Dear editors,

Thank you very much for your advices. We have carefully revised manuscript and marked every change in red.

The changing in the manuscript as follows:

1. New section 3.3: you should call it "Discussion"

Response: Thank you very much for your suggestion. It was changed in the manuscript.

Changes in manuscript: P26L19 **3.3 Discussion**

2. P27L1: "They used less profile shapes". I don't understand. Please rephrase

Response: Thank you very much for your advice. It was changed to make it clear.

Changes in manuscript: P27L1

But compared to this study, they used less scenario profile shapes (Bösch et al. 2018) or they restricted their investigations to a set of profiles with fixed combinations of shapes and vertically integrated quantities (VCDs and AOD).

3. P27L10: After "the most important findings are:", you should itemize your results.

Response: Thank you very much for your advice. It was changed to make it clear.

Changes in manuscript: P27, P28, and P29

The most important findings are:

(1) With increasing AOD the retrieved AODs systematically underestimate the true AODs. The underestimation reaches values of >40% and >50% for AODs of 3 and 5, respectively. The largest underestimation is found for Gaussian profiles, while for exponential profiles with scale height of 0.5 km the smallest underestimation is found. These results confirm results from previous studies with similar findings (e.g. Irie et al., 2008; Bösch et al., 2018; Frieß et al., 2019; Tirpitz et al., 2021). However, in this study, the range of AODs and the variety of profile shapes is much larger, which allows a more detailed interpretation of the results. Interestingly, the underestimation is systematically smaller for MAPA compared to PriAM, which indicates that only a part of the underestimation can be attributed to the missing sensitivity of MAX-DOAS measurements towards higher altitudes. In most cases, the larger effect for OE algorithms is probably due to the smoothing effect.

(2) Another important finding of this study is that the NO_2 profiles are not very sensitive to the aerosol profiles confirming similar findings by Frieß et al. (2019).

(3) Further, it was found that the influence of the assumed asymmetry parameter and single scattering albedo have typically a minor effect on the retrieval results. This is an important result, because usually the optical properties of aerosols are not well known. However, for aerosol inversions, the errors can still be up to 25%. Thus it is still important to use reasonable values for both parameters to minimize the remaining uncertainties. For the NO_2 inversion the influence of the asymmetry parameter and single scattering albedo is smaller, similar as found by Hong et al. (2017).

(4) Another important finding of this study is that the NO_2 VCDs either systematically overestimate (for low NO_2 VCDs) or underestimate (for high NO_2 VCDs) the true NO_2 VCDs.

Interestingly, these results are rather insensitive to the shape or the AOD of the respective aerosol profiles. The underestimation for high NO_2 VCDs is a new finding which was not reported so far. It is probably caused by non-linearities in the radiative transport for strong NO_2 absorptions. It can reach deviations of more than –30% for a NO_2 VCD of 10^{16} molecules cm^{-2}. A tendency of an overestimation for small NO_2 VCDs was already observed (for OE algorithms) by Frieß et al. (2019), but not discussed in detail. Our results clearly indicate that the overestimation systematically increases towards small NO_2 VCDs (with deviations >50% for an NO_2 VCD of 0.1×10^{16} molecules cm^{-2}). Here it is interesting to note that similar results are found for different profile shapes. This finding is probably caused by the fact that the trace gas VCD is mostly constrained by measurements at high elevation angles and the fact that the trace gas SCDs for these elevation angles only weakly depend on the profile shape.

Overall, the reason for the underestimation of the retrieved NO_2 VCD for low NO_2 VCDs is not yet fully understood. However, for the OE algorithm it might be caused by the influence of the a priori profile on the retrieval result. Interestingly, in this study a similar underestimation was also found for the parameterised algorithm (which was not observed by Frieß et al., 2019). This finding is currently unexplained, but might be caused by the different radiative transfer models used for the generation of the synthetic data (SCIATRAN) and in the MAPA inversion algorithm (MCARTIM). This aspect should be further investigated in future studies.

Interestingly, an overestimation of the true NO_2 VCDs (derived from direct sun observations) by the retrieved NO_2 VCDs from MAX-DOAS observations was also reported by Tirpitz et al. (2021) for low NO_2 VCDs (but not for HCHO VCDs).

(5) Another important finding of our investigations confirms the results from earlier studies (e.g. Wang et al., 2017; Bösch et al., 2018). Changing the covariance matrix changes also the retrieval results from OE retrieval as it results in different weighting of a priori and measurements in the inversion.

4. P16 and P15: "... the retrieval results if exactly the a priori profiles ...". You should say instead "... the retrieval results in a perfect scenario in which the a priori profile agrees with the true profile"

Response: Thank you very much for your suggestion. It was changed in the manuscript.

Changes in manuscript: P16L21-22

We also investigated the retrieval results in a perfect scenario in which the *a priori* profile agrees with the input profile.

Thank you for taking care of our manuscript.

Kind regards,

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