

Review of “Evaluating CHASER V4.0 global formaldehyde (HCHO) simulations using satellite, aircraft, and ground-based remote sensing observations” by Hoque et al.

This paper presents the evaluation of HCHO columns from the CHASER model against the TROPOMI, OMI, ground-based MAX-DOAS observations, and the CHASER HCHO vertical profiles against the Atom-4 flight dataset. The authors compare the modelled regional HCHO columns with the TROPOMI and the OMI HCHO columns and analysed the model-observation differences comprehensively. The authors also compare the modelled HCHO columns with the MAX-DOAS columns at three locations in Thailand and Japan respectively. The modelled HCHO profile and the profile from the Atom-4 flights are compared for Amazonia and for the Remote Pacific region, respectively. The authors have also performed sensitivity simulations to assess the impact of anthropogenic, biogenic, and biomass burning VOC emissions, as well as NO_x emissions on modelled HCHO. However, I find that one limitation is the lack of discussions on the important role of chemical mechanisms in simulating HCHO in the models, despite that the authors did mention this in the conclusion. There are some previous studies that the authors could cite which addressed inter-model differences in modelled HCHO (see below suggestions).

Overall, the analysis is thorough and robust. The paper is generally well-written, and the materials are well organised, and is within the scope of GMD. However, the presentation of the paper can be improved. I encourage the authors to make a thoroughly revision of the manuscript.

Below are two relevant papers on model differences in modelling HCHO (and CO):

Anderson, D. C., Nicely, J.M., Wolfe, G. M., Hanisco, T. F., Salawitch, R. J., Canty, T. P., ... Zeng, G. (2017). Formaldehyde in the tropical western Pacific: Chemical sources and sinks, convective transport, and representation in CAM-Chem and the CCMI models. *Journal of Geophysical Research: Atmospheres*, 122. <https://doi.org/10.1002/2016JD026121> (Figure 13)

Zeng, G., Williams, J. E., Fisher, J. A., Emmons, L. K., Jones, N. B., Morgenstern, O., Robinson, J., Smale, D., Paton-Walsh, C., and Griffith, D. W. T.: Multi-model simulation of CO and HCHO in the Southern Hemisphere: comparison with observations and impact of biogenic emissions, *Atmos. Chem. Phys.*, 15, 7217–7245, <https://doi.org/10.5194/acp-15-7217-2015>, 2015. (Figure 15 and Table 4)

My specific comments are listed below.

Abstract

It feels that the abstract is overly concise and does not reflect fully what are presented in the paper.

L19-20: Please state which comparison this is for, i.e., TROPOMI.

L30: It is the comparison between the CHASER and MAX-DOAS HCHO columns, not mixing ratio. Please also state the disagreement, i.e., CHASER underestimates the HCHO peak in comparison with the MAX-DOAS data at all three locations. You speculate that the model data

averaged over a large area might not be able to capture the observed peak at these locations. A mention of this would be useful in the abstract.

Introduction

L82: How do you evaluate OH?

Model, observations, and methods

L93: Is there a reference for this?

L99-101: A list of the reactions in a table (in supplementary) could be considered if they have not been published before.

L110-123: It will be helpful to tabulate these emissions.

L117: Do you calculate lightning NO_x emissions online or prescribe them?

L124-125: Are there OH observations from OMI and Atom? Please provide details.

Table 1: ANI and OLNE appear first time in Table 1. Please define these simulations in the text.

L137: What are the TROPOMI grids?

L139: Do you mean that the TROPOMI data are interpolated onto the CHASER horizontal grid?

L174: Should be “2.3 OMI”

Results and discussion

L231: This section is essentially the comparison of CHASER HCHO with TROPOMI. Maybe “TROPOMI” should be reflected in the section title?

L235-239: I am not sure how meaningful these statistics are in terms of the global means as the global HCHO distribution is so inhomogeneous.

L243-245: Would it more suitable to note this in the MAX-DOAS comparison section?

Table 2: These numbers don't have to be in a table. You could include them in the Figure 1 caption. Is the correlation coefficient spatial or temporal?

Figure2: The panels can be larger. Mark the position of the MBE numbers in the panels consistently. Add identifiers to the sub-figure, e.g., (a), (b), ... for each region. Then refer to Figure2(a), Figure 2(b), etc., when you discuss them in the following subsections.

L293-: Please refer to the figure(s) and table(s) that your discussions are based on at the beginning of each subsection. Same as the following subsections of (b), (c), etc.

L300: Do you mean direct HCHO emissions or indirect (degradation of VOCs) HCHO emissions? Please clarify.

L319: Can you speculate what drives these model-satellite discrepancies in the Europe and W-US in summer and autumn?

L328-329: Please refer to the figure you are referring to. Please also note that the C-Africa off-peak HCHO is overestimated by CHASER compared to TROPOMI (Figures 1 and 2).

L333: Figure S4: There is no black curve in Figure S4. Please revise this figure or the caption.

L338: Please mention the figure you refer to for these discussions.

L339: Missing “)” in “(De Smedt et al., 2008”. Again, please mention the figure here you are referring to over the next few lines.

L340-341: “*The lower CHASER columns in Southern Africa are likely attributable to underestimated pyrogenic emissions.*” - Can you confirm this from the following sensitivity simulations?

L355-356: Why particularly mention the biomass burning in N Africa here?

L358-359: Could the chemical mechanism in the model be at play?

L370: Refer to relevant figure(s) and table(s) earlier in your discussion of the results. Do you have an estimate how the biogenic and biomass burning emissions in India compared to other regions? Are there any specific meteorological conditions in this region that lead to low HCHO and the lack of seasonality?

L387: The figure number is missing here.

L422-423: I am not sure what you try to convey here?

Figure 5: Could you increase the size of the panels in this figure?

L552: It is important to summarise the NO_x emissions in the two inventories you used. What are the differences in NO_x emissions between these two inventories? It will help to understand the impact of NO_x on HCHO and OH.

L553: you need to define the OLNE simulations before referring to it.

L565-566: Which figure that you are referring to here?

Figure 6: It will be helpful to understand this figure if the differences in NO_x emissions are displayed or mentioned.

L595-: This section should be condensed where appropriate. You have compared CHASER and TROPOMI HCHO columns in detail already, so the focus here should be on what those most significant differences between OMI and TROPOMI HCHO are and how they compare with the CHASER HCHO.

L612: Referring to Figure 7 at the beginning of this paragraph.

L680: Which “observation” do you refer here?

L688-689, L703: what are differences between OMI SOA and OMI BIRA HCHO products? A brief introduction will be helpful.

L762-764: Is this coincidental?

L808: “*In Kasuga, modelled diurnal variations correlate strongly ($R=0.85$) with the observations*”. But in Figure 9, the R value is 0.41, not 0.85. Please check.

L837-839: Could you elaborate a bit more on this mechanism?

L844: Please check the coordinates for Amazon. You could draw two boxes on the map (Fig. S2) to represent the two studied regions.

L872-873: Have you already defined these sensitivity simulations?

L932-934: Does the model's course resolution play a role in this case?

L944: The last half sentence doesn't read well; do you mean the model underestimates the biogenic contributions?