

Response to comments from editor

Please find below our response (in roman font) to your comments (in italic font).

General comments

- *I tend to agree with Rev#2 casting some doubt on whether the observational data clearly show a low bias on the order of tens of % in the NO₂ vertical column. In the end, your Figure 14 seems to point in that way, but this mainly appears as an indirect, statistical indication. The evidence from the synthetic data is much stronger. The manuscript needs to (re-)written such, that the reader is clearly guided that the 'observational evidence' is much more indirect and weaker than the synthetic argument. For example on page 1, line 11 and page 8, L11-12 it is mentioned that the low bias in tropospheric NO₂ can be derived from observational data. I think this statement should be toned down.*

We have toned down the observational data in the Abstract and in the Conclusions. In the Abstract (a similar change has been made in the Conclusions) the last three sentences have been replaced by the following:

For a solar zenith angle less than about 40° the synthetic data show that the NO₂ TVCD bias is typically below 10%, while for larger solar zenith angles the NO₂ TVCD is low-biased by tens of %. The horizontal variability of NO₂ and differences in TROPOMI and VIIRS overpass times makes it challenging to identify a similar bias in the observational data. However, for optically thick clouds above 3000 m a low bias appears to be present in the observational data.

On page 8, L11-L12 the text now reads.

For the observational data the true NO₂ TVCD unaffected by clouds is in general not known and is difficult to estimate due to the horizontal variability of NO₂. An attempt to estimate the true NO₂ TVCD from the observational data is discussed in section 4.2, which also include the analysis of the observational data.

- *Please consider moving the subsection on cloud movement to the Supplementary Material*

Please see answer below to comment about section 4.2 and Figs. 10 and 11.

- *I find Figure 9 quite difficult to interpret. That SZA is an important driver of cloud-shadow induced errors has been made clear already before. Please consider removing this figure, or moving it to the supplement, and shortening the discussion.*

We have moved Fig. 9 and the discussion of it to the supplement.

- In section 4.2 Figures 10 and 11 are merely telling us that VIIRS data can be useful to inform us about cloud properties relevant to shadow working, but the figure does not show a strong relationship between shadow indicators with TROPOMI NO₂ levels. Indeed spatial variability in NO₂ is stronger than the shadow effect. There may still be good reasons to keep the figure (which in my opinion is the basis for Figure 14), but refer to it in a supplement rather than in the main manuscript, where it takes quite some mental space from the reader to follow what you are driving at, which seems to be the statistical indications for a low bias effect shown in Figure 14.

We have moved Figs. 10-12 to the supplement. As the discussion of these Figures are full of references to them, we have also moved the discussion the supplement. We have also moved the appendix to the supplement as it is coupled to the cloud shadow band cases.

- P21, L23-27: please make clear here that the low bias is found specifically for clouds with high cloud optical thickness.

This has been made clear.

- Overall, please carefully read the entire manuscript and assess how the text can be made more concise. The current manuscript is quite lengthy and technical, and it should be possible to reduce the text and material by at least 10%. This will improve the readability of the paper, and guide readers to the main take-home messages of the study.

We have carefully read the manuscript. The movement of material to the supplement has shortened the main text by about 25%. Furthermore, text in the introduction that was duplicated in section 2 has been removed.

Minor comments

- In some places you mention 'TROPOMO' instead of TROPOMI.

Corrected.

- 4% → 4% or 4.0%

Changed to 4.1%. Also 0.1% changed to 0.2% and 20.3% changed to 20.1% in the same sentence so numbers agree with those reported in Fig. 3.

- Page 3, line 2: please provide a reference to the operational TROPOMI NO₂ data product, i.e. van Geffen, J.H.G.M., Eskes, H.J., Boersma, K.F., Maasakkers, J.D. and Veefkind, J.P., TROPOMI ATBD of the total and tropospheric NO₂ data products, Report S5P-KNMI-L2-0005-RP, KNMI, De Bilt, The Netherlands.

Reference included as suggested.

- Page 3, L4-5: I suggest to introduce the small differences in overpass time here.

We have added the sentence below. However, as the introduction as been shortened, this sentence comes in a later section.

The difference in overpass time is slightly more than four minutes and care must be taken to for example movement of clouds when combining data from the two platforms (e.g. Trees et al., 2021).

- *P21: please make clear what the source of information is for the SCOT.*

The following explanation has been added:

SCOT = COT/cos(θ), where COT is the VIIRS cloud optical thickness.

Bibliography

Trees, V., Wang, P., Stammes, P., Tilstra, L. G., Donovan, D. P., and Siebesma, A. P.: DARCLOS: a cloud shadow detection algorithm for TROPOMI, Atmospheric Measurement Techniques Discussions, 2021, 1–29, <https://doi.org/10.5194/amt-2021-377>, URL <https://amt.copernicus.org/preprints/amt-2021-377/>, 2021.