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10, C14482–C14487, 2011

Interactive Comment

Interactive comment on "Technical Note: Methods for interval constrained atmospheric inversion of methane" *by* J. Tang and Q. Zhuang

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We sincerely thank the anonymous referee for the insightful comments to help us improve the technical note. Our specific responses follow each comments are documented below.

Comments: *Tang and Zhuang describe three different interval constrained optimization methods for atmospheric trace gas inversions and use a pseudo data inversion of methane to evaluate the interval constrained inversions and their unconstrained counterparts. Due to the limited number of observations available to constrain inverse estimates of methane and other atmospheric species, it is common for atmospheric tracer inversions to estimate physically unrealistic fluxes unless some form of regularization is applied, such as aggregation to large regions, correlations between regions, or strong* *constraints from a priori estimates. The authors suggest that these non-physical results could be alternatively eliminated using an interval constraint approach. This topic is potentially of great interest to the atmospheric tracer inversion community, and the work is promising, but I cannot recommend the paper for publication without substantial revisions as described below.*

Most importantly, the Results and Discussion section was thin, with very little analysis of the results of the synthetic data inversions. Tang and Zhaung show a series of figures in which they plot the a priori methane fluxes against the true fluxes used to generate the methane mixing ratios used in the inversion, and then fit these data to a line. If the inversion were working perfectly, all the points should line up on a line with a slope of 1 and an offset of zero. However, all of the pseudo data inversions have slopes that are much less than one, meaning that they all systematically under-estimate the methane emissions (with slopes of 0.63-0.75). The reasons for this are never discussed or explored, even though the under-estimate common to all the inverse methods tested here appears to be a much larger than the differences between inverse methodologies. I suspect it may be related to biases from the a priori estimates, which have a slope of 0.44. If so, the extent to which the priors bias the inversion is an important point and should be discussed, particularly if the interval constrained technique could be used to reduce reliance on the a priori estimates.

Our reply: In order to highlight the advantage of the proposed interval-constrained approaches, in the revision, we present the results by comparing with inversion using the linear batch method. The linear batch method is often used as a standard inversion approach because it integrates the uncertainty of all the fluxes with the constraint from all observations simultaneously. As can be envisaged, the unphysical results from an inversion using a fixed-lag smoother could be resulted from insufficient constraint imported from the sequentially assimilated observations, or due to various errors that are involved in the problem setup (Engelen et al., 2002). For the problem in this note, our previous study (Tang and Zhuang, 2011), which is also shown in the revision, even

ACPD
10, C14482–C14487, 2011

Interactive Comment

the linear batch method can result in unphysical values. This can be caused by both the numerical errors in dealing with large matrices in the inversion and also the insufficient constraint from observations for a poor prior. This justifies the necessity to propose the methods in this note. As for the bias in the prior estimates, we find it is caused by the small number of state variables (38 fluxes for a given month in Tang and Zhuang (2011) and also in the revision) considered, such that any specific prior estimates obtained by randomly perturbing the known true fluxes will be biased. It is typical in an aggregated inversion with a relatively poor prior, because we could neither know the truth fluxes in a real world nor we are able to resolve the variability at all scales in our approximation to the real world using a mathematical model. With our proposed interval constraint approach, we are able to restrict the inversion results within their feasible ranges, and in good agreement with the known true fluxes.

Comments: *In addition, I found Figures 1,2,3,5, and 6 to be a bit unclear. Since the purpose of this paper is to compare the effectiveness of the optimization, it would be easier for the reader to judge how accurate a particular approach was if all of the plots were on the same scale, the x and y axes of a given plot were on the same scale, and the "perfect inversion" (e.g. 1:1 line) were shown. If feasible, it would also be interesting to see regional groupings of points highlighted in different colors to try and understand if there is some spatial coherence in the errors and where the outliers are coming from. Furthermore, the paper does not stand on its own well. Interval constraints are not widely used in the field of atmospheric tracer inversions, and very little background is provided in the paper. Likewise, I wasn't able to fully understand the methods section without first reading the methods section of Tang and Zhuang (2010) in detail, which was also unclear and difficult to follow in places. While I appreciate that material published elsewhere should not need to be repeated in full, a more thorough, detailed discussion of interval constrained inversions in the introduction and methods would be appreciated*

Our reply: In the revision, we presented the results in a more straightforward way. Also,

ACPD

10, C14482–C14487, 2011

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Interactive Discussion

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we added more details to justify why methods such as those proposed in this note are necessary for an atmospheric inversion. In addition, we reduced the introduction of the interval-constrained fixed-lag Kalman smoother, because it has been presented in Tang and Zhuang (2011). The extra spaces are left to discuss the method proposed in this note.

Comments: *In addition to these broader issues, I have the following minor suggestions:*

p. 19982, lines 15-18: This is already a somewhat method-specific description of atmospheric inversions. Please broaden to a more general description. In this paragraph or the one that follows, it would be helpful if you expanded on the errors and biases inherent in other inverse methodologies or regularization techniques that might be improved or eliminated by an interval constrained approach.

Our reply: In the revision, we expanded the descriptions for our methods and to present them in a more meaningful and broader sense.

Comments: *p. 19983, lines 1-5: I'm not aware of any inverse studies of methane or other greenhouse gases that report non-physical inverse estimates. This is because inverse modelers generally recognize this problem and use some form of regularization (e.g. constraints based on a priori estimates, co-variances between parameters, etc.). The authors should recognize this and instead build a case for why the interval constraint approach might be better than these alternatives, as suggested in my previous comment. Throughout the paper, the authors refer to the inversions without interval constraints as "unconstrained" inversions. This was a bit confusing on the first read, because the inversions are constrained by observations (or at least synthetic observations), they just don't include an interval constraint.*

Our reply: First, we noticed that the problem of spurious results from inversions has been discussed many times in the inversion community, e.g. Engelen et al. (2002) and reference therein. Many approaches and suggestions exist to alleviate such problem.

ACPD
10, C14482–C14487, 2011

However, the interval-constrained approach has not been discussed explicitly. In doing atmospheric inversions, we found it is quite easy to encounter spurious results in inversion. And often it takes much time to find a good prior, both in terms of spatial pattern and uncertainty specification in order to solve such problem. The interval-constraint approach provides a quick fix to such spurious inversion.

Second, we revised the text to make it clear when we are referring to an inversion with interval constraint or when we are refereeing to an inversion only with constraint from observations. Also, we justified the necessity of interval-constrained approach by comparing with inversions using the linear batch method.

Comments: *Figure 1: I was surprised by the large bias in the priors, since the authors say that the priors are obtained by adding random perturbations to the true fluxes (19992, lines 8-10). If these errors are truly random, then shouldn't Figure 1 have a slope of 1?*

Our reply: We found that this is caused by the relatively small number of state variables involved in the aggregated inversion. Since any prior is only a specific perturbation to the true fluxes, and we are showing the perturbed fluxes rather than the perturbed normalized scaling factors that have identical mean and covariance for all the fluxes, thus it is not surprised that the prior fluxes are far from slope of 1.0 when they are linearly fitted against the true fluxes.

Comments: *Finally, there were quite a few English grammatical mistakes in the paper that should be corrected before resubmission.*

This study is potentially quite promising, and I look forward to reading it again once the authors have addressed my concerns.

Our reply: We improved the languages and corrected typos and mistakes in the revision.

References

ACPD

10, C14482–C14487, 2011

Interactive Comment

Engelen, R. J., Denning, A. S., Gurney, K. R., and TransCom3 modelers: On error estimation in atmospheric CO2 inversions, J. Geophys. Res., 107, 4635, doi:10.1029/2002JD002195, 2002.

Tang, J. and Zhuang, Q.: Technical Note: Propagating correlations in atmospheric inversions using different Kalman update smoothers, Atmos. Chem. Phys., 11, 921-929, doi:10.5194/acp-11-921-2011, 2011.

Tang, J. and Zhuang, Q.: Technical Note: Methods for interval constrained atmospheric inversion of methane, Atmos. Chem. Phys. Discuss., 10, 19981-20004, doi:10.5194/acpd-10-19981-2010, 2010.

Interactive comment on Atmos. Chem. Phys. Discuss., 10, 19981, 2010.

ACPD

10, C14482–C14487, 2011

Interactive Comment