Review of "Regional CO2 inversions with LUMIA, the Lund University Modular Inversion Algorithm, v1.0" by Monteil and Scholze

This manuscript (MS) describes a regional flux inversion framework that was designed to have modular functionality. The performance of the system was demonstrated with a series of Observing System simulation experiments and real data experiments. It is a model description MS. I reviewed this manuscript by following the GMD model description papers guideline, https://www.geoscientific-model-development.net/about/manuscript_types.html. This MS has relatively deep level of details about the LUMI framework. The authors made the code and documentation available online so the community can easily use it for their work. I will skip those requirements this MS meets and only list those ones it does not meet. The unmet requirements are listed below, and I would not recommend this MS for further publication if they are not carefully addressed.

Technical details are not completely clear to me. In section 3.2.1, the authors mentioned that FLEXPART was driven with ERA-I. In section 3.2.2, they used TM5-4DVar posterior CO2 mole fraction as boundary condition. So, the transport models used in the domain of interest and outside were different. Have the authors studied the conservation of mass in the boundaries? The mismatch can cause the biases in the flux estimation. Additionally, in the later text, it said that FLEXPART was driven with the TM5 transport. Please clarify and correct it throughout the text.

Back to section 3.2.1, the authors only ran FLEXPART even days backward. It seems too short to me, but I am not positive. This will be determined by the weather system in the regions. How did the authors come up this number? Do the users have the flexibility to change this number for their work?

In section 3.2.2, the description of TM5-4DVAR is misleading. It was only used to provide the 3D CO2 mole fraction fields. The description of the posterior fluxes is unnecessary. Additionally, the description of CarbonTracker CT2016 is not correct. CT2016 used CASA-GFED for prior instead of SibCASA. Please check other components and correct it if anything is inaccurate. https://www.esrl.noaa.gov/gmd/ccgg/carbontracker/CT2016/CT2016_doc.php

Lack of the evaluation against standard benchmarks or observations. The MS provided OSSE and real data experiment. The results are hard to justify because no reference is used. There are quite some inversion results publicly available, such as CarbonTracker posterior fluxes at global scale, CarbonTracker-Lagrange system at regional scale, etc. The comparison against those state-of-art system are necessary to justify the suitability of LUMIA.

Another related point, the description of the difference/improvement of LUMIA compared to those inversion systems would be helpful and appreciated for users to choose a framework that is more appropriate for their research. The authors could also compare their results with the flux measurements if the observations are available, such as AmeriFlux, Fluxnet, etc.

Last but not least, the authors should use "ensemble" more carefully. Technically, the experiments designed only leads this work to a sensitivity study. The transport error is a big deal in inversion. The authors didn't even offer an experiment that uses different transport models in this study. Thus, the experiments designed are far from ensemble, and the RMSD over these experiments are far from model uncertainty.

Some other special concerns below.

Abstract:

I would not include any citation in the abstract. The authors should articulate the problem clearly instead of simply giving citations in the abstract.

The authors used the first two paragraphs for the background information in abstract following by introducing LUMIA starting with “some of these new topics”. What exactly are the topics the authors are referring to? Please clarify them.

L30: LUMIA is an inversion framework. It has nothing to do with “predict the evolution”

L39: I would not use “robust estimates”. Reducing the uncertainty is the nature of the Bayesian inversion, but it doesn’t mean the final estimation is robust.

Figure 2: please use height above ground level instead of altitude. It would be more informative by using height so that readers (like me) would have sense in the mixing depth, etc.