Review of "A joint data assimilation system (Tan-Tracker) to simultaneously estimate surface CO_2 fluxes and 3-D atmospheric CO_2 concentrations from observations" by X. Tian et al.

General comments:
This paper describes the Tan-Tracker data assimilation system which estimates CO_2 surface fluxes and atmospheric CO_2 concentrations simultaneously. The paper explains the methodology and shows the results of some test experiments. At this stage the description of the system is not clear enough to me to be able to follow exactly how the methodology of the authors works. I will add some specific questions below about parts which are unclear to me (and probably to other readers as well).
The paper does not include any results using real data and any new estimates of the carbon fluxes or CO_2 concentrations. I therefore think that the manuscript in its current form is not suitable for publication in ACP. One option would be publish an updated version in a journal focusing on model development (such as Geoscientific Model Development). On the other hand it would also be good to see an updated version of the manuscript including analysis of the global carbon fluxes in comparison to other models which might suit better to the scope of ACP.

Specific comments:
- It is not clear to me how the joint assimilation actually works. The authors use both the CO_2 concentrations as well as the surface fluxes in their statevector. How does the system decide which of those is adjusted? If the system adjusts CO_2 concentrations without changing the CO_2 fluxes simultaneously, where does this CO_2 come from/go to? In other words, does the system conserve the mass of carbon?
- Figure 1 is not clear to me. It does not explain well how the background and sampling runs are connected and how information is transferred between them. Also in combination with the text in section 2.1 it is still not very clear. The explanation of the methodology should be improved significantly.
- Section 3.1: It's not stated what the "True" fluxes consist of, please clarify. From figure 3 they seem to be monthly fluxes and there are big jumps at the beginning of a new month. Since the system uses the identity operator as the CF dynamical model, it is not clear how the model can follow those monthly jumps so well.
- Section 3.1: The authors explain that their fluxes consist of several components: fossil fuel combustion, biosphere and ocean exchange, biomass burning, etc. First of all: why are emissions from shipping and aviation not included under fossil fuel combustion? How do the authors estimate fluxes per category? Do they optimize all fluxes simultaneously? Will they be able to separate fossil fuel combustion from the biosphere after the inversion? Are emissions from shipping and aviation also optimized? How are (will) the different fluxes (be) separated in the final results?
- Figure 7 and 8: Why are there hardly any RMSE values above the oceans? And why are the values always the same above the oceans in 8b? This figure comes back to my earlier question on how the system decides to adjust either the

CO_2 concentration or the flux. They don't seem correlated. E.g. the flux in Australia has some RMSE but the concentration seems to have a better RMSE.

- P24770 L2-4: "Evidently, a relatively definite conclusion can be drawn that the uncertainty of the initial CO_2 concentrations cannot be ignored and the joint assimilation framework contributes a lot to the final Tan-Tracker performance." I don't understand how this conclusion follows from the mentioned figures.
- The uncertainty analysis is missing and would be a good addition to the manuscript.
- P24767 L16-17: The authors state that TT-S is somewhat similar to CarbonTracker. It would be a good addition to the manuscript to actually perform simulations with real fluxes and real observations, and compare the results of TT-S to CarbonTracker. In that way it is much more clear to the reader how similar the systems actually perform.

<u>Minor comments:</u>

- The grammar and language use in the manuscript would benefit greatly from review by a native speaker. At points it is hard to follow because of issues with the language. Some examples:
  - P24767 L20-21: "Since the CO_2 concentrations are not assimilated …": assimilated should be estimated, or otherwise it is very unclear what data has been assimilated.
  - P24768 L16-21: "… and its assimilated errors don't a trend of becoming less even though its performance behaves substantially better than the background simulation case …". The term assimilated is used incorrectly again and the grammar is not correct.
  - P24769 L23-24: "Complementarily, their corresponding RMS errors for the assimilated (optimized) CO_2 concentrations are also shown in Fig. 8". Optimized or assimilated?
  - P24762 L9: The term "simulated observations" seems incorrect, probably "simulated concentrations" is a better choice.
- P24757 L8: Add reference for the TM5 model instead of webpage link (e.g. Krol et al ACP 2005).
- P24766 L10: Add reference for the GEOS-Chem model, instead of webpage link.
- Figure 4 and 5: The legend and labels is not well readable.