Responses to Review #3

We thank you for your comments, please find 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 #3
Received and published: 2 May 2020

The authors have conducted a validation of TROPOMI CO retrievals using data from MOPITT and aircraft profiles of CO from ATom. The TROPOMI data are fairly new and provide tremendous observational coverage at high spatial resolution. However, MOPITT offers a uniquely long record of space-based measurements of CO, therefore there is significant value in the validation analysis presented here. My main concern is that when comparing two remote sensing data sets it is critical to account for the influence of the a priori profiles on the retrievals and for the different vertical sensitivities of the measurements, which was not done in this study. The manuscript is well written and appropriate for AMT. I would recommend publication of the manuscript after the authors have addressed my comments below.

General Comments
1. Lines 111-114: The discussion here is somewhat confusing. The authors state that the NIR retrievals are significantly constrained by the a priori, whereas the TIR are less strongly weighted by the a priori profile. However, on lines 159-160 they explain that they do not transform the MOPITT and TROPOMI profiles when comparing them. It would seem that the different contributions of the a priori to the two sets of retrievals would necessitate accounting for the influence of the a priori profiles to meaningfully compare the two data sets. What is the justification for neglecting this?

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. Lines 162-163: What is the impact of the differences in the overpass times of TROPOMI and MOPITT when selecting "collocated" pairs of data? Quantifying this for the ROIs selected in the study would be helpful for interpreting the results of the intercomparison. Quantifying the effect of differences in passing times in CO retrievals is an interesting topic, but it is outside the scope of this work. Please note that validation papers allow time differences substantially larger than the 3 hours between MOPITT and TROPOMI, e.g., Deeter et al., 2019 (12 hours); Clerbaux et al, 2008 (24 hours). The lifetime of CO (several weeks) is much greater than the time difference between MOPITT and TROPOMI passing times. Differences in total CO column amounts due to transportation would be equally likely to be positive or negative; thus, they would not contribute to an apparent bias between the two products.

3. Lines 307-308: What is the implication of the tendency of the reference profiles to have too much CO near the surface for the intercomparison with MOPITT, considering that no attempt is made to mitigate potential biases arising from the a priori? Thank you for this comment. Please see response to Comment #1 above. As explained there, the manuscript now includes text describing (and results from) an additional analysis where we quantify the effect on biases of the differences between MOPITT *a priori* CO profiles and TROPOMI reference CO profiles. We 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.

4. Lines 354-357: It is certainly possible that the differences in overpass times could contribute to these biases over Africa, but this can be confirmed with a model, for example. Modeling the effect of differences in passing times in CO retrievals is an interesting topic, but it is outside the scope of this work. Also, please note that lines 354-357 discuss results obtained for the China ROI; furthermore, please note that the ROIs analyzed in this work do not include fire regions in Africa. Furthermore, what about the impact of the different vertical sensitivities of the measurements here? It seems critical to me to account for the influence of the averaging kernels before speculating that these differences could be due to temporal variations in the African fires. Thank you for this comment. Please see response to Comment #1 for more details regarding additional text now included in the manuscript to address this point.

Technical Comments

1) Line 46: This is not the first use of the acronym MOPITT. Thank you for catching this. We have reworded lines 33-35 to include definitions of TROPOMI, MOPITT, and ATom the first time they are mentioned in the Introduction: "The aim of this work is to facilitate the extension of the current satellite record with newly available TROPOMI (TROPOspheric Monitoring Instrument) measurements by evaluating those with respect to satellite MOPITT (Measurements Of Pollution In The Troposphere) and *in situ* ATom (Atmospheric Tomography mission) CO data." Also, the MOPITT and ATom acronym definitions in lines 46-47 have been removed and the sentence reworded to: "Here we analyze daily global TROPOMI retrievals acquired between 7 November 2017 and 10 March 2019 with respect to MOPITT and ATom."

2) Line 110: Please insert "the" before "total column AK". Please note line 110 does not contain the text "total column AK". That text appears, though, in lines 109 and 111; we have added "the" to the

latter occurrence. That sentence now reads: “With respect to vertical sensitivity, the total column AK for the NIR-only product are most similar in shape to the TROPOMI total column AK”

3) Line 119: Please make it clear that “(∼480; note 1 km resolution)” here is referring to the number of MODIS observation, and that these observations have a resolution of 1 km. Thank you for this comment. For increased clarity that sentence has been reworded to: “The ~480 MODIS observations at 1 x 1 km^2 horizontal resolution acquired at the same time as a single MOPITT observation and within the MOPITT footprint are identified and collected”

Interactive comment on Atmos. Meas. Tech. Discuss., doi:10.5194/amt-2020-63, 2020.