

Response to reviewer 2

We thank the reviewer for the insightful comments which have been thoroughly addressed below and have contributed to improving the clarity of the manuscript. In the following sections, the reviewer’s original comments are in [blue](#) and our response are in [black](#).

Zheng et al. present the tangent linear and adjoint models for MIPAS-CO2 v7.3 and evaluate the performance of the these new models. In addition, a comparison of adjoint sensitives is performed against CarbonTracker Lagrange. This work is of significant scientific value to the community. I found the manuscript to be well written and concise, and recommend publication after minor revisions. Aside from technical comments below, I would encourage the authors to expand on details of the implementation of the tangent linear model and adjoint in Sec. 3 and 4. For example, I find that Sec. 3.3 and 3.4 of Henze et al. (2007) provide a bit more detail.

Thanks for providing us with the constructive comments. The following sentences have been added to Section 4.1 to provide more details of the adjoint model development: “Another strategy we adopted for developing the adjoint code is to have the forward sweep save some immediate variables that are needed by the subsequent backward sweep so that they do not need to be recalculated. For instance, the values of some variables related to mass fluxes in the KF convective scheme (Kain 2004) are saved by the first sweep in the memory to speed up the subsequent backward sweep execution. This strategy not only increases the adjoint model efficiency but also simplifies some of its code development. ”

Technical Comments

1) L30: I think better references re-transport error would be:

Schuh et al. On the role of atmospheric model transport uncertainty in estimating the Chinese land carbon sink. Nature 603, E13–E14 (2022). <https://doi.org/10.1038/s41586-021-04258-9>

Schuh et al. (2019). Quantifying the impact of atmospheric transport uncertainty on CO2 surface flux estimates. Global Biogeochemical Cycles, 33, 484–500. <https://doi.org/10.1029/2018GB006086>

Agreed. The two references have been added in the revised manuscript.

2) L100-104: “e” should be defined at first mention.

A definition for **e** has been added.

3) L249-251: The state vector elements being optimized need to be somewhat coarse, but not the transport model. (e.g., <https://amt.copernicus.org/articles/14/5521/2021/>).

Agreed. The sentence has been revised to “The computation of observation footprints using forward models requires a large number of model runs, making it impractical, except for optimizing state vector elements at coarse horizontal resolutions.”

4) Figure 2 caption: This caption is a bit hard to read, I suggest re-wording to something like: The (a)-(d) column average (units: ppm/ppm) and (e)-(h) surface sensitivity (units: ppm/ $\mu\text{mol m}^2 \text{s}^{-1}$) for CO2 observed at the WKT tower at 00:00 UTC on March 31 2018. Top-to-bottom shows the sensitivities at 5, 10, 20, and 30 days before the observation. The WKT tower (31.3149°N, 97.3269°W) measurements used here are taken 457m above the ground level and labeled by the

red color cross in the figures of the left column.

Agreed. The Fig. 2 caption has been revised as “Sensitivity of CO₂ mixing ratio at the WKT tower at 00:00 UTC on March 31, 2018 to the initial CO₂ mixing ratio (left column, units: ppm/ppm) and the surface flux scaling factor (right column, units:ppm/ $\mu\text{mol m}^{-2} \text{ s}^{-1}$).The four rows from top to bottom show the sensitivities at 5, 10, 20, and 30 days before the observation. The sensitivities to the initial CO₂ mixing ratio (left column) are plotted as the column average. The WKT tower (31.3149°N, 97.3269°W) measurements used here are taken at 457 meters above the ground level and labeled by the red color cross in the figures of the left column.”

5) L274: “The figures show” should be either “The figure shows” or “The figure panels show”

Agreed. It has been corrected to “The figure panels show ...”

6) Figure 5: I can't see the red cross, maybe enlarge?

Figure 5 has been redrawn with enlarged red crosses to mark the locations of OCO-2 sounding.

7) L300-321: If I understand correctly, Figure 5 and Figure 6 are examining sensitivities for different OCO-2 soundings? Then why not use the same altitudes for both Figures?

Good suggestion. Figures 5, 6, and 7 have been redrawn and now the three figures all compare footprints of CT-L and MPAS-CO₂ adjoint at a set of same altitudes: 500m, 2000m, 4500m, and 10,000m.

8) L359-379: This feels quite unrelated to the rest of the manuscript. I don't have an objection to including it, but could it be its own subsection?

Good suggestion. In the revision, this segment of text is included in a separate subsection (Section 5.2).

9) Figure 11: It is hard for me to make sense of the magnitudes on here. Could you show the results with a linear color scale? Perhaps as a right-hand column.

Good suggestion. Figure 11 has been redrawn and now a linear color scale is used to show the differences in OCO-2 footprints between the two vertical distribution profiles.