

## ***Interactive comment on “TCCON and NDACC $X_{CO}$ measurements: difference, discussion and application” by Minqiang Zhou et al.***

### **Anonymous Referee #2**

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Zhou et al. provide a comprehensive intercomparison between two remote sensing Fourier transform infrared (FTIR) spectrometer measurement techniques: sensing carbon monoxide (CO) in the near infrared (NIR) and mid-infrared (MIR) spectrum. They compare column average CO volume mixing ratios ( $X_{CO}$ ) at 6 sites that are a part of both the TCCON and NDACC networks. The study makes a direct comparison, as well as analyzes the impact of the uncertainty budget on the difference found between the two methods. Overall, this study presents a valuable comparison that allows for future synergy when using CO measurements from both the TCCON and NDACC networks.

The subject matter of measurement intercomparison is well within the scope of AMT. The paper meticulously describes the methodology, and draws on previous work in the field. Writing style is clear and descriptive. The study includes rigorous analysis

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and sound mathematical procedures. Subsequent to addressing and/or responding to the minor comments and clarifications below, I recommend that the manuscript be accepted for publication in AMT.

### Specific Comments:

#### *Comment 1: AirCore comparison*

Using the NDACC a priori profile in section 4.3 to extend the AirCore profile presents a circular argument. It is not necessarily surprising that the AirCore total column was higher than the TCCON total column, because the scaled NDACC a priori profile was used to "fill in the blanks".

(a) First of all, it is unclear where the "scaled NDACC a priori" (P14, L5) originates, because it is stated that Sodankylä is not an operational NDACC site (P13, L8). Please clarify how the scaled a priori is calculated - i.e. are there non-operational data available? If so, are they up to the same standard as the rest of the NDACC network?

(b) I suggest to use the TCCON a priori above the top of the AirCore measurements, perhaps scaled by the AirCore:TCCON profile difference that exists between 15 to 20 km. Figure 5 suggests that the shape of the TCCON a priori profile above 10 km might be better than the NDACC at Lauder and Wollongong. While the profile above 20 km may not contribute a large amount to the total column, it is important to remove potential bias in the comparison. Alternatively, the authors could calculate how much the "extended profile" contributes to the total column and explain why it doesn't convolute the results.

#### *Comment 2: "Low" Mean Bias for the Southern Hemisphere*

It is stated that the Southern Hemisphere has a low mean bias of 0.3% (P6, L6) and that the values "agree well" (P18, L2). I am a little nervous about how good the 0.3% seems, because it is the result of averaging positive and negative numbers. In particular, the Lauder station uses different a priori protocol than Wollongong and St Denis (P8, L25-28). If only the two latter stations are included, the Southern Hemisphere bias is 1.5%, which may be more representative. I would appreciate a small discussion of this in the

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manuscript. Perhaps it would also be useful to discuss the absolute relative error.

*Comment 3: Double-check main text values with figures and tables for consistency*

(a) Figure 1 - Bremen shows a mean difference of 6.518 +/- 7.044 ppb. This seems inconsistent with Table 4 Bremen 6.4 +/- 4.3%. (b) P16, L21-22 - the values in the data range do not match Table 6. For example, I think 2.1 to 6.1% should be 2.1 to 8.1%.

*Comment 4: Relevance of calculations on Page 10*

It was unclear to me why the systematic uncertainty was kept here (Eq. 12) while on P8, L12 it was eliminated. Also, how is the choice of optimal common a priori made to ignore the first component (P10, L10)? The comment on P12, L2-3 suggests that the first component should not be ignored. There is a missing link/clarification needed between the theory presented on this page and exactly how it relates to this study. Also, would the main text on page 10 work better inside section 4.1?

#### **Minor Comments:**

*P1, L10-11:* Reword to clarify what is meant by this sentence. For example, does this convey what is meant: "The TCCON smoothing error is significant because it is higher than the reported uncertainty".

*P2, L21:* Mention briefly why the measurements are assimilated into models.

*P3, L29 L30:* Describe acronym ATM and JPL.

*P3, L32:* Add the equation definition after the "CO total column".

*P4, Table 1:* I suggest site reference papers rather than "Research group".

*P4, L1:* What is meant my "indirectly validated" against AirCore measurements?

*P4, L11:* Please clarify why 3.0% and not 3.5% is used as the upper limitation on random uncertainty.

*P4, L12-14:* I am confused by the last sentence in section 2.1. How does it relate to WMO scaling? Was public data not used in this study?

*P5:* I suggest to swap the order of Tables 2 and 3, and move sentence line 8-9 to the end of the paragraph.

*P5, L12:* Unclear purpose for the last sentence of Section 2.2. Are the authors

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suggesting these smoothing errors be included in reported NDACC data?

*P5, Table 3 caption:* Mention that the "Total" uncertainties are calculated by adding the sub-types in quadrature. Also, why can "-" be ignored? Are they simply too small to worry about?

*P5, Fig1:* Is the seasonality in the Lauder difference plot related to that NDACC station using a different a priori than the other NDACC stations?

*P7, Table 4 caption:* I suggest to work on reducing the repetitive wording.

*P7, L4-L9:* Is the conclusion from this section that NDACC adequately accounts for SZA dependence in the retrieval algorithm?

*P11, L3:* Describe why the scaled NDACC a priori were used as common a priori, rather than the NDACC a priori.

*P11, Figure 5:* Please add uncertainty/standard deviation to the HIPPO data points.

*P11, L13-14:* Unclear why 7% (links to specific comment #4).

*P12, L8:* The 2.0% assumption on diagonal systematic bias is lower than any value presented in Table 2 - clarify why this value was chosen.

*P12, L25-26:* Discuss why the random smoothing error is larger here than in Wunch et al. (2015).

*P14, L2:* Briefly mention how diffusion inside the AirCore coil can impact the measurement, and how it is minimized.

*P14, L6-7:* How are the 3.0% and 6.0% assumed uncertainties chosen?

*P15, L13:* What is "a truncation of T511"? Does it relate to the model altitude level?

*P16, L4:* Is the CAMS model interpolated in both time and space?

*P16, L10:* Mention that fewer satellite observations improve the CAMS model at higher latitudes due to measurement difficulties, which may cause the poorer performance at Ny-Ålesund.

*P16, L13:* Mention that high locally impacted values are not expected to be captured by the model due to dilution: both temporally (6 hr compared to minutes) and spatially (40 km square compared to site location).

*P17, Figure 9:* Consider moving this to a supplement because details are in Table 6.

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**Technical Corrections:**

The paper is well written and there are only minor technical corrections.

*P1, L5:* A direct comparison shows the NDACC  $X_{CO}$  measurements...

*P1, L14:* To determine the source of the bias, regular...

*P2, L8:* ...), and biomass burning (...)

*P2, L8:* There are also small quantities of CO...

*P2, L11:* biomass burning

*P2, L13:* ...thus affects the...

*P3, L1:* Despite the similar...

*P3, L14:* ...carried out in Section 3.

*P3, L15:* ...investigated in relation to...

*P4, L13:* ...in public TCCON...

*P4, L19:* The reference spectroscopy database is...

*P5, L15:* At Northern Hemisphere stations...

*P5, L17:* At Southern Hemisphere stations...

*P6, L1:* ...dominated by biomass burning...

*P8, L1:* ...investigate the causes of the difference between...

*P8, L27:* The a priori profile...

*P9, L7:* ...is relatively clean, coming mainly...

*P9, L9:* At Bremen, the CO VMR in...

*P9, L10:* ... free troposphere, because there are strong local anthropogenic emissions (European Commission, 2013).

*P9, L16:* ...total columns correctly capture a...

*P9, Fig. 3 caption:* ...a priori profiles change every day,...

*P11, L9:* ...is the most reasonable...

*P13, L5:* ...measurements have been performed...

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*P13, L9:* ...a long coiled tube...

*P13, L10:* ...tube is transferred to a gas analyser...

*P15, L15:* The model output...

*P16, L10:* ...model at this site.

*P16, L19:* According to the AirCore measurements in Sect. 4.3, the bias...

*P18, L6:* ...data products are more consistent (5.6...

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