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## ***Interactive comment on “Evaluation of the LOTOS-EUROS NO<sub>2</sub> simulations using ground-based measurements and S5P/TROPOMI observations over Greece” by Ioanna Skoulidou et al.***

### **Anonymous Referee #1**

Received and published: 26 November 2020

Review on the manuscript: “Evaluation of the LOTOS-EUROS NO<sub>2</sub> simulations using ground-based measurements and S5P/TROPOMI observations over Greece” by Skoulidou et al. The manuscript describes the comparison between LOTUS-EUROS NO<sub>2</sub> model simulations and in situ, max-doas and TROPOMI data. The comparison shows that the model reproduces well the spatial variability of in situ measurements and TROPOMI NO<sub>2</sub>

Discussion paper

observations. Overall the agreement changes with the season and at different sites. The paper is scientifically sound, but it is missing deeper analysis of the uncertainties and it is quite busy. The manuscript could be published after addressing the following points:

Specific comments:

1) As a general point the paper is not enough focused in my opinion. The results are a bit scattered (presented for many instruments and conditions) and it is difficult to derive a clear take home message. Perhaps the authors could try to rewrite more clearly the abstract and conclusions (now they are just summaries), for example highlighting under which conditions the model performs best and worst and the main reasons for discrepancies and ideas for improvement. Most of this is perhaps already indirectly mentioned in the text, but I think it could be rewritten in a different manner, so that the model capabilities and limitations can be better highlighted.

Following the reviewer's suggestions changes in the structure and the writing of the manuscript are made in order to make the take home message clearer.

New sections were added in the section 3, where results are shown, to discuss the capabilities and limitations in each comparison section. As a result, the sections added are:

3.1.1 Discussion on the validation of surface NO<sub>2</sub> concentrations

3.2.3 Discussion on the validation of tropospheric NO<sub>2</sub> columns against ground-based MAX-DOAS observations

3.3.1 Discussion on the validation of tropospheric NO<sub>2</sub> columns against S5P/TROPOMI observations

Moreover the conclusions are changed to Conclusion and Discussion and are rewritten in order to make the take home message clearer.

Finally some Figures and Tables are moved to the supplement or removed completely (i.e. Table 3, Figure 9) in order to make the paper less busy.

2) sect. 2.2.1 you mention that "For this reason, stations characterized as urban traffic stations, localised close to busy traffic roads of the city and showing very large values, are excluded from the validation." But then you analyse some urban traffic stations in the results. Which criteria you used to exclude these stations? Also, I think you will still have differences in spatial representativeness, also when NO<sub>2</sub> values are not "very large": please clarify.

The official designation of the station type was assumed to be that one reported in the official databases, however due to our detailed knowledge of where those stations are located we decided to exclude ones that are exactly over busy thoroughfares in Athens. It follows that those stations are directly affected by the smallest changes in road emissions and their reported measurements far noisier than stations that are within the city canopy but not directly on a busy road. We have included the following in the text:

"For this reason, stations characterized as urban traffic stations, localised close to busy traffic roads of the city and showing extremely high concentrations were excluded from the validation, based on local knowledge of their actual locations. As a result, we include in our analysis stations that are officially characterized as "traffic stations" (e.g. Marousi station, Athens) but which are not placed directly over the major thoroughfares."

3) It would be useful to plot the actual grid of the model for the Greek (nested) domain

( $0.1 \times 0.05$  deg ) in figure 1 and 2. This would show that actually sometimes more than one in situ station fall into one grid cell of the model (at least in Thessaloniki). Did you try (if applicable) to average spatially the values from the stations within one grid cell and see if it reduces some of the discrepancy in the representativeness between model and point measurements?

Two pairs of air quality stations in Thessaloniki are indeed located in the same grid as can be now seen in the updated Figure 2, which includes the actual grid we are working with. We now include in our analysis the average observational levels of the two urban background stations (Malakopi and AUTH) that are situated in grid-pixel [22.95E, 40.625N] and the average of the urban industrial stations Sindos and Kordelio in grid-pixel [22.85E, 40.975N] in Thessaloniki. However Figure 1 becomes very busy when the actual grid of the model run is plotted, and since the main purpose of Figure 1 is to depict the orography of the two areas and to give the reader a general idea of the regions of study and their surroundings, we opted to keep the original gridlines. We have included the following in the text:

“When more than one in-situ station is located at one grid-pixel their average value is considered, as a result in the case of Thessaloniki the mean values of the urban background stations “Malakopi” and “AUTH” is calculated as well in the case of the urban industrial stations “Kordelio” and “Sindos”.”

4) The discussion on the uncertainty is a bit qualitative sometimes. Many figures lack errorbars (see technical points below). For example, what are the uncertainties associated with individual max-doas measurements? If you use an average over time, could you include some estimation of the variability in this time range? Also, how much do you expect your geometric AMF calculation to change the result compared to the calculation that takes into account the actual NO<sub>2</sub> profile? The same applies for the comparison with TROPOMI NO<sub>2</sub>. A more quantitative description of the uncertainties would also help in understanding how the discrepancies you find compare with these uncertainties

Following the reviewer's suggestions, error bars referring to the standard deviation of the averaged MAX-DOAS observations and LOTOS-EUROS simulations are added to Figures 7 and 10. Further, new figures were added to the updated text which show the diurnal variability of the in-situ measurements and the LOTOS-EUROS simulations including their standard deviation as a shaded area (see Figures S3, S9 and S10 in the supplement).

The following comment on the uncertainties associated with the geometric AMF calculation is added in the manuscript:

"The evaluation of the magnitude of the differences introduced by using the geometric AMF instead of a full AMF calculation is ongoing for both these instruments. We mention here the work of Shaiganfar et al., 2011, who reported that tropospheric NO<sub>2</sub> columns deviate by approximately  $\pm 20\%$  for NO<sub>2</sub> layer heights  $\leq 500\text{m}$  and a moderate aerosol optical depth, when using the geometric approximation instead of a full AMF calculation."

As far as the TROPOMI data are concerned, the tropospheric NO<sub>2</sub> precision field provided by the TROPOMI product is added at Figure S11, as a shaded area, to provide a more quantitative description of the variability of the TROPOMI observations.

5) Sect. 3.2 Maybe I lost this information but which direction you use for AUTH: 1 or 2?

Initially one direction was used for the analysis but after the corrections in the manuscript the average of the direction 1 and 2 is used and the statistical analysis was similarly updated. A more clear comment about which direction is used is added to the manuscript:

“For this study, we used the average value of the two azimuth angles: 220° and 255° designated in Figure 2 by the purple lines 1 and 2, respectively.”

6) Sect. 3.3 Could you please clarify how do you apply the averaging kernels of TROPOMI to the model? How do you spatially and temporally collocate TROPOMI and the model? How do you interpolate vertically? Which level you use for the tropopause (from TROPOMI perhaps)?

The process of the implementation of averaging kernels onto LOTOS-EUROS model is made directly by a module of the model. It is true that it is not clear in the text how the averaging kernel are applied so a better description is added in the manuscript, as follows:

“The TROPOMI averaging kernels are applied onto the LOTOS-EUROS profiles using an online module of LOTOS-EUROS. After regridding the TROPOMI data onto LOTOS-EUROS gridding, the module maps the model profile to the retrieval a-priori layers, while in order to cover the atmosphere above the model’s vertical levels boundary conditions are added from the CAMS NRT product. The averaging kernels are applied to the simulations made at the



closest time of the observations. The entire process is fully automated within the LOTOS-EUROS post-processing analysis tools.”

Technical comments

7) Table 7 you write in the caption: “The positive biases are shown in bold.” But there is no bolded text in the table. Also, one horizontal line is missing.

The part in the caption about the positive biases is removed, as well as the line.

8) Figure 7. The y-axis title of the second panel is not visible here

Thank you very much for noticing. The figure is changed.

9) Figure 7 and 10 should have errorbars.

Error bars referring to the standard deviation of the averaged observations and simulations are added to figures 7 and 10 as recommended.

10) Figure 9. Please write in the caption what the errorbars are.

Figure 9 now appears at the Supplement in Figure S6. Thank you very much for noticing that the error bars explanations is missing. These were added in Figure 8 and S6 and S7 as follows:

“The horizontal error bars refer to the standard deviation of averaged MAX-DOAS observations while the vertical error bars refer to the standard deviation of averaged LOTOS-EUROS simulations”

11) Overall, the paper is a bit figure and table -heavy in my opinion and a bit repetitive sometimes. Maybe you can try to shorten some text throughout. For example, while it is useful to have these summaries at the end of each paragraph, it could be written in a more concise manner. Also, some of the tables and figures could go to the supplement. For example, Fig. 4, Fig. 13, Table 7 could be moved to the supplement. Perhaps some figures could be also grouped together. Following the reviewer’s suggestions new sections were added in the section 3, where results are shown, to make the discussion more concise. The added sections are:

3.1.1 Discussion on the validation of surface NO<sub>2</sub> concentrations

3.2.3 Discussion on the validation of tropospheric NO<sub>2</sub> columns against ground-based MAX-DOAS observations

3.3.1 Discussion on the validation of tropospheric NO<sub>2</sub> columns against S5P/TROPOMI observations

Finally some Figures and Tables are moved to the supplement (i.e. . Figure 9 and 13) or completely removed (i.e. Table 3, Figure 9) in order to make the paper less busy.

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