Atmospheric
Measurement
Techniques
Discussions

Interactive comment on "Background CO_2 levels and error analysis from ground-based solar absorption IR measurements in central Mexico" *by* Jorge L. Baylon et al.

Jorge L. Baylon et al.

baylon@atmosfera.unam.mx

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We are very grateful for the comments received from both reviewers and each point is addressed below individually:

Answers to comments from Referee #1

1) Is there some reference that supports the validity of comparing the total column amount of CO2, XCO2, with the in situ CO2 amount , as shown in Figure 6. I believe that when averaging kernels and error covariances are taken into account there is little valid overlap. See Rodgers and Connor, JGR, 108, 4116,

2003.

The CO_2 in situ time series in MLO is used here to characterize a global background atmosphere at 19°N latitude. The behavior of the surface concentration can be assumed to be valid as the lifetime of CO_2 is sufficient long. The following sentence was modified in lines 168-172 in order to clarify that a direct comparison between MLO (in situ) and Altzomoni (FTIR) was not sought in this exercise: "Although both data sets show a similar behavior, the intention of using MLO in this context was to investigate the relative bias between both beamsplitter ensembles with a common reference by arranging the data into bins."

The sentence in lines 203-205 was also changed to: "For comparison, the detrended diurnal cycle of the MLO data is also shown in the figure and despite that it is at a different location and corresponds to in situ measurements, it shows a similar behavior with a smaller amplitude and a minimum which occurs 3 hours later."

2) Since one of the main objectives of the work is to compare the error contributions of KBr and CaF2 beamsplitters, which of the error sources in Table 2 might have some physical justification for being different between the two beamsplitters. In Table 3 the largest differences in error for CO2 between the splitters seems to be in the noise and solar line contributions. Is there a reason for this?

Temperature and solar lines are expected to have small contributions to the errors and these differences depend mostly on the chosen ensembles, but the only error source that is expected to differ significantly because of the beamsplitter is the noise. This is due to the fact that the SNR changes with the optical set-up as it can be inferred from Figure 1. Errors due to the solar lines in the case of CO_2 are less than 0.01%, the differences in percentage in both the Statistical and the Systematic contributions

might seem big but they are rather small compared to the other sources. The following sentence was added in <u>line 125</u>: "The largest error difference between beamsplitters is expected to originate from the noise for a given ensemble, since the spectral windows used for the retrievals are measured with different signal/noise ratios (see Fig. 1)."

Minor points

Line 7 define XCO2

Done

Line 17 water vapor contributes more than any other gas to radiative forcing

The sentence in <u>lines 16-17</u> was changed to: "... contributing more than any other anthropogenic gas to the positive total radiative forcing of the Earth ..."

Line 24 it might be good to add some numbers to describe where the near infrared is, various readers may have various ideas about what is near or far (also line 90)

The sentence in <u>lines 24-25</u> was changed to: "... in the near infrared (NIR, 3,300-13,000 cm^{-1}) spectral region ..."

We also changed <u>line 90</u>: "... spectra in the mid-infrared (MIR, 200-3,300 cm^{-1}) region ..."

Line 55 /characterisitc/characteristic/

Done

Line 59 /begun/began/

Done

Line 62 /is part/has been part/

Done

Line 104 comment on how effective the removal of the baseline curvature is wrt the retrieval

The removal of the baseline curvature with the radiometric calibration has very low impact on the retrieval, the average change in the total columns of CO_2 and O_2 for three days of measurements (85 measurements) is +0.021 $\pm$ 0.00086 % and +0.0053 $\pm$ 0.00033 %, respectively. This might be due to the 20 baseline points used in the retrieval code, similar to what was recommended by Kiel et al., 2016.

<u>Lines 101-104</u> were changed to: "The baseline curvature in the spectral region around the dip introduced by the KBr beamsplitter is removed using a simplified radiometric calibration, assuming that the tungsten lamp produces a blackbody spectrum (T=1700 K) and that there is no self-emission of the optical set-up in the spectral region above 4000 cm^{-1}. This calibration has a low impact on the columns (+0.021% for CO_2, +0.0053% for O_2) due to the simultaneous fit of the baseline in the retrieval code."

Line 115 /to assess/an assessment of/

Done

Line 117 /determine where does/determining where/

Done

Line 120 /allows to/allows one to/

Done

Line 154 /ensamble/ensemble/ also in Line 168,215

Done

Line 246 <sub>2<sub> also Line 257, 287

Done

Line 254 n/a-n/a also Line 301, 310

Done

Figure 5. The reference that we found mentioning the TCCON precision goal (0.25) is Wunch et al., 2011.

The caption in Fig. 5 was changed to: "The black lines depict the existing precision goals for CO_2 found in the literature."

Answers to comments from Referee #2 (P. O. Wennberg)

Major comments:

1. As clear from the abstract and introduction, a major motivation for this work is to enable the Mexico UNAO group to develop XCO2 capability and join TCCON. I thus suggest that the group expand the scope of this investigation to include processing of their spectra (at least the ones obtained with the CaF2 beamsplitter) using the standard TCCON processing code. Both Hase and Blumenstock

run TCCON sites and are thus fully versed in the mechanics of assisting in this extension of scope. Given the clear desire of Baylon et al to join the network, such a modest expansion of scope will thus serve additionally to provide additional knowledge transfer from the KIT group to the Mexico group.

We agree with the reviewer that a site like Altzomoni, with the available instrumentation, has the potential to join the TCCON network and contribute to global carbon cycle studies. We will look into the possibilities to develop the capability in Mexico to use the community code GFIT in the near future. However, the intention of this work is to present an assessment of the precisions of CO2, O_2 and X_{CO_2} obtained when using both beamsplitters so that we can prove the value of our measurements and use this data with confidence for reporting and analyzing X_{CO_2} variability in the region. This is relevant to the community since several NDACC instruments use a KBr beamsplitter and could easily add-on their capability by including an InGaAs detector in their measurement routines. Moreover, doing routine measurements with the CaF_2 beamsplitter and analyzing the data according to the TCCON guidelines would require extra resources in funding and manpower which at the moment we have in limited amounts.

2. Likely not unrelated to 1), the observed diurnal dependence of XCO2 (Fig 10) is almost certainly a result of airmass dependent bias in the retrievals. TCCON processing includes an attempt to account for such bias. Thus, I expect that the TCCON retrievals will substantially reduce the airmass dependence shown in Fig. 10 and additionally alter the seasonal structures (modestly).

This is a very valid point. At the moment we cannot provide precise evidence that an airmass dependence is not contributing to the diurnal variability which we observe (presented as an average curve in Figure 10). As shown in Dohe, 2013 and Kiel et al., 2016 when using PROFFIT as the processing code, a refined treatment of the background continuum level and, for the case of O_2 retrievals, using a detailed model

of the O_2 CIA band can reduce the airmass dependence of CO_2 and O_2 retrievals. We followed this recommendations for the analysis of our data set so we believe that an airmass dependent bias might not be responsible for all the diurnal variability of X_{CO_2} observed at Altzomoni.

The TCCON strategy fits a set of time and zenith angle dependent functions which would assume a symmetrical dependence, a correction which would not fully remove the observed daily dependence at Altzomoni (see Fig.1). This tropical mountain site is surrounded by forests covering large areas and can also be influenced by polluted air which reaches the site in the afternoon (Ochoa et al., 2012), favoring the argument that carbon capture and transport processes are dominating the diurnal variability. This is also supported by what is observed from collocated in situ CO_2 measurements.

Thus, following the reviewer's comment, we have removed the sentence in <u>line 200</u> which stated that CO_2 was lowered in average 1.5 ppm only through photosynthesis. The following sentence was added in its place: "Although a treatment of the airmass dependence for X_{CO_2} has been considered following Dohe, 2013 and Kiel et al., 2016, this may still not be fully corrected in the reported X_{CO_2}. However, a qualitative analysis correlating these observations with in situ measurements indicate that carbon capture and transport processes are responsible for most of the diurnal variability observed over the Altzomoni site."

Both topics focusing on the reprocessing with the community code GFIT and the development of an airmass correction at Altzomoni will be addressed in future studies.

Minor comment:

1. Ln 17. Changes in H2O vapor is likely close to changes in CO2 in net change in radiative feedback over past decades.

The sentence in lines 16-17 was changed to: "... contributing more than any other anthropogenic gas to the positive total radiative forcing of the Earth ..."

2. Ln 99. When the KBr UNAO spectra are processed with TCCON software, suggest using same continuum model described by Kiel et al.

Yes, we followed the recommendation of Kiel et al., 2016. See answers above.

3. Ln 185-187 Please explain more fully how the bias (DeltaCO2 = -0.030+-0.070%) is translated into the scaling factor (0.9986).

The scaling factor for XCO_2 (0.9986) comes from the fact that the bias obtained was of $+0.14 \pm 0.064$ % for KBr-CaF_2 differences.

4. Ln 200. This is (at best) a hypothesis. Given the (relatively) low biomass in the area, I'm exceedingly doubtful. (see above major comment 2).

An answer to this point is given above.

References

C. Ochoa, D. Baumgardner, M. Grutter, J. Allan, J. Fast, and B. Rappenglueck. Physical and chemical properties of the regional mixed layer of Mexico's megapolis part ii: evaluation of measured and modeled trace gases and particle size distributions. Atmospheric Chemistry and Physics, 12(21):10161–10179, 2012.

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