dSCD error (for details see Beirle et al., 2018), ...**

Page 10, line 12 - (2011, 2015a)

Done

Page 10, line 19 - a-posteriori is hyphenated here but nowhere else

The hyphen has been removed

Page 10, line 26 - algorithm WAS developed ...

Done

Page 11, line 14 - atmospheric radiative transfer models

Done

Page 11, line 19 - for the forward MODELLING than ...

Done

Page 11, line 31 - during THE CINDI-2 ...

Done

Page 12, Figure 2 - Add a reference in the figure caption to Tables 2 and 3 for definitions of the profiles indicated in the legends.

The following sentence has been added to the caption of Figure 2: **The properties of the individual profiles are described in Tables 2 and 3.**

Page 14, line 1 - Table 5. RTM parameterS for ...

Done

Page 14, line 7 - serve as A reference

Done

Page 14, line 13 - as THE forward

Done

Page 14, line 14 - in THE case

Done

Page 14, line 19 - "some of" or "a portion of" rather than "parts of" ?

Replaced with **some of**

Page 14, line 20 - representationS

Done

Page 15, Figure 3 - Add more tick marks to the horizontal axes.

The number of x-axis ticks has been increased in Figure 3

Page 16, Figure 4 caption - root mean square (no S) ... correlation BETWEEN the ...

compared to the medianS from ...

This sentence has been replaced with **Slope, intercept, regression coefficient and root mean square difference (RMS) of the correlation between the SCDs from the individual forward models and the median SCDs from all models.**

Page 17, line 9 - similar magnitude to the

We feel that the preposition "as" is more appropriate here.

Page 17, line 14 - trace gas profileS

Done

Page 17, line 15 - azimuth angleS

Done

Page 17, line 22 - interpolated onTO the

Done

Page 19,20 Figure 7 and 8 captions - Same as Figure 5 ...

Done

Page 21, line 5 - RMS has already been defined - delete "root mean squares difference"

Done

Page 21, line 7 - problems retrievING the

Done

Page 23, line 2 - in THE case of

Done

Page 27, line 4,5 - requires, however, excludING

Done

Page 28, line 12 - values FOR altitudes

Done

Page 28, line 30 - as is the case (delete "it")

Done

Page 28, line 31 - prevents THE retrievAL of negative

Done

Page 28, line 33 - in THE case of

Done

Page 29, Figure 16 - The label on the top of the left column says "AOD" but the caption refers to "AOT". Choose and use one consistently throughout.

We intend to use AOT throughout the paper since the term 'density' usually refers to an intensive variable, but AOT is an extensive quantity. **AOD** has been replaced with **AOT** in Figure 16.

Page 29, Figure 16, last line of caption - all data ARE shown

Done

Page 30, Figure 17 caption - not correct to say this is the same as Figure 16. This uses the TG profiles, while Figure 16 uses the AER profiles. Revise.

The legend has been replaced with **Box-whisker plots of the retrieved HCHO (left) and NO_2 (right) VCD for the different trace gas scenarios (rows) and retrieval algorithms (columns) based on retrievals using noisy dSCDs. Crosses show the mean, dashed horizontal lines the median. Shaded areas indicate the (25% -75%) percentile, whiskers the (5% - 95%) percentile. The true VCD is shown as blue**

vertical line. For each algorithm, all data is shown on the left in black, and data marked as valid on the right in green. Also shown is the percentage of valid data. The median for each aerosol scenario is shown as coloured symbol as indicated in the legend.

Page 30, line 2 - high-altitude cloud

Done

Page 32, Figure 19, last line of caption - all data ARE shown

Done

Page 35, line 6 - algorithm, MAPA. (add comma)

Done

Page 36, line 10 - have showN that bePRO generally performs well with ...

Done

Page 36, line 20 - which is particularLY the case

Done

Page 37, line 4 - median dSCDs (add s) . . . ARE available

Done

Page 37, line 5 - THEY can serve as

Done

Page 37, line 7 - delete definition of CINDI-2 as it was defined on page 10

Done

Page 37, line 10 - available on REQUEST. (what about the availability of the other algorithms?)

This has been corrected. The other algorithms are not (yet) readily available.

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