We thank all reviewers for their constructive comments, which helped to improve the paper. Below, we address all comments point-by-point.

Anonymous Referee #2,

This manuscript analyses the impact of spectral resolution on the performance of a CO 2 satellite mission, which is relevant for future large-swath imaging instruments. To this end, satellite measurements from OCO-2 and GOSAT are spectrally degraded and the retrieval results are compared to corresponding results using the original spectral resolution. It is concluded from the spectrally degraded satellite measurements and from synthetic measurements that the lower resolution mainly induces a larger random error and has only little effect on the systematic error.

The manuscript covers an important topic, falls into the scope of AMT, and is well written. However, I think that a more detailed analysis is necessary to support the conclusion that a degradation of the spectral resolution does not impact systematic errors significantly. Therefore, I recommend publication after major revisions have been incorporated.

General Comments

The main concern is the discussion of the systematic errors depending on the spectral resolution.

1) The validation with the TCCON shows that the station-to-station variability (standard deviation of the local biases) is similar for the retrievals based on the degraded and original spectral resolution. However, the local biases for the MSR and original instrument at a fixed site can differ considerably (see Figures 3 and 8). Hence, the good agreement of the standard deviations may become worse when adding or removing specific sites and is possibly not representative globally. This should be discussed in the manuscript. It would be helpful to harmonise and maximise the sites used in the OCO-2 and GOSAT comparison. Is it possible to add additional high latitude sites, e.g., East Trout Lake and Eureka?

R1- Indeed, the limitation of spatial coverage of TCCON sites should be emphasized in the paper. Therefore, we added the sentences (Page 7, line 204) "The validation with TCCON measurements is limited by its spatial coverage. To compensate the spatial sparseness of TCCON sites, we start with synthetic retrievals for global ensembles."

In the study, we included as many TCCON sites as possible. We used 16 sites in OCO-2 validation and 10 sites in GOSAT validation. Some sites are not used in this study due to following reasons:

(1) limited overpass, for example, for high latitude sites and island sites. At high latitude area, satellite observations over land usually have low SNR and low Sun which has large uncertainties and has to be filtered out.;

(2) sites located within polluted or elevated areas, such as Caltech, USA and Zugspitze, Germany.

Explanations are now added at (Page 6, line 179) of "Some TCCON sites are not used in this study mainly due to following two reasons:(1) limited overpass, for example, for high latitude sites and island sites. At high latitude area, satellite observations over land usually have low SNR and low Sun which has to be filtered out; (2) sites located within polluted or elevated areas, such as Caltech, USA and Zugspitze, Germany.".

In summary, we are afraid that it is not possible to include TCCON sites like East Trout Lake and Eureka into the validation since we do not have enough good quality retrievals around those high latitude stations. In the paper, the TCCON station Sodankyla Finland (67.3668N, 26.6310E) is the one at highest latitude and so represents high latitude regions.

To compensate the limitation of the TCCON comparison, in the original manuscript we included the regional comparison between OCO-2 and MSR-c type retrievals in Section 4.3, although only relative differences can be studied in this manner.

2) Since the spatial representativity of the TCCON comparison is limited, the analysis of the synthetic spectra is particularly important to assess the impact of the spectral resolution on the systematic errors globally. Unfortunately, the corresponding discussion is rather short and the results are condensed to a single number "bias" in Table 3. How is this number defined? It would be very desirable to show the errors based on the global ensemble on seasonal global maps like in Butz et al. (2012) for OCO-2 and for all MSR concepts a-d to better track the impact of successive spectral degradation on the systematic error and to check if the decreased convergence rate clusters in certain regions.

R2-The bias is the mean of differences between XCO2 retrievals and truth of all the good quality retrievals. We add a sentence in the caption of Table 3 to explain the definition of the bias, "The bias and the single sounding accuracy are the mean and standard deviation of differences between retrievals and truths, respectively."

For the global error distribution maps, we added Figure 2 and 3, which include global XCO2 retrievals errors for MSR-d and OCO-2 type measurements. A paragraph is added in Section 4.1 (Page 8, line 230) to describe the comparison,

> "Figure 2 and 3 show the global XCO2 retrieval errors from the MSR-d and OCO-2 synthetic spectra for the test-1. In both cases, XCO2 retrieval errors are typically smaller than 4 ppm in most regions. As discussed by Butz et al. (2012), aerosol introduced uncertainties strongly depend on the concentration, the profile and the micro-physical properties of the aerosol, like size distribution and refractive index, as well as on the surface albedo. Although it is difficult to identify the exact source of retrieval errors, we see that with reduced spectral resolution MSR-d retrievals have similar error distribution and global coverage as that of OCO-2. Large errors usually occur at high latitude regions with low surface albedo or in the Sahara and Asia with seasonal high aerosol loading.".

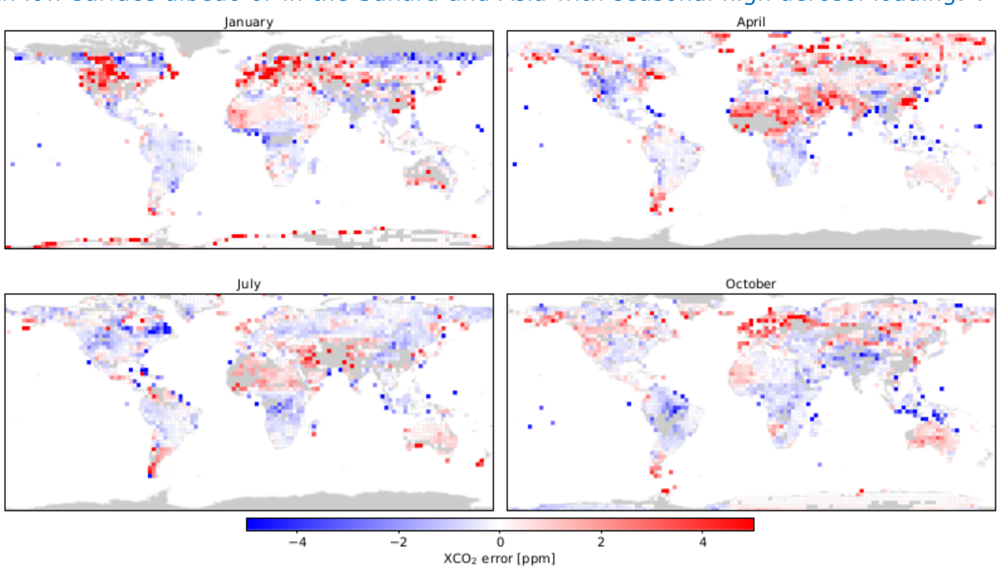

Figure 2. XCO_2 retrieval errors from MSR-d synthetic spectra in the test-1 for the global ensemble of Butz et al. (2009). Gray areas over land are not processed or retrievals do not converge.

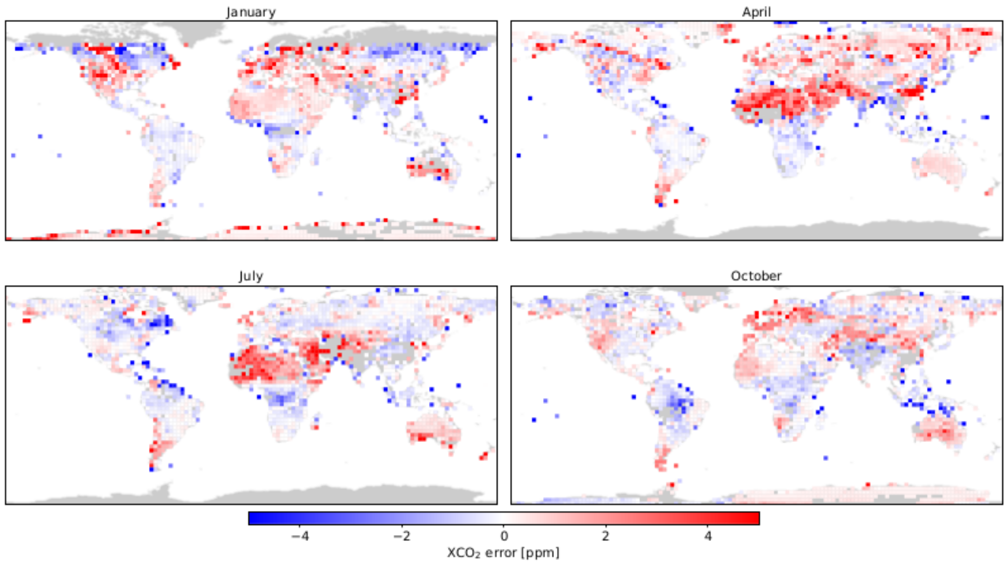

Figure 3. Similar as Fig. 3 but for OCO-2 type synthetic spectra.

See also specific comments for more details.

OCO-2 synthetic spectra

More details are needed here. Please show and discuss the seasonal global maps of the errors obtained from the ensemble for the original OCO-2 spectral resolution and for MSR-d at least for test-1. If possible, it would be very helpful to also show maps for all MSR concepts a-d as proposed in the general comments. Moreover, it would be beneficial to show an additional map in each case for a 2-band retrieval without the 2.06 µm band (MSR-e) and to extent Table 3 accordingly to verify that the spectral resolution of 0.55 of MSR-d in this band is actually useful to reduce systematic errors.

R3-Seasonal global maps of the errors are now included in Figure 2 and Figure 3 for MSR-d and OCO-2 type spectra, respectively.

The 1.6 um band is normally used for the so-called proxy retrieval (Schepers et al., 2012). For the CO2M mission, the baseline is that the 2.06 um band is available. Thus, the 2-band retrieval (NIR+1.6 um) is not discussed in the paper. However, we made a preliminary study using only the NIR and 1.6 um band for XCO2 full-physics retrieval. For the 2-band retrieval, we use the same retrieval settings for aerosol properties as that in 3-band retrievals. From the comparison shown in Fig. S1, we see that retrieval errors increase when omitting the 2.0 µm band. The standard deviation of the errors increases by more than 1.0 ppm when compared with that of 3-band retrievals. We are convinced that 2.06 um band is important for characterizing aerosol properties in the retrieval.

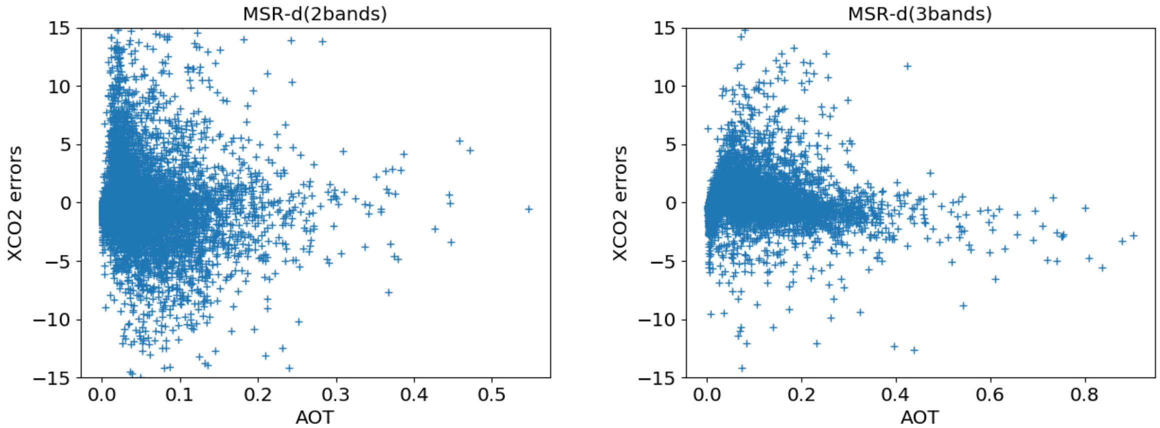

Figure S1. XCO2 retrieval error as a function of aerosol optical depth in the NIR band. The 2-band and 3-band retrieval for MSR-d concept are shown in left and right panels, respectively. The overall bias is similar in both retrievals while the standard deviation of errors is increased by more than 1.0 ppm in 2-band retrievals.

TCCON validation

Please harmonise and maximise the sites used in the OCO-2 and GOSAT comparison, if possible. Additional high latitude sites would be particularly interesting. Please also harmonise the ordering of sites in Figure 2 (arbitrarily?), Figure 3 (by latitude), and Figures 7&8 (alphabetically); I would prefer to sort the sites by latitude in all Figures. Please add and discuss bars to include all MSR concepts (a-d and ideally the proposed 2-band test MSR-e) in Figures 3 and 8 to better track the impact of successive spectral degradation.

R4- Thanks for the suggestion. We have adjusted those figures accordingly. Figure 2 and Figure 7 and 8 are now sorted by latitude. Figure 3 (Figure 5 in the revised version) is updated to include the variation of biases for all MSR concepts. Figure 8 already includes both GOSAT and MSR-d type retrievals.

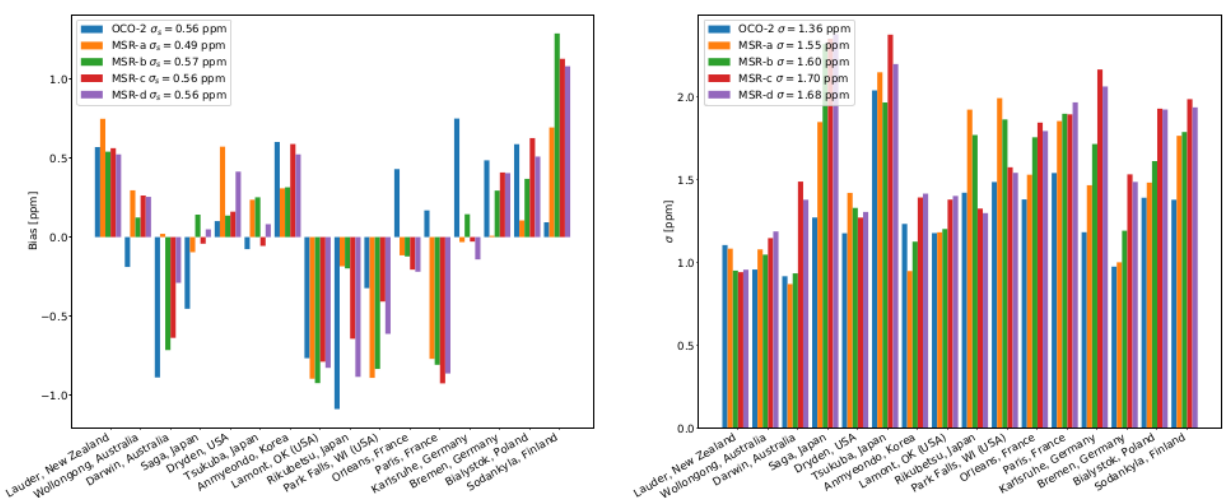

Figure 5. Bias and standard deviation (σ) at different TCCON stations for OCO-2 and MSR type retrievals. Mean biases are subtracted accordingly for OCO-2 and MSR type retrievals to show the bias variation on the same reference level. The station-to-station variability (σ_s) and single sounding accuracy (σ) is included in the left and right panel legends, respectively. Here, MSR type measurements are reproduced from OCO-2 measurements.

OCO-2 hot spot and regional gradient detection

Why is MSR-c used in this section and not MSR-d as before? Are the different averaging kernels considered in the comparisons of Figures 5 and 6? Is it possible that the 20-30% higher enhancement for the MSR-c concept in Figure 6 is due to the increased surface sensitivity of the spectrally degraded concept (see Figure 4)?

R5- MSR-c is used because at current stage the CO2M mission is considering a spectral resolution around 0.3 nm in the 2.06 um band. In the comparisons of Figures 5 and 6, averaging kernels have been taken into account and that differences in the averaging kernel leads to difference null-space contribution in the product. It is difficult to conclude if the 20-30 % difference in the enhancements come from different prior contribution or from different retrieval biases due to different spectral resolution.

Conclusions and discussion

Please adjust the conclusions concerning systematic errors depending on the spectral resolution according to the new analyses or weaken the conclusions in terms of the general comments above.

R6-The conclusions are adjusted following reviewer's comments. In the conclusion section, we added the sentences (Page 11, line 338) "The investigation using OCO-2 and GOSAT observations are limited by the spatial sparseness of TCCON sites. Therefore, we also investigated the impact of spectral resolution with synthetic spectra of global ensembles."

Is there a reference showing that the MAP instrument will actually characterise aerosol contributions in the CO_2 absorption bands well and that the XCO_2 retrieval accuracy "will benefit greatly" from its measurements? Otherwise, please weaken the conclusions by saying that the MAP instrument is aiming at reducing systematic errors.

R7- The synergistic use of a MAP and a XCO_2 spectrometer is a new research field, a corresponding study is ongoing and a manuscript in preparation. Therefore, we have weakened the conclusions in the paper.

Technical Corrections

P6, EQ7: Replace "S y =" by "S y deg ="

P6, L153: 3.29 here, but 3.3 in Table 1

P8, L230: 1.37 ppm here, but 1.36 ppm in Figure 3

P23, Table 5: Replace "SD" by "σ a "

R9-Thanks for the corrections. These is now adjusted accordingly in the paper.

References

Butz, A., Galli, A., Hasekamp, O., Landgraf, J., Tol, P., and Aben, I.: TROPOMI aboard Sentinel-5 Precursor: Prospective performance of CH 4 retrievals for aerosol and cirrus loaded atmospheres, Remote Sensing of Environment, 120, 267–276, 2012.

Schepers, D. and Guerlet, S. and Butz, A. and Landgraf, J. and Frankenberg, C. and Hasekamp, O. and Blavier, J. F. and Deutscher, N. M. and Griffith, D. W. T. and Hase, F. and Kyro, E. and Morino, I. and Sherlock, V. and Sussmann, R. and Aben, I. (2012) Methane retrievals from Greenhouse Gases Observing Satellite (GOSAT) shortwave infrared measurements: Performance comparison of proxy and physics retrieval algorithms. Journal of Geophysical Research. Atmospheres, 117 (D10).