Review of: Impact of 3D radiative transfer on airborne NO2 imaging remote sensing over cities with buildings (Schwaerzel et al., 2021)

The manuscript discusses the study of 3D radiative transfer effects on NO_2 retrievals from airborne hyperspectral imaging systems. Also the impact of buildings on the light path is addressed. These effects are demonstrated in detail based on a 1 km x 1 km built-up region in Zurich and a realistic synthetic NO_2 field. The scientific content of the paper fits well within the scope of AMT and is valuable for (future) (NO2) retrievals from airborne and high resolution spaceborne observations. The manuscript is well-written and generally well-structured. Therefore, I highly recommend its publication in AMT. However, a number of revisions (detailed below) need to be conducted in the paper before publication.

General comments

-The studied 3D effects are indeed a very relevant problem in case of airborne/high resolution spaceborne trace gas retrievals over urban areas. A comment I had on the previous study of Schwaerzel et al., 2020 and also here is that I'm eager to see the impact on the VCD of using 3D BOX-AMFs (with/without building layer) instead of 1D layer-AMFs on a real-world airborne data set. Just as demonstrated with the synthetic data, a sample of an APEX data set acquired over Zurich could be used for this.

-Sect 3.3: I suggest to add a figure and description where you compute back the VCDs, e.g. based on the SCD-3D (considered that this is the typical smoothed NO2 field observed with an airborne imager) and the AMF-1D. This could demonstrate the impact of smoothing on the retrieved VCD (when compared to the 'true' simulated NO2 field of Fig. 2c) when not considering 3D effects. Same could be done by computing the VCD based on SCD-3D-UC and AMF-3D to demonstrate the impact of adding/neglecting the urban canopy. This would help the interpretation and avoid that a non-careful reader could have the impression that the 3D case leads to a more smoothed NO2 field when looking at the SCDs in Figure 6.

-p.2, l.51: This work is building further on an earlier work, i.e. Schwaerzel et al. (2020), and there is clearly an overlap. Please add here explicitly in which way this new study differentiates from the previous study. The full study is not only focusing on the addition of the urban canopy.

-p.5, l.125: Although each building surface can have its own albedo, for reasons of simplicity everything is given the same albedo of 0.1 in the study discussed in 3.3. It is somewhat confusing as sometimes "building shadows" are mentioned in the discussion (pointing to a different albedo). However, I think the authors refer with 'building shadows" rather to areas of the surface that cannot be 'seen' or are 'shielded' due to building obstruction of the lightpath. If this is the case, I would suggest to be more careful with the use of "shadows" or "shadowing effects" in the further discussion and maybe mention it as a 'shielding' effect. I also would explicitly repeat the made assumptions on the albedo in Sect. 3.3.

Minor comments

-Title: "Cities with buildings" sounds a bit weird. Maybe replace by "built-up areas"?

-p.2, l.28: You might consider adding the following reference : Vlemmix, T., Ge, X. (., de Goeij, B. T. G., van der Wal, L. F., Otter, G. C. J., Stammes, P., Wang, P., Merlaud, A., Schüttemeyer, D., Meier, A. C., Veefkind, J. P., and Levelt, P. F.: Retrieval of tropospheric NO_2 columns over Berlin from high-resolution airborne observations with the spectrolite breadboard instrument, Atmos. Meas. Tech. Discuss. [preprint], https://doi.org/10.5194/amt-2017-257, in review, 2017.

-p.4, l.105: Not clear what the difference is between 'material' and 'material type'. Please specify.

-p.5, l.125: Albedo typically has a strong impact on the AMF. Since the focus of this study is on adding the urban canopy (and its impact), it would be useful for further studies to do a sensitivity test to show the impact on the AMF of different typical roof types (even if the focus of the study here is not specifically on the building albedo).

-p.7, l.155: I assume this is done for each along-track pixel?

-p.9, l.205: "The slight increase in the column AMFs in the right is induced by scattering events in the right side of the domain appearing on the left of the domain due to circular boundaries" → This effect is not well understood.

-p.11, l.251: AMFs calculated with 3D-box AMFs but without buildings (Figure 6b) are lower over the roads and slightly larger just aside the roads." → it would help the reader to repeat why this is the case.

-p.12, l. 268: "Not including the urban canopy would therefore underestimate VCDs by 12%..." → I first thought to elaborate a bit on this in the conclusion. However, I think it is difficult to generalize, depending on the complexity of the urban canopy and also due to the fact that the bulk of the NO2 can be in elevated layers in real-world conditions which would reduce the impact of adding the UC.

-p.15, 322: "When buildings are included, NO2 SCDs are generally lower due to the shadows of building" → As you assume a same surface reflectance in the study I assume this is rather due to the blocking of the lighpath?

-Conclusions: Some suggestions would be helpful for future airborne/spaceborne missions and/or instrument design to reduce 3D effects over urban areas, e.g. to operate close to local noon and maybe operate with small VZA, or to put some thresholds on SZA and VZA? The latter is of course a trade-off with the amount of data than can be acquired during an overpass.

Technical corrections

-p.2, l.31: to → towards the instrument

-p.2,l.40: is NO2 maps → is that NO2 maps

-p.7,l.180: Fig.2c → Fig. 2c (Note as well that references to figures are not always consistent throughout the manuscript. Sometimes written as Figure 1, sometimes as Fig. 1)

-p.15, 314: in the direction **of**

-p.16, 326: Two times "have"

-Fig. 8: This caption is not self-explanatory. Also in the text the figure is not clearly explained.

-Please have a close look at the supplement to correct for typos, e.g. p.2, l. 55: should be 'emission'; add space between 15 and [; 'this' parameters → 'these' parameters, etc.