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## ***Interactive comment on “Evaluation of a new middle-lower tropospheric CO<sub>2</sub> product using data assimilation” by A. Tangborn et al.***

**Anonymous Referee #2**

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This paper describes the use of PSAS data assimilation method to assimilate a new CO<sub>2</sub> retrieval product using AIRS infrared radiances in the GEOS-5 model. The authors show a positive impact of the assimilation by comparing the results to independent in-situ observations. However, the impact is very regional dependent, both because of the availability of the AIRS retrievals and the systematic errors in the model (surface fluxes). This results in decreased bias but increased standard deviations. Although the data assimilation system used is different from earlier studies, the presented results are not very new. However, the authors do show how their system can be used to validate AIRS retrievals against in-situ observations and the system will hopefully be further used to assess and assimilate observations from the GOSAT and future OCO-2 sensors. I therefore recommend publication of the manuscript after revision taking my comments below into account.

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Major comments:

Page 26687, lines 4-5: This is a very optimistic statement to make and it is not further addressed in the rest of the paper. Chevallier et al. (2009) already showed that using AIRS assimilated fields in a flux inversion provides very little information compared to flask inversions. Also, the very sparse data set used in this manuscript causes artificial gradients in the 3D CO<sub>2</sub> fields as the authors show with their validation. I suggest removing the statement altogether.

Page 26688, line 24: How are the averaging kernels calculated? This should be clarified. Averaging kernels are mix of instrument sensitivity, instrument error estimates, and prior error estimates. The dependence of the presented averaging kernels on the particular retrieval should therefore be made clearer.

Page 26689, line 22: the term “superobbed” should be explained. It might be clear within the data assimilation community, but probably not to any other readers.

Page 26689, line 25: I do not except the statement that there was no a priori used in the retrieval. Some assumptions must have gone in. For example, what is used for the CO<sub>2</sub> profile shape? Please, clarify.

Page 26691: I am not convinced that the chosen method for the background error standard deviations is adequate. The errors in the CO<sub>2</sub> fields are mostly caused by the errors in the surface fluxes. Just making the errors a function of the CO<sub>2</sub> concentrations does not account for that in a realistic way. I appreciate the further tuning against in-situ observations, but this method is also limited. For instance, the correction factor does not make a distinction between land and ocean. I accept the proposed method as an initial attempt to characterize the errors, but I think the caveats need to be stated more clearly.

Page 26693, lines 14 - 20: These results again confirm the result by Chevallier et al. (2009) that AIRS can only correct for the bias and global growth rate. Adjustments to

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the seasonal cycle or adjustments on smaller spatial scales are probably a bridge too far. The findings of this manuscript should be clearer discussed in relation to earlier results, such as Chevallier et al. (2009). This also applies to page 26694, lines 16 - 27, which provides very similar results to Engelen et al. (2009).

Page 26698, lines 9 - 16: the results presented here are clearly caused by a biased data assimilation system. The PSAS algorithm assumes unbiased statistics for both the observations and the model. With incorrect surface fluxes the model is biased and corrections made by the observations will be overruled by the biased model away from the observation locations. It would be nice if the authors could elaborate a bit more about this problem and which ways forward they see.

Page 26699, lines 11 - 27: this forms an important part of the discussion, but in my view lacks the most important conclusion. Having different adjustments to the CO<sub>2</sub> fields based on strength of surface fluxes and data availability creates an analysis field that becomes almost impossible to use in flux inversions. Artificial spatial gradients are created, which will be interpreted as needed flux increments in a flux inversion. In order for AIRS to have a real impact on flux inversions, the data density needs to be much higher and more homogeneous and the increments in the lower-tropospheric need to dominate the incorrect prescribed surface fluxes.

Minor comments:

Abstract, line 14: “retrieved channel”; this should be replaced either by “used channels” or “retrieved values” Page 26688, line 21: “A number of” should be replaced by “Many”. Page 26689, line 21: “screen” should be replaced by “screening” Page 26692, line 1: “results” should be “result” Page 26692, line 25: “Comparisons” should be “Comparison” Page 26693, line 18: the first “the” should be replaced by “there”; after “cycle” introduce a comma and add “this”

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