Atmospheric
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Discussions

Interactive comment on "On the use of satellite derived CH$_4$ / CO$_2$ columns in CH$_4$ flux inversions" *by* S. Pandey et al.

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We thank the referee for his/her useful comments. We have included the referee's comments and comment specific replies (AC) in blue below. The corresponding changes made in the manuscript are written in *italics*.

1   Summary of review:

Authors develop and test surface CH4 flux inversion scheme designed to ingest the XCH4/XCO2 ratio retrieved from satellite observations. Authors mention that similar

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method was applied earlier by Fraser et al 2014 using a different transport model and inversion method, thus the new results extend the analysis to the case of grid-scale inversion. The pseudo-data experiment is used to quantify the theoretical performance of the method. The advantage of the developed technique is its ability to use soft constrain on CO2 fluxes instead of hard constrain applied in a traditional approach when only XCH4 retrieved with proxy method is used. According to the conclusions, the advantage of the technique is limited to regions of large uncertainties in CO2 fluxes and simulated XCO2. The manuscript is well written, except for several mistypes, the originality and scientific value of the results justify acceptance for publication. Minor revision addressing the comments below is needed.

2   Comments:

8807 line 5. Authors suggest that CONGRAD is different from M1QN3 in assuming the cost function as multidimensional parabola, and thus less applicable to nonlinear problems. There are two considerations that do not go along with this discussion. Firstly, Meirink et al, (2008) point that the origin of CONGRAD is a code applied by Fisher and Courtier, (1995) to the nonlinear problem of weather forecast. Secondly, M1QN3 makes estimate of Hessian which is equivalent to approximating the cost function as multidimensional parabola, thus this can not be mentioned as disadvantage of CONGRAD. The actual reason for M1QN3 to perform better in nonlinear case could be ability to rebuild Hessian approximation several times on the course of descent to minimum.

AC: We agree with the referee. We have made the following update in our manuscript:

"Mathematically, it has the fastest convergence rate for linear inversions, but it may perform poorly for non-linear inversions." *"Our inversion setup for the proxy approach is linear. However, for the new ratio method operator H includes Eq. (2), and hence,*

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the inversion becomes non-linear making M1QN3 a more suitable optimizer than CON-GRAD. M1QN3 is a quasi-Newton algorithm based optimizer (Gilbert and Lemaréchal, 1989), which is commonly used in non-linear inverse modeling (Cressot et al., 2014; Krol et al., 2013; Muller and Stavrakou, 2005). It has the ability to rebuild the second derivative of the cost functions several times during its descent to minimum, and therefore, performs better for non-linear inverse problems."

8810 line 24. Authors use both CONGRAD and M1QN3, for consistent comparison single method could be better. So, why single method M1QN3 is not used for all inversions? Need to check if the results are stable with respect to the method applied.

AC: CONGRAD is generally our first choice optimizer for proxy inversions using real data, as it is the most efficient optimization method for linear inversions problems. This is an important advantage of proxy inversions, and we did not want to take away this advantage from PROXY. However, we have included results from new proxy inversions using M1QN3 and CONGRAD in Appendix A.

"To compare the difference in convergence between M1QN3 and CONGRAD, we performed additional proxy inversions using both optimization methods (see Appendix A)"

"Appendix A: M1QN3 and CONGRAD

We tested the convergence rate of CONGRAD and M1QN3 using PROXY setup described in Section 2.4. For this purpose, we carried out inversions with both optimizers for 30, 60 and 100 iterations and compared these to the standard inversion using 50 iterations. Figure 1 shows the corresponding posterior CH4 flux departures from PROXY that are also shown in figure 7. We find that both the optimizers converge within 100 iterations. After 60 iterations, CONGRAD already reaches the solution, whereas M1QN3 shows slower convergence. Significant flux differences are found between the optimizers for inversions with 30 and 60 iterations. For CONGRAD, the difference between inversions with 50 and 60 iterations is negligible."

3 Typos

8811 line 4. Sounds better to say "Transcom land regions" instead of "land Transcom regions"

8811 line 8, 10 and below. Should variables cor and bias be written in italics to separate them from the rest of the text?

8812 line 15. Written as "for 100 M1QN3", it looks incomplete, would be more understandable when text is extended as "for 100 iterations of M1QN3"

8807 line 19. assumned -> assumed

8809 line 21. 'Transport model' starts with capital T here, could be mistype?
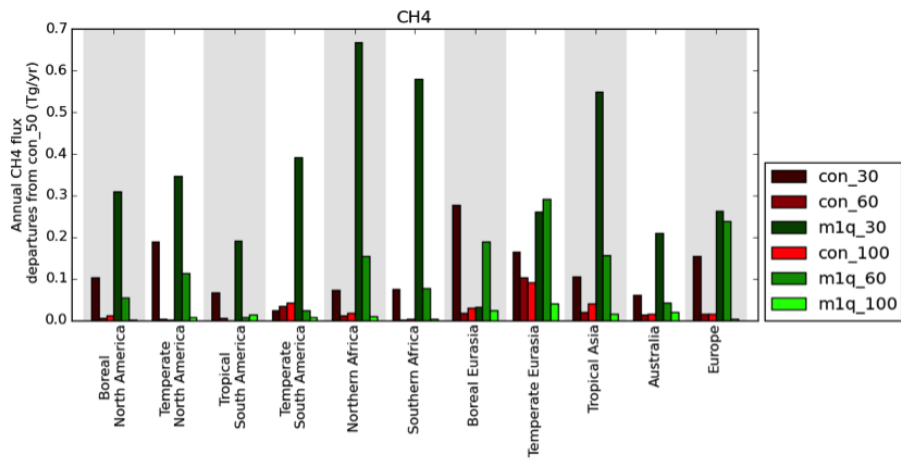
8812 line 16. in-comparioson -> in comparison

AC: All minor corrections are addressed in the revised manuscript.

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Interactive comment on Atmos. Chem. Phys. Discuss., 15, 8801, 2015.

Fig. 1. Annual CH4 flux departures from PROXY (see figure 7). The first part of a legend's label indicates the optimizer used and the second part indicates number of iterations