# Responses to the reviewer 2

The review comments and our responses are colored in blue and black texts, respectively. The changes in the manuscript corresponding to the comments are highlighted in yellow. The line and figure numbers refer to the revised manuscript.

I trust this meassage finds you in good health. I am writing to offer my review of your article titled "Evaluating CHASER V4.0 global formaldehyde (HCHO) simulations using satellite, aircraft, and ground-based remote sensing observations" After a thorough evaluation of your research, I would like to extend my appreciation for the valuable contributions your work brings to the field.There are some areas where minor enhancements could be made to elevate the clarity and coherence of the text. I would like to highlight these areas for your consideration:

We thank the reviewer for the insightful comments

Line 70: Any result or outcome that reflects that "good agreement"?

**Response:** We have added the following information in response to this comment.

L75– 77 Ryan et al. (2021) and Chan et al. (2020) reported good agreement (temporal correlation, $R > 0.70$) between TROPOMI and MAX-DOAS in Melbourne and Munich

Line 143: Reprocessed and Offline TROPOMI products are different datasets. Please provide more detail about how and when each one is used.

**Response:** We thank the reviewer for identifying this issue. We have used the offline product only. The revised version is as follows:

L163-164: The TROPOMI operational L2 offline (OFFL) HCHO vertical column density (VCD) (ver. 1.1.5.7) data from 2019 to 2020 have been used for this study.

174: Typo: "2.2" where it should read "2.3".

**Response:** 2.2 has been replaced with 2.3

190: 2018 is out of the original study period (2019-2020). Please clarify why this year was chosen.

**Response:** The Atom campaign spans from 2016 to 2018. Thus, we used the 2018 simulations for comparison. This has been updated in the revised abstract.

194-196: Typo: "TOGO" where it should read "TOGA" (Trace Organic Gas Analyzer).

**Response:** We have corrected the typo error.

201: Why were those specific locations chosen? Please provide more detail about that decision.

**Response:** The sites were selected because continuous observations from 2019 to 2020 were available for these sites. We have added the following line in the revised manuscript.

L238-239 The sites were selected because continuous measurements from 2019 to 2020 were available for these sites

208: Typo: "Kasugai" where it should read "Kasuga".

**Response.** Kasugai has been changed to Kasuga

257: Figure 1 is a valuable result and should appear in a larger size. With the current layout, the visualization is very difficult.

**Response:** We thank the reviewer for the comment. Figure 1 has been revised.

279: Figure 2 and similar ones: The temporal axis should specifically detail the study period, indicating whether it represents an average of both study years (2019-2020).

**Response**. We thank the reviewer for the comment. We have mentioned about the study period in each figure and Table caption. We have also mentioned it in the text. We adopted this method, because we found that mentioning the time period for every subplot reduced the clarity of the figures.

467: Typo: "Fig. ", without a number.

**Response:** The Figure number is S6 which has been added in the revised manuscript.

489: Please place the MBE values always in the same position in the graphs.

**Response:** The position of the MBE values has been fixed in the revised figures.

725: THat is still a high negative bias. Are there any further possible reasons for this result?

**Response:** The differences in the ground-based and satellite sensor sensitivity can also be a potential reason for the significant biases. This has been discussed in the following lines:

L799-801: Moreover, MAX-DOAS observations are most sensitive to altitudes near the surface, whereas satellite sensitivity decreases near the surface. Consequently, the air masses

sampled by the instruments at the same local time might be different, leading to inconsistent observation peaks.

756: TROPOMI spatial resolution is 3.5 x 5.5 $km^2$. Would there be any chance to perform this comparison at a higher resolution instead of 200 km spatial averaging?

**Response**: Yes, the comparison can be performed at a higher resolution. CHASER can run on a horizontal resolution of 2.8º, 1.4º, and 0.56º. 2.8 is the most commonly used horizontal resolution for CHASER studies (global and data assimilation), so it has been chosen for evaluation. The supplementary information includes a comparison (FigS1 and Table S1) between simulations performed on two horizontal resolutions (2.8 º and 1.4 º).

The difference between the TROPOMI and CHASER horizontal resolution will lead to representative errors. However, the random horizontal representative errors are mostly limited to 5-10% and are included in the individual retrieval error (Boersma et al., 2015). The most relevant representative error is associated with the vertical sensitivity of the satellite sensor. Our simulations have accounted for the averaging kernel information needed to address this issue. A detailed assessment of the horizontal resolution effect on the comparison results is out of the scope of the current study. We will address this issue separately. However, we have added the following text in the revised manuscript.

L196-205TROPOMI observations are averaged spatially and temporally to the CHASER grid (T42) daily, leading to horizontal representativeness errors. However, the random horizontal representativeness errors are in the order of 5-10%, which is lower than the individual retrieval error of the satellite observations (Boersma et al., 2015). If the model horizontal resolution is increased by 50% (i.e., simulated at a horizontal resolution of 1.4º × 1.4º), the change in HCHO abundances is less than 6% (Fig S1 and Table S1 in supplementary information). The vertical sensitivity of the satellite retrievals is the most relevant source of representativeness error (Boersma et al., 2015). The current study utilizes the TROPOMI AK information to minimize the representativeness error. Therefore, the horizontal representative error will likely affect the results less than other error sources, such as uncertainties in satellite retrieval, emission inventories, and model chemical mechanisms.

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