# Authors' answer to the interactive comments of anonymous referee #2 on paper Heymann et al., Atmos. Meas. Tech. Discuss., 8, 1787-1832, 2015

First of all we would like to thank the referee for the helpful comments and questions. Below we give answers and clarifications to all comments and questions made by the referee.

***Referee:*** "*Firstly, the 10 by 10 degrees collocation area used in the analysis is very crude. Not only does using such a degrees based approach put high latitude stations at a disadvantage, Guerlet et al.(2013) showed that methods that take atmospheric dynamics into account yield significantly better sampling sizes and are thus more robust. The reason why this is critical, is that by using such a large static collocation area, the collocation bias (i.e. the bias between $XCO_2$ at the TCCON site and the general collocation area) might become very significant. Therefore a matching pattern in the station to station biases between SCIA BESD and GOSAT BESD as described on page 1808 would NOT confirm, “that using the same retrieval algorithm for the evaluation of ob servations from different satellite instruments can help to make satellite-based $XCO_2$ datasets consistent”, but could merely be an expression of a quasi-identical collocation bias.*"

**Authors:** We have also tested other collocation criteria such as a 5° radius around a TCCON site (used also by Butz et al. 2011 and Guerlet et al. 2013) and a 350 km radius. Table S1 and S2 in the supplement show the summary statistics of the comparison of the individual data points and the daily means for all three collocation criteria (10°x10° box, 5° radius and 350 km radius). The results for all three criteria are very similar and the conclusions remain the same. As we found the largest amount of collocations using the 10°x10° box we decided to use this criterion. To clarify this in the manuscript, we have added the following paragraph to the methods part of the intercomparison section:
"We have also tested other collocation criteria such as a 5° and 350 km radius around the TCCON sites. The results of the intercomparison of the data sets using these collocation criteria have been similar to the 10°x10° box (see Tab. S1, S2 and S3 of the supplement). For the results presented here we have decided to use the 10°x10° box criterion as it provided the largest amount of collocated data points."

***Referee:*** "*Secondly, when analyzing the consistency between GOSAT and SCIAMACHY BESD, the authors limit themselves to the TCCON collocation areas. This makes no sense. The TCCON network is very sparse and unevenly distributed around the globe. Furthermore Reuter et al. (2013) showed that differences between different $XCO_2$ retrieval algorithms are fairly small at these TCCON sites, while they are substantial over regions that are not (yet) covered by TCCON, such as the Amazon rainforest. Therefore, the investigation of the potential reduction of the bias between GOSAT and SCIAMACHY by using the same algorithm, a key selling point for GOSAT BESD, should take a global look at the data.*"

**Authors:** We agree that it would be good to present an extended performance evaluation. We have therefore added a comparison with CarbonTracker to get additionally a more global view on the consistency of the data sets. For this purpose, two figures and the following section have been added to the manuscript:

"In addition to the comparisons with TCCON, we have also compared the BESD data sets with the model results of CarbonTracker. For this purpose, we have used data of two months in 2011: We selected May where the atmospheric $CO_2$ concentration in the northern hemisphere peaks and August where it reaches its minimum.

CarbonTracker is NOAA's modelling and assimilation system and has been developed to estimate global $CO_2$ concentrations and $CO_2$ surface fluxes (Peters et al., 2007). We use CarbonTracker version CT2013B downloaded from http://carbontracker.noaa.gov. Global monthly maps of GOSAT BESD, SCIAMACHY BESD and CarbonTracker $XCO_2$ have been generated in a grid of 5°x5°. All grid boxes with less than 15 measurements have been excluded to achieve robust results. A global mean offset has been added to GOSAT BESD (1 ppm) and SCIAMACHY BESD (0.4 ppm) to better compare the differences to CarbonTracker. From the intercomparison of the global maps the mean difference, the standard deviation of the difference and the correlation coefficient between the data sets have been computed.

Figure 6 shows the comparison results for May 2011. The GOSAT BESD, SCIAMACHY BESD and CarbonTracker maps show a similar strong latitudinal dependence of $XCO_2$ with high $XCO_2$ in the northern hemisphere and low $XCO_2$ in the southern hemisphere. The number of grid boxes filled with sufficient observations is larger for SCIAMACHY than for GOSAT BESD. In comparison to CarbonTracker, GOSAT BESD as well as SCIAMACHY BESD has a small mean difference (GOSAT: 0.06 ppm; SCIAMACHY: −0.18 ppm) and a similar standard deviation of the difference (~ 1.2 ppm). The correlation coefficient between the BESD data sets and CarbonTracker is similarly high (~ 0.9). The direct comparison between GOSAT BESD and SCIAMACHY BESD shows a mean difference of 0.38 ppm, a smaller standard deviation of the difference of 0.95 ppm and a similar correlation coefficient ($r = 0.92$) as compared to the difference to CarbonTracker.

The results for August 2011 are shown in Fig. 7. The northern hemispheric carbon uptake in this time period explains the low $XCO_2$ values in the northern hemisphere shown in all three datasets. The number of grid boxes is again larger for SCIAMACHY compared to GOSAT BESD. The comparison with CarbonTracker shows for SCIAMACHY a small offset (0.32 ppm). The standard deviation of the difference is somewhat smaller for GOSAT (1.06 ppm) as compared to SCIAMACHY BESD (1.32 ppm) and the correlation coefficient is high for both (GOSAT: 0.84; SCIAMACHY: 0.87). The direct comparison of the BESD data sets shows a smaller/similar standard deviation of the difference (1.06 ppm) and has a similarly high correlation coefficient (0.87) as obtained for the comparison with CarbonTracker.

We have also investigated other months of 2011 and found similar results as for May and August. The remaining differences between GOSAT and SCIAMACHY BESD are likely due to the non-perfect spatial and temporal collocations and a non-perfect BESD algorithm. However, the smaller/similar differences of the BESD data sets as compared to CarbonTracker are another indication for the high degree of consistency between GOSAT and SCIAMACHY BESD."

***Referee:*** "*p1801, line 19: I don't see a collocation criteria based on altitude, nor do I see any methodology described on page 1802 on how to deal with strong differences in altitude. This is something that needs to be addressed given the inclusion of the Izana (2370m a.s.l.) TCCON site.*"

**Authors:** We have included measurements from the Izaña TCCON station for the sake of completness. The comparison results for Izaña have not been used for the computation of the summary statistical values shown in Tab. 5, 6 and 7 as the number of collocations is limited. Nevertheless, we have added the following sentences to Sec. 6.3.1: "The comparision results at the Izaña TCCON site should be interpreted with care as some of the collocated GOSAT data could be measured over scenes with large altitude difference to the Izaña site (altitude of 2.37 km)."

***Referee:*** "*p1804, line 1: ...coefficient on the length of the...*"

**Authors:** Done.

***Referee:*** "*p 1805 line 13: becomes better*"

**Authors:** Done.

***Referee:*** "*Table 4: add altitude of TCCON sites*"

**Authors:** Done.

***Referee:*** "*Figures 5,6 and 8: The statistical parameters in the plots are too small and already featured in the tables*"

**Authors:** We have moved Figures 5, 6 and 8 to the supplement.

**References**


- *Butz, A., Guerlet, S., Hasekamp, O., Schepers, D., Galli, A., Aben, I., Frankenberg, C., Hartmann, J.-M., Tran, H., Kuze, A., Keppel-Aleks, G., Toon, G., Wunch, D., Wennberg, P., Deutscher, N., Griffith, D., Macatangay, R., Messerschmidt. J., Notholt, J. and Warneke, T.: Toward accurate $CO_2$ and $CH_4$ observations from GOSAT, Geophys. Res. Lett., 38, L14812, doi:10.1029/2011GL047888, 2011.*

- *Guerlet, S., Butz, A., Schepers, D., Basu, S., Hasekamp, O., Kuze, A., Yokota, T., Blavier, J.-F., Deutscher, N. M., Griffith, D. W. T., Hase, F., Kyro, E., Morino, I., Sherlock, V., Sussmann, R., Galli, A. and Aben, I.: Impact of aerosols and thin cirrus on retrieving and validating XCO2 from GOSAT shortwave infrared measurements, Journal of Geophysical Research, Vol. 118, Issue 10, pp. 4887-4905, doi:10.1002/jgrd.50332, 2013.*

- *Peters, W., Jacobson, A. R., Sweeney, C., Andrews, A. E., Conway, T. J., Masarie, K., Miller, J. B., Bruhwiler, L. M. P., Petron, G., Hirsch, A. I., Worthy, D. E. J., van der Werf, G. R., Randerson, J. T., Wennberg, P. O., Krol, M. C., and Tans, P. P.: An atmospheric perspective on North American carbon dioxide exchange: CarbonTracker, P. Natl. Acad. Sci. USA, 104,18925-18930, doi:10.1073/pnas.0708986104, 2007.*