Atmospheric Chemistry and Physics Discussions

Atmos. Chem. Phys. Discuss., referee comment RC2
https://doi.org/10.5194/acp-2021-45-RC2, 2021

Comment on acp-2021-45

Anonymous Referee #2

Referee comment on "Technical note: Evaluation of profile retrievals of aerosols and trace gases for MAX-DOAS measurements under different aerosol scenarios based on radiative transfer simulations" by Xin Tian et al., Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2021-45-RC2, 2021

Review of "Technical noteï¼□Evaluation of profile retrievals of aerosols and trace gases for MAX-DOAS measurements under different aerosol scenarios based on radiative transfer simulations" by Tian et al.

In this manuscript, the authors report on an extensive sensitivity study on MAX-DOAS retrievals of aerosol and NO2 profiles. The study is based on synthetic slant columns derived by radiative transfer modelling and the inversion by the two retrieval models PRIAM and MAPA.

The study set-up is straight forward and clear and follows good practice of earlier studies on the same topic. Both retrieval codes have been evaluated by similar studies before, the main difference being the inclusion of high AOD cases and variation of aerosol parameters here.

The topic covered is relevant for ACP but would have been a better match for AMT. The study is well designed and executed, and the results are of interest to anyone using MAX-DOAS retrievals under high aerosol conditions, in particular for PRIAM and MAPA users. I therefore suggest publication after revisions as suggested below.

Major comments

1) My main criticism of this study is that it shows literally hundreds of figures without coming to clear conclusions. This is not the first study of its kind, so the main question is: What are new and interesting results of this study not yet published elsewhere, and how can these new results be understood?

From what I understood, the main results are:

- Aerosol parameters SSA and asymmetry factor are not as critical as one may have thought for the aerosol retrieval
- Changing the covariance matrix changes the results of the OE retrieval as it results in different weighting of a priori and measurements in the inversion
- NO2 profiles are not very sensitive to the aerosol profiles used
- AOD is systematically underestimated by MAX-DOAS retrievals
- Low NO2 columns are overestimated, high NO2 columns are underestimated

The first four points have already been discussed in the literature before but maybe not with this level of detail. The last one is new to me and would deserve more discussion as it is unexpected and surprising. What could be the reason for such a behaviour?

2) As this study is on synthetic data which are necessarily idealized in many ways, the question is: Which of these results are of relevance for real MAX-DOAS measurements? Are there any take-home messages for people working on MAX-DOAS profiles? What is specific to the two inversion codes used, what is fundamental to MAX-DOAS retrievals?

3) In general, I think a section on comparison of the results found here with what was reported in earlier studies should be added.

4) Something I could not find in this manuscript is information on the uncertainties assumed for the slant columns. I assume that no noise was added to the results from the RTM but still the retrievals must have made an assumption on the uncertainties. This is an important point which needs to be added to the manuscript as it can have a large impact on the results.

5) Another information I'm missing is what the atmosphere in the forward simulations looked like above 4 km. Was there any NO2 or aerosol present at higher altitudes as well?

6) Throughout the manuscript, results are shown for two wavelengths, but there is no discussion whatsoever of similarities and differences between these results. If there is no discussion then I do not see the reason for adding all these figures.

7) The authors decided to put the figures showing relative differences in the manuscript and the other figures in the supplement. I'd suggest to do the opposite and to show the

retrieved profiles in the main text, adding the true and the a priori profiles. In my opinion, these figures give a more rapid access to the performance of the retrievals while the relative differences are additional information, which can be moved to the supplement.

8) I found it a bit unfortunate that the authors decided not to include a perfect scenario, where the profile shape and AOD of the a priori agree with the true profile. It would be very interesting to see, if in this case PRIAM also underestimates the AOD / NO2.

Detailed comments

- Abstract: It is claimed that the finding of the AOD underestimation in the sensitivity study explains the underestimation seen in real data. I think this is neither new, nor an explanation – the explanation as far as I see it is the insensitivity to the upper part of the extinction profile in combination with the forcing of the profile shape from a priori or parametrisation.
- Page 11: The selection of profiles to be used later appears completely random – at least from the text, it is not clear how the "representative" profiles have been selected.
- Page 11: The selection of the scenario used for evaluation of the sensitivity to aerosol parameters could be critical. Have other relative azimuth angles be evaluated as well? I would have expected the effect of the asymmetry factor to be different for different scattering and relative azimuth angles.
- Page 11: Which aerosol model has been used?
- Page 15: Which 4 diagonal elements of Sa are you talking about? I assume there are 20 or 21 diagonal elements in Sa? Do the relative values of the diagonal elements in Sa not depend on altitude?
- Page 16, Line 6: "the higher the Sa values, the lower the upper limits are for the inversion" – this is not clear to me.
- Page 16, line 22: must be related to systematic performances … or RTM differences
- Page 20, Line 8: "The artificial smoothing effect of the profile inversion algorithm mistakenly overestimates" => "The smoothing effect of the profile inversion algorithm overestimates"
- Summary: "We found that both algorithms can reasonably retrieve the 4 aerosol profile shapes" – I'm not sure that readers will agree to this point after having studied the figures with the results. It is clear that the retrievals cannot retrieve the extinction profiles above 1.5 km, and at low and high AOD, they also fail in the lower altitudes for many scenarios.
- Table 1: Why are there stars for both 0.5 and 1.5 km exponentials?
- Table 2: not needed
- Figure 2: There is confusion about MAPA excluding scenarios with AOD 2 – please check
- Figure 7: Typo "deviatiobs"
- Figure 16: It looks as if the bars of the lower 2 lines are partially clipped – please check and change scale if needed