Responses to Review #1

We appreciate your comments. Please find our responses below. Line numbers refer to the manuscript as submitted for the discussion phase.

Interactive comment on “1.5 years of TROPOMI CO measurements: Comparisons to MOPITT and ATom” by Sara Martínez-Alonso et al.
Anonymous Referee #1
Received and published: 6 April 2020

General Comments:
The authors provided a validation for the TROPOMI CO observations by using MOPITT and Atom CO measurements. I found the paper is well written. The authors demonstrated good agreement between TROPOMI and MOPITT CO observations, which is helpful for people who are interested in the sources and variations of CO from global to regional scales. I recommend the paper for publication after consideration of the minor points below.

Specific Comments:
1. Lines 154-160: It is difficult to follow this paragraph. I checked Section 2 again but didn’t find the details to support the direct comparison without transformation. It would be better to provide more details here.

Thank you for this comment. New text and two tables with results from an additional analysis have been included in the manuscript to 1) better justify the direct comparisons without transformation and 2) investigate the effect on biases of the differences between MOPITT *a priori* CO profiles and TROPOMI reference CO profiles. New Section 3.1 discusses in more detail the differences between the MOPITT and TROPOMI CO retrieval algorithms, as well as the challenges these differences impose when comparing the two datasets. New Section 3.3.1 discusses the main sources of error in satellite CO retrievals; it also discusses sources of error when comparing satellite datasets, e.g., differences in *a priori* information used by each dataset and differences in vertical sensitivity (represented by the averaging kernels, or AKs) between instruments.
Determining whether or not observed differences in retrievals from these two instruments are consistent with differences in their *a priori*, AKs, and instrument noise would require knowledge of the true atmosphere during observation; this information is often unavailable, here included. Our main goal in comparing MOPITT and TROPOMI total CO column retrievals is to quantify differences between the two retrieval products available to users, rather than quantify the actual bias of either product. This goal is addressed by direct “end to end” comparisons of the two untransformed products in various regions of interest, after colocation of the MOPITT and TROPOMI retrievals. These comparisons quantify the MOPITT/TROPOMI difference statistics due to all effects: AK differences, *a priori* differences, and instrument noise.
Additionally, we now investigate the effects of differences between the *a priori*/reference information used by MOPITT and TROPOMI in their retrievals; we do so by applying a null-space adjustment (based on the MOPITT *a priori*) to TROPOMI. We present results from this additional analysis in Sections 4.1.4 and 4.2.3 and show that differences in *a priori*/reference CO profiles affect MOPITT/TROPOMI relative biases by 1-2 percentage points, well below TROPOMI’s required 15% accuracy.

2. Section 4.1. The comparison between TROPOMI and MOPITT is very interesting. I have some suggestions, which may be considered in this work or the following study: 1) The differences between two datasets show obvious seasonal variabilities. What are the possible explanations? We thank you for this observation. The following text has been added to address this point (line 363): "There appears to be a seasonal component in MOPITT/TROPOMI bias values in the two hemispheric ROIs and Australia. Polluted ROIs (USA, Europe, India, China) and the Sahara do not seem to be affected (Fig. 3, 4, and 5). Biases between MOPITT and null-space adjusted TROPOMI retrievals show the same seasonal component, indicating that it is not caused by the MOPITT *a priori*. The seasonal variability of MOPITT has been validated in the past using ground-based measurements. In their comparison to NDACC data (Network for the Detection of Atmospheric Composition Change; De Maziere et al., 2018), Buchholz et al. (2017) found no significant seasonally dependent bias for MOPITT products. Hedelius et al. (2019) compared MOPITT to the TCCON dataset, reporting no persistent seasonal trend globally and some seasonal variability for individual sites. Further work will be needed to identify the origin of a possible seasonal component in MOPITT-TROPOMI bias values." 2) We know that MOPITT show some latitude-depended differences relative to surface and aircraft measurements. Do the differences between TROPOMI and MOPITT have similar latitudinal dependence? It has, indeed, been shown that V7 MOPITT TIR products exhibited a latitudinal dependence in partial CO column biases; the latitudinal dependence in total column biases was less prominent (see Fig. 2 from Deeter et al., 2019, shown below). This latitudinal dependence of biases could have been caused by issues in modeled water vapor absorption in the MOPITT TIR passband (Edwards et al., 1999) or accuracy of water vapor data used in the MOPITT retrieval (Pan et al., 1995; Wang et al., 1999). According to Deeter et al. (2019), "MOPITT V8 biases […] do not exhibit a clear latitudinal dependence"; this is particularly the case for total column values (see Fig. 6 from Deeter et al., 2019, shown below). Enhancements in the V8 retrieval algorithm addressing this issue include updated spectroscopic information used by the radiative transfer model and improved radiance bias correction. We have added wording to the MOPITT description section to clarify this point (page 5, line 116): "Here we use daytime archive MOPITT data from version 8 (Deeter et al., 2019); among other improvements, V8 products do not exhibit a latitudinal dependence in partial CO column biases observed in V7."

References

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Wang, J., Gille, J. C., Bailey, P. L., Drummond, J. R., and Pan, L. (1999) Instrument sensitivity and error analysis for the remote sensing of tropospheric carbon monoxide by MOPITT, J. Atmos. Ocean. Tech., 16, 465–474, https://doi.org/10.1175/1520-0426(1999)016%3C0465:ISAEAF%3E2.0.CO;2.

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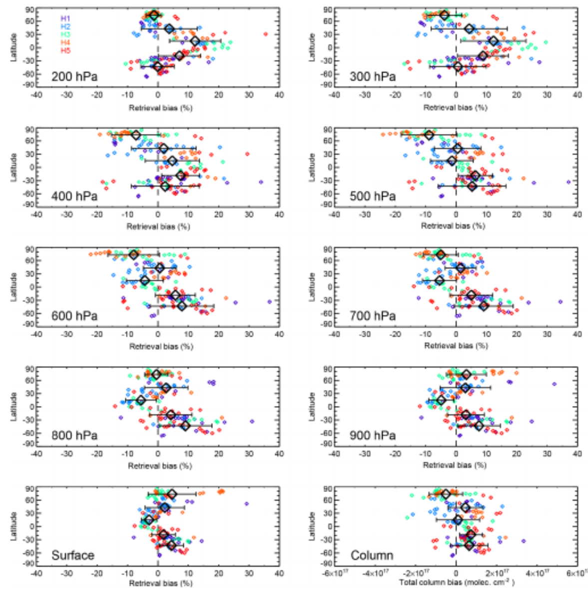

Figure 2. Latitude dependence of V7 TIR-only biases based on the HIPPO CO profiles. Results from each of the five stages of HIPPO are color-coded, as indicated by the key in the top-left panel. Large black diamonds and error bars in each panel indicate bias statistics (mean and standard deviation) representing each 30° wide latitudinal zone.

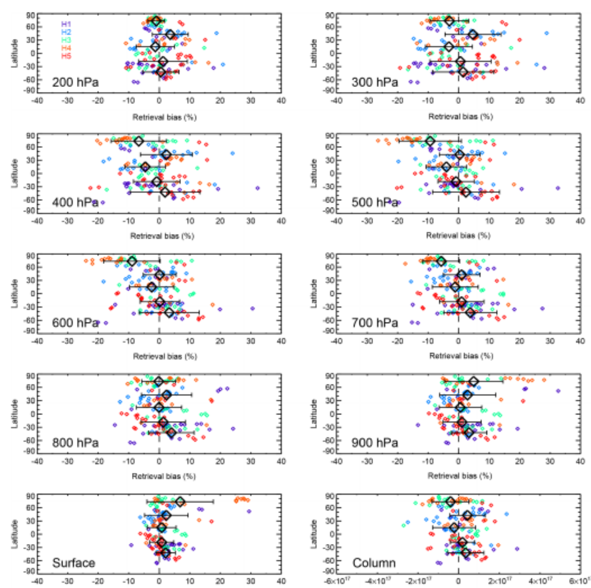

Figure 6. Latitude dependence of V8 TIR-only biases (expressed in percent) based on the HIPPO CO profiles. See caption to Fig. 2.