Atmos. Meas. Tech. Discuss., 8, C5689–C5695, 2016
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Atmospheric Measurement Techniques Discussions

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Interactive Comment

Interactive comment on "Validation of GOSAT/TANSO-FTS TIR UTLS CO_2 data (Version 1.0) using CONTRAIL measurements" *by* N. Saitoh et al.

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Received and published: 15 March 2016

To Associate Editor and Referee #2,

We appreciate you reading our paper carefully and giving valuable comments and suggestions again. We have considered your recommendations for revisions and made the necessary changes. The major points that we deal with in the revised manuscript are as follows:

1. We have changed "V1.0" to "V1" throughout the text. The GOSAT project has released V01.00, V01.01, and V01.20 produces, but the CO2 products of all the three

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versions are exactly the same data.

2. We have eliminated Figure 2 of the original manuscript not to defocus the scope of this paper that discusses UTLS CO2 data. We have described that the simultaneous retrieval of surface parameters did not affect retrieved CO2 concentrations in the UTLS regions, but could increase the number of normally retrieved CO2 data.

3. Following the recommendations of the two Referees, we have investigated the effect of considering TIR CO2 averaging kernel functions on CO2 concentrations in the UTLS regions. For this purpose, we have done the two types of analysis.

3-1. We have compared TIR and CONTRAIL CME CO2 data with and without TIR CO2 averaging kernel functions over each of the nine airports, and showed the comparison results in Figure 4 of the revised manuscript. Here, we have created CO2 vertical profiles using CME ascending/descending CO2 data below the tropopause and stratospheric CO2 concentrations taken from the Nonhydrostatic Icosahedral Atmospheric Model (NICAM)–Transport Model (TM) (Niwa et al., 2011) that introduced CONTRAIL CO2 data to the inverse model (Niwa et al., 2012), and then applied TIR CO2 averaging kernel functions to the created profiles.

3-2. Keeping the detailed evaluation of 2-1 in mind, we assumed a CO2 vertical profile on the basis of the combination of CONTRAIL CME level flight CO2 data ("CONTRAIL (raw)") and CarbonTracker CT2013B monthly-mean CO2 profiles (Peters et al., 2007) at each of the CME level flight measurement locations, applied TIR CO2 averaging kernel functions to the assumed profiles, and then compared the CO2 data with averaging kernels ("CONTRAIL (AK)") with TIR CO2 data in the UTLS regions. In Figure 5, 6, and 7 of the revised manuscript, we showed the comparison results of both the CONTRAIL (raw) and CONTRAIL (AK) data. We have explained the methods of the comparisons in Section 5, and showed the comparison results in Section 6 in the revised manuscript.

4. We have eliminated Figure 5 of the original manuscript. This is because we have evaluated the effect of considering TIR CO2 averaging kernel functions on TIR and

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CONTRAIL CME CO2 comparisons quantitatively in the revised manuscript.

5. Following the suggestion of Referee #1, we have showed the comparison results for each latitude band, instead of showing the comparison results for each airline route, in Figure 7 of the revised manuscript. We have also modified Table 2 to show the bias values of TIR CO2 data against CONTRAIL (AK) CO2 data.

6. We have eliminated Figure 10 of the original manuscript to avoid speculative discussion.

Individual responses to the two Referees' comments are listed below.

Reply to Referee #2

General comments:

- Authors compare GOSAT TIR CO2 retrievals to carbon dioxide observations by CONTRAIL flights, both to vertical profiles and to level flight data. The comparison study is an important step towards improving the TIR CO2 retrieval product and should present a valuable source of information to potential users of CO2 product. However, current version of the manuscript requires revisions that are likely to alter the results and conclusion before the paper can be considered fully suitable for publication. The reported results include TIR CO2 comparison with vertical profiles around Narita airport and with level flight data observed around the world. Comparisons for Narita profiles are made with averaging kernel (AK) smoothing applied and reveal low bias (Fig. 2) with respect to CONTRAIL data in mid troposphere along with a significant random error at the range of several ppm. This part of comparison looks valid. In the following sections the TIR CO2 retrievals are compared to the level flight data, but it is done without applying corrections with averaging kernel (as presented in Eq. 5). Comparison without applying correction is, however, of a limited value for this type of remote sensing product. As authors state in multiple occasions the TIR retrieval does show strong dependence on the retrieval prior, indicating large weight of the prior in the retrieval. Potential users of

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the product for inverse modeling applications have to apply corrections themselves according to established practice, otherwise they would end up using mostly prior model simulation instead of observations by GOSAT TIR. Which is not what they intend. For the same reason there are few or no known published attempts to compare similar TIR product to level flight data that do not resolve vertical concentration profile. Accordingly, revision of the level flight part is strongly recommended. As the manuscript title suggests the comparison at UTLS level making a major contribution to the study results, a major revision is required.

Reply:

We appreciate your comments. We have seriously taken your comments, and made comparisons between TIR and CONTRAIL CME level flight CO2 data with considering TIR CO2 averaging kernel functions in the revised manuscript. As described above, we have used CarbonTracker CT2013B monthly-mean CO2 profiles (Peters et al., 2007) to assume a CO2 vertical profile at each of the CME level flight measurement locations. Then, we applied TIR CO2 averaging kernel functions to the assumed profiles to smooth them to the vertical resolution of TANSO-FTS TIR observations, and defined them as "CONTRAIL (AK)." Then, we extracted CONTRAIL (AK) data that corresponded to the TIR retrieval layers where TIR CO2 data were compared with original CONTRAIL CME data ("CONTRAIL (raw)"), and compared their averages with the TIR CO2 averages in the several layers. In Figure 5, 6, and 7 of the revised manuscript, we showed the comparison results of both the CONTRAIL (raw) and CONTRAIL (AK) CO2 data.

Specific comments:

- 1. On Page 13006, Line 19 authors state they did not apply "TIR CO2 averaging kernels to CONTRAIL CME CO2", and in the following discussion provide mostly verbal argument that skipping the correction is justified. Instead the reader would expect to see results of numerical tests supporting authors' position. For products like GOSAT

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SWIR XCO2 comparison with uncorrected values produce essentially same result, but in TIR case the value of averaging kernel is well below 1 (Fig. 9) which implies large weight of the prior in the product. As follows from Eq 5, application of the said correction with relatively small values of averaging kernel (in the order of 0.2 or less as shown on Fig 9) may attract the corrected value strongly to prior concentration, reducing difference between CONTRAIL and prior, from what is shown on Figs 6 and 7 by several times and compromising much of discussion in Section 6. From the reviewer's standpoint, revision and improvement of comparison with CONTRAIL level flight data is essential, which could be most easily done by extending the level flight data vertically using modeled or climatological profiles, and applying the averaging kernel afterwards. Importance of the correction given by Eq. 5 is emphasized by its use as a regular practice in the inverse modeling applications, where the model vs observation difference is estimated using same equation. Use of the Eq. 5 by modelers in calculating model to observation misfit effectively implies replacing the retrieval prior by model simulated profile. Comparison with uncorrected data, such as shown on Fig 7, may divert potential users from understanding strong and weak points of TIR L2 data.

Reply:

We appreciate your comments. In the revised manuscript, we have quantitatively discussed the effect of considering TIR CO2 averaging kernel functions on CO2 concentrations in the UTLS regions. Over the nine airports, we have created CO2 vertical profiles using CONTRAIL CME ascending/descending CO2 data below the tropopause and stratospheric CO2 concentrations taken from the Nonhydrostatic Icosahedral Atmospheric Model (NICAM)–Transport Model (TM) (Niwa et al., 2011), and applied TIR CO2 averaging kernel functions to the created profiles. Then, we have compared TIR and CONTRAIL CME CO2 data with and without TIR CO2 averaging kernel functions over each of the nine airports, and showed the comparison results in Figure 4 of the revised manuscript. The NICAM-TM CO2 data used in this evaluation were calculated on the basis of surface flux data that were estimated in the inverse model that introduced

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CONTRAIL CO2 data in addition to surface CO2 data; therefore, we think they are appropriate datasets to evaluate the impact of considering TIR CO2 averaging kernel functions on the CONTRAIL CME UTLS CO2 data. Furthermore, we have assumed a CO2 vertical profile on the basis of the combination of CONTRAIL CME level flight CO2 data and CarbonTracker CT2013B monthly-mean CO2 profiles (Peters et al., 2007) at each of the CME level flight measurement locations, applied TIR CO2 averaging kernel functions to the assumed profiles, and then compared the CO2 data with averaging kernels with TIR CO2 data in the UTLS regions. The CarbonTracker CT2013B CO2 data are available to the public, so that readers can refer to the dataset that we used as a CO2 climatological dataset. We have also modified Table 2 to show the latitudinal dependence of the bias of TIR CO2 data against CONTRAIL CO2 data with averaging kernels, so that it should be useful for users to correct the TIR CO2 data.

- 2. In the abstract (P12994 L24) and other locations authors mention the retrieval prior CO2 they use have several biases. Another source of retrieval biases is spectral bias. It is not clear how large is relative contribution of these two. Comparison of the TIR product made with another prior or bias corrected prior appears desirable, given contamination of the product with prior biases. Also, from the absence of the prior contributors in the coauthors list and acknowledgements one can suspect that there wasn't enough contact between prior developers and retrieval team.

Reply:

Following your suggestions, we have evaluated the effect of L1B spectral bias on retrieved CO2 concentrations in the UTLS regions by the equation of dCO2 = GCO2 dspec. GCO2 is a gain matrix for CO2 retrieval, dspec is a spectral bias vector that was created assuming that the V161.160 spectra had the same bias as V130.130 L1B spectra reported in Kataoka et al. (2014), and dCO2 is a vector of bias errors in retrieved CO2 concentrations attributable to the spectral bias. In order to evaluate the effect of a priori uncertainty on retrieved CO2 concentrations, we arbitrarily decreased a priori concentration by 1% in test TIR CO2 retrieval, and then compared the retrieved

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CO2 concentrations with those retrieved using the original a priori data. Please see the second and third paragraphs of Section 7 of the revised manuscript for further details. We had reported a negative bias seen in the a priori UTLS CO2 data with Dr. Saeki and Dr. Maksyutov who are responsible to create the a priori data for the TANSO-FTS retrieval processing, and discussed this problem with them. As you suggested, we should have acknowledged them in this paper. They have a plan to recreate a priori data for the future reprocessing of both TANSO-FTS SWIR and TIR L2 data.

Technical corrections:

- P12994 L2. The first sentence better to rewrite to avoid using construct as “thermal infrared (TIR) band . . . has been observing carbon dioxide . . .”. Clearer phrase could sound as “TANSO-FTS has been observing carbon dioxide in thermal infrared (TIR) band”. Similar wording appears later as well. Authors write on P12996 L10 “. . . (TES) has retrieved CO2 concentrations . . .”. One may argue that TES can measure or observe radiances, but retrieval would be done on the ground. The paper should be checked again to correct places with somewhat tentative language.

Reply:

We have rewritten the text following your suggestions. We greatly appreciate your suggestions.

Please also note the supplement to this comment:
http://www.atmos-meas-tech-discuss.net/8/C5689/2016/amtd-8-C5689-2016-supplement.pdf

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Interactive comment on Atmos. Meas. Tech. Discuss., 8, 12993, 2015.