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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Validation of satellite formaldehyde (HCHO) retrievals using observations from 12 aircraft campaigns" *by* Lei Zhu et al.

Anonymous Referee #2

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Zhu et al. present a new validation platform for satellite HCHO products, using different aircraft measurements and the model GEOS-Chem as the inter-comparison method. The model is used to make the link between the localised aircraft vertical measurements and the global satellite vertical columns. The method was introduced by Zhu et al. (2016). It is now extended to a larger number of aircraft campaigns, covering a broad range of conditions. An extensive evaluation of the NASA operational OMI HCHO satellite product is presented as an application of the platform. The retrieval steps of the satellite product are examined separately in order to explain the differences between satellite and aircraft results. The paper concludes with a slight bias of the OMI satellite product for high HCHO level, and to a high positive bias for low

columns. This study addresses the need for more systematic validation of the satellite products. The use of several aircraft measurements combined with 3D-CTM is pretty new. It allows for direct and indirect validation of the vertical HCHO profiles, which is lacking in the community. A significant amount of work has been dedicated to this goal, and to present the results in an honest and clear way. However, the paper would benefit from some clarifications, especially at the end of the discussion. I recommend publication after the following points have been improved:

The authors claim for a global validation platform. This is supposed to be achieved through the model, but nothing is shown about this extension of the validation beyond the aircraft domains. Can the author add an illustration of this extension? A global map, or a comparison at another location? Alternatively, remain focused on the regions covered by the aircraft campaigns and leave out the reference to the global method. In the abstract, it is stated that the high biases are due to slant column fitting and radiance sector correction. It is not clearly demonstrated in the paper. The last paragraph of section 4 needs to be revised. The explanations are not clear, and conclusions are drawn without showing any results. It does not hold by itself, and needs to be extended (see my comments below). The study look for systematic biases: Pay attention to data selection that can also introduce systematic bias (see my comments below). Does the biases found in this study match the error provided in the satellite product? What about precision? Does the validation results agree with provided satellite product precision?

Introduction p3, line83: "global validation platform . . ... Using observations from 12 aircraft campaigns all over the world". I don't fully agree that this study is global. Results are shown only at the aircraft campaign locations. And those cover mostly US, Pacific and one over Korea. Important emission regions are missing all over the world. I would rather mention here the diversity of the seasonal coverage.

Application to NASA operational HCHO product Line 169: the so called "radiance reference sector correction term s0" is a slant column. Why do you use the term "radiance"? It is confusing. Does it refer to the reference spectra used during the DOAS fit? If yes,

it should be better explained. Line 174: it is said that s0 is the difference between the retrieved SCD over the Pacific Ocean the GEOS-Chem climatology. Please explain if the model vertical columns are directly subtracted from the satellite slant columns (assumption AMF $\sim\sim$1 over Pacific Ocean, which is not true), or if an air mass factor is used to convert the GEOS-Chem vertical columns into slant columns. Line 194: selection criteria (4): VCD within the range -0.5x1016 molecules cm-2 to 1.0xe1017 molecules cm-2. Please provide the dispersion of the OMI HCHO VCD. If the VCD dispersion is, let's say, 0.8x1016 molecules cm-2, the lower limit might be too strict, removing a significant part of the distribution (negative columns) when the averaged column is close to zero, therefore biasing the averaged column to high values (case "high biases under low-HCHO conditions"). I suggest to test the impact on the comparisons if a more relaxed selection, based on a classical 3approach, is used. Line 207: Is the limit of 1.1 x 1016 for high-HCHO conditions based on satellite or model results? It looks like it is based on satellite columns, which is strange since it is the dataset to be validated, and it presents biases. Line 213: (2) please elaborate on the differences between the "radiance reference sector correction". Same for point (3) "selection criteria". Line 223: Half of the bias in high-HCHO conditions can be attributed to a priori profiles but not the full bias. Please discuss other possible reasons for the remaining bias. Line 229: Second case, low-HCHO conditions: I don't agree with the first conclusion. The a priori profiles are not the unique error source in the AMF calculation. It is not because the use of a more precise profile does not improve the comparison that the error is not due to AMF uncertainties. It could be due to albedo uncertainty; or imperfect cloud correction. However, I agree with the rest of the paragraph. Please reformulate the second line. Line 240: "The SAO retrieval algorithm conducts the radiance reference sector correction by removing the contribution of HCHO over the remote Pacific Ocean to the radiance reference." What are the units of this contribution? A slant column or a radiance? Please explain what you mean by radiance reference. Line 241: Could you give a number for this HCHO contribution? Line 245: What do you mean by "suppressing removal of HCHO contribution in the radiance reference"? Line 246: "the mean

bias is reduced from 147% to 128%". Where does this 128% come from? Furthermore, the bias reduction is not significant. Line 248: "we attribute the remaining biases to (2) the latitudinal dependency of the radiance reference sector correction." Again this needs further explanations. Is there a latitudinal dependency of the slant columns, if yes positive or negative? And is there a latitudinal dependency in the current reference sector correction of the SAO product? Line 249: You find a significant correlation of the satellite HCHO columns with the surface albedo during some campaigns, maybe even larger than the correlation with the model columns. It is interesting. Please specify for which campaigns? If the reflectance climatology contains uncertainties, it will reflect in AMF uncertainties, that will not correct the slant columns for this kind of dependency. Therefore, it is important to know if AMF are used to compute s0. See my comment for line 174. Also, have you tested to remove sun glint scenes from the comparison for the Pacific regions? Figure4 and supplement: spatial correlation between model and satellite column seems rather low. Please add correlations in Table 2. Why not using the same scale for OMI and the model? for example from 0 to 20x1015 molecules cm-2? As it is now, it seems badly chosen for OMI.

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