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Review of acp-2022-202

Anonymous Referee #1

Referee comment on "Tropospheric and stratospheric ozone profiles during the 2019 TROpomi vaLIdation eXperiment (TROLIX-19)" by John T. Sullivan et al., Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2022-202-RC1, 2022

Review of manuscript Measurement Report: Tropospheric and Stratospheric Ozone Profiles during the 2019 TROpomi vaLIdation eXperiment (TROLIX-19) by J.T. Sullivan et al.

The paper submitted to ACP by J.F. Sullivan and co-workers is a measurement report of data collected during a joint NASA-KNMI field experiment designed to validate ozone retrieval by the TROPOMI spaceborne mission. On 11 days, lidar O3 observations in the troposphere and the stratosphere are carried out for several hours at the Cabauw site. The two NASA lidars are indeed very valuable tools for the assessment of TROPOMI. Observations of total ozone column (TOC), stratospheric limb sounders (MLS), and nearby ECC launched at De Bilt are also analyzed in this work, in addition to the daily ozone simulations of the GEOS-CF model. The time evolution of TOC and tropospheric O3 partial columns (0-2km, 0km-Tropopause level) is used to assess TROPOMI observations and GEOS-CF model ozone mapping. Considering the value of satellite validation exercises and comparisons between model and observations, the paper is appropriate for publication in ACP (or AMT considering the focus on experimental data analysis). It is well written with some remaining errors in figure legends. I fully agree that there is a general good agreement between the different observations and that the GEOS-CF model performs quite well. My main criticism would be that detailed discussions of the differences observed in the troposphere are sometimes missing and that these differences need to be acknowledged in the conclusions: TROPOMI overestimate in the lowermost stratosphere (10-15 km), GEOS-CF low performance during the 9/20-21 episode (not only at 4 km but also below the tropopause leading to small differences of tropospheric columns without a good agreement in the vertical profile), ECC/lidar positive differences in the free troposphere on 9/12,17,21 (De Bilt/Cabauw spatial differences ?).

Specific comments

Line 45 : Lidar is also sensitive to cloud cover. Are missing lidar data during the campaign related to cloud cover ?

Fig. 1 : Fig. 1 is not referenced in the text. What is the purpose of this figure ? Please also show De Bilt and Cabauw on the NO2 map.

Line 108 : Addition of lidar O3 measurement accuracy and vertical resolution would be useful in Table 1. Since partial tropospheric columns and TOCs are discussed in section 3.2 and 5, the expected accuracy of the lidar retrieval on these columns would help.

Line 151 : Give a more recent reference i.e. Smit and Thompson 2021 GAW report 268 describing ASOPOS 2.0 error calculations.

Line 171 : What is the expected difference when using the 2.5 PVu instead the 3 PVu tropopause definition taken for the lidar tropospheric ozone column calculation ?

Line 206 : What is the typical GEOS-CF model vertical resolution in the UTLS ?

Line 225 : Add 2f in the list of panels with large lidar/model differences.

Line 229 : It is also true on 9/13-14.

Line 233 : What is the thickness of the 4-km layer used for plotting ozone in Fig. 3 ?

Figure 2 : Ozone unit is not specified in the caption or color scale. Please add the pink tropopause altitude on the ozone plot and the vertical limits of the 4-km layer used in Fig. 3. What is the time end of panel e ? This plot is very nice. It's a shame not including the two days with ECC at De Bilt on 9/12 and 9/17.

Line 243 : The O3 vertical structure in the UTLS is also missed by the model (no low O3 at 11 km). It is then likely that the mesoscale ozone 3D transport in the frontal system is not very well resolved by the model for this specific event.

Line 246 : Why are 9/17 ECC ozone concentrations significantly larger than model, TROPOMI and lidar O3 values ? Did you see any horizontal O3 gradients near Cabauw in the model or TROPOMI mapping ?

Line 271-274 : This discussion is unclear. The difference between the tropospheric columns are in fact not too bad but are fortuitous because the effect of the missing layer at 4 km is cancelled by the high model ozone at 11 km. Please reformulate this part of the discussion.

Line 279 Figure 4 low panel (not top panel)

Line 282 I do not understand this sentence.

Line 285 What are the reasons for low 0-2 km column in some lidar data on 9/12 and 14 and in TROPOMI data on 9/17 ?

Line 288 A discussion on the TROPOMI retrieval of the partial column is needed in this section. While the 0-2 km columns remain within the range of the diurnal variability, several full tropospheric columns (9 /12,13, 18,19,20) are well above this diurnal variability. It is likely related to the limited vertical resolution in the UTLS. The TROPOMI overestimates are also quite clear in the ozone profiles shown in Fig. 5.

Line 299 Reading this sentence, I am not sure which altitude range is critically needed for monitoring of the column

Line 308 What is OMPS-LP ? The stratospheric MERRA-2 profile used for the OMPS tropospheric ozone column calculation ? Do hybrid lidar profiles combine daytime TROPOZ data with nighttime STROZ-LITE data or are nighttime profiles only considered in the hybrid version ? Please clarify this point.

Fig. 5 I believe that the titles of the bottom panels are wrong otherwise Fig.3 and Fig.5 are not consistent.

Line 320 Comparisons of the stratospheric profiles are extensively discussed while the general agreement is quite good in the stratosphere. The discussion of the tropospheric differences is however limited while there are some interesting differences (TROPOMI in the UTLS, lidar ECC differences).

Fig. 7 Color scale is missing

Line 339: Why do you say that OMPS-LP underestimates O3 concentrations at altitudes below 20 km ? I see both positive and negative differences. Regarding TROPOMI, it looks like TROPOMI versus MLS is better between 10 and 20 km than the large lidar/TROPOMI differences in the UTLS. Is it related to similar UTLS vertical resolutions for MLS and TROPOMI ?

Line 358: A 7% difference on TOC is already quite significant. What are the reasons for the low TOCs given by the hybrid lidar retrieval on 9/14-15 or by Pandora on 9/23 ?

Line 371: GEOS-CF indeed performs well reproducing the ozone downward transport in the UTLS, but a sentence could be added about GEOS-CF failure to resolve some high resolution laminae related to specific mesoscale ozone 3D transport from the UTLS, e.g. 09/19-20.

Line 374: The overestimate of the TROPOMI retrieval between 10 and 15 km needs to be mentioned in the conclusions.