

Geosci. Model Dev. Discuss., referee comment RC2
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Comment on gmd-2021-375

Anonymous Referee #2

Referee comment on "Improving the joint estimation of CO₂ and surface carbon fluxes using a constrained ensemble Kalman filter in COLA (v1.0)" by Zhiqiang Liu et al., Geosci. Model Dev. Discuss., <https://doi.org/10.5194/gmd-2021-375-RC2>, 2022

The authors present an improved EnKF approach to consistently estimate atmospheric CO₂ concentrations and surface fluxes from satellite and surface GHG observations. This approach is computationally very efficient, and has been shown to be able to well reproduce the 'true flux' in OSSE experiments. Overall this manuscript is clearly written, and the results are meaningful. But I think revisions are needed to address some concerns.

Major comments:

- This approach estimates atmospheric CO₂ concentrations and surface fluxes simultaneously. But I don't see much assessment of the quality of the resulting CO₂ concentrations by comparing with the 'true' (model) atmosphere etc. I can see some benefits from additional constraint on global atmospheric CO₂ mass on the a posteriori flux estimate. It is interesting to know how the imposed mass constraint will affect the horizontal and vertical CO₂ distributions in a long (such as 1 or 2 years) run. Inconsistency is a potential concern, when adjustments from global atmospheric CO₂ mass conservation (instead of the more solid mass balance between total surface emission/sink and atmospheric CO₂ mass) are applied only on CO₂ distributions, but does not the flux distributions accordingly. Regions with poor constraints (such as the boreal Eurasia) can be used to 'dump' the mass imbalance of other better constrained regions, leading to degraded agreements with the 'true' fluxes (see for example the boreal Eurasia in Figure 9 & 10).

- In my opinion, deviations between a posteriori and the 'true' flux (see for example Figures 9 and 10) are still significant over many regions, in particular over, northern high latitudes. Our understanding of the global carbon cycle has been hindered by unquantified discrepancies in the posterior fluxes inferred by different top-down flux inversion models. I think, robustness is now more important than the computational speed. It would be interesting to know whether the agreement with the 'true' can be further improved, for example, by using a longer window or using a larger ensemble etc. If possible, it is also interesting to know how the traditional top-down inversion will perform in those OSSEs. It becomes increasingly important to understand the discrepancies between different approaches.

Minor comments:

- As pointed out by other reviewers, some sentences are ambiguous or poorly structured. There are also a lot of typos for example: Line 304, Page 14: 'the acculation of the annual global imbalances ...' I think the manuscript will benefit from a careful revision.
- No prior or posterior uncertainties presented in most of Tables and Figures such as Figures 5 and 6, and 9. Uncertainty is an important part of data assimilation product, which are particularly useful for us to assess whether improvements are substantial.
- Figure 10. I'd like to see the difference shown as percentage of the true fluxes.

- Figure 11. Will the increments improve or degrade the agreement with 'true' model concentrations ?