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comment on acp-2022-183

Anonymous Referee #2

Referee comment on "Global and regional carbon budget for 2015–2020 inferred from OCO-2 based on an ensemble Kalman filter coupled with GEOS-Chem" by Yawen Kong et al., Atmos. Chem. Phys. Discuss., <https://doi.org/10.5194/acp-2022-183-RC2>, 2022

General comments.

The authors applied a flux inversion system based on LETKF algorithm to estimating the global and regional CO₂ fluxes based on OCO-2 satellite observations. They obtained useful results indicating ability to reconstruct the regional surface fluxes fitting within a spread of the recent global inverse modelling results by other modelling systems. On the other hand, there are deficiencies of the method that authors could not overcome and hope to improve in further developments. Paper is well written and illustrated and can be accepted after minor revisions.

Detailed comments.

- The length of optimization window of 1 week limits the power of the remote observations to constrain the fluxes. One can see a difference between fluxes retrieved with Kalman smoother when applying 1-month and 3-month assimilation window (Bruhwiler et al, 2005). The deficiency has been noted in the abstract as 'Four sensitivity experiments are performed herein to vary the prior fluxes and uncertainties in our inversion system, suggesting that regions that lack OCO-2 coverage are sensitive to the priors, especially over the tropics and high latitudes', which authors hope to address in future.
- There are visible problems with posterior fluxes, as shown on Fig. 4, the range of annual mean grid fluxes occasionally goes out of reasonable range, exceeding 100 gC/m²/year, pointing to a poor balance between large scale and grid scale uncertainties, lack of a spatial correlation constraint on flux correction gradients. The results with the presumably similar algorithm in Liu et al (2019) do not show such

noise, which point to having some important differences that must be documented. Similar flux noise problem was encountered by Miyazaki et al, (2011) and later studies. Can authors isolate the cause of the problem? Could it be a result of using random grid fields as ensemble flux perturbations, while there is an alternative of using smoother random fields?

- Another issue related to the grid flux noise is the ensemble size. As shown by Chatterjee et al (2012), Chatterjee and Michalak, (2013) the inversion results are sensitive to ensemble size, and useful improvements are achieved by increasing the ensemble size beyond 100. Miyazaki et al (2011) also obtained visible improvement of flux constraint by increasing the ensemble size from 48 to 96. Compared to those designs a system presented in this study relies on rather small ensemble size.

Despite of the visible success in weather forecast applications, LETKF use in carbon flux inversion has been tried in several studies but did not become widely used due to limitations, presumably not providing a better computational efficiency over adjoint-based variational or low rank inversion algorithms. In a revised manuscript it is advisable to mention the deficiencies of the LETKF system: limitations of small ensemble size and short window length (which may be reasonable for coupled weather-carbon cycle assimilation) and provide better arguments in support of this direction in comparison to other settings, for example Kalman filter approaches formulated by Feng et al, (2009).

Detailed comments

Line 72 In addition to Liu et al 2019, it is useful to mention the results by Miyazaki et al 2011 who also studied adding GOSAT satellite observations.

References

Bruhwiller, L. M. P., Michalak, A. M., Peters, W., Baker, D. F., and Tans, P.: An improved Kalman Smoother for atmospheric inversions, *Atmos. Chem. Phys.*, 5, 2691–2702, <https://doi.org/10.5194/acp-5-2691-2005>, 2005

Chatterjee, A., A. M. Michalak, J. L. Anderson, K. L. Mueller, and V. Yadav (2012), Toward reliable ensemble Kalman filter estimates of CO₂ fluxes, *J. Geophys. Res.*, 117, D22306, doi:10.1029/2012JD018176

Chatterjee A., A. M. Michalak, Technical Note: Comparison of ensemble Kalman filter and variational approaches for CO₂ data assimilation, *Atmospheric Chemistry and Physics*, 10.5194/acp-13-11643-2013, 13, 23, 11643-11660, 2013.

Miyazaki, K., Maki, T., Patra, P., and Nakazawa, T. (2011), Assessing the impact of satellite, aircraft, and surface observations on CO₂ flux estimation using an ensemble-based 4-D data assimilation system, *J. Geophys. Res.*, 116, D16306, doi:10.1029/2010JD015366.