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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Global methane budget and trend, 2010–2017: complementarity of inverse analyses using in situ (GLOBALVIEWplus CH_4 ObsPack) and satellite (GOSAT) observations" *by* Xiao Lu et al.

Anonymous Referee #3

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"Global methane budget and trend, 2010–2017: complementarity of inverse analyses using in situ (GLOBALVIEWplus CH4 ObsPack) and satellite (GOSAT) observations" presents long-term global inversions based on different available observation datasets. The authors present an inversion system based on the analytical solution of the Bayesian Gaussian problem which allow to better understand the weight of each piece in the system. The authors analyze the outputs thoroughly and use relevant comprehensive metrics to assess the usefulness of each type of observations.

The manuscript is well written, well structured and of significant importance for the

community to be published in ACP after some weaknesses are properly addressed. Main problems are detailed in dedicated sections below and technical revisions are listed in Sect. 5. Overall, the manuscript is of high quality but falls short of properly exploiting the full potential of the system presented here. Sensitivity tests and additional inversions should be added to the manuscript (without computing additional response functions) to prove fully relevant to the community and to stand out of more regular inversion papers. It can be done with relatively little efforts considering all the material and the quality of the background work done to reach the present submitted manuscript.

1 Bias correction

p.7 l.191: Bias correction is mentioned. This is a critical point. It may have a huge impact on the inversions. Putting it under the carpet in one line is a little bit short. Please add details on this aspect and possibly some quantification of the impact of such a bias correction. Is the bias correction put in the constant c in eq. (2)? Or is it use on-line in the computation of GEOS-Chem? Or posterior to it? What is the impact on the response functions? If it is the constant c, please include (at least in supplement) your results with/without/with another bias correction to really see how sensitive your results are to that aspect.

2 Non-linearity of GEOS-Chem and OH chemistry

This is a little bit harsh to neglect it straight away. Could you run forward runs with your different posterior states and compare with what you get with the matrices Kx to have an idea of how negligible it is?

This may indeed be negligible, but the entire paper is based on that very strong assumption. Please justify it better and more extensively.

3 Regularization term

The authors use a regularization term to correct for ill-specified observation errors. However, their estimation is based on approximate matrices. Why not using the rigorous Chi-square criterion? such as in Desroziers et Ivanov (2001, https://rmets.onlinelibrary.wiley.com/doi/10.1002/qj.49712757417)

4 Computation cost and sensitivity tests

It is nowhere stated what is the computation cost of the system (computing response functions on the one hand, solving the matrix products on the other hand). Once the response functions are computed it is in principle quite straightforward to change parameters in the R/B matrices to see the impact.

I think the main strength of the system presented here comes from this very fact (other wise, a variational inversion would give posterior fluxes at reduced cost, even if DOFS can be retrieved easily). This is a critical limitation of the present paper.

Different horizontal and temporal correlations should be tested in the prior matrix, as well as standard deviation of errors, to see the impact of such modifications, given that we never really know how good are our prior/obs errors.

More critically are observation errors. Even though the observation data set is very large, it should be possible to imagine a matrix that is diagonal only by block, allowing to consider correlations between GOSAT neighbour observations, while keeping it

possible to compute the inverse easily.

As stated by the authors, the inversions are not consistent with each others (Fig. 13). This comes probably from ill-specified error matrices, which the authors have the tools to inquire into.

5 Technical comments

1. p.4 l.89: aircraft measurements: those can be particularly challenging to ingest inversion systems as CTMs never really excel in representing the vertical distribution of CH4 concentrations. Plus it is never clearly stated whether or not they are really used in the inversion or only in the posterior evaluation. Please discuss more about the aircraft measurements and justify better their use (is it only vertical profiles, very hard to assimilate? or transects, easier to use?)

2. p.4 l.104: how exactly the linear trend are computed as response functions? same for OH? A start of explanation is given p.8, but additional information would be welcome

3. p.7 l.163: What is the corresponding total error on the prior budget when using your prior distributed errors? Please represent it on Fig. 13

4. p.8 l.208-213: observation error: it is not clear what ensembles are taken. Do you separate each station? Some regions for GOSAT? etc.

5. p.9 l.284: not correct. The other way around. the analytical solution is the solution of the Bayesian Gaussian problem. The cost function is derived from the formulation of the Gaussian problem when the analytical solution cannot be computed explicitly. Actually, writing the cost function in Eq. (1) in a paper using analytical inversions is superfluous; the factor gamma can be introduced differently

6. p.11 l.376: This warning should also be repeated in the method section. Actually as response functions are computed for each pixels individually, why not duplicating the corresponding time series to separate sectors in the target vector? This would not add new response functions to compute and allow you to assess how good is the distribution in sectors. You could even imagine specifying different correlation lengths to different sectors.

7. p.11 l.382: Is GEOS-Chem really suitable with very coarse resolution to constrain US emissions? the resolution is fine for background sites, but what about sites nearby emission hotspots. Representation errors will likely bias your results at such stations, making it very important to filter properly data prior to the inversion.

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