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Comment

## ***Interactive comment on “Improved agreement of AIRS tropospheric carbon monoxide products with other EOS sensors using optimal estimation retrievals” by J. X. Warner et al.***

**J. X. Warner et al.**

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We appreciate very much this reviewer for the valuable contributions and comments that will make this paper better. Please see below (after Answer) for our response to all the comments.

General comments:

1. When comparing the OE AIRS product with TES, it would be interesting to discuss also the covariance matrix or other parameters to show what is the information brought by the measurement itself. For example the percentage of a priori contamination in the measurement and/or the error of the measurement for each level of OE AIRS profiles

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could be useful to estimate the quality of data. The authors could comment on this.

Answer: We agree that it is important to understand the detailed components that contribute to the differences in the CO products especially related to the prior information and the measurement error influence. We are adding in the text a summary to illustrate these factors. In addition, we are in the process to validate our products, carry on sensitivity studies, and continue a comprehensive inter-comparison study between AIRS, TES, and MOPITT CO products. The subject of the retrieval sensitivities will be a focus in a future study.

2. The DOF of both OE AIRS and operational AIRS CO data are less than 1 meaning there is less than one information in the vertical. That means also probably the best information from AIRS is the total column. Why not comparing AIRS with the total column using the aircraft data? The authors should add comments on this.

Answer: We agree that AIRS CO sensitivity represented by the weighting function is broad around mid-troposphere and generally less than 1 piece of information. The AIRS OE retrieval codes provide both CO VMR profiles and integrated total column. The aim of this paper, however, is to discuss the areas where the OE and V5 differ the most, which is best represented by profiles, and emphasize the improved agreements between AIRS and TES CO by using the OE method. We are in the process to carry through extensive validation for the AIRS OE CO products, and will certainly incorporate this reviewer's suggestion to compare the total column CO with the aircraft in situ measurements in a future paper.

3. It would be also useful to study the sensitivity of the sensor over land or over sea and during daytime and nighttime to estimate the quality of this new set of OE AIRS data as it is done for the operational products. Could the authors add something about this in the text?

Answer: The differences between AIRS OE and TES CO over different scenes are not large as opposed to the differences between AIRS V5 and TES V3 shown in Fig. 1

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and 2, and therefore, we used a global summary instead. We are adding the ranges of these differences over NH, SH, Land, and Ocean in the text. Again, we intend to publish thorough validation and inter-comparison results in follow up studies.

Minor comment and technical corrections: Introduction p 11853: Earth is written with a capital letter and not in the rest of the paper. Please be consistent.

Answer: corrected.

I 24 and I 28 : The version numbers of AIRS operational products are confusing, which one is used ? V5 or version 4. What are the differences. Please clarify.

Answer: The version used in this paper from Sec. 2 through 6 is from AIRS operational products V5, but some of the published studies that were quoted in the Introduction were from AIRS operational V4. We've made necessary clarification in the Introduction.

P 11854 : Give also the spectral sample spacing for AIRS as well as the Signal to Noise Ratio for both TES and AIRS. (see other comment below). Please also add which spectral sampling is used for TES in the CO band (is it 0.08 or 0.02 cm<sup>-1</sup>)? The pixel sizes of AIRS, TES and MOPITT should be the values at nadir. Please add nadir for AIRS and MOPITT. The grid of MOZART model at global scale is higher (should be 2.8x2.8 degrees)

Answer: We added in the AIRS spectral discussion: “with a spectral spacing of ~1.8cm<sup>-1</sup> and an instrument Noise Equivalent Differential Temperature (NEDT) at typically 0.14K.” and in TES spectral discussion in comparison to AIRS: “lower Signal-to-Noise Ratio (SNR) (NEDT at 1.5K at 300K) and lower global coverage.” Spectral range for TES CO is also added. The pixel sizes at nadir for AIRS are added as 15x15km<sup>2</sup> and for MOPITT are listed as 22x22 km<sup>2</sup>. We added the sentence in the Introduction: “Note that AIRS algorithm utilizes cloud clearing processes that increase the global coverage significantly, however, reduce the spatial resolution from AIRS single Field-Of-View (FOV) at 15x15km<sup>2</sup> to 45x45km<sup>2</sup> (Susskind et al., 2003).” The grid

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for MOZART model is added as: “in 2.8x2.8 degree grids from the MOZART climatology and interpolated to measurement locations, ...”

2 background : CO differences between AIRS and TES operational products P 11856 : AIRS and TES have different sizes of footprint and then the scene measured by each sensor is probably different. Then the representiveness of measurement for AIRS and TES is also different and could add a bias or larger variability. The authors should comment this in that section.

Answer: We are well aware of this fact, but forgot to discuss it in this section. We are adding it to the end of Sec. 2.

P 11857 : Could you add also the bias in terms of percent.

Answer: Added.

P 11860 : Define X (should be the Truth).

Answer: Corrected.

4 AIRS CO retrievals using OE p 11861 : I 1: add operational or V5 for AIRS CO.

Answer: Added.

L 26 Please add the number of levels for MOPITT V4

Answer: Added.

Figure 3: Please add time of the aircraft spiral profile and if possible error bars for each level of AIRS CO products (for example the diagonal of the covariance matrix). On this figure, there is a clear maximum at about 500 hpa which probably represents the transport of a CO plume at this altitude. However, the sensor is also supposed to have a good sensitivity at this altitude. Then why there is a corresponding local minimum at this altitude for all AIRS retrievals and even in the convolved profile? Perhaps it comes from the sensitivity of AIRS with a DOF less than 1 and in this case only allows the

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capture of the total column. The authors could add a comment probably linked to the question of what kind of measurement information brings AIRS vs the a priori?

Answer: The time for the spiral profiles are added in the text as “at 20:33:37 (left panel) and 18:10:30 UTC time (right panel).” It is a good point for adding error bars. Instead of adding the error/RMS in Fig. 3, which will make the figures very crowded, we added Fig. 3b with a pair of new panels to show the variability of the profiles within 200km circles surrounding the in situ profiles as usually done and change the original figure to Fig. 3a (see attached). Since the weighting function for AIRS CO is broad in the free troposphere centered at 500hPa, the retrieved CO profiles represent the smoothed column amount over a thick layer. The local minimum merely represents a “turn” in the profile direction and does not represent a true measure of a minimum.

P 11863 : I 24: The second maximum near 850 hPa is not really obvious to see. Could you help the reader by adding an arrow or changing the axis of Fig 5. Is this slight second maximum sufficient for adding some measurement information at this level? Please comment.

Answer: There are some profiles that show the secondary maximum more obviously, but this example is not a good representation. So we are removing the statement in the text.

5-Comparison of global tropospheric CO of AIRS OE with TES and MOPITT P 11864 : I 15 : Could you please give more explanation on how to reduce the effect of the apriori by using the averaging kernels? Do you replace the X in the formulae (5) by TES CO? I don't see mathematically the point since TES is not the Truth and has its own averaging kernels and a priori profiles. Please could you add more information.

Answer: We meant to say to reduce the smoothing errors in the inter-comparison and we have changed the text as “To reduce the differences in smoothing errors between AIRS OE and TES CO retrievals, we use AIRS OE averaging kernels to smooth TES CO profiles as suggested by Rodgers and Connor [2003].” Yes, we used TES CO as

X in Equ. 5 since we are treating TES CO as a reference to evaluate AIRS OE CO retrievals in this case. This is an approximation and ideally we should use “truth” or in situ data as described by Rodgers (2000). This approach has been used regularly in the previous inter-comparison studies such as those by Warner et al. (2007) and Ho et al. (2009).

P 11865 : I 20: MOPITT CO (blue) replace by MOPITT CO (black) same in figure 9

Answer: Corrected.

I 25-26: The DOF depends on the SNR and spectral resolution, not just the resolution. TES is a spectrometer and AIRS a grating spectrometer, the couple (SNR and spectral resolution) gives the adequate instrument to measure CO. Probably for a grating spectrometer, we might have a coarser resolution but a higher SNR whereas for a spectrometer this is the opposite.

Answer: We have added the SNR and spectral resolution comparison as a background for AIRS and TES in the introduction. This discussion was aimed to explain the factors that justify the higher DOFS at low latitudes by TES, which is the spectral resolution, not the lower SNR.

Figure 9: I don't see why the DOFs of AIRS are better than TES or MOPITT at higher latitudes? Do the authors have an explanation? If yes please add in the paper.

Answer: We believe this is partly an artificial effect due to the cloud clearing process in AIRS algorithm, and we've included the statement in the text: “The latitudinal dependence of the DOFS for MOPITT and TES are largely due to the change in the surface temperature contrasts, while the flatness in the latitudinal dependence of AIRS maybe partly due to the cloud clearing uncertainties.”

I 28 : MOPITT V4 instead of V3

Answer: We actually did use V3 data for this DOFS study.

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P 11866 : I 12-15 : Please add the overpass time at the equator for each satellite.

Answer: Added.

I 14 : I think when there is high thermal contrast, there is more vertical sensitivity of Infrared sensor and probably because the CO is directly emitted from the surface then the CO is relatively larger in the lowest troposphere. I think there is no direct link between high thermal contrast and larger value of CO in the mid troposphere?

Answer: The reviewer is correct that we were not very clear on this. We modified the sentence as: "In general, the retrieved tropospheric CO VMRs are higher when there are higher surface thermal contrasts due to the enhanced sensitivity that samples closer to the sources near the earth's surface."

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Interactive comment on Atmos. Chem. Phys. Discuss., 10, 11851, 2010.

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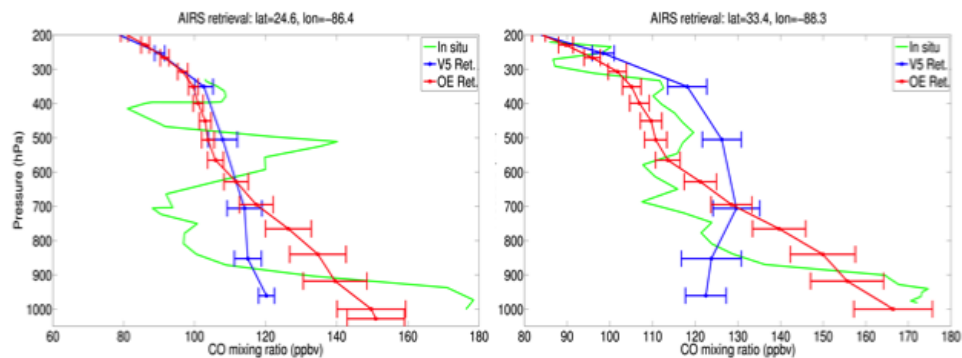
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**Fig. 3b.** Similar to Fig. 3a except that AIRS V5 CO (blue lines) and AIRS OE CO (red lines) include the RMS within 100km radius surrounding the in situ spiral profiles (green).

**Fig. 1.**