

Response to reviewers

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Title: “Inter-comparison of CO measurements from TROPOMI, ACE-FTS, and a high-Arctic ground-based FTS” by Wizenberg et al.

We would like to thank both reviewers for their helpful and thoughtful comments and suggestions. Reviewer comments are in blue, author responses are in black, and any additions to the text are underlined. The line and page numbers provided correspond to the version of the manuscript available on AMTD.

Responses to Reviewer #1

Comment C1.1 – L50: add TES +reference

Reply: Reference has been added for TES: “The TROPOspheric Monitoring Instrument (TROPOMI) provides the highest spatially resolved measurements of CO from space currently available, and is extending the global CO record established by previous satellite instruments including Measurements of Pollution In The Troposphere (MOPITT; Drummond and Mand, 1996), the Tropospheric Emission Spectrometer (TES; Beer et al., 2001), the Atmospheric Infrared Sounder (AIRS; Chahine et al., 2006) , the Infrared Atmospheric Sounding Interferometer (IASI; Clerbaux et al., 2009), and the Cross-track Infrared Sounder (CrIS; Han et al., 2013).”

Comment C1.2 – L85: methodology used for comparing each instrument IS described

Reply: This has been corrected: “...and the methodology used for comparing each instrument is described in Sect. 3.”

Comment C1.3 – L221: add units of CO reference profiles

Reply: We have added the units of the CO reference profiles to the text: “First, however, the CO reference profiles (provided in units of mol mol⁻¹ with respect to dry air) must be converted to partial columns, and then summed to obtain the total column concentration...”

Comment C1.4 – L265: null-space error e_n (also known as the smoothing error). Why not prefer the smoothing error? You should add the Rodgers reference. If you want to use the null-space error, you have to explain why. You give references of different studies but we need explanations.

Reply: We agree with the reviewer and we have changed all references to “null-space error” in the text to “smoothing error” as this is more common terminology. The notation used to denote this error has also been changed from e_n to $e_{\text{smoothing}}$ throughout the text.

Comment C1.5 – L285: In the following section describes.. Remove “In”

Reply: This has been corrected: “~~In~~The following section describes the methods used to compare the TROPOMI and PEARL-FTS datasets.”

Comment C1.6 – L300: A is the VMR averaging kernel > A is the VMR/VMR averaging kernel (A is unit less). Same thing in L343.

Reply: We have implemented this suggestion on Pg. 11, L300: “...where I is the identity matrix, A is the unitless VMR/VMR averaging kernel of the PEARL-FTS...”, and on Pg. 12, L343: “ACE-FTS VMR profiles are then smoothed using the VMR/VMR averaging kernel A of the PEARL-FTS using a similar form to Eq. 6...”

Comment C1.7 – L328-330: What reference should you give when talking about sensitivity ? Rodgers 2000? Rodgers and Connor 2003? As already said, you mention a work published in a paper “following xx et al.”. You should be more specific and cite the proper reference for terminology.

Reply: We believe Rodgers (2000) is the correct reference for the concept of retrieval “sensitivity”, as this concept is introduced on Pg. 46 of Rodgers (2000). We have added a reference to Rodgers (2000) to Pg. 9, L250 where we first define sensitivity: “However, since ACE-FTS performs solar occultation measurements, a sensitivity (i.e., the ratio of information coming from the measurement versus the information from the a priori as defined by Rodgers (2000))”.

We have also added a reference to Rodgers (2000) on Pg. 12, L328: “To achieve this, the sensitivity of the retrievals (as defined by Rodgers (2000)) at each level k was first computed by summing the corresponding rows of the averaging kernel matrix, $\sum_i A_{ki}$, following the method of Vigouroux (2008).”

Comment C1.8 – L362: SEM. Define (to understand the difference with standard error and standard deviation) and justify your choice for using SEM. Make uniform notation.

Reply: We acknowledge that SEM (i.e., standard error of the mean) was not properly defined in the text, and also that using “SEM” in the text might have been confusing and is not a commonly used abbreviation. To make things clearer, SEM was changed to “standard error of the mean” throughout the text to avoid confusion. Pg. 14, L362: “with a small mean bias of $-3.70 \times 10^{15} \pm 1.37 \times 10^{15}$ molec. cm^{-2} (-0.68 ± 0.25 %; bias \pm ~~SEM~~standard error of the mean)...”.

Furthermore, to differentiate the standard deviation and the standard errors of the mean, and to explain why both are reported in the comparisons, we have added a sentence to the end of §3.2 briefly describing the differences. Pg. 10, L281: “For each comparison, we provide the standard deviation of the differences σ_{bias} as a measure of the spread in the observed differences as well as the standard error of the mean, defined as $\sigma_{\text{bias}}/\sqrt{N}$ with N the number of collocations, as a metric for the statistical significance of the reported bias.”.

Comment C1.9 – Caption of Table 3: “standard deviations of the differences” in the first sentence. “standard error of the mean” in the last sentence. It is confusing. The caption should be reformulated.

Reply: We have modified the caption of Table 3 to make it less confusing and to differentiate the standard deviations of the differences from the standard errors on the means a bit more clearly: “Summary of the number of collocations, the mean partial column differences, and the standard deviations of the differences between ACE-FTS and TROPOMI globally, and in each latitude region. The relative bias and standard deviation values are computed with respect to ACE-FTS (i.e., $100 \times (\text{TROPOMI} - \text{ACE-FTS}) / \text{ACE-FTS}$). The uncertainties provided for the absolute and relative biases ~~corresponds to~~ are the standard errors ~~of~~ on the means.”

Comment C1.10 – L481: coming from the measurement IN this range?

Reply: We have implemented this correction on Pg. 22, L481. However, it should be noted that due to a suggestion by reviewer #2, the altitude range of the partial column comparison between ACE-FTS and the PEARL-FTS has now been extended from 10.25-40.17 km to 9.33-66.58 km, which has led to an increase in the partial column DOFS from 0.55 to 0.72. The text now reads as follows (Pg. 22, L480-481): “...however a DOFS of ~~0.55~~ 0.72 implies that there is approximately a ~~third-quarter~~ of the total vertical information coming from the measurement in this range.”

Comment C1.11 – L487: “do not overlap within their bounds of uncertainty on the standard error” Not clear, please reformulate

Reply: Similar to our comment above, the altitude range of these partial column comparisons has been extended, and now the results fall within the bounds of standard error on the mean from Griffin et al. (2017), so the original sentence has largely been altered. The new sentence is now (Pg. 23, L486-481): “Although the ACE-FTS and PEARL-FTS retrievals have each been updated in the meantime since this earlier study, the findings presented here are within the range of the standard errors on the mean of those from Griffin et al. (2017) indicating reasonable agreement.”

References

Beer, R., Glavich, T. A., and Rider, D. M.: Tropospheric emission spectrometer for the Earth Observing System's Aura satellite, *Appl. Opt.*, 40, 2356–2367, <https://doi.org/10.1364/AO.40.002356>, <http://ao.osa.org/abstract.cfm?URI=ao-40-15-2356>, 2001.