General suggestions

Sect.3: Why are the fitting windows so variable from instrument to instrument (DOAS instruments)? Please comment on this in the instrument description. Looking at the comparison it doesn't seem to make much of a difference, but I would suggest commenting on this.

Sect. 3, make sure to include uncertainty estimates of all instruments and include references to existing validation papers. The sections 3.3.4, and 3.4.1 to 3.4.4 lack references.

l. 550-555: I would suggest to check the TROPOMI AOT in the area for that day, available from https://data-portal.s5p-pal.com/; e.g. you could include maps of this in the appendix or at the very least state the average (and std) for the flights. Alternatively, VIIRS AOD or MODIS MAIAC AOD are very good AOD products (but this might be a little too much effort to include here, maybe just something to keep in mind for future studies).

l. 619: just a thought: there was no snow during the campaign; there could be a larger difference between the DLER and LER TROPOMI product for snow covered surfaces with high reflectivity. It would be nice to include a little comparison of the DLER and LER product for snow covered surfaces. Nothing extensive, just a sentence (near l. 619) and a scatter plot (TROPOMI DLER vs TROPOMI LER) in the appendix (if time permits).

Technical/minor suggestions

l. 1: suggesting to change to "Airborne, ground-based stationary and car imaging differential optical absorption spectroscopy (DOAS) measurements…"

l. 4: emitters -> sources

l. 5: "The DOAS measurements…"

l. 7… suggest using "observations" instead of measurements throughout the text (technically measurements are in situ measurements), and remote-sensing are observations

l.13: data create

l. 13-31: This paragraph can be shortened, I think the most important points are: 1) The PAL version improves the bias significantly, 2) cloud height and NO2 profile have a major impact, 3) surface reflectivity has a minor impact (in this region and time of year – this is likely different when there is snow on the ground). These points get a little lost in the lengthy paragraph, maybe include the correlations and biases inside the sentence in brackets rather than writing whole sentences about it (a little repetitive).

l.36: change to "…combustion processes, such as power plants and engines, as well as anthropogenic biomass burning." (How much does anthropogenic biomass burning impact the Ruhr area? Consider removing the last half of the sentence.)

l. 37: "NOx is primarily emitted as NO, the reaction…"

l.37: "The NOx sources are …" (remove the characteristics)

l. 38: chemically active -> reactive and short lived

l. 38/39: "…, there is a high spatial and temporal variability of NO2 near emission sources." (there is not much variation in background areas)

l. 39: remove "on"

l.44: "is remotely observed from different platforms" -> " can be observed remotely on a variety of platforms"

l.46f: is identified -> can be identified; are -> can be

l. 53: remove "on board the European…satellite."

l. 55 TEMPO is planned for launch in March 2023

l. 56-58: *consider re-wording this sentence, maybe change it to 2 shorter sentences*

l. 86: include a sentence about the new TROPOMI version and what changed/improved in comparison to the previous version. Maybe include studies that validated this new version, I know of Zhao et al. (2022) see reference list, there might be others too. E.g. Riess et al (2022) also talks about the improvements of the new TROPOMI version.

l. 89: industrial estates -> industrial facilities, arterial highways -> busy highways (or large highways)

l. 89: "Back-ground areas with low pollution, as well as moderately polluted regions are also observed…"

l. 96: remove "In the following,"

l. 107: 5 million inhabitants -> has a population of 5 million

l. 108f: "The region, including nearby metropolitan centres along the Rhine and populated surroundings is called Metro… and is comprised of a population of over 10 m, large power plants [*can you include a number here*], … industrial facilities and several large highways."

l. 110: above the campaign location -> in the MRR

l.120:"… dominated by the emissions of three lignite fire power plants in the area (see European Pollutant Release and Transfer Register (E-PRTR)[*include reference or url here*]).

l. 121: "…around Cologne and Duisburg…" , remove latter part of the sentence "and the flight area around Duisburg has a similar character to that of the Cologne area with a mixture of urban and industrial emitters but includes the central metropolitan Ruhr area, which has a large variety of pollution sources. "

l. 137: here and any other occurrences: don't shorten Table to Tab. as per AMT guidelines, "are given in Table 1"

l. 143: "…comparison of the aircraft and TROPOMI NO2…"

l. 143: remove "prior to the dedicated evaluation … satellite pixel area", I'm not sure what you mean here, but I think it's not necessary

l. 144f: remove: "In this manner", " on the one hand", "on the other hand"

l. 145: local -> ground-based , with restricted -> that have restricted, with satellite -> to satellite

l. 151: Table 2

l. 157: of aerosol -> aerosol

l. 160: thus by far -> currently

l. 167: AMFs. The AMFs are generated using the OMI…

l. 167: , and cloud fraction

l. 171: (e.g. Verholst et al, 2021). *(there are many others)*

l. 173f: very long sentence, consider numbering the reasons and removing unnecessary details: " other factors that could contribute are: (1)…"

l. 186: recipe provided-> approach as detailed

l. 231: Tab.->Table

l. 255: remove "used"

l. 261: *438-490nm; is this the same or different to TROPOMI?, and other DOAS fits used in this study*

l. 265ff: *it's unusual to trop as a superscript, subscripts would be more common, e.g. subscript of $_{trop,ref}$ could be used*

l. 271: during -> near

l.272:change to: " There is a maximum difference of 3h between the time of the reference background and the actual measurements."

l. 276: *how small, do you have a reference that it is negligible?*

l. 279: (see ERA5 reanalysis; Hersbach et al. (2018). *You can include the data source in the data availability section, and data source reference*

l. 298: comprises of

l. 300: remove "further details can be found therein."

l. 352: *why is the spectral window different to the AirMAP window?*

l. 371/379: *again why is the spectral window different?*

l. 397: "different target areas" -> "three target areas"

l. 411: do you have a reference for this? This paragraph in general could benefit from a couple of reference.

l. 413: The same AMF (1.3) is used to convert to a VCD, wouldn't it depend on the SZA? How much of an impact does the SZA have?

l. 423: insert reference here

l. 440-450: what is the uncertainty of the PANDORA observatons. Also please include references in this paragraph.

l. 465: is it really +- 10-90 percentile, I think it is just the 10th and 90th percentile.

l. 470: data is -> data are

l. 473: As a result of having more opportunities to make near simultaneous synchronized measurements, -> Consequently,

l. 487: is it really +- 10-90 percentile, I think it is just the 10th and 90th percentile.

Fig. 7: I would suggest moving one of these (I suggest Fig. 7b) to the appendix, as they essentially show the same.

l. 637: areas -> areas,

l.642: scatter -> scatter,

l.642: measurements -> measurements,

l. 687: dataset -> data set (either or but be consistent, I found both dataset and data set used in the study, please fix this)

l. 704: Sentinel-4 -> Sentinel-4,

References

Zhao, X.; Fioletov, V.; Alwarda, R.; Su, Y.; Griffin, D.; Weaver, D.; Strong, K.; Cede, A.; Hanisco, T.; Tiefengraber, M.; McLinden, C.; Eskes, H.; Davies, J.; Ogyu, A.; Sit, R.; Abboud, I.; Lee, S.C. Tropospheric and Surface Nitrogen Dioxide Changes in the Greater Toronto Area during the First Two Years of the COVID-19 Pandemic. *Remote Sens.* **2022**, *14*, 1625. https://doi.org/10.3390/rs14071625

Riess, T. C. V. W., Boersma, K. F., van Vliet, J., Peters, W., Sneep, M., Eskes, H., and van Geffen, J.: Improved monitoring of shipping NO2 with TROPOMI: decreasing NOx emissions in European seas during the COVID-19 pandemic, Atmos. Meas. Tech., 15, 1415–1438, https://doi.org/10.5194/amt-15-1415-2022, 2022.