

## ***Interactive comment on “Bias assessment of lower and middle tropospheric CO<sub>2</sub> concentrations of GOSAT/TANSO-FTS TIR Version 1 product” by Naoko Saitoh et al.***

### **Anonymous Referee #2**

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Review of Saitoh et al., “Bias assessment of lower and middle tropospheric CO<sub>2</sub> concentrations of GOSAT/TANSO-FTS TIR Version 1 product”

Overall, this is a good paper dealing with difficult but necessary bias corrections to TANSO-FTS observations of mid-troposphere CO<sub>2</sub>. It’s a tricky subject, but the methodology is generally sound. However, the paper is difficult to follow in some sections, and in many cases, the figures need some improvement and clarification. I would recommend publication after some revisions in the text, and if the authors could better address the issue of the number of layers in the forward model (see comment for pg 10, line 32 below.)

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General comment: Throughout the paper, the authors refer to the retrieval layers by number (layer 3, layer 4, etc.), rather than, say, its log mean pressure. These layer numbers are specific to their algorithm, and referencing the layers by number is a little burdensome to the reader, even where the pressures are provided. For example, Page 6, line 23 reads “Saitoh et al. (2016) showed that TIR V1 CO<sub>2</sub> data agreed well with CME level flight CO<sub>2</sub> data in the UT region corresponding to retrieval layers 9 and 10.” This would read better if the pressures were given instead of the layer numbers. I suggest they prepare a table listing the retrieval layer numbers, layer boundary pressures, and the log-mean pressures of the layers (similar to Table 1 of Saitoh et al., 2016), and then just refer to a layer by its mean pressure rather than its number.

Pg 1, line 14: “. . .good spatial representability.” It’s not obvious what ‘representability’ means here. Would “resolution and precision” be a better phrase to use?

Pg 1, Line 24: “(retrieval layers 5–6), . . .” It’s not necessary to get into the details of their retrieval method in the abstract.

Pg 2, line 3: Suggest changing “(e.g., Gurney et al., 2002 Gurney et al., 2004)” to “(e.g., Gurney et al., 2002; 2004)”.

Line 24: “spatial representability.” Again, not obvious what it means here.

Pg 3, line 16: Suggest changing “. . .and has continued CO<sub>2</sub> and CH<sub>4</sub> operational measurements for approximately eight years.” to “and has continued operational measurements of CO<sub>2</sub> and CH<sub>4</sub> for approximately eight years.”

Line 23: Suggest shortening “These studies showed the following: 1) TIR UT CO<sub>2</sub> data agreed. . .” to “These studies showed: 1) TIR UT CO<sub>2</sub> data agreed. . .” Page 5, line 14: Suggest more explanation of why the averaging kernels are applied to the CME data and then comparison made. This would be useful to the reader not well versed in averaging kernels etc.

Page 6, Section 4.2: It’s not obvious why an “average” averaging kernel can be applied

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and not sometimes be misleading. In addition to the effect of instrument parameters (SNR, spectral resolution, view angle etc.) and assuming clear scenes only, the averaging kernel could vary by temperature gradient and thermal contrast with the surface. How much does an averaging kernel vary within a grid box? It would help if the authors briefly explain why they're using an averaged AK here and discuss the limitations of doing so.

Page 7, line 14 "In addition, negative biases of TIR CO<sub>2</sub> data against NICAM-TM CO<sub>2</sub> data increased by 1 ppm or less per year in all seasons, judging from the mode values, although the increase in negative biases was not evident in the comparisons over airports shown in Figure 6." I did not quite understand what is meant by this. Do they mean the bias varied by 1ppm or less?

Pg 8, line 27: Typo: "... in the LT and ML regions." Did they mean "MT" regions?

Pg 9, line 13: "As shown in Figure 6, the largest negative biases in TIR V1 CO<sub>2</sub> data existed in the MT region in middle and low latitudes during spring and summer, where TANSO-FTS TIR measurements have relatively large sensitivity to CO<sub>2</sub> concentrations and thus the retrievals are less constrained to a priori concentrations." Some kind of comparison is in order to quantify the difference in CO<sub>2</sub> sensitivity here – say average row-sum of averaging kernels, or total DOFS as a function of latitude.

Line 15: "This implies that biases in L1B spectra are a major cause of the negative biases in retrieved CO<sub>2</sub> concentrations, as Saitoh et al. (2016) noted in the UT region." The wording is confusing. Does this mean there are biases in the L1b radiances related to latitude and season, or are there fitting biases from the retrieval algorithm? Judging from the rest of the paragraph where the authors write about retrieval of surface parameters, I think they're referring to fitting bias, but whatever the bias is, it should be explicitly described.

Page 10, line 4: "From these results, we conclude that using the 10- $\mu$ m band in conjunction with the 15- $\mu$ m and 9- $\mu$ m bands in the V1 retrieval algorithm is a probable

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cause of the negative biases in retrieved CO<sub>2</sub> concentrations in the LT and MT regions." While I don't disagree with this, this would be more convincing if the authors compared their results using the different mixes of CO<sub>2</sub> bands directly against the aircraft measurements.

Line 13: "According to Figure 13 in Kuze et al. (2016), there was no distinct uncertainty in the 10- $\mu$ m band in the latest version of the TANSO-FTS TIR spectra." The wording of this leaves me uncertain of what they're claiming. Uncertainty of linestrengths or low fitting residual? Are they saying that using the 10 micron band of CO<sub>2</sub> does not add significant bias? This should be clarified.

Paragraph beginning line 17: As noted earlier, it would really help the reader if the authors referred to the retrieval layers by pressure and not layer number.

Line 32: "In retrieval from TIR spectra, the more atmospheric layers in which we retrieve CO<sub>2</sub> concentrations, the lower the information content of the retrieval result in each layer becomes; as a result, the retrieved concentrations are constrained by a priori model data. Thus, there is a high possibility of large biases in retrieved TIR CO<sub>2</sub> concentrations in low latitudes." This assertion needs to be tested. It is true that with more layers, the information is spread out more, but the overall information content, as measured by the degrees-of-freedom-of-signal (trace of the averaging kernel) can be the same or very similar, as can the retrieved profiles (depending on what the off-diagonals are for the a priori background covariance.) It's quite possible that if the background a priori is biased, then a TIR retrieval can also be biased not because of the number of retrieval layers, but, particularly at low latitudes, because of water vapor interference, undetected boundary-layer clouds changing the thermal contrast with the surface, or biases in the temperature. Again, this needs to be tested, or the statement removed or at least reworded as a hypothesizing.

Figure 5: It would be much clearer to the reader if they provided guidance to the different panels and lines in a legend box on the figure, rather than only in the caption.

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It would also help, for a reader skimming the paper, to describe what "CME-AK CO2" means in the caption as well as the text of the paper.

Figure 6: Use pressures and not layer numbers on vertical axis. It would also be better if latitude information and season (line color) were provided as a legend on the figure. It would help if the lines in the top panels had slight vertical offsets to clarify how different the error bars are from each other.

Figure 7: It's not clear here (or in the text) at what pressures they are comparing avg CO2 with NICAM. The contrast between the mid-gray and light-gray lines is not enough to easily distinguish between them.

Figure 8: Please use pressures instead of layer numbers. Again, the contrast between the mid-gray and light-gray lines is not enough to easily distinguish between them.

Figure 9: Again, please state the pressures instead of "layer 7-8."

Figure 10: Please also describe the lines and the location/times the different panels represent as a legend rather than just in the caption.

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