

Comment on amt-2021-274

Anonymous Referee #2

Referee comment on "Enhancing MAX-DOAS atmospheric state retrievals by multispectral polarimetry – studies using synthetic data" by Jan-Lukas Tirpitz et al., Atmos. Meas. Tech. Discuss., <https://doi.org/10.5194/amt-2021-274-RC1>, 2021

General comments

Tirpitz et. al 2021 present an extensive and interesting study on possible improvements of aerosol and trace gas parameter retrievals from ground-based MAX-DOAS measurements when multispectral polarimetry data is included. A novel approach is shown to retrieve aerosol microphysical properties from MAX-DOAS measurements. Clear advantages for the retrieval of aerosol parameters were found!

The results are promising and aim at the general lack of knowledge of an accurate aerosol characterization when ancillary data sets are not available. However, the advantages for the retrieval of trace gas vertical profiles are either small or not existing showing a clear benefit for aerosols only. This analysis was made on synthetic data leaving it open if the approach will also show clear advantages for measured data and unfavorable conditions as temporal and spatial inhomogeneities and larger measurement uncertainties. These points have been discussed shortly but a second study including validation data sets would be interesting to assess the actual importance for the community.

This paper is well written, the figures are presented in a clear and structured way and the analyses have been performed thoroughly and consistently. Therefore, I suggest publication in AMT but please consider some minor comments:

Specific comments

P1, L2: "analysis ultra-violet") "analysis of ultra-violet"

P1, L7 & L8: "measurement") "measurements"

P1, L12: "retrieval aerosol") "retrieval of aerosol"

P8, L234: The aim of inverse model) inverse modeling

Table 1: Since 360nm and 477nm are used to cover the O₄ absorption and 343nm and 460nm are more or less central wavelengths for HCHO and NO₂ respectively, I was wondering why did you use 415nm and 532nm? What is the benefit and how would the neglect of these wavelengths deteriorate the results?

P13, L337: Why did you decide for an exponential grid? Most retrieval algorithms use an equidistant spacing in all retrieval altitudes.

P17, L401: DOFS in table S2 are larger so I would write larger instead of smaller here.

Table 6: I was wondering if e.g. the UV only mode means that for the trace gases only one wavelength is used but for aerosols both? If yes, how large is the DOFS for individual parameters of aerosols at different O4 absorption bands? I would assume that the aerosol information content of the absorption band at 343nm is extremely small and the benefit of including this wavelength is insignificant.

Fig. 3: What do the thick vertical lines mean? Please add also rows for Vis. Why do trace gases show double peaks for Multi-S-P-A and Multi-S-P-A-I? Do we see different results for HCHO and NO2 here? Please discuss!

Fig. 4: This is the first time you show box-whisker plots. Please give a short explanation in the caption of this figure.

P21, L444-L445: Could you please explain more about where the sensitivity for the surface albedo comes from? You do not look to the surface so photons must be scattered into line of sight mainly due to multiple scattering. Would a negative elevation angle increase the sensitivity?

Fig. 9 and 10: It would be interesting to compare with what the normal uv and vis mode would retrieve since this is what the community is mostly doing. Could you please add this as well or are results similar to UV-S? Could you please change the noiseless lines in a different way? It is hard to identify them. What does the shaded area around the a priori mean? The caption indicates that this is the uncertainty of a priori? I thought one fix a priori is used? Please explain!

Fig. 11: I am surprised by the VCD results. In general, common MAX-DOAS profiling algorithms perform strongly for integrated quantities but might have larger deviations for certain profile features. If possible, please add a discussion and maybe another column to Table 6 for VCDs.

Section 11: This section is interesting but I would assume even larger uncertainties for real data. Especially when thinking about measurements of elevation scans at different azimuthal directions and subsequent Almucantar scans, temporal changes in the atmospheric composition might vary strongly. Which part of Kreher et al. 2020 supports 5% and why do you assume that this is enough based on the study of synthetic data by Frieß et al. 2019?

Fig. S14: Please change color and name of "Multi-S-P-A-I" mode in legend. And add the description of random noise magnitudes for the x-axis in the caption.

Table 7: Please add another column and discussion of the data presented in section 11 for 6% because this analysis is most likely closest to real measurements.

References

Frieß, Udo, Steffen Beirle, Leonardo Alvarado Bonilla, Tim B^osch, Martina M. Friedrich, Francois Hendrick, Ankie Piters, u. a. "Intercomparison of MAX-DOAS Vertical Profile Retrieval Algorithms: Studies Using Synthetic Data". Atmospheric Measurement Techniques 12, Nr. 4 (10. April 2019): 2155-2181. <https://doi.org/10/ghx39n>.

Kreher, Karin, Michel Van Roozendaal, Francois Hendrick, Arnoud Apituley, Ermioni Dimitropoulou, Udo Frieß, Andreas Richter, u. a. "Intercomparison of NO2, O4, O3 and HCHO Slant Column Measurements by MAX-DOAS and Zenith-Sky UV-Visible Spectrometers during CINDI-2". Atmospheric Measurement Techniques 13, Nr. 5 (6. Mai 2020): 2169-2208. <https://doi.org/10/gm4xsg>.