Authors are grateful to the anonymous referee for helpful and thoughtful comments. Each comment is addressed individually below. The referee comments are indicated in green, and our responses are described in black.

Interactive comment on "Bias corrections of GOSAT SWIR XCO2 and XCH4 with TCCON data and their evaluation using aircraft measurement data" by M. Inoue et al.

Anonymous Referee #2

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In this paper the authors describe the application of an empirical method for bias-correcting the operational GOSAT XCH4 and XCO2 datasets based upon a multivariate linear regression of various geophysical retrieval parameters with the TCCON ground-based FTS data used as the reference dataset.

This paper is very well written and provides extensive details and analysis of the findings.

The main issue with this work is that the approach itself is certainly not novel or distinctly different from previous approaches as suggested in the manuscript. See for example Cogan et al., (2012) who utilise a very similar linear regression method for the University of Leicester GOSAT XCO2 data against TCCON data, in fact using many of the same regression parameters as used here. Furthermore, Guerlet, S., et al. (2013) also perform a multi-variate linear regression using TCCON data as the reference for the bias correction of the SRON GOSAT XCO2 data, including an aerosol size parameter as one of their regression variables. Neither of these previous publications are referenced at all in this manuscript which is a large oversight on the part of the authors who instead compare primarily to the different method used by Wunch et al. This work does provide a far more extensive analysis, performing the correction for both land/ocean XCO2 and XCH4 data so does provide a valuable contribution to the literature but references and discussion should be made regarding the previous work in this area, Cogan et al., (2012) and Guerlet, S., et al. (2013). Indeed, a qualitative comparison of the bias correction obtained from this work compared to previous work may be of interest and provide further understanding of the underlying effects which can cause biases in various different retrieval algorithms.

Thank you very much for your good suggestion. We added the following sentences in Sect. 1.

"Following Wunch et al. (2011b), Cogan et al. (2012) performed bias correction of GOSAT XCO_2 data retrieved from the University of Leicester Full Physics (UoL-FP) retrieval algorithm using pseudo observations based on GEOS-Chem model calculations. Guerlet et al. (2013) used XCO_2 measurements from 12 TCCON sites around the world as a reference for correction of GOSAT XCO_2 data retrieved from the Netherlands Institute for Space Research/Karlsruhe Institute of Technology (SRON/KIT) Full Physics retrieval algorithm."

In addition, we revised the sentences in Sect. 1 as follows.

"Our method has three primary differences from Wunch et al. (2011b): (1) we explicitly use TCCON data from numerous sites throughout the world as reference values for the regression analysis; (2) the regression variables and coefficients for correction of GOSAT data are determined separately for observations made over land and those made over the ocean; and (3) we perform this analysis for both XCO_2 and XCH_4."
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"Similar to Guerlet et al. (2013), we explicitly use TCCON data from 22 sites throughout the world as reference values for the regression analysis. Our method has two primary differences from the previous bias correction studies: (1) the regression variables and coefficients for correction of GOSAT data are determined separately for observations made over land and those made over the ocean and (2) we perform this analysis for both XCO_2 and XCH_4."

The following sentences were added in Sect. 3.1.

"Here, we discuss the spatiotemporal co-location criteria for calculations of the regression analyses. The ideal co-location criteria should be measurements at the same place during the same time (Zhou et al., 2016). In general, geographical co-location defines a spatiotemporal neighborhood region near the location of interest, and collects summary statistics (hereafter referred to as "geophysical co-location method", Cogan et al., 2012; Nguyen et al., 2014; Zhou et al., 2016). A disadvantage of the geophysical co-location method is that the number of matched data can become small when the spatiotemporal criteria are somewhat small. Therefore, several sophisticated methods were devised to obtain a sufficient number of co-located data. Following Keppel-Aleks et al. (2011) who implied a relationship between meridional gradients of free-tropospheric potential temperature and CO_2 concentrations in mid-latitudes over the Northern Hemisphere, Wunch et al. (2011b) used the distribution of potential temperature at 700 hPa when defining the co-location criteria in the Northern Hemisphere. Expansively, Nguyen et al. (2014) utilized a modified Euclidean distance weighted average of distance, time, and temperature at 700 hPa. Since this method is based on the fact that the distribution of potential temperature at 700 hPa is deeply related to that of CO_2 density in the Northern Hemisphere, it is hard to apply this method to defining the co-location criteria in the low latitudes over the Northern Hemisphere and in the Southern Hemisphere. In addition, this method is not applicable to XCH_4. Guerlet et al. (2013) and Lindqvist et al. (2015) were based on the distribution of XCO_2 simulated by atmospheric transport model (e.g., the region where there is a modeled XCO_2 value within ±0.5 ppm of standard deviation for the modeled value at the observation site). This can lead to much larger matched data and be applied to the entire globe including the Southern Hemisphere. However, reliable XCH_4 modeled data are hard to obtain, and the sophisticated method for XCH_4 remains to be established. In this study, five years of GOSAT SWIR V02.21 XCO_2 and XCH_4 data are used for the validation and correction. Because the number of available TCCON site has rapidly increased after the GOSAT launch, we can obtain enough matched data by the geophysical co-location method."

Based on your comment, we performed a brief comparison of the bias correction obtained from our work with previous works. However, it was hard to discuss the effects which can cause biases in various different retrieval algorithms in this study. The following sentences are added in Sects. 3.2 and 3.3.

"We here compare our results to those by other XCO_2 bias correction study. Cogan et al. (2012) showed the annual mean global difference to be reduced by about half (-1.22 ppm to -0.68 ppm) and the correlation coefficients to increase from 0.61 to 0.74. Thus, our correction method is effective for removing the biases significantly."

"The differences between corrected XCO_2 and uncorrected XCO_2 were about 2-4 ppm and less than 2 ppm in western part and eastern part of North America, respectively (Fig. 6c). This larger spatial gradient over North America is consistent with the result of Guerlet et al. (2013), though the months analyzed in their study (August and September) and our present study (July) differ."

The article would also benefit from a discussion of the potential effects of the final bias correction on flux inversions using the data (i.e. how are different sources/sinks likely to be affected), especially in regions where the bias correction is correlated to parameters such as albedo which themselves may be linked to surface type/vegetation. One example of this is the strong bias correction west-east across the US which correlates to croplands and hence will have a large effect on any carbon flux derived over the US.

We added the following sentences in Sect. 3.3.

"The differences between corrected XCO_2 and uncorrected XCO_2 were about 2-4 ppm and less than 2 ppm in western part and eastern part of North America, respectively (Fig. 6c). This larger spatial gradient over North America is consistent with the result of Guerlet et al. (2013), though the months analyzed in their study (August and September) and our present study (July) differ. This feature over North America may be due to the differences in the type and condition of vegetation which have a strong impact on the surface albedo. Finally, this can have an influence on the estimation of regional CO_2 fluxes over North America by inverse analysis."

Minor comments:
It would be useful to cite the recent Kuze et al., 2016 paper regarding the performance of the GOSAT TANSO-FTS instrument.

The following sentence was added in Sect. 2.1.
"More recently, Kuze et al. (2016) reported update on the performance of GOSAT TANSO-FTS sensor and important changes to the data product which has been made available to users."

In various places the authors refer to "horizontal distributions" but later to "latitudinal distributions". These are presumably the same thing and consistency in the usage should be checked.

Based on your comment, we decided to use "spatial distribution" when describing findings from global map (e.g., Fig. 6) and use "latitudinal distribution" when describing findings from latitudinal distribution (e.g., Fig. 7). In addition, we revised the sentence in Abstract as follows.

"Finally, we present latitudinal distributions and temporal variations of the derived GOSAT biases."
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"Finally, we present spatial distributions and temporal variations of the derived GOSAT

biases."

Figures 2 and 3. The scale used on these figures is far too large. They should be updated with appropriate scales. Furthermore, the statistics for the regression lines should be included on the plots.

In Figs. 2 and 3, we modified the scale and added statistics for the regression lines. We hope that new Figs. 2 and 3 look better.

Figure 6: This appears to show the GOSAT data plotted as individual points. The issue with plotting the data in this manner is that GOSAT performs many measurements at the same location, and overplotting them on top of each other can potentially be misleading as only the last plotted is visible. I would recommend gridding the data in an appropriate way.

Thank you very much for your good suggestion. As you suggested, GOSAT XCO_2 and XCH_4 data were binned in 5° by 5° grid elements. We hope new Fig. 6 looks better.

References:

Cogan, A. J., et al. (2012), Atmospheric carbon dioxide retrieved from the Greenhouse gases Observing SATellite (GOSAT): Comparison with ground-based TCCON observations and GEOS-Chem model calculations, J. Geophys. Res., 117, D21301, doi:10.1029/2012JD018087.

Guerlet, S., et al. (2013), Impact of aerosol and thin cirrus on retrieving and validating XCO2 from GOSAT shortwave infrared measurements, J. Geophys. Res. Atmos., 118, 4887–4905, doi:10.1002/jgrd.50332.

Kuze, A., suto, H., Shiomi, K., kawakami, S., Tanaka, M., Ueda, Y., Deguchi, A., Yoshida, J., Yamamoto, Y., Kataoka, F., Taylor, T. E., and Buijs, H.: Update on GOSAT TANSO-FTS performance, operations, and data products after more than six years in space, Atmos. Meas. Tech. Discuss., doi:10.5194/amt-2015-333, in review, 2016.