Red : referee's comments Black : authors' answers

Referee 2#

Review of "Validation of TANSO-FTS/GOSAT XCO2 and XCH4 glint mode retrievals using TCCON data from near-ocean sites" by M. Zhou et al. General comments: This paper describes an intercomparison of the GOSAT XCO2 and XCH4 retrievals from NIES v02.21, SRFP v2.3.5, SRPR v2.3.5, and ACOS v3.5 algorithms with FTIR measurements in five TCCON stations. In particular, the authors focus on the validation of the GOSAT sun glint data over ocean. This is an interesting subject, and the writing is clear. However, I would advise that the manuscript be revised thoroughly before publication. Specific suggestions and comments are given below.

We want to thank the referee for the detailed analysis of our paper.

Major comments:

[1] p10905, line18: "The co-location area is finally set as ±5 latitude ±15 longitude around each TCCON site. Within this co-location box, we do not detect any significant latitude or longitude dependent bias for XCO2 and XCH4." Previous studies have validated the GOSAT data retrieved within ±2 latitude/longitude box or 5 latitude/longitude radius of respective TCCON sites (e.g., Butz et al., 2011; Yoshida et al., 2013). Please add an explanation why the co-location area was set as ±5 latitude ±15 °longitude in this study. I would show the latitudinal and longitudinal variations of GOSAT XCO2 and XCH4 in the co-location box quantitatively. Moreover, can the authors compare the validation results in this study to those in previous validation studies over land in Sect. 4 Results?

This is a very good question. For the model group, it is very interesting to know the regional scale (1000 km × 1000 km) biases for the space-based XCO_2 measurements. Therefore, ±2 latitude/longitude box or 5 latitude/longitude radius of respective TCCON sites are usually used to do the independent calibration and validation. The reason why we choose ±5 latitude ±15 longitude box is that the sun glint data is scarce and far away from the TCCON site. If we select ±2 latitude/longitude box or 5 latitude/longitude radius of respective TCCON sites, quite few glint data was located in such area. Following is one example for the SRFP XCH_4 data with 4 different co-located method (within 500 km; 1000 km; 5 latitude/15 longitude and potential temperature at 700hPa with 2K criteria). Figure 1 show the co-located footprints around 4 TCCON sites, and the numbers of nadir land data and sun glint data are listed in Table 1. All TCCON stations, in this paper, are located near the equator, where the XCO_2 gradients correlation with potential temperature is invalid. If we choose 500 km box or even less, the number of ocean data and near-site land data are too few to get a reliable result. It is better to keep the latitude within 500 km (about 5 °), and 1000 km (about 10 °) is too large.

Figure 2-3 show the latitude and longitude biases within ±5 latitude ±15 longitude for NIES_v02.21 XCO_2 and XCH_4 products at 5 TCCON sites (other products are similar but not shown here). We do not detect any significant latitude or longitude dependent bias for XCO_2 and XCH_4. We also tested with the Guerlet approach (Guerlet et al., 2013), and it gives more sounding matches than ±5 latitude ±15 longitude box found, but not a lot. Meanwhile, both methods come out with the similar results for the biases of the GOSAT product. Therefore, we can reliably use this spatial collocation criterion (±5 latitude ±15 longitude) to validate the GOSAT sun glint data.

Guerlet, S., Butz, A., Schepers, D., Basu, S., Hasekamp, O. P., Kuze, A., Yokota, T., Blavier, J.-F., Deutscher, N. M., Griffith, D. W., Hase, F., Kyro, E., Morino, I., Sherlock, V., Sussmann, R., Galli, A., and Aben, I.: Impact of aerosol and thin cirrus on retrieving and validating XCO_2 from GOSAT shortwave infrared measurements, J. Geophys. Res. Atmos., 118, 4887–4905, 2013.

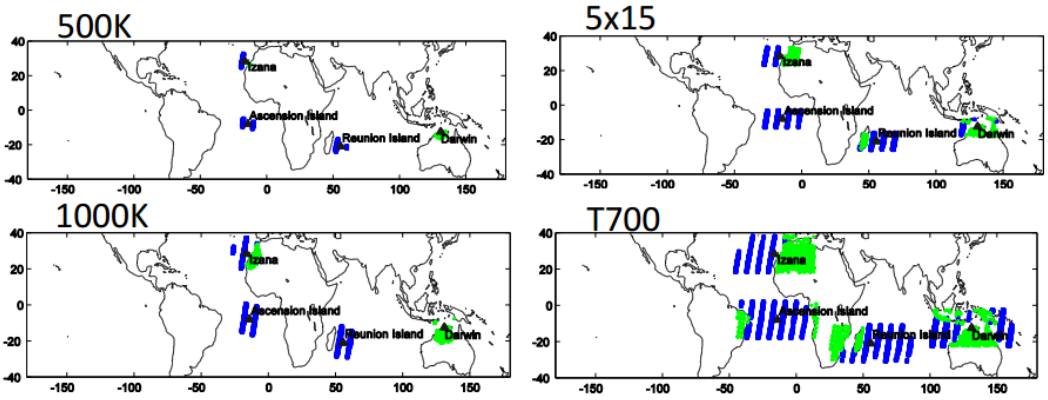

Figure1. Four TCCON stations and co-located SRPR_XCH_4 footprints from May 2009 to Dec 2013. The blue ones are glint data over ocean and green ones are normal nadir data above land.

Table 1. the numbers of SRFP nadir land data and sun glint data (in the bracket) from May 2009 to Dec 2013 with different co-located box.

station	500K	1000K	5x15	T700hPa
Izaña	282(223)	641(1979)	631(2582)	947(4793)
Ascension	150(0)	604(0)	754(0)	1877(636)
Darwin	0(1834)	4(7071)	544(5336)	4760(9760)
Reunion	165(0)	697(267)	719(906)	1385(2672)

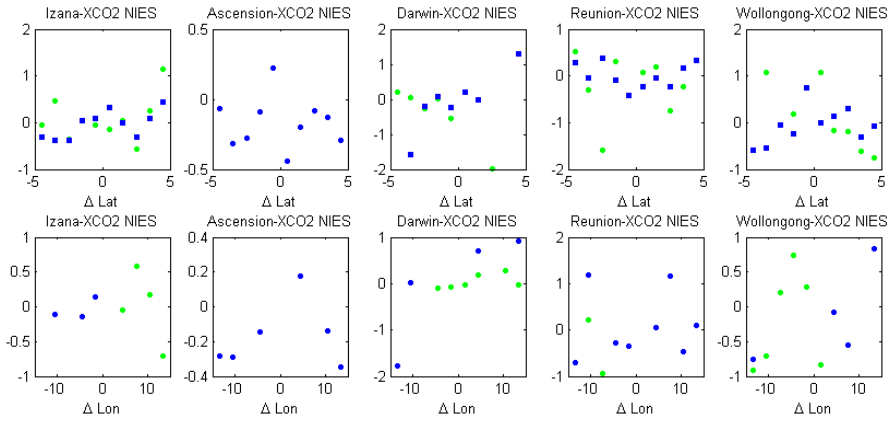

Figure 2. The latitude and longitude biases within ±5 ٩latitude ±15 ٩ongitude for NIES_v02.21 XCO2 products at 5 TCCON sites. The blue ones are glint data over ocean and green ones are normal nadir data above land.

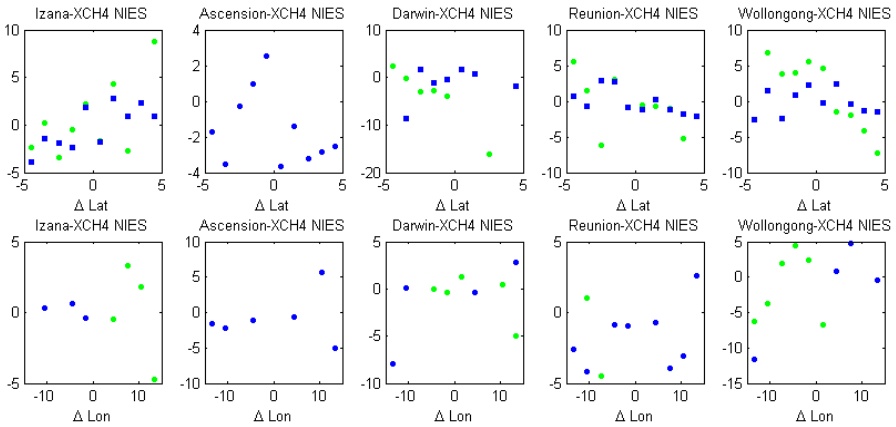

Figure 3. The latitude and longitude biases within ±5 latitude ±15 longitude for NIES_v02.21 XCH4 products at 5 TCCON sites. The blue ones are glint data over ocean and green ones are normal nadir data above land.

[2] In this study, relative bias is defined as follows. p10910, line6: "relative bias = mean(x)×100%" p10910, line8: "with x = (XTCCON −XSAT)/XTCCON" I think that the bias should be shown as "GOSAT data minus TCCON data" (not "TCCON data minus GOSAT data") because the aim of this paper is to validate GOSAT data.

Thanks for your suggestion. We change the formula as $x = (X_{SAT} - X_{TCCON})/X_{TCCON}$ and correct all the related values in this paper.

[3] p10913, line23: "4.3 Stability" I don't understand the meaning of "stability (and stable)" in this section. Does this mean that the mean biases of GOSAT data (or the difference between the three algorithms) are small during whole analysis period (2009-2013)? Please specify it. Though the authors showed annual mean biases of GOSAT glint data (XCO2 and XCH4) over ocean relative to TCCON data (Figs. 8), it is difficult for me to see temporal behaviors of the GOSAT biases. Can the authors comment on the possibility of the temporal behaviors (trend and seasonality) of the GOSAT biases over ocean, and the difference between ocean and land?

The stability here has two meanings. First, the difference of biases (mean and standard deviation) of each algorithm between 5 TCCON sites to see spatial distributions of the GOSAT biases. Second, the difference of biases between each year during analysis period (2009-2013) to see temporal behaviors of the GOSAT biases. Because the land data has already been validated by the previous studies, we only look into the stability of the ocean data in this section.

As the sun glint data only exist at specific seasons at each TCCON site, there is difficult to find any seasonality behavior. We make the Figure 8 more clear to identify the annual biases at 5 TCCON sites during analysis period. There is no obvious annual variation of the GOSAT biases according to these 5-years data.

Figure 8 shows the annual mean biases and corresponding standard deviations of the ocean data from the different algorithms and molecules at each TCCON station, based on individual co-located ocean data pairs. Almost all annual mean biases are within 1% during the measurement period 2009-2013 and the differences between adjacent years at are within 0.4% for XCO_2 and 0.7% for XCH_4 at each station. The maximum differences between each station in the same year are about 0.3% for XCO_2 and 1.2% for XCH_4. The XCO_2 ocean data from ACOS seem more

stable than the NIES and SRFP data; their biases are close to zero and the standard deviations are smaller. The XCO_2 ocean data from NIES have a systematic bias (less than the FTIR measurements), and their standard deviations are similar to those of SPFP. The stability of XCH_4 ocean data from SRFP tends to be slightly better than that from NIES and SRPR, but the biases of all three algorithms at Darwin are quite large compared with other sites in 2009 and 2010. In addition, we should keep in mind that the XCH_4 data from SRFP algorithm have the lowest data density.

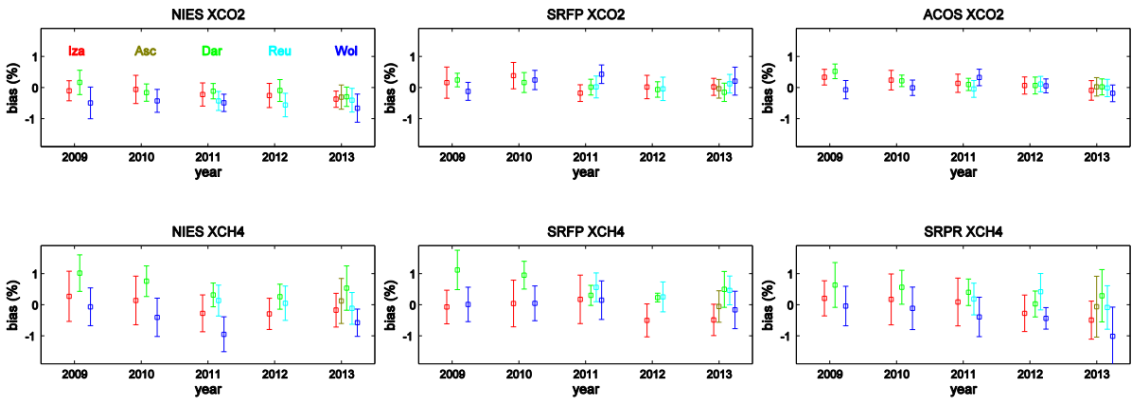

Figure 8. Annual mean bias of ocean data for each TCCON stations from different algorithms from 2009 to 2013. The error bar represents the standard deviation. Each color represents one TCCON site (red : Izaña; olive-green : Ascension Island; green : Darwin; light blue : Reunion Island; navy blue : Wollongong).

Other minor revisions:

[a] p10899, line3: "The" ---> "the"

Corrected

[b] p10902, line3: "For this paper, we have selected XCO2 and XCH4 products from the NIES v02.21, SRON/KIT v2.3.5 and ACOS v3.5 algorithms (see Table 1) with a good quality flag." Please add an explanation how the authors have selected the GOSAT data.

For this paper, we have selected XCO_2 and XCH_4 products from the NIES v02.21, SRON/KIT v2.3.5 and ACOS v3.5 algorithms (see Table 1) with a good quality flag, which is provided by each algorithm according to the spectral residual, retrieval errors and other parameters.

[c] p10903, line12: "Spurr et al., 2006" Spurr et al. (2001) in References

Corrected

[d] p10903, line21: "have been applied bias correction" ---> "have applied bias correction"?

Corrected

[e] p10904, line3: "(Yang 2002)" ---> "(Yang, 2002)"

Corrected

[f] p10904, line11: "Dohe et al. (2012)" Dohe et al. (2013) in References

Corrected

[g] p10905, line12: “mid-Tropospheric” ---> “mid-tropospheric”
Corrected

[h] p10906, line16: “CO2 profile” ---> “CO2 profiles”
Corrected

[i] p10906, line23: “Meirink et al., 2006” This is not listed in References.
Added in References

[j] p10907, line24 to p10909, line8: Please replace “P1 (or P2)” including Eqs. (3) and (7) by “P1 (or P2)”.
Corrected

[k] p10908, line13: ”we use the ECMWF interim reanalysis specific humidity (SH)” I would add the detailed information and reference of the ECMWF data used.
We add the detailed information and the following reference of the ECMWF data used.

To compute f_{H2O}^{dry} we use the 6-hour European Centre for Medium-Range Weather Forecasting (ECMWF) interim reanalysis specific humidity (*SH*), interpolated linearly in space and time to the GOSAT field-of-view, which is given as the ratio of the mass of water vapor to the mass of moist air (Dee et al., 2011)
D. P. Dee et al (2011), The ERA-Interim reanalysis: configuration and performance of the data assimilation system, Q.J.R. Meteorol. Soc., Vol. 137: 553-597, DOI: 10.1002/qj.828

[l] p10910, line9: “XTCCON(SAT)” ---> “XTCCON(SAT)”
Corrected

[m] p10917, line8: Crisp et al. (2004) is not cited in text.
Corrected

[n] p10922, line20: “Network” ---> “Network’s”
Corrected

[o] p10922, line28: Yokota et al. (2009) is not cited in text.
Corrected