Responses to reviews of "Observations of XCO_2 and XCH_4 with ground-based high-resolution FTS at Saga, Japan and comparisons with GOSAT products" by H. Ohyama et al.

Anonymous Referee #1

The manuscript by Ohyama et al. provides an overview of the measurements and activities at the TCCON station at Saga, Japan, during the first 3.5 years of operation. Like other TCCON stations, the site provides column-averaged dry-air mole fractions of CO_2, CH_4, CO, and other greenhouse gases. Setup and operation follow TCCON recommendations and standards with a notable exception: the solar tracker is protected by a glass cover instead of being outside like it is at most other TCCON sites. The TCCON observations were compared to aircraft profiles over Saga three times and agreed within expected limits. The authors also compared their data to XCO_2 and XCH_4 observations from the TANSO-FTS instrument on the GOSAT satellite and found agreement well within the uncertainties. In addition, they analyzed seasonal patterns in their observations and tried to correlate anomalies and patterns with different origins of the observed air parcels (derived from trajectory analysis).

The manuscript is solid and well written. It provides a good overview of the activities at the Saga site. However, I believe it could be improved by cutting parts that just describe standard TCCON procedures and elaborating more on issues that are special to the Saga station (see list below). In the current version, the manuscript tries to cover many things but lacks focus.

We thank you for your careful reading and constructive comments. We shortened Sect. 3.1, added the detailed explanations on the glass cover and data screening, and made a subsection that describes the aerosol-induced effects on the TANSO-FTS NIES L2 retrievals in detail. Detailed responses to your comments are included below and indicated in red. In addition, we revised our manuscript according to the comments and added some explanations for clarity. Please see our specific responses below.

Topics that should receive more attention:

- I am not so happy with this stand-alone approach for the Saga station. Japan has a relatively high density of TCCON sites and aircraft overpasses. How do your results compare to the other Japanese stations? Are the anomalies in Sec. 4.3 specific to Saga or can they also be seen at other Japanese stations?

Ishizawa et al. (2015) discussed the CH_4 variations on synoptic scale including East China and Japan areas, which were observed with the g-b FTS at Saga and Tsukuba, the GOSAT TANSO-FTS, and the g-b in situ instrument. They investigated the causes of the CH_4 variation using simulation result from the NIES transport model (Belikov et al., 2013), and stated that pressure pattern (i.e., wind pattern) produced the CH_4 variation in the East China and Japan areas during the summer seasons. This result is consistent with the present study.

In this manuscript, we focused on the Saga TCCON data and added the following sentences in Sect. 4.3: “Ishizawa et al. (2015) demonstrated that the XCH_4 variation at Saga was consistent with those obtained from the g-b FTS data at Tsukuba (36.05°N, 140.12°E) and the GOSAT TANSO-FTS data in East China and Japan areas. Additionally, on the basis of simulation output from the global atmospheric transport

model of NIES (Belikov et al., 2013), they concluded that pressure pattern (i.e., wind pattern) is attributed to the XCH_4 variation on synoptic scale including the East China and Japan areas during the summer seasons, and this statement is consistent with the facts that, in summer 2013, the types I and II of the trajectory calculations were dominant and the larger variability of XCH_4 was observed at Saga."

References:

Ishizawa, M., Uchino, O., Morino, I., Inoue, M., Yoshida, Y., Mabuchi, K., Shirai, T., Tohjima, Y., Maksyutov, S., Ohyama, H., Kawakami, S., and Takizawa, A.: Large XCH_4 anomaly in summer 2013 over Northeast Asia observed by GOSAT, Atmos. Chem. Phys. Discuss., 15, 24995-25020, doi:10.5194/acpd-15-24995-2015, 2015.

Belikov, D. A., Maksyutov, S., Sherlock, V., Aoki, S., Deutscher, N. M., Dohe, S., Griffith, D., Kyro, E., Morino, I., Nakazawa, T., Notholt, J., Rettinger, M., Schneider, M., Sussmann, R., Toon, G. C., Wennberg, P. O., and Wunch, D.: Simulations of column-averaged CO_2 and CH_4 using the NIES TM with a hybrid sigma-isentropic (σ-θ) vertical coordinate, Atmos. Chem. Phys., 13, 1713-1732, doi:10.5194/acp-13-1713-2013, 2013.

- Saga is the only station in the TCCON network that uses a glass cover. There should be more on how this cover affects the retrieved spectra and how this effect is corrected.

We added the following sentences: "To indicate the effect of the glass cover on the measured spectra and retrieved values, we show the measured spectra (Fig. S1) and the retrieved XCO_2 values (Figs. S2 and S3) before and after the glass cover was installed. These data were acquired at the JAXA Tsukuba Space Center (36.01°N, 140.13°E), Japan, in June 2010, before the instruments were located at Saga. Figure S1 indicates

that the glass cover did not cause a significant fringe pattern on the measured spectra. Figures S2 and S3 indicate that a bias and degradation in XCO_2 were not observed and that the effect of the glass cover on the XCO_2 retrieval is negligibly small."

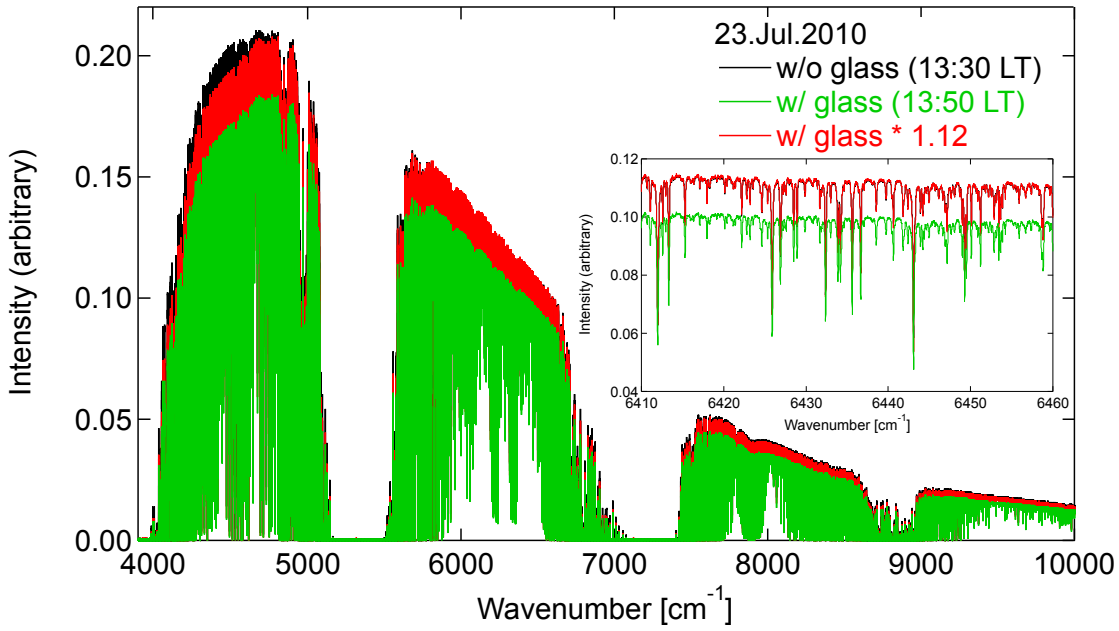


Figure S1. The solar absorption spectra measured without glass (black) and with glass (green) at Tsukuba, Japan, on 23 July 2010. The spectrum with glass multiplied by 1.12 (red) is also shown. The inset shows expansion of a portion of the spectra.

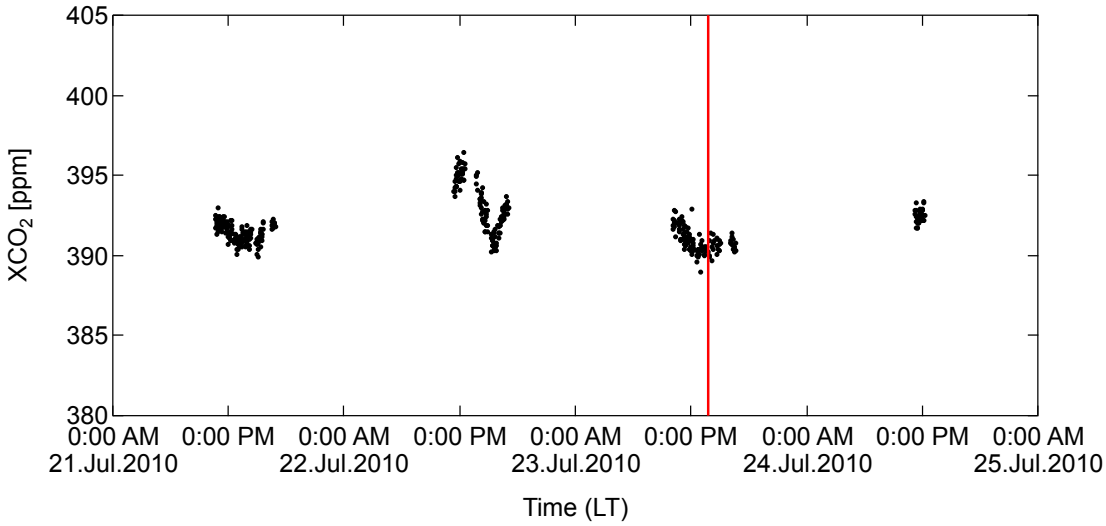


Figure S2. The XCO_2 values observed with our instrument at Tsukuba, Japan, in July 2010. Red line indicates a time when the glass cover was installed.

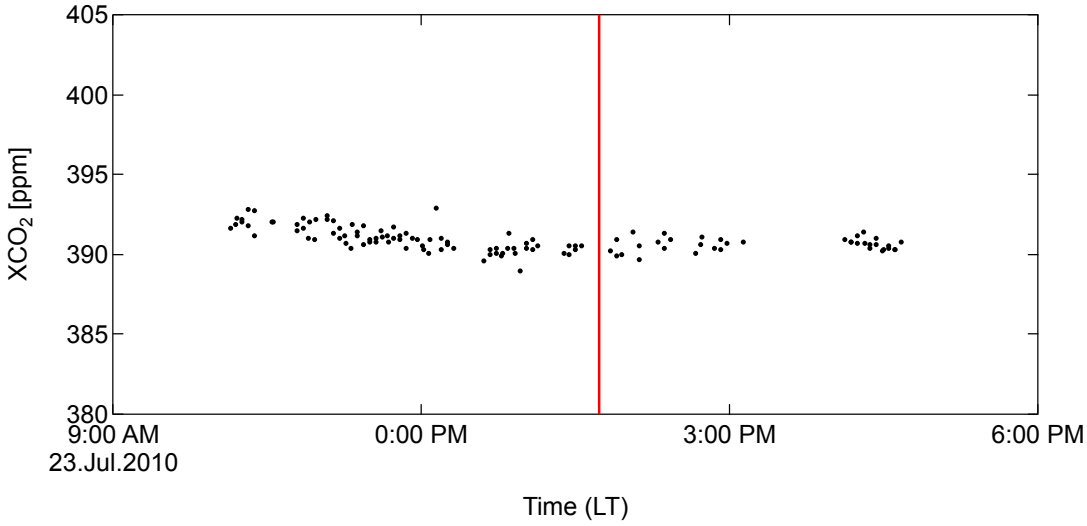


Figure S3. Same as Fig. S2, but for only 23 July 2010.

- I think one of the most important features of the Saga station is the availability of aerosol profile observations from a lidar instrument. This is quite unique in the TCCON

network. The analysis of the aerosol-induced effects deserves its own section or at least subsection.

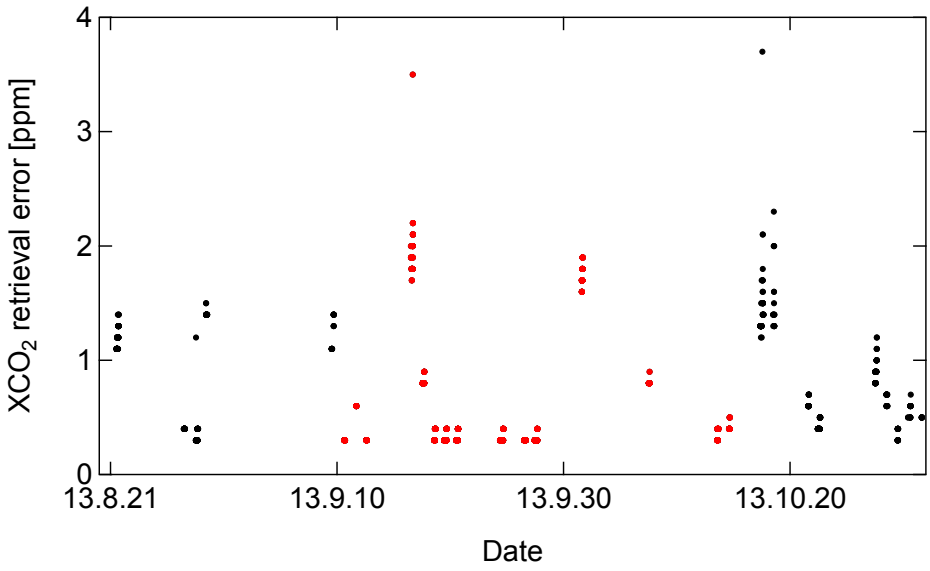
We made a new subsection "4.5 Particulate effects on the TANSO-FTS NIES L2 retrievals" in the revised manuscript. Please also refer to the response to the general comment of Referee #2.

Minor issues:

- Section 2.1 (p. 8262, l. 26-27): do you keep the pump running during the measurements? Most TCCON sites prefer not to in order to avoid vibrations from the pump influencing the measurements.

At present, we keep the pump running during the measurements. We investigated the effect of the pump on the measurement by checking the retrieval errors in the GGG2014 output, which are mainly based on fitting residual (i.e., spectral noise). If the retrieval errors during operation of the pump are larger than those during non-operation, we consider the effect of the pump is significant. During the period from 10 September 2013 to 14 October 2013, the pump was stopped due to mechanical trouble. The figure below indicates the retrieval errors of XCO_2 in August to October 2013, and the retrieval errors during operation or non-operation of the pump were almost equivalent.

In either case, in the future, we have a mind to stop the pump during the measurement according to your advice.



- Section 2.3: looking at Fig. 1, I find that the variations in modulation efficiency are not that small. The more or less continuous loss from July 2011 to July 2013 is more or less expected (slow degradation of initially optimal alignment). But what happened after that?

An instrumental change during that period was a replacement of the Si diode detector with the new one at the end of August 2013, but this would not affect the HCl cell measurements using the InGaAs diode detector. Although we can not exactly mention the causes of the variation in modulation efficiency, a small change in an arrangement of the cell might affect the cell measurement.

- Section 3.1: is there any difference in your described procedure compared to standard TCCON/GGG operation? If not, the whole section could be shortened.

Sect. 3.1 was shortened by removing several sentences.

- Section 3.2: the 0.1 Hz resolution of your pyranometer should be good enough to detect solar intensity variations (SIV) for data screening. Most TCCON sites only use 1 Hz data from the solar tracker quadrant diode to accomplish the same task. However, I have my doubt that a global radiation measurement from a pyranometer is a good way to detect SIV. A small cloud passing in front of the sun will only have a very small effect on global radiation (if at all). That is why the quadrant diode signal (which is a proxy for direct solar radiation) is probably a much better indicator - even at a low sampling rate.

Although we agree that the solar tracker quadrant diode signal is one of the most useful indicators of the solar intensity variation (SIV), we used the pyranometer signal as a substitute for the quadrant diode signal for a technical reason. Even though the threshold of the SIV from the pyranometer signal was changed from 5% to 2% (to investigate the effect of the low sensitivity of the pyranometer on a small cloud passing), bad quality data remain. We therefore consider that the low sampling rate of once every 10 s would affect the data screening using the SIV. Please also refer to the response to the technical comment of Referee #2.

- Section 3.2 (p. 8265, l. 19-24): did I misunderstand something? Are the PVC side walls of the solar tracker dome transparent?

Transmittance of the PVC used in this study is approximately 65% around 1.6 μm, which was roughly estimated from the continuum levels of spectra obtained through the glass cover (SZA <70 degrees) and the PVC (SZA >70 degrees).

- Section 4.1: please be more explicit about the results from the aircraft campaign. You cite Messerschmidt et al. 2011 for CO_2 but not Geibel et al. 2012 for CH_4 - even though the profile extension errors for CH_4 are more critical due to your limited flight altitude coverage. Was Saga the only station that was overflown during these campaigns?

We added the reference: "Geibel et al. (2012)."

During the campaigns, the spiral flights over Saga and Tsukuba were performed. The method described in Geibel et al. (2012) is appropriate for determining a scaling factor common to several sites (or multiple aircraft-FTS datasets). In this paper, we intended to ensure that the TCCON common scale factors could be applied to the Saga FTS data. Therefore, only the Saga FTS data were compared with the aircraft data, in terms of validation of the Saga FTS data. The analysis based on the method in Geibel et al. (2012) using Japanese TCCON sites (Saga, Tsukuba, and Rikubetsu) data will be performed in a following paper (Inoue et al., in preparation).

- Tables 1 & 2: maximum flight altitude would be useful to compare to the tropopause height.

We added the maximum flight altitude to Tables 1 and 2.

Language:

I did not find enough typos to start a list and the manuscript will be copy-edited anyway. However, I noted that very often present tense is used to report about past events (e.g. p. 8274, sentence spanning l. 24-26).

We made changes to use present tense instead of past tense.

References:

Geibel, M. C., Messerschmidt, J., Gerbig, C., Blumenstock, T., Chen, H., Hase, F., Kolle, O., Lavrič, J. V., Notholt, J., Palm, M., Rettinger, M., Schmidt, M., Sussmann, R., Warneke, T., and Feist, D. G.: Calibration of column-averaged CH_4 over European TCCON FTS sites with airborne in-situ measurements, Atmos. Chem. Phys., 12, 8763-8775, doi:10.5194/acp-12-8763-2012, 2012.